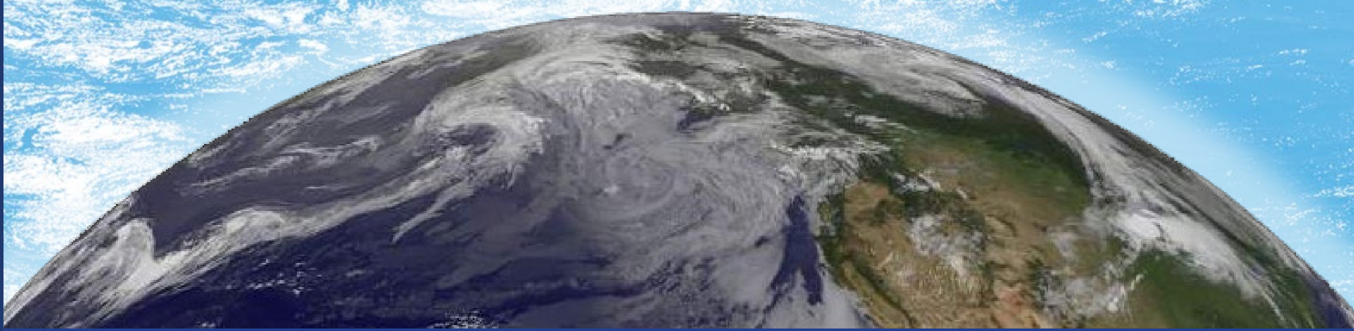
BOOK OF ABSTRACTS



5th INTERNATIONAL SYMPOSIUM

ECCWO5

Effects of Climate Change on the World's Ocean

17 - 21 April, 2023
BERGEN, NORWAY

http://www.pices.int/ECCWO-5 | #ECCWO5

ICES CIEM
PICES
Institute of Marine Research
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Food and Agriculture Organization of the United Nations

Prepared by PICES Secretariat

List of Sessions and Workshops

Schedule: https://meetings.pices.int/meetings/international/2023/ECCWO-5/schedule

- **Opening Plenary Session**

- **Topic Sessions -** Concurrent Topic Sessions every day, following a morning plenary session
  - **S1**: Marine spatial management supporting climate change adaptation and mitigation
  - **S2**: Smart fishing for climate change mitigation and adaptation
  - **S3**: Assessing climate change vulnerability of marine and coastal areas and associated communities
  - **S4**: Improving decision-making in response to change in marine-dependent coastal communities using transdisciplinary approaches
  - **S5**: Measuring and predicting responses of marine social-ecological systems to climate extremes
  - **S6**: Deep-Sea responses to, and solutions for, Climate Change
  - **S7**: Nature-based Solutions for Climate Adaptation and Mitigation - From Planning to Practice
  - **S8**: Advances in coupling regional climate and social-ecological models to improve climate-ready ecosystem management
  - **S9**: Transitioning from Vulnerable to Resilient and Viable Fisheries Social-Ecological Systems
  - **S10**: Beyond species on the move: emerging climate change impacts on the spatial dynamics of marine species, from detecting to forecasting and projecting
  - **S11**: Ocean Deoxygenation: Physical, Biogeochemical and Ecological Research Advances and Future Needs
  - **S12**: Improving pathways for delivery of multi-disciplinary ocean observations into marine assessments across multiple scales
  - **S13**: Detectability of non-linearities, abrupt shifts and tipping points in marine ecosystems
  - **S14**: Cumulative anthropogenic impacts on key Arctic species
  - **S15**: Using Management Strategy Evaluation to establish robust fishery management in a changing ocean
  - **S16**: Emerging challenges in socio-ecological systems brought about by climate-related ecosystem changes and how to equitably manage them
  - **S17**: Coupling social science and economics in integrated marine climate modeling efforts
  - **S18**: Beyond blue carbon: Ocean-based carbon dioxide removal (CDR) approaches
  - **S19**: Ocean Acidification Research for Sustainability

- **Workshops**
  - **W1**: A systematic and rapid assessment of climate vulnerability and adaptation in marine and coastal areas
  - **W2**: The Climate-Fisheries Nexus Within the UN Decade of Ocean Science for Sustainable Development:
  - Co-Designing Actions and Solutions for a Productive, Healthy and Resilient Ocean
  - **W4**: A global ensemble of comparable marine ecosystem models to project climate risk to species and human communities
  - **W5**: S-CCME/SICCME Workshop on integrated modeling to identify climate change tipping points in marine ecosystems

Schedule: https://meetings.pices.int/meetings/international/2023/ECCWO-5/schedule

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APPENDICES

(will be created ***following*** *ECCWO5)*

ECOP participants are identified in the ECOP column: Current list of registrants.

Registrant information is on the ECCWO5 Symposium website under: Current list of registrants.

Please report all errors to PICES (Lori.Waters@pices.int AND secretariat@pices.int)

Keynote Speaker Bios

Christian Clauwers
Fine Art Photography
Ocean & Polar explorer | Photographer | Impact reporter (Belgium)

Christian Clauwers is a Belgian photographer, explorer, public speaker and author. His work covers the polar regions and oceans, including some of the most remote islands on the planet, focusing on documenting the vulnerable relation and conflict between man and nature.

After studying Political Science at the University of Antwerp and Global Management at the Antwerp Management School, Christian worked as a Communications Manager in the Flemish Parliament. Following this, he decided to fully dedicate his life to inspire audiences by capturing pristine nature and (indigenous) communities threatened by climate change. Christian Clauwers has been on the frontline of climate change for over 9 years, exploring both the North and South Pole several times. He sailed the five oceans and joined several international scientific teams to document beauty, vulnerability and impact, caused by the relationship between man and nature.

With multiple lectures and conferences (such as COP25, COP26 and COP27), Christian inspires and shares his work with leaders, youth, NGO's, businessmen and game-changers, with the aim of increasing awareness. Christian believes in the power of image, showing what is at stake, as well as the consequences of human footprints, by documenting, witnessing, capturing…

He collaborates with the Belgian, French, Italian, Swedish and Norwegian governments on multiple projects, all in the context of documenting climate impact and raising awareness through photography. Besides multiple publications in quality media, organising exhibitions, attending major international conferences and giving lectures, Christian collaborates with scientific institutions, publishes articles and books with the purpose of engaging and inspiring people, bridging the gap between science and policy.

Christina Hicks
Lancaster Environment Centre, Lancaster University, UK

Christina is an Environmental Social Scientist interested in the relationships individuals and societies form with nature; how these relationships shape people's social, environmental, and health outcomes; and how they create sustainable livelihood choices. Christina is a professor within the Political Ecology group at Lancaster University's Environment Centre. She gained her PhD in 2013 from the ARC Centre of Excellence for Coral Reef Studies, James Cook University; after which she held an Early Career Social Science Fellowship at the Center for Ocean Solutions, Stanford University. Christina main source of research funding conmes from an ERC Starting Grant: FAIRFISH, and she was awarded the 2019 Philip Leverhulme Prize for Geography. Christina's work is global with particular field sites on the east and west coasts of Africa and in the Pacific.

Randi Ingvaldsen
Institute of Marine Research, Bergen, Norway

Dr. Randi Ingvaldsen is a senior scientist at Institute of Marine Research in Bergen, Norway working with polar oceanography, climate variability and change, and climate impacts on single species and marine ecosystems. Focus areas are the Barents Sea and the adjacent Arctic Ocean. She has co-authored >60 peer-reviewed publications and 7 book-chapters focusing on atlantification and borealization of the Arctic regions, as well as bio-physical interactions focusing on zooplankton, fish, shrimp and benthos. Ingvaldsen is also involved in integrated ecosystem assessments and advice, including the central Arctic Ocean fisheries agreement that entered into force in 2021.

Ingvaldsen earned her PhD in 2003 in physical oceanography at Geophysical Institute, University of Bergen. She has been employed at Institute of Marine Research throughout the working career and was also professor at UiT The Arctic University of Tromsø during 2016-2022. She has been Principal Investigator in >30 international and national research projects, and lead or participated in numerous interdisciplinary oceanographic sea cruises including in ice-covered waters. Ingvaldsen is Principal Investigator for the long-term monitoring of the marine climate of the Barents Sea and is leading the "The living Barents Sea" as part of the Nansen LEGACY project. This large, Norwegian project focus on building critical knowledge of how organisms in the northern Barents Sea ecosystem respond to current and changing environmental conditions on the species and community level.

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Plenary Speaker Bios

Session 2: Smart fishing for climate change mitigation and adaptation

Antonello Sala
Italian National Research Council, Italy

Dr. Antonello Sala is a senior fisheries scientist ("Director of Research" highest level in the Italian system) with more than 30 years of experience studying the wider ecosystem effects of fishing on the marine environment at the National Research Council (CNR, Italy). Expert knowledge of physical and biological impacts in the marine environment produced by human activities, as well as impacts and operations of global fisheries, including marine litter, efficiency and selectivity of fishing gears, performance of fishing gears using underwater instrumentation, fishing gear design and modelling, and energy saving measures in fisheries operations. Lead scientist in numerous international research projects (>20) and national projects (>30). Chief scientist in more than 40 interdisciplinary oceanographic sea cruises. Since 2020, fishing technology consultant (COF.REG) in the Fishing Technology and Operations team (NFIFO) of the Food and Agriculture Organization of the United Nations (FAO, Rome). Since 2014, external statistical expert for the European Fisheries Control Agency (EFCA, Spain). In 2019, programme officer providing scientific advice on the implementation of the Common Fisheries Policies and Fisheries Dependent Information at the European Commission DG Joint Research Centre (JRC, Italy). From 2020, chairperson of the ICES/FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB). From 2010 to 2019, member and vice-chair (in 2018-2019) of the EU-STECF Committee (European Scientific, Technical and Economic Committee for Fisheries). Author of numerous peer-reviewed publications (90) and holder of 3 pending patents. Author's h-index in Scopus and Web of Science: 25 (Google scholar: 29, with 3472 citations).

Session 5: Measuring and predicting responses of marine social-ecological systems to climate extremes

Renato Salvatteci
Kiel University, Germany

Dr. Renato Salvatteci has worked almost 20 years on reconstructing past changes in fish population variability at multiple time scales using an interdisciplinary approach, including paleoceanography, biogeochemistry and fish ecology. He is particularly interested in the local and remote factors driving changes in productivity and sub-surface deoxygenation in Eastern Boundary Upwelling Systems during the last 140 000 years, and the respective response of small pelagic fishes to past changes in oceanic and climatic conditions at multi-decadal to millennial time scales. His core issue is to provide scientific evidence to develop an adaptive local fishery management under globally warmer ocean conditions. Renato has studied fisheries engineering in Lima, Peru, and marine ecology in Mexico. He earned his PhD in Environmental Sciences at the Université Paris VI, France, and was then affiliated as an Alexander von Humboldt post-doctoral fellow to the Institute of Geosciences at Kiel University, Germany. After several years as a post-doctoral researcher in the SFB 754 project "Climate – Biogeochemistry Interactions in the Tropical Ocean", Renato is now the principal investigator of the second phase of the Humboldt Tipping Points project at the Center for Ocean and Society at Kiel University.

Session 6: Deep-Sea responses to, and solutions for, Climate Change

Roberto Danovaro
Polytechnic University of the Marches, Ancona, Italy

Roberto Danovaro is Professor of Marine Ecology at the Polytechnic University of Marche. President of the Stazione Zoologica "Anton Dohrn" from 2013 to 2022. Past-president of the Italian Society of Ecology, of the Italian Society of Limnology and Oceanography and of the European Federation of Scientific Societies. President of the Scientific Council of WWF Italy. Member of several international panels (IUCN, UNEP). Member of the EU Academy of Science and of the Academia Europaea (London). He received the Prize BMC Biology (London, 2010), the Award of French Society of Oceanography (2011), and the ENI Award "Protection of the Environment" (2013). According to ExpertScape is one of the most influential World Scientist in the Category "Ocean and Seas" and "Marine Biology". Authors of >400 scientific articles and 3 books, his research interests are focused on the ecology of deep-sea ecosystems and the impacts on global climate change.

Session 10: Beyond species on the move: emerging climate change impacts on the spatial dynamics of marine species, from detecting to forecasting and projecting

Barbara Muhling
NOAA and University of California Santa Cruz, USA

Barbara Muhling is a Project Scientist at the University of California – Santa Cruz, based at the NOAA Southwest Fisheries Science Center in La Jolla, CA. She completed her PhD in Perth, Australia, and did her postdoc on the spawning dynamics of tunas in the Gulf of Mexico and Caribbean Sea, through the NOAA Southeast Fisheries Science Center in Miami, Florida. Her current research focuses on the distribution and ecology of pelagic fishes in the California Current System, and the broader North Pacific. She is particularly interested in how these species may respond to environmental variability and climate change, as well as the potential impacts of shifting species distributions on fisheries and fishing communities. She is a member of the CLIOTOP Scientific Steering Committee, and has co-chaired working groups on climate change and species distributions through PICES and NOAA.

Session 11: Ocean Deoxygenation: Physical, Biogeochemical and Ecological Research Advances and Future Needs

Laure Resplandy
The Resplandy Research Group, Princeton University, USA
Laure Resplandy is an assistant professor in the Geosciences department and the High Meadows Environmental Institute at Princeton University. Resplandy did her undergraduate studies at Ecole Normale Supérieure in Paris and received a PhD in Oceanography from Sorbonne Universités (Paris, France) in 2010. She arrived at Princeton in February 2017 after working as a postdoctorate researcher in leading oceanographic and climate sciences institutions, including the National Oceanography Centre in the UK, the French Climate and Environment Sciences Laboratory and the Scripps Institution of Oceanography in San Diego. Resplandy received several awards, including the Sloan Foundation Research Fellowship and the NSF CAREER award. Resplandy is a biogeochemical oceanographer and climate scientist. Her goals are to understand how climate and ocean dynamics influence marine ecosystems and global carbon and oxygen cycles, and how these changes can in turn impact the climate itself. Her group designs and develops cutting edge numerical models, from high-resolution ocean models to global Earth system models, and combines them with statistical tools to interpret the variability observed from space and in-situ.

Session 14: Cumulative anthropogenic impacts on key Arctic species

Katrine Borgå
Department of Biosciences, Aquatic biology and Toxicology (AQUA), University of Oslo, Norway
Katrine Borgå is Professor at the University of Oslo, Norway, focusing on stress ecology and how multiple stressors, including climate change and pollution, affect ecosystems especially Arctic marine ecosystems. Her research career in ecotoxicology began as one of the first biology students at the University Studies on Svalbard almost 30 years back, where she developed an interest in understanding the movement of energy and pollutants across and within ecosystems. After research stays in Italy and the USA, she returned to the University of Oslo as a Professor in Toxicology, leading a research team studying the combined impacts of multiple stressors on organisms. In particular, she is interested in how climate change and environmental conditions affect accumulation and toxicity of pollutants in non-target organisms, from marine copepods and killer whales, to terrestrial springtails and bumblebees, with particular focus on responses in life history traits for extrapolation to population level effects.

Borgå is PI of several international research projects, lead national network of marine pollution related to Horizon Europe, has served on panels for UNEP Stockholm convention Global Monitoring Plan, board member on program for marine science of the Research Council of Norway, expert member on pollutants and climate change for the Arctic Monitoring and Assessment Programme, and lead the task on pollution impacts in the large Norwegian research project Nansen Legacy in the Arctic Barents Sea. Borgå has published extensively on the subject, with a focus on the influence of global climate change on the accumulation and toxicity of pollutants in Arctic food webs, and the effects on key Arctic species. She is a frequent speaker at international conferences and is excited to share her expertise at the upcoming Climate Change Symposium ECCWO5.

Session 15: Using Management Strategy Evaluation to establish robust fishery management in a changing ocean

Laura Blamey
CSIRO, Brisbane, Australia

Dr. Laura Blamey is a quantitative marine ecologist at CSIRO based in Brisbane, Australia. She completed her PhD and a Postdoctoral fellowship at the University of Cape Town, South Africa before being awarded a prestigious NRF Research Career Advancement fellowship. She then went on to work at the University of Seychelles as a Senior Lecturer, and in 2019 she moved to Australia, where she took up her current role with CSIRO. Laura has experience with a range of modelling techniques as well as field work experience in both temperate and tropical ecosystems. She is interested in coastal socio-ecological systems and fisheries and her research integrates field data, ecosystem modelling and local knowledge to help better understand changes in these systems. Her research has involved modelling changes in key trophic species in reef ecosystems; detection of climate regime shifts and links to ecosystem change; and more recently, the inclusion of environmental variables into population models to dynamically quantify the impacts of a changing environment and assess robustness of harvest strategies to these changes, through use of management strategy evaluation.

Session 19: Ocean Acidification Research for Sustainability

Punyasloke Bhadury
Indian Institute of Science Education and Research Kolkata (IISERs), West Bengal, India

Punyasloke Bhadury is a Professor of Biological Sciences and also leads the Centre for Excellence in Blue Economy at the Indian Institute of Science Education and Research Kolkata in India. Punyasloke did his M.Sc. from Heriot Watt University (Edinburgh) followed by a PhD in marine microbial ecology from Plymouth Marine Laboratory and University of Plymouth in the United Kingdom. Subsequently, he did his postdoctoral research with Bess Ward at Princeton University, USA. His research interests encompass understanding how coastal oceans shape biological complexity and functional consequences on regional carbon and nitrogen fluxes, quantifying long-term consequences on marine bioresources and blue economy in a changing climate as well as addressing sustainability of coastal oceans of South Asia through sharing of knowledge (policy) and innovations. He leads the South Asia Regional Hub on Ocean Acidification (SAROA), a regional hub of GOA-ON. He is an Editor of a number of peer-reviewed international journals including iScience, Geoscience Letters, PeerJ and Ecological Solutions & Evidence. He is presently co-editing a special issue 'Sustainable Oceans in a Changing Climate' as part of iScience.

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Invited Speaker Bios

Session 1: Marine spatial management supporting climate change adaptation and mitigation

Lodewijk Abspoel
Ministry of Infrastructure and Water Management, Netherlands

Lodewijk Abspoel is a senior policy advisor for European Integrated Maritime Policy, including Ocean Governance and Maritime Spatial Planning (MSP) at the Dutch coordinating ministry for the North Sea since 2010. He was involved in drafting the EU MSP Directive (89/2014 EU) and project leader of the Dutch North Sea 2050 Spatial Agenda. He has since been involved in the various projects to optimize and future proofing MSP, including work on land-sea interactions, cross-border cooperation, and emerging topics in MSP. Both in the North Sea and beyond.

Currently Lodewijk is leading the Greater North Sea Initiative project. The Netherlands's government has started this initiative to jointly explore a new governance approach for marine/maritime spatial planning & development. The initiative aims to bring all North Sea(s) countries and partners on board around a holistic agenda which can help deliver the 2030 and 2050 sustainability targets, the European Green Deal objectives for renewable energies, biodiversity (restoration) and the transformation to the truly sustainable blue economy

Lodewijk initiated the development of the MSP Challenge, aiming to prototype a Digital Twin of the sea. The MSP Challenge board game, used in MSPglobal trainings by the Intergovernmental Oceanic Commission of UNESCO, he designed in his workshop at home, and serves to bring together the oceans' and coastal communities, scholars, civil servants and politicians.

In 2020 Lodewijk was guest editor of the special on Maritime Spatial Planning of the Journal of Ocean Technology (JOT), a scientific periodical published by the Fisheries and Marine Institute of Memorial University of Newfoundland Canada.

Publication: Communicating Maritime Spatial Planning: The MSP Challenge approach
Lodewijk Abspoel, et al., Marine Policy, https://doi.org/10.1016/j.marpol.2019.02.057

William Cheung
Institute for the Oceans and Fisheries, The University of British Columbia, BC, Canada

Dr. William Cheung is a Professor and Director of the Institute for the Oceans and Fisheries, the University of British Columbia. He is also a Canada Research Chair in Ocean Sustainability and Global Change. He is an international leader in developing and using scenarios and models of biodiversity and ecosystem services to understand the responses and vulnerabilities of marine human-natural systems to global change. His work addresses policy-relevant research questions and cuts across multiple disciplines, from oceanography to ecology, economics and social sciences. His research ranges from local to global scales.

He is the Principal Investigator of the Changing Ocean Research Unit at UBC. He served as Director of Science for the Nippon Foundation Nereus Program, a nine-year international program, which focuses on key threats to ocean sustainability with the goal of predicting what the world's future oceans will look like under global change. William is actively involved in international and regional initiatives that bridge science and policy. For example, he served as Coordinating Lead Author for the Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). He serves as Associate Editor for Global Change Biology and Ecological Society of America's Frontier in Ecology and the Environment.

William obtained his BSc and M.Phil. from the University of Hong Kong. He completed his PhD in Resource Management and Environmental Studies at UBC. From 2009 to 2011, he was Lecturer in Marine Ecosystem Services in the University of East Anglia.

Session 2: Smart fishing for climate change mitigation and adaptation

Carlos Groba
Marine Instruments S.A, Spain

Dr. Groba is R&D director at Marine Instruments S.A, focused mainly on IT with a special interest in artificial intelligence, where he got his PhD solving dynamic optimization problems.

He has been working at Marine Instruments for more than 17 years. During this time, he has managed many different projects, with an emphasis on determining how technology can be applied to fishing products, like satellite buoys for the tuna fishing industry, and with the aim of reducing the gap between academia and industry, reaching suitable solutions that help increase the sustainability of the fishing sector.

Session 3: Assessing climate change vulnerability of marine and coastal areas and associated communities

Jon Day
James Cook University, Australia

Jon Day was an Australian protected area planner and manager for 39 years, 28 of which were in the Great Barrier Reef Marine Park (GBRMPA). In 1998 he was appointed as a GBRMPA Director and for the following 16 years was variously responsible for GBR-wide matters including biodiversity conservation, park planning, World Heritage and other heritage matters, and commencing the first 5-yearly GBR Outlook Report. Jon's career highlight was his leadership role in the Representative Areas Program (RAP), the major rezoning program for the entire GBR that occurred between 1999-2003. RAP is today widely considered 'best practice', receiving numerous national/international awards. Jon's World Heritage (WH) experience included attending eleven WH Committee meetings as an Australian government official (1998-2013) and he was appointed as one of three experts comprising Australia's formal delegation during Australia's four-year term on the WH Committee (2008-11). Jon's expertise in this area has been instrumental in his co-development of the Climate Vulnerability Index (CVI) to assess the climate vulnerability of World Heritage properties (cvi-heritage.org) and other areas of significance. Jon retired from GBRMPA in 2014 and completed a post-career PhD at James Cook University, where he is currently an Adjunct Senior Research Fellow.

Scott Heron
James Cook University, Australia

Scott Heron is an environmental physicist with focus on linkages between physical oceanography, natural biology and human communities in coastal and near-shore zones. He has a keen interest in the effects of climate change effects on natural and cultural heritage, and has co-developed the Climate Vulnerability Index (CVI) to assess the climate vulnerability of World Heritage properties (cvi-heritage.org). This work involves collaboration with UNESCO World Heritage Centre and its advisory bodies, as well as several international partners. The CVI is also being extended for use with First Nations groups, co-developed with Yuku Baja Muliku (northeastern Australia), recently announced as a winner of the 2022 EarthShot prize. Scott holds the position of Associate Professor in Physics at James Cook University, where his research lab studies coral bleaching and disease, reef resilience, seagrass impacts and conservation management, within the context of climate change.

Mercy Mbogelah
Ruins of Kilwa Kisiwani and Ruins of Songo Mnara World Heritage Site, Tanzania

Mercy Mbogelah is the site Manager of Ruins of Kilwa Kisiwani and Ruins of Songo Mnara World Heritage Site. She holds a Bachelor on history and archaeology and a master in tourism and management planning. She is currently working on conserving and protecting the archaeological site of Kilwa Kisiwani. She has been working with Climate Heritage on the Edge program (Google), the Climate Heritage Network and CVI (Climate Vulnerability Index Africa) to develop climate change adaptation measures for Kilwa Kisiwani. She is also one of the leader of the Interim Committee of African Site Managers Network.

Session 5: Measuring and predicting responses of marine social-ecological systems to climate extremes

Regina R. Rodrigues
Dept. of Oceanography, Federal University of Santa Catarina, Brazil

Regina R. Rodrigues is an Associate Professor of Physical Oceanography and Climate with a Doctor of Philosophy (PhD) in Physical Oceanography from the Graduate School of Oceanography, University of Rhode Island, USA. Her research interests include understanding how tropical ocean basins interact and affect the extra-tropics leading to extreme events, using observations and modelling. In recognition of her expertise in the dynamics and variability of the tropical and South Atlantic, she co-chairs the World Climate Research Program (WCRP) Atlantic Region Panel and is a member of the SSG of the international program "Prediction and Research Moored Array in the Tropical Atlantic". Recently, her research focuses on understanding compound extreme events of drought, land and marine heatwaves, as well extremes of high acidity and low productivity in the ocean. She is involved in several international activities with the mandate of increasing diversity and representation from the Global South. She is the co-chair of the WCRP Lighthouse Activity "My Climate Risk", with the primary objective of developing a bottom-up framework to construct climate information involving local communities. She served as review editor of IPCC-SRCCL Chapter 7 and is currently a member of the editorial board of Nature's journal Communication Earth & Environment. Twitter

Session 6: Deep-Sea responses to, and solutions for, Climate Change

Natalya Gallo
Dept. of Biological Sciences, University of Bergen and Bjerknes Center for Climate Research, Norway

Natalya Gallo is a postdoctoral scholar in the Department of Biological Sciences at the University of Bergen and an affiliate of the Bjerknes Centre for Climate Research. She currently studies the effects of deoxygenation and acidification on deep-sea pelagic and demersal communities in western Norwegian fjords. Prior to arriving in Bergen, she studied at the Scripps Institution of Oceanography and her Ph.D. focused on how oxygen gradients in deep-sea ecosystems such as oxygen minimum zones affect the community ecology of demersal fishes. At Scripps, she was a member of the Center of Marine Biodiversity and Conservation and an NSF IGERT Scholar in Global Change, Marine Ecosystems, and Society. After receiving her Ph.D., she worked as a quantitative fisheries and ecology postdoc with the CalCOFI ecosystem monitoring program at Scripps and the NOAA Southwest Fisheries Science Center. As a seagoing scientist, she has spent over 100 days at sea collecting data on deep-sea communities on the U.S. West Coast, the Gulf of California, Costa Rica, and western Norway. She is passionate about the science-policy interface and the role scientists can play in informing sustainable ecosystem management strategies for deep-sea ecosystems. She is a member of the Early Career Ocean Professionals network of the UN Decade of Ocean Science for Sustainable Development, and the Deep Ocean Stewardship Initiative Climate Change working group.

Session 8: Advances in coupling regional climate and social-ecological models to improve climate-ready ecosystem management

Ryan Heneghan
Queensland University of Technology, Australia

Ryan Heneghan is a Lecturer in Mathematical Ecology at Queensland University of Technology, and a coordinator of the Fisheries and marine ecosystem Model Intercomparison Project. He completed his PhD in 2019 at the University of Queensland developing the first global marine ecosystem model that resolved multiple zooplankton functional traits. Afterwards, he spent 2 years in Barcelona identifying critical drivers of structural uncertainty in global marine ecosystem models. Ryan's research uses quantitative modelling to uncover fundamental processes that structure marine ecosystems, from the Great Barrier Reef to the global ocean. He uses these quantitative approaches to assess the impacts of climate change, human demand, and management strategies on marine ecosystems.

Session 9: Transitioning from Vulnerable to Resilient and Viable Fisheries Social-Ecological Systems

Katherine Mills
Gulf of Maine Research Institute (GMRI), USA

Dr. Katherine Mills is a research scientist at the Gulf of Maine Research Institute in Portland, Maine. She earned her Ph.D. in Natural Resources at Cornell University. As a quantitative fisheries ecologist, Kathy studies marine ecosystem changes and fish-ecosystem-fishery relationships with a focus on the Gulf of Maine and Northeast US Shelf regions. Specifically, her research investigates (1) how physical and ecosystem conditions are changing; (2) how these changes affect fish populations, biological communities, and marine fisheries; and (3) how fisheries and fishing communities can effectively respond.

Much of her work is interdisciplinary, seeking to understand and inform management of fisheries as coupled social-ecological systems. This research integrates climate, ecological, social and economic information to link changes in the ecosystem to societal outcomes. Climate adaptation within marine fisheries has become a major recent focus, with emphases on assessing vulnerabilities, evaluating adaptation strategies, and providing new forms of information to support forward-looking planning by fishery participants, fishing communities and fishery managers. She is currently leading a global working group on Climate Resilient Fisheries to develop information, approaches, and tools for assessing and enhancing resilience to climate impacts in marine fisheries. This work will be continued and advanced at global, regional, and local scales through a UN Ocean Decade program she leads—Fisheries Strategies for Changing Oceans and Resilient Ecosystems by 2030 (FishSCORE). In addition, she is the lead author for the 'Oceans and Marine Resources' chapter of the US National Climate Assessment and serves as a chair of the ICES-PICES Strategic Initiative on Climate Change Impacts on Marine Ecosystems (SICCME).

Jenia Mukherjee
Dept. of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, India

Jenia Mukherjee is an Assistant Professor at the Department of Humanities and Social Sciences in the Indian Institute of Technology Kharagpur. She is investigating several large-scale international projects, funded by the European Union, ICHR-AHRC and SSHRC (Canada), focusing on coastal and river island livelihoods. She is the member of the five-member global committee and the only Indian representative for the Association for East Asian Environmental History (AEAEH). Jenia has received prestigious awards including the DAAD Grant (2022), Nippon Foundation Fellowship (2021), Australian Leadership Awards Fellowship (2010, 2015) and the UNESCO World Social Science Fellowship (2013). She was conferred the Carson Writing Fellowship (2018-19) by the Rachel Carson Center for Environment and Society, Munich (Germany) for executing her book project Blue Infrastructures: Natural History, Political Ecology and Urban Development in Kolkata (https://link.springer.com/book/10.1007/978-981-15-3951-0).

Session 10: Beyond species on the move: emerging climate change impacts on the spatial dynamics of marine species, from detecting to forecasting and projecting

Lisa Kerr
Gulf of Maine Research Institute (GMRI), USA

Dr. Lisa Kerr is an Associate Professor in the School of Marine Science at the University of Maine and based at the Gulf of Maine Research Institute. She is broadly interested in research that informs progress toward sustainable management of marine fisheries and ecosystems as a whole. Core objectives underlying her work include: 1) understanding the influence of climate, harvest, and management on fishery resources, 2) advancing the study of fish population structure and its implications to resilience, and 3) applying management strategy evaluation toward improved stock assessment and management. A major goal of her lab's current work is to bring climate information to bear on fishery stock assessment and management processes. She regularly advises on regional, national, and international fisheries management issues. She earned her Doctor of Philosophy in Marine, Estuarine, & Environmental Sciences from the University of Maryland, Master of Science from Moss Landing Marine Laboratories- California State University, and a Bachelor of Science from the Tufts University.

Session 11: Ocean Deoxygenation: Physical, Biogeochemical and Ecological Research Advances and Future Needs

Maggie Johnson
King Abdullah University of Science and Technology (KAUST), Saudi Arabia

Maggie Johnson is an Assistant Professor of Marine Science at King Abdullah University of Science and Technology (KAUST). After completing postdoctoral fellowships with the Smithsonian Institution and Woods Hole Oceanographic Institution, she joined the Red Sea Research Center where she is developing a research group focused on Global Change Ecology in marine habitats. Maggie studies coral reefs across the globe, from the central tropical Pacific to Caribbean Panama and the Red Sea, and seeks to understand what role humans are playing in the rapid degradation of these valuable ecosystems. She uses a combination of field and laboratory-based approaches to 1) evaluate and monitor the structure and function of coral reef ecosystems, 2) quantify inherent natural heterogeneity in key environmental parameters including temperature, dissolved oxygen, and pH, 3) explore the implications of environmental variability for ecophysiology of coral reef primary producers, 4) and determine the implications of local and global environmental change for these foundational coral reef taxa. Through her work in Caribbean Panama, she began exploring the role of deoxygenation in coral reef decline. Maggie continues her deoxygenation research in the field and lab, and is focused on identifying how foundational coral reef taxa are impacted by acute and persistent declines in dissolved oxygen, in combination with other co-occurring environmental stressors.
More...

Session 12: Improving pathways for delivery of multi-disciplinary ocean observations into marine assessments across multiple scales

Michelle Heupel
Integrated Marine Observing System (IMOS), Australia

Dr. Michelle Heupel is the Director of Australia's Integrated Marine Observing System (IMOS). In this role she leads Australia's core ocean observing efforts, including over 60 national-scale sub-Facilities ranging from shelf moorings, Argo floats, and ocean gliders to animal tagging and more. IMOS was established in 2006 as a consortium of Australia's premier marine research institutions and is funded by the Australian Government. The IMOS model includes research, government and industry partnerships to deliver the program. Prior to joining IMOS, Michelle was a successful research scientist with over 25 years' experience working on ecology, conservation and management of sharks and fish. She has published over 200 peer-reviewed scientific publications.

Adam Martiny
University of California, USA

Adam Martiny is a professor at the University of California, Irvine. Martiny did his undergraduate and graduate studies at the Technical University of Denmark and postdoctoral training at MIT with Penny Chisholm. His research aims at understanding how drivers of phytoplankton biodiversity and biogeochemistry in the context of a changing ocean. Martiny is also the lead coordinator of Bio-GO-SHIP which is supported by NOAA, NASA and NSF. Bio-GO-SHIP is an international collaboration to quantify, understand, and predict the distribution and biogeochemical role of pelagic plankton communities. This will be achieved through systematic, high-quality, and calibrated sampling of 'omics, plankton imaging, particle chemistry, and optical techniques as operational oceanographic tools. Integration with regular GO-SHIP measurements and their analyses of the physical and chemical environment will allow us to understand (and eventually predict) how plankton communities respond to ocean changes and how biological processes feeds back on carbon, oxygen, and nutrient cycles.

Patricia Miloslavich
Scientific Committee on Oceanic Research (SCOR)

Dr. Patricia Miloslavich is the Executive Director of the Scientific Committee on Oceanic Research (SCOR) an interdisciplinary body aimed to advance ocean science and address global issues requiring a multidisciplinary approach. She is a marine biologist with a PhD in Oceanography from the University of Quebec at Rimouski, and a retired senior professor from Simon Bolivar University in Venezuela from which she remains an ad honorem researcher. She was the International Project Officer of the Biology and Ecosystems Panel from the Global Ocean Observing System (GOOS) coordinating activities to implement global sustained observations of marine biodiversity and ecosystems to help mitigate or manage changes resulting from anthropogenic pressures.

Her focus has been to address education, scientific, technological, capacity development, and sustainability challenges in biological oceanography and marine biology and biodiversity with international groups. She has successfully established and coordinated regional and international science networks and implemented multi-national, global scale research programs in ocean sciences and marine biodiversity, especially focused on implementing global sustained observations of essential ocean variables to help mitigate or manage changes resulting from anthropogenic pressures. She is a committed science communicator to policy makers and the public with extensive media contributions.

Session 13: Detectability of non-linearities, abrupt shifts and tipping points in marine ecosystems

Mary Hunsicker
Northwest Fisheries Science Center, NMFS, NOAA, USA

Dr. Mary Hunsicker is a research ecologist at the National Oceanographic and Atmospheric Administration's (NOAA) Northwest Fisheries Science Center (NWFSC) in Newport, Oregon. She also holds a courtesy faculty position in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University. Mary's research interests focus largely on understanding the effects of climate variability and change on species distributions, food web interactions, and community dynamics, and on advancing the science of ocean tipping points. Some of her recent research efforts include co-leading collaborative projects that aim to quantify thresholds that may be useful for informing ecosystem-level reference points and to identify pathways for the uptake of threshold information in fisheries management. She and her colleagues are also developing indicators that can be used to track and forecast changes in ecosystem state in effort to provide early detection of ecosystems shifting into a novel state. Mary co-chaired the PICES WG36 on Common Ecosystem Reference Points (CERP) across PICES Member Countries. She is also a co-chair of the ICES CERP working group.

Session 14: Cumulative anthropogenic impacts on key Arctic species

Nadja Steiner
Fisheries and Oceans Canada

Dr. Nadja Steiner is a senior scientist with the departments of Fisheries and Oceans (DFO) and Environment and Climate Change (ECCC) in Canada. She develops and analyses coupled ocean-ice-ecosystem models for Arctic marine ecosystems, Sulphur and carbon cycles. This includes evaluations of environmental drivers such as ocean acidification, sea-ice retreat, and increasing temperatures to help understand marine ecosystem responses to climate change and their impacts on ecosystem services in general and Inuit subsistence harvesting specifically. She is a member of the Arctic Monitoring and Assessment Program (AMAP) Climate Expert Group and has been a contributing author to several AMAP assessment reports. Nadja Steiner also co-chairs the international expert community on Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII), previously a Scientific Committee of Ocean Research (SCOR) working group and the new SCOR working group on Coupling of ocean-ice-atmosphere processes from sea-ice biogeochemistry to aerosols and clouds (CIce2Clouds). She is an adjunct professor at the School of Earth and Ocean Sciences, University of Victoria.

Session 15: Using Management Strategy Evaluation to establish robust fishery management in a changing ocean

Jose De Oliveira
Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK

José De Oliveira is Head of International Fisheries Methods Development and Principle Adviser at Cefas with a long record of experience with fish stock assessments, management strategy evaluation and providing fisheries management advice. He has chaired several ICES working groups and workshops, including on conducting MSEs for five jointly-management North Sea stocks and on the development of MSE Guidelines. He developed one of the earliest examples of a multi-stock MSE for commercial fisheries in the early- to mid-1990s when he worked on the small pelagic sardine-anchovy complex off the coast of South Africa. He was invited as a key-note speaker and panellist for the subtheme "Management Strategy Evaluation & Harvest Strategies" at the World Fisheries Congress in 2021.

Session 16: Emerging challenges in socio-ecological systems brought about by climate-related ecosystem changes and how to equitably manage them

Samiya Selim
University of Liberal Arts Bangladesh

Samiya Selim is an Associate Professor and the Director of Center for Sustainable Development at the University of Liberal Arts Bangladesh (ULAB). She is a marine social scientist and specializes in interdisciplinary areas of social-ecological systems – sustainability science, climate change adaptation and resilience, and the science-policy interface. In the past 10 years, Samiya has worked in UK and Bangladesh, where her work focused on interdisciplinary research around climate resilience in coastal regions, circular economy, nature conservation and mobilizing communities to bring about sustainable behavioral change in daily life. At present, she is doing a part time Postdoc at the ZMT Leibniz Centre for Tropical Marine Research, Germany on resolving marine conflicts. Her current work focuses on ensuring equity in small scale fisheries, achieving sustainable development goals, ecosystem-based adaptation and sustainable livelihoods. Samiya has published several peer reviewed articles including the first book on achieving the Sustainable Development Goals relating to the environment in Bangladesh. She is the country coordinator of Vulnerability to Viability (V2V): Global Partnership for Building Strong Small-Scale Fisheries Communities funded by the Government of Canada SSHRC. She is also CO-Chair of the Integrated Marine Biosphere Ecosystems Research (IMBeR) Human Dimensions Working Group and Chair of the Interdisciplinary Marine Early Career Network (IMECaN).

Session 18: Beyond blue carbon: Ocean-based carbon dioxide removal (CDR) approaches

Sarah Cooley
Ocean Conservancy, USA

As Director of Climate Science at Ocean Conservancy, Sarah combines her science and communication skills to educate and engage decision-makers and stakeholders from every political perspective on ocean acidification, identifying ways that different groups can take action. Her goal is to show that this issue is relevant and impacting people today in order to gain long-term support to protect communities, cultures and livelihoods from the threat of ocean acidification.

Sarah is currently a Coordinating Lead Author on Working Group II of the IPCC's 6th Assessment Report, and chapter author on the 5th National Climate Assessment. She has also served as Review Editor on the 4th National Climate Assessment, and Lead Author on the 2nd State of the Carbon Cycle Report, as well as the author of dozens of peer-reviewed scientific journal articles in high-impact journals including Science and Nature Climate Change.

Session 19: Ocean Acidification Research for Sustainability

Samantha Siedlecki
University of Connecticut, USA

As an oceanographer, Dr. Siedlecki focuses on coastal regions where she implements numerical simulations to investigate and identify processes within that environment responsible for the biogeochemical dynamics in both the modern and future oceans. She received her PhD from the University of Chicago where she focused on largely on theoretical systems of the ocean. As a postdoctoral fellow at JISAO at the University of Washington, she began simulating Washington and Oregon waters using realistic simulations of ocean acidification variable and hypoxia developed as part of the Coastal Modeling Group there. At JISAO, she extended that work to include seasonal (J-SCOPE) and short term (LiveOcean) forecasts. Now an assistant professor at the University of Connecticut, she has begun exploring regional climate projections of ocean conditions on both the west and east coast of the US. Through work with colleagues on the west coast as well as new collaborators part of the Early Career Faculty Innovators Program at NCAR, she is partnering with social scientists to bring these tools into decision making frameworks.

WORKSHOPS INVITED SPEAKERS

Workshop 2: The Climate-Fisheries Nexus Within the UN Decade of Ocean Science for Sustainable Development: Co-Designing Actions and Solutions for a Productive, Healthy and Resilient Ocean

Gretta T. Pecl
Centre for Marine Socioecology & Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Australia

Gretta Pecl is a Professor of marine ecology at the Institute for Marine and Antarctic Studies (IMAS), and the Director of the Centre for Marine Socioecology (CMS) at UTAS. She has deep expertise exploring the impact of climate change on natural systems, and developing adaptation options for conservation, fisheries and aquaculture. She is a Lead Author for the IPCC AR6 report, an Australian Research Council 'Future Fellow', and an associate editor for several international journals. Gretta excels at building transformative collaborations and has been prominent in UN Decade of Ocean Science programmes, actions and working groups, including co-leading Future Seas 2030 and other major international initiatives. She has a strong passion for science communication and engagement with the public.

Ana Queiros
Marine Life Support Systems, Plymouth Marine Laboratory, UK

Dr Ana Queirós is a senior benthic and climate change ecologist at Plymouth Marine Laboratory (UK) with 10+ yrs of research experience in the UK, EU, Eastern Africa, Australia and SE Asia. Ana is an internationally recognised expert in climate-smart approaches to marine spatial planning, leading modelling based research, and advising national and international policy, promoting effective conservation and blue growth (Queiros et al 2021, GCB, UN Global Compact 2021). She is the climate change co-lead for the ICES WG on Marine Planning and Coastal Zone Management (2020-), and the co-chair of the ICES Workshop on Climate Change Considerations in Marine Spatial Planning (2023). Ana is also an internationally recognised expert in seaweed blue carbon (Queirós et al. 2019), and is leading and advising on global programmes developing management strategies for its conservation and carbon market access. She is the 2022 winner of the Axa IM Research Award. Key current programmes include SMMR MSPACE and H2020 FutureMares. Ana's work is highlighted in agenda setting documents, both nationally and internationally. Twitter & Mastodon - #dranaqueiros

Workshop 4: A global ensemble of comparable marine ecosystem models to project climate risk to species and human communities

Juliano Palacios Abrantes
Institute for the Oceans and Fisheries, UBC, Canada

I am a multidisciplinary scientist motivated to answer complex, real-life questions threatening the ocean and its social-ecological systems. I am particularly interested on how climate change is affecting the oceans and the management and conservation of marine resources. Currently, I hold a position as a Postdoctoral fellow at the Institute for the Oceans and Fisheries for the University of British Columbia.

Overall, my research focuses on three main areas that relate to ocean health and responsible usage of marine resources: i) the management of shared fisheries under a changing world, ii) exploring the social-ecological impacts of climate change to conservation and iii) improving fisheries management and marine conservation in Latin America. These are complex narratives which require a mix of quantitative and qualitative methods, interdisciplinary collaborations, and genuine partnerships with local not-academic institutions.

I support collaborative interdisciplinary work and I believe that all scientific work (and data) should be public and open access. As a Brazilian-Mexican citizen, I am committed to support policy-making and resource management decisions in Latin American countries with a strong interdisciplinary science. In parallel with my research, I work with different governmental and non-governmental organizations to tackle important problems facing fisheries and marine conservation in Latin America.

Workshop 5: S-CCME/SICCME Workshop on integrated modeling to identify climate change tipping points in marine ecosystems

Christian Möllmann
Institute for Marine Ecosystem and Fisheries Science, Center for Earth System Research and Sustainability (CEN), University of Hamburg, Germany

Christian Möllmann is Professor of Fisheries Science at the Institute of Marine Ecosystem and Fisheries Science, University of Hamburg, Germany. He holds a PhD from University of Kiel, Germany, and conducted a Post-Doc in Copenhagen, Denmark. The research of his group addresses changes in structure and functioning of marine ecosystems under anthropogenic pressure such as climate change and fisheries exploitation. The ultimate goal of his work is to contribute to a sustainable, ecosystem-based management that considers the needs, world views and potentials of resource users and stakeholders involved in fisheries systems. While based in the natural science, his approach is increasingly transdisciplinary, involving direct interaction and knowledge creation with non-scientific individuals and groups. A major part of his present research is on regime shifts and tipping points in social-ecological systems related to fisheries.

Session Abstracts

Session 1: Marine spatial management supporting climate change adaptation and mitigation

Convenors:
Ana Queiros (Corresponding), (Plymouth Marine Laboratory, UK)
Caitirona Nic Aonghusa, (Marine Institute, Ireland)

Invited Speakers:
Lodewijk Abspoel, (Ministry of Infrastructure and Water Management, Netherlands)
William Cheung, (Institute for the Oceans and Fisheries, The University of British Columbia, BC, Canada)

Climate change is redistributing ocean biodiversity, including species and habitats we want to protect as well as exploited marine resources. These changes challenge the effectiveness of Marine Spatial Planning processes. Climate-adaptive solutions for the spatial management of the ocean are therefore a global ambition for policy developers. We invite examples from around the world, where climate change evidence is informing the design of spatial mechanisms supporting adaptive management practices. Case-studies focused on observational, modelling, social science and science-policy dialogue are welcome contributions, including those focused on adaptive climate change mitigation solutions, when showcasing approaches currently implemented or in development.

(S1-16371 Invited)

Achieving climate-resilient nature futures for the ocean through marine spatial management

William W. L. **Cheung**[1]

Institute for the Oceans and Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada, V6T 1Z4

The ocean's capacity to sustain life and support human wellbeing is increasingly threatened by intensifying climate change that exacerbates other non-climatic human stressors such as overfishing, pollution, and invasive species. Solutions to achieve 'desirable' ocean futures that support climate mitigation and adaptation, sustainable food production, and biodiversity conservation are urgently needed. Here, we examine the pathways through which marine spatial management contributes to solving the challenges at the nexus of climate, food and biodiversity dimensions. We first examine the compounded risks from climate change-caused impacts and multiple non-climatic stressors on marine ecosystems and their dependent human communities. We then explore the pathways through which spatial management can address these compounded risks and contribute to climate, food and biodiversity goals. We elucidate the effects of climate change in exacerbating key uncertainties and potential trade-offs of spatial management as a solution to achieve different nature futures perspectives. We highlight how scenarios and models with participatory approaches can be used to facilitate the co-development of climate-resilient spatial management that bring together knowledge and perspectives from stakeholders, right-holders and knowledge holders. Illustrative examples from diverse social-ecological context from the tropics to the Arctic, including those in Indonesia, British Columbia, Beaufort Sea and the high seas are used to highlight the importance of considering social-ecological context in MSP. Overall, this study provides insights into the key considerations in developing climate-resilient MSP to achieve nature futures.

(S1-16467 Invited)

Climate change predictions (for) and actions in Marine/Maritime Spatial Planning

Lodewijk Abspoel

European Integrated Maritime Policy, MSP and North Sea
Ministry of Infrastructure and Water Management, The Hague, The Netherlands

Ecosystem based Marine/Maritime Spatial Planning (eMSP) is a holistic policy instrument to tackle a wide range of societal issues. Issues in focus of eMSP are spatial and temporal and deal with space in the ocean, seas, coasts and the connected land-sea interactions. eMSP is a politically guided and stakeholder driven process to make well informed decisions on the use/protection of marine space. The concrete maritime spatial plan is usually set for a period of 6 to 10 years. To bring in the future perspective beyond this period in eMSP a vision is recommended for the ocean space under view.

In terms of (1) the effects of Climate Change in the eMSP focus area, (2) the mitigation challenges, and (3) the adaptation needed to take appropriate actions, predictions on these three aspects are needed. Hence moving from vision to prediction in eMSP, and stretching the temporal scope of our plans.

In the North & Baltic Sea Regions this upcoming mindset for eMSP practise is driven by the acceleration in deployment of offshore renewables aiming for a net-zero carbon footprint by 2050 and protecting and restoring nature to a net-gain.

Safeguarding a future for our ocean and the services it provides in changing climate conditions asks for action now, also in eMSP. This leads to three relevant science to policy questions: (1) What can we do, based on the evidence and predictions at hand? (2) Where do we need to be precautious and accelerate our knowledge? And (3) What type of eMSP governance for our sea basins is suited to bring us the ocean we need for the future we want?

(S1-15849 Oral)

Bright spots as climate-smart marine spatial planning tools for conservation and blue growth

Ana M **Queirós** [1], Elizabeth Talbot[1], Nicola J Beaumont[1], Paul J Somerfield[1], Susan Kay[1], Chris Pascoe[1], Simon Dedman[2], Jose Fernandes[3], Alexander Jueterbock[4], Peter I Miller[1], Sevrine F Sailley[1], Ginaluca Sará[5], Liam M Carr[6], Mel C Austen [7], Steve Widdicombe[1], Gil Rilov[8], Lisa A Levin[9], Stephen C Hull[10] , Suzannah F Walmsley[10] and Caitriona Nic Aonghusa[11]

[1]Plymouth Marine Laboratory, United Kingdom
[2]Hopkins Marine Station, Stanford University, United States of America
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[4] Facutly of Biosciences and Aquaculture, Nord University, Norway
[5]University of Palermo, Department of Earth and Marine Science, Laboratory of Ecology, Italy
[6]National University of Ireland Galway, Ireland
[7]Plymouth University, United Kingdom
[8]National Institute of Oceanography, Israel Oceanographic and Limnological Research Institute, Haifa, Israel
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[10]ABPmer, United Kingdom
[11]Marine Institute, Ireland

Marine spatial planning addressing ocean climate change ("climate-smart MSP") is a global aspiration supporting economic growth, food security and ecosystem sustainability. Ocean

climate change ("CC") modelling may become a key decision-support tool for MSP, but traditional modelling analysis and communication challenges prevent their broad uptake. We employed MSP-specific ocean climate modelling analyses to inform a real-life MSP process; addressing how nature conservation and fisheries could be adapted to CC. We found that CC may render the planned distribution of these activities unsustainable during the policy's implementation, leading to a shortfall in its sustainability and blue growth targets. Supporting adaptation, we then identified: CC refugia (areas where the ecosystem remains within the boundaries of its present state); CC hotspots (where climate drives the ecosystem towards a new state, inconsistent with each sectors' present use distribution); and for the first time, identified bright spots (areas where oceanographic processes drive range expansion opportunities that may support sustainable growth in the medium-term). This method allows the identification of where sector-relevant ecosystem change is attributable to CC; resilient delivery of conservation and sustainable ecosystem management through MSP; and harnessing of blue growth opportunities where they may exist. Capturing CC bright spots and refugia within protected areas is an opportunity to meet sustainability targets whilst supporting fisheries under changing climate. By capitalising on the natural distribution of climate resilience within ocean ecosystems, such climate-adaptive spatial management strategies are nature-based solutions limiting the impact of CC on ocean ecosystems and dependent blue economy sectors, delivering climate-smart MSP.

(S1-15856 Oral)

The challenges of the sustainable management of tropical fisheries in the face of climate change

Elizabeth **Talbot**[1]; Jean Beth Jontila[2]; Benjamin. J. Gonzales[2], Roger G. Dolorosa[2]; Recca Sajorne[2], Edgar D. Jose[3], Sevrine Sailley[1], Susan Kay[1], and Ana De Moura Queirós[1]

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Tropical marine fisheries substantially contribute to societal well-being, particularly in coastal communities dependent on fisheries for food security, livelihoods and economic development. However, tropical capture fisheries are increasingly vulnerable to several climate change impacts, affecting the habitat distribution and abundance of fish stocks and consequently, fisheries production. Understanding the impacts of climate change on tropical marine fisheries is therefore an important step towards developing sustainable, climate-adaptive fisheries management measures. We used spatial meta-analysis to assess species distribution modelling datasets for key species targeted by the Philippines capture fisheries, using the province of Palawan as a case study. We analysed datasets under two global emissions scenarios (RCP4.5 and RCP8.5) and varying degrees of fishing pressure to quantify potential climate vulnerability of the target community. Pelagic species in particular were negatively impacted by climate change. Abundances were projected to decline across much of the case study area, highlighting the challenges of maintaining food security in the face of a rapidly changing climate. We argue that reducing global emissions is critical if the Philippines capture fisheries sector is to be sustainable. Management strategies must also allow for the mitigation of, and adaptation to, pressures already locked into the climate system for the near term. Our work may support the latter, providing fisheries managers with the means to identify potential climate change hotspots, bright spots and refugia; supporting the development of adaptive, "climate-ready" management plans; and highlighting what can be done to support sustainability, rather than focussing only on what will be lost.

(S1-15934 Oral)

The future of aquaculture for the Atlantic Surfclam *Spisula solidissima*: Offshore *In situ* observations and multi-stressor laboratory experiments

Laura **Steeves** and Daphne Munroe

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Aquaculture, or the farming of aquatic organisms, is the fastest growing food industry globally, and its sustainable expansion depends on careful selection of both where to establish farms, and which species to farm. Although aquaculture farms are often established in protected coastal areas, farming in the open ocean presents an opportunity to farm where space is less competitive and water quality is often higher. The Atlantic surfclam (*Spisula solidissima*) is a widely distributed species along the Atlantic coast of North America, and in the United States is the most fished clam species by weight. However, the fishery is currently facing potential loss of fishing areas due to the approval of offshore wind developments that overlap with fishing grounds. Further, changing ocean conditions (primarily temperature) are driving shifts in surfclam habitat. Offshore aquaculture is an opportunity to support surfclam production while maximizing production in offshore waters. Selecting a site for offshore farming requires consideration of both current and predicted future environmental conditions that will promote the successful growth and survival of surfclams. For this project, we are collaborating with fishing industry partners to explore the potential for the surfclam to be cultivated at commercial scales in the open ocean through an experimental farm. Further, to examine how changing ocean conditions in potential aquaculture areas may impact surfclam survival and growth rates, we will use laboratory experiments to observe surfclam performance (feeding, absorption, excretion, metabolic, and growth rates) at ambient and stressful levels of temperature and carbonate chemistry (reflective of ocean acidification).

(S1-15989 Oral)

How can multi-criteria analysis support the design of climate-smart marine spatial plans?

Océane Marcone

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Climate change is already impacting the marine environment and related human activities, therefore it is crucial to design efficient Marine spatial planning (MSP) that account for and addresses those climate-driven changes, known as climate-smart MSP.

Conceiving management alternatives that account for climate change is key to the design of climate-smart MSP but, it is just as important to address sociocultural and economic issues and to deal with the various preferences and values of interested parties. How can multi-criteria analysis (MCA) support the design and implementation of climate-smart MSP?

Multi-Criteria Analysis are decision-support tools designed to systematically explore the advantages and disadvantages of different management options and to unveil trade-offs between them. MCA assess the performance of management alternatives based on a set of criteria (defined with experts and interested parties) deemed key for the decision considered. Such a method can help identify the most preferred alternative, rank the management options, short-list a subset of alternatives or highlight acceptable and unacceptable options.

The UK-based MSPACE project is using the MCA approach to identify management alternatives that are climate-smart, economically viable and socially acceptable. We will introduce the approach adopted to transparently synthesise the extensive and various information (data, biophysical and economic models, values and preferences of interested parties) needed to support the design of climate smart MSP in four case study sites.. MCA implementation challenges such as data needs and stakeholders engagement will also be discussed as well as possible ways to overcome them.

(S1-16080 Oral)

Developing Marine Spatial Plans in India to support the Blue Economy under climate change

M V Ramana Murthy[1], Tune Usha[1], Sisir Kumar Dash[1], Satya Kiran Raju[1], Prashant K Srivastava[2], A Muthamma[3], Thirup Vipin Babu[4], Harendra Kharakwal[5], Vikranth Raja[6], Lene Buhl-Mortensen[7], Kerry M Augustsson[8], Eva Degrée[8], Erik Olsen[7]

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India's EEZ covers nearly 2 372 298 km^2 of coastal and oceanic waters, supporting an increasing coastal population, with great importance for local livelihoods, ecosystem health and the national economy. In 2022 a draft Blue Economy Policy was presented by the national government, where the development of Marine Spatial Plans for all of India's ocean areas was identified as a key activity to reach the policy goals. To initiate this process MSP are being developed for two pilot areas, Puducherry on the Indian mainland, and Lakshadweep Islands in the Arabian sea west of India. The development process has been streamlined through the use of the same national GIS resources, but the focal objectives of the plan differ between the two areas. Puducherry is a densely populated region on the main-land where tourism, fisheries and coastal protection are key issues, while in the Lakshadweep Islands fisheries, energy production, coastal livelihoods and indigenous culture/society are the key issues. For both areas planning is carried out under scenarios for future climate change and how it will impact all aspects of the social and ecological systems.

(S1- 16083)

Designing a large-scale Marine Protected Area network in a warming Mediterranean Sea

Clea **Abello**, Bruno Ernande, Fabien Moullec, Nicolas Barrier and Yunne Shin

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Climate change can have decisive effects on the effectiveness of Marine Protected Areas (MPAs) due to induced changes in species composition, spatial distribution of species, physiology and demography. Identified as a biodiversity hotspot, the Mediterranean Sea is also one of the fastest warming ocean regions. In the context of a required increase in the extent of protected areas in the Mediterranean Sea in line with international objectives (30% of protected areas by 2030 of which 10% under high protection), this study aims to evaluate the impacts of climate change on the ecological efficiency of different large-scale MPA networks scenarios. Using an integrated modelling chain including a high-resolution regional climate model, a regional biogeochemistry model and a food web model (OSMOSE), we quantified the cascade of impacts of climate-induced changes in the spatial distribution of fish and primary production under a high emission scenario (RCP8.5) for the periods 2022-2050 and 2071-2100. Future projections on species biomass and fisheries catches under climate change were compared with present biomass and catches and according to different MPA network configurations, either randomly drawn or suggested from the scientific literature. By undertaking a systematic comparison between the outcomes of a diversity of MPA scenarios and expliciting fish population dynamics under climate change, our study brings some insights on large-scale spatial planning in a warming Mediterranean Sea.

(S1-16088 Oral)

Mapping global fishery management for climate change readiness using Marine Stewardship Council (MSC) fishery assessment scores

Lauren M. **Koerner**[1], Catherine Longo[1], Beth Polidoro[1,2], Rohan J.C. Currey[1,3]

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Climate change readiness of fishers and management institutions can largely be affected by the governance systems in place. Several studies have tried to understand global patterns of species shifts and changes in productivity, and conceptualized what key traits of governance systems can help better respond to impacts of climate change. Evaluating the global governance landscape can provide key information on the presence of climate-resilient management traits. One standardized way of evaluating fisheries management structures is through the Marine Stewardship Council (MSC)'s Fisheries Standard.

The MSC program is an incentive system using market recognition through its ecolabel to recognize sustainable fishing practices. Third-party assessors audit fisheries against the MSC Fisheries Standard to evaluate whether they meet its 28 Performance Indicators on sustainability of the stock, ecosystem impacts, and effective management, which determine whether the fishery can be MSC certified.

With 539 fisheries worldwide in the MSC program as of 31 March 2022, MSC hosts a unique asset of independently assessed scoring details on fishery management indicators. As part of a global climate change risk assessment being conducted by MSC, this study, for the first time presents a spatially explicit map of fisheries' management sustainability scores using MSC indicators as a proxy. Here we present the spatial structure and patterns found in MSC governance scores, we discuss insights gained into appropriate scale and data coverage for measuring climate resilience in different locations, and we illustrate next steps for the project.

(S1-16273 Oral)

Marine spatial planning under a changing climate: adaptation approaches for marine social-ecological systems

Sara **García-Morales**[1], Elena Gissi[2,3], Yorgos Stratoudakis[4], Francisco Andrade[1], María José Martínez-Harms[5] and Catarina Frazão-Santos[1,7]

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Marine spatial planning has been used as a holistic, strategic, and operational instrument to support the sustainable use and management of the ocean but several challenges, such as climate change, can compromise its efficacy. From both conceptual and operational perspectives, marine spatial planning can incorporate climate change to ensure more adequate management responses by improving adaptation capacity, building social-ecological resilience and reducing the risk of maladaptation. The present work focuses on two management approaches with highly relevant results to promote adaptation to global climate change in marine spatial planning processes: adaptive management and anticipatory zoning. These approaches simultaneously present a high relevance to achieving Sustainable Development Goals 13 and 14, respectively, "Climate Action" and "Life Below Water", and related targets. This work highlights the potential benefits of using adaptive management and anticipatory zoning to support climate-smart marine spatial planning, and analyses how these approaches differ from alternative, less appropriate procedures and outcomes (i.e., anticipatory bidding for future use rights). Decision-making processes related to marine conservation and ocean management must build on integrated and comprehensive perspectives, and use approaches that simultaneously consider the environmental and human dimensions of the area of study. In a changing ocean, adaptation approaches that recognise such interdependencies are of the utmost relevance to support sustainable marine spatial planning.

(S1-16383 Oral)

MSPOLAR project: Marine spatial planning in Polar regions

Catarina **Frazão Santos**[1-3], José C. Xavier[4,5], Elena Gissi[6], Tundi Agardy[7], Charles N. Ehler[8], Renuka Badhe[9], Kevin A. Hughes[5], Susie M. Grant[5], David Santos[2], Sara García-Morales[2], Catarina Pereira Santos[2,3] & Rui Rosa[1,2]

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The Arctic and Antarctica are changing rapidly, with potential repercussions around the planet, particularly for sea-level rise, ocean circulation, climate regulation, and marine ecosystem structure and functioning. With the acceleration of global environmental change, and the increase of human activities and related pressures in these regions, developing sustainable, ecosystem-based, climate-smart marine spatial planning (MSP) processes is crucial. Despite MSP global acceptance, no formal MSP initiatives are envisioned for the Antarctic and Southern Ocean. Concomitantly, while benefits of developing sustainable MSP have been recognized for the Arctic Ocean, a much needed "Pan-Arctic" MSP initiative is still to be developed. This is a critical oversight in a rapidly changing world. This talk will present the recently funded MSPOLAR project, which aims to support the development and implementation of sustainable MSP in polar regions. The project will take an interdisciplinary, holistic approach to address three main research questions, namely: (1) How can a sustainable, ecosystem-based, and climate-smart MSP initiative be developed in Antarctica? (2) How can a transboundary, Pan-Arctic MSP initiative be implemented in the Arctic? (3) What are the crosscutting challenges and opportunities to developing MSP in polar regions, and what are the potential solutions that can be designed based on lessons learned? Answering these questions is a challenge of paramount importance as it will provide needed and novel insights on a topic that plays a vital role in shaping the future of our changing planet.

(S1-16442 Oral)

Rethinking climate change spatial governance for the Gulf of Guinea region: The Need to enhance regional approaches to the threatened seas

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Sixteen coastal countries in the Gulf of Guinea (GoG) region of Africa are concerned by climate effects on the waters under their respective jurisdiction. Notably, several initiatives such as the WACA program or the MAMI WATA project have been set in place within the region and relatively benefited a few countries, resulting globally in increased and variable vulnerabilities of individual countries and their adjacent sea; especially those in the central African sub-region. Following the ongoing United Nations Decade on Ocean Sciences, the agenda 2063 of the African Union, and the mandate of regional conventions such as the Abidjan Convention, this document reflects on these initiatives together and argues that there is need for a more integrated regional approach to

climate governance in the GoG region, that would expand on the traditional practice to sea level rise, coastal protection and community adaptation for example, to take into account (i) the marine transboundary aspects of the climate threats, (ii) the need to strengthen regional efforts to spatial climate-smart accounting mechanisms, and (iii) the need to commit for a unique momentum across the region.

(S1-16465 Oral)

Making marine spatial planning more climate smart across marine basins - first lessons from a communities of practice based approach in the Baltic and North Sea areas

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Marine spatial planning (MSP) is widely applied to tackle complex marine issues such as climate change (CC), ecosystem health, and sustainable energy and food provision. The demands on oceans by various stakeholders do not always align and MSP has to cope with various uncertainties. Engaging stakeholders, citizens and scientists and finding workable mechanisms is a key challenge when developing MSP as a formal and informal practice. MSP occurs in a context of institutional complexity with varying responsibilities across borders and levels and a fragmented system of knowledge provision. A chain of international projects, financed by the European Union, has set out to address these challenges. Making MSP across marine basins more climate smart is one focus of the cross-border collaboration project *Emerging ecosystem-based Maritime Spatial Planning topics in North and Baltic Sea Regions*, running 2021-24. The consortium encompasses marine planning and data agencies from 9 countries around the Baltic and North Sea, international organisations, and knowledge actors. To promote collaborative learning, a reflective communities of practice approach was chosen, inspired by Dutch work in the North Sea. Researchers and practitioners and project external participants collaborate in five thematic communities of practice: data and knowledge, ecosystem based approach, monitoring and evaluation, ocean governance, and sustainable blue economy. Regular mentoring sessions and a scientific advisory board provide method input, reflection and scientific back-up. Using surveys, observation and documents, we showcase the project as cross-country collaboration forum to deal with CC and share first concrete lessons on how the communities are addressing it.

POSTER BOARD ID: S1-P1
(S1-15836 Poster)

Future-proofing marine conservation planning in the Northwest Atlantic Ocean

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Climate change is altering marine ecosystems on local to global scales and is projected to do so for centuries to come. Marine conservation agencies can use short- and long- term projections of species-specific or ecosystem-level climate responses to inform marine protected area managers conservation planning, yet integration of climate change adaptation, mitigation and resilience into marine conservation planning is limited. Here, we analysed future trajectories of climate change impacts on marine animal biomass and six key physical and biogeochemical drivers across the Northwest Atlantic Ocean, to evaluate the consequences for Marine Protected Areas (MPAs) and Other Effective area- based Conservation Measures (OECMs) in Atlantic Canada. We also identified climate change hotspots and refugia where the environmental drivers will most change or remain close to their current state by 2050 and 2100. To do so, we used standardized outputs from the Fisheries and Marine Ecosystem Model Intercomparison Project and the 6th Coupled Model Intercomparison Project. Our analysis revealed that no existing marine conservation areas in Atlantic Canada overlap with identified climate refugia. Most established MPAs and almost half of the established OECMs lie within climate hotspots. Our results provide important long-term context for climate change adaptation and future proofing spatial marine conservation planning and decision-making in Canada and the Northwest Atlantic region.

POSTER BOARD ID: S1-P2

(S1-15905 Poster)

Projections of suitable habitat for vulnerable species and commercial fish: how will fisheries allocation and conservation objectives be affected?

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Climate change is expected to result in shifts to distributions of marine organisms, including protected species and commercial fish. We describe projections from models, showing the future suitable habitat for 21 vulnerable species, and 49 species of commercially valuable fish and shellfish in the Exclusive Economic Zone (EEZ) of the United Kingdom. We employed an ensemble of species distribution models together with downscaled climate projections for three different climate change scenarios. Of the fish species examined, around half were projected to witness consistently more suitable habitat within the UK EEZ in the future (e.g. black seabream, sole, red mullet, sardine, cuttlefish, anchovy), and for the rest, the seas will become less suitable (e.g. wolfish, halibut, cod, saithe, lemon sole, herring). Of the vulnerable species, which included biogenic reef-building species and ecosystem engineers, decreases in suitable habitat were anticipated, although for other species including vulnerable elasmobranchs, the models showed a general increase in suitable habitat. The increases tended to be focussed in the north and central North Sea, with decreases in suitable habitat located in the English Channel and the Irish Sea. These modelling studies tell us which areas may remain suitable for certain designated

conservation features (species or habitats) in the future, or which commercial fisheries species will persist within national jurisdictions and thus be available for continued sustainable exploitation.

POSTER BOARD ID: S1-P3

(S1-15931 Poster)

Towards estimating marine ecosystem impacts of geoengineering

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An increase in global temperature from 1.5 degrees Celsius to 2 degrees Celsius compared to the pre-industrial period (1861–1880) will pose significant risks to marine biodiversity, fisheries, and ecosystems. Recent comprehensive assessments suggest that large-scale mitigation efforts to limit warming to crucial thresholds are falling short. Geoengineering, broadly defined as deliberate large-scale manipulation of the environment to counteract anthropogenic global warming, is rapidly receiving attention as all future climate projections exceed the 1.5 degree warming threshold, at least temporarily. Geoengineering-driven changes in global temperature and hydrological cycle intensity can impact the ocean in many ways – for instance, by altering the loss of sea ice and the stratification of the water column, with consequences on ocean biogeochemistry, nutrient distributions, and oxygen concentration. There is a high level of uncertainty in how marine ecosystems will respond to geoengineering scenarios. We explore the potential tradeoffs of three geoengineering schemes on marine ecosystems, with a particular emphasis on fisheries. We distinguish regional vs. global proposed efforts and summarize research pathways for marine ecosystem models to synergize with existing and forthcoming geoengineering simulations. We also emphasize the need to consider what fields will be chosen as model input such that they are best for generating metrics that will be used to inform the decision context. This review represents a critical first step in identifying and prioritizing research pathways for the marine context in geoengineering and highlights the importance of incorporating ocean-, ecosystem- and fisheries-based metrics in future decisions related to climate intervention.

POSTER BOARD ID: S1-P4
(S1-16053 Poster)

Digital twins of the ocean – opportunities to inform sustainable ocean governance

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The Digital Twin Consortium defines Digital Twins (DTs) as 'a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity.' Recent advances in High Performance Computing and Earth System Model resolution have enabled the Earth Science community to envision DTs as an innovative approach to global environmental problems.

Digital Twins of the Ocean (DTO) merge marine system models with observational data and machine learning analytics to produce virtual replica of the real ocean. In addition to natural phenomena, DTOs can include socio-economic factors (e.g. ocean-use, pollution). DTO can be used to monitor the ocean state, but also to simulate 'what-if' scenarios for varying human interventions. DTOs can be used by many stakeholders: by scientists to understand the ocean, by policy makers to make well-informed decisions, by citizens to improve ocean literacy. DTOs are tailored to a specific ocean area or purpose, hence a DTO framework is needed to implement data connectivity and interoperability, ease of access, standards and highlight gaps. DTOs offer the technology for building a social-ecologically integrated ocean ecosystem with observation- and modelling networks that support sustainable ocean governance.

The UN Ocean Decade Program DITTO advances worldwide collaboration between scientists, data and IT experts with the ambition to establish effective design and operation of DTOs.

The Digital Europe Programme lists DTOs as one of the technologies that realize Europe's digital and green ambitions. Several projects aim towards implementing DTOs, like Iliad for localized twins and blue economy, a public DTO core, and others.

POSTER BOARD ID: S1-P5
(S1-16367 Poster)

A holistic approach to support the adaptation of global marine conservation to the impacts of climate change.

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The United Nations Convention on Biological Diversity (CBD) is discussing protecting 30% of the world's oceans by 2030. Among the most prevalent strategies for achieving these targets is closing areas of the ocean to extractive activities such as fishing. However, as climate change shifts species distributions, the effectiveness of spatial management tools to protect marine biodiversity and fish biomass is challenged. Here, we rely on an integrating assessment model forced by outputs from an ensemble of a new-generation Earth System Model from the Phase 6 of the Coupled Model Intercomparison Project (CMIP6) under different scenarios of marine conservation to investigate adaptation and mitigation pathways for achieving conservation goals under climate change. Our results are presented in a holistic way accounting for the consequences of climate change to global ocean conservation targets (e.g., biomass or biodiversity), and the economic (e.g., fishing revenue in surrounding areas) and social (e.g., protection of culturally important areas) components of human communities dependent of the ocean. This modelling exercise generates valuable knowledge to inform pathways for international ocean conservation efforts under a changing world. Thoughtful future designations of conservation areas are needed in regions where the effects of climate change may be severe, but also in areas where species will most likely be moving in the future.

POSTER BOARD ID: S1-P6

(S1-16372 Poster)

Promoting Sustainable Marine Planning in the Arctic and Antarctic

David Santos, Rui Rosa, Renuka Badhe, Charles Ehler, Susie Grant, Kevin Hughes, Anton Van de Putte, José Xavier, Catarina Frazão Santos

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The Arctic and Antarctic regions are two of the Earth's most unique places, both enshrining a range of environmental, scientific, historic, and intrinsic values that need to be protected. With the acceleration of global environmental change, and the increase of human activities and related pressures in these regions, developing sustainable marine spatial planning planning (MSP) and governance processes is crucial. Several studies have addressed the benefits and challenges of developing MSP in polar regions. However, and despite MSP global acceptance, no formal MSP initiatives are envisioned for the Antarctic and Southern Ocean. Concomitantly, while benefits of developing sustainable MSP have been recognized for the Arctic Ocean, a much needed "Pan-Arctic" MSP initiative is still to be developed. This is a critical oversight in a rapidly changing world.

The present study analyses and discusses how to support the development and implementation of sustainable, ecosystem-based, climate-smart marine spatial planning (MSP) initiatives in Polar regions. More specifically, it does so by (1) investigating the existing MSP initiatives and governance mechanisms for the Arctic and the Antarctic; (2) identifying the main challenges, issues, and constraints related to such initiatives; and (3) pinpointing a set of recommendations to overcome identified challenges and support a sustainable use of the ocean in polar regions supported by MSP mechanisms, especially under a changing climate. The study builds on a global survey conducted online, specifically on MSP and Polar Regions, which collected over 200 responses from c. 31 countries. Results highlight that the most identified human pressures and challenges in these regions pertained to climate change and the loss of ice-dependent species, followed by new navigation routes and the demand for new conservation areas. As for respondents' knowledge on MSP initiatives applicable to the Arctic and the Antarctic, several initiatives were identified, although many did not correspond to actual marine spatial plans. The most identified challenge for the development of MSP initiatives in polar regions pertained to realpolitik factors, followed by the integration of social and cultural dimensions, or access to monitoring and evaluation tools. At the same time, the Antarctic Treaty System has been considered as a successful example of international governance. Nevertheless, to respond to climate change and the increasing demand for economic development, new specific goals and objectives need to be established.

POSTER BOARD ID: S1-P7

(S1-16384 Poster)

Lessons learned from project OCEANPLAN: Marine spatial planning in a changing climate

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The acceleration of global warming and increased vulnerability of marine social-ecological systems affect the benefits provided by the ocean. Spatial planning of marine areas is vital to balance multiple human demands and ensure a healthy ocean, while supporting global ocean goals. To thrive in a changing ocean though, marine spatial planning (MSP) must effectively integrate climate change. Project OCEANPLAN (2018-2022) focused on exploring the interconnections among climate change, MSP, and ocean sustainability. It highlighted management challenges, identified potential pathways to guide action towards the effective integration of climate impacts in MSP, and raised awareness and fostered discussion on the topic at the global level. In this talk, the key results and lessons learned from OCEANPLAN will be presented and discussed, together with needed next steps in climate-smart MSP research.

Session 2: S2: Smart fishing for climate change mitigation and adaptation

Convenors:
Jose A. Fernandes (Corresponding), (AZTI, Spain)
Pingguo He, (University of Massachusetts, USA)
Kayvan Pazouki, (University of Newcastle, UK)
Karl-Johan Reite, (SINTEF, Norway)

Plenary Speaker:
Antonello Sala, (Italian National Research Council, Italy)

Invited Speaker:
Carlos Groba, (Marine Instruments, Spain)

Recent high impact scientific publications show that global wild fish landings are now the same as twenty years ago, but requiring 20% more fuel while climate change is likely to reduce landings. Moreover, fuel use in capture fisheries emits greenhouse gases, which in turn impacts the capture fisheries. Recent technological and scientific advances can help adapt to climate change and mitigate emissions from capture fisheries. The term 'smart' is starting to be used to highlight how the primary sector of the economy can benefit from these developments. This session aims to gather the latest research on evaluation of fuel use and emission, strategies to reduce fishing-related emission, and measure to adapt to climate change in capture fisheries, and will serve as the foundation of a 'smart fishing' transition decade aiming to reduce emissions from fishing by up to 50%.

The session will cover topics (but not limited) on fishing gear and fishing vessel design and operation, new and efficiency engines and fuel types for fishing vessels, measures to monitor fuel use and emission, use of artificial intelligence for selective fishing and route optimization for fuel consumption reduction, and means to adapt to and mitigate climate change in fisheries.

(S2-15947 Plenary)

Carbon footprint and contribution of marine capture fisheries to global energy use

Antonello **Sala**[1] and Emilio Notti[1]
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Coherent monitoring of the energy profile of fishing vessels may efficiently highlight inefficiency sources, enabling the deployment of informed and economical corrective measures. We conducted energy audits on three major trawl fisheries in the Mediterranean: the midwater pair trawl, the bottom otter trawl, and the Rapido beam trawl. On average, these fisheries use 2.9 litres of fuel per kilogram of fish landed, however the rate of fuel use varies greatly depending on the type of gear and vessel size. This amount of fuel burned from capture to landing generates approximately 7.6 kg·CO2/kg fish on average. Another crucial component to lowering fishing's environmental costs may be minimising effects and energy use along the whole supply chain. Our results provided a set of recognised benchmarks that can be used for monitoring progress in this field and contribute to quantify fuel inputs and GHG emissions for the global fishing fleet.

(S2-16476 Invited)

Essays in logistics optimization: Algorithms for solving the Traveling Salesman Problem in dynamic scenarios

Carlos Groba

VIGO, Pontevedra, Spain

We face the optimization problem of tuna vessels recovering FADs. The study addresses the synergies from combining a heuristic method with a predictive technique to solve the Dynamic Traveling Salesman Problem (DTSP). Our empirical evidence stems from the recovery of fish aggregating devices (FADs) by tuna vessels.

After this first study we focus on solving the problem from a more generalized approach: how to optimize the recovery of FADs from a group of vessels that are sharing information about their FADs. To solve this, we delve into the mTSP (multiple Traveling Salesman Problem), which is a widespread phenomenon in real-life scenarios, and has been addressed using multiple perspectives in recent decades. However, mTSP in dynamic circumstances entails a greater complexity that recent approaches are still trying to grasp. Beyond time windows, capacity and other parameters that characterize the dynamics of each scenario, moving targets is one of the underdeveloped issues in the field of mTSP.

Based on historical real data provided by GPS buoys attached to the FADs, we first estimate their trajectories to feed a genetic algorithm that searches for the best route considering their future locations. We build a genetic algorithm that feeds on Newton's motion equation to show how route optimization can be improved when targets are constantly moving. Thus, although valid for static cases for both the TSP and Vehicle Routing Problem (VRP), the main contribution of the presented solutions over existing literature lies in their application as a global search method to solve TSP and mTSP with moving targets in many dynamic real-life optimization problems.

(S2-15901 Oral)

The VISTools project - Fishing vessels as automatic data-gathering platforms - a win-win for fishers and scientists

Lancelot **Blondeel**, Pedro Rappé, Brahim Al Farisi, Anthony Van De Sompele, Wim Allegaert, Els Vanderperren and Hans Polet

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A skipper of a fishing vessel has access to various sources of information that help in managing his/her work. Conventional on-board equipment track the location (e.g., GPS), monitor fishing activity (e.g., towing force), measure fuel consumption and register landed catch (i.e., via an electronic weighing scale). This equipment gathers valuable data, but none of that are of any use if data are not integrated, stored or processed.

By automating data collection from these sources and coupling this information with economic parameters (e.g. fish prices and fuel prices), the VISTools-project developed (1) a reliable IoT solution for fishing vessels, (2) a business intelligence tool for fishers and (3) a framework for sharing data for research purposes. With this approach, fishers gain new insight in the economic performance of their fishery, while exchanging valuable high resolution data with research institutes.

The current system is operational on 5 vessels, with a planned upscaling to the entire Belgian fleet in 2023. The fleet-wide coverage of the data offers new avenues for research including catch prediction and fuel-efficiency models. To develop this case, ILVO is participating as a pilot in the development of the Digital Twin of the Ocean, where the fuel data from VISTools will be enriched with oceanographic and meteorological data to better understand the fuel consumption of fishing vessels within the marine environment. With these models, decision support tools can be developed that balance the trade-offs between the profitability of a vessel, and reducing fuel consumption and the impact on the environment.

(S2-15903 Oral)

How could UK fisheries move towards Net Zero by 2050?

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Aspiring to mitigate human-induced climate change, UK Government has committed to reaching 'Net Zero' carbon emissions by 2050. Fisheries, however, typically use fossil fuels for propulsion and many other activities, so the question arises: How could UK fisheries move towards Net Zero by 2050? In a recent analysis of 'at-sea' carbon emissions by the UK fishing fleet, we found that total emission levels are still substantial (estimated as 802 and 702 kt CO2e in 2019 and 2020). However, there have also been significant emission reductions: down by 32% over a 15-year period (from 1150 and 1065 kt CO_2e in 2004 and 2005), during which total fisheries landings showed some fluctuations but generally remained stable. While recent trends indicate significant progression can be achieved, major change will still be needed to fully reach Net Zero. A 'roadmap' of pathways for reducing emissions in fisheries, should incorporate (1) technological changes (e.g. propulsion, fuel types, electrification, port facilities); (2) operational changes (e.g. fishing methods, gear design, trip planning); and (3) policy changes (e.g. management of fisheries, ports and the maritime sector generally). Only in combination, and through partnership between industry, science and policy could these ultimately lead to carbon neutrality, while maintaining sustainability and profitability for fisheries.

(S2-15904 Oral)

Decarbonization of the fishing sector – outcome of a pilot study for the European Parliament

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There are many opportunities for fisheries to mitigate greenhouse gas emissions. Whereas other animal-based production systems also include complex biogenic emissions, emissions from fisheries are primarily driven by their current dependency on fossil fuels during fishing and potential use of climate-forcing refrigerants. Fisheries also show major variability in emissions which may indicate improvement potentials. For example, gear use, target species, stock status, fishing strategies, vessel and navigation technology – all influence fuel efficiency. This also implies that emission cuts are associated with different challenges today. This study has reviewed the state of the art regarding status and knowledge gaps related to different fisheries' energy

and refrigerant use, opportunities and challenges for emissions cuts including implementation of renewable energy solutions for fishing vessels. Different mitigation measures have been evaluated in terms of their reduction potential and feasibility through interviews with relevant expertise in different areas including industry. The most promising opportunities and pressing challenges will be presented, as well as an identified path towards decarbonization of the fishing sector in the EU and what is needed to achieve it.

(S2-15946 Oral)

SusTunTech project: a showcase of FAIR data generation from fishing vessels

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Fishing vessels have been increasing their CO_2 emissions over 20% despite catches remain quite constant during the last two decades. The improvement of fishing grounds selection and routes optimization using artificial intelligence and numerical ocean model forecasts could reduce emissions significantly. However, models require as much as possible oceanographic in-situ data to provide the best forecasts. Although data collection capacity has increased in the last years, there is still a substantial gap in the open sea databases and there is also a gap in their storage, processing and openly sharing. Fishing vessels benefit directly from the improvement of the ocean forecasting models and they can also directly contribute to providing in-situ measurements needed for the models, collected while they are fishing in large areas of the open sea. Validation process, together with QA/QC tests guarantee the suitability of these in-situ collected data to be used by the ocean models. However, datasets need to be provided under FAIR (Findable, Accessible, Interoperable and Reusable) principles to ensure their accessibility and exploitation. In this sense, SusTunTech project aims to be a showcase of datasets generated from fishing vessels as Vessels of Opportunity to see how to achieve these useful datasets using fishing vessels as cost-effective oceanographic data gathering platforms. The final aim is to obtain datasets, according to the requirements of the main global data repositories (such as Copernicus or EMODNet), following their quality requirements and under the FAIR principles.

(S2-15980 Oral)

Fishing route optimization to enhance the economic and environmental sustainability

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Ship routing methods offer an opportunity to the fishing industry to enhance its efficiency, sustainability, and safety. However, the use of decision support systems in the optimization of routes, which have been widely used in the shipping industry, is limited in the case of the fishery. This work introduces a general framework for fishing route optimization decision support systems (FRODSS) and describes the dynamic fishing routing problems (DFRP) for a tuna fishing fleet. Furthermore, a new mathematical formulation is proposed for the DFRP, which is solved with a commercial solver (CPLEX) for small size instances. However, for real case instances an exact algorithm is not able to solve the problem within a reasonable time. Hence, we propose a heuristic algorithm to solve real case instances, which are based on real data from a fishing fleet. To validate and test the proposed heuristic performance, a comparison with the CPLEX results is carry out. In addition, a more realistic application of the proposed heuristic is compared with different historical fishing trips of tuna purse seiners, showing a potential saving in fuel consumption and time at sea of around 50% and 30%, respectively. However, this comparison is not fully equivalent due to the assumption made and the problem modelling. Therefore, the use of a FRODSS can assist skippers in the fishing planning process, and also help the fishing industry to mitigate and adapt to climate change while decreasing one of their main operational costs.

(S2-15990 Oral) REVISION: Oral Presentation CANCELLED.

Smart fishing towards sustainable fisheries in times of rapid change: results and perspectives from the skipjack tuna fishery in the southwestern Atlantic Ocean

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The southwestern Atlantic Ocean (SWAO) is among the most prominent warming hotspots worldwide. We conducted a Fishery Improvement Project for skipjack tuna (*Katsuwonus pelamis*) fishing in the SWAO. In 2012, we started working with a fleet of 6 vessels, with a 25 years long experience, depending mostly on sardines as live-bait. Between 2012-2013, we tested and introduced successfully anchovy (*Engraulis anchoita*) as an alternative bait. Anchovy was available much closer to the summer fishing grounds, in comparison to sardines, decreasing the time and displacements required for bait fishing. A decision tool based on oceanographic data was installed on all vessels. Our team had an extra license to monitor the fishing area and develop a crew training program. From 2014-2021, we collected fishing data to define optimal

ranges in environmental variables for supporting smart fishing within a dynamic oceanographic environment. A reduction of up to 30% in fuel use was achieved with the alternative bait and filters applied to oceanographic variables. Fishing hotspots were described by catch data and 3D maps of bottom topography, indicating that most profitable fishing grounds were related to shelf break peculiarities and feeding aggregations near frontal areas. Sardine was an important prey item, and we explored the effects of environmental conditions and El-Niño events in skipjack and sardine (*Sardinella brasiliensis*) catches between 1992-2017. A sequence of positive temperature anomalies reduced skipjack catches by 50%, while sardine production decreased by 85%. We suggest that during strong El-Niño events, there may be an increase in Brazil Current influence, and also a decrease in upwelling strength, wind intensity, and nutrient supply. Our study will support smart fishing initiatives and may be useful to understand the effects of climate change on fisheries in the SWAO.

(S2-16094 Oral)

Evaluating consumption-side approaches to reduce carbon emission in fisheries via Life Cycle Assessment

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Globally, commercial fishing remains an important source of protein with most commercial stocks either fully exploited or overfished. Fishing can be a carbon intensive activity with emissions primarily stemming from fuel use by vessels. There is now increasing focus on how to reduce emissions from fishing activities, both from the sector itself and among retailers and consumers. Carbon emissions can be reduced by either improving fishing technology or management to reduce fuel use (decarbonizing production), or by steering consumers towards more low-emission products (decarbonizing consumption). The latter requires product-specific carbon footprints to be calculated and that the sector must in principle supply more of specific fish products to meet the increasing demand. Carbon footprints are calculated by means of life cycle assessments (LCAs) building on complex models, often retrospectively ('attributional' LCA). However, from the point of view of consumption, we would argue, due to the limited capacity of the fishery sector to increase supply it is the changes in production triggered beyond such sector that are driving the emissions. What happens when consumers are driven to demand more of specific fish and when fisheries - based on a limited resource - cannot necessarily respond by increasing production? This can be in principle addressed by including constraints to production in a 'consequential' LCA model. Our work intends to contribute to an open discussion of how fish products are assessed through LCA and how it can best be ensured that changes in consumer behavior lead to lower emissions.

(S2-16149 Oral)

Using machine learning to reduce CO2 emissions and bycatch in tuna purse seine fishery

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Recent research has highlighted that fish catches have remained stable for the last 20 years, whereas the fishing fleet fuel consumption has increased by 20% with the consequent greenhouse gas emissions. Tropical tuna purse seine fleet is among the most fuel-intensive fishing fleets mainly due to the distance travelled searching and sailing to fishing grounds. The present study aims at contributing to more sustainable and cleaner fishing (catching the same amount of target tuna, with less fuel consumption and lower bycatch). The machine learning probabilistic models can predict areas of high tuna biomass, with a low rate of areas incorrectly forecasted as good fishing grounds (i.e., false positives), and excluding areas of high bycatch risk. Yet some good fishing grounds with high biomasses are missed. The reduction of fuel consumption due to the reduction in the effort devoted searching for optimum fishing grounds would be a contribution to mitigate climate change consequences by fishing industry while also reducing their operational costs.

(S2-16310 Oral)

Integrative surface-to-bottom carbon footprint of fisheries: economic benefits and sustainable fishing of contrasting Mediterranean fisheries

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Ensuring economically viable, sustainable and low CO_2 emissions of extractive fisheries is critical in the most overexploited region of the world: the Mediterranean Sea. We developed an integrative assessment of the CO_2 emissions combining different gear, vessel size classes as well as a wide range estimation of low spatial resolution carbon release from the seafloor by bottom trawling of the Western Mediterranean commercial fisheries (Alboran Sea, Northern Spain and the Balearic Islands). We also consider detailed socio-economic and ecosystem indices of the trophic structure of extractive fishery.

While sea surface CO_2 footprint of purse seine and bottom trawling is among the lowest of animal protein production, our results evidence that considering sweeping released CO_2 from the seafloor the bottom trawling footprint becomes the animal protein production with the highest CO_2 footprint. Moreover, the lowest bottom released CO_2 estimation overrides 3-10 times the CO_2 buried in the seafloor through the biological pump in trawled areas. Net profit per fuel derived of CO_2 emission for all fleets is lower than 1 € $kgCO_2^{-1}$, being the lowest for large trawlers (0.025 € $kgCO_2^{-1}$). We evidence spatial variation of the carbon footprint, with the Alboran Sea requiring a reduction in purse seine fishery and Northern Spain a reduction in trawling. Our results provide the scientific basis for urgent mitigation and adaptation measures

needed to obtain sustainable fishery in terms of net profit, sustainable seafood extraction and CO_2 emission reduction through an integrative assessment of different sources of CO_2 emissions and spatial variation of fleets.

(S2-16312 Oral)

A green portfolio? - Trends in CO2 efficiency in North Atlantic fisheries

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To meet our sustainability challenges, capture fisheries need to produce nutritious food with a low CO2 footprint (emissions of CO2 equivalents per edible weight). Maintaining healthy fish stocks is crucial for energy efficient fisheries, but recent research underlines that the types of fish targeted matters greatly; emissions per edible weight can be many times higher for some seafoods than for others. Thus, if the portfolio of target species in fisheries change over time – for natural, economic or management reasons – so will the CO2 footprint . Moreover, while technology-driven improvements in energy efficiency are potential drivers of reduced emissions in fisheries, these effects are often obscured by changes in stock abundance, or even negated by the effects of overfishing. Here, we combine catch and fuel use intensity data to explore the long-term development of the CO2 footprint in Norwegian fisheries. The portfolio-based CO2 footprint in Norway shows no clear trend over time, though peaks in CO2 footprint coincide with drops in small pelagic catches. Building on this analysis, we then expand our scope to the Canadian East Coast. Here, we find that the shift to an invertebrate-dominated fishery after the collapse of the groundfish fishery in the 1990s has greatly increased the CO2 footprint. By showing how emissions of the whole fishery depend on target species and their abundance, our analysis highlights the potential role that both managers and consumers can play in decreasing the CO2 footprint of fisheries.

POSTER BOARD ID: S2-P1 **Revision: moved to S2-Oral presentation**
(S2-15916 Poster)

Evaluating the effect of oceanic environmental factors on narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Taiwan Strait using ensemble modelling: An approach towards sustainable development

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Ocean resources are crucial to the future of our planet because of the essential ecosystem services it provides and it is effected by the overfishing and climate change. Overfishing can be reduced or knowledge about habitat changes due to climate changes can be gained by having the knowledge about the habitat preferences of any species (SDG 14.6). Present study tried to depict the habitat preferences and distribution pattern of Spanish mackerel before the proportion of species stocks can be maintained within the biologically sustainable levels (SDG 14.4). A generalized linear based model with various standardizing factors used to standardize the Spanish mackerel data supplied by the Taiwan Fisheries Agency. The standardized catch per unit effort of Spanish mackerel was at peak mainly near the sea surface temperature, sea surface chlorophyll, sea surface salinity, mixed layer depth, sea surface height, and Eddie kinetic energy of 24.5-25.5°C, 0.41 mg m^{-3}, 34.2 psu, 11 m, 0.62 m and 0.661-0.724 m^2s^{-2}, respectively. Statistical analyses confirmed sea surface height and sea surface chlorophyll as the top contributors for describing the distribution and Eddie kinetic energy as with least important. No significant biasedness was observed in the predictive performances of single-algorithm models and used to construct ensemble habitat model. Higher standardized catch per unit effort was mainly distributed from 117-119^{0}E and 22-24^{0}N throughout the year followed by the predicted catch per unit effort. In conclusion, habitat modelling is one of the good approach before moving towards sustainable fishing that can leads to eco-system-based fisheries management.

POSTER BOARD ID: S2-P2
(S2-15919 Poster)

Fishery-based adaption to climate change: the case of migratory species grey mullet in Taiwan Strait, Northwestern Pacific

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Because of the vital ecological services that the oceans provide and because they are impacted by climate change, they are essential to the future of our world. Knowing the habitat preferences of any species can help to learn more about how habitats are changing because of climate change. The Grey mullet one of the most important commercial species in Taiwan. It migrated into the coastal waters of the southeastern Taiwan Strait around 22-25°N.for spawning in wintertime, while the feeding grounds are located in the coastal and estuarine waters of China around 25-30°N. The PDO and ENSO index play a role in affecting the migration, but increases in SSTs may be a main reason for the decreased catches after 1980. Annual catches considerably dropped and continually remained at an extremely low level during the period of 1986 to 2010. This work investigate impacts of climate variability in fishing conditions and fishing variability of mullet fishing grounds in the coastal waters of Taiwan. Due to the subsequent decreased catch, the types of fleet with fishing methods in the coastal waters of Taiwan were changed from the purse seiner with two boats before 1986, to the drift net and trawl net as the abundance was at the low level between 1990 to 2010. Recently, the fleet with the Taiwanese purse seiner was dominant when the abundance increased since 2012. It suggested that the fishing fleet was significantly changed and autonomously adapted with the catch of grey mullet in the Taiwan waters.

S3: Assessing climate change vulnerability of marine and coastal areas and associated communities

Convenors:
Scott Heron (Corresponding)
(James Cook University, Australia)
Jon Day
(James Cook University, Australia)

Invited Speakers:
Jon Day, (James Cook University, Australia)
Scott Heron, (James Cook University, Australia)
Mercy Mbogelah, (Ruins of Kilwa Kisiwani and Ruins of Songo Mnara World Heritage Site, Tanzania)

Marine and coastal protected areas are at the forefront of impacts from climate change. There is an urgent need to assess climate change vulnerability systematically and rapidly. This session will incorporate existing tools used to evaluate the vulnerability of the values recognised within protected areas but also include assessments of the vulnerability to economic, social and cultural aspects of the associated community. Applications of climate change vulnerability assessments to all types of marine and coastal protected areas are welcome, including for locations recognised internationally (World Heritage, RAMSAR), nationally (national heritage/trust, MPAs) and locally (First Nations land/sea country, community-based).

(S3-15958 Invited)

Preserving 'One of the most beautiful cities of the World': Results from the Climate Vulnerability Assessment (CVI) of the Ruins of Kilwa Kisiwani and Ruins of Songo Mnara World Heritage Site and its value to Archaeology Heritage Management.

Mercy Mbogelah, Revocatus Bugumba, Jon Day, Scott Heron, and Will Megarry.

Climate change is the single largest threat facing cultural and natural heritage globally. Directly and indirectly, climate hazards threaten both the archaeology and physical structure of sites, and also their associated communities. It is amongst the most important issues in archaeological heritage management as climate hazards impact both surface structures and subsurface archaeological deposits. These hazards are and will be accurately felt on the continent of Africa and there is a need for a systematic tool to assess their future impacts. In October 2021, the CVI Africa project ran a workshop with stakeholders from the Ruins of Kilwa Kisiwani and Ruins of Songo Mnara World Heritage Site in the United Republic of Tanzania to apply the Climate Vulnerability Index (CVI). Most participants met in Tanzania with others joining online, including from the UK and Australia. Using downscaled climate projections, the vulnerability of both heritage and socio-economic values to climate hazards were explored. To facilitate wider participant and international engagement, the workshop was preceded by a series of seminars, the outputs of which fed into the workshop and its subsequent report. The background to the wider project, the workshop and its results will be presented in this paper which will also explore lessons learned from the first ever application of the CVI technique on the continent of Africa.

(S3-16322 Invited)

Assessing the climate vulnerability of coastal and marine World Heritage properties

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Climate change is impacting natural and cultural heritage around the world, including locations with one of the highest levels of recognition: World Heritage. With further climate change impacts projected, even in best-case scenarios, there is an urgent need to systematically assess climate vulnerability. We present outcomes from applications of the Climate Vulnerability Index (CVI) in World Heritage properties located in coastal and marine areas, as well as giving context from other properties. The CVI is a values-based, science-driven and community-focused process that employs the vulnerability framework approach from the Third and Fourth IPCC Assessment Reports. The CVI process begins by deriving key values from the Statement of Outstanding Universal Value (OUV), the foundational description of the recognised values for all World Heritage properties, and then assessing their current condition and recent trend. Two major assessments – the vulnerabilities of the OUV and of the associated community – are complemented by several other outcomes, including adaptive strategies for potential implementation; and the identification of knowledge gaps, research opportunities and policy needs. In coastal and oceanic properties, the CVI has been applied both in-person and online (during pandemic-related travel limitations) and in several modes: Snapshot (a small number of property managers assess only OUV Vulnerability), Consult (a larger group, including members of the community, assess both OUV and Community Vulnerability) and Workshop (a diverse group of participants provide broad perspectives to assess the two major assessments). The CVI has now successfully demonstrated its utility across a diverse range of World Heritage properties.

(S3-16325 Invited)

Expanding and enhancing assessments of climate vulnerability using the CVI

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Whilst initially developed for application to individual World Heritage properties, the Climate Vulnerability Index (CVI) approach has been further progressed to expand and enhance applications for protected areas that are vulnerable to impacts from climate change. One approach has been to identify thematically-grouped World Heritage properties (i.e., those that have similar attributes that contribute to their Outstanding Universal Value) and then evaluate the potential impacts from climate-related threats for exemplars of that thematic group. Examples will be discussed based on analyses of (i) specific geographic regions; and (ii) a specific attribute that contributes to the significance of a group of properties. However, climate change is impacting natural and cultural heritage beyond World Heritage, in locations recognised by other international conventions (e.g., Ramsar wetlands) or in areas of national or local significance. In these, the need for a systematic assessment approach for assessing and responding to climate vulnerability has been acknowledged – and, with slight modifications, the CVI has been identified as capable of responding to this need. A further important development of the CVI has been through the collaboration with a First Nations community in Australia, to modify the process for application to traditional land and sea country. This partnership has provided numerous valuable lessons on how to effectively assess climate impacts upon values of significance to First Nations people. Through each of these approaches, the CVI process is proving to be effective in supporting rightsholders' and stakeholders' understanding of and responses to climate vulnerability.

(S3-15819 Oral)

Assessment of flood risk along the Coast OF Rivers State

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Nature-based solutions involves protecting our natural ecosystems, not just our forests but our wetlands, grasslands and marine habitats through locally led projects that support communities. It involves sustainably managing our walking lands and replenishing soil health by growing trees and crops. It also involves bring nature into our towns and cities with connected. These are referred to as Nature-based solutions (NbS) because it combines biodiversity and ecosystem services as an approach in addressing major societal challenges. Through implementing NbS, people build stronger relationships, networks and knowledge which gives them the capacity to adapt and to be resilient in a rapidly changing world. All of these benefits and more support human well-being and biodiversity which are in turn the foundation of sustainable development. Climate change is one of the most pressing existential threats to humanity in recent times. The Intergovernmental Panel on Climate Change (IPCC, 2021) has reported a continued increase in the concentrations of the major greenhouse gases (GHGs). Along the African coastlines, the relative sea-level rise will contribute to an increase in the frequency and severity of coastal flooding in low-lying areas, like the recent flooding in Lagos State (IPCC, 2021). This will impact the ecosystem services aggravating existing environmental conditions (Gallay et al., 2021; Talbot et al., 2018; Kalantari et al.,2018 ; Kundzewicz et al, 2013). Across the globe, there are initiatives established to aid communities adapt to impacts from climate change and to mitigate its effects (Chausson et al., 2020; Kalantari et al.,2018; Kabisch et al., 2017). One approach is the nature-based solutions (NbS).

This study is being carried out in some selected coastal communities in Rivers State, like Kula, Oyorokoto, Bonny etc. The coastline of Rivers State is about 116km (Kelly, 1982), extending from the Ramos to the Imo River. The Niger Delta geomorphic unit is longest (450 km) and the richest in biodiversity and mineral resources. The Niger Delta has Africa's largest expanse of mangroves, which are major breeding and nursery grounds for many commercially important fin and shellfishes, and is rich in biodiversity in the Gulf of Guinea. This study aims to assess the role coastal ecosystems play in reducing flood risk under different ecosystem management scenarios. Using INVEST Coastal Vulnerability model to assess the role of coastal ecosystems in reducing flooding. This study answers this question; Which coastal ecosystem has the greatest potential to protect against flooding? InVEST Coastal Vulnerability model designed by the Natural Capital Project will be used to assess the role of coastal ecosystems in reducing flooding.

(S3-15826 Oral)

Understanding Patterns of Hard Coral Demographics in Kenyan Reefs to inform restoration

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Coral reefs in Kenya are becoming more vulnerable due to climate change and overfishing, which has increased management and conservation efforts to protect them and facilitate their recovery. The study examines the spatial pattern of coral recruits and how it relates to the adult community, including thermal resistance, sensitive genera, and restoration needs. The surveys were conducted between 2020 and 2022 at 48 sites in 24 locations along the Kenyan coast, counting corals in 23 genera using belt transects and 1 m^2 quadrat for all small colonies. A

total of 44 recruits' genera, ranging from 3 at Marereni to 30 at Watamu Marine Reserve were observed. There was a significant difference in recruit density from 1.2±1.5 m-2 at Likoni to 10.3±8.4 m-2 at Kisite Marine Park. Correlation between recruit density and hard coral cover was strong and statistically significant ($r = 0.64$, $p = 0.03$). But negative correlations between recruit density with macroalgae cover ($r = -0.13$, $p = 0.57$), and herbivore biomass ($r = -0.038$, $p = 0.87$) which were not statistically significant. Low-recruit locations like Likoni, Kinondo, and Marereni had high macroalgae cover, low hard coral cover, and herbivore biomass. A strong positive correlation between recruit and adult communities may indicate self-recruitment or distance seedings (of the same recruit genera). However, most locations with high recruit densities were dominated by thermally sensitive genera that could be affected by future thermal stress. Therefore, reducing coral reef threats like overfishing could allow for natural regeneration.

(S3-15868 Oral)

A climate risk index in support of marine conservation

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Climate change is affecting marine life through a complex web of pathways. Depending on the context, these impacts can be beneficial or harmful, making it difficult to understand the net effects of climate on individual species and ecosystems. Notwithstanding these challenges, we must understand how changing climate conditions affect marine life to plan and develop adaptation approaches to protect marine life under climate change. To address this need, my co-authors and I developed the Climate Risk Index, which estimates the climate risk for marine species and their ecosystems under different future ocean scenarios. The risk index is derived from 12 climate indices that express how the innate traits of species, such as their body size and temperature tolerance, intersect with past, present and future ocean conditions at all locations where they exist. The resulting risk scale ranges from negligible (lowest) to critical (highest) and represents both the severity of harmful climate impacts on species and their likelihood of occurring. We used this approach to estimate the global climate risk for ~25,000 marine species and their ecosystems globally. With high emissions, 87% of species are at high or critical climate risk, with the risk being systematically greater for exploited species in low-income countries with high dependence on fisheries. Mitigating emissions reduces the risk for virtually all species (98.2%), enhances ecosystem stability, and disproportionally benefits populations in low-income countries. Lastly, we present ongoing work exploring how this approach could be used to support climate adaptation to fisheries management in Atlantic Canada.

(S3-15902 Poster)

Marine heatwaves in the Cape Peninsula Upwelling Cell, Southern Benguela.

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Due to global warming, marine heatwaves are considered to be one of the emerging threats to marine ecosystems globally. South Africa's fisheries and coastal communities depend on the Southern Benguela's upwelling for the high marine productivity. Marine heatwaves are prolonged periods of extreme warm Sea Surface Temperatures (SST) anomalies which could have severe ecological impacts on marine ecosystems by decreasing biodiversity, negatively affecting cold water species and increasing ocean stratification. Council for Scientific and Industrial Research (CSIR) half-hourly *in situ* SST from the Cape Point station about 5.4 km of the coast, ECMWF Reanalysis 5th Generation wind speed and direction time series from January 2003 to March 2020 were examined to quantify the occurrence, formation and decay of marine heatwaves in the Southern Benguela. The marine heatwaves were identified using the SST values which exceed the 90th percentile of the timeseries for at least five days. In the CSIR SST time series 18 marine heatwaves were identified at the Cape Point station. The occurrence of strong north-westerly winds was found to be the main driver of marine heatwaves. While southeasterly winds was observed to have a large role in the decay of marine heatwaves. Marine heatwaves are expected to worsen with climate change by lasting longer with high temperature increases but an increase in southeasterly winds has led to an observed decrease in the occurrence of marine heatwaves in the Southern Benguela upwelling system.
Key words: Southern Benguela, marine heatwave, upwelling

(S3-15936 Oral)

Analysing shoreline change and evaluation of coastal protection measures in Navsari and Valsad districts of Gujarat, India

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Shoreline change is a gradual natural process, but with increasing anthropogenic activities and climate change, such processes have accelerated. This leads to a direct impact on adjacent coastal populations. The coastline of Navsari and Valsad in southern Gujarat is 96.98 km long and it has undergone significant change from 1985 to 2020. Approximately 60.81 km2 of land area has been eroded in the last 35 years. The protection of the coast from erosion should be done on a long-term basis, keeping in mind the in- depth field investigation and available data which clearly requires observations over a prolonged period of time. However, there are areas where acute steps are crucial to stop the advance of sea erosion and to prevent serious damages immediately, short-term measures will become essential. When we look at the measures that are implemented in the study area we found that mostly seawalls and gabions have been used to prevent coastal erosion towards the land. Not much diversity has been shown in the application protection measures both on the structural and non- structural measures. It is required that the government should look into more viable measures that are successful in the long term. The study evaluates shoreline erosion from 1985 to 2020, using Landsat images, and then with the

support of quantitative and qualitative analysis, it discusses how the protection and prevention of the coast from erosion should be planned on long-term basis and prioritising the particular site conditions.

(S3-15994 Oral)

Cloudiness delays projected impact of climate change on coral reefs

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The increasing frequency of mass coral bleaching and associated coral mortality threaten the future of coral reefs. Even though light plays a central role in the coral bleaching process, future projections of the impacts of climate change on coral reefs have to date focused on temperature change and not considered the role of clouds in attenuating the bleaching response of corals. Here, we develop temperature -and light- based bleaching prediction algorithms using historical sea surface temperature, cloud cover fraction and downwelling shortwave radiation data together with a global-scale observational bleaching dataset. The model is applied to CMIP6 output from the GFDL-ESM4 Earth System Model under four different scenarios to estimate the effect of incorporating cloudiness on future bleaching frequency, with and without thermal adaptation or acclimation by corals. The results show that in the low emission scenario SSP1-2.6 incorporating clouds into the model delays the bleaching frequency conditions by multiple decades in some regions, yet the majority (>70%) of coral reef cells still experience dangerously frequent bleaching conditions by the end of the century. In the moderate scenario SSP2-4.5, however, the increase in thermal stress is sufficient to overwhelm the mitigating effect of clouds by mid-century. Thermal adaptation or acclimation by corals could further shift the bleaching projections by up to 40 years, yet coral reefs would still experience dangerously frequent bleaching conditions by the end of century in SPP2-4.5. Nonetheless, the long-term future of coral reefs remains questionable if the world stays on a moderate or higher emissions path.

(S3-16007 Oral)

Vulnerability to climate change of managed stocks in the California Current Large Marine Ecosystem

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Understanding how abundance, productivity and distribution of individual species may respond to climate change is a critical first step for developing strategies to adapt to and mitigate that change. This study applies the NOAA Fisheries Climate Vulnerability Assessment method to 64 federally-managed species in the California Current Large Marine Ecosystem to assess their vulnerability to climate change, where vulnerability is a function of a species' exposure to environmental change and its biological sensitivity to those changes. Overall, two-thirds of the species were judged to have moderate or greater vulnerability to climate change, and only one species was anticipated to have a positive response. Species classified as highly or very highly vulnerable share one or more characteristics including: 1) complex life histories that utilize a wide range of freshwater and marine habitats; 2) habitat specialization, particularly for areas likely to experience increased hypoxia; 3) long lifespans with low population growth rates; or 4) high commercial value combined with impacts from non-climate stressors such as anthropogenic habitat degradation. Species with low or moderate vulnerability are either habitat generalists, occupy deep-water habitats or are highly mobile and likely to shift ranges. This information will inform near-term advice for prioritizing species-level data collection and research on climate impacts, help managers to determine when and where a precautionary approach might be warranted, in harvest or other management decisions, and help identify habitats or life history stages that might be especially important to protect or restore.

(S3-16030 Oral)

Is the Indian Ocean experiencing the biggest threats of climate change?

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The Indian Ocean (IO) includes several hundred Marine Protected Areas (MPAs). These range from smaller ones along the coasts to the very large MPAs around the French territories in the south and the British Chagos in the central IO. The MPAs are established to reduce fishing pressure on threatened species, to protect coral reefs, mammals, and in some cases whole ecosystems. However, MPAs and the protected biodiversity are increasingly being impacted by climate change. The IO provides ecosystem services to about one third of the global population vulnerable to climate impacts. This large marine ecosystem has been subjected to unprecedented rising temperatures during the last two decades, with recent climate scenarios identifying that surface warming in the IO is the highest among the world oceans. Rapid ocean warming due to climate change is regarded as the main cause for the rise in marine heat waves (MHWs). Increasing ocean acidification over the last four decades, together with frequently occurring MHWs, put protected coral reefs at high risk with habitat and diversity loss of vital species. In addition, seasonal changes in monsoon primary productivity and its intensity observed in the coastal upwelling areas due to warming will threaten the rich and diverse shellfish, fish, and mammal populations in the northern region. Strategic responses to the impact from these fundamental changes in protected areas are vital. Here, we present vulnerability assessments of key abiotic and biotic components of the ecosystem to climate change and discuss management measures for sustainable fisheries in the region.

(S3-16074 Oral)

Insights into fish asymptotic length from the world's hottest sea and implications to fisheries

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Models projecting the size of fish indicate shrinking fish under continued ocean warming. One primary fisheries implication of such projections is a reduction in yields. The Arabian/Persian Gulf ("Gulf") is the world's hottest sea, with temperatures reaching 34–36 ^{o}C in the summer; these temperatures also drop precipitously during winters. Given these thermally extreme conditions, the Gulf's marine ecosystem is considered as "natural laboratory" that can provide a present-day view of future warming impacts on fish and habitats elsewhere. Here, we compare fish species of a wide range of asymptotic lengths (18–178 cm) in the Gulf to their counterparts in the adjacent, more environmentally benign Oman Sea; then, we ask: what are the implications of smaller asymptotic sizes on fisheries yield per recruit. We find that species in the Gulf have consistently smaller asymptotic lengths than those in Oman Sea. Additionally, when other fish vital rates (e.g., natural mortality, growth coefficient) are assumed equal for species in both locations, our outcomes are consistent with findings that fish of lower

asymptotic lengths have decreased yield per recruit. However, when vital rates of each species are set based on location, results from yield per recruit become variable: lower asymptotic lengths do not necessarily result in a reduction of yield per recruit. Our findings suggest that while smaller fish are found in the warm waters of the Gulf, the impacts on fisheries yield may depend on other vital rates in addition to asymptotic lengths.

(S3-16117 Oral)

Future extreme wave events in the Mediterranean Sea by 2100

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Climate change impacts threaten coastal areas all over the world, driven by increasing extreme sea levels. With higher sea surface and air temperatures, continued sea-level rise and high exposure and vulnerability of about 20 million people living in low-lying coastal areas, climate change affects the Mediterranean Sea significantly more than the world average and is therefore defined as a vulnerability hotspot. Projected changes in waves vary on a regional and local scale and play a crucial role in future extreme coastal water levels and coastal impacts. Several past studies used GCMs with coarse spatial resolution to study the future changes of wave climate. However, wave models driven by high-resolution dynamically-downscaled surface winds from RCMs allow an enhanced characterization of wave climate at local scale, which is fundamental for coastal impact assessment and adaptation studies. Here we present the analysis of extreme wave events and their seasonality using a regional ensemble of wave climate projections developed with the numerical wave model Wavewatch III forced by surface wind field data of 17 GCM-RCMs. Future changes for mid-century and end-of-the-century conditions were evaluated for a weighted ensemble mean against a validated hindcast generated with the same setup for 1979 until 2020 and used as reference for the bias correction. Extremes wave events were analyzed by means of the ETCCDI extreme indices rough wave days and high wave days. Additionally, to analyze the future temporal variability in waves extremes, the indices were analyzed seasonally and the temporal variability of the highest percentiles was analyzed.

(S3-16131 Oral)

Effect of climate change on marine benthic animals

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Multiple stressors related to climate change are now threatening ocean ecosystems: 1. Ocean warming 2. Deoxygenation 3. Acidification and 4. Freshening. Ocean warming can actually influence benthic animals more than pelagic animals because movement of benthic animals is restricted within short range. Benthic animals will be threatened when the habitat is out of optimal temperature range. Ocean warming also facilitates deoxygenation. The interaction between high temperature and low oxygen would be more stressful to animals than single stressor would. Ocean acidification is the other CO_2 problem. We should think also CO_2 level in the local areas rather than atmospheric CO_2 level. Recently freshening is a rising concern both in polar regions and coastal areas because of glacial retreat or heavy rains. I will discuss the effect of climatic multiple stressors on benthic animals by showing the recent studies on a variety of benthic animals such as abalones, Manila clams, sea urchins, Antarctic clams and limpets. Most of species are vulnerable to those stressors but there could be also species which have defensive mechanism against climate change.

(S3-16139 Oral)

Climate-driven responses of Mediterranean fisheries across geographic gradients and seasons

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An accelerating rate of warming along spatial gradients is leading to changes in climate velocity, (i.e., speed and direction of isotherm movements). Using climate velocity to assess the threat of climate change has enabled researchers to document global patterns of poleward changes in biodiversity. However, less is known about regional, sub-regional and seasonal responses of commercial marine species, which often represents the efficient scale of management. Using climate velocity as a metric of potential range shifts (1987-2021), we explore how seasons, shifts in fisheries landings (2007-2021), temperature preferences and life-history traits influence the distribution of commercial species in the Western Mediterranean Sea. We found spatial and seasonal differences in climate velocities and some changes in climatic areas (i.e., novel and vulnerable climate areas, climate refugia and climate corridors). The most captured commercial species exhibits a strong relationship with seasonal climate velocity. Shifts in landings also differ in relation to community temperature preferences and life-history traits. Our results suggest that climate velocity is a useful metric that can help to understand regional and sub-regional responses of commercial marine species in the Western Mediterranean Sea. This provides insights into climate-smart management, thereby contributing to the conservation of biodiversity and associated ecosystem services to avoid future maladaptation.

(S3-16170 Oral)

Enlightening Climate Risk Assessments with local Participatory approaches

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Climate change is rapidly becoming one of the biggest threats to marine life, and its impacts have the potential to strongly affect fisheries upon which millions of people rely. This is particularly crucial for the Mediterranean Sea, which is one of the world's biodiversity hotspots, one of the world's most overfished regions, and where temperatures are rising 25% more than in the rest of the ocean on average. To have a better understanding of the current risk for its fisheries we calculated a vulnerability index for 100 species that compose 95% of the Mediterranean fisheries catches, following a trait-based approach. Through the Climate Risk Assessment methodology (CRA) we subsequently assessed all Mediterranean fisheries' risk to climate change based on their catch composition. This work allowed to contrast the southern and northern Mediterranean regions but has shown its limits by only relying on macro indicators, particularly when trying to quantify fisheries' adaptive capacity. Having an accurate understanding of local efforts in management and socio-economic assets is essential to reliably address the adaptive capacity of a community. To address these gaps in knowledge, participatory approaches can help to integrate local knowledge and co-construct adaptive responses while considering scientific

assessments and projections, as well as local perspectives on feasibility, risks, and benefits. With these objectives in mind, we conducted participatory workshops with fisheries' stakeholders in France and Tunisia (case studies in the northern and southern Mediterranean Sea, respectively). Their purpose was to co-construct a semi-structured interview guide that then allowed us to collate further information with a significant number of direct fishers' interviews in the field. Through macro and local approaches that complement each other, we are able to more reliably determine the main challenges and risks faced by Mediterranean fisheries, their main concerns and their current capacity to overcome them.

(S3-16204 Oral)

Socioeconomic vulnerability of coastal communities in Mexico to climate change

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Marine socio-ecological systems dependent on fishing are particularly vulnerable to effects of climate change and global change, such as rising sea levels, acidification, ocean warming, and the increase in the intensity and frequency of climatic phenomena. For communities dependent on artisanal fisheries, the complex interactions between their socio-economic, demographic, and political characteristics may limit their adaptive capacity to respond to climate change. We developed a vulnerability analysis for coastal communities in Mexico, based on the three different components, exposure, sensitivity, and adaptive capacity using existing quantitative indices. To measure exposure we used indices of human impacts, in both the marine and terrestrial environments and under future climate change scenarios. Sensitivity was based on the dependence of each coastal community on fishing and aquaculture, as a reflection of how these economic activities contribute to the economy, well-being, and food security. Adaptive capacity is estimated from indicators that will allow communities to respond and recover after a negative event, under the assumption that communities with a high degree of education and services, a low level of poverty, infrastructure, employment opportunities and economic diversification, and a low degree of disruption in the characteristics of the population, will have a greater capacity to adapt. We found that the susceptibility and adaptive capacity of coastal communities showed wide variability by region, and ultimately drove changes in vulnerability. Our results can be used to design adaptation and mitigation measures at the scale of municipalities and coastal localities.

(S3-16207 Oral)

Model Arctic marine food webs to support sustainable and resilient traditional food systems for future generations of Nunavimmiut.

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Traditional foods are fundamental to the culture and health of Inuit communities. The consumption of processed and expensive market foods places today's Inuit among the most vulnerable to food insecurity in Canada. Climate change and demographics add to the pressure, as shifting seasonal patterns affect the abundance, distribution, and condition of culturally important species such as arctic char, beluga whale, and caribou when the Inuit population is growing three times faster than that of non-native Canadians. In this context, the question arises as to whether there will still be enough traditional foods for future generations in an environment that is in the throes of upheaval. In collaboration with Nunavik partners from several sectors and within the 3 coastal regions (Hudson Bay, Hudson Strait, and Ungava Bay) and thanks to the Ecopath with Ecosim model, this project aims to inventory the annual biomass of the traditional foods of these three marine and coastal ecosystems of Nunavik (Ecopath model), and to assess the impact of environmental and anthropogenic factors on their temporal variation (Ecosim model) to ensure their sustainability and Nunavimmiut food security.

(S3-16213 Oral)

NOAA Fisheries' marine mammal and sea turtle climate vulnerability assessments

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Climate change and the associated changes in coastal and ocean conditions pose significant challenges to management of protected species such as marine mammals and sea turtles.To characterize the relative vulnerability of marine mammals and sea turtles to climate change, NOAA Fisheries developed trait-based climate vulnerability assessment frameworks: the Marine Mammal Climate Vulnerability Assessment (MMCVA) and the Sea turtle Climate Vulnerability Assessment (STCVA). The frameworks combine sensitivity/adaptive capacity (characterized using published literature and expert elicitation) with exposure (characterized using projected climate and ocean conditions within current population geographic ranges) to calculate a climate vulnerability score and relative vulnerability index.

The MMCVA framework has been used for two regional implementations: the first with marine mammal stocks in the western North Atlantic, Gulf of Mexico, and the Caribbean and the second with marine mammal stocks in the Pacific and Arctic. The STCVA framework has been used for a single global implementation with sea turtle Regional Management Units (RMUs) and Distinct Population Segments (DPS).

Factors including temperature, ocean pH, and dissolved oxygen were the primary drivers of high climate exposure across all implementations. Primary drivers of sensitivity/adaptive capacity varied between and within implementations. These assessments provide managers and researchers with population-specific climate vulnerability information that can focus conservation decision-making and seed hypotheses for future study. Results at the regional level highlight species and populations that are most vulnerable to climate change.

(S3-16326 Oral)

The Impact of Climate Change on Indonesia's Fisheries and Coastal Communities

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This talk will describe a multi-institutional collaboration that investigated climate change impact on Indonesia's oceans, fisheries and coastal communities, and adaption options to tackle those impacts. While some understandings on the past and current status of Indonesia's fisheries exist, less is known about the past and potential future impacts of climate change. Previous studies have underscored the exceptionally high impacts and risks of climate change on marine biodiversity and fisheries in the Indo-Pacific region. Developing appropriate and effective policies and actions to reduce these impacts and support climate-resilient development pathways requires knowledge about specific climate risks on marine species and the dependent sectors and communities in relation to their specific social-economic context. To do so we i) conducted a climate impacts and risks assessment and ii) explored adaptation strategies and options. In the first component, published literature, observation-based data and computer simulation modelling outputs were used to elucidate the biophysical and socio-economic risks and projected impacts of climate change on marine ecosystems, fisheries and dependent human communities in Indonesia. In the second component, scenarios and other participatory methods were applied through stakeholder workshops to identify the priority climate risks on Indonesia's oceans, fisheries and coastal communities, as well as to explore potential adaptation strategies. Both components were then synthesized with the aim to support discussions for developing national climate adaptation strategies.

(S3-16330 Oral)

Temperature and food chain length, but not latitude, explain region-specific responses of kelp forests to an unprecedented heatwave

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Over the past decade, unprecedented heatwaves and associated changes in trophic dynamics have altered the abundance and extent of kelp forests in the Northeast Pacific. Although impacts have been documented from Mexico to Alaska, the trajectories of kelp forests remain poorly characterized across large stretches of coast. This is especially true in coastal British Columbia which represents a significant percentage of the range of floating kelp species. In this study,

we explore local and regional variation in floating kelp forest persistence across a >675 km (6^{O}) latitudinal gradient in British Columbia, asking whether kelp forest change is potentially of conservation concern in the province. Focusing on 11 regions that span a range of sea temperatures, we compared aerial imagery from before (1994 – 2007) and after (2018 – 2021) recent warming events to assess changes in kelp extent. We also assembled time series from all available regions (n = 7). We provide strong evidence that kelp forest extent has declined in many regions in response to increased temperatures and urchin prevalence. In southern British Columbia, kelp persistence negatively correlated with local sea surface temperatures, which varied by ~6^{O}C on average. In northern regions, kelp loss was primarily driven by urchins, which have begun to form extensive barrens. However, regions with sea otters had greater kelp persistence between time points than those without. Overall, our results demonstrate that regional and local-scale factors, such as food chain length or ocean mixing, can increase the resilience of kelp forests to climate change-driven perturbations.

(S3-16332 Oral)

Assessment of landscape dynamics of the Kutch Biosphere Reserve (KBR), Gujarat, India: in the context of local marine sustainability Initiatives through geo-spatial mapping

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The coastal region of Kachchh in Gujarat, India, is undergoing major environmental issues, owing to anthropogenic influences in particular. Using satellite images from Landsat TM, ETM, and OLI, this study assesses morphological, total vegetation, water index, and coastline changes during the last three decades (1990–2020). Due to various anthropogenic and natural activities, the study area is constantly changing at an alarming rate. Significant variations in the shape of vegetation and coastline modifications were discovered during an investigation of changes in the coastal region of Kachchh, Gujarat. In addition, for the years 1990, 2000, 2010, and 2020, land-use and land-cover (LULC) maps for the study region are created utilizing the band ratio, followed by a combination of supervised and unsupervised classification. Each dataset is subjected to an accuracy assessment, with overall accuracy ranging from 90 to 95 percent. The purpose of the LULC study is to identify different areas of the region that are vulnerable to environmental degradation. This study shows that the coastal region of Kachchh, Gujarat, is under severe stress as a result of the rapid development of the surrounding artificial landscape, where socioeconomic factors, changes in the immediate environment, and salt production, all have an impact on the quality of the coastal ecosystem and other activities. The maps created as part of this study will aid in the formulation of a sustainable land use plan as well as coastline conservation measures, all of which will contribute to the region's long-term marine sustainability.

(S3-16377 Oral)

Past perspectives on the vulnerability of a unique Arctic ecosystem to climate change: Pikialasorsuaq (The North Water polynya)

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The North Water (*Pikialasorsuaq* in West Greenlandic) is the largest coastal polynya in the Arctic. The marine resources of this highly productive ecosystem have sustained the northernmost human communities on the planet for millennia, and several keystone Arctic species. The opening and maintenance of the polynya are dependent on sea ice conditions in the Arctic Ocean and the consolidation of ice arches across the Nares Strait. Satellite observations have revealed a weakening of ice arches due to climate warming, raising concerns about the future viability of the polynya. To assess its long-term sensitivity to climate, we reconstructed key parameters including ocean circulation, sea ice, primary production, and protist community composition changes through multiproxy analysis of Holocene marine sediment records. Our records indicate a large and productive ecosystem 4400-4200 years ago, coincident with the arrival of the first humans in Greenland. Between c. 2200-1200 years ago, episodes of polynya contraction or failure and productivity decline are coeval with climate changes during the Roman Warm Period and Medieval Climate Anomaly. This past regime shift in the polynya ecosystem was also coincident with human abandonment of Greenland lasting c. 1000 years. After centuries of stability, our marine proxy data reveal polynya instability forced by climate warming and thinning sea ice in the past decades, in line with satellite observations. The Arctic Ocean region is transitioning to a seasonally ice-free regime that is detrimental to polynya formation. These past perspectives highlight the future decline of this unique ecosystem as an important climate change risk.

(S3-16388 Oral)

Micro Level Climate Change Vulnerability Assessment in Fishing Villages in Gulf Of Mannar, Tamil Nadu, India

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Gulf of Mannar Marine (GoM) Biosphere Reserve, located in the southern-most tip of India harbors over 4,223 species of fish and provides livelihood to over 100,000 fishing communities living in the Reserve's buffer zone. They make their living from fishing, seaweed collectiom, or other marine-based activity. There are signs of climatic and non-climatic stressors acting on this ecosystem increasing the vulnerability of coastal ecosystem and livelihood of the fishers. Sea surface temperature has increased by 0.3 degree Celsius and there are instances of coral bleaching and erosion of islands. Vann Island, one of the 21 islands of GoM has shrunk in area by 2-3 hectares due to shoreline erosion in three decades. The destruction of these resource rich ecosystems is impacting livelihood of the fisher-folks as these ecosystems serves as a breeding and nursery grounds to many fish varieties. The current study assessed the vulnerability of 42 villages clustered into ten biophysical zones in 364.9 Km of coast. The vulnerability assessment was conducted in two steps- (a). scoping the vulnerability of the whole ecosystem in a rapid manner by Integrated Coastal Sensitivity, Exposure, and Adaptive

Capacity for Climate Change (I-C-SEA Change) (b). more detailed assessment by method called Tool for Understanding ***Fisheries Resilience*** (TURF). Under both the processes, data on exposure, sensitivity and lack of adaptive capacity are collected and the zones are ranked in order of their vulnerability. The result has been communicated to policymakers for developing the adaptation options for different zones.

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(S3-15804 Poster)

Enhanced ecotoxicity of Gadolinium in a warmer and acidified changing ocean using a multibiomarker approach: the case of the surf clam S*pisula solida*

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Humans have exhaustively combusted fossil fuels, and released pollutants into the environment, at continuously faster rates resulting in global average temperatures increase and seawater pH decrease. Furthermore, climate change is forecasted to exacerbate the effects of pollutants such as the emergent technologically critical rare earth elements. Therefore, the objective of this study was to assess for the first time the combined effects of rising temperature and decreasing pH on the bioaccumulation and elimination of gadolinium (Gd) in the bioindicator bivalve species *Spisula solida.* We exposed surf clams to 10 µg L^{-1} of GdCl3 for seven days, followed by a depuration phase lasting for another 7 days and then investigated oxidative stress-related responses after 1, 3 and 7 days of exposure and the elimination phase. Gadolinium accumulated after just one day with values reaching the highest at T7. Gadolinium was not proficiently eliminated and seems to be less successful under climate change scenarios. Even though no significant differences in Gd concentration were observed between animals exposed to Gd under current conditions, warming, acidification, and warming & acidification conditions, the bioaccumulation factor was greater under climate change and their interaction impacted the clams' biochemical response. Our results showed that Gd impacted the oxidative stress response, however, in combination with Warming further augmented TAC and LIPO while in combination of Warming & Acidification further enhanced SOD and CAT values. Ultimately, lipid damage was greater in clams exposed to warming & Gd, which emphasizes the enhanced toxic effects of Gd in a changing ocean.

POSTER BOARD ID: S3-P2
(S3-15816 Poster)

Large Marine Ecosystems changes under future climate projections

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Human-induced climate change produces significant global environmental effects on the Earth, including in crucial ocean productive areas. These marine ecosystems consist of coastal regions to the seaward boundary of continental shelves and the outer margins of coastal currents. Around the world, there are 66 high-productive regions designated as Large Marine Ecosystems (LMEs), which are classified by their bathymetry, hydrography, trophic relationships, and productivity. The LMEs can produce ~80% of the annual world's marine fisheries catch. Understanding how physical oceanographic (sea surface temperature, SST) and biological (chlorophyll concentration, CHL) conditions have changed and will continue to change is fundamental for marine ecosystems' socio-ecological and economic sustainability. To quantify past and predict future changes, we utilize remote sensing data for the periods 1985 to 2021 for SST and 1997 to 2021 for CHL. Furthermore, from 2022 to 2100, we use global climate projections derived from over 25 models for three future socioeconomic scenarios (ssp126, ssp245, and ssp585). The past and future SST and CHL were standardized and analyzed at monthly and 1°x1° resolution to be consistent with the future climate data. Our results show that while SST increases, CHL decreases globally, with some LMEs having complex SST vs. CHL relationships through to the end of the century.

POSTER BOARD ID: S3-P3
(S3-15839 Poster)

Review of California coastal adaptation and scientific gap analysis

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California's coastal communities face a difficult challenge in adapting to climate change-driven sea level rise and increased threats from erosion, flooding, and other coastal hazards. While many communities are taking bold and decisive steps towards planning and implementing a response to climate change impacts in coastal zones, the approach, implementation status, and science use vary between communities and regions.

The University of California System, through the Coastal Resilience Initiative, aims to enhance the research capacity and leadership of the UC system to address adaptation to climate change along California's coast and other coastal regions. The Initiative has three main objectives: (1) review understanding of coastal hazard impacts, (2) convene scientific experts, and (3) coordinate with communities and other stakeholders.

In this poster presentation, we will present the preliminary findings of the Initiative in California, map out the current adaptation planning process and the science that has informed it, and propose priorities for science-based solutions. We aim to share our initial insight but, even more importantly, seek input for research priorities and solutions-focused science during

the Effects of Climate Change on the World's Ocean conference. Strategies across various coastal landscapes and nations can be incorporated to improve the effectiveness and efficiency of adaptation planning along California's shoreline.

POSTER BOARD ID: S3-P4

(S3-15841 Poster)

Network of marine protected areas in a changing climate in West Africa: An appraisal of vulnerabilities, impacts and adaptive capacity

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West Africa's marine protected area (MPA) network is critical to maintaining environmental resilience and rebuilding declining marine resources. They protect coastal habitats and reduce human vulnerabilities to climate change, including reduction of food insecurity. However, the West African region is challenged to withstand devastating effects of global climate change, despite emitting very little GHG to the atmosphere. We have examined the vulnerability of people and of West African marine protected areas using the IPCC standard vulnerability assessment framework. Our findings reveal that the adaptive capacity of MPAs against climate change in the West African region is only 10% of the actual capacity needed for resilience. This weak capacity can be attributed to climate financing deficit in the region and the degradation of important coastal habitats. Mangrove forests in West Africa have seen net loss of about 980 km^2 over the past five decades. This undermines the capacity of West African states to meet their nationally determined contributions of reducing GHG emissions through sinks. Sea levels for low elevation coastal zones are projected to rise over 1.2m by 2100, creating livelihoods vulnerability for people in MPA communities. The exposure metrics of torrential rainfall, flooding, marine heatwaves, and drought are increasing vulnerability of MPA habitats and ecosystems. We estimated that a CO_2 offset of about 140.05 MtCO2e by mangroves in MPAs are increasing adaptive capacity of people and ecosystems. We recommend tree planting, the upgrade of coastal defenses and early warning systems as sensitive actions against climate vulnerability in West Africa.

POSTER BOARD ID: S3-P5

(S3-15845 Poster)

Long-term impacts of climate change in Indian Sundarbans: An automatic computation & geospatial approach

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The global coastal region witnessed significant change due to the rising sea level and rapid developmental activities, the growing population along the coastal front regions leading to loss of property and ecosystem, therefore, proper monitoring of the dynamic changes along the coastline is essential for the coastal management and conservation. The study was carried out along the Indian Sundarbans, using multi-temporal satellite imagery from 1972 to 2021. The present study estimated the historical shoreline change by using DSAS statistical tools and

analysed spatiotemporal analysis on mangroves to estimate the impact by the shoreline change. The study revealed that the rate of erosion is higher in the river islands where land and ocean meet, whereas rate accretion is observed in the river creeks between river island and mainland coast. The average rate of shoreline between 1972 and 2021 is estimated at 0.64 m/y and -2.65 m/y in mainland and island coastlines respectively. Besides, around 82.99 sq.km area is observed as net loss due to the erosion process, however, total 197.13 sq.km is eroded between 1972-2021 whereas 114.14 sq.km are got deposited during the same period. Long-term trend analysis for the Sundarbans mangroves depicted a greening trend in the river creeks, while browning trend were observed in the sea front coast. Increasing sea level and SST along with the fluvial process are significantly contributed to the shoreline migration and wetland loss. The study indicated that, both ocean and fluvial process are playing keen role in changing shoreline positions.

POSTER BOARD ID: S3-P6

(S3-15869 Poster)

A triple threat: ocean warming, acidification and rare earth elements exposure triggers a superior antioxidant response and pigment production in the adaptable *Ulva rigida*

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Anthropogenic increased atmospheric CO2 concentrations will lead to a drop of 0.4 units of seawater pH and ocean warming up to 4.8 °C by 2100. Contaminant's toxicity is known to increase under a climate change scenario. Rare earth elements (REE) are emerging contaminants, that until now have no regulation regarding maximum concentration and discharge into the environment and have become vital to new technologies such as electric and hybrid-electric vehicle batteries, wind turbine generators and low-energy lighting. Studies of REE, namely Lanthanum (La) and Gadolinium (Gd), bioaccumulation, elimination, and toxicity in a multi-stressor environment (e.g., warming and acidification) are lacking. Hence, we investigated the algae phytoremediation capacity, the ecotoxicological responses and total chlorophyll and carotenoid contents in Ulva rigida during 7 days of co-exposure to La or Gd (15 µg L-1 or 10 µg L-1, respectively), and warming and acidification. Additionally, we assessed these metals elimination, after a 7-day phase. After one day of experiment La and Gd clearly showed accumulation/adsorption in different patterns, at future conditions. Unlikely for Gd, Warming and Acidification contributed to the lowest La accumulation, and increased elimination. Lanthanum and Gd triggered an adequate activation of the antioxidant defence system, by avoiding lipid damage. Nevertheless, REE exposure in a near-future scenario triggered an overproduction of ROS that requested an enhanced antioxidant response. Additionally, an increase in total chlorophyll and carotenoids could also indicate an unforeseen energy expense, as a response to a multi-stressor environment.

POSTER BOARD ID: S3-P7
(S3-15881 Poster)

Climate Change, Global Warming and its Impacts on Oceans.

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An abrupt climate change occurs throughout the world. The levels of greenhouse gas CO2 are increasing in different parts of the world. The other greenhouse gases are water vapors, methane, ozone, nitrous oxide, fluorinated gases. The greenhouse effect is a process that keeps the earth warm enough for people, plants and animals to live on. Over the past decade the surface air temperatures have not risen very much whereas the temperatures of deep oceans have risen very much. Oceans store 97% of world's water. This water absorbed the 90% of energy of the atmosphere. The increase in the energy and temperatures of the earth is due to increase in the greenhouse gases. The human activity is changing the amount of greenhouse gases by three ways. The rain forests are cut down. The fossil fuels are being burned. The world's population has been increased. Global warming is affecting the world. The oceans and atmosphere interact both physically and chemically. They exchange energy, water, gases and particles. This exchange influences the earth's climate. It also changes the state of oceans. The salinity of the oceans has been changed, which accelerated the global rainfall and evaporation, which is responsible for climate change. The sea levels are expected to rise as the water expands due to rise in temperature. The sea levels also rise as a result of melting of polar caps. Rising sea levels impact many coastlines, and a large mass of humanity lives near the coasts or by major rivers. More CO2 in the atmosphere more CO2 in the oceans. This CO2 is dissolved in water and reacts with it forming carbonic acid. The water becomes more acidic. This acidification of water significantly impacts upon the health of some fish and coral species. There are many millions of species in the oceans and each will have different sensitivities to acidification and respond in different ways. It is likely that acidified sea water will alter the makeup of marine ecosystem.

POSTER BOARD ID: S3-P8
(S3- 15894 Poster)

Future changes in joint waves and storm surge events in the Mediterranean Sea.

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Coastal areas around the world are threatened by sea-level variations and extreme waves leading to significant coastal hazards, such as flooding, erosion and damages in coastal protection structures with huge environmental and economic losses. Coastal impacts are induced by the combination of different processes acting at varying spatial and temporal scales such as sea-level change, tides, waves, and storm surge. Locally, storm surge and extreme waves are a predominant factor in many nearshore processes and structural safety of structures. Therefore, there is a need to understand their future joint occurrence under a climate change scenario because the elevation due to one component can be heightened by the presence of the other. Hence, we present the joint analysis of significant wave height and storm surge, by means of copulas functions, in the Mediterranean Sea for hindcast and RCP8.5 projections to assess the variation in the occurrence probability of the joint events of wind waves and storm surge in the future and study if some fixed extreme events are expected to become more frequent in future with a consequent bigger hazard for the most sensitive areas.

The analysis concerns four different locations representative of as many regions of the Mediterranean Sea and it is performed using future projections obtained from several different Global and Regional Climate Models, so the main differences arising will be presented and discussed.

POSTER BOARD ID: S3-P9
(S3-15898 Poster)

Thermodynamics of the local Hadley circulation over Central Africa

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This study describes the local Hadley circulation (HC) during the December-February (DJF) and June-August (JJA) seasons, respectively, in Central Africa (CA) from the divergent component of the mean meridional wind and also from a new method called the variation of the ψ vector. Historical data from the ERA5 reanalysis for the period 1983 to 2013 were used. The results show that the maximum of the upward branch of the local Hadley circulation in the DJF and JJA seasons is located under the Congo Basin (CB). However, seasonal and horizontal variations in the mean temperature gradient and thermodynamic properties are largely associated with the distribution of convection and large-scale upward motion. Thus, temperatures beneath the CB show a slight variation between the DJF and JJA seasons. Moreover, energy transport of the moist static energy (MSE) adequately captures the mean flow component of the HC over the tropics. By the way, the divergence under the CB is enhanced by the presence of the low pressure of western Cameroon and the contribution of the warm and dry air currents coming from the Sahara.

POSTER BOARD ID: S3-P10 – Cancelled.

POSTER BOARD ID: S3-P11
(S3-15920 Poster)

Reports on the prevalence of benthic harmful algae in the Red Sea coast – A potential bioindicators for Climate Change

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Although the Red Sea has long been recognized as a region of high biodiversity and endemism, our understanding of its ecology remains to be highly insignificant which should mainly be incurred to the stagnation of research activities in the region. In such regard of endemism, the Red sea as one of the world's most biodiverse coral reef regions has a significant role to play in our understanding of coral reef ecology at a global scale. As timely reliable reports indicate many of the coral reef environments in the Red sea experience a wide range of comparatively higher sea surface temperature from about 26°C in cold season to more than 32°C in hot season and a salinity range of 36-41psu. This fact has now challenged the argument that the Red Sea is considered as a tolerant ecosystem to such natural disturbances has been put into question when an extensive damage of coral reefs was reported recently in summer 2010 from the coral reef area of the Central Red Sea (CRS) off the coast of Saudi Arabia which experienced a 10–11 degree heating weeks. Global climate change is a continuing reality of unpredictability and increase in temperature is becoming a common scenario which is strongly affecting the marine ecosystems in general and the coral reefs in particular. In general, the Red sea remains hugely understudied muddling up its susceptibility to climate change and thence public awareness of such a challenge is a step towards resolution.

POSTER BOARD ID: S3-P12
(S3-15950 Poster)

Multiple climate change stressors impact fundamental subcellular stress response in marine calcifiers: Novel approaches for stress detection and quantification

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Coastal habitats are already rapidly changing due to climate change, including ocean acidification (OA), warming (W), marine heat waves (MHW). The impacts on ecologically and economically relevant marine calcifiers remain poorly understood. Climate change stressors can trigger subcellular damage, with evident responses such as changes in the mitochondrial integrity and cytoskeleton activity and accumulation of oxidative products, with direct energetic constraints and subsequent physiological impairments. Research approaches related to the measurements on the subcellular level provide an early detection and quantification of stress, with insights into potential energetic implications. We set up lab-based experiments with projected combination of multiple stressors, including W, OA, and food availability, with particular emphasis on the MHW conditions based on the physical and biogeochemical observations over the last 30 years. Based on the rates of the MHW onset and decline, we also conducted experiments to establish the time and species recovery scope. We developed novel subcellular methods to detect and quantify stress by using microscopic, flow cytometry and immunohistochemical techniques focusing specific on the measurements of the mitochondrial integrity and oxidative stress accumulation. Through controlled exposure to stressors, we observed the occurring subcellular changes and quantified stress relationship for economically important Mediterranean mussel (*Mytilus galloprovincialis*) and the invasive green shore crab (*Carcinus aestuarii*). Novel cutting-edge methods offer quick visualization and assessment for the stress response, which is critical in the already stressed coastal and aquaculture habitats towards informed conservation efforts and climate change adaptation.

POSTER BOARD ID: S3-P13
(S3-15957 Poster)

A positive temperature-dependent effect of elevated CO_2 on growth and lipid accumulation in the planktonic copepod, *Calanus finmarchicus*

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C. finmarchicus were reared from eggs to adults at 12 and 16°C with non-limiting food in combination with ambient (600 µatm) and high (1100 µatm) pCO_2. These conditions are likely to be encountered by the species at the southern margins of its biogeographical range by the end of the century. Dry weight (DW), carbon (C) and nitrogen (N) mass, oil-sac volume (OSV), fatty acid composition (FA), and oxygen consumption rates (OCR) were measured on newly molted stage CV copepodites and recently molted adult females. By focusing our measurements on these precise events in the life cycle, we were able to obtain a more accurate comparison of growth and respiration across treatments. Copepods raised at 12°C had a significantly greater

DW, OSV and C and N mass than those raised at 16°C High pCO_2, independent of temperature, was associated with a further increase in the DW and C content of the copepods. Interactive effects of temperature and pCO_2 resulted in a larger OSV at low temperature and high pCO_2. Mass-specific respiration rates were significantly lower at lower temperatures and elevated pCO_2 suggesting that the increase in mass (DW, C and OSV) resulted from reduced metabolic cost. The composition of fatty acids in the copepods varied mainly with temperature. Two fatty acids varied with pCO_2: 16:0 tended to decrease with higher pCO_2 and 18:3n-3 tended to increase with higher pCO_2. These observations suggest that elevated pCO_2 /lower pH in future oceans may have a beneficial effect on *C. finmarchicus*.

POSTER BOARD ID: S3-P14
(S3-15999 Poster)

Cloudiness reduces the bleaching response of coral reefs exposed to heat stress

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Since the 1980s, there has been an increase in mass coral bleaching and associated coral mortality due to more frequent and severe thermal stress. Although most research has focused on the role of temperature, coral bleaching is a product of the interacting effects of temperature and other environmental variables such as solar radiation. High light exacerbates the effects of thermal stress on corals, whereas reductions in light can reduce sensitivity to thermal stress. Here, we use an updated global dataset of coral bleaching observations from 1985 to 2017 and satellite-derived datasets of SST and clouds to examine for the first time at a global scale the influence of cloudiness on the likelihood of bleaching from thermal stress. We find that among coral reefs exposed to severe bleaching-level heat stress, bleaching severity is inversely correlated with the interaction of heat stress and cloud fraction anomalies, such that higher cloudiness implies reduced bleaching response. A Random Forest model analysis employing different set of environmental variables shows that a model employing Degree Heating Weeks and the 30-day cloud fraction anomaly most accurately predicts bleaching severity. Based on these results and global warm-season cloudiness patterns, we develop a 'cloudy refugia' index which identifies the central equatorial Pacific and French Polynesia as regions where cloudiness is most likely to protect corals from bleaching. Our findings suggest that incorporating cloudiness into prediction models can help delineate bleaching responses and identify reefs which may be more resilient to climate change.

POSTER BOARD ID: S3-P15
(S3-16026 Poster)

Impact of climate change, sea level rise and natural hazards in the coastal zones of India

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Indian coasts are highly vulnerable to climate change, storm surges, tsunami and sea level rise, due to the extensive low-lying area, high population density, frequent occurrence of cyclonic storms, high rate of coastal environmental degradation and non-sustainable development. Life of millions of people directly depends on natural resource bases of coastal ecosystems.Three megacities number of growing cities with large population are at high risk. Climate change is reflected in sea

surface temperature and characteristics of tropical storms. Frequency and intensity of cyclonic storms are increasing. Floods associated with heavy rainfall often paralyse life in the coastal cities. Rising sea level may degrade the rich cultivable land and freshwater resources, causing damage to coastal biodiversity and affecting food security. Damage to the nursery areas for fisheries may affect Indian economy, as India is one of the major exporters of fishery products. Changes in SST, upwelling and coastal circulation has already affected the fish population. Studies indicate that mean sea-level-rise trends along the Indian coasts are upto 2.5 mm/year and it may increase to 3.8 mm/year under the A1B scenario. Coastal zones are already under threat from environmental degradation. Coral bleaching has seriously affected fish population. Several social issues such as migration to interior and conflicts over the allocation of land and water can be expected in near future. This paper analyses the multiple issues associated with climate change in the coastal zones of India and critically reviews the existing strategies and policies. Guidelines for an appropriate adaptation strategy have been provided.

POSTER BOARD ID: S3-P16
(S3-16042 Poster)

Adapting to climate change: sustainable livelihood initiative in coastal region of Bangladesh

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The people of southern Bangladesh are gradually forced to change their traditional livelihoods due to natural disasters related to climate change i.e., cyclone, drought, floods, storm surges, sea level rise, saline intrusion etc. Besides, the major problem is identified that the production of paddy and fish are very low due to lack of sufficient fresh water. To lighten these climate change vulnerabilities and to ensure sustainable livelihood practices, this study sought to analyze how integrated farming can contribute to adapt with climate change. Satkhira from southern part are chosen as research area. The research employed both qualitative and quantitative tools to collect data during the study period. The study found capacity building, access to fresh water and adapting with climate-smart farming system options can ensure sustainable livelihood practices for community people. It is enabling higher yields in more saline areas and less land as well as simultaneous cultivation of two varieties of paddy, different types of vegetables, fruits and fish in the same land where one crop used to be. Also, this initiative is reducing the salinity of the topsoil which is making it easier to reduce their agricultural related climate induced vulnerabilities. The findings suggest that strengthening local organization's capacities, arranging diversified training session especially for women and youth, ensuring long-term adaptation strategies, arranging fresh water for both irrigation and fisheries and awareness building can contribute to climate change adaptation in the vulnerable areas.

POSTER BOARD ID: S3-P17

(S3-16054 Poster)

Did changes in surface sea temperature effect human populations of Espíritu Santo Island (Gulf of California, Mexico) during the Holocene?

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Holocene oceanic characteristics can be reconstructed from past surface sea temperatures (SSTs) using stable oxygen isotopes in bivalve shells, enabling the study of climatic patterns and phenomena that affect marine and human communities. The objective of this study is to calculate Holocene summer SSTs of La Paz Bay, by analyzing and comparing *Pinctada mazatlanica* and *Chione californiensis* shells' $\delta^{18}O$ of a ^{14}C dated Holocene shell midden, located in Isla Espíritu Santo, Baja California Sur, México. Aragonite was extracted from each shells' umbo, representing the shells' first summer growth season. Presently $\delta^{18}O$ values of *P. mazatlanica* and *C. californiensis* are -1.8 ± 0.2‰ and -1.9 ± 0.1‰ respectively, varying from -1.2‰ and -0.8‰ to -2.3‰ and -1.8‰ during the last 9.2 ky. $\delta^{18}O$ values (-1.5‰ and -1.9‰) for 9.2 ky suggest similar to slightly colder SST than at present, while enriched values (-1.1‰ to -1.6‰) for 3.8 ky and 3.2 ky suggest colder SST. Finally, between 1.9 ky and 1.5 ky $\delta^{18}O$ values (-1.3‰ to -1.6‰) decreased gradually, suggest a tendency towards current SST. Our results coincide with other paleotemperature studies for the region, allowing for an in-depth analysis of changing SST on this marine resource, and its effects on human presence in the area with respect to climate variability.

POSTER BOARD ID: S3-P18

(S3-16056 Poster)

Biomass and geographical distribution of seven small pelagic fish species in relation to temperature conditions in Mauritanian waters

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The focus of this study was to acquire knowledge to scrutinize raw acoustic backscatter, collected during scientific surveys, onboard R/V Dr. Fridjof Nansen from June 27 to 9 July 2017, researching small pelagic fish resources within the Mauritanian EEZ. To calculate stock biomass index from survey data and relate species distribution to temperature conditions.
Acoustic data were post-processed using the post-processing software Large-Scale Survey System (LSSS) Version 2.0, for data processed after fixing the bottom and surface line, for the surface line we allocate backscatters fish from 10m, then excluding sailing between transects. The acoustic data was preprocessed. Species allocation is based on the species proportion in the catch, and biomass estimate calculated following FAO guidelines. The study results show that temperature influences species' geographical distribution. (Chub mackerel, Atlantic horse mackerel, and sardine prefer colder waters of the northern part of the EEZ and round sardinella, flat sardinella, and cunen horse mackerel prefer the warm waters, of the the central and southern part of the EEZ. Though anchovy and cunen horse mackerel could adapt themselves in both colder and warmer waters from the north to the southern area.The biggest biomass estimate was the anchovy followed by cunen horse mackerel and flat Sardinella, generally, these species were found in a shallower area.

POSTER BOARD ID: S3-P19
(S3-16065 Poster)

Climate Change Impacts on Eastern Boundary Upwelling Systems

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The world's eastern boundary upwelling systems (EBUSs) contribute disproportionately to global ocean productivity and provide critical ecosystem services to human society. The impact of climate change on EBUSs and the ecosystems they support is thus a subject of considerable interest. Here, we review hypotheses of climate-driven change in the physics, biogeochemistry, and ecology of EBUSs and summarize projected changes over the twenty-first century from global climate models. Similarities in projected change among EBUSs include a trend toward upwelling intensification in poleward regions, mitigated warming in near-coastal regions where upwelling intensifies, and enhanced water-column stratification and a shoaling mixed layer. However, there remains significant uncertainty in how EBUSs will evolve with climate change, particularly in how the sometimes competing changes in upwelling intensity, source-water chemistry, and stratification will affect productivity and ecosystem structure. We summarize the projected changes in the processes affecting coastal upwelling across EBUSs, consider implictions of these changes for ecosystem services provided by EBUS, and conclude with an assessment of key remaining uncertainties and questions. Future studies will need to address these questions to better understand, project, and adapt to climate-driven changes in EBUSs.

POSTER BOARD ID: S3-P20
(S3-16097 Poster)

Baltic sediment archives reveal increased loading of carbonaceous pollution from biomass burning

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Black carbon (BC), spheroidal carbonaceous particles (SCP), and polycyclic aromatic hydrocarbons (PAH) are carbonaceous pollutants affecting the climate, environment, and human health. International regulations limit their emissions, and the present emissions are followed by monitoring programs. However, the monitoring programs have limited spatio-temporal coverage and only span the last decades.

We can extend the knowledge of historical emission rates by measuring pollution levels in radiometrically dated marine and lacustrine sediment sequences. Here we use marine sediments as an environmental archive and present data over BC, SCP, and PAH from a sediment core

sampled in the Öresund strait, between Denmark and Sweden and dated back to CE 1850. Our data show a massive increase in the burial rates of all measured pollutants starting in the 1940s. The pollution deposition peaked in the 1970−1980s and declined through the 1990s. However, the declining trend was reversed in the 2000s. Source appointment of PAHs shows a relatively higher contribution of emissions from woodburning since CE 2000. This coincides with a change towards the increased use of biomass for both municipal and regional energy production in Scandinavia. Our results demonstrate that changes in energy production have caused changes in the delivery of carbonaceous pollution to marine environments. The increase in particle emissions from wood burning is potentially posing a future environmental and health risk.

POSTER BOARD ID: S3-P21

(S3-16109 Poster)

How does the climate change impact to the estuarine, coastal ocean and lakes?

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Under climate change, the dynamics of the geophysical and biological nature of estuarine systems and lakes are likely to be influenced by a combination of natural processes and anthropogenic activities. In recent decades, coastal regions around the world have experienced frequent and intense storm activities. Global and regional climate models have predicted exposure of coastal regions to more frequent wet storms in future. In addition, the circulation pattern and wave climate are subject to climate change in the Great Lakes. The Lake Michigan, Chesapeake Bay, and also Maryland Coastal Bays (MCBs), a shallow interconnected coastal lagoon system with two unique inlets, both are actively influenced by climate change, sea/water level variation, and storm surge. The Finite Volume Community Ocean Model was applied to simulate potential impacts of storms including surge, wind, and waves on these systems. It was found that the model simulated currents and lake gyres showed strengthening pattern with Representative Concentration Pathway (RCP) scenarios in Lake Michigan. In the face of rising mean sea level, storm surge will cause further flood damage in addition to the typical responses to winter storms and will also increase breaking wave forces and circulation patterns. Numerical model analysis will be conducted for further investigating the local hydrodynamics and their changes incorporating different large scale hydrodynamic conditions and future climate scenarios during fair and extreme weather conditions.

POSTER BOARD ID: S3-P22
(S3-16127 Poster)

Ecosystem turnover in an urbanized subtropical seascape driven by climate and pollution

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Climatic and anthropogenic factors shape present-day benthic marine ecosystems. Understanding their combined influence on benthic communities is limited, however, by a lack of biological monitoring. Using a conservation paleobiology approach, this study establishes biological baselines and assesses the effects of climatic and anthropogenic environmental changes on benthic communities in an urbanized subtropical seascape. We compared subsurface ("past", covering approximately the last 50–100 years) and surface ("present", covering approximately the last 5 years) faunal assemblages in sediment grab samples in Hong Kong, one of the busiest ports and urbanized areas in the world. Results show that both natural (climate, monsoon) and anthropogenic factors (metal pollution, damming) were associated with recent faunal changes (dissimilarities between subsurface and surface faunal assemblages). Changes in freshwater and sediment discharge from the Pearl River due to monsoon rains and dams produced a strong west-east gradient in the turnover of rare species. Pollution from metals resulted in the turnover of abundant and dominant species in the central part of Hong Kong. Examining these data in the context of published results from other urbanized coastal areas around the world suggests that metal pollution may be important and understudied factor, responsible for benthic turnover in regions where pollution levels exceed thresholds for sediment toxicity.

POSTER BOARD ID: S3-P23
(S3-16141 Poster)

Decadal variability of the Benguela upwelling system with global warming

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The Benguela upwelling system (BUS) is one of the most productive marine systems in the world. However, the system is highly vulnerable to climate change effects, since it has been hypothesized that as global warming proceeds, the land-sea atmospheric pressure gradient increases, intensifying the upwelling favorable winds and consequently leading to several alterations in the upwelling event's intensity and frequency. Such alterations could have drastic changes in the BUS's primary production and the system dynamics entirely. Therefore,

understanding the past changes in the system regarding global warming, is of high importance for anticipating how the BUS might respond to future scenarios.

Thus, a highly resolved 3D coupled physical-biogeochemical model is designed based on NEMO (Nucleus for European Modelling of the Ocean) and BFM (Biogeochemical flux model, for simulating physical and biogeochemical interactions over the last four decades of the 20th century (1980 - 2020). Coupling approach is being conducted as an offline coupling with precomputed physical fields from NEMO and then being interpolated at each time step with the BFM. The model applies online nesting approach to maintain a high resolution and better boundary conditions for the BUS domain. The nesting grid covers the global ocean with a horizontal resolution of 1/4°, while the nested grid for the BUS domain has a resolution of 1/16°, and both grids have 75 vertical layers. The coupled model's structure encompasses most of state variables and processes that represent the BUS comprehensively. Finally, the model is validated using in-situ and satellite observational data.

POSTER BOARD ID: S3-P24

(S3-16150 Poster)

Carbon turnover and sequestration of algal forest communities in shallow rocky reefs along urbanized shores and pristine reefs in the central Mediterranean Sea

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Macroalgal forests are declining worldwide, as a consequence of local and global anthropogenic perturbations. Knowledge on the consequences of these declines in terms of ecosystem functions specifically their blue carbon capacity and services that these ecosystems provide is still limited. In this study, we measured rates of carbon turnover due to photosynthesis, respiration, calcification and CaCO3 dissolution, in benthic algal communities on reefs along an urbanized coast and at a pristine island in the NW Mediterranean, by means of in-situ incubations under dark and light conditions. We found small differences between the pristine and urbanized site, in terms of both producer and animal biomass. Net community production (NCP) and respiration (CR) were also very similar between both sites. Under these circumstances, despite differences in dominant macroalgal and associated species, benthic communities in the pristine and urbanized reefs appear to provide similar blue carbon capacities. This also suggests that urban rocky reefs could support ecologically valuable benthic communities. Ongoing analyses of data collected at other times of the year and the experimental exposure to a marine heatwave will provide additional insights into the role of environmental conditions (e.g., solar irradiance, seawater temperature, nutrient concentrations) in regulating the ecosystem functions and services of these reefs.

POSTER BOARD ID: S3-P25
(S3-16182 Poster)

Towards a systematic review of climate change effects in the Western Mediterranean Sea

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Despite the essential role of marine ecosystems in regulating climate and providing food security and livelihoods for millions of people, the ecological, and above all, socio-economic effects of climate change on the ocean are partially known. In this context, the Mediterranean Sea is particularly interesting as it is surrounded by densely populated areas and it is considered a miniature ocean and a hotspot of biodiversity that is warming faster than other areas of the world.

Here we systematically reviewed the scientific evidence on the effects of climate change in the Western Mediterranean Sea, focusing on the environmental, ecological, as well as social and economic dimensions. Results show an increasing number of papers published that largely target the environmental and ecological effects of climate change, with respect to general publication trends. Publications dealing with environmental effects dominates the literature followed by the ecological ones. Regarding the publications that dealt with biota, the predominant group is the fish species followed by phytoplankton and zooplankton. However, a lack of studies assessing and quantifying the social and economic effects of climate change in the Western Mediterranean Sea is evident. This is a relevant result as there are many economic sectors, ecosystem services and communities that depend upon this marine ecosystem.

Our study highlights the need to study climate change with an integrative and interdisciplinary approach, taking into consideration the interdependence and existing feedback between environment, ecology, society and economy.

POSTER BOARD ID: S3-P26 CANCELLED
(S3-16197 Poster)

Structural and functional heterogeneity of the bacterial communities associated with a stony coral across shallow water hydrothermal vent, copper mining site and non-vent habitats.

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The azooxanthellate Scleractinia *Tubastraea coccinea,* native to Indo-Pacific region, has been known to be invasive marine species which has significant environmental, economic, and social impacts on ocean ecosystems. Apart from their invasive capacity, the knowledge about the role of their symbiotic microbiota in host resilience and invasion is indeed limited. Here we analyzed the symbiotic bacterial communities of *T. coccinea* tissue and mucus, from four different habitats including hydrothermal vent (HV), nuclear power plant II inlet (NPP), conservation zone (CZ) and copper mining site (CM) by 16S rRNA full-length (~1.5 kbp)

sequencing to characterize bacterial community structures and to reveal the coral associated microbiome response to local environments. We observed difference in dominant bacterial communities in tissue and mucus samples between sites. Chemoheterotrophic bacterial genera *Endozoicomonas* has increased abundance in tissue samples of HV site. Also sulfur oxidisers such as *Sulfurovum*, *Sulfurimonas* was significantly enriched in HV site tissue samples. While phototrophic cyanobacteria *Synechococcus* was observed abundant in NPP and CZ sites. Overall, we observed heterogeneity in bacterial dominance and functional groups between hydrothermal vent and non-vent habitats. The bacterial communities associated with *T. conccinea* varies in its structure and functional profiles to help with host adaptation towards extreme environmental conditions, including the most acidic shallow water HV site. In light of forecasted climate change scenarios, our study will provide insight into how these bacterial communities may support this invasive coral species in adapting to the changing ocean acidification situation.

POSTER BOARD ID: S3-P27

(S3-16210 Poster)

Temperature effects on the ecology of the coastal fucoid *Ascophyllum nodosum* in a climate change context.

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Temperate and high latitude macroalgae species are subjected to strong seasonal changes in the radiation, climate, anthropogenic nutrient inputs and temperature regimes. These dynamics impact ecological interactions that macroalgae are part of and selects for a range of life history adaptations. Macroalgae growing in dynamic zones such as the intertidal are expected to be affected heavily by increased warm temperatures due to climate change. For example, higher metabolic rates of herbivores could severely impact seasonal trends of some of these species. We investigated the effects of warm temperatures on the grazing pressure experienced by the fucoid *A. nodosum*. This manipulative study was conducted in the summer, from July to October of 2022 at four zones of two islands located close to the South-west Norwegian coast. The grazers *Patella vulgata* and *Littorina obtusata* were removed weekly from one area per island to reduce grazing pressure. We measured growth rates of *A. nodosum* attending to their apical growth and grazer abundance. The proximity of the individuals to the subtidal zone was also studied through the division of zones in the intertidal since grazing activity can also differ depending on their location on the shoreline. Differences in growth rates between the two grazing pressures and intertidal zones were found. Hence, understanding the biotic effects of a hypothetically extended grazing period is imperative to know more about coastal interspecific interactions under increased warmer conditions. These short-term experiments can be of use to create conservation management plans and the elaboration of coastal use policies.

POSTER BOARD ID: S3-P28

(S3-16266 Poster)

Latitudinal biodiversity gradients in a greenhouse world: were Eocene tropics too hot to support high biodiversity? A test using shallow-marine ostracods

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The negative impacts of climatic warming on tropical marine ecosystem may be aggravated if the greenhouse gas emission maintains IPCC scenario RCP 8.5 (business-as-usual) in the next

100 years. One of these effects is the changing of latitudinal biodiversity gradient (LBG) that the parabolic pattern will convert into bimodal as the tropical diversity peak is lost, since the raising temperature may exceed the thermal optimum range of many species in tropical region. To better understand the possible future, we use benthic Ostracoda fossils from the Eocene period to study the effect of high temperature on global diversity. Eocene period is chosen not only due to the fact that during this time the tropical temperature reached to 35°C which is higher than the predicted temperature in 2100 (32°C) and maintain a 30°C level, but also because of that its continental condition is similar to the condition of present day. Ostracoda, as a class of crustacean that well preserved in sediment and sensitive to marine ecosystem change, combined with quantified sea surface temperature and habitat complexity data, will reveal the validity of past ecological events in predicting future and that temperature could be the main driver of large-scale marine diversity patterns. More detailed will be discussed in the conference.

POSTER BOARD ID: S3-P29

(S3-16309 Poster)

On peculiarities of ocean climate variability north of Gulf Stream

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The ocean climate variability in the Northwestern Atlantic region between the North Wall of the Gulf Stream and Nova Scotia coast is determined by interplay of two major circulation systems—the Gulf Stream and Labrador Current. To better understand regional long-term ocean climate trends caused by the Gulf Stream decadal variability we analyzed all existing in-situ data acquired from 1965 to 2017 in the World Ocean Database 2018. This analysis confirms continuous slow warming within the Gulf of Maine, Scotian Shelf, and Slope Sea areas over the last five decades. It also shows that the warming has accelerated in the recent 10-12 years in concert with strengthened summer northward incursion of warm water. Such strong northward migration of warm water was not seen in the four preceding decades. We argue that the recent decadal-scale warming is unique and may signal that the shift of the thermal regime in this region might have been at least partially caused by changing of the Gulf Stream long-term variability in the Gulf Stream extension region, east of 50ºN. We found that the Scotian Shelf and Slope Water regions have recently been warming much faster than the Gulf of Maine itself, both in the subsurface (the upper ~50 m) and deeper layers (down to 300m), implying that the probable cause of the faster warming in the most recent decade is due to the regime change in the Gulf Stream extension region.

POSTER BOARD ID: S3-P30
(S3-16360 Poster)

Is the parasitation of the eggs an additional threat for the Mediterranean sardine?

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European sardines are threatened by rising water temperature, overfishing, pollution, and parasitism. Infection by the protozoan *Icthiodinium chabelardi* could be especially worrying, since it causes the death of 100 % of the eggs infected, with a potential negative effect to the recruitment of the population. Although previous studies visually identified the presence of this dinoflagellate in sardine eggs caught in the Atlantic Ocean, the infection status in the Mediterranean is still unknown.
We developed and validated a genetic method based on DNA barcoding to record the presence of *I. chabelardi* in European sardine eggs. We applied this methodology in samples from the Northwestern Mediterranean Sea.

The egg samples were collected with a bongo in the coastline of the NW Balearic Sea. Sample collection was carried out in three samplings during the spawning season of European sardine (autumn-winter). Bongo nets with mesh size of 300 µm were pulled horizontally at depth of 5-15 m. Fish eggs attached to the nets were visually and genetically identified and then multiple PCRs were used to confirm parasite presence. Eggs infected by this protozoan were detected in a low prevalence (less than 5 %). However, in a changing environment in the highly impacted Mediterranean Sea, it is of main interest to keep studying the presence of *I. chabelardi* due to the consequences that may entail for sardine stocks.

POSTER BOARD ID: S3-P31
(S3-16370 Poster)

Response of hydrodynamic processes in the Maryland Coastal Bays under the impact of climate change

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Except for a few seasons, increased storm activity has been observed in the Atlantic basin almost every year recently due to climate change-driven shifts. Many climate models have predicted that this region will be exposed to more frequent wet storms in future setting the perfect condition for fluvial flooding from overbank river flows and coastal storm surges. The Maryland Coastal Bays (MCBs), a shallow interconnected coastal lagoon system with two unique inlets, is heavily influenced by tides-currents and sensitive to climate change, sea level rise, and storm surge. This study focuses on coupled hydrologic-hydrodynamic model application to compound flooding to understand the response of shallow lagoon system and its watershed to extreme events. Finite Volume Community Ocean Model was applied to simulate potential impacts of Atlantic winter storms including surge, wind, and waves on the MCBs' two-inlet system. Validated by observed data including water level, current velocity and salinity, the model accurately captures wind and wave patterns, which are found to be the primary regulators of flow. The currents of the St. Martin River, which feeds into the MCBs, are sensitive to high river flow and wind fields. In the face of rising mean sea level, storm surge will cause further flood damage in addition to the typical responses to winter storms. Numerical model analyses will be conducted for further evaluating

potential changes and the relative roles of different forcing mechanisms in local hydrodynamics using future climate scenarios during fair and extreme weather conditions.

POSTER BOARD ID: S3-P32

(S3-16387 Poster)

Identifying cascading links from large scale climate processes to plankton ecology in the Gulf of Guinea

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Climate variability shapes the marine environment and nutrient dynamics in the water column thereby moulding the temporal structure and abundance of plankton communities. The Gulf of Guinea is an important fisheries ground exposed to the influenced of hemispheric-scale climate phenomena, which together with growing anthropogenic pressures warn on potential negative effects for ecosystem services. We here explore decadal variations in the interplay between large-scale climate phenomena, regional climate, small pelagic fish, and zooplankton abundance in the southern Gulf of Guinea. We quantified the impact of large-scale climatic phenomena (Atlantic Multidecadal Oscillation (AMO) and Southern Oscillation Index (SOI)) on regional and local hydroclimate patterns and the subsequent influence on small pelagic fish and zooplankton. Partitioning effects of climate forcing were quantified by General Linear Model revealing a positive link of AMO (parameter estimate 0.75, $p < 0.05$), through the action of heat waves in the South Atlantic region, while SOI (parameter estimate -1.09, $p < 0.001$) showed an inverse effect, leading by heavy rainfall. Structural Equation Modelling was used to quantify direct and indirect interaction between large-scale and regional climate, small pelagic fish and zooplankton. Results showed that zooplankton abundance was driven by negative effects of SOI, regional temperature and small pelagic fish (path coefficient: -0.70, -0.36 and -0.55 respectively, $p < 0.05$), the variability of small pelagic fish was driven by regional temperatures (path coefficient: 0.53, -0.46 respectively, $p < 0.05$). These results have implications for ecosystem-based management actions which cannot avoid considering zooplankton changes as fundamental component for sustainable forage fish fisheries.

POSTER BOARD ID: S3-P33

(S3-16391 Poster)

Comparison of Sea Surface Salinity during the land fall of tropical cyclones in pre and post-monsoon season in Bay of Bengal using Global Reanalysis (GLORYS12V1) data and WGS84(EPSG4326) coordinate system

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Bay of Bengal is a one of the most tropical cyclone occurrence prone area in the North Eastern India Ocean region. Here the attempt has been done to analyze characteristics of Sea Surface Salinity (SSS) during two deadliest tropical cyclone FANI and BULBUL in the year 2018. Previous one was pre monsoon and later one was post monsoon storms. According the Saffir –Simpson scale FANI was Extremely Severe Cyclonic Storm (ESCS) of Category 5. On the other hand BulBul was Very Severe cyclonic storm of category 3. 133 human lives and around

11 billion USD was the cost of these two disasters in eastern cost of India.

The variation of SSS in the depth of 0.49m from sea level in all locations of the cyclone track has been studied. The Global Reanalysis data, which is known as GLORYS12V1 product is the CMEMS global ocean eddy-resolving ($1/12^0$ horizontal 50 vertical levels) reanalysis covering the altimetry (1993 onward) gridded data has been used here. More over a 3D-VAR scheme provides a correction for the slowly evolving large scale biases in temperature and salinity.

Some highly significant result we have found in the SSS fluctuation at the time of landfall of the cyclones as well as few days before and after of that.

POSTER BOARD ID: S3-P34
(S3-16392 Poster)

Oceanographic variability in Cumberland Bay, South Georgia and implications for fisheries management

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South Georgia is a heavily glaciated sub-Antarctic island in the Southern Ocean in the path of the Antarctic Circumpolar Current. The island hosts a rich ecosystem supported by krill and fish and is in one of the world's largest Marine Protected Areas (SGSSI-MPA). Cumberland Bay is the largest fjord on South Georgia, split into two arms, Cumberland East and West Bay, with a large marine terminating glacier at the head of each arm. Water circulation in such fjords, and associated transport and exchange of heat, directly governs the stability of glaciers at the ice-ocean interface and the subsequent glacier dynamics. Cumberland Bay is an important spawning ground for the commercially fished mackerel icefish, with the transport and retention of icefish larvae controlled by fjord circulation and shelf exchange. Understanding of the variability in circulation and exchange in Cumberland Bay cannot be derived from limited observational data alone. A new high-resolution simulation of the fjord water circulation in Cumberland Bay is built using the NEMO4 modelling framework. The model will help determine the dominant physical drivers of variability in our changing climate and implications for glacier retreat. Model flow fields will drive an Individual Based Model to investigate the transport and retention of mackerel icefish larvae, aiding fisheries management in the MPA.

POSTER BOARD ID: S3-P35
(S3-16397 Poster)

Climate change co-stressors and their effects on the biological, physiological, and genomic responses of juvenile Pacific oysters

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Climate change, driven by increasing anthropogenic greenhouse gas emissions, is leading to increases in global atmospheric and oceanic temperatures with coinciding rises in oceanic carbon dioxide (pCO_2), which is driving ocean acidification (OA). Certain marine animals, including various bivalves (e.g. oysters, mussels, clams), are negatively impacted by the independent impacts of increasing temperature and OA, but the effects of combined stressors on marine organisms can be unpredictable. Here we focused on warming and low pH, two climate change stressors expected to interact, particularly in the northeast Pacific ocean where low-pH-water upwelling events are common. We determined potential independent (one stressor) and cumulative (two stressors) effects on biological (growth), physiological (dissolved oxygen uptake), and genomic (gene expression) responses of juvenile Pacific oysters (*Crassostrea gigas*). Responses were measured over a 16-week experimental duration with two factors (pCO_2 and temperature) and two levels (current summer average and future summer level) in a fully crossed design including six replicate tanks per treatment, with 20–24 oysters per tank. Oysters were sampled at regular intervals (bi-monthly/monthly) over the experimental duration to examine shell length, shell height, shell width, condition index, dissolved oxygen uptake, and gene expression of a suite of genes related to energy budgets and metabolism. Results of condition index, gene expression, and carbonate chemistry of the experiment will be presented and interpreted in the context of mitigations to combat climate impacts on marine life.

POSTER BOARD ID: S3-P36
(S3-16398 Poster)

The impact of climate change in the development of sustainable blue economy in the Mediterranean: case study – Albania

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This paper takes into consideration the impact of climate change in the development of sustainable blue economy in the Mediterranean, focusing on the case study of Albania. The Mediterranean region is a prominent "climate change hotspot", what emerged also from the recent IPCC report where, for the first time, we also had a detailed and rather scary analysis of the current and projected impacts on all land and marine ecosystems of the region and its key economic sectors. Climate change impacts on the Mediterranean Sea include increased surface warming, salinity anomalies and more frequent heatwaves and other climate extremes. Today, in the Mediterranean region, significant investment is still targeting industries, starting with oil and gas extraction, driving the degradation of critical marine ecosystems, and further exacerbating the impacts of climate change. Efforts are still needed to make the transition towards truly sustainable blue economic activities, such as: investing in the development of sustainable offshore renewable energy; the decarbonization of the maritime transport; the implementation of governance tools and approaches, such as nature-based solutions and enlargement of effective marine protected areas; and the protection of blue carbon sinks like

seagrasses and other marine habitats to further mitigate the effects of climate change. As part of the Mediterranean basin, Albania as a country and its blue economic sector, will also be impacted by climate change. This impact and the ways to mitigate it and adapt to it, will be analysed in more detail in this paper.

POSTER BOARD ID: S3-P37

(S3-16414 Poster)

Integrating climate change vulnerability assessments and adaptation strategies into United States Fish and Wildlife Action Plans

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State Wildlife Action Plans (SWAPs) are proactive planning documents that assess the health of priority fish and wildlife, identify current management challenges, and outline long-term conservation strategies. SWAPs are revised every 10 years, with the last revision in 2015 and the next revision anticipated in 2025. The threats and actions listed in SWAPs support socioecological planning processes across local to regional scales and are broadly used by state and federal agencies to set priorities. Of the ~420 Regional Species of Greatest Conservation Need (RSGCN) identified in the Northeast U.S., over 320 are marine resources including diadromous and marine fishes, marine invertebrates, seaturtles, and shore/seabirds. Marine resources have received less attention than terrestrial species in past SWAP iterations, but due to the acute and immediate threats posed by rising sea levels, warming waters, and non-native invasive species, they are a major focus for the 2025 revisions. This presentation will describe how climate risks are being assessed for marine RSGGN through a combination of downscaled climate model outputs, Climate Change Vulnerability Assessment framework outputs, information derived from a systematic literature search, and quantitative evaluations of range and distribution shifts. Initial results have found the number of vulnerability studies and assessments conducted over the last decade for marine species (e.g., seaturtles, Atlantic cod) far exceed all other RSGCN and demonstrate major advances in understanding of climate risk. Overall findings will synthesize available data at species and functional group levels and provide habitat-specific and scale-appropriate climate adaptation actions to guide decision-making and future research.

POSTER BOARD ID: S3-P38

(S3-16418 Poster)

Climate-related vulnerability and risk assessment of main ocean uses: An overview

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Vulnerability and risk analyses have been increasingly used in a wide variety of contexts to support ocean management processes. Depending on the context, such analyses may focus on different dimensions, spatial scales, and hazards. In the context of climate change, the variability

inherent to the developed assessments has led to the emergence of numerous frameworks, allowing for advances in the field while raising uncertainties on applied concepts, definitions and approaches. In the present study, we developed a systematic literature review to analyze and discuss the key concepts, methodologies, and limitations of existing vulnerability and risk assessments of main ocean uses to global climate change. We analyzed over 314 scientific references regarding the elements considered in the analysis, dimensions, type of indicators, maritime activities, climate-related drivers of change, and spatial scales. Results show that most vulnerability and risk assessments address fisheries and marine conservation, and that sea-level rise and extreme events are the most frequently considered climate-related drivers of change. The main identified limitations pertain to the level of subjectivity and the tremendous variety of concepts, areas of expertise, and systems addressed in such studies. We highlight that further research is needed particularly on the development of cross-sectoral studies and integrative approaches, using multiple indicators and frameworks. There is also a need for assessments explicitly designed to support ocean planning and integrated marine management processes. Review processes such as the present one provides a "big picture," allowing for a global view on complex topics, and contributing to advances in the field.

POSTER BOARD ID: S3-P39

(S3-16427 Poster)

Cellular, physiological and genotoxicity responses of the mussel *Mytilus galloprovincialis* to multiple stress: low pH, low dissolved oxygen and microplastic

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Since the industrial revolution, the acidity of ocean surface water has increased by about 30% due to anthropogenic CO_2 emissions. On the other hand, global warming causes deoxygenation in the oceans by reducing the oxygen-holding capacity of seawater and increasing its horizontal stratification. On a regional scale, human activities on the coasts increase the frequency of coastal hypoxia events. Microplastics are one of the most abundant and common xenobiotics in marine ecosystems and have been shown to accumulate in the bodies of marine organisms. Acidification, hypoxia, and microplastic pollution occur together on coasts and open seas. Marine ecdotherms have to cope metabolically with this multiple stress. In the current study, we exposed adult mussels (*Mytilus galloprovincialis*) to two pH_T (7.35 and 8.09), dissolved oxygen (DO) concentrations (7.65 and 1.91 mg L^{-1}), and two MP concentrations (polyethylene spheres: 0 mg L^{-1} and 0.026 mg L^{-1}) over 15 days in a full-factorial design. The biological effects of those stressors on the mussels were evaluated by considering several treatments such as respiration, excretion, filtration and assimilation rates, hemocyte count, hemocyte viability, and genotoxicity. Respiration, excretion, and assimilation rates were not impacted by low pH, low DO, and MP alone or in combination. However, they significantly decreased clearance rate, total hemocyte count, hemocyte viability, and increased genotoxicity.

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(S3-16439 Poster)

Exposure to Toxic Metals and Health Risk Assessment Through Ingestion of Anchovies Across African Countries Along the Atlantic Ocean

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Heavy metal contamination of aquatic environments is a major concern due to their toxicity and accumulation in aquatic habitats. This study assessed the health effects of chemical contaminants (Cr, V, Co Cu, Fe Zn, Ag, and Ni) across the Atlantic Ocean. Samples of anchovy were sampled in eleven African countries with the Research Vessel Dr. Fridtjof Nansen. Fish samples were whole, without head, tail, and viscera. Heavy metal concentrations were measured by ICP-MS. Hazard Quotient (HQ) and Carcinogenic Risk (CR) of metals were estimated for adults and children. The study found significant differences in heavy metal content between countries. Mean concentrations for V, Cu, Cr, Zn, and Ag ranged from 0.014 to 0.27 mg/kg, 0.95 to 1.18 mg/kg, 0.08 to 0.064 kg/mg, 8.33 to 17.14 mg/kg, and 18.43 to 32.92 mg/kg. Hazard quotient, hazard index, and carcinogenic risk were used to assess metal intake and health risk. Except for Fe, Zn, Cr, and Ni, all metals' EDI was below the MTDI. HQs for single metals were less than one for all metals, indicating that anchovy consumption poses no health risk, except for Fe, Zn, and Cr. All metals had a HQ greater than 1, indicating a health risk to consumers. Cancer risk profiles of adults and children, Co, and Ni showed a modal risk of 10^6 or 1 in a million. This study found that the health risk indices associated with anchovies consumption vary across African countries and that constant surveillance is needed to protect populations that consume this fish.

POSTER BOARD ID: S3-P41
(S3-16473 Poster)

Climate change and small-scale fishing in South Africa: A community scale social vulnerability assessment for the southern Cape handline fishery.

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Climate change is majorly affecting marine social-ecological systems. This study, carried out in five historically disadvantaged, coastal communities of South Africa's southern Cape region, adjacent to an ocean climate change hotspot, assessed the vulnerability of small-scale fishers who also act as crew in the region's commercial handline fishery. In addition to social, governance, and financial stressors, these fishers also face biophysical stressors, such as changes in wind and sea state. Using a vulnerability survey and framework developed by the Belmont Forum's "GULLS" project, we present a quantitative analysis of the data collected in 2014-15. Univariate and multivariate analyses were performed to investigate the different vulnerability categories (Sensitivity, Exposure, and Adaptive capacity). The results suggest that the fishing communities differed significantly in overall social vulnerability. Sensitivity and Exposure were similar between the communities, where Sensitivity also was the main driver of vulnerability for all fishers due to their low self-sufficiency and attachment to fishing and their communities. There was no significant difference in the dispersion of the fishers' responses within the communities. Differences between the communities were driven by Adaptive capacity, corroborating previous qualitative research. Recommendations are made for an improved survey, which offers a quicker methodology that can easily be communicated with decision-makers and paves the way for consistent temporal comparisons that stimulate a long-term understanding of social vulnerability. Most importantly, this assessment method can contribute to the implementation of system-based fisheries management, and improved sustainability.

POSTER BOARD ID: S3-P42
(S3-16481 Poster)

Precarious livelihoods in small-scale fisheries in North Atlantic Canada

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Socio-ecological and regulation changes within the past thirty years in Atlantic Canada have modified the way in which people fish. Changes came as a response to the collapse of fish stocks and included limiting access to the fishery and modifying fishing seasons. These regulations along with climate changes have posed additional obstacles for coastal communities to sustain their livelihoods from fishing. Even though "fish work has always been precarious", in this study we explore how policy and ecological changes in the last thirty years render fish work precarious in diverse ways, from informal work arrangements to unsafe working conditions. Policies that were designed to modernize the fishery often ignore the socio-ecological contexts in which small-scale fisheries take place producing unintended consequences that hinder sustainable fishing livelihoods. Through a series of interviews, fish harvester surveys and a literature review we found that workers in small-scale fisheries in North Atlantic Canada are exposed to multiple vulnerabilities including intrinsic environmental and physical risks associated with working in the North Atlantic Ocean, and regulations that impede the development of decent employment for current and future generations of the fishery. Fisheries management focused on the viability of the fishery that benefitted the "insiders" paying little attention to new entrants, crew and the onshore crew often composed by women. As fish harvesters reach retirement age, precarious conditions drive new entrants away from the fishery placing small-scale fisheries at the edge of sustainability.

S4: Improving decision-making in response to change in marine-dependent coastal communities using transdisciplinary approaches

Convenors:
Louise Gammage (Corresponding), (University of Cape Town, South Africa)
Kelly Ortega Cisneros, (University of Cape Town, South Africa)
Lynne Shannon, (University of Cape Town, South Africa)

Plenary Speaker:
Sebastian Villasante, (University of Santiago de Compostela, Spain)

Invited Speaker:
AJ Smit, (University of the Western Cape, South Africa)

Marine-dependent communities, particularly fishery-reliant communities, are especially vulnerable to the impacts of environmental variability and climate change. The inherent complexity of the marine environment, together with the uncertainty brought on by anthropogenic change, hampers decision-making at all scales, undermining adaptive capacity and resilience within communities. Inclusive transdisciplinary approaches are thus required to address existing vulnerabilities whilst building resilience to the effects of future changes on various system scales. In this session, we share case studies on how coastal communities can improve resilience to climate change by using diverse co-design and participatory approaches. We also aim to identify barriers and opportunities to develop adaptive capacity and resilience of vulnerable coastal communities through improved multi-scalar decision-making.

(S4-16483 Plenary)

Resilience and Social Adaptation to Climate Change Impacts in Small-Scale Fisheries

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Small-scale fisheries are important for livelihoods, food security, jobs and income worldwide. However, they face major challenges, including the increasing effects of climate change that pose serious risks to coastal ecosystems and fishing communities. Although scientific research on climate change impacts has increased in recent years, few studies have explored the social impacts on small-scale fisheries. Using Galicia (Spain) as a case study, we investigated individual and household-level adaptive responses to climate change among fishers in three fishing guilds. Specifically, we estimated the economic vulnerability of shellfishers and assessed the diversity of social adaptive responses used to deal with climate change. Although fishers' income strongly depends on shellfishing in all studied areas, our findings show that less fishing experience and lower engagement in fisher associations tend to increase the economic vulnerability of the fishers. The fishers' vulnerability decreases as the size of households increases, while fishers who pay a mortgage and who live in households with fewer active members tend to be more vulnerable. The findings also show that Galician shellfishers have developed a wide range of adaptation strategies to anticipate and respond to climate change impacts, namely harvesting pricier and more abundant species, reducing household expenses and increasing social involvement in shellfishery associations. Although the adaptive strategies have helped Galician fishers to deal with climate change impacts, several threats to the sustainability of shellfisheries remain, such as a decrease in the abundance of key native shellfish species, and a high dependence on public and private aid to ensure reasonable incomes for shellfisheries. These findings are of interest and relevance to other similar small-scale fisheries around the world facing similar climate change challenges.

(S4-16302 Invited)

The impact of extreme events in the Benguela Upwelling System

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The Eastern Boundary Upwelling System (EBUS) bordering South Africa, Namibia, and Angola is one of the most productive Large Marine Ecosystems (LMEs) globally. The region's importance stems primarily from its productive fisheries, but mining and oil and gas extraction and maritime commerce also significantly contribute to the countries' GDP. This system is already experiencing changes in the coupled atmosphere-marine climate, both within the system and beyond, that are affecting the livelihoods of millions of people who benefit from the services that nature contribute to the region. All sectors, from informal (subsistence, artisanal) through to small scale commercial and industrial, are vulnerable to various impacts at varying time and space scales. The Extreme Events in the Benguela Upwelling System (EXEBUS) programme is concerned with understanding the experience of people, who derive their livelihoods in the BUS, which are impacted by the manifestation of climate change through extreme environmental phenomena. EXEBUS has identified extreme winds, marine heatwaves, and extreme 'sea state' issues of central concern for the region. In this presentation, we will provide insights across a series of Case Studies about how knowledge co-generated across the diverse world views of actors (lay-person to a scientist) can be employed to quantify user experiences, identify measurable geophysical timeseries that contain signals of impact, and so triangulate towards improving adaptive capacity in anticipation of the extreme climatic uncertainties of the future.

(S4-15875 Oral)

Assessing climate change risk to fisheries: real world applications, capacity building, and social learning

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Supporting fisheries managers and fishers to understand the risks climate presents to their fishery – and how climate proofed alternative management strategies would be – is an urgent need. We collaborated with researchers, fisheries managers, and fishers from around Australia to develop an approach (handbook and online application) to support a structured vulnerability/risk analysis. The first step in the approach is to identify the aspects of climate change and their ecological impacts that might pose a risk to commercially important stocks. This is followed by considering the extent to which fishers can autonomously adapt as well as what future management instruments or regimes could help mitigate the fisheries climate risk.

Different fisheries work at different scales and in (or across) different jurisdictions. By working with fisheries managers and fishers in multiple Australian states to provide workshop-based training to use the tools for selected fisheries, we are building capacity beyond the original application of the work to federal fishereis. This involves users adjusting the assessment

as needed for the context of their fishery, adding or removing ecosystem factors, industry operations and management actions based on relevance. The rollout process is also testing the scalability and transferability of the risk assessment to recreational fisheries and to marine aquaculture sectors.

We share insights on co-producing climate decision support tools for real-world applications. These include the technical insights for decision support tool design, and the social learning outcomes concerning climate risk, responses, and proofing, and how these contribute to capacity-building for fisheries practitioners and scientists alike.

(S4-15963 Oral)

U.S. perspectives on evolving decision-making under climate change and shifting marine ecosystems: addressing fishery management challenges

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NOAA Fisheries is responsible for managing marine fisheries within the U.S. exclusive economic zone. Our work is guided by two core mandates: ensure the productivity and sustainability of fisheries through science-based decision-making and compliance with regulations, and recover and conserve protected resources. Climate affects our regions and coastal communities differently, and social and economic indicators demonstrate that many of our key fishing communities are particularly vulnerable to economic or environmental disruption. As such, and recognizing that social vulnerability and resilience influence a community's ability to respond and adapt to change, our response needs to be both holistic and region-specific. Our approach includes the use of climate vulnerability assessments, socioeconomic indicators, and quantitative projections of climate change – all of which bolster "on-ramps" for an integrated suite of climate, ecosystem, and socioeconomic information into decision-making. We are also examining our existing governance structures to ensure they have the adaptability to act on this information. To achieve this, we are modernizing our data and modeling systems that process, provide, and ultimately generate climate-ready information. Building on NOAA's Climate, Ecosystem and Fisheries Initiative, our aim over the next five years is to improve our capacity for forecasting fishery system dynamics, more realistically capture the interactions of fleets, fisheries, the environment, and thereby provide the needed science and socioeconomic advice that will lead to more robust management responses in our effort to increase our coastal communities' resilience.

(S4-16045 Oral)

Ecological forecasting and operational information systems support sustainable ocean management

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In times of rapid change and rising human pressures on marine systems, information about the future state of the ocean can provide decision-makers with time to avoid adverse impacts and maximise opportunities. An ecological forecast predicts changes in ecosystems and its components due to environmental forcing such as climate variability and change, extreme weather conditions, pollution, or habitat change. Here we summarise examples from several sectors and a range of locations. We describe the need, approach, forecast performance, delivery system, and end user uptake. This examination shows that near-term ecological forecasts are needed by end users, decisions are being made based on forecasts, and there is an urgent need to develop operational information systems to support sustainable ocean management. An operational information system is critical for connecting to decision makers and providing an enduring approach to forecasting and proactive decision making. These operational systems require significant investment and on-going maintenance but are key to delivering ecological forecasts for societal benefits. Iterative forecasting practices could provide continuous improvement by incorporating evaluation and feedback to overcome the limitations of the imperfect model and incomplete observations to achieve better forecast outcomes and accuracy.

(S4-16073 Oral)

One marine hotspot, two coastal communities, multiple views on climate change and the sustainability of marine livelihoods off Western Australia

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The coastal waters in south-west Western Australia are influenced by a warm poleward-flowing Leeuwin Current and sit in a global 'marine hotspot'. The region has experienced an extreme 'marine heatwave' in 2011 with significant impacts to marine flora, fauna and commercial fisheries. We used transdisciplinary approaches to investigate whether two communities whose livelihoods and knowledge are intrinsically linked to the marine environment, rank climate change as an important priority requiring further knowledge in order to sustain their future and improve decision making. The Abrolhos Islands are home to a thriving seasonal fishing community and valuable rock lobster fishery. We recorded a cascade of change, from climate and environmental change, government intervention, economic responses, and eventual social collapse. Following a co-designed exhibition using fishers' photographs, we also examined if the fishers' views about climate change had altered. The second community in Shark Bay, supports a valuable multispecies fishing industry, an iconic tourist destination and World Heritage Property. Many in the community were knowledgeable about the effects of a marine heatwave, from both lived experiences and workshops. To understand and prioritise what knowledge is needed to manage the environmental issues and sustain futures, we canvassed a range of stakeholders including community, researchers, managers and the Indigenous Malgana people. By addressing community knowledge needs and aligning this with science priorities, we look at opportunities to ensure coastal communities are cognisant of climate change, can adapt their business decisions to sustain future livelihoods, while providing government decision makers justification for focused research investment.

(S4-16105 Oral)

New tools to advance climate resilience and equity in Alaskan coastal communities

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Climate change is exacerbating social and environmental justice concerns for Alaskan communities. Collapses in crab and salmon species are jeopardizing local economies, subsistence access, food security, and Indigenous cultures. We describe a dual approach to begin addressing social and environmental justice issues, working both within and beyond traditional fishery management frameworks, to build onramps for advancing climate and equity considerations in fisheries management:

1. In conjunction with Tribes and federal and state scientists, we developed a conceptual model for use in the 2022 Eastern Bering Sea Ecosystem Status Report that details life-stage specific vulnerabilities for salmon in their marine and freshwater phases, as well as for subsistence salmon fishing communities.
2. In conjunction with Tribes, fishers, and non-governmental organizations, we developed a novel Ecosystem Matrix concept that evaluates fishery and ecosystem indicators by emphasizing communities, subsistence, species interactions, and climate vulnerabilities, and link these data to potential management outcomes.

The efforts described above must be part of larger efforts to better represent community and ecosystem considerations in fisheries management by way of increased Tribal Consultation, co-management efforts, and inclusion of local, Traditional, and Indigenous Knowledge. Salmon, crab, and the communities dependent on them, are highly vulnerable to the impacts of climate change. It is essential that managers use existing and emerging adaptive management tools to ensure equity and climate are key components in the future of climate resilient fisheries management.

(S4-16237 Oral)

Predicting the adaptive capacity of fishing communities to changing climate conditions: A case study of the Northeastern U.S. Atlantic sea scallop fishery

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A challenge for using ecosystem approaches in managing marine resources is to find practical methods to link assessments of both human and natural systems. A key component of this system is the ability of fishing communities to respond to changing climate conditions and management decisions. To address this need, indicators of fishing community capacity to adapt to changing climate conditions were developed for the Northeastern U.S. Atlantic sea scallop fishery. These indicators identify relationships between changing land and sea based fishing community dependence on sea scallop, community catch diversity, vessel port affiliation, and the social and economic vulnerability and resilience of these communities. We will discuss how these findings can be used to inform fishery management and to enable communities that rely on this fishery to plan and become more resilient to future change.

(S4-16248 Oral)

Selecting climate linked decision relevant and adaptation informing scenarios for ecosystems: A case study for the eastern Bering Sea

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In recognition of the profound impact of climate change on marine ecosystems worldwide, integrated research teams have coupled climate change projections of ocean systems with socio-ecological models to inform management and evaluate adaptation strategies. These emerging planning networks provide decision support and adaptation strategy evaluations to advance climate informed management and adaptation. A key step in this process is the selection of decision relevant and adaptation informing scenarios that are useful to constituents with diverse interests in future use of marine resources. Narrowing the diverse landscape of possible scenarios is needed to maintain an informative suite of model permutations that allow quantitative evaluation of the trade-offs between scenarios. This paper presents a case study based on the process used and experiences gained from an effort to select climate informed socio-ecological scenarios for groundfish and crab fisheries in the eastern Bering Sea. The paper describes three critical elements to successful scenario planning: a) initial model development to provide worked examples for managers, fishery dependent communities and the public; b) formation of on-ramps for uptake of climate informed decision support information into existing scientific review and transparent management systems; and c) use of forums to seek input and guide scenario planning to ensure that scenarios are addressing relevant issues for fishery dependent communities and the public. Examples of this three-pronged effort will be presented to share lessons learned with similar climate teams around the world.

(S4-16336 Oral)

Planning for sustainable marine socio-ecological futures in the context of tipping points: a participatory gaming approach

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Climate change and people are driving rapid change in marine ecosystems, and marine dependent communities need to plan adaptation pathways that enhance their resilience to these changes. However, this is particularly challenging in the context of tipping points – when incremental changes can trigger reorganization of system structure and function. These rapid and dramatic changes are difficult to foresee and increasingly likely as unprecedented conditions occur in our global oceans. Tipping points have been studied in both human and natural systems, however understanding how tipping points interact across human and biophysical dimensions remains a major challenge. In this context, understanding how people perceive and respond to tipping points of all dimensions is critical.

For a case study on Tasmania's east coast – a marine climate change hotspot – we combine knowledge co-production (with representatives from research, government, industry and communities) and scenario modelling to forecast socio-ecological system trajectories in the context of tipping points. Through interviews, we elicited perspectives on tipping points and how people manage significant change, and concerns and visions for the future. We then used a participatory game to explore collective responses to tipping points in social, financial and environmental domains. Together with participants, we used behavioural insights from the game to co-develop future socio-ecological scenarios for adaptation. In this presentation we report early findings from these co-production activities, and highlight community needs and values in identifying and managing risks and trade-offs associated with shocks and tipping points, as well as perspectives on driving tipping points with desired socio-ecological outcomes.

(S4-16378 Oral)

Transdisciplinary approaches in US marine research: the role of multiple knowledge systems in climate informed decision-making

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The Arctic is undergoing rapid and unprecedented ecological and social change, requiring responsive resource management strategies based on the best available information. US marine management frameworks have increasingly embraced interdisciplinary research to guide climate-informed marine policy; however, there remains a lag in effective transdisciplinary approaches. Marine resources are critical to coastal Alaskan communities for food security, social cohesion, subsistence practices, and cultural continuity. Indigenous Peoples in the region have enduring, cross-generational, social, ecological ties to the marine environment, and extensive Indigenous Knowledge (IK) about changing marine ecosystems. Inclusive transdisciplinary research rooted in IK can increase ecological understanding and improve decision-making, while supporting community resilience in the face of change. Focusing on recent efforts to conduct an Integrated Ecosystem Assessment (IEA) in the Northern Bering Sea/Chukchi Sea, this work highlights the role of transdisciplinary approaches in improve climate-informed research. The IEA framework draws on the best available expert knowledge to understand the past, present,

and future of social and ecological conditions in a region, providing a pathway between IK and Federal decision-making. Including multiple knowledge systems in IEAs offers a longitudinal perspective across generations of ecological observations, and supports community resilience through information sharing, relationship building, and informed decision-making. The results of this work offer an innovative model for broader knowledge synthesis and transdisciplinary within marine research, while strengthening relationships among managers, community members, and scientists.

(S4-16452 Oral)

Ten years of SES research for improved marine fisheries decision making in the southern Cape, South Africa - lessons learnt

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The southern Cape is a largely rural region on South Africa's south coast influenced by the Agulhas Current, a global warming hotspot, as well as by southeastern trade winds. Handline and bottom trawl fishing, agriculture, tourism and service industries associated with retirement represent the main economic activities in the rural areas, complemented by Mossel Bay's industrial harbour and refinery. The Southern Cape Interdisciplinary Fisheries Research (SCIFR) project, 2012-2022, focused on inter- and transdisciplinary marine SES research which was participant-led where appropriate, and aimed at improving strategic decision-making around fisheries management in the region. We asked three questions, (i) How are natural and social changes in the southern Cape shaping and interacting with marine social-ecological systems?, (ii) More specifically, how are selected natural resources users in this area responding to global change, and how are they shaping change in their region?, and (iii) How can the knowledge of the current state of the SES be used to build a more resilient, sustainable system? This contribution reflects on lessons learnt in SCIFR's three phases, and explores possible ways forward. Reflections include extended partnerships in this global south context, through the lenses of ecosystem services and full-spectrum sustainability.

POSTER BOARD ID: S4-P1
(S4-15862 Poster)

New interventions for marine ecosystems in rapid transition: a first-cut global assessment

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Marine ecosystems are in decline. The scale and intensity of ocean change mean that effective mitigation and adaptation are urgently needed to sustain marine ecosystems and marine-dependent people. Equally imperative is that marine policymakers ensure that new interventions do not produce unintended and maladaptive outcomes. This knowledge is urgently needed, because many management agencies, local and national governments, non-governmental organizations and industry operators already engage in ad hoc and uncoordinated efforts to intervene in the social-ecological resilience of marine systems. Such efforts include offshore energy development, seaweed restoration, assisted species migration, climate refuge protection, and solar-radiation control. Yet without an understanding of what kinds of intervention are being undertaken, and of how they are effectively being governed, interventions risk being unproductive, or at worst, contributing to adverse outcomes. In this talk, we will present new empirical data on the global state-of-play of new interventions and their governance. Our analysis forms the first part of a three-year project on Governing Changing Oceans.

POSTER BOARD ID: S4-P2
(S4-15867 Poster)

Anticipation of the future in transdisciplinary coastal research in the Global South: a systematic literature review

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Sustainability challenges threaten the integrity of coastal ecosystems worldwide. Especially countries of the Global South are affected by the impacts of climate change, pollution, and changing land use in coastal social-ecological systems now and in the future. Adapting to these changes is a significant challenge for coastal communities in Global South countries. Anticipation of the future using transdisciplinary approaches is critical to provide the basis for appropriate action to cope with current and future risks. A systematic literature review was conducted to answer how far transdisciplinary approaches in coastal research in the Global South take the anticipation of the future into account. It showed that the majority of the literature conducted past and current state analysis. Only 23% used anticipation methods whereby scenario construction was the most common method. The conceptualization of plausible futures relating to the second anticipation approach was most popular. The more transformational third approach and visioning research was rarely found. With regard to giving stakeholders a voice transdisciplinary anticipation research has emerged as having the potential to motivate stakeholders to participate in transformation processes. Furthermore, it can provide a basis for intervention research on the way to a desirable future. There is a high potential to conduct more anticipation research in the Global South concerning coastal ecosystems, which can help manage future sustainability problems. The findings of the literature review provide important insights on how the concept of the future can be better considered by transdisciplinary research.

POSTER BOARD ID: S4-P3
(S4-15889 Poster)

Linking transboundary stock shifts, fisheries conflict and adaptive governance through case studies

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Climate change is causing fish stocks to shift around the world, upending governmental, economic, and societal systems that rely on the historic distributions of these shifting stocks. Conflict is an ever-present yet understudied outcome of species on the move. The movements of internationally shared stocks across borders (i.e. transboundary stock shifts) are especially concerning – they bring into play a variety of geopolitical factors surrounding the under-regulated high seas and potentially contentious international border zones. While we know that stocks are shifting and that negative impacts can occur, there is a dearth of climate-specific case studies that directly link shifting transboundary stocks and fisheries conflict, and that describe the role that adaptive capacity or lack thereof may play in preventing or fomenting conflict. This paper explores this vital topic by drawing on the knowledge of a diverse group of experts to comparatively analyze four case studies that focus on regions of the world where substantial transboundary stock shifts, geopolitical or governance tensions, and uncertainty regarding the future of the marine environment collide. We find that a complex history of power imbalances, internal and external conflicts, unequal access to resources, minimal multinational cooperation, and a lack of consistent and transparent data collection can blur the links between shifting stocks and conflict. Other context-specific insights allow us to discuss resilience factors that promote proactive and conflict-ready fisheries governance.

POSTER BOARD ID: S4-P4
(S4-15992 Poster)

Linking knowledge and action for climate-ready fisheries: emerging best practices across the United States

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Substantial progress has been made in producing climate science to understand and predict potential impacts and opportunities for fisheries in the US. However, limited uptake of this information in federal fisheries management decisions remains a bottleneck hindering climate resilient fisheries. While many fisheries councils are taking innovative approaches to incorporate climate knowledge into their management process, they have identified lack of information sharing or opportunities to coordinate these individual initiatives as barriers to broader-scale progress. To promote cross-regional learning, we distill best practices and lessons learned thus far from these emerging efforts, drawn from the literature and a workshop with participants from science centers, regional councils, and management offices across the US. These best practices include 1) map governance processes to identify climate information "on-ramps," 2) translate climate information to relevant scales, 3) frame climate initiatives within existing management mandates, 4) frame climate impacts within stakeholders' experiences, 5) employ structured processes, 6) strategically incorporate qualitative information, 7) pilot initiatives with healthy, low-controversy stocks, 8) engage stakeholders early, 9) dedicate staff and funding, and 10) leverage collaborative research to overcome capacity constraints. We highlight bright spots demonstrating how these practices were implemented, discuss continued challenges, and identify opportunities where these practices could be expanded in support of climate-ready fisheries.

POSTER BOARD ID: S4-P5
(S4-16075 Poster)

Ocean-climate literacy as a consequence of environmental education

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An ocean climate-literate individual is one who understands the interdependence of human society and the ocean. Such an understanding allows the individual to communicate clearly and make responsible decisions regarding ocean resources. An understanding of ocean-climate literacy can have far-reaching implications for mitigation and adaptation strategies in its provision of baseline information for evidence-based decision-making and good practice. However, this should include an understanding of aggregate behaviour as a consequence

of ocean-climate literacy. This link has been explored theoretically and empirically by the Norm Activation Model that argues for a casual chain in which the awareness of consequences eventually results in environmental behaviour. Once people have recognised the risks and consequences of unsustainable behaviour on the natural environment, they ascribe responsibility for environmental consequences. This is proposed to activate a personal norm or moral obligation which, according to the NAM, leads to environmental behaviours. The purpose of the study is to explore what influences awareness of consequences within the NAM causal chain. We argue that ocean-climate literacy would inform the awareness of consequences of individuals which in itself would be informed by a variety of factors including cultural norms, religion, environmental education, media exposure, social learning and socialisation. We find that a contextualised understanding of ocean-climate literacy is required for evidence-based decision-making and good practice which ultimately contributes to the development of adaptation and mitigation strategies.

POSTER BOARD ID: S4-P6

(S4-16295 Poster)

Supporting transdisciplinary collaborations in graduate education

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We summarize evaluations from students and faculty participating in the Oregon State University NRT program, *Risk and Uncertainty Quantification and Communication in Marine Science and Policy.* Initiated in Fall 2015, the program focuses on transdisciplinary collaborative training. A key program component is students' work in small multi-disciplinary teams to formulate and conduct original, transdisciplinary research. Four student cohorts have completed the one-year training program, with a total of 45 students and 44 advising faculty participating in the program. The program evaluation involved formative and summative assessments. The formative evaluation points to the importance of positive peer interactions and faculty involvement promoted via professional training in collaboration and communication, awareness of diversity, equity and inclusion, clear communication about program expectations, and informal community building practices. The applied nature of the team research projects and participation in student internships outside of academia were also important program elements. Summative evaluation indicates students' increased preparedness and motivation to work collaboratively across disciplines, stronger communication skills to convey complex research topics and to engage stakeholders, and greater understanding of core concepts from multiple disciplinary perspectives. Participating faculty reported that the NRT program heightened their exposure to new ideas outside their discipline, improved mentoring skills, and increased opportunities for co-advising, co-teaching, and co-writing research proposals. We conclude that TD collaborative training provides benefits by broadening perspectives among both graduate students and advising faculty. We discuss these programmatic considerations reflecting on the personal experiences of the leadership team over the course of the five-year NRT project.

POSTER BOARD ID: S4-P7
(S4-16320 Poster)

Projecting climate-related shifts in culturally important species within community waters: Opportunities and barriers to adaptation

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Shifts in the distribution of marine species are driven by the changing ocean conditions that are caused by climate change. These biogeographic shifts are having a disproportionate impact on Indigenous communities due to their social, ecological, and cultural integration with marine systems. Moreover, concerns exist that these shifts might exacerbate losses and interruptions caused by colonialism. This study assesses the projected change in distribution of culturally important marine species (CIS) for the Haida community of Skidegate, an Indigenous community in the Northeast Pacific under two climate change scenarios. CIS were identified in consultation with knowledge holders and relevant community documentation. Initial projections indicate an overall decline in abundance for 16 CIS under both low (-8.8%) and high (-10.8%) emissions scenarios by 2050 relative to 2000 within waters 100 km of Skidegate. We explore the implications of these projected changes in abundance on the wellbeing of the Haida People, opportunities for building adaptive capacity, and barriers to adaptation. We integrate quantitative projections with qualitative analysis from multiple expert interviews and one focus group to gain a more comprehensive depiction of adaptive capacity on a community scale by considering the local social-ecological context and non-climatic drivers affecting the community. This integrated information is intended to increase Skidegate's and, by extension, the Haida Nation's decision-making capacity and support the development of local adaptation strategies.

POSTER BOARD ID: S4-P8
(S4-16344 Poster)

Eco-ACE: Building multi-scalar adaptive capacity to ocean change by promoting ecosystem-based adaptation and community engagement

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Fishery-reliant and other coastal communities are especially vulnerable to the impacts of environmental variability and climate change. At the same time, limited implementation of systems-based approaches to management (such as ecosystem-based management) exacerbate the day-to-day challenges experienced by communities, further eroding adaptive capacity. Participatory and inclusive approaches to management are required to address this complex challenge at both small and large scales. We here introduce the Ecosystem-based adaptive capacity through community engagement (Eco-ACE) project. This project aims to facilitate and improve the adaptive capacity of vulnerable groups in coastal communities by following a co-design and collaborative research approach that uses multiple methods. We take a community-based research approach to co-design and develop interventions and tools with stakeholders to improve adaptive capacity at the local level. At the same time, decision-makers will be engaged to identify and implement interventions to promote ecosystem-based decision-making.

The project will integrate social and ecological knowledge into ecosystem models using a participative modelling approach and facilitate science and stakeholder engagement in climate change and variability and its effects through these various interventions. By defining and outlining a field-tested approach, our project will directly contribute to strengthening the adaptive capacity of vulnerable communities and create awareness of climate change at the local level, integrate small-scale fishers' knowledge into existing ecosystem models and contribute to the promotion of ecosystem-based management approaches in South Africa through capacity building at larger scales and policy recommendations.

POSTER BOARD ID: S4-P9

(S4-16359 Poster)

Do the indigenous knowledge systems of marine fishers increase their resilience in the face of climate change and risks? Observations from tsunami-hit fishing villages of South India.

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In recent decades, a rising body of research has shown that climate change is real and has harmed the livelihoods of small-scale marine fishers worldwide. Research strongly indicates that the Southeast coastal regions of South India are one of the climate change hotspots in South Asia. The indigenous expertise of marine fishers around the coastlines of India has been documented in a corpus of anthropological literature. However, there are huge study gaps in investigating indigenous knowledge in the context of climate change. This paper explores how fishermen perceive indigenous knowledge systems in responding to climate change and risks and their positives and limitations. This paper used data gathered via rigorous fieldwork along the selected fishing villages in South India. Marine fishers along this coast have been victims of climate change for decades. Also, the 2004 Indian Ocean Tsunami had a catastrophic effect on them. The findings of this study indicate that, via their indigenous knowledge, fishermen have consistently felt the consequences of climate change over the past few decades. However, marine fishers of these regions are gradually losing faith in their indigenous knowledge systems to face climate change, and they have continuously been more dependent on scientific knowledge, resulting in various debates on smart fishing and pushing the policymakers and the scientific community to show attention to this. Through its field observations, this paper adds value to the climate change literature and emerging smart fishing strategies of small-scale fishing communities and critically questions their livelihood resilience and ocean sustainability.

S5: Measuring and predicting responses of marine social-ecological systems to climate extremes

Convenors:
Stephanie Brodie (Corresponding), (University of California Santa Cruz, USA)
Lisa Colburn (Corresponding), (NOAA Fisheries)
Kathy Mills (Corresponding), (Gulf of Maine Research Institute, USA)
Gabriel Reygondeau (Corresponding), (University of British Columbia, Canada)

Plenary Speaker:
Renato Salvatteci, (Kiel University, Germany)

Invited Speaker:
Regina R. Rodrigues, (Dept. of Oceanography, Federal University of Santa Catarina, Brazil)

Over the last few decades, extreme climate events are interacting with longer-term climate change, leading to unprecedented environmental conditions for marine ecosystems and interconnected social systems across the globe. These events include rapid or episodic physical events (marine heatwaves, hurricanes, storm surge) as well as disequilibrium triggered by biological responses to changing climate (ocean acidification, HABs, bleaching). These changes have caused widespread impacts on marine ecosystems, including increased physiological stresses, mass mortalities of marine life, community spatial shifts and destruction of coastal biogenic habitats. Ecosystem changes have affected coupled social systems, altering human activities such as commercial fishing and subsistence harvest, and impacting livelihoods, communities, and cultures. Simultaneous occurrences of multiple climate extremes, termed compound events, have the capacity to exacerbate societal and environmental impacts beyond any extreme event in isolation, challenging the resilience of ecosystems and coastal communities. Near-term forecasting at seasonal, annual, and decadal timescales offers the potential to develop information that will enable ocean stakeholders and resource managers to better prepare for and respond to extreme events.

In this session, we encourage submissions related to climate extremes and associated compound events that: (1) improve understanding of the physical and biogeochemical processes of extreme events; (2) describe ecological and/or socio-economic consequences; (3) describe potential adaptation and management strategies that could mitigate these impacts, including those that advance forecasting of extreme and compound events.

(S5-15978 Plenary)

Response of fish populations in the Humboldt Current System to extreme climate changes during the last 140 000 years

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Climate change will drive marine ecosystems beyond the range of natural variability observed during the instrumental period, impacting the distribution, abundance and diversity of fish communities. Geological records can provide insight on the response of fish populations to past climatic changes, especially during time periods warmer than present. Here, we focus on the highly productive Humboldt Current system (HCS) and show multiple fish debris records together with proxies for environmental conditions spanning the last 140,000 years. This timescale encompasses a variety of combinations of productivity, oxygen, and global temperature and the response of fish populations to these conditions are crucial to understand the effects of future climate change on hotspots of fish productivity. The records reveal multiple modes and timescales of variability in response to past large-scale climate changes of larger magnitude than those observed in the instrumental period. Small pelagic fishes in the HCS are currently in a 'sweet spot' considering that they almost disappeared 125,000 years ago when the world was warmer than today and 20,000 years ago when the world was colder than today. Surprisingly, the warmer-than-present time period was dominated by gobies and mesopelagic fishes; smaller fish species of low economic value that are specially adapted to low oxygen conditions. I discuss how the combined results can be used for adaptation and management strategies. Our rapidly warming world poses a threat to fish productivity in tropical regions and emphasize the need for multidisciplinary research combining paleoceanographic and historical observations with model predictions.

(S5-15899 Invited)

Extreme Compound Events in the tropical and South Atlantic

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Marine heatwaves (MHWs) are analogues to atmospheric heatwaves. They have devastating effects on marine ecosystems, ranging from habitat shifts and changes in population structure to high mortality of various marine species. The impacts of MHWs can be amplified when combined with other extreme events that can act synergistically. Here we investigate the temporal-spatial distribution of compound events of MHW, high acidity and low chlorophyll in the tropical and South Atlantic, using observational datasets and reanalysis products. We show that the frequency and intensity of these compound events have increased dramatically over the past two decades in the tropical and South Atlantic, peaking in the most recent years, putting in check the capability of the marine ecosystems to recover from these compound extremes. We also show that the strong El Niño event in 2015/16 was responsible not only for generating MHWs but also for compound extremes of low chlorophyll and high acidity in the most biologically rich regions of the tropical and South Atlantic. The fact that triple compound extremes are widespread over the tropical and South Atlantic during an El Niño event is important because recent studies have shown that MHWs can be skilful predicted mainly due to ENSO. Thus, the results presented here can help improve models' performance that, in turn, will be used in early warning systems and integrated into disaster preparedness and long-term adaptation.

(S5-15870 Oral)

Marine heatwaves are not a dominant driver of change in North Atlantic and Pacific fish communities

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Marine heatwaves have been linked to a range of negative biological and environmental effects in recent decades. If marine heatwaves regularly induce community reorganization and collapses in animal biomass, the consequences could be catastrophic for ecosystems, fisheries, and human coastal communities. However, the extent to which marine heatwaves have negative impacts on fish abundance or even whether their effects can be distinguished from natural variability remains unclear. The empirical consequences of heatwaves for ocean species have yet to be systematically quantified across systems and events. Here, we investigate the effects of 507 historical marine heatwaves on marine fishes as recorded in 96,606 long-term scientific (i.e., fisheries-independent) bottom trawl surveys from North America and Europe from 1981 to 2019. We find that marine heatwave effects on fish biomass are often minimal and cannot be distinguished from natural background variability. Further, marine heatwaves are not consistently associated with tropicalisation (gain of warm-affiliated species) or deborealisation (loss of cold-affiliated species) in these systems. While certain historically-abundant species did exhibit steep declines following marine heatwaves, this appears to be the exception, not the rule. Against the highly variable backdrop of ocean ecosystems, we find that marine heatwaves have not yet emerged as a consistent driver of biomass decline or community turnover in communities that support many of the world's largest and most productive fisheries.

(S5-16078 Oral)

Large potential impacts of marine heatwave on ecosystem functioning

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Ocean warming is driving significant changes in the structure and functioning of marine ecosystems, shifting species' biogeography and phenology, changing body size and biomass, and altering prey-predator relationships. In addition, extreme temperature events such as marine heatwaves (MHWs) are affecting marine ecosystems in conjunction with long-term ocean warming. MHWs have been increasing in intensity, duration, and frequency with large-scale ecological impacts such as coral bleaching, mass mortality of seagrass meadows, and alternation of populations of marine organisms in the last decades. However, substantial knowledge gap exists in our understanding of the cascading impacts of MHWs on ecosystem functioning and the ability to predict the ecological consequences of MHWs. In this presentation, based on biological data coupled with a trophodynamic approach, we highlight a possible path by which

MHWs affect marine ecosystems. Using EcoTroph-Dyn, a quasi-physical model allowing for the integration of the long-term effects of one-off events, and various scenarios of mortalities MHW-associated algorithms, we show that depending on their characteristics and location, MHW can lead to a significant biomass reduction. The highest trophic levels would be ever more affected, leading to an MHW-induced change in the ecosystems' trophic structure. Results also suggest that tropical ecosystems would be the most sensitive to low-intensity MHW, while temperate ecosystems would be strongly impacted by strong MHW. Findings also support that time to recover can be longer in polar ecosystems. This study highlights the importance of increasing our knowledge of these extreme weather events which will become the norm in the coming decades.

(S5-16100 Oral)

Extreme and compound events are key drivers of low fish biomass

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Harmful impacts on marine ecosystems often result from extreme and prolonged events of anomalous ocean conditions. Of particular concern are compound events, namely when conditions are extreme for multiple ecosystem stressors. Compound events elevate risk for biodiversity, as their effects sometimes interact synergistically. Although ocean compound events have been the subject of an increasing number of studies over recent years, little is known about their impacts on marine species at the global scale. Not all compound events may drive high impact events and not all high impact events may be driven by extreme or compound events. Here, we identify and characterize the combinations of ecosystem stressors associated with the most severe impacts on marine species. Using a global marine fish model, the Dynamic Bioclimate Envelope Model, forced by a large ensemble simulation from an Earth system model, the GFDL-ESM2M, we first identify the immediate drivers of extreme reductions in pelagic fish biomass, e.g., high temperatures, low oxygen, and low net primary production. We then investigate potential lagged effects of ecosystem stressors on fish biomass, and significantly improve the prediction of low biomass events by considering drivers of one up to two years before the event. Finally, we categorize the drivers into moderate, extreme, univariate and compound events. Drivers must either be extreme or compounded, or both, over the majority of the global ocean to result in extremely low fish biomass. Overall, our findings highlight the key role of extreme and compound events in driving severe impacts on marine species.

(S5-16124 Oral)

Can climate and seasonal forecast models help manage fisheries trapped in a cycle of ocean extremes?

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Over the past decade (2010-20), Australia's west coast has experienced a roller coaster of sea-surface temperature (SST) variability driven by extreme climatic events. Strong La Niña, El Niño and Indian Ocean Dipole (IOD) events compounded with anomalous wind and ocean current conditions have caused moderate to extreme marine heatwaves (MHW), multi-year marine cold-spells, and unusual cyclonic activities. Management of wild fisheries under this increased climate variability is becoming one of the biggest challenges facing regulatory agencies and stakeholders.

Here we present examples of fisheries based on species (abalone, scallops, crabs) that have reduced capability to escape an extreme event, and therefore their adaptive capacity to changing ocean conditions is very limited. Assessing stock status and determining catch predictions relies on two key components, (1) pre-fishing season surveys that provide measures of recruitment and spawning biomass and (2) good understanding of stock-recruitment-environment relationships. Together they provide a time series of predictive responses of a stock to a range of changing ocean conditions and their extremes. This has paved the way to invest in utilising near-term seasonal climate and MHW forecast models as additional resource tools. For Western Australia, a warmer than average summer forecast for ocean conditions, increases the likelihood and frequency of MHWs and foreshadows poor recruitment into these fisheries. Therefore, forecast information can inform potential near-future shifts in stock productivity that can be monitored more closely to facilitate proactive management measures, while also helping to manage some of the expectations of stakeholders around climate change uncertainties.

(S5-16144 Oral)

Prediction of marine heatwaves from a seasonal forecast model and a machine learning approach

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Warm ocean temperatures above certain thresholds leading to marine heatwaves have implications for many marine ecosystems and industries. The impacts felt include mass coral bleaching and mortality, altered aquaculture yields and changes in wild fish migration patterns. In a changing physical environment due to anthropogenic climate change and the increased frequency of these extreme events past experience is less valuable, requiring the development of new approaches. Given these changes, seasonal forecasts of marine heatwave risk can be very useful for marine managers, businesses and researchers. We have developed two approaches. The first is based on the Australian Bureau of Meteorology's seasonal forecast model ACCESS-S2. This dynamical ocean-atmosphere model currently produces operational real-time forecasts of global sea surface temperatures. Experimental products based on marine heatwave metrics using daily and monthly forecasts and probabilities of exceeding the 90th percentile are currently being developed and assessed. The second approach is based on machine learning Convolutional Neural Network model. We use sea surface temperature and upper ocean heat content anomalies from the historical runs of a subset of the Coupled Model Intercomparison Project (CMIP) models, which reasonably capture the broadscale

and regional ocean dynamics to train the machine learning model against marine heatwave indices purposely defined for a set of select regions around Australia. These new products will complement existing forecast products to improve both the understanding and the management of these extreme events in a changing climate.

(S5-16199 Oral)

Marine heatwaves erode winter waters in the Southern Indian Ocean

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The Southern Indian Ocean (20:120°E, 70:30°S) is a region of ecological interest, host to several endemic species and to an exceptional biodiversity that contributed to the inscription of the French and Australian natural reserves on the UNESCO World Heritage List. This region is expected to undergo important warming and intense marine heatwaves (MHW). MHW are today mostly studied at the surface, generally due to the lack of daily observations at depth. However, as marine ecosystems may be sensitive to temperature changes over the whole water column, it is essential to evaluate how MHW at the surface can impact deeper layers. Here, the deeper impacts of surface MHW are investigated using *in situ* observations collected from elephant seals and Argo data, MERCATOR reanalysis and OSTIA sea surface temperature observations. Temperature anomalies associated with MHW are found to extend to the subsurface and MHW are associated with a lower probability of presence of the "winter waters", a water mass characterized by a minimum of temperature at around 200 m deep which plays an important ecological role. As MHW are expected to intensify, we investigate the future position of winter waters in Coupled Model Intercomparison Project 6 models and find a southward shift of the Polar Front over time, which is delayed east of Kerguelen, probably due to topographic constraints. This study highlights the potential shift, at different timescales (synoptic to decadal) of ecologically significant vertical temperature structures and the impacts of such change on ecosystems is discussed.

(S5-16230 Oral)

Tracking changes in social-ecological systems along environmental disturbances with the ocean health index

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The well-being of coastal communities is intimately tied to a healthy ocean, but coastal social-ecological systems are among the most vulnerable to global change. Improving the resilience of coastal communities requires an understanding of how local social-ecological systems respond to shocks to better inform decision-making and adapt local management interventions. However, assessments of social-ecological changes throughout a disturbance regime are scarce at the local level, although critical for efficient natural resource management and sustainable use of ocean ecosystem services. Here, we apply the Ocean Health Index (OHI) to assess the status of the marine social-ecological system of a tropical island (Moorea, French Polynesia), and track changes of the system before, during and after a disturbance regime. Our results show that while there are signs of social-ecological recovery, coastal protection was most affected along the disturbance, and that there is room for improvement toward biodiversity conservation. In addition, our study highlights some context-specific challenges associated with local OHI assessments, particularly those driven by limited fisheries data and appropriate reference point selection for coastal protection. Our results demonstrate the value of localized, regular OHI assessments through time to track changes in marine social-ecological systems, while uncovering important data gaps, to inform management at appropriate scales for decision-making.

(S5-16250 Oral)

Application of ecological forecasting to dynamic ocean management tools: a comparison between global and downscaled seasonal forecasts

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Forecasting physical conditions and ecological responses on short timescales, from sub-seasonal to annual, is highly useful to marine resource users and decision makers to anticipate environmental variability and change. We applied seasonal forecasts to two dynamic ocean management tools to provide forward looking information up to 12 months ahead. The tools use ocean temperature anomalies to: (1) guide the timing of a fishery closure to protect loggerhead sea turtles; and (2) inform risk assessments that seek to reduce whale entanglement. In both cases, skillful forecasts were possible 1 to 12 months ahead, providing forward looking ecosystem information for resource managers and conservation practitioners. We then compared the utility of using readily available global forecasts versus forecasts dynamically downscaled to the California Current System. Importantly, we find that both tools can be skillfully forecast using readily available global ocean forecasts. We show that regionally downscaled forecasts

are not a necessity and can, under certain conditions, be less skillful than global forecasts. Our results showcase the capacity for existing dynamic ocean management tools to transition to forecast systems, allowing stakeholders to anticipate and adapt to future climate variability.

(S5-16264 Oral)

Forecasting Northeast Pacific ocean variability and extremes to support ecosystem management

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The ecological and socioeconomic impacts of climate variability – particularly extreme events such as marine heatwaves (MHWs) - present significant challenges to marine resource managers, who would benefit from forewarning to facilitate proactive decision making. A variety of climate and ocean forecast systems have been developed and could potentially support this decision making, provided they can reliably produce skillful predictions of environmental conditions. Here we discuss both global and regional forecast systems, with a focus on the northeast Pacific and on seasonal timescales (1-12 months). The global forecasts include large ensembles, which are well suited to extreme events like MHWs, and to setting probabilistic decision thresholds that are tailored to the user's risk profile. On the other hand, higher resolution regional forecasts may enable better representation of fine-scale dynamics and vertical structure of the water column. We present forecast skill assessments for a suite of ecologically relevant physical variables, among which predictability varies widely; anomalous conditions may be forecast a year in advance for some (e.g., sea surface height), but only a month or less for others (e.g., surface currents). Finally, we suggest that a qualitative alignment of physical forecast skill and ecological forecast requirements is an important first step to identifying forecast applications with the greatest potential for success.

(S5-16280 Oral)

Understanding potential ecosystem impacts of climate-driven increases in moon jelly (*Aurelia labiata)* aggregations

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The Northeast Pacific experienced a marine heatwave in 2015-2016 that coincided with observations of exceptionally large and persistent aggregations of moon jellyfish (*Aurelia labiata). Aurelia* aggregations can contain millions of individuals, span broad areas, and respond to environmental changes. Additionally, overall jellyfish abundance in Puget Sound has appeared to increase since the 1970's. This long-term trend in combination with episodic events like the heatwave may have compounding effects. We investigated the impacts of increased *Aurelia* populations on zooplankton communities, water column chemistry, and the marine food web in Puget Sound. We used laboratory experiments to evaluate predation rates of *Aurelia* on natural zooplankton assemblages and field surveys to quantify *in-situ* impacts of *Aurelia* on their environment. Aerial photographs revealed larger and more abundant *Aurelia* aggregations during the heatwave, particularly in August. Experiments revealed that *Aurelia* were able to remove up to 75% of available copepods in just two hours. *In situ*, copepod density was up to 73% lower within aggregations than outside of aggregations. Across sites, copepod abundance was more strongly related to *Aurelia* abundance than other environmental variables. Results from this study will be integrated into an end-to-end Atlantis ecosystem model, to investigate scenarios of jellyfish effects on salmon, forage fish, and broader ecosystem impacts. We demonstrate that *Aurelia* aggregations significantly alter zooplankton communities, potentially limiting the prey availability for zooplanktivorous fish and other important taxa. Understanding the impacts of *Aurelia* aggregations will help us to predict ecological changes caused by warming and future extreme climate events.

(S5-16311 Oral)

The adaptation strategies of small-scale fishers to storms and extreme climatic events in the coastal region of Bangladesh

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Small-scale fisheries in Bangladesh provide a dynamic setting of ecosystems, vulnerabilities, adaptation, resilience, and uncertainties caused by changing climate. As the intensity and frequency of extreme weather events are expected to increase, it is important to understand how fishers and the fish resources are affected by it and how their daily responses contribute to their ability to adapt to changing weather conditions. The way in which fishers make weather-related decisions specifically during extreme events is poorly understood.Understanding how small-scale fishers respond and adapt to tropical storm and other climatic extreme events are essential for supporting coastal communities and reducing the vulnerabilities of those dependent on fisheries for life and livelihood.

Using mixed method approach, this paper identifies and investigates the adaptation strategies adopted by small-scale fishers in Barguna and Patharghata upazila of Bangladesh to deal with extreme weather events.

(S5-16361 Oral)

Rapid Attribution of Ocean Temperatures

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With notable exceptions like the North Atlantic "warming hole," ocean temperatures around the world are rising. The long-term trends are punctuated by periods of even more extreme temperatures such as marine heatwaves. While trends are clear and likely strongly connected to human-cased climate change, the oceans also exhibit variability at the scale of days-to-decades due to processes unrelated or loosely connected to climate change. We are developing an operational system to estimate the impact of human-cased climate change on daily sea surface temperatures anywhere in the ocean. This system uses a multi-model approach that combines observed trends, trends from large ensemble climate simulations, and paired control and forced climate model runs from CMIP6. The system builds on Climate Central's Climate Shift Index operational, daily climate change attribution system for air temperatures. We will provide an overview of how daily ocean temperatures can be linked to climate change and will introduce a new metric to quantify and communicate these linkages. We will also present attribution assessments for recent temperature events that had significant ecological or socio-economic impacts.

(S5-16382 Oral)

On the impact of interannual climate variability and marine heatwaves on poleward expansion of African sardinella stocks.

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Shifts in species' ranges are one of the most ubiquitous effects of climate change in the global ocean. The associated increase in the intensity of marine heatwaves exacerbates these effects by prompting tropical species to shift their distributions into rapidly warming regions. The coastal ocean off tropical West Africa is warming steadily at an unprecedented rate and is experiencing marine heatwaves on both sides of the Equator. The highly migratory *Sardinella aurita* is evidently exposed to the impact of such climatic pressures.

This article looks at how the interannual climate variability and marine heatwaves influence changes its range at the poleward limit of its distribution (the Cap Blanc – Cabo Verde Front for the Northwest Africa stock and the Angola-Benguela Front for the Southeast Atlantic stock). *S. aurita* undertakes a regular poleward migration annually in response to the seasonal severing in its principal habitat during warm seasons. The major MHWs events (the Dakar and Benguela Niño in the north and south, respectively) occur in the same season, thus tend to amplify the migration of adult fish. However, the potential distributional shifts due to the amplified migration are counteracted by the increasing exploitation pressures at the far ends of their migration range (in southern Angola and Mauretania, respectively). Furthermore, contrary to the sardinella's main habitat in the tropical Atlantic, which is warming, the permanent upwelling cells at the end of their migration range are cooling, thus increasing the thermal barrier, which further limits the poleward expansion of their range.

(S5-16405 Oral)

Ecological complexity, prediction, and management of socio-ecological systems in the wake of extreme climate events off California

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Ecological complexity makes prediction of extreme climate impacts a major challenge for marine social-ecological systems. Off California, recent marine heatwaves (MHW), including a major extra-tropical event in the North Pacific (dubbed 'The Blob') offer compelling examples of how once-seemingly rare climatic events can affect both the ecology of regional ecosystems, as well as management systems designed to minimize human impacts on these systems. Starting in the mid-late 2010s, entanglements of recovering baleen whale populations in regional crab fisheries began to increase in conjunction with ocean warming, reductions in favorable cool-water upwelling habitat (i.e., upwelling habitat compression), and distributional shifts in prey species poleward and shoreward. Concurrently, ocean warming related to harmful algal bloom events and an increase in domoic acid (a neurotoxin) in the system, caused early closures of the crab fishery and reduced economic opportunities. The State of California now manages this system using a stakeholder-based (fishers, ecologists, managers) risk assessment model and procedures that utilize species distribution models (SDMs) to better predict shifts in prey populations and the related shifts of whales into the nearshore crab fishing grounds where they may become entangled. In this presentation, we provide an update overview of this case history of MHW effects, as well as select results of new prey SDMs and possible management approaches. As baleen whales in California and elsewhere continue to recover from over-exploitation during this period of ocean climate change, better near-real time predictions and nimble social systems will be needed to simultaneously maintain sustainable fisheries and meet biodiversity conservation goals.

(S5-16438 Oral)

Effects of heatwaves on zooplankton-to-salmon connections differ across contrasting regions of the U.S. Pacific coast.

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Salmon are among the most culturally and economically important fish to native communities and U.S. West Coast fisheries. In many regions, their populations have been in decline for decades. Particularly catastrophic returns followed recent marine heatwaves. Salmon survival from outmigration to adult depends on many factors, with zooplankton prey availability during a critical juvenile growth phase hypothesized to play a key role. We used data from monitoring programs in the upwelling system of the Northern California Current, the downwelling system of the Gulf of Alaska, and the estuarine fjord of the Salish Sea to explore spatial variability in ecosystem response to environmental change during the recent Pacific marine heatwaves. We will show how the unprecedented temperatures related to physical and lower trophic level changes across these different systems, with a focus on the link between zooplankton prey and salmon abundance trends. Large-scale shifts in conditions were observed, with contrasting responses across systems. The northern California Current experienced oligotrophic conditions, lower biomass of lipid-rich zooplankton, and reduced salmon abundance. The Gulf of Alaska experienced increased zooplankton, but reduced salmon abundances. In the Salish Sea, zooplankton, juvenile salmon growth, and some adult returns were elevated during the heatwave. Across systems, most adult salmon returns (especially coho and Chinook salmon) decreased dramatically, resulting in fishery closures, job losses, and significant declines in revenue. These differential responses provide a unique research opportunity, and a challenge for managers who seek fishery projections from readily available metrics such as temperature.

(S5-16448 Oral)

Borealization of the Bering Sea and collapse of the snow crab fishery: perspectives for informing adaptation decision-making

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Rapid warming and borealization of the eastern Bering Sea in 2018-2019 resulted in the collapse of the snow crab (*Chionoecetes opilio*) population, resulting in the closure of a fishery worth ~$200 million USD. As the fishery enters a rebuilding period, stakeholders are faced with a range of challenging adaptation decisions. Here, we advance an approach for informing this decision-making, based on: 1) the use of climate attribution time series to track growing human influence on Bering Sea climate; and 2) probabilistic ocean temperature projections to evaluate changing climate risk for the snow crab fishery. Using output from 23 CMIP6 climate models, we construct a 1950-2021 time series of the Fraction of Attributable Risk (FAR, a common attribution statistic), for Bering Sea temperature. These FAR values track the

growing human influence on Bering Sea climate since the 1970s, and show that the warming associated with the collapse was overwhelmingly associated with human-caused climate change. Hindcasts and projections from the same climate models indicate that warming similar to 2018-2019 was absent in the preindustrial climate, but is expected in 17% of years in the current climate. This risk is projected to exceed 30% by the 2030s or 2040s, depending on emissions trajectories. Humans naturally evaluate risk with a historical (backwards-looking) perspective based on lived experience. By documenting changing climate risk in a simple but empirically robust framework, our approach may help individuals and institutions to make the transition to a forward-looking perspective that assumes current trends will continue.

POSTER BOARD ID: S5-P1

(S5-15921 Poster)

Sensitivity of the upwelling system along the North-West African margin to extreme climatic events and ecological consequences

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Previous analyses have shown that the upwelling along the North-West African margin has experienced multi-scale changes in the last three decades. In this paper, we first present improved coastal upwelling indices (Ekman transport based (ECUI) and a thermal SST based (TCUI)). The seasonality of these indices and Chlorophyll-a (CHL-a) signature shows a wind-to-chlorophyll-to-SST lag relationship at all latitudes studied over the period from 1993 to 2021. The two indices, CHL-a, Biomass of Sardine, and three basin-scale forcing factors, North Atlantic Oscillation (NAO), Azores High (AH) and East Atlantic Oscillation (EAO) are then analyzed to identify the interannual variability and sensitivity to extreme climatic events. Our analysis suggests three common bands of periodicity for the upwelling indices: one near-decadal and two inter-annual, 4-5 years and 2-3 years. It appears that the inter-annual bands are forced by the AH and related to the EAO; while the near-decadal bands might be forced by NAO. The extreme event analysis shows that the year 1994 experienced an extreme positive NAO value, also reflected in upwelling indices and a bit delayed in CHL-a and Sardine biomass. This extreme positive event is followed by a strong negative phase 1996/1998 for NAO/TCUI with one-unit delay in CHL-a/Biomass/ECUI. These revealed interannual variability, lag relationship between variables, and the results on the sensitivity to extreme climate events might have profound implications on fisheries management strategies of small pelagic fish. Future research aligned with such directions will advance forecasting of stock size of small pelagic fish.

POSTER BOARD ID: S5-P2
(S5-15926 Poster)

Impacts of marine heatwaves and cold-spells on North Sea fisheries

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The North Sea supports many important commercial fisheries and has also been described as a 'hotspot' of marine climate change; so it is unsurprising that many studies on climate change impacts have been carried out in the region. Very few studies, however, have so far looked at temperature extremes in the North Sea, and how these might impact fisheries. For the southern North Sea, we found evidence of widespread anomalous heatwaves and cold-spells throughout the period 1993–2019. Winter cold-spells occurred in 1994, 1996, 1997, 2010, 2011, 2013 and 2018. In years with cold-spells, fisheries catches of sole and sea bass increased, while catches of red mullet and edible crabs decreased. Widespread heatwaves occurred in 1998, 2002, 2003, 2006, 2007 and in each of the years 2014–2019. For heatwaves, lagged effects on fisheries catch data were found, by five years following the temperature events: sole, European lobster and sea bass catches increased whilst red mullet catches reduced. Clearly, the marked warming trend in the North Sea over the past three decades has been punctuated by both heatwaves and cold-spells, that can be linked with changes in fisheries catches – either negative or positive. Lagged effects are suggestive of effects on the recruitment and survival of juveniles, only witnessed in the fisheries catches once individuals are sufficiently large to be caught. The immediate, negative effects following cold-spells suggest direct mortality impacts.

POSTER BOARD ID: S5-P3
(S5-16019 Poster)

Warming affects physiological performance and growth of ark clams in seasonally different manners in a temperate coastal embayment of Korea

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Knowledge of physiological responses of shellfish species to rising temperatures is crucial in assessing the impacts of warming on shellfishery production. We tested the effects of winter minimum (3–8°C) and summer maximum (23–28°C) temperature elevations on individual physiological processes (ingestion, respiration, egestion, and excretion) and the combined energetic physiology (scope for growth [SFG] and net growth efficiency [K_2] measures) in the ark clam (*Anadara kagoshimensis*) cultured in the shallow bottom in Yeoja Bay, Korea. The seasonal cycle of dry tissue weight (DW) was investigated in 2016–2018 to compare its variation at contrasting cold vs. warm regimes. The weight exponents of the allometric equations between physiological rates and DW were low at the winter minimum compared with the remaining season temperatures, indicating a higher thermal sensitivity in larger individuals. The physiological rates for individual components increased with increasing temperature, generating negative SFG and K_2 values at 3 and 28°C. The interannual difference in the seasonal cycle of clam DW displayed variations in the period of increment prior to spawning and the post-spawning loss/recovery. Overall results indicate that warming is projected to affect physiological performance and the seasonal DW cycle of clams in different manners between winter and summer: physiological benefits and advanced weight gain vs. heat stress and

progressive weight loss, respectively. The mechanistic adjustment of the clam energy balance across thermal conditions seems to explain the recent advancement in its seasonal biological cycle, as well as the failure in spat collection and the mass summer mortality observed.

POSTER BOARD ID: S5-P4
(S5-16044 Poster)

Forecasts do not determine actions- they are part of a complex decision space

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Forecasts of marine environmental and ecosystem conditions are now possible at a range of time scales, from nowcasts to forecasts over seasonal and longer time frames. This presentation will cover two aspects of forecast development and delivery – the ethical considerations and the ability of end users to respond to these future environmental conditions. First, the ethical aspects. The pace of progress in forecast development is so rapid that the scientific community may not be considering fully the impacts on stakeholders and their incentives. Delivery of information, particularly about future conditions and the uncertainties associated with it, involves a range of judgements, or "ethical" considerations, including treatment of forecast failure, inequity in stakeholder response options, and winners and losers in commercial markets. We suggest a set of ten principles that might be considered by developers and users of ecological forecasts to avoid these ethical pitfalls. Second, to benefit from a forecast, a marine business will need to be agile to respond to changing information and response options. The management agility of different marine businesses in fisheries, aquaculture, and tourism can influence their ability to use seasonal forecast information effectively, and potentially modify the usual negative relationship between resilience and the frequency of the stress event, thus reducing the impact of extreme events. Engagement between forecast developers and marine users can also improve responses, while at the same time, improving the agility of businesses can enhance overall resilience to extreme events and lower their risk. Overall, an interdisciplinary approach, and co-production with end users will provide insurance against many unanticipated consequences.

Hartog, J. R., C. M. Spillman, G. Smith and A. J. Hobday (in review). Forecasts of marine heatwaves for marine industries: reducing risk, building resilience and enhancing management responses. Deep Sea Research II.

Hobday, A. J., J. R. Hartog, J. P. Manderson, K. E. Mills, M. J. Oliver, A. J. Pershing and S. Siedlecki (2019). Ethical considerations and unanticipated consequences associated with ecological forecasting for marine resources. ICES Journal of Marine Science: https://doi.org/10.1093/icesjms/fsy1210.

POSTER BOARD ID: S5-P5
(S5-16063 Poster)

Exploring the ecosystem-level effects of the 2013-2016 marine heatwave in the Gulf of Alaska with an Atlantis ecosystem model

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The Gulf of Alaska (GOA) is a large marine ecosystem with complex bathymetry and oceanography that supports high fishery revenues. In recent decades, the GOA has been exposed to climate events like marine heatwaves, which have had complex effects on multiple ecosystem components and resulted in productivity fluctuations and trophodynamic shifts. Alaska's marine ecosystems are warming fast, and heatwaves are predicted to occur more frequently in the future. Ecological models can help explore climate events and their effects on ecosystem status and productivity. We present the development of an end-to-end Atlantis ecosystem model for the GOA, and its application to investigate the ecological effects of the 2013-2016 North Pacific marine heatwave (dubbed "The Blob") on the GOA marine ecosystem. The model area extends along the GOA continental shelf, from Vancouver Island (Canada) to the Aleutian Islands (Alaska). Atlantis GOA captures the GOA food web using 78 functional groups, encompassing all size classes from nutrient pools and plankton to megafauna. It also features a geophysical sub-model forced with outputs from oceanographic models (ROMS-NPZ) for the Northeast Pacific. The main sources of commercial fishing in the GOA for 1991-2020 are represented by reconstructing historical biomass removals. We ran Atlantis GOA to simulate the years 1991-2020, forcing the model with ROMS output for the same period, and explored the ecosystem-level effects of the 2013-2016 heatwave. We present how Atlantis GOA can be used to evaluate, predict, and strategically manage adverse effects of climate events on the GOA marine ecosystem.

POSTER BOARD ID: S5-P6
(S5-16087 Poster)

Fishery services from degraded coral reefs

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Ocean warming is expected to impact reef fisheries by inducing habitat turnover and restructuring fish assemblages. Climate-driven shifts in fisheries productivity threaten the supply of nutritious seafood in tropical coastal nations, and yet our understanding of both fish production and fish nutrient content on degraded reefs is limited. Here, we integrate reef fish nutrient concentrations into a fish production framework to estimate three fishery services from coral reef fishes: standing biomass, biomass production, and nutrient turnover. These metrics provide information for understanding food and fisheries provisioning from future coral reefs. We use underwater survey data from four Indo-Pacific countries to show that low trophic level fishes dominate fishery services on most reefs, and will likely become increasingly important sources of nutritious seafood from climate-impacted reefs owing to their resilience to coral declines and fishing pressure. These reefs span gradients in benthic composition, and we develop statistical models to quantify change in the standing biomass, productivity, and nutrient turnover of reef fishes in four alternate habitat regimes (hard coral, turf algae, macroalgae, and rubble). We predict that reef fisheries will continue to support tropical food and nutrition security despite coral declines, but that trophic turnover will cause catch composition to vary among benthic regimes. Our results provide a new framework for estimating nutrient production from fisheries that can help inform efforts to manage reef fisheries amid accelerating climate impacts.

POSTER BOARD ID: S5-P7
(S5-16099 Poster)

Sea Surface Temperature and Environmental Reconstruction of La Paz Bay, Gulf of California: New Evidence from *Pinctada mazatlanica* $\delta^{18}O$

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Reconstruction of Holocene oceanic characteristics, climatic patterns and phenomena that affect marine and human communities can be reconstructed from past surface sea temperatures (SSTs) using stable oxygen isotopes in bivalve shells. With the objective of calculating Holocene summer SSTs for La Paz Bay, Gulf of California, we analyzed $\delta^{18}O$ of *Pinctada mazatlanica* and *Chione californiensis* shells belonging to a ^{14}C dated Holocene open camp site, located in La Cañada de la Enfermería, Baja California Sur, México. Presently the summer season $\delta^{18}O$ value of *P. mazatlanica* is -1.8 ± 0.2‰, varying between -1.3‰ and -1.9‰ during the last 8.4 ky. Between 8396 BP and 7070 BP $\delta^{18}O$ was slightly enriched (0.2‰ to 0.1‰), suggesting slightly colder SSTs vs. the present, while in 7805 BP, $\delta^{18}O$ values were very similar to those of the present. Finally, in 6945 BP and 2087 BP, $\delta^{18}O$ was enriched (0.4‰ to 0.5‰), suggesting colder SSTs vs. the present. Our results coincide with other paleotemperature studies for the region, enabling in-depth analysis of changing SST, and its effects on bivalve resources and human presence in the bay area with respect to climate variability.

POSTER BOARD ID: S5-P8
(S5-16232 Poster)

Assessing the potential for resilience towards Marine Heatwaves and Artificial Light at Night in Kelp species

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Identifying adaptive or mitigating solutions for climate change is especially important for high conservation value ecosystems, such as kelp forests. The effects of Marine Heatwaves (MHWs), on their physiology have been greatly overlooked when addressing thermal stress impacts, with a greater attention given to ocean warming. Studies of MHWs combined with ocean acidification, have demonstrated that the extra CO2 helped organisms on their thermal resilience, yet the effect extra light sources could have has never been analyzed. In this study the combined effect of MHWs (+3ºC) and Artificial Light at Night (ALAN), exposure was tested on the photosynthetic parameters, growth and respiration (R) rates and C/N tissue ratio of the species Laminaria digitata. A 14-day MHW simulation was performed followed by a 10-day recovery period, in mesocosm experiments at the Plymouth Marine Laboratory. A "collapsed factorial design", was used with "SW Temperature" set as the main driver and "Light availability nested within SW Temperature" as the secondary one. MHW alone caused significant negative impacts on growth and C/N tissue ratios, with organisms presenting the lowest rates, even in the recovery period, while it increased their fluorescence responses. On the other hand, MHW combined with ALAN treatments showed the highest's values of growth and C/N ratios, while presenting the lowest values of quantum efficiency, due to down regulations of light consumption mechanisms. It was concluded that by exposing organisms to ALAN this could help them on their resilience to MHW events, by enhancing their carbon fixation rates, and energy production.

POSTER BOARD ID: S5-P9
(S5-16244 Poster)

Changes in Modern Foraminiferal Assemblages Associated with Recent Northeast Pacific Marine Heatwaves

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Planktic foraminifera are globally ubiquitous, shelled microzooplankton that are often preserved in deep sea sediments, forming fossils commonly utilized in paleoclimate research. Modern foraminifera species assemblages and their shell chemistry reflect ocean conditions at the time of calcification, providing insight into the past. Foraminiferal assemblages frequently correlate with sea surface temperature, typically reflecting broad, latitudinal regions, with higher-frequency variability occurring over smaller spatial scales. Foraminifera assemblages respond to anomalous events such as El Niños, providing information on the frequency of these events in the paleo record. How do extratropical, transient warming events like the recent Northeast Pacific marine heatwaves influence foraminiferal assemblages?

This study presents a multi-year, seasonal, and cross-shelf record of planktic foraminifera

collected from a long-term time series in the Northeast Pacific. We present results from 2014-2021 from quarterly cruises conducted along the Newport Hydrographic Line (44.6ºN) from 46 to 370 km offshore of Oregon, USA. During this period, two marine heatwaves impacted the region. Here, we show variability in diversity and community composition in response to season, distance offshore, variation in marine heatwave strength and duration, upwelling and downwelling. During marine heatwaves, warm water species dominated the foraminiferal assemblage, and during prolonged warming, novel species were encountered. These results provide important insight into how foraminifera assemblages will respond to future warming, and how the fossil record may be used to describe marine heatwaves in the past. Rare or unexpected taxa, often excluded from analysis, could lend insight into the frequency and severity of marine heatwaves.

POSTER BOARD ID: S5-P10

(S5-16267 Poster)

The impacts of acute stressor events on survival and stress response of Pacific oysters

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Acute stressor events in marine environments are increasing in both duration and frequency due to climate change. Of particular concern are heatwaves, which can lead to a range of detrimental impacts, most notably mass die-offs of shellfish. In recent years, cultured Pacific oysters (*Crassostrea gigas*) have demonstrated a high susceptibility to summer mortality events. Research has shown mortality to typically occur when summer temperatures reach >19°C and there is growing awareness that heatwaves are a contributing factor. In addition to thermal stress, warming events also cause oxygen limitation due to forced rises in organismal metabolic rates and oxygen demand and parallel reductions in water oxygen concentration, thereby magnifying challenges to survival. However, the roles of heatwaves and hypoxia in Pacific oyster summer mortality remain poorly understood thereby limiting the development of mitigative measures. This talk will address these knowledge gaps including discussion of both field trials and laboratory-based heatwave and hypoxia experiments. Additionally, a number of potential techniques for mitigation of acute stressor events will be presented. Results of this work will contribute to a better understanding of climate change impacts on shellfish species and promote the development of practical solutions to summer mortality for shellfish growers across the globe.

POSTER BOARD ID: S5-P11
(S5-16303 Poster)

Extreme thermal fluctuations in the Benguela Upwelling System

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The Eastern Boundary Upwelling System (EBUS) bordering South Africa, Namibia, and Angola is one of the most productive Large Marine Ecosystems (LMEs) globally. The region's importance stems primarily from its productive fisheries, but mining, oil and gas extraction, maritime commerce also significantly contribute to the countries' GDP. The long-term changes to the marine thermal climate shows very strong warming trends in the Agulhas Retroflection region, and on the shelf off southern Angola, with localised cooling in small patches in the coastal southern Benguela. In this presentation we reflect on the consequences this long-term warming/cooling has for marine heatwave (MHW) dynamics and cold snaps (CSs) and extreme thermal transitions (ETTs) and subsequent impacts on ecosystems and livelihoods. Ecological impacts stemming from 'pulses' of hot water intruding into the region are due to i) Agulhas Rings impacting coastal areas along the Southwestern Cape coast, ii) coupled variation in low O_2 events and MHWs near Lüderitz in Namibia, and iii) the intensification of poleward flow coupled with weakened upward flow and atmospheric forcing in regions around southern Angola. We then discuss the activities the Extreme Events in the Benguela Upwelling System (EXEBUS) programme are developing to capacitate the stakeholders of the region to mitigate and adapt to plausible future scenarios expected for the region.

POSTER BOARD ID: S5-P12
(S5-16335)

Challenges of simulating ecosystem-level impacts of marine heatwaves: from physiological studies to ecosystem modeling.

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Marine heatwaves (MHW) affect a wide variety of organisms with diverse ecological roles and positions in food webs. These extreme events have direct positive or negative impacts on individuals' physiology that can upscale to the population level, leading to dramatic changes in population size (e.g., recruitment, mass-mortalities), and modified distributions and migrations. For previously occurred MHWs, these impacts have been reported to propagate through trophic interactions or habitat (e.g., foundation species) to affect other ecosystem components. Beyond a posteri analyses, via simulation, ecosystem models (EM) have the potential to provide a more comprehensive understanding of MHW impacts at broader ecological levels. However, challenges still remain for representing MHW in EM. Here, we review a broad spectrum of existing EM to identify if/how their characteristics (e.g., spatio-temporal resolution, biological/ecological mechanisms integrated), make them appropriate for simulating MHW. We then highlight why representing the mechanisms of MHW impacts and their consequences in EM is challenging, focusing on knowledge gaps about (i) metabolic, physiological, behavioral and life-history responses of organisms to MHW, (ii) their dependence on multiple features of MHW (i.e., intensity, duration, frequency), and (iii) the effects of associated conditions other than extreme temperatures. Lastly, we focus on MHW-induced mortalities to illustrate how physiology concepts, laboratory experiments, and meta-analyses can help model the ecosystem impacts of MHW. Informed in such a way by multidisciplinary research efforts, EM may help anticipate the impact of future extreme events and contribute to designing a climate-ready management of socio-ecological systems.

POSTER BOARD ID: S5-P13
(S5-16376 Poster)

Spatio-temporal trends of marine heatwaves in the western Baltic Sea between 1950-2020

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Marine heatwaves (MHW) are a phenomenon causing periods of high-temperature in the oceans that may have long-lasting ecological and socioeconomic effects. The Western Baltic Sea (WBS, subdivisions 22-24 from the International Council for the Exploration of the Sea (ICES) is a region in northern Europe of importance for providing numerous ecosystem services and it is crucial to gain insights about the regional trends and effects of MHW in the region. We analyzed MHWs in the WBS using historical daily sea temperature (surface and bottom) from 1950 until 2020 on a 0.25x0.25° resolution, originated from the Baltic Sea Ice Ocean Model (BSIOM). Preliminary results show ~23% more events in the last decade (2011-2020) than in the previous decade (2001-2010) and ~428% more events than the first measured decade (1951-1960). Further, the analysis showed frequent and stronger surface events during summer months (May-August) with longer but milder events during October-December, while bottom events were stronger between winter months (November-February). We also identified an ongoing bottom event since 2019, possibly related to the strong change in temperature in relation to its long-term climatology. Seasonally, surface and bottom events became stronger, with modern events observed also across seasons. Spatially, the majority of modern events between 2011-2020 happened south of Danish Zealand and southeast of the German Rügen islands. Next steps aim to identify the MHWs relation with hypoxic events in the WBS. With such a dramatic increase of events in the last years, we expect to observe increased risks of compound extremes in the WBS.

POSTER BOARD ID: S5-P14 **REVISION:** Poster CANCELLED.
(S5-16412 Poster)

Investigating the ecological impacts of marine heatwaves on the eastern Gulf of Alaska using an Ecopath with Ecosim ecosystem model

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The Gulf of Alaska (GOA) hosts numerous federally protected species and valuable fisheries, both of which were adversely impacted by a severe marine heatwave in 2013-16 ('the Blob') and a second, weaker one in 2019. Such events are expected to increase in frequency and strength with global ocean warming. The eastern GOA (EGOA) is distinguished from waters to the west (WGOA) by many features of its oceanography, ecology, and fisheries, but has received less scientific attention than the WGOA. We remedy this situation by presenting a mass-balance (Ecopath with Ecosim) model of the EGOA food web. The study area includes the continental shelf and slope from 54º40'N northwest to 147ºW, excluding large fjords. Ecosystem structure is represented as a network of biomass pools and fluxes informed by fisheries-independent surveys, fisheries catches, and ROMS-NPZ oceanographic models. This mass-balance model includes 74 functional groups, spanning all trophic levels from phytoplankton to whales, and 19 fishing fleets. Group and fleet structure focuses on protected species and commercial fisheries. This model was fitted to time series and driven with ROMS-NPZ outputs to generate hindcasts of ecosystem dynamics before, during, and after each marine heatwave. These hindcasts revealed the trophic paths followed by heatwave impacts propagating through the EGOA food web in 2013-16 and 2019. This model is expected to support projections of future ecosystem dynamics under various climate change scenarios. It also presents an opportunity for multi-model inference together with a mass-balanced WGOA model, a GOA end-to-end Atlantis model, and a GOA multi-species model.

POSTER BOARD ID: S5-P15
(S5-16433 Poster)

Characterization of marine heatwave events in a tropical coral reef system in the Gulf of Mexico: The Veracruz Reef System

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The Veracruz Reef System (VRS) is a Natural Protected Area located on the continental shelf of the state of Veracruz in the southwestern Gulf of Mexico. It features two conglomerates of reef structures: one to the north, in front of Veracruz City and the Port of Veracruz, and the other to the south, in front of Antón Lizardo City. The VRS differs from other tropical reef systems worldwide as it is one of the most complex and anthropogenically disturbed. It is in an area of strong seasonal oceanographic and atmospheric phenomena, including upwelling and downwelling, hurricanes, severe northerly winds, constant terrigenous and agricultural

discharges, and extreme heat stress events. Anomalously warm temperature events such as marine heatwaves (MHWs) are detrimental to reef ecosystems. Our study would be the first to contribute to the understanding of extreme heat stress events in the VRS and the reefs' ecological response to MHWs, thus allowing the crafting of science-based conservation solutions. This study aims to characterize MHW events in the VRS through the processing and analysis of sea surface temperature (SST) data from 2012 to 2019 of 15 reef structures distributed in the VRS. Preliminary results show evidence of several MHW events in all reef structures from 2015 to 2019. Results also show that MHWs vary locally within the VRS. Statistical analysis and discussion of data are set to be completed by January 2023.

POSTER BOARD ID: S5-P16
(S5-16451 Poster)

Climate change and greenhouse gas related impacts on contaminants in the ocean – Working Group 45 of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

Justin P. **Gwynn**[1], Vanessa Hatje[2], Manmohan Sarin[3], Alessandro Tagliabue[4], Christoph Voelker[5], Dario Omanovic[6], Núria Casacuberta Arola[7], Ricardo O. Barra[8], Sylvia Sander[9], Pamela Noyes[10] and Iolanda Osvath[11].

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The effects of climate change (CC) on contaminants and their potential consequences to the marine environment are increasingly important, as they pose overlapping risks. The Group of Experts on the Scientific Aspects of Marine Environmental Protection Working Group 45 (GESAMP WG45) has been tasked to better understand the interactions of observed and predicted CC impacts and contaminants in the marine environment. Climate impacts on the land, cryosphere and oceans will ultimately have consequences for the sources, fate, behaviour, uptake and effects of contaminants for marine ecosystems and humans. Climate impacts, such as changes in precipitation and run-off, sea-level rise, ocean warming, ocean deoxygenation, changes in circulation, extreme events as well as ocean acidification impacts, will interact with contaminants in a complex manner that is currently poorly understood.

Overall, the holistic consideration of the contaminants-climate change nexus has significant knowledge gaps and the identification of these gaps will be key to promote further research in fundamental aspects of assessing the risks from contaminants such as transport, inventories, speciation, bioavailability and toxicity. Greater focus on the uncertainties associated with these issues would improve our ability to predict the consequences of future changes in the global marine biogeochemical cycling of contaminants to marine ecosystems and ecosystem services as well as human well-being.

GESAMP WG45 combines the efforts of a multidisciplinary group of scientists with expertise covering trace elements, radionuclides, organic pollutants, and nutrients. This paper will present some of the findings of the GESAMP WG45.

POSTER BOARD ID: S5-P17
(S5-16461 Poster)

Climate, currents and species traits contribute to early stages of marine species redistribution

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Anthropogenic climate change is causing a rapid redistribution of life on Earth, particularly in the ocean, with profound implications for humans. Yet warming-driven range shifts are known to be influenced by a variety of factors whose combined effects are still little understood. Here, we use scientist-verified out-of-range observations from a national citizen-science initiative to assess the combined effect of long-term warming, climate extremes (i.e., heatwaves and cold spells), ocean currents, and species traits on early stages of marine range extensions in two warming 'hotspot' regions of southern Australia. We find effects of warming to be contingent upon complex interactions with the strength of ocean currents and their mutual directional agreement, as well as species traits. Our study represents the most comprehensive account to date of factors driving early stages of marine species redistributions, providing novel evidence for the assessment of the vulnerability of marine species distributions to climate change.

S6: Deep-Sea responses to, and solutions for, Climate Change

Convenors:
Lisa Levin (Corresponding), (Scripps Institution of Oceanography, UC San Diego, USA)
Nathalie Hilmi, (Centre Scientifique de Monaco, Monaco)
Telmo Morato, (University of Azores, Portugal)
Moriaki Yasuhara, (University of Hong Kong, China)

Plenary Speaker:
Roberto Danovaro, (Polytechnic University of the Marches, Ancona, Italy)

Invited Speaker:
Natalya Gallo, (Department of Biological Sciences, University of Bergen and Bjerknes Center for Climate Research, Norway)

This session will examine the intersection of deep-sea climate science, management, conservation, economics and governance. We invite contributions relevant to deep-ocean climate impacts, interface with human uses (e.g., energy, mining, fishing), climate adaptation, carbon services (storage and sequestration), and ocean-based climate interventions. Contributors from different disciplines (physical oceanography, chemistry, biology, social sciences) and approaches (modeling, observations, paleo studies, policy) are invited to think broadly about how their understanding of climate change in the deep ocean can inform actions going forward.

(S6-16479 Plenary)

Deep-Sea responses to, and solutions for, Climate Change

Roberto Danovaro

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The deep sea encompasses the largest, most extreme and remote ecosystems on Earth. Deep seafloor ecosystems host a huge, yet largely unexplored biodiversity, and provide crucial services that are vitally important to the entire humankind. Despite their remoteness, these ecosystems are not immune from direct and indirect anthropogenic impacts. Rising CO2 and greenhouse gases are causing significant changes in ocean properties in terms of seawater temperatures, water column oxygenation, pH and food supply, with concomitant impacts on deep-sea life. Projections for deep-sea ecosystems suggest that ocean temperatures could increase by 1°C down to abyssal depths over the next ca 80 years. Bathyal depths worldwide will undergo to the most significant changes, with relevant decrease of the pH values (0.3-0.4 pH units) by 2100, along with the decline of O_2 concentrations. These changes will be coupled with the decrease of the supply of particulate organic matter to the deep seafloor (by ca 50%) by the end of this century. How these changes will affect deep-seafloor ecosystems and their biodiversity is still largely unknown. In this presentation, I will provide an overview of the current knowledge of deep-sea ecosystems response to climate change, including episodic climate driven events, how these changes may interact with other anthropogenic stressors, and which are the possible solution to increase the adaptation of these ecosystems to ongoing climate change.

(S6-16408 Invited)

Norwegian fjords as microcosms for examining deep-sea ecosystem responses to climate change and cumulative human stressors

Natalya D. **Gallo**[1,2], Mari S. Myksvoll[2,3], Martine Røysted Solås[1,2], Arild Folkvord[1], Arved Staby[3], Lisa A. Levin[5], Francesco Saltalamacchia[1,2], Shuang Gao[2,3], Joâo Bettencourt[2,4], Karin Limburg[6], Elin Darelius[2,4] and Anne Gro Vea Salvanes[1,2]

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Fjords are iconic and economically important marine ecosystems in Western Norway that are home to abundant deep-sea organisms. The bathymetric characteristics of fjords – deep 200-1400 m basins separated from continuous exchange of oceanic waters by shallow sills – make these deep-sea ecosystems particularly sensitive to climate-related changes in circulation. When fjord basin water is not renewed, the deep-sea environment can become hypoxic, and this deoxygenation coincides with deep-water acidification. However, little is known about how sensitive deep-sea organisms are to these periods of stagnation, or how community recovery follows a basin water renewal event. A unique time series from Masfjord, a fjord near Bergen, can shed light on this knowledge gap. Between 2011 and 2018, the basin water of Masfjord experienced a ~67% decline in dissolved oxygen and turned hypoxic due to stagnation and aquaculture inputs. Additionally, basin water pH was estimated to have decreased by 0.29 pH units and become undersaturated with respect to aragonite. Then, in 2021, the basin water was renewed and Masfjord transitioned back to a well-oxygenated state. A time series of depth-stratified net-based samples taken in Masfjord from 2011-2022 newly reveals how the deep-sea community responded to basin water stagnation and subsequent renewal. I will present the results of this analysis and share how the HypOnFjordFish and CLIFORD projects combine field observations, climate model projections, and physical, biogeochemical, and ecosystem models to examine the impacts of past and future stressors on Masfjord. The talk will conclude with how these efforts can inform sustainable fjord management.

(S6-15852 Oral)

Mitigation or Mutilation? Deep-sea Consequences of Ocean-Based Climate Intervention

Lisa A. **Levin**[1], Joan M. Alfaro-Lucas[2], Ana Colaço[3], Erik E. Cordes[4], Neil Craik[5], Roberto Danovaro[6], Henk-Jan Hoving[7], Jeroen Ingels[8], Nélia C. Mestre[9], Sarah Seabrook[10], Andrew R. Thurber[11], Chris Vivian[12], and Moriaki Yasuhara [13]

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Climate crisis recognition has accelerated consideration of ocean-based climate interventions (OBCI) that remove carbon dioxide, manage solar radiation, or produce alternative forms of electricity. These include ocean fertilization, seaweed culture and sinking, crop waste disposal, ocean alkalinity enhancement, downward pumping of acidic seawater, deep injection of liquid CO2, cloud brightening, bubble dispersion, and OTEC. Most of these approaches remain conceptual, model-based, or at the pilot study stage. The majority of these technologies will not only act to mitigate climate change but are likely to impact ocean ecosystems, including those in deep waters (below 200 m). The deep sea, with low energy supply, typically stable conditions, and a low density of organisms with reduced growth and metabolic rates, requires specific attention. Here we highlight the range of impacts of OBCI on deep- ocean physics, chemistry, ecology and ecosystem services and point to challenges for OBCI governance affecting the deep sea. We call for comprehensive research focused on deep-sea responses that can be factored into OBCI decision-making and governance, ideally in a mode that leverages information across climate intervention technologies.

(S6-15983 Oral)

Assessing biodiversity changes through time in the world's most productive fishery and hadopelagic ecosystem with the use of environmental DNA.

Diego Elihú Rivera Rosas[1], Nathan Geraldi[2], Gould Ronnie[3], Kazumasa Oguri[3] and Carlos M. Duarte[1]

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Time-series sampling is often difficult and expensive to perform. This work presents an alternative tool using sediment eDNA to study pelagic fauna in one of the world's most productive ecosystems: The Atacama Trench. Having a history of overfishing events and effects of ENSO of differing intensities, it has been expected that the diversity and abundance of pelagic taxa has decreased yet has not been documented. We sampled five different sites using sediment cores at water depths going from 2400 to nearly 8000m. Sediment cores were dated using Pb^{210} and metabarcoding primer pairs that target different sections of the 18S rDNA gene (V9 and V7) were used to assess pelagic fauna. With this, the communities dated through a period from 1847 to 2018 were compared and the differences in diversity were checked against environmental and anthropogenic effects. Results indicated a drop in biodiversity from 1977 to 2002. We found it is possible for these changes to be a result of natural and human influence, as the extensive fishing efforts in this period of time combined with the escape of salmonids from farms and adverse ENSO events contributed to the reduction of diversity. This is a first step in understanding how events, including human related, can alter understudied ocean communities. Overall, it is shown that sediment eDNA is a valuable emerging tool not only for research on the current state of communities in pelagic and deep-sea environments, but also as a snapshot of the past that allows for comparisons within an ecosystem.

(S6-16043 Oral)

ENSO-like variabilities of mass and foraminiferal shell fluxes in the deep basin of northern South China Sea: a decadal time series study

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A time-series station, the South East Asia Time-series Study (SEATS, 18°N, 116°E) station, was established in 1998 in the northern South China Sea (nSCS) as a part of the time series study in the Joint Global Ocean Flux Study (JGOFS, 1987–2003). Decadal sinking particle flux data collected at 1000 m, 2000 m, and 3500 m at the SEATS station show that the mass and the foraminiferal shell fluxes undergo strong seasonal and interannual variabilities. Changes in the flux data are correlated with the satellite-derived chlorophyll-a concentration, indicating that the mass fluxes are largely controlled by the export production at or near the SEATS station. The variation of chlorophyll-a concentration in the nSCS shows a strong response to wind speed under the influence of El Niño–Southern Oscillation (ENSO). The reduction in wind speed and the intensification of Kuroshio intrusion during the ENSO warm phases reduce the nutrient inventories and then the productivity, mass and shell fluxes, and *vice versa* in the case of the ENSO cold phases. The imprint of an ENSO cold phase (La Niña event) in 2017 was signified by 2–3-fold higher values than the averages of total mass and foraminiferal shell fluxes. Such results imply that an 15%–17% reduction in wind speed might lead to a several-fold decrease in the mass and foraminiferal shell fluxes and *vice versa*. Using the fluxes of mass and foraminiferal shells as examples, this study provides insight into how climatic change might cause significant changes in the biological pump of marginal seas.

(S6-16140 Oral)

Gelatinous macrozooplankton response to climate change and implications for the deep sea

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Gelatinous zooplankton (GZ) are likely to benefit from increasing anthropogenic pressure under climate change (CC). In particular, large pelagic tunicates (namely salps, doliolids and pyrosomes) are likely to be favored over other macrozooplankton due to their filter feeding mode which gives them access to small preys expected to be less affected by CC than larger preys. In addition, due to their rapidly sinking carcasses and fecal pellets, they play a key role in the export of particulate organic carbon (POC) to the deep ocean. Here we provide a first model-based estimate of potential community shifts in macrozooplankton composition and their effects on planktonic community structure and benthic food supply under a high-emission scenario. The model, that explicitly represents one salps-like gelatinous and one crustacean-like non-gelatinous macrozooplankton, shows that gelatinous zooplankton biomass decreases less than that of non-gelatinous zooplankton. Therefore, the climate-induced decline in the supply of organic carbon to the deep ocean is mitigated when gelatinous zooplankton are considered. This effect is particularly important in low-latitude oligotrophic regions where GZ dominate the macrozooplankton. As the flux of organic matter to the seafloor is a crucial source of food for benthos, our study suggests that gelatinous zooplankton should be considered when assessing future changes in the deep sea.

(S6-16261 Oral)

Climate Change and Governance of the Central Arctic Ocean: Cooperative Currents, Foggy Future

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With decreasing sea ice cover in the Arctic, political and legal attention has turned to governance of the Central Arctic Ocean (CAO), the large "donut hole" of the high seas beyond the 200 nautical mile zones of the five coastal States. The planting of the Russian flag on the North Pole in August 2007 raised the prospect of an international scramble for deep seabed resources. Prospects for transpolar shipping and new commercial fishing opportunities have also fueled the attention.

This presentation will review the international law and policy dimensions governing the CAO from two perspectives. First, international cooperative currents will be described. At the global level, the UN Law of the Sea Convention continues to set the overarching governance framework with its granting of high seas freedoms but also corresponding responsibilities such as the duty to protect and preserve the marine environment. The International Maritime Organization's Polar Shipping Code has established vessel-source pollution and shipping safety standards for shipping on the Arctic high seas. An array of multilateral environmental agreements (MEAs) are also relevant to the CAO including the Convention on Biological Diversity (CBD) and the Convention on International Trade in Endangered Species (CITES).

Regional cooperative currents will also be highlighted. The role of the Arctic Council in addressing CAO governance will be summarized including the conclusion of two regional treaties applicable to the CAO, the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (2011) and the Agreement on Cooperation on Marine Oil

Pollution Preparedness and Response in the Arctic (2013). The role of the five Arctic coastal States (Arctic 5) will next be reviewed including their adoption of the 1973 Polar Bear Conservation Agreement and the subsequent addition of a Circumpolar Action Plan for Polar Bears in September 2015. Broader Arctic 5 + 5 cooperation on CAO fisheries will round out the regional overview with adoption of the Agreement to Prevent Unregulated High Seas Fisheries in the CAO in October 2018 whereby the Arctic 5 plus China, Japan, South Korea, Iceland the EU committed to a precautionary approach to possible future CAO commercial fisheries. Parties have agreed to develop a Joint Program of Scientific Research and Monitoring and to not authorize their flagged vessels to conduct commercial fishing in the CAO unless conservation and management measurements have been adopted by one or more regional or subregional fisheries management organizations or arrangements or pursuant to interim measures that may be adopted by Parties under the Agreement.

The "foggy future" of CAO governance will be a second perspective provided with four main uncertainties looming on the law and policy horizon. Those uncertainties include: sorting out the future of CAO fisheries governance; deciding on future steps within the IMO to address Arctic high seas shipping; determining extended continental shelf boundaries in the Arctic and seabed development futures; and resolving how a new global treaty on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction (BBNJ agreement) will affect CAO governance.

(S6-16268 Oral)

Paleo-environment study of the Moroccan Atlantic coast

Hasnaa Nait Hammou[1,2], Mohammed **Idrissi** [2], Bendahhou Zourarah [1], Melissa Chierici [3], David Cervantes[4], Beat Gasser [5], Pere Masque Barri[5], Ahmed Aajjane[1], Abdelouaheb El Haissen[1,2], Omar Ettahiri[2], Peter Swarzenski [5,6] and Khalid El Khalidi[1]

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The knowledge of the response of Moroccan Paleo-marine environments to past climate changes at various amplitudes and pacing serves as a basis for the assessment of future resilience of marine ecosystems to the anticipated impacts of global warming. On the continental shelf, the sedimentary sequences are the only possibility to better understand the natural envelope of climate variation. These series have continuously trapped the environmental evolutionary history of the region that hosts them. It is on the study of such series that this work focuses, proposing an integrated analysis of the response of Moroccan paleoenvironments to recent climate changes. To achieve this objective, an oceanographic survey, onboard of the vessel Dr. Fridtjof Nansen, EAF-Nansen Programme/FAO, was carried out to collect a series of undisturbed sediment cores from strategic sites in the Moroccan Atlantic coast and especially in the south because there is a lack of data, using the preserved signatures through specific analyses to reconstruct the paleoclimate, the postglacial, Holocene evolution, functioning of the coastal and neritic system and the historical reconstruction of low-oxygen events. On three transects perpendicular to the coast, six sediment cores were collected and analyzed to determine their sedimentological, mineralogical and geochemical characterization through: particle size analysis, radionuclides (Pb, Cs), foraminifera, organic matter, X-ray diffraction and X-ray fluorescence. Preliminary results show significant variation in the geochemical composition of the sediments along the core. Organic carbon values range from 0.45% to 0.72% while X-ray diffraction analysis has identified the following mineralogical phases: quartz, calcite and dolomite.

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(S6-16307 Oral)

High uncertainty in fish-mediated carbon transport into the ocean's twilight zone

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Mesopelagic fishes dominate the global biomass of fishes. These abundant fishes contribute to marine carbon transport when they consume organic carbon near the surface at night and release it in the mesopelagic zone during the day. However, we do not understand well the magnitude of this transport, carbon sequestration times, or associated uncertainties. We estimate fish-mediated carbon transport in the context of other carbon fluxes using data from a collaborative, three-ship research cruise during the North Atlantic spring bloom in 2021. We measured fish abundance and respiration rates while colleagues measured various other passive and active carbon fluxes. By analyzing these data together, we can estimate the relative contribution of fish to the biological carbon pump. We use sensitivity analysis to determine the parameter uncertainties in estimates of fish-mediated carbon transport, and which parameters contribute most to total uncertainty. Our sensitivity analyses reveal that, for each individual fish modeled, respiration-related parameters contribute most to parameter uncertainty. Carbon flux estimates associated with each fish vary six-fold. Scaling up from the individual fish level to the ecosystem-level using fish biomass data from the cruise could add an order of magnitude of uncertainty. We conclude that it is not currently possible to estimate fish-mediated carbon flux precisely, but that these estimates may be incrementally constrained through dedicated empirical work on the most influential parameters. We highlight the importance of considering not only carbon transport but also carbon storage times in evaluating the role that fish play in carbon sequestration.

POSTER BOARD ID: S6-P1
(S6-15965 Poster)

Primary productivity in the transitional zone of the Mexican Pacific: inference of organic carbon in the last 5.5 kyr

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The transitional zone of the Mexican Pacific is a complex region in terms of its oceanographic conditions. This leads to changes in primary and exported productivity over various time scales. These changes can be inferred by analyzing and quantifying geochemical tracers that have been preserved in the sedimentary record. Sedimentary organic carbon has been widely used to infer changes in primary productivity in various regions of the global ocean. Specifically, the late Holocene and the late part of the middle Holocene (ca. 5500 years before present) were characterized by periods of warming and cooling, such as the Medieval Warming or Little Ice Age, respectively. The objective of the present study was to quantify organic carbon content and to infer changes in primary and exported productivity in the transitional zone of the Mexican Pacific for the late Holocene and the final part of the middle Holocene. The organic carbon content was quantified using an elemental analyzer every 1 cm. The sediment core had a length of 137 cm and was collected at 680 m depth. The organic carbon content varied from 8 to 14%. Over the last 5500 years, organic carbon values showed decreases in the Dark Age Cold Period (1700 to 1100 years) and in the 4200-year event with sudden changes occurring at a periodicity of ~300 years. This suggests that primary and exported productivity responds to oceanographic conditions over various time scales.

POSTER BOARD ID: S6-P2
(S6-16008 Poster)

Recognizing effects of past warming in deep-sea ecosystems: evidence from benthic foraminifera

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Deep-sea benthic foraminifera are useful proxies to reconstruct the effects of past environmental changes on biota in the largest habitat on Earth, being sensitive to changes such as Paleogene (66-34 Ma) hyperthermals. These rapid, extreme warming events punctuated existing greenhouse conditions, and were caused by perturbations of the carbon cycle. Therefore, they can (to some extent) be considered analogues for current - future climate change. The most extreme hyperthermal was the Paleocene-Eocene Thermal Maximum (PETM), followed by Eocene Thermal Maxima-2 and -3 (ETM2, ETM3). Analysis of the benthic foraminiferal response to hyperthermals is typically assessed by quantifying changes in faunal groups, as compared to the carbon isotopic signal delineating the extent of the hyperthermal. However, subjective faunal grouping may obscure relevant biotic changes. We thus apply perturbation detection analysis (PDA; Hayek et al., 2019) to databases from ODP Sites 1262 and 1263 at Walvis Ridge (SE Atlantic; 3500 and 1500 m paleodepths) to investigate the effects of the PETM, ETM2 and ETM3 on benthic foraminiferal assemblages. PDA implies that changes in the trend of accumulated heterogeneity index plots indicate disruption of faunal assemblages. We show that perturbation of the assemblages occurred somewhat earlier than the beginning of ETM2 and ETM3 at both sites (relative to the event interval as delineated by the isotopic signal), whereas the beginning of the PETM coincided with a clear disruption. We conclude that PDA may give additional details on the pattern of effects of past climate change on deep-sea ecosystems.

POSTER BOARD ID: S6-P3
(S6-16009 Poster)

Increased transport of ocean currents due to global warming and its relationship to atmospheric pressure systems

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Future changes in ocean circulation are expected under climate change scenarios, however the extension and intensity of these changes as well as their driving factors, are still poorly investigated. The volume transport of Brazil and California Current, for instance, was reported to increase by the end of the century, while their counterparts, the Alaska and North Brazil Current, respectively, are expected to decrease. These changes may be related to the displacement of ocean currents and also to the migration and expansion of atmospheric systems. Therefore, the present work aims to quantify the changes in the main ocean currents, both in intensity and positioning, of the global ocean and to evaluate their relationship with atmospheric variables based on projections of the Coupled Model Intercomparison Project Phase 6 (CMIP6). For this end, monthly projections are analyzed for the SSP2-4.5 scenario, which represents a condition in which a global warming of 2ºC, relative to the beginning of the century, is extremely likely to be exceeded. Surface winds, sea level pressure, sea surface height, and ocean velocities were extracted from six CMIP6 models. The volume transport of ocean currents present in the

Pacific, Atlantic and Indian Oceans was calculated along cross-current sections and the position of their origin was estimated. The projected end-of-century changes in these parameters were then compared with projected changes in pressure systems and wind fields.

POSTER BOARD ID: S6-P4

(S6-16353 Poster)

Effect of climate change on the ocean currents system along the Brazilian coast, focusing on Brazil Current

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Ocean currents play an important role in heat transport throughout the globe and consequently on climate regulation, however the increase in greenhouse gases emissions on a global scale affects the ocean dynamics. Therefore, this work aims to evaluate the effect of climate change on the ocean currents system along the Brazilian coast, focusing on Brazil Current (BC) dynamics, its meandering and the consequent formation of eddies in the Southeastern region. Since general circulation models used in CMIP5 (Coupled Model Intercomparison Project Phase 5) do not resolve properly these features, the results of the Brazilian Earth System Model (BESM) were downscaled to a eddy-resolving nested grid using ROMS (Regional Ocean Modelling System). In order to evaluate the future changes in reference to the present climate, results from BESM were extracted from the historical run and from the projections based on RCP4.5 scenario, which indicates the increase of kinetic energy in the region dominated by BC. These results were used as lateral boundary conditions and surface forcing into a two-way nested model composed by a donor and a receiver grid with 1/5° and 1/15° of horizontal resolution, respectively.

S7: Nature-based Solutions for Climate Adaptation and Mitigation - From Planning to Practice

Convenors:
Myron Peck (Corresponding), (Royal Netherlands Institute for Sea Research, the Netherlands)
Silvana Birchenough, (Cefas – Centre for Environment, Fisheries & Aquaculture Science, UK)
Fabio Bulleri, (Università di Pisa, Italy)
Ana Queiros, (Plymouth Marine Laboratory, UK)

Nature-based Solutions (NBS) have been defined as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptably, simultaneously providing human well-being and biodiversity benefits" by the IUCN. Implementing climate-ready NBS within marine habitats (i.e. restoration of habitat-forming species, establishment of marine protected areas, sustainably harvesting seafood) requires in-depth knowledge on the impacts of climate change on marine flora and fauna and the feedback processes whereby increasing ecosystem health and biodiversity reduce climate impacts. Contributions in this session will promote dialog on the relationships among NBS, climate change adaptation and mitigation, biodiversity and ecosystem services within marine social-ecological systems using real-world examples.

(S7-15876 Oral)

Operationalizing blue carbon principles in France: methodological developments and institutionalization

Adrien **Comte**[1,2], Jeanne Barreyre[2], Roman de Rafael[2], Charles-François Boudouresque[3], Gérard Pergent[4], Briac Monnier[4] and Sandrine Ruitton[3]

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Protection, management, and restoration of ecosystems are important tools for climate change mitigation climate change. Seagrasses, mangroves, and other marine and coastal ecosystems have particularly high capacities to sequester and store organic carbon commonly referred as blue carbon. The potential of these blue carbon ecosystems has been highlighted in scientific literature and several calls have been made to mainstream them into mitigation policies, including carbon markets. France is a relevant country to develop these policies, as it has the second largest Exclusive Economic Zone in the world, which contains large areas of blue carbon ecosystems. In addition, there is a need to strengthen protection and restoration as marine ecosystems are being degraded due to human impacts. Building on the scientific literature and on the newly formed French voluntary carbon standard, the '*Label Bas-Carbone*', we develop a methodology to assess the emission reduction potential of projects to protect *Posidonia oceanica* seagrasses from anchoring, in the French Mediterranean area. We show that it is possible to institutionalize this methodology using a tiered approach on key parameters including carbon stocks, degradation rates (*i.e.* the surface area degraded by physical abrasion), and decomposition rates (*i.e.* the amount of carbon lost due to degradation). We also explore future needs regarding (i) science on key parameters to strengthen the robustness of the method, notably on decomposition rates of seagrass meadows, and (ii) expansion of the method to restoration of seagrasses and to other blue carbon ecosystems.

(S7-16022 Oral)

Offshore carbon as a nature-based solution: Expert interviews on the potential governance of the offshore carbon system for climate change mitigation.

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The threat represented by global climate change demands novel approaches to the management of the world's natural systems of carbon sequestration and storage to assist in mitigation attempts. Drawing upon extant work on blue carbon, research suggests that an approach similar to that currently used on coasts could be applied to the offshore environment by including the carbon fixed through primary production and biological processes, subsequently sequestered in shelf sea sediments, referred to here as Offshore Carbon (Graves et al., 2022; Luisetti et al., 2020). This paper explores the concept of the emerging natural resource of Offshore Carbon to inform its future governance. A series of semi-structured interviews were conducted with experts in relevant fields to explore the feasibility, utility, and aspects of governance of a system of offshore carbon, as a nature-based solution. Following a qualitative, thematic analysis, two overarching themes of Concept and Implementation emerged including subsequent subthemes. From these, three main areas – "hinges" – were identified for further research of a future offshore carbon governance. These hinges are: the need to better understand human disruptions of the offshore carbon system; the exploration of different forms of political cooperation; and the possibility of devising different concepts of value for offshore carbon. This study identifies key knowledge gaps of this novel and emerging topic and areas for future research.

(S7-16028 Oral)

Nature-based climate protection – various marine ecosystems with blue carbon storage potential

Claudia **Morys**[1], Jochen C. Krause[1], Ulrich Claussen[2] and Manuela Krakau[2]

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Marine ecosystems, such as sea grass meadows or kelp forests, as well as marine sediments are already in focus of climate mitigation measures due to their capability of storing carbon in the long term. Especially undisturbed marine sediments have been recognized to contribute considerably to the overall carbon storage inventory. Thus, measures for climate mitigation would be effective in marine areas where potential for such "Blue Carbon" storage is high. In German seas, large-scale investigations aim to provide scientific basis on additional Blue Carbon hotspots for identifying possible carbon-relevant protected areas in the future. So far, the role of biogenic reefs, such as blue mussels and oysters, as a carbon source or sink has remained underexplored. Thus, their role for climate protection shall be investiagted, based on the restoration of biogenic reefs in the German North Sea initiated to address mitigation of biodiversity loss. Likewise, our understanding of the complex processes within the pelagic zone needs to be improved. While the key role of the biological pump within the oceanic carbon cycle is unquestioned, the Blue Carbon potential within the changing pelagic food web needs further investigations. Because plankton in the pelagic is subject to rapid seasonal changes, innovative monitoring methods to obtain data at high frequency are addressed. This will be an important step towards developing suitable indicators for climate change induced effects within marine protection frameworks and shall support implementing measures for nature-based climate protection.

(S7-16049 Oral)

How can we measure the effectiveness of nature-based solutions in combatting climate change? A framework of marine ecosystem service indicators to measure social, economic and ecological responses

Stefanie **Broszeit**[1]*, Arantza Murillas[2], Sarai Pouso[2], Jorge Terrados[3], Juan Bueno-Pardo[4], Ana Ruiz-Frau[3], Marina Dolbeth[5], Ane Iriondo[1], Stelios Katsanevakis[6] , Susanna Jernberg[7], Jose A. Fernandes-Salvador[2].

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A key problem in assessing climate change mitigation and adaptation measures such as nature-based solutions is the appropriate selection of indicators that capture changes in response to these measures. An assessment framework for marine ecosystem services indicators to quantify the effectiveness of three nature-based solutions (NBS) under climate-driven changes was developed. It creates a common understanding about the health status of ecosystems, their services, and the impact of implementing NBS to inform policymakers and the general public. The three NBS considered here were restoration, conservation and the sustainable harvesting of marine resources. The interaction between the biodiversity indicators with the socioeconomic, response and pressure indicators was established using the ecosystem service cascade and linked to relevant environmental and economic frameworks such as the Drivers-pressures-state framework and the UN System of Environment Economic Accounting. The framework was developed using workshops with marine multidisciplinary scientists. It was then used to select 201 multidisciplinary indicators from peer reviewed literature, global, regional and local indicator frameworks, reports and initiatives such as from the Convention on Biological Diversity and the Intergovernmental Platform on Biodiversity and Ecosystem Services. Further workshops with practitioners in 20 different European case study sites were conducted to evaluate which of these indicators are already in use and if they can be used to compare NBS success across regions. The presentation will show the process and results from this work.

(S7-16055 Oral)

A novel approach for assessing intertidal biodiversity in anticipation of coastal adaptation projects and climate change impacts

Michelle D. **Staudinger**[1,2], Marc Albert[3], James Garner[2], Lucy Lockwood[4], and Aly Putnam[2]

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The Boston Harbor Islands National Recreation Area (BOHA) is the only coastal drumlin archipelago in the United States. These glacial remnants contain irreplaceable ecological, environmental, and cultural resources and provide protective ecosystem services to the greater Boston area. BOHA was recently named one of America's 11 Most Endangered Historic Places due to threats from sea level rise, warming waters, and non-native invasive species. The National Park Service (NPS) and partners are considering a range of coastal adaptation actions including nature-based solutions to bolster BOHA island shorelines in the face of climate threats. Site prioritization and selection for adaptation projects must balance the NPS's mission of maintaining ecological integrity, biodiversity, and cultural heritage. This talk

will describe a novel and standardized biodiversity monitoring framework designed to track changes in the unique intertidal habitats of BOHA due to gradual and acute disturbances from climate change, pre and post-installation of coastal adaptation projects, and other stressors. Three site types were identified for assessing impacts: those with cultural or management importance, biodiversity hotspots, and controls. Biodiversity data collected at each site type and across islands considered the occurrence and distribution of native and emergent species (non-indigenous species, native range shifters) and identified species that could serve as climate indicators in BOHA. Traditional survey methods, molecular approaches (e.g., eDNA) and image analyses were tested to provide NPS a range of cost-effective options for rapid and comprehensive monitoring to fulfil regulatory needs for planned adaptation projects or assess changes after major disturbances, all while avoiding maladaptation.

(S7-16137 Oral) **Revision: presentation CANCELLED**

A universal methodology for estimating the effectiveness of marine nature-based solutions

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Nature-based solutions (NBS) for adaptation and mitigation are now at the forefront of global climate policy. NBS help promoting the resilience and adaptive capacity of social-ecological systems, with a consequent potential decrease on climate-change risks. To test this effect, we present a new methodology based on a climate-risk assessment where the different dimensions of risk are estimated before and after the implementation of the NBS, using environmental projections and expert elicitation. The difference of risks obtained is used as a proxy for *how much* climate risk and human threats can be mitigated due to the NBS. The methodology has been applied at more than 20 case studies in Europe within the framework of the EU project FutureMARES. Across studies, the methodology has been used for 3 marine NBS: active restoration, conservation, and nature-inclusive harvesting. The climate-risk decrease is estimated mid and long term (2040-2060 and 2080-2100), and following three shared social-ecological pathways (global sustainability, national enterprises, and world markets). Performing the climate risk assessments allows to identify the components of the ecosystem that are most at risk when the NBS is applied and when it is not, giving us key information on the benefits of NBS implementation. Additionally, the use of future climatic and socio-economic scenarios makes possible to identify tipping points for the NBS effectiveness. The application of a common methodology allows to investigate geographic and temporal drivers of the effectiveness and problems associated to each NBSs using different units of analysis: species, habitats, ecosystem services and social groups.

(S7-16351 Oral)

Developing science-based actions to address South African marine ecosystem implications of the combined biodiversity and climate crisis

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Given the urgency of the global crisis in biodiversity loss and climate change, there is a strong focus in the international arena on formulating and actioning targets to address these interlinked crises that are seriously threatening life on earth, and the sustainability of humankind. Global initiatives such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the Global Biodiversity Framework of the Convention on Biodiversity (CBD), are working towards actioning global solutions to curbing biodiversity loss, loss of ecosystem services and overall sustainability. A parallel and even longer-standing process has been underway to address climate change, its impacts and possible solutions via the Intergovernmental Panel on Climate Change (IPCC). In 2021, a comprehensive global report was published following a workshop co-hosted by IPCC and IPBES on Biodiversity and Climate Change. The challenge remains in interlinking climate and biodiversity targets and formulating supportive actions that can inform local scale activities. Here, we use the South African marine ecosystem as a case study to identify locally-meaningful actions that would address globally-relevant biodiversity and climate targets in a connected and unified manner.

(S7-16373 Oral)

Nature Based Solutions for climate change mitigation and adaptation

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The recent reports by the Intergovernmental Panel on Climate Change (IPCC) provide a rich scientific knowledge base on ocean and climate change risks, adaptation and mitigation. This presentation will distill the IPCC assessment findings on nature-based solutions, discussing options and ways forward and the role of the ocean action in climate resilient development. Nature-based solutions provide adaptation and mitigation benefits for climate change as well as contributing to other sustainable development goals. Impacts and risks posed by climate change are evident and increase with global warming level. Climate change has caused damages, and increasingly irreversible losses in coastal and ocean ecosystems. Increased ocean warming is leading to changes in biodiversity patterns across the ocean, with serious impacts on species richness and distribution and the function of ecosystems. Global warming, reaching 1.5°C in the near-term, would cause unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans. There is an urgent need to reduce greenhouse gas emissions and increase resilience to ocean ecosystems and the people that depend on them. There are a broad range of adaptation and mitigation options. Effective Ecosystem-based Adaptation reduces a range of climate change risks to people, biodiversity and ecosystem services with multiple co-benefits. Above 1.5°C global warming level, some Ecosystem-based Adaptation measures will lose their effectiveness in providing benefits to people as these ecosystems will reach hard adaptation limits. Embedding effective and equitable adaptation and mitigation in development planning can reduce vulnerability, conserve and restore ecosystems, and enable climate resilient development.

(S7-16380 Oral)

Historical contributions of spatial measures to halt the impact of climate change and intense fishing in the Western Mediterranean Sea

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The Western Mediterranean Sea has been heavily exploited historically, with several commercial species being depleted. In addition, it has become a hotspot of climate change. Diverse spatial measures have been implemented to conserve marine resources and biodiversity, including the implementation of a mosaic of no-take areas, highly, moderately and poorly protected areas, Natura 2000 sites, EBSAs, and spatial restrictions to fishing such as GFCM Fisheries Restricted Areas. However, their collective effectiveness remains unknown due to the lack of regional analyses. We use a spatial-temporal Ecospace marine ecosystem model representing the Western Mediterranean Sea to assess the contribution of existent spatial measures to overcome the cumulative effects of fishing and climate. The model is driven with historical fishing effort and climate hindcasting (1995-2016) and forecasting (2017-2030) projections under two representative concentration pathway scenarios (RCP4.5 and 8.5) using the biogeochemical GETM-MedERGOM model. Climate variables include temperature, salinity and primary production. We run combinations of scenarios with and without spatial measures under different climate trajectories considering historical fishing dynamics. Our results confirm the depletion of several commercial species over time and the impacts of climate change, with consequences for the structure and functioning of the marine ecosystem. Results highlight the limited role that spatial management measures have played to date. Our counterfactual study aims at motivating further action to better manage towards a more sustainable and resilient future of the Western Mediterranean Sea.

(S7-16385 Oral)

The future north-east Baltic Sea marine protected areas based on species distribution scenarios

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The north-east Baltic Sea is a brackish water sea area. It has unique set of fresh water and marine species. Due to climate change, the Baltic Sea has warmed faster than the world ocean. The area also suffers from eutrophication and hypoxia. These pressures have led in decline of several key habitat forming species, such as the brown alga bladderwrack (*Fucus sp*) and eelgrass (*Zostera marina*).

To conserve the shallow water habitats in the future, we need to understand how changes in environmental conditions impact the distribution of key habitat forming species.
To do that, we combined future Baltic Sea scenarios with explicit data on species and habitats. The range shifts of key species are based on species distribution models. Climate change refugia and hotspots are identified based on projected changes in temperature, salinity, oxygen, pH and chlorophyll-a for present (2001-2020), mid-term future (2041-2060) and long-term future (2081-2100) conditions.

We used three scenarios with different pathways for greenhouse gas concentrations and socioeconomic development. The scenarios were created for the entire Baltic Sea. The historical simulations were created with trend preserving statistical downscaling of a multi-model ensemble Earth System Model. The future projections from the CMIP6 archive were trained on reanalysis datasets from the Copernicus Marine Environment Monitoring Service.
Our work would contribute to complement the geographical extent of Marine Protected Areas in a way which considers climate change hotspots and refugia rich in biodiversity.

(S7-16389 Oral)

Implementing climate-ready marine habitat restoration, conservation and lower trophic level harvesting: Examples from the EU FutureMARES program

Myron A. **Peck**[1], Dorte Krause-Jensen[2], Elena Ojea[3], Fabio Bulleri[4], Juan Bueno Pardo[3], Marie Maar[2], Marta Coll[5], Momme Butenschön[6], Stelios Katsanevakis[7] and Vera Köpsel[8]

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This presentation summarizes recent results from the EU-funded "FutureMARES" program providing science-based advice on how to sustainably implement nature-based solutions (NBS) to safeguard marine biodiversity and ecosystem services and promote climate adaptation and mitigation. Activities span the restoration of habitat-forming species (seagrasses, macroalgae, shellfish and other reef-forming animals) in coastal and shallow water habitats, planning the extent and designation of Marine Protected Areas (MPAs), and understanding how these interact with sustainable seafood harvesting. Activities are conducted across 40 "Storylines", mostly located throughout European waters but also in Belize and Chile. The program includes historical and new ecological analyses, ensemble projections of physical and

biogeochemical climate impacts, species, habitat and food web projections as well as Climate Risk Analyses contrasting different degrees of NBS and/or NIH implementation. Effective stakeholder engagement activities at the local, regional and international levels is a critical to the success of our work. We highlight program activities occurring in several Storylines such as: i) eelgrass and shellfish restoration in the southern North Sea, ii) blue mussel farming in the Western Baltic, seagrass (*Posidonia oceanica)* restoration, MPAs and fisheries in the NW Mediterranean, and iv) MPAs and biogenic reef restoration in the Eastern Mediterranean.

(S7-16393 Oral)

Evaluating blue carbon natural climate solutions across climate, ecological and socio-economic dimensions

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The ocean and coastal ecosystems play a powerful — yet largely under-appreciated — role in global carbon storage, constituting a massive carbon “sink” that moderates the effects of climate change. In an effort to help preserve and enhance the ocean’s ability to serve as a natural climate solution (NCS) and to meet global decarbonization goals while ensuring a “do no harm” approach, a team of multidisciplinary experts conducted a comprehensive evaluation of a suite of ocean-based NCS. This effort explored more common blue carbon solutions such as restoration or protection of coastal habitats and the cultivation of seaweed in nearshore and open ocean waters. Additionally, more novel solutions proposed for the open ocean were explored, including the restoration of populations of large epipelagic fishes and whales and limiting the release of carbon from ocean sediments disturbed by bottom trawling, mining and other benthic activities. These analyses revealed that some solutions, even those that are currently being pursued as carbon crediting opportunities, require more research to clarify the potential for climate benefits as well as a more thorough evaluation of other ecological and socio-economic benefits, costs and risks. Even when the climate potential was estimated to be lower for some solutions, the presence of other ecological and social benefits warranted pursual. The evaluation also shed light on some of the governance and socio-cultural feasibility considerations that are needed to ensure that benefits are being accounted for appropriately and that risks are evaluated across both natural and human systems.

(S7-16409 Oral)

Sustainable harvesting of commercial species in the Belize Exclusive Economic Zone.

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The Caribbean region is widely recognised to be a hot spot for marine biodiversity. The area hosts a wide range of habitats and species of conservation and fisheries importance. The main and most economically important fisheries in the area concentrates on spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*). These species are key to sustain sources of protein intake, livelihoods, and economic trade for local Caribbean communities. These two species have fluctuated throughout the years and their distribution has remained in similar quantities in landings since 2005. The queen conch peaked in 2012 following high sample density and increasing shell length, whilst the spiny lobster has generally remained stable in terms of landings, however there are limited data sets across some years, which have created gaps in the current assessments. The general concept of effort was described by the number of fishing days, which has generally increased from 1990 to 2011. The rate of change in effort from 2006 to 2011 was mirrored by that in queen conch landings, but these values were inverse when compared to the spiny lobster landings, due to limited distribution of conch due to overexploitation. The country's new government and new ministries have enacted new legislation and new opportunities to continue to explore and protect queen conch and spiny lobster, whether by a remit for Marine Protected Areas (MPA) or under dedicated Nature-based Solutions (NBS) approaches. This presentation showcases options to support economic development and conservation measures with the underlaying challenges of climate change.

(S7-16458 Oral)

Multi-use platforms combining offshore wind farms with low-trophic aquaculture show great potential to support the global sustainability goals

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Multi-use platforms combining offshore wind farms with low-trophic aquaculture can provide sustainable energy, nutritious seafood, and positive ecosystem services through emission (CO_2 and nutrients) capture and utilization. Our study from the transition zone between the saline North Sea and the brackish Baltic Sea showed that by allocating 10% of existing and projected wind farm areas to blue mussel and sugar kelp aquaculture, 81, 74 and 41 kt-fresh weight per farm hectare could be harvested from the North Sea, the Danish Straits, and the western Baltic Sea, respectively. This corresponds to 5% and 3% of the required N and P reductions, respectively, in the Baltic Sea Action Plan and 35% of the CO_2 emissions from the Danish agricultural sector. Current and projected wind farm areas were compiled for the different

continents and the potential for multi-use was upscaled. Globally, there is great potential to mitigate the eutrophication effects and produce blue biomass offshore with less user conflicts and a negative or low carbon footprint supporting the global sustainable development targets.

POSTER BOARD ID: S7-P1
(S7-15809 Poster)

Integrated coastal ecosystem restoration, climate change impacts and livelihood concerns in Gulf of Mannar, India - lessons learned

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The Gulf of Mannar (GoM) situated in the southeast of Tamil Nadu, India is spread over an area of 10,500 sq km. The 365-km long coastline of GoM is densely populated with over 100,000 small-scale fisher-folk, who depend for their livelihood solely on the fishery resources associated with the productive coastal habitats like coral reefs, seagrass beds, and mangroves. Coral mining and destructive fishing practices, temperature anomalies and sea level rise have degraded key coastal ecosystems like low-lying islands, coral reefs and seagrass beds in GoM. The Union and State Governments have initiated integrated ecosystem restoration through coral and seagrass restoration and deployment of multipurpose artificial reefs (AR). The objectives of these measures are: to increase the area cover of live corals and seagrass in the degraded regions, and thereby to protect and augment associated biodiversity particularly fish populations. Protection of islands from submergence, provision of stable substrates to biodiversity enhancement in particular coral recruits, and service as fish habitats for fish production improvement is some of the benefits of the ARs. The focused ecosystem restoration initiatives bring about climate change adaptation by protecting biodiversity and ensuring sustainable livelihood to the fishing population. The outcomes of the recent implementation of the National Adaptation Fund for Climate Change programme by Government of India in association with Government of Tamil Nadu demonstrate the success of the integrated approach, and hence this model can be replicated in other coastal regions facing similar climatic and non-climatic issues.

POSTER BOARD ID: S7-P2 **Revision: moved to S7-Oral presentation**

(S7-16066 Poster)

Evaluating regional shoreline adaptation effort in the San Francisco Bay Area, California through an equity lens

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The San Francisco Bay is a highly urbanized estuary in California bordered by diverse human communities and greatly threatened by climate change-related sea-level rise impacts. Increasingly, multi-benefit, nature-based or "living" shoreline adaptation approaches are promoted as mechanisms for addressing natural threats while also providing a suite of benefits such as habitat creation, pollution filtration, and recreational green space provisioning. Regional planning actors are challenged to ensure that the Bay's shorelines are resilient to future threats and that future adaptation interventions and targeted benefits are distributed equitably. This project seeks to develop a baseline understanding of how shoreline adaptation effort has been distributed across the San Francisco Bay Area region to date by analyzing the influence of sociopolitical and biophysical characteristics on what kinds of shoreline adaptation projects have happened where. Using the Bay Conservation Development Commission's permit database, permitted shoreline projects in the region will be coded for targeted benefits, "living" character (gray, hybrid, or green), adjacent community census data, and biophysical characteristics. As planners across the region look to drastically scale up multi-benefit living shoreline adaptation solutions, the findings from this research will provide the necessary baseline information to calibrate equity-driven strategic adaptation planning going forward.

POSTER BOARD ID: S7-P3
(S7-16251 Poster)

How will climate change affect the demersal fisheries of the North Sea? Using a bio-economic model to predict climate-induced changes in fisheries profitability and identify pathways to nature-inclusive harvesting strategies

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The consequences of climate change, especially rising water temperatures, are already showing significant effects on all aspects of marine life. At the same time, the human use of the marine realm steadily intensifies, and competition for space has been emerging in recent years. Fisheries are heavily affected by the aforementioned factors in often interdependent ways, and they themselves are a central pressuring factor on marine habitats. Therefore, developing nature-inclusive harvesting strategies for fisheries with respect to their complexity is emergent. We applied the bio-economic fleet optimization model FishRent to simulate the effects of different climate change scenarios, including their socio-economic consequences, on the North Sea demersal fisheries' profitability. Demersal fisheries comprise an essential part of the fishing fleets operating in the North Sea. They range from small-scale coastal vessels to highly mechanized industrial trawlers and contribute a significant share of the fisheries revenue generated in the region. Yet, climate change already strongly affects their target stocks, and their regular fishing grounds largely interfere with other nature-based solutions like marine protected areas. By applying novel, innovative fleet segmentation techniques, we assembled specific and extensive catch, effort, and cost data for those fleets, which allowed us to model changes not only in catch quantities but also in the cost structure of those fleets, e.g., increased fuel use due to longer steaming times.

S8: Advances in coupling regional climate and social-ecological models to improve climate-ready ecosystem management

Convenors:
Jonathan Reum (Corresponding), (NOAA Fisheries, USA)
Tyler Eddy, (Memorial University of Newfoundland, Canada)
Camilla Novaglio, (University of Tasmania, Australia)
Steven Bograd, (NOAA Fisheries, USA)
Phoebe Woodworth-Jefcoats, (NOAA Fisheries, USA)
Kirstin Holsman, (NOAA Fisheries, USA)
Roger Griffis, (NOAA Fisheries, USA)

Invited Speaker:
Ryan Heneghan, (Queensland University of Technology, Australia)

The effects of global climate change vary widely across ecosystems, and regional modeling frameworks are critical tools for evaluating impacts, risks, and the efficacy of management strategies. This session will highlight current approaches and identify critical gaps for coupling climate models to regional social-ecological systems. In particular, presentations on modeling efforts that integrate climate impacts across spatial scales, disciplines, and aim to generate near- to long-term projections are encouraged. The session will emphasize approaches to incorporate statistically or dynamically downscaled climate projections into single species, food web, and social-ecological projections and identify strategies to support climate-ready ecosystem-based management advice.

(S8-16128 Invited)

New approaches to understand humanity's impact on the world's oceans

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In Earth's history, no other animal has so profoundly and swiftly altered the structure of the world's marine ecosystems as humans. Humans affect ocean life directly through fishing and hunting, and indirectly via the accelerating impacts of climate change. Since the effects of climate change and fishing are global in extent, global-scale models are needed to give the required perspective on humanity's impact on the world's oceans. At the same time, robust regional models are required to guide strategic marine resource management in local ecosystems. To advance the development of human impact modelling, global and regional marine ecosystem modellers have combined projections in multi-model ensembles, through the creation of the Fisheries and marine ecosystem Model Intercomparison Project (FishMIP). In this presentation, I will discuss the present challenges and opportunities for the FishMIP project, and marine human impact assessment more broadly. In particular, I will explore how the combination of ever-growing observational datasets and recent advances in machine learning applications in climate modelling offer an unmissable opportunity to tackle some of the challenges for robust human impact assessment. I will finish by outlining how these new methods can further advance our understanding of the world's marine ecosystems and build confidence in model projections of future change.

(S8-15864 Oral)

More or less fish in future oceans? The importance of scale for climate change projections

Tyler D. **Eddy**[1], Ryan F. Heneghan[2,3], Elizabeth A. Fulton[4,5], Julia L. Blanchard[5,6], Derek P. Tittensor[7], Heike K. Lotze[7], Cheryl Harrison[8], Andrea Bryndum-Buchholz[7], Daniele Bianchi[9], Matthias Büchner[10], Catherine Bulman[4], David Carozza, William W.L. Cheung[11], Marta Coll[12], Jason D. Everett[13,14,15], Eric D. Galbraith[2,16], Simon Jennings[17], Steve Mackinson[18], Olivier Maury[19], Susa Niiranen[20], Ricardo Oliveros-Ramos[19], Chiara Piroddi[21], Anthony J. Richardson[13,14], Jacob Schewe[10], Yunne Shin[19], Jeroen Steenbeek[22], Jan Volkholz[10], and Nicola D. Walker[17]

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Climate change is affecting ocean temperature, acidity, currents, and primary production, causing shifts in species distributions, marine ecosystems, and ultimately fisheries. Global Earth system models simulate climate change impacts on physical and biogeochemical properties of future oceans under varying emissions scenarios. Coupling these models with an ensemble of global marine ecosystem models to project climate change impacts indicates decreasing fish biomass as global temperatures increase. Here, we employ climate change projections to evaluate agreement among regional and global marine ecosystem models for seven regions using both CMIP5 and CMIP6 forcing data. We found that models developed at different scales can lead to different conclusions, with projections of fish biomass differing in direction about half of the time between global and regional marine ecosystem models. Our analysis suggests that using marine ecosystem models to make climate change projections at different scales is uncertain at present and depends on the modelling scale and the resolution of the forcing data.

(S8-15914 Oral)

Climate change ecosystem scenarios with a physiology-linked end-to-end model in the Northeastern Pacific

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Physics-to-fisheries ecosystem models (or end-to-end models, E2E) are useful platforms for estimating how interacting species respond to changes in physical ocean conditions, to changes in inter-species interactions, and to alternate resource management policies. Few studies have considered reorganizations in food web structure arising from distinct physiological responses amongst the component model units (species or species complexes). Characterization of eco-physiological responses of different taxonomic groups within an E2E model is necessary for understanding the potential impact that climate change may have upon fish stocks and fishery yields, protected species, and large-scale ecosystem dynamics. In this study, we've incorporated physiological temperature coefficients into a 3D E2E multispecies model of the Northern California Current (NCC-ECOTRAN). We have run different physiological response scenarios given different temperature regimes and potential ranges of variability. Here we present preliminary results of climate change projections using a Regional Ocean Model System coupled with a biogeochemical model (ROMS-NEMUCSC) and forced by different Earth System Models: ISPL, Hadley, & GFDL-ESM2M under the RCP8.5 emission scenario (from the NOAA/UCSC FutureSeas team). This is the first study in the Northeastern Pacific Ocean that incorporates an ecophysiology component within a fully end-to-end model framework.

(S8-16001 Oral)

Application and development of the Northeast U.S. Atlantis model (NEUSv2) to address climate change impacts on a regional socio-ecological system

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Waters along the United States Northeast continental shelf are warming faster than 90% of the world's oceans. Managers and stakeholders within the region are actively engaged in climate scenario planning to evaluate and mitigate continued climate impacts on regional fisheries, ecosystems, and fishing communities. The Northeast United States Atlantis model (NEUSv2) is an end-to-end ecosystem model that simulates the environmental, ecological, and socio-economic dynamics of this region. The NEUSv2 hindcast (1964 to 2018) incorporates new lower trophic level and physical forcing and newly calibrated to regional surveys and commercial landings. NEUSv2's ability to capture indirect effects and provide holistic ecosystem-level outputs, allows it to serve as a useful strategic management tool to stakeholders and to act as a test bed for alternative adaptation scenarios. The ongoing development of NEUSv2 seeks to incorporate more temperature-dependent processes (growth, mortality, and movement), utilize downscaled regional climate projections, and redefine its fleet behavior. We also plan to co-develop climate adaptation scenarios with stakeholder groups, improving the applicability of the strategic advice NEUSv2 can provide. In this presentation, we will provide an overview of NEUSv2, the development of regional ecosystem projections under climate change, and our approach to providing strategic management advice to stakeholders.

(S8-16095 Oral)

Assessing climate change impacts in the Southern Benguela using a model ensemble

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The southern Benguela upwelling system supports a productive fisheries sector that provides jobs and livelihoods for thousands of people living along the southern African coastline. This system has experienced considerable environmental variability and change in recent decades, and climate projections indicate that this is likely to continue into the future. A number of ecosystem models are available for the southern Benguela system and these have captured many aspects of the observed variability and dynamics of this ecosystem. This study aims to evaluate the possible impacts of climate change in the southern Benguela ecosystem using an Atlantis, Ecosim and Ecospace ecosystem models. These models are forced with climate projections from the Geophysical Fluid Dynamic Laboratory (GFDL) ESM2M model and the Institut Pierre Simon Laplace (IPSL) Earth system models to evaluate the effects of warming and primary productivity changes on the southern Benguela upwelling system under Shared Socioeconomic Pathways 2.6 and 8.5. Results from the ecosystem models are compared to determine agreement and differences in the biomass, catches and spatial distribution of functional groups in this system under two climate change scenarios. This comparative (ensemble) approach provides information on bounding uncertainty around climate-forced projections of the southern Benguela ecosystem. The results of this study have the potential to inform future ecosystem-based management decisions and increase understanding of climate change impacts at the system level but also to increase adaptive capacity at the local scale.

(S8-16122 Oral)

Assessing the time of emergence of global oceanic ecosystems using ensemble climate to fish simulations

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Climate change is altering ocean ecosystems at an increasing pace, potentially pushing them towards radically different states with no analogue in the past. Using the concept of "Time of Emergence" (ToE: the time at which the climate change "signal" exceeds the magnitude of the "noise" induced by natural variability), many studies have assessed the ToEs of physical ocean variables. However, this has not yet been attempted for marine ecosystems. Here, we assess for the first time when changes in marine ecosystem are likely to emerge using simulations from the APECOSM Global Marine Ecosystem Model forced by an ensemble of physical and biogeochemical simulations from the CNRM-ESM2-1 Earth System Model for the SSP1-2.6 and SSP5-8.5 scenarios.

We show that surface temperature consistently emerges 20-30 years earlier than biological variables (phytoplankton, zooplankton and large pelagic organisms). Despite regional disparities, biological variables emerge at comparable times globally. While temperature has already emerged in 80% of the ocean in 2020, biological variables have emerged in less than 10% and this proportion reaches 60% in 2100 in SSP5-8.5. We also highlight a strong sensitivity of the fish biomass ToEs to the organisms' size and the community (epipelagic, mesopelagic, migratory) considered. Finally, we show that if the temperature ToEs are not very sensitive to the scenario used, it is not the case for the biological variables for which the surface impacted by climate change would be divided by more than three by the end of the century if strong mitigation measures were taken.

(S8-16160 Oral)

A systematic exploration of ecological responses to divergent climate trajectories in initialised Earth system predictions

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Linked Earth System Models (ESMs) and Marine Ecosystem Models (MEMs) are increasingly used to better understand marine ecosystem dynamics, and to plan management efforts for marine ecosystems under potential scenarios of global change. However, policy and commercial activities typically benefit from predictive capabilities on seasonal-to-decadal time scales, a time span widely used in the global climate modelling community, for which skill level assessments of MEMs are in their infancy. This is because the global MEM community is generally struggling to perform systematic skill assessments due to limited access to high-performance computing and IT expertise.

Here, we present a novel execution framework constructed of low-tech and freely available technologies to enable the systematic execution and analysis of linked ESM / MEM prediction ensembles. We apply the execution framework by focussing on the seasonal-to-decadal time scale, assessing how retrospective forecast uncertainty as characterised by the annually diverging trajectories in an ensemble of initialised decadal Earth system predictions, delivered by EC-Earth3 and Nor-CPM1, propagates through EcoOcean v2, a mechanistic and spatiotemporal explicit marine food web model for the global ocean.

Preliminary results indicate that ESM internal variability has a relatively low impact on the MEM predictability in comparison to the broad assumptions related to reconstructed fisheries. Our case study warrants further systematic exploration to disentangle the impacts of climate change, fisheries scenarios, MEM internal ecological hypotheses, and ESM variability. Our case study also demonstrates that our framework can be used effectively to make the process of marine ecosystem modelling better.

(S8-16196 Oral)

Quantification and communication of uncertainty in climate-forced regional food web projections

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Regional food web models are critical tools for evaluating potential tradeoffs associated with different management actions under climate change. However, estimating projection uncertainty (variance) is also necessary for building confidence in projections. By representing uncertain processes, parameters, or assumptions in projections, analysts can identify management strategies robust to different uncertainty sources. Further, analysis of uncertainty may provide insight on where additional research might yield the largest improvements in projection reliability or where errors may remain irreducible. Despite its importance, efforts to characterize uncertainty in climate-forced ecological projections remain limited. Here, we developed a size-structured food web model of the Eastern Bering Sea and coupled it to environmental projections obtained from a suite of Earth System Models that were dynamically down-scaled to the region using a Regional Ocean Model System (plus ice and biogeochemistry) framework. We generated projections of potential change in species biomasses and catches over the 21st century under different fishing and greenhouse gas emissions scenarios, and explicitly evaluated the relative contribution of model structural uncertainty at both the Earth System and regional food web model levels over different time horizons. We further characterized how uncertainty associated with systematic shifts in conditions due to climate change compared with variability due to different levels of stochastic recruitment. We provide an overview of potential methods for the quantification and standardization of projection uncertainty for uptake by decision-making bodies and recommend the representation and decomposition of projection uncertainty when possible to better understand the strengths and limitations of climate-linked ecological projections.

(S8-16258 Oral)

Forks in the road: Models (and choices) to support climate-ready ecosystem management in the California Current

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In the context of the "Future Seas" and "GC5" projects in the California Current, our research group has refined an Atlantis ecosystem model to understand potential climate change impacts on the socio-ecological fishery system. As explained in more detail by Liu et al. (THIS SESSION), the Atlantis model simulates oceanographic changes and shifts in species distributions, and the subsequent impacts on the food web and fish stock dynamics. This coupled regional approach involved a careful series of decisions related to climate forcing, downscaling techniques, and the interface between species distribution models and the more complex Atlantis ecosystem model. Here we focus on the decisions related to the modeling of fleets, ports, human communities, and future fishing trends. These choices are crucial if outputs of biophysical models are to be used to evaluate human vulnerability to climate change. Focusing on fleets that target coastal pelagic species (e.g. market squid *Doryteuthis opalescens* and sardine *Sardinops sagax*) and then separately on bottom-trawl fleets (targeting species such as sablefish *Anoplopoma fimbria* and Dover sole *Microstomus pacificus*), we illustrate port-level impacts of projected shifts in target species distribution and future productivity. For both of these fleets, new understanding of fleet composition and behavior allows us to disaggregate port-level catch into métiers or vessel clusters, to predict climate change risk both by port and métier or cluster. Our modeling is evolving from coupled bio-physical projections into a framework to evaluate climate risk to human communities and to test management strategies robust to this climate risk.

(S8-16281 Oral)

The Alaska Climate Integrate Modeling (ACLIM): challenges and successes in design and delivery of climate informed advice.

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Climate change and attendant climate shocks pose an unprecedented challenge to the sustainable management of marine fisheries worldwide. In Alaska, substantial climate driven changes and extreme environmental conditions have profoundly altered marine ecosystems, differentially impacted fishery and subsistence resources, and induced novel and compounding challenges to the management of resources. At the same time, adaptation by fisheries and coastal communities has been rapid, largely reactive, and evolving. The confluence of climate-driven changes and fisher, fishery, and management responses has heightened the immediate need for

operational climate-integrated tools and advice to inform tradeoff analysis and decision making in Alaska. The Alaska Climate Integrated Modeling (ACLIM) project uses a multidisciplinary approach and program collaborations to advance and evaluate climate integrated tools and climate-informed management actions.Specifically ACLIM uses an end-to-end informational framework of coupled oceanographic- biological- socioeconomic models and information exchange through workshops and coordination with regional decision makers and resource managers to identify tools and actions to address climate risk. Here we present results and lessons learned, including approaches to overcome common bottlenecks and hurdles in providing climate-informed decision support tools.

(S8-16288 Poster Oral)

Contrasting impacts of climate change on the trade-offs in achieving social-ecological ocean futures' targets between low- and mid-latitude ecosystems

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Climate change effects on marine ecosystems are causing cascading impacting on livelihood, food security and culture through fisheries. Such impacts interact and exacerbate the effects of over-fishing on marine social-ecological systems, complicating rebuilding of ecosystems to achieve desirable and sustainable ocean futures. Developing effective pathways for ecosystem rebuilding requires consideration of their co-benefits and trade-offs between ecological and social dimensions. However, the effects of intensifying climate change on such co-benefits or trade-offs have not been well understood, particularly in regions where ecosystem rebuilding is most needed. Here, we use ecosystem models to simulate the rebuilding of the northern South China Sea (SCS) and the East China Sea (ECS) ecosystems, representing over-exploited low- and mid-latitude systems respectively, to achieve different ecological and economic targets. We apply a numerical optimization routine to define the scope for improvement towards Pareto-frontier for ecological and economic benefits from the current status through fisheries management. In the NSCS, intensifying climate change are projected to decrease the habitat suitability of most marine species and increasingly reduce the scope to restore biodiversity, rebuild ecosystem structure and increase economic benefits from its current status. The maximum economic benefits attainable by the fisheries in the NSCS are projected to decrease by 60–65%% by 2050 across climate change scenarios, relative to the scenario without climate change. In contrast, in the ECS, driven by the increase in biomass of tropical species, the maximum attainable economic benefits would increase by approximately 55%-100% under climate change. Nevertheless, the scope for rebuilding biodiversity are projected to decrease substantially under intensifying climate change. In addition, the possibility of devastating biodiversity loss increases in both NSCS and ECS under higher climate change scenario. This study highlights the contrasting impacts of climate change on the co-benefits/trade-offs in ecosystem rebuilding even in neighboring ecosystems. It also underscores the importance of considering climate change in developing effective ecosystem rebuilding plan.

(S8-16337 Oral)

Evaluating emergent size-spectra from Fish-MIP models compared with data

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Global Marine Ecosystem Models that are coupled with Earth System Models are routinely used to explore climate change impacts on marine ecosystems. These models have been developed relatively recently, and a standardised approach for model benchmarking lacks due to reduced availability of global ecological datasets and limitations in what common outputs the models can produce. To overcome such barriers, we assess global marine ecosystem models using size-spectrum theory. We show that global Marine Ecosystem Models overall conform to theoretical expectation as they produce a size-spectrum slope of about -1. However, geographical patterns in size-spectrum slope differ substantially across models, and modelled estimates show varying agreement with empirical information, but a generally lower variability, low correlation and high error compared to data. Our results highlight the potential use of size-spectrum theory and data to help inform ecosystem model improvement, to work towards developing emergent ecological constraints, and to ultimately enhance confidence in future projections of multiple ecological properties.

(S8-16366 Oral)

Future Seas: an interdisciplinary multi-model approach to assess impacts of climate change on the California Current forage assemblage and the fishing communities it sustains

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In the California Current Large Marine Ecosystem (CCLME), forage fish are a key trophic link between the planktonic food web and a host of top and mid trophic-level predators. This fish assemblage also supports a range of commercially important activities, from targeted fisheries to bait. To be able to sustain their mandate of maintaining a resilient ecosystem and fishing economy under future climate change, fisheries managers require a climate-informed,

decision-support tool to evaluate how harvest of forage fish impacts ecosystem health, the trade-offs between increasing predator populations and target fisheries, and the performance of management strategies under climate and ecosystem uncertainty. We present a multidisciplinary project, Future Seas, that uses multi-model inference to quantify climate impacts on forage fish in the CCLME and assess the vulnerability of protected species, predators with high commercial values such as tunas, and fishery participants to projected variability in forage and fishing portfolios, respectively. The project is also developing a climate-informed multi-model management strategy evaluation framework to assess performance of current and alternative management strategies in meeting management objectives, given the potential future impacts of climate change on the ecosystem and fishery participants. Our modeling framework, results to date and key challenges will be highlighted.

(S8-16390 Oral)

Inconsistent fishing effort can lead to unrealistically optimistic future projections

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The future of fisheries yields will depend on environmentally driven ecosystems' production and socio-economically controlled exploitation. While multiple marine ecosystem models have been developed to project the ocean's biomass, their coupling with this socio-economic component is ongoing. The spatial distribution of fishing effort that connects biomass to fishing yields is particularly sensitive. Here we discuss the implications of the consistency of such spatial distribution by comparing 3 simulations of the BiOeconomic mArine Trophic Size-spectrum (BOATS) model. Forced by the same observed climatologies of the physical-biogeochemical environment that constrain where and when fish biomass is produced, each simulation adopts a different fishing effort distribution for the same global nominal effort. (i) Effort is estimated dynamically as a function of local profits on a one-degree grid of the global ocean. (ii) Effort is coarsely forced at the level of large marine ecosystems and spatially distributed proportionally to the simulated biomass distribution within the region. (iii) Effort is finely forced on a one-degree grid, independently of the simulated regional biomass distribution. Simulations (i) to (iii) lead to decreasing global fishing yields for the same global fishing effort. We suggest that increasingly stringent effort spatial distributions locally deplete fish biomass in heavily fished regions and leave unrealistically high fish biomass where forced effort is low. In projections, these untouched high biomasses can lead to unrealistically optimistic future projections. This inconsistency can affect both global and regional projections.

(S8-16449 Oral)

Building regional scenarios of climate change impact on fisheries: the OSMOSE model of the Peru Current Ecosystem as case study

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Earth System Models (ESM) are the main tool to forecast the impacts of climate change, but a systematic spatio-temporal bias in ESMs makes bias-correction necessary for impact applications where the absolute scale of the forcing is relevant, like when predicting species distributions or physiological responses. In addition, regional climate change impact studies need fine scale projections to devise on long term strategic planning and management measures, making downscaling often necessary. In this respect, statistical downscaling provides a fast way to produce regional ocean forcing from ESMs and can produce bias-corrected outputs, while dynamical downscaling uses physical principles to reproduce a more detailed regional dynamics but at a much higher computational cost.

In this work, we use the marine ecosystem model OSMOSE to forecast the impact of climate change in the Peru Current Ecosystem. The model is forced by downscaled products of the IPSL CM5A-LR and GFDL-ESM2M models for the period 2009-2100, using both statistical and dynamical downscaling. From this comparison, we conclude that not only downscaling but bias-correction are of crucial importance for impact applications driven by or fitted to observed data, like most regional models of social-ecological systems. Finally, using as near-term projection the period 2009-2019, we also highlight the importance of a realistic implementation of the impacts of fishing to explain future variability in fish production, particularly since the "business as usual" scenarios are unlikely and changes in fisheries dynamics are expected as result of socio-economic and climatic interactions, and this need to be considered to produce relevant management advice.

(S8-16455 Oral)

Cannibalism and other trophic dynamics of Pacific hake in a changing ocean

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CEATTLE (Climate-Enhanced Age-based Model with Temperature-specific Trophic Linkages and Energetics) is a multi-species statistical catch-at-age assessment model (MSCAA) that has been used to explore the effects of predation on the multi-species population dynamics of groundfish in the Bering Sea and Gulf of Alaska, with the goal of supporting climate-informed, ecosystem-based management. In the California Current Ecosystem, Pacific hake (*Merluccius productus*) is one of the most abundant predators and most important commercial fisheries. CEATTLE expands on the existing single-species stock assessment for hake by incorporating temperature-dependent consumption and predator-prey dynamics. Our initial model for Pacific hake considers the role of cannibalism in their diets. Hake are generalist predators and while previous research has suggested that cannibalism forms a significant part of their diet, we found that rates were highly variable (between 1988 and 2019), ranging between 0 and 80%

of stomach contents by weight, possibly following trends in the number of juvenile hake and their overlap with older individuals. The amount of cannibalism, and therefore the degree of effect on biomass and recruitment, depends on the age structure of the population. These dynamics interact with changes in growth and recruitment due to environmental drivers. Using CEATTLE to simulate the response of the hake population to varying levels of recruitment and to different temperature scenarios supports climate-ready fisheries management and provides a basis for incorporating more predator-prey dynamics into the model.

POSTER BOARD ID: S8-P1
(S8-15835 Oral)

The North Water Polynya: Assessing an Arctic oasis in a changing world

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The North Water Polynya, referred to as "Pikialasorsuaq" by Inuit in Greenland and "Sarvarjuaq" by Inuit in Canada, is the largest and most biologically productive polynya north of the Arctic circle, sustaining, for millennia, the word's northernmost Inuit communities and several keystone Arctic species, including Arctic cod, Beluga whales, Walrus, and Polar bears. Climate change, fisheries, tourism, oil and gas exploration and development, is threatening this unique sea-ice system. Recent observations suggest there may be a decline in resources at the foundation of the food-web in response to a less stable ice-free system, indicating that the North Water ecosystem is already being negatively impacted by climate change. Assessing the North Water ecosystem, in particular the food web dynamics, in a rapidly changing climate is critical to evaluate ecosystem resilience and potential repercussions for the local Inuit communities. This study aims to assess the basic ecosystem ecology of the North Water Polynya, using a regional ecosystem approach that synthesizes traditional and Western knowledge about the entire ecosystem ranging from phytoplankton, to zooplankton, to fish, marine mammals (e.g., seals, whales, polar bears), sea birds, and humans. More specifically, , using a regional ecosystem modeling approach (Ecopath, Mizer), ecosystem dynamics and the flow of energy trough the food-web within the North Water Polynya are being assessed. Understanding the ecology of the North Water ecosystem under climate change will help to understand how Arctic ecosystems more broadly will respond to climate change. As polynyas may be the first Arctic regions that will show ecosystem responses to human caused climate change, making them invaluable areas to study polar responses to climate change. As such, understanding polynya ecosystem responses will shed light on other marine regions beyond the Arctic Ocean.

POSTER BOARD ID: S8-P2
(S8-15897 Poster)

The use of ocean models to inform a marine fish stock assessment

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The productivity of many fish populations is influenced by the environment but developing environment-linked stock assessments remains challenging and current management of most commercial species assumes that stock productivity is time-invariant. Over the last decade, progress has been made on identifying relationships between stock productivity and climate variables (e.g., demographics, recruitment, population growth) and developing stock assessment models incorporating environmental covariates. However, the heterogeneity and scarcity of *in situ* ocean observations can undermine the development of climate-enhanced fishery stock assessments. Here we show that using validated ocean model products as environmental covariates in stock assessments may improve predictions and facilitate operationalization in management. We demonstrate this using the Southern New England-Mid Atlantic yellowtail flounder (*Limanda ferruginea*) stock on the northeast U.S. continental shelf, where recruitment is closely related to the strength of the Cold Pool, a seasonally formed cold water mass. First, we developed environmental indices from a regional hindcast ocean model and two global ocean data assimilated reanalyses. Then, we incorporated these indices into recruitment estimates in a state-space, age- structured stock assessment framework. We demonstrated that incorporating environmental effects into yellowtail flounder recruitment estimates reduces the retrospective patterns and may improve the predictive skill of recruitment. We also show that the performance of the stock assessment models that incorporated ocean model-based indices improved compared to the model using the observation-based index.

POSTER BOARD ID: S8-P3
(S8-16081 Poster)

knobi: An R package implementing Known-Biomass Production Models under climate change scenarios

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Rising demand for food resources in conjunction with climate-related alterations in marine ecosystems and declining trends in fishing catches around the world suggests little room for expansion of fisheries and a greater need for simple and efficient approaches to fisheries management. Many tools have been developed in order to understand how the effects of climate change could affect the different species and consequently what the socio-economic impacts would be. In this respect, biological reference points (BRPs) are important tools in the management of fisheries species. BRPs are not static, they change when the environment or the population itself changes. However, few tools allow you to calculate them under climate change scenarios. Here we present knobi, a new R package that implements Known Biomass Production Models (KBPMs), allowing the estimation of BRPs taking into consideration the environmental variability, and the projection of the population under future different environmental and exploitation scenarios. European hake (Merluccius merluccius), a commercially important resource in the European waters, is considered as a case study to highlight the advantages and illustrate the use of this new tool. knobi software provides to the scientific community a simple and powerful tool to analyze the environmental effects over the current and future states of the population, as well as on the associated BRPs to prevent the ecological and socioeconomic impacts of climate change.

POSTER BOARD ID: S8-P4
(S8-16096 Poster)

Rewilding Marine Habitats through More-than-Human Co-operative Research

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The restoration of marine ecosystems is a critical component of addressing global climate change (GCC), and the United Nations General Assembly has declared 2021-2030 as the "Decade on Ecosystem Restoration." However, the UN declaration reflects the dominant axiological standpoint, which values the living world in terms of its utility to humans. As long as conservation and environmental sciences are premised on what matters to humans, as opposed to the needs of the more-than-human world, the incremental destruction of the biosphere will continue. Co-operative research methods, applied extensively in human social sciences, erase traditional researcher/research subject hierarchies, and allow the myriad subjective voices of all research participants to emerge. Based on an expanded and reflexive epistemology, co-operative research methods embrace experiential, presentational, propositional, and practical ways of knowing. Rather than holding objectivism as the paramount research goal, co-operative research prioritizes flourishing and practical solutions as primary objectives. An emerging field of co-operative inquiry conducts research *with* rather than *on* more-than-human beings. Our work combines co-operative methods with rewilding restoration science techniques to foster economically viable, climate-resilient, ecosystem renewal. Ravaged by GCC and disease, live coral cover on Caribbean coral reefs has plummeted, providing opportunities for case studies in co-operative rewilding. Costly traditional coral reef restoration efforts often leave reestablished

reefs vulnerable to the same forces that caused their degradation in the first place. But, by working with and supporting coral reefs to evolve themselves toward resiliency, practical solutions for universal flourishing could emerge, leading to a truly restorative ecology.

POSTER BOARD ID: S8-P5
(S8-16102 Poster)

Simulating fish stock dynamics under climate change projections with a coupled bioenergetics and population model.

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Understanding the link between environmental drivers and fishery resources is key to project their future state and plan their management at medium and long terms in the context of climate variability and change. However, populations' responses to environmental variability are complex and results from a combination of numerous processes occurring at several spatial, time and organisational scales (e.g. biological stage, individual, population or community). We developed a mechanistic approach to explore the fate of two seabass stocks (ICES IVbcVIIh-d & VIIIab) in the North East Atlantic at the 2050 and 2100 horizons, using projections of IPCC RCPs 4.5 and 8.5 from the hydrodynamic-ecosystem model POLCOMS-ERSEM (from the Proudman Oceanographic Laboratory and the Plymouth Marine Laboratory). This modelling approach accounts for both individual and population processes and relies on a DEB-IBM framework. While the Dynamic Energy Budget (DEB) simulates the full life cycle of individuals (development, growth, reproduction and survival) as a response to environmental forcings (temperature and prey availability), the Individual Based Model (IBM) simulates processes occurring at the scale of the population (e.g. such as fishing pressure or density dependence). First, we calibrated the model on the historical time series using a combination of observations (landings, length frequencies distribution and biomass indices) and estimations (SSB, F) from the ICES working groups WGCSE and WGBIE. Second, we used climate projections to explore future stock productivity (SSB, recruitment), individual performance (growth, reproduction, survival) in relation to simple fishery management scenarios.

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POSTER BOARD ID: S8-P6
(S8-16104 Poster)

The impact of biogeochemical representation in end-to-end modeling frameworks

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Projecting the impact of long-term climate change on regional living marine resources requires the use of many different model types, each with their own inherent uncertainties. In the case of dynamical downscaling, an end-to-end pathway can encompass the emissions scenario, global earth system model, regional ocean/ice/biogeochemical model, upper trophic level model, and socioeconomic model. An ensemble approach can be used to quantify the uncertainty in each of these components and incorporate that uncertainty into the projected metrics of climate change impact on specific resources. However, thus far the ensemble approach often neglects regional model complexity and uses one model with particular biogeochemical processes and parameters. This can create a bottleneck in the uncertainty envelope at this step, particularly with metrics (such as primary and secondary production, oxygen concentration, and pH) that are strongly controlled by the biogeochemical components of the regional model. Here, we perform a biogeochemical model intercomparison, coupling an identical physical regional ocean model to several biogeochemical models, covering a range of functional parsimony versus complexity and parameter tuning to a specific region versus a more generic environment. This comparison will allow us to better constrain the potential uncertainty arising from different representations of lower trophic level dynamics and the impact of that uncertainty on living marine resource applications.

POSTER BOARD ID: S8-P7
(S8-16107 Poster)

Revealing climate impacts on recruitment drivers through application of Dynamic Factor Analysis, a coastal pelagic fish case study

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Small pelagic fishes exhibit boom-bust cycles driven by interannual fluctuations in recruitment success likely linked to environmental forcing. These drivers remain poorly understood and are rarely accurately predicted. Pacific sardine and northern anchovy in the California Current Ecosystem are well-monitored small pelagic stocks that are understood by fisheries management to respond to the environment. Without a mechanistic understanding of these environment-recruitment linkages, the risks to managing these stocks may increase as climate changes and the underlying linkages shift or break down. We developed an approach to identify, test, and project the influence of multiple drivers of recruitment success on small pelagic fishes. Recruitment, or the culmination of parental fecundity and early life stage growth and survival, is influenced by 1) behavioral and physiological responses to oceanographic conditions, 2) maternal condition, 3) forage availability, and 4) predation. Based on literature review and expert elicitation, we identified indicators of sardine or anchovy recruitment success for each of these general drivers. Using these process-based indicators and Dynamic Factor Analysis, we derived composite indices for each species from the 1990s to present and integrated

these indices in stock assessment models to test their information content relative to other data sources. We then projected the indices through the end of the century under multiple climactic and predation scenarios. Finally, we projected the environmentally-linked assessment models forward under various fishing conditions to understand the effect of these scenarios on stock dynamics through 2100 and the management consequences of climate change on these foundational forage species.

POSTER BOARD ID: S8-P8

(S8-16142 Poster)

Vulnerabilities of a socio-ecological system using bio-economic modeling under multiple scenarios

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It is becoming more evident that changes of multiple drivers have strong impacts on a Socio-Ecological System (SES). Particularly, changes of drivers in one sub-system generate cascading effects in other sub-systems and holistic analyses are necessary to understand these multiple interactions. Changes in ecological drivers such as temperature or pollution, or abrupt changes in economic drivers such as prices and people's preferences affect SESs in unexpected ways. To bring clarity in this area we use an existing analytical framework to assess the vulnerabilities of an SES to multiple drivers. We determine to which drivers the SES is more or less vulnerable. The assessed vulnerabilities, however, change depending on the future scenarios resulting in different predicted effects within an SES. This is relevant for policymakers since conditional on each scenario the desired or undesired effects of drivers on the SES can change dramatically. Our study disentangles the effects of multiple drivers on an SES for multiple scenarios and allows us to determine policy options that are safe in almost all possible scenarios.

We use this analytical framework to assess the vulnerabilities of North Sea German Fishers' profits to multiple drivers from the economic and ecological side. Using a calibrated bio-economic model we quantify the most critical drivers affecting fishers' profits. Additionally, from joint work with stakeholders and literature, we select possible future scenarios to be applied within the framework. We conclude that there are multiple trade-off effects of each scenario affecting fisheries' profits, and we disentangle specific cascading effects.

POSTER BOARD ID: S8-P9
(S8-16187 Poster)

Challenges of developing a consistent view of future climate projections in the global coastal ocean: The Future Coastal Ocean Climates (FLAME) UN Decade project

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The recently endorsed UN Decade Project FLAME (https://projects.noc.ac.uk/flame/) is part of the CoastPredict (coastpredict.org) programme, and aims to generate innovative, high-resolution, downscaled decadal to centennial projections of future coastal ocean climates and to explore climate change impacts on coastal ecosystems, hazards, services and resources at the local-regional scales necessary for informed decision making. A long-term objective of FLAME is the inception of a global coastal-ocean model intercomparison project to inform future IPCC assessment reports. As a first step towards this objective, we convened a workshop in February 2023 bringing together coastal-ocean climate modelling practitioners and analysists from around the world, crossing regional and disciplinary boundaries, to develop collectively a road-map towards such an intercomparison project. These cover multiple approaches, including dynamical downscaling, regional climate models, and direct use of global climate models, to deliver stakeholder-led objectives. In this presentation we provide a synthesis of the outcomes of this workshop, exploring the challenges, and suggesting solutions, to developing a consistent view of the impacts of climate change in the global coastal ocean. These challenges include, for example: cross-comparable experiment design with multiple modelling systems; a consistent approach to uncertainty, including model biases, scenario and natural variability; coupling strategies for downscaled earth-system climate models; and approaches to regional capacity building to empower practitioners and stakeholder around the world to take advantage of these approaches.

POSTER BOARD ID: S8-P10
(S8-16190 Poster)

Projections of the eastern Bering Sea food web to support climate-informed ecosystem-based fisheries management

Andy **Whitehouse**[1], Kerim Aydin[2], Wei Cheng[1], Amanda Faig[3], Alan Haynie[4], Al Hermann[1], Anne Hollowed[3], Kirstin Holsman[2], Kelly Kearney[1], Jonathan Reum[2] and Andre Punt[3]

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The eastern Bering Sea is a productive sea that supports several commercial fish and crab fisheries and subsistence harvests. Climate change is impacting the eastern Bering Sea ecosystem by altering physical and chemical conditions, which has implications for the food web and production that supports commercial fisheries. Thus, there is a need to develop climate-enhanced projections of the eastern Bering Sea food web to identify risks to the Bering Sea ecosystem, its fisheries and to assess climate-resilient fisheries management strategies. To address this need, we simulate future climate impacts to the eastern Bering Sea ecosystem through 2099 with a dynamic food web model (Rpath) that has been fit to time series data. We

represent primary and secondary production in our food web model with outputs from a regional ocean and biogeochemical model that has been driven by multiple earth system models, run under multiple climate scenarios. We directly incorporate the physiological effects of climate change on groundfish with a bioenergetics module that represents their changing metabolic demands in response to changing temperatures. Additionally, we include a fisheries sub-model that incorporates social and economic tradeoffs into dynamic predictions of groundfish catch quotas under different management scenarios and harvest control rules.

POSTER BOARD ID: S8-P11

(S8-16202 Poster)

Climate change effects in the marine system of Puget Sound

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In Puget Sound, an urban estuary in the Pacific Northwest, USA, climate change will reshape the ecosystem through bottom-up processes, affecting the abundance of groups at the base of the food web (i.e. phytoplankton and marine plants) and through top-down processes. Climate change impacts on salmon, in particular, will scale to their predators, including an endangered killer whale population. As part of an analysis of cumulative impacts, we examine the impact of future ocean conditions, under climate change scenarios, in Puget Sound. We used empirical downscaling to derive regionalized future ocean warming and salinity projections from coarse Global Circulation Models (GCMs). We then estimated 30-yr climatologies from both the historical simulations and future scenarios (for a mid-century period, 2020–2050, and an end-of-century period, 2070–2100), and derived temperature anomalies. These anomalies were superimposed onto the temperature and salinity time series in the oceanographic model used to drive an ecosystem model for Puget Sound, built with the Atlantis modeling framework. Atlantis simulations will link changing ocean conditions to biological processes in scenarios that test to what extent 'speeding up' ecosystem-wide anabolic processes (e.g. gains due to higher growth rates) will be balanced by 'speeding up' catabolic processes (e.g. losses due to declines in assimilation rates or increases in predation mortality). We expect that higher trophic level species including killer whales and salmon will be affected both by their own direct physiological responses to temperature, and to the temperature-driven responses of the forage base.

POSTER BOARD ID: S8-P12
(S8-16203 Poster)

Multispecies eco-evolutionary dynamics of North Sea exploited fish under climate change

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Marine ecosystem models for fisheries management have been used to project interspecific biodiversity under several climate change and management scenarios considering ecological dynamics only. However, fish populations may also adapt to climatic and fishing pressures via evolutionary changes leading to modifications in their life history that could either mitigate or worsen pressures' consequences.

A multispecies eco-evolutionary model, Ev-Osmose, has been developed to account for evolutionary dynamics in marine fish biodiversity projections. In this model, life-history traits are mechanistically described by a bio-energetic model: the processes of somatic growth, sexual maturation and reproduction emerge from energy fluxes sustained by food intake resulting from predation and responding to temperature and oxygen concentration. Life-history traits are allowed to evolve as their values are transmitted through cohorts by gametic inheritance of parents' genes. An offspring's genetic structure, defined by a finite number of loci and alleles per locus, then determines its maturation and energy fluxes. Under the selection pressures generated by climate change and fishing scenarios, energy fluxes and the resulting life-history traits may thus respond through phenotypic plasticity and microevolution.

The Ev-Osmose model has been used to simulate the changes in the genetic, trait and species diversity of North Sea exploited fish under two climate change scenarios (RCP4.5 and RCP8.5) for the period 2010-2100. We present the results of forecast simulations with and without evolution to understand (i) the capacities of exploited fish to adapt to climate change and (ii) the importance of accounting for eco-evolutionary dynamics in future projections of biodiversity.

POSTER BOARD ID: S8-P13
(S8-16212 Poster)

Downscaling global socio-political scenarios for the Western Mediterranean Sea to test nature-based solutions within an ecosystem-based approach

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For marine ecological models to be useful for management processes, it is essential to account for plausible future scenarios of climate and socio-economic drivers of change. We downscaled global narratives of socio-political scenarios developed during previous EU projects, and we tailored them to the Western Mediterranean Sea. These scenarios are based on Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs) and include: 1) global sustainability (RCP2.6, SSP1); 2) national enterprise (RCP8.5, SSP3); and 3) global markets (RCP8.5, SSP5). For each scenario, we quantitatively characterised key drivers and linked them with the implementation of three nature-based solutions: effective conservation, effective restoration, and sustainable harvesting (e.g., fishing effort and mortality levels, surface and location of marine protected areas and recovery targets for degraded marine habitats). Under a global sustainability scenario, we envisioned full implementation of European

legislation and the General Fisheries Commission for the Mediterranean new commitments in line with the 2030 strategy, reaching precautionary maximum sustainable yield (MSY) targets, the 30 % protection target by 2030 and the recovery of degraded habitats in EU waters. Under national enterprise, we expected only partial achievement of European directives and GFCM strategy, with lower targets for protection, fisheries management and recovery of degraded habitats. Under a world market scenario, we foresee actions to optimise activities towards benefitting high commercial species and poor achievement of multiannual plans of the EU and GFCM, protection and restoration targets. Developing these future scenarios is key to assessing the long-term effects of plausible and contrasting management actions using modelling tools.

POSTER BOARD ID: S8-P14

(S8-16220 Poster)

REVISION: NEW TITLE: **"Modeling the effect of climate on recruitment within single-species assessment models, with implications for management for eastern Bering Sea walleye pollock"**

Modeling the effect of climate on predation and recruitment within single-species assessment models, with implications for management and projections for eastern Bering Sea walleye pollock

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Rapid warming in parts of world's oceans has necessitated the consideration of climate in assessing the abundance and productivity of marine fish stocks. The purpose of this study is to use eastern Bering Sea walleye pollock (*Gadus chalcogrammus*, a commercially important stock) to illustrate methodologies for estimation of climate influences on recruitment and mortality within a single-species stock assessment model. Increased temperature can lower the survival of pre-recruit pollock, and a model with temperature dependence in the stock-recruitment curve shows lower posterior predictive loss (i.e., improved predictive performance) relative to a model not informed by climate. Additionally, environmentally-driven overlap between juvenile pollock and arrowtooth flounder (*Atheresthes stomias*) can affect predation mortality. We predicted spatial distributions of walleye pollock and arrowtooth flounder using two independent spatiotemporal models conditioned on bottom trawl survey observations, and used the resulting spatial patterns in stock densities to estimate predation functional responses within the pollock assessment model. Climate-driven stock dynamics are projected into the future using dynamically downscaled climate projections under a range of Shared Socio-economic Pathways emission scenarios and both static and dynamic harvest control rules. For walleye pollock, a particular challenge is that climate-enhanced stock assessment models results in slight changes in the estimation of abundance and recruitment strength (which were well-informed from age and size composition data), but has important implications for future levels of stock productivity.

POSTER BOARD ID: S8-P15
(S8-16259 Poster)

Advances in linking data to models to understand ecosystem dynamics under climate change in the California Current

Owen R. **Liu**[1], Pierre-Yves Hernvann[2], Elizabeth A. Fulton[3], and Isaac Kaplan[1]

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Ecosystem models allow for the exploration of bottom-up and top-down effects of human and natural processes on species and resources of economic and cultural value. End-to-end ecosystem models like Atlantis can simulate cascading effects of climate change on entire social-ecological systems, including fisheries and fishing communities. However, complex models like Atlantis can be intimidating to build and appropriately parameterize. In this talk, we introduce an updated Atlantis ecosystem model for the California Current that describes the dynamics of more than 80 key species groups, more than 50 localized fishing fleets, and incorporates state-of-the-art, downscaled climate change projections out to the year 2100. We describe several key advances in improving the data-driven parameterization of the model, including new techniques to incorporate climate-driven species distributions, spatial fishing footprints, and comprehensive marine diet data into Atlantis. We then use Atlantis model simulations to project the effect of climate change on key bottom-dwelling groundfish species—their diets, their distribution, and their fisheries. Throughout, we emphasize the utility of the tools we use to other geographies and ecosystem models, and conclude with exciting new applications of Atlantis to tackle key questions concerning social-ecological resilience to climate change.

POSTER BOARD ID: S8-P16
(S8-16265 Poster)

Eastern Bering Sea dynamical downscaling from CMIP6: results and caveats

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In this study we present projected changes in the Eastern Bering Sea shelf (EBS) biophysical processes in response to climate forcing scenarios from the Coupled Model Intercomparison Phase 6 (CMIP6). Ensemble mean results suggest that, contrary to an anticipated increase in ocean stratification under warming, diminishing ice cover in the future *weakens* EBS stratification in the melt season. Modeled ensemble mean phytoplankton and zooplankton biomass exhibits subsurface maxima during the growing season, and the amplitude of these maxima decreases with warming, along with a reduction in primary productivity and oxygen concentration over much of the water column. Phenology of both phytoplankton and zooplankton biomass shifts earlier, leading to an increase (decrease) in biomass averaged between April-July (August-November) while the annual mean biomass decreases under warming. Projected changes of plankton biomass at the end of the 21st century are not well separated between the SSP126 and

SSP585 scenario in light of the inter-model spread under each forcing scenario. However, these results are obtained from a limited ensemble. Increasing the ensemble size using dynamical and/or statistical methods, along with improvement in modeling the essential physical and biogeochemical processes for the region, remains a high priority in our future research.

POSTER BOARD ID: S8-P17

(S8-16282 Poster)

NOAA Climate, Ecosystems and Fisheries Initiative: An end-to-end decision support system for climate ready resource management

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Climate variability and change are significantly impacting marine ecosystems, fisheries and the many people, businesses and communities that depend upon them. These changes affect every part of NOAA's mission, from fisheries management and aquaculture to protected species and habitat conservation. To effectively prepare for and respond to these changes, decision makers need robust information on likely future conditions and best options for resilience and adaptation. The NOAA Climate, Ecosystems and Fisheries Initiative (CEFI) is a nation-wide integrated ocean modeling and decision support system designed to provide decision-makers at national, regional and local levels with actionable information to reduce impacts and increase resilience. The CEFI system will use state-of-the-art climate, ocean and ecosystem modeling to provide robust future scenarios across multiple timeframes, and actionable advice for climate-informed decision-making. The CEFI system is composed of five inter-linked components that ensure operational delivery of information, services, and feedback for sustained performance and innovation: (1) Regional ocean modeling that provides state-of-the-art ocean forecasts and projections based on multiple climate/ocean modeling systems for use in developing climate-informed management advice; (2) Information Hub to provide data standards and easy access to model output and other information; (3) Operational decision support that uses the ocean forecasts and projections to provide ecosystem-related outlooks, risk assessments, strategies and advice for climate-informed decisions; (4) Decision maker capacity to incorporate climate-informed advice into decisions regarding fisheries, protected species, marine protected areas and ocean ecosystems; (5) Targeted observations and research for continuous validation, innovation and improvement of the system.

POSTER BOARD ID: S8-P18
(S8-16300 Poster)

More frequent ENSOs could reduce probability of overfishing in long-lived California Current fishes

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Population models in stock assessments often incorporate the effects of environmental stochasticity on recruitment survival and most assume variance in the environment is white noise. However, in many locations the environmental spectrum is not white and may change with climate change. In the California Current, environmental variation is dominated by El Niño-Southern Oscillations (ENSO) which has a peak variance at periods 5-7 y and is predicted to become more frequent with climate change resulting in environmental variability peaking over shorter periods. This study investigates if the risk of overfishing in 12 commercially managed fisheries is sensitive to such changes. Using stochastic age-structured density-dependent models, with four environmental noise scenarios: white noise, frequency of historical ENSO cycles, ENSO sped up 2x, and ENSO slowed down by half. We find that if population models assume the environment is composed of ENSO variability compared to white noise, the probability of overfishing nearly doubles for all species, but if ENSO frequencies speed up then probability of overfishing is less compared to historical ENSO frequencies. If we assume ENSO frequencies slow down, then probability of overfishing is higher compared to fast ENSO, and this is especially true for long-lived species. These findings show that stock assessments may be missing an important source of uncertainty when setting target limits to minimize the probability of overfishing, but also that the risk of overfishing for the species in this study may decrease if ENSO cycles speed up as is expected with climate change.

POSTER BOARD ID: S8-P19
(S8-16345 Poster)

Identifying strategies to support climate-ready ecosystem-based management advice for a collapsed cod stock

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Marine capture fisheries have a history of overfishing that is nowadays exacerbated by the effects of climate change on living marine resources. Ocean warming has already caused significant losses in maximum sustainable yields of major fish stocks and global projections anticipate mean global animal biomass to decline even without fishing. Such reductions in productivity due to climate change are especially bad news for resource species that are already collapsed such as many Atlantic cod stocks that failed to recover even under reduced fishing pressure. Management strategies for such collapsed species under climate change are hence challenged by the need to rebuilt low-productive stocks under deteriorating environmental conditions. We here forced a climate-ready, age-structured single-species model for the collapsed Western Baltic cod stock by temperature projections based on representative concentration pathway RCP4.5 and RCP8.5 emission scenarios. Projected temperature trajectories serve as climate forcing in two environmentally-sensitive stock-recruitment functions that represent historical and recent productivity conditions of the stock. We used the model to stress test the robustness of the presently in place advisory procedure of the International Council for the Exploration of the Sea (ICES) to the effects of climate change. Our simulations revealed that while recovery of the stock is possible independent of stock productivity and emission scenario, there is a high risk that under low productivity conditions the advisory process fails to achieve MSY targets under progressed warming. We show that such adaptation tipping points can be postponed or even avoided when applying more precautionary management targets.

POSTER BOARD ID: S8-P20
(S8-16394 Poster)

Projections of climate-driven changes in marine fish stocks across European Regional Seas: Social-ecological winners and losers

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This presentation summarizes the findings of the EU CERES project examining social-ecological impacts on European fish stocks and their fisheries. We compare projected climate-driven changes in the distribution and productivity of commercially important European fish stocks based on the results of ten, state-of-the-art biological models. Projections were made in seven European regional seas spanning sub-polar to tropical habitats: Barents & Norwegian Seas (BSNS), NE Atlantic (NEA), North Sea (NS), Baltic Sea (BS), Bay of Biscay (BoB), western Mediterranean Sea (WM) and Aegean Sea (AS). Climate impacts on demersal and pelagic fish stocks were species- and region-specific with warming (2 to 4°C in RCP 8.5 by 2100) and altered levels of secondary production leading to stock declines (BSNS herring) and increases (BoB anchovy). Importantly, those ecological projections were consistent despite differences in model structure (e.g. whether trophic interactions were included). Although some temperate and cold-water stocks markedly declined in some regions (e.g. NEA, NS, WM), the immigration of thermophilic and/or increased productivity of sub-tropical species will provide novel opportunities for fisheries. These ecological estimates are compared to projected economic impacts via SSP-RCP scenario modeling and a previous risk assessment conducted across European stocks to 2050. Our simulations underscore the importance of climate-ready management measures for the future sustainability of European marine fish stocks and their fisheries.

POSTER BOARD ID: S8-P21
(S8-16395 Poster)

Mechanistic population projections for sardine and anchovy in the California Current under ocean warming and changing food availability

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The combined impacts of different environmental drivers and fisheries to the population dynamics of marine fish stocks remain incompletely understood. In the California Current, contrary to expectations after recent warm ocean conditions, Pacific sardine (*Sardinops sagax*) remains at low biomass, while Northern anchovy (*Engraulis mordax*) appears to recover.

We developed process-based population models for sardine and anchovy driven by high-resolution ocean-biogeochemical models, simulating early life stage survival and offshore transport, food availability for larvae and adults, predation, migration and egg production. An ensemble model configuration set fit to observations is used to identify response mechanisms and quantify ecological uncertainty. Population abundance, catch and distribution for the 21st century are projected under three downscaled earth system models (ESM).

The model reproduces the last boom-and-bust and lack of recent recovery of sardine, and the recent resurgence of anchovy. Ensemble projections show a likely sardine recovery to early 2000's abundance and catch by mid-century, driven by increasing recruitment success under warming temperatures. A long-term anchovy increase is prevented by low egg production under decreasing food availability. Ecological process uncertainty is generally of the same magnitude as uncertainty associated with different ESM projections, and uncertainty related to the thermal optimum of early life stage survival dominates after 2070.

This work advances understanding of the combined impacts of multiple drivers on fish population dynamics, abundance and distribution under novel environmental conditions, and quantifies sources of uncertainty in linking to regional ocean models, helping to develop climate-responsive fisheries management strategies under both climate variability and change.

POSTER BOARD ID: S8-P22
(S8-16400 Poster)

Climate intervention impacts on marine ecosystem drivers and intervention scenario development

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Humanity is facing growing risks due to climate change, however there are no obvious political pathways that can limit warming to 1.5°C, a requirement to prevent detrimental impacts on human and natural systems. Given the severity of climate impacts being already experienced, there is a need to explore how a portfolio of combined climate intervention strategies including mitigation, carbon dioxide removal and solar radiation management could achieve a climate-resilient future, avoiding climate and ecological tipping points. To determine plausible scenarios for climate intervention, impacts studies are needed, including potential benefits and risks to marine ecosystems, which can provide potential "exit ramps" to climate intervention implementation. Here we report on simulated impacts of two proposed climate intervention scenarios, marine cloud brightening and stratospheric aerosol injection, on global and regional physical and biogeochemical marine ecosystem drivers using the Earth system model CESM2 and the ARISE simulations. We also report on how these impacts studies are being used within a broader framework to develop future climate intervention scenarios, and engagement opportunities for scientists, managers, and policy experts in this international interdisciplinary effort.

POSTER BOARD ID: S8-P23
(S8-16406 Poster)

Hybrid dynamical-statistical methods for climate downscaling: A comparison of methods with examples from the Northeast Pacific

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The process of dynamical downscaling entails the use of high-resolution regional models driven by lower resolution global re-analyses and projections. Such regional models, given their higher spatial resolution and sometimes higher biogeochemical detail relative to the global models which drive them, are typically computationally expensive. This expense limits the ultimate size of any downscaled regional ensemble (including parameter sensitivities), which in turn constrains both the skill and uncertainty estimates of the regional forecasts, needed for their effective use in fisheries management. Statistical downscaling based on presently observed correlations between large-scale forcing and small-scale response is an alternate approach but lacks the ability to capture future emergent behaviors of complex, nonlinear regional biogeochemical systems. Here we describe several alternative techniques for the statistical expansion of dynamically downscaled ensembles. These "hybrid" methods offer a compromise between the spatial, temporal and trophic detail of dynamical methods vs. the numerical efficiency of purely statistical methods. We illustrate several methods, including the use of Machine Learning, with examples from ongoing Management Strategy Evaluation research in the Bering Sea and the Gulf of Alaska.

S9: Transitioning from Vulnerable to Resilient and Viable Fisheries Social-Ecological Systems

Convenors:
Katherine Maltby (Corresponding), (Gulf of Maine Research Institute, USA)
Catie Alves, (ECS Federal, Inc. In support of NOAA Fisheries, NFSC, Social Science Branch)
Jacob Eurich. (Environmental Defense Fund)
Prateep Nayak, (Faculty of Environment, V2V Global Partnership, University of Waterloo, Canada)

Invited Speakers:
Katherine Mills, (Gulf of Maine Research Institute, GMRI, USA)
Jenia Mukherjee, (Indian Institute of Technology Kharagpur, India)

Fisheries provide income, jobs, food, and cultural connection to the oceans. Yet these systems are vulnerable to climate change, and are also influenced by broader ecological, socioeconomic, and governance dimensions. Pathways to reduce vulnerability and operationalise climate resilience within fisheries are often context-, scale-, and resource-dependent. Identifying and understanding opportunities, as well as challenges or trade-offs, to meeting these aims is critical for achieving global Sustainable Development Goals. This is particularly important for small scale fisheries, many of which remain economically and politically marginalised, are highly vulnerable to change, and remain invisible in policy debates. This session welcomes contributions that examine the diverse factors and conditions contributing to fisheries vulnerability and/or resilience, characterise ways fisheries are responding to climate change, and reflect on pathways that facilitate transitions from vulnerability to resilient and viable fisheries systems. We encourage case studies reflecting a range of fisheries contexts.

(S9- 15884 Invited)

Dealing with risks, dwelling in the delta: viable stories of SSF from transboundary Sundarbans

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The Sundarbans, the world's largest mangrove cover and an active delta is shared by Bangladesh and India. It is exposed to the disruptive risks of the Anthropocene including erratic monsoons, sea level rise, frequent cyclones and flooding, etc. Perception of the Sundarbans as a 'riskscape' has shaped the debate on 'retreat and emigration' of island communities in the global, national, regional and local platforms (such as World Worldlife Fund, Observer Research Foundation, etc.) and generated controversies among multiple actors. By showcasing success stories in small-scale fisheries (SSF), co-planned and co-implemented along transdisciplinary research and experimentation in selected island villages of the Indian and Bangladesh Sundarbans, this presentation will unleash possibilities of dealing with climate risks and 'dwelling' in the delta as an adaptation strategy. [1] The case stories will convey local stories of 'social resilience' with SSF as the alternative livelihoods provision in transboundary Sundarbans, also attesting the need to coproduce knowledge and actions particularly across regions where impacts of climate change are already pronounced, community vulnerability high and disasters common.

[1] 'Dwelling' as opposed to 'emigration'. I am influenced by Pemberton et al. (2021) paradigm of 'staying' as adaptation strategy against climate change.

(S9-16444 Invited)

Assessing and operationalizing climate resilience in marine fisheries

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Marine fisheries provide income, jobs, and nutrition for millions of people, but impacts of climate change are altering the productivity and distribution of fish stocks and the flows of benefits from fisheries. The nature of these impacts and ability of fishery stakeholders to respond to them are mediated by the ecological, socio-economic, and governance context within which fisheries operate. A recent Science for Nature and People Partnership (SNAPP) working group on Climate Resilient Fisheries has developed a framework and toolkit to support integrated assessments and planning for climate resilience in marine fisheries. This framework helps identify climate risks to a fishery; evaluate ecological, socioeconomic, and governance attributes that influence resilience; and prioritize actions to enhance climate resilience. By considering fisheries as coupled social-ecological systems, this framework can help identify approaches to operationalize climate resilience across multiple dimensions of fishery systems. Applications to resilience assessment and planning will be demonstrated through case examples drawn from fisheries around the world. In these cases, multifaceted strategies have supported climate resilience, including measures to enhance stock and ecosystem health, reinforce social strengths, expand economic opportunities, and enhance governance responsiveness and effectiveness.

(S9-15857 Oral)

Climate change risk and adaptation for fisher communities in Ghana

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Artisanal fisheries in Ghana account for more than two thirds of the country's food fish production and employ or support around 2 million people. However, many fish stocks are close to collapse through overexploitation. Climate change is expected to affect the fish themselves as well as fishing activities, increasing the already high risk to fishers' livelihoods and Ghana's food security. We used a climate change risk assessment framework to assess vulnerability of Ghanaian fisheries, considering climate hazards, fish species sensitivity and socio-economic vulnerability of fisheries sectors and regions. The results show that some species constituting the highest catches in Ghana are highly sensitive to climate change. Some species assessed as having low sensitivity to climate change in the region are migratory pelagic fish. Species caught by artisanal fleets are typically more sensitive than those captured by semi-industrial and industrial fleets. Regionally, the highest climate risk is found for Volta, and the lowest

for the Greater Accra region. This information can be used to identify climate adaptation opportunities that are location specific, accounting for socio-economic differences between regions, and species caught. Options include market diversification to encourage targeting of least sensitive species, by switching to fishing methods that distinguish between species and reduce pressure on overfished stocks. Alternative livelihoods could be adopted to maintain an income while lowering impact on fisheries. Possible alternatives include crop farming, real estate, and transport. Adaptation will help the country achieve its aims of restoring fish stocks, safeguarding livelihoods and improving climate resilience for artisanal fishers.

(S9-15942 Oral)

Adaptative small-scale fishing effort in the eastern Cantabrian coast

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During the last decades the general picture of most harbours in the Basque region (eastern Cantabrian coast) suggest a decline in small-scale fisheries (SSF) activity which is carried out by vessels with LOA<15m. However, since knowledge on SSF has been trapped in a data-poor cycle due to lower importance in data collection when compared to other commercial fleets, details regarding the recent development of the different fleet segments or temporal changes in landed species remain unknown. The present study shows that during the last decade (2010 – 2020) trolling lines targeting albacore (*Thunnus alalunga*) in summer and especially handlines fishery targeting mackerel (*Scomber scombrus*) in spring was the most important seasonal SSF in the region. Moreover, they intensified the fishing effort and showed the highest landings, especially for mackerel. In contrast, a decline in vessel number, fishing effort and therefore in landings was observed for netters i.e., gillnets and trammelnets. The use of longlines and pots did not show any time trend. Regarding targeted species, while fish diversity landed by handliners decreased probably due to the mackerel fishing intensification, netters targeted on a wider variety of small fish species. Observed landing incomes suggest that Basque SSF fleet is shifting to specialized hookers probably driven by specific market demands; i.e., intensifying seasonal mackerel and albacore fishing, while netters, which are declining in number, are landing a wider range of target species. Understanding such developments might contribute towards future management plans on regional scale.

(S9-16050 Oral) **REVISION: Presentation CANCELLED**

How to foster the capacity of a fisheries social-ecological system to adapt to global change

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Climate change challenges coupled human- and natural systems such as fisheries socio-ecological systems (SESs). Understanding the capacity of an SES to adapt to changing ecological or socio-economic conditions is complex and entails a clear differentiation between the system´s properties such as resilience, vulnerability and adaptive capacity. We quantified autonomous adaptation strategies of the German mixed demersal fishery in the southern North Sea SES to environmental and socio-economic change at regional and local scales over the last two decades. Deploying the modified Ostrom framework for institutional analysis and development allowed us to analyse spatio-temporal dynamics of SES attributes and their linkages. SES actors have shown autonomous adaptations to environmental and socio-economic change which entailed a shift of target species, fishing strategies, as well as a distinct decrease of the number of actors over the past two decades. We found that the ability of the SES to adapt decreased with time, with the SES being now on the brink to weather future to environmental and socio-economic change. Our results showed that the key barriers to adaptation for the fisheries SES related to fishing cultures, economic structures, a complicated political setting and pressures from other marine sectors potentially undermining fishing activities in relevant areas. Hence, an in-depth understanding of the SES components and linkages of SES attributes is a key requirement to develop future management approaches to enhance SES adaptive capacity to global change. Tailored and context specific co-management approaches are required for all decision-making processes to which the SES are exposed.

(S9- 16052 Oral)

Factors determining small-scale fisheries survival rate under increasing climate change impact

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Small-scale fisheries (SSF) are increasingly being impacted by climate-driven changes in the coastal ecosystems they depend on, threatening their livelihood and food security. As climate change accelerates, fishers opt for a wide variety of adaptations, ranging from less drastic options that enable the continuation of their social-ecological systems (i.e. coping and adaptive strategies) to transformative strategies, such as livelihood diversification, or even abandoning SSF. Existing literature suggests that, as the climate pressure increases on the SSF, transformative responses become more common because coping and adaptive strategies are no longer sufficient. There is, however, little empirical evidence showing at what level of impact fishers adopt transformative strategies or how their individual adaptive capacity enables or hinders them to adopt this kind of strategies. Therefore, we used primary data from 445 small-scale fishers from six coastal communities at the climate change hotspot Nayarit, México, where fishers were asked how they would respond to hypothetical climate change impact scenarios (50% and 75 % decrease in catch and income). We also collected the socioeconomic information representing six different adaptive capacity domains at the individual fisher level. Through a survival analysis, we studied the relationship between the adaptive capacity indicators and fishers' choices to diversify or leave SSF under the different climate change impact scenarios. This study contributes to a better understanding of the adaptation strategies of SSF in Nayarit and the factors that allow fishers to secure their livelihoods and ensure their well-being in the future.

(S9-16069 Oral)

Responding to an ocean of change: Small-scale fisheries transitioning from vulnerability to viability

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Strongly anchored in local communities, small-scale fisheries reflect a way of life, and they provide critical contributions to nutrition, food security, poverty alleviation, livelihoods, and local / national economies. Yet, their multiple benefits and contributions are often overlooked as many SSF communities remain economically and politically marginalised, are highly vulnerable to change, and remain invisible in policy debates. Nonetheless, the survivability of many small-scale fisheries suggests certain strengths and forms of resilience. A holistic understanding of what causes vulnerability and what makes small-scale-fisheries viable is required. The goal of this paper is to critically examine the diverse factors and conditions contributing to the vulnerability of SSF, and to reflect on ways that are crucial to enhance and facilitate their transition to viability. Even though small-scale fisheries are often characterized as vulnerable, and their viability is a key issue in fisheries governance, both the terms vulnerability and viability are hard to define. Moreover, these concepts have almost always

been treated exclusively, and the inherent linkages between vulnerability and viability have largely remained unaddressed. We use "Vulnerability To Viability (V2V)" as a novel approach and conceptual framing to highlight their interconnected nature and the potential for vulnerable small-scale fisheries to transition towards viability. As such, we recognize V2V as a process that is multidimensional, complex, highly dynamic, and relative, the study of which needs to be inter- and trans-disciplinary.

(S9-16153 Oral)

Climate adaptation pathways in small pelagic fisheries' dependent livelihoods

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Small-pelagics are shifting their distribution due to climate change, impacting fishing communities that heavily rely on these species for food and income. They are, at the same time, key to sustain the nutritional intake for millions of coastal livelihoods, and of utmost nutritional importance to vulnerable population. Understanding how fishers that rely on these species adapt to climate change impacts can inform us on the best adaptation pathways. In this study we look at the adaptive capacities of small-pelagic fishers from the six classical domains of adaptation: material assets, organizational settings and processes, individual agency, flexibility and learning. We explore a case study with 9 communities of small-scale fishers in Galicia (Northern Spain), to understand how fishers respond to increasing levels of climate change impacts. We find that while small-pelagics' fishers have high flexibility and a diverse species portfolio, they also have low adaptive capacity in terms of organization. From this new evidence, we derive lessons learnt and policy implications in order to foster adaptation, secure nutritious food supply, and identify potential maladaptation.

(S9-16183 Oral)

Species diversification, economic portfolio and connectivity within small-scale fisheries in the Balearic Islands

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Small-scale fisheries (SSF) face complex ecological and societal challenges at multiple spatio-temporal scales due to climate change. While species targeted by SSF tend to be more vulnerable to shifts in climate than those targeted by demersal fisheries, seasonal diversification in species portfolio, through changes in use of type of fishing gear, increases the adaptive capacity of SSF to climate change and maintains stable economic incomes. However, fisheries diversification depends on species distribution and abundance, which may vary locally with contrasting ecological (e.g. habitat diversity), and/or socio-economic factors (e.g. generational turnover). In the Balearic Islands, there has been a 50% decline in the number SSF vessels since 2005, but the combined impacts of this decline and climate change on species diversification and economic portfolio are unclear. Thus, we analysed spatio-temporal changes in species landings, stability in fishing incomes and levels of between-port connectivity to evaluate the adaptive capacity of Balearic SSF. Using multivariate and network analysis of daily landing

data for 10 ports distributed across the Balearic Islands between 2007 and 2020, we found landing weight and revenue of dominant target species were stable; however, there were spatial and temporal fluctuations in species portfolio diversity, due to shifts in abundance of accessory species. Connectivity in species portfolio increased over the period between ports of each island. Overall, these results may be used as an indicator of resilience for climate risk assessment of SSF in the Balearic Islands, and contribute to the identification of adaptative strategies to mitigate risks of biodiversity declines.

(S9-16238 Oral)

Understanding the roles of knowledge and learning in climate resilient fisheries

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Fisheries management decisions often rely on multiple types of knowledge. In data-limited, co-managed, or customary fisheries, stakeholders have historically relied on their lived experience and indigenous local ecological knowledge to make decisions. In data-rich fisheries, in the absence of climate-informed stock assessments, communities and stakeholders increasingly rely on a diversity of knowledge sources of differing veracity to make decisions. Availability of and access to diverse knowledge sources, learning capacity, and adaptive governance (i.e., learning-related attributes) are critical to climate resilience. Yet, we do not fully understand their mechanistic underpinnings and how they are operationalized in practice. This study synthesizes findings from 18 expert-led global case studies to examine i) roles of learning-related attributes, ii) how different fishery systems integrate multiple knowledge sources, and iii) what other attributes complement learning-related attributes in building resilience. We found, in some cases (e.g., California Dungeness crab, Kiribati outer island subsistence), the process of knowledge-sharing and multi-stakeholder participation is designed (e.g., workshops) and goal-oriented (e.g., prioritizing scientific needs). This process can be costly and time-consuming but can arrive at deliberative adaptation. In other systems (e.g., Japanese spiny lobster, Papua New Guinea reef fishery), learning and knowledge-sharing happen as part of customary processes, and interactions are more spontaneous and responsive, which may confer agility, but may be limit the ability to plan long time horizons. By providing concrete examples and lessons and drawing connections, we develop practical understandings of how learning and knowledge sharing support climate resilient fisheries.

(S9-16255 Oral)

Social-ecological feedbacks associated with climate adaptation, and implications for fishing community resilience

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As marine social-ecological systems experience extreme events of increasing frequency and intensity under climate change, efforts to mitigate short-term impacts could unintentionally amplify negative environmental or societal effects. Our research explores how coping, adaptive, and transformative responses to extreme events may amplify or dampen impacts to human well-being and adaptive capacity in U.S. West Coast fisheries. We first present a "status quo" qualitative network model (QNM) that captures key social-ecological dynamics for representative West Coast fishing communities, centered around the commercial Dungeness crab fishery. We then describe a set of existing and potential response strategies, drawing on output from regionally-focused climate change scenario planning workshops, peer-reviewed literature, and expert knowledge. Response strategies represent actions that may be undertaken at the individual to the institutional level, and although they are considered in the context of West Coast commercial fisheries, they reflect broader conversations around climate adaptation and mitigation. We use qualitative network modeling to simulate extreme events, including harmful algal blooms and marine heatwaves, with and without the addition of response strategies. Our results (1) highlight influential system relationships that may affect the impacts of response strategies across different events and communities; and (2) identify important sources of risk to well-being and adaptive capacity in the form of amplifying feedbacks.

(S9-16263 Oral)

The influence of mobility and flexibility on the vulnerability of fishing fleets to climate change: a case study of the groundfish bottom trawl fishery on the US West Coast

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From fishers to farmers, people that rely directly upon natural resources for their livelihoods and well-being face extensive impacts of climate change. While there is widespread appreciation that ecological impacts will intersect with existing socioeconomic conditions to determine vulnerability, for fisheries there remains a limited understanding of how these influences vary geographically and therefore how adaptation pathways may differ for specific communities. We developed a coupled social-ecological approach to assess the risk posed to fishing fleets by climate change and to evaluate their capacity to mitigate that risk through existing adaptive capacity, applying it to a case study of groundfish bottom trawl fishing fleets along the US West Coast. We found that fleets in the southern part of the study region will experience the greatest environmental change within their present-day fishing grounds, but within the northern region fleets more economically-dependent on groundfish are also more exposed to future environmental change. Our analysis suggests some geographic variation in the abilities of fleets to shift their fishing grounds in response to future change, but clear regional differences in flexibility to shift to new fisheries. Through integration of climatic, ecological, and socio-economic data, this case study illustrates the potential for more widespread implementation of vulnerability assessment at scales relevant to fishers, communities, and fisheries managers. Such applications will help to identify where there are the greatest opportunities and needs to mitigate climate risks through adaptation that enhances mobility and flexibility in fisheries.

(S9-16277 Oral)

Distinct patterns in historical mobility and catch flexibility underscore intra-port variation in potential adaptive capacity to climate change

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As oceans warm, marine species are shifting their distributions to stay within preferred temperatures. For coastal fishing communities, these shifts in availability can result in loss of important historical species or gains of species not traditionally harvested. To understand the relative vulnerability and adaptive capacity of fishing communities throughout the Northeast, we used historical fishing patterns to identify mobility of fishing grounds and the extent of flexibility in their catch composition as a metric of potential future adaptive capacity. We find

that gear types had predictable differences in interannual variability in catch composition or fishing grounds. Gear types that were more selective for a small number of species had lower flexibility in catch composition than less selective gear types like bottom trawl. Lobster and small trawl fishing communities were dominated by those that utilized a consistent fishing ground, while many large trawl and dredge communities varied widely in the areas harvested. However, ports within a gear type could demonstrate substantial variation around these averages, suggesting distinct constraints or opportunities for adaptation that vary by port. Likewise, within a port, different gear groups varied substantially in their mobility and catch flexibility. In some cases, nearby ports with similar fleet portfolios were shown to demonstrate categorically different capacities for change, suggesting resilience does not map cleanly to geographic regions. This highlights the potential power for considering distinct fleets within a port that can complement port-level social vulnerability metrics.

(S9-16329 Oral)

Fisher perceptions of a changing ocean: a case study from a small-scale coastal fishery in Japan

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The port of Shimoda in Shizuoka Japan is the centre of the Japanese kinmedai (*Beryx splendens*) fishery. A total of 40 pole-and-line fishers (of 49 commercial fishing boats sailing under the Izu Fishers' Cooperative) sail approximately 13 nautical miles from the Izu Peninsular coast, an area of the ocean through which the Kuroshio Current flows. These fishers contribute to the port's 1,161 metric tons total annual kinmedai catch which, in recent years, has been in decline. While regulations have been introduced to prevent overfishing, it is considered that climate-driven changes in ocean conditions may also be playing a part in the falling catch. This research utilizes participant observation as part of an ethnographic approach to explore the experiences of small-scale coastal fishers sailing from Shimoda, examining their fishing practices and perceptions in response to the changing ocean environment to better understand how the impacts of climate change may be affecting the kinmedai fishery and local livelihoods. Furthermore, this study identifies research priorities to support resource management decision making.

(S9-16396 Oral)

Developing climate-ready indicators of sustained resource access, fishery participation, and economic well-being for U.S. fisheries management and conservation

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Fisheries managers and policymakers worldwide are rapidly developing new management measures to promote fishery sustainability under climate change. Assessing the efficacy of these "climate-ready" policies requires tractable indicators that measure policy-driven changes in fisheries social-ecological systems, while disentangling management effects from the effects of climate and other non-fisheries drivers. While many physical and biological fisheries indicators are well-established, there is much less consensus on how to track performance of management actions for climate-vulnerable human communities. In the U.S., the Magnuson-Stevens Fishery Conservation and Management Act (MSA) is the nation's guiding law for federal fisheries management. MSA requires that fisheries conservation and management actions use social and economic data to: take into account the importance of fishery resources to fishing communities; provide for the sustained participation of those communities in fisheries; and, to the extent practicable minimize the adverse economic impacts of fisheries management on those communities. To develop climate-ready social and economic indicators for policymakers, we present here: (1) a range of focal attributes of fishery resource access; (2) indicators for each attribute that enable accounting for the role of climate; and (3) case studies with quantitative indicator analysis, supplemented by qualitative information to better link outcomes to causes. While we work within the framework of U.S. laws, our aim is to develop and test indicators that could be useful in a variety of social-ecological systems with priorities for mitigating or adapting to the effects of climate on marine ecosystems.

(S9-16428 Oral)

**Climate change adaptation of the German small-scale fisheries.
Mapping and assessing the governance system using a transdisciplinary approach.**

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Unsustainable exploitation of fish stocks is one of the greatest anthropogenic impacts on oceans and coastal waters worldwide with consequences for the health of marine ecosystems, but also for the livelihoods of fishers and local fishing communities. The reason is often a non-transparent and top-down fisheries governance and management system.

Using the example of the German small-scale fisheries, we here conducted a comprehensive governance mapping exercise and conducted semi-structured interviews with stakeholders from small-scale fisheries, eNGOs, management and science. This was followed by a detailed literature review. Eventually, we created a total of 6 governance maps representing the multitude of actors at the different governance levels as well as its various linkages. Based on the results of the governance mapping, a participatory workshop was conducted to assess the adaptive capacity of the SSF to climate change with relevant stakeholders.

Our results clearly demonstrate the multi-level complexity of the EU fisheries governance system. We argue that this complexity poses risks to the sustainable development of the German SSF, particular in light of climate change, the current poor stock status of cod and herring and thus, the constant reduction of fishing opportunities and the decline of fishers. As the majority of roads in the EU fisheries governance system lead to Brussels the paths to implement adaptation processes to current risks are often indirect, very long, and pass through several governance levels. These structural constraints are slowing down and hindering a timely and urgent adaptation to current changes of the German SSF.

POSTER BOARD ID: S9-P1
(S9-15910 Poster)

Assessing the risk of climate change to aquaculture in Oman

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Aquaculture is crucial for world food security, yet climate change causes substantial risks. These may impact through many mechanisms varying by location and culture type with implications for future productivity. Understanding the risks that climate change poses on different culture systems in different locations is important to enable the design of targeted adaptation actions. We provide a framework for assessing climate change risks to aquaculture, applied to the aquaculture sector of the Sultanate of Oman, that identifies the sensitivity and exposure of different culture systems to climate change risk. Oman aspires to significantly expand aquaculture but is also situated in one of the hottest regions on earth. The focus is on coastal shrimp ponds, finfish sea cages, land-based recirculating aquaculture systems, and ponds and raceways. We quantify overall climate risk as the combination of four risks: (1) species' temperature sensitivity, (2) flooding and storm surge exposure, (3) low-oxygen hazard and (4) disease vulnerability. Shrimp culture is identified as highest risk due to high exposure of shrimp ponds to flooding and storm surges, and high disease vulnerability. Seabream cage farming also faces high risk due to high thermal sensitivity and high potential of low-oxygen levels affecting sea cages. Following the risk assessment, a stakeholder workshop was conducted to identify targeted adaptation measures for each culture type. The framework for assessing climate risk to aquaculture demonstrated here is equally applicable elsewhere in the world at regional, national or sub-national scales, to support design of targeted resilience building actions and enhance food security.

POSTER BOARD ID: S9-P2
(S9-15940 Poster)

Risks of climate change to seafood sustainability through the lens of the MSC ecolabelling program

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Climate change-driven impacts on marine ecosystems are exacerbating current challenges and creating new obstacles to the sustainable management of the world's fisheries, with consequences for the environment and the socioeconomic activities associated with seafood harvest.

To improve fisheries sustainability, ecolabeling programs have been proposed to provide market-based incentives to drive positive change in fisheries' operations and, ultimately, their management. They do so by providing market recognition to fisheries that meet sustainability requirements set by a standard. However, as climate change threatens the effectiveness of existing governance systems, and creates new scientific advice and monitoring needs, eco-certification and rating standards rely on best practice to evolve at the pace of such changes, so that they can recognise and reward these advancements.

Here we describe a global, spatially explicit, risk assessment launched by the Marine Stewardship Council (MSC), an internationally-renowned seafood ecolabeling and supply chain assurance program, to evaluate threats to fisheries being able to meet MSC sustainability requirements in the near future, under different climate scenarios. This approach is also intended to identify aspect of fisheries assessment, monitoring and management where eco-certification is well-placed to incentivise the adoption of practices leading to resilient and climate-smart fisheries.
Through the lens of the MSC Fisheries Standard performance indicators for stocks, ecosystems and governance, we present a reproducible, global scale evaluation approach to how key climate-resilient management traits can be studied in different parts of the world, considering their implications for sustainable seafood value chains.

POSTER BOARD ID: S9-P3
(S9-15970 Poster)

Does crab farming offer viability to climate change vulnerability in coastal Bangladesh?

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Long-term climate change impacts in the southwest coastal zone of Bangladesh caused drastic changes in the agroecological system. Salt-tolerating shrimp and prawn farming mostly replaced the traditional crop agricultural system. However, encroaching salt water, recurrent cyclones, rising water temperature, and rainfall variability are causing the unsuitability of the agroecological environment, even for shrimp and prawn farming. Consequently, many farmers in the coastal zone are switching to crab farming as the species is more adaptive to drastic climate change impacts. Does this transformation in the aquatic food culture system indicate a threshold level of the local agroecological system or offer long-term human adaptation to changing coastal ocean systems? The findings of this study suggest that local transformation in the aquaculture system provides a buffer against environmental risks posed by climate change impacts. Finally, this study calls for capacity building of small-holder farmers through enhancing socio-economic capital, disseminating better farming technology, and facilitating better market access through institutional support for long-term viability to the vulnerability of climate change in coastal Bangladesh.

POSTER BOARD ID: S9-P4
(S9-16000 Poster)

Developing usable science to help managers advance climate-ready fisheries

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As oceans warm, many marine species are moving to new locations at different life stages in search of their preferred habitats. The challenges these climate-driven changes pose for managers, stakeholders, and scientists are cross-cutting, cross-disciplinary, and often contentious. The ability to move beyond this complexity to manage fisheries as species shift their distribution will require information that is tailored to the decision-making context and developed with the input of fisheries managers, stakeholders, and other community leaders.

Recognizing the need for usable scientific research in this arena, the Lenfest Ocean Program (LOP) has been funding research projects on the impacts of shifting marine species since 2016. In 2019, the Program held an Ideas Lab that brought together an interdisciplinary group of fisheries managers, scientists, and stakeholders from the U.S. East and West Coasts all with different perspectives on the issue to foster open and creative thinking to co-develop research ideas. The goal was to germinate new projects that if supported, could help managers meaningfully advance on addressing this challenge. The Ideas lab participants generated multiple ideas that received Program support ranging from understanding changing ecosystems and what that means for target species, assessing the vulnerability of fishing communities, applying climate data and information to managed species, and evaluating different management and policy options to foster adaptation. In this presentation we will (1) share the Lenfest approach to supporting usable science, including how we co-design research and foster strategic outreach throughout projects; (2) provide insight on how current projects are helping managers overcome hurdles, and engage stakeholders in discussing new and creative solutions; and (3) discuss our latest effort to draw out themes, ideas, and lessons from across our climate change and oceans funding portfolio to inform the larger challenge of adapting fisheries to the many impacts of climate change.

POSTER BOARD ID: S9-P5
(S9-16037 Poster)

Examining social resilience in the American lobster fishery

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Climate change is increasingly impacting fisheries along the Northeast US coast. The American lobster fishery, which forms an integral part of the cultural fabric of many coastal communities in the region, is vulnerable to further warming. Since the late 1990s, landings in the Gulf of Maine have continued to climb while those in Southern New England (SNE) have declined due to a multitude of factors, including disease and warming waters. These parallel experiences raise two key questions: 1) how have people in SNE responded to declines in the lobster resource to the south, and 2) what lessons can be learned for lobster communities to bolster their resilience to potential future climate impacts and declines?

Using a combination of news article analysis and semi-structured interviews, we identify resilience pathways lobstermen have undertaken, determine factors influencing their resilience, and examine potential strategies for supporting social resilience in the fishery. Resilience pathways formed 'cope', 'adapt' and 'transform' typologies, although these were often overlapping across the lobstermen's life course. A range of broad overarching factors were identified that influenced these resilience pathways including access to assets; occupational, financial and institutional flexibility; emotional entanglements; family support and pressure; and agency and collective action. Strategies for supporting resilience will require actions from a broader diversity of stakeholders than conventional sector-based management currently engages. Further, such strategies should consider multi-scale influences that extend beyond the traditional ecologically-centric boundaries of fisheries management, including bringing together land-sea connections and bridging current mis-matches between coastal and fishery management and policy.

POSTER BOARD ID: S9-P6

(S9-16233 Poster)

Approaches to 'fishing community' in the context of groundfish and climate-generated shifts in the California Current

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This work explores the ways in which fishing communities are defined, using a particular fishery and a set of climate-generated shifts to advance rubrics for fishing communities in the context of integrated social-ecological research. Our results point to limitations of singularly land-based and place-designated approaches to fishing communities within the milieu of both broad and specific changes wrought by climate shifts. Given the cultural, commercial and recreational salience of the approximately 90 species federally managed as 'groundfish' along the U.S. West Coast, we introduce an overlapping conceptual approach to defining and identifying those communities that might be reasonably described as 'groundfish communities.' In particular, we explore how a range of approaches to 'community' on the West Coast differ in their implications for adaptive capacity and vulnerability to potential climate impacts, including the spatial shifts of socially and economically important marine species managed within the broad 'groundfish' category. In introducing our approaches to defining groundfish communities, we further operationalize these definitions of community with data specific to the groundfish fishery, highlighting how differing approaches might be more or less appropriate given various climate impact scenarios. We engage in this effort with an eye toward informing and integrating with attendant climate-oriented groundfish species distribution and management modeling efforts.

POSTER BOARD ID: S9-P7
(S9-16245 Poster)

A pathway to transition from vulnerable to resilient Fisheries Social Ecological Systems: a transdisciplinary case study of the US Atlantic sea scallop fishery

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Social ecological systems (SES) built around fishing stocks with potential for sustainable catch are key to achieving multiple U.N. Sustainable Development Goals. Atlantic sea scallops (sea scallops) have demonstrated the potential for sustainable yield, but are increasingly threatened by effects of ocean warming and acidification. As calcifiers with limited mobility and high revenue potential, this fishery is particularly suited to a transdisciplinary approach combining coastal fishing community assessments with sea scallop population dynamics, ocean models, and sea scallop physiological response. The vulnerability and resilience of fishing communities to the effects of warming and ocean acidification (OA) on target species such as sea scallops is dependent on their adaptive capacity in relation to both social and environmental exposure and sensitivity factors. In the Northeast United States, the regional contribution of sea scallops to total regional landed value has steadily increased over recent decades to more than $500 million per year. As a result, the dependence of the regional fisheries SES has shifted to this species. This dependence, and the ecosystem-wide changes predicted for sea scallop decline, make this study particularly relevant. Here, we provide spatially explicit regional projections of changes within the sea scallop fishery based on ocean models and physiological assessment. These projections have been combined with social indicators of fishing community vulnerability and reliance to structure workshops with fishery managers and fishing-dependent communities. The workshops assist stakeholders to explore scenarios to become more resilient to future change. Challenges, lessons learned, and next steps toward achieving a transdisciplinary understanding of SES vulnerability in this fishery are explored.

POSTER BOARD ID: S9-P8
(S9-16362 Poster)

Turning the focus to the potentials of blue food in island developing countries: Insights from the Pacific and Caribbean.

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Food Systems have been central of attention recently highlighting the importance of transforming them to cope with social and environmental challenges such as global warming and unsustainable use of resources. In 2021, countries around the world carried dialogues at local, national, and international level to design the best solutions to set the path for achieving Agenda 2030 through food systems. Nearly 300 commitments were drawn by different countries around the world, Pacific and Caribbean member countries, 12 and 4 respectively, submitted guidelines to transform their national food systems towards more sustainable, inclusive, and resilient. This review gives a close look to the opportunities underlined for transforming food security in island countries, highlighting the priorities to action and investment to increase food resilience facing

climate change. Many of the submitted pathways acknowledged challenges such as limited land and water resources, low productivity and limited competitiveness, low labor force, expensive imported unqualified food supply, rising sea level and temperature, within others. Countries in the Pacific and Caribbean Basins included Blue Foods in an important set of game-changers solutions to transform their food systems, such as IES schemes between near-shore /coastal and off-shore fisheries. Thus, it is imperative that governments bring blue food systems into their food-related decision-making.

POSTER BOARD ID: S9-P9 **REVISION:** Poster moved to S-9 Oral presentation.
(S9-16435 Poster)

Linking fishery ecosystem models with indicators of coastal community well-being in the Northeast US

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End-to-end fishery ecosystem models can integrate environmental drivers, ecological dynamics, and the geographically varying consequences of human uses, forming an important part of the toolbox for evaluating the holistic consequences of policy alternatives for marine ecosystem-based management. However, regional-scale performance indicators can mask variable place-based outcomes for individual fishing sectors and coastal communities. Here we link the output of fishing and climate change scenario simulations from the Northeast US Atlantis Ecosystem Model (Atlantis NEUS) to a set of social indicators for coastal communities to more closely evaluate likely effects of change. The social indicators, developed by NOAA Fisheries, characterize well-being for coastal communities engaged in fishing activities in the Northeast and Mid-Atlantic US, and include metrics describing environmental justice impacts. By mapping the output of Atlantis NEUS to the finer spatial resolution of coastal communities we track how expected changes in fishery production over time interacts with the social and economic realities and constraints of individual fishing communities. Results demonstrate the disparate impacts of fishing management and climate for Northeast and Mid-Atlantic US coastal communities, and point towards construction of more holistic societal indicators of fishery performance, to help understand how management actions may increase robustness of outcomes or lead to improved resilience to change for individual human communities. Our results also suggest a need to consider a broad range of fishery management scenarios when developing alternatives for ecosystem-based fisheries management to fully explore the range of decision space that can satisfy (or not) management goals.

S10: Beyond species on the move: emerging climate change impacts on the spatial dynamics of marine species, from detecting to forecasting and projecting

Convenors:
Manuel Hidalgo (Corresponding), (Spanish Institute of Oceanography, IEO, CSIC, Spain)
Rebecca G. Asch, (East Carolina University, USA)
Lorenzo Ciannelli, (Oregon State University, USA and Stazione Zoologica di Napoli Anton Dohrn, Italy)
Shin-ichi Ito, (University of Tokyo, Japan)
Lauren Rogers, (NOAA, USA)

Plenary Speaker:
Barbara Muhling, (NOAA and University of California Santa Cruz, USA)

Invited Speaker:
Lisa Kerr, (Gulf of Maine Research Institute, GMRI, USA)

Many marine fish are shifting their horizontal and vertical distributions because of changing ocean conditions, with consequences for species interactions, assessments, management, and coastal economies. Mechanistic and statistical approaches developed to quantify distribution shifts still have unresolved challenges, which are both operational (model resolution, bias-correction, model parameterization and validation) and conceptual (ontogenetic constraints, non-stationarity, adaptive responses, depth gradients). In addition, further impacted spatial properties of marine species go beyond distribution shifts, including the population structure, early life dispersal, spatially-dependent critical processes, collective behavior, and spatial co-occurrence and interactions of species. We invite contributions that present advances in forecasting and projecting spatio-temporal dynamics of marine species, as well as advances in understanding climate change impacts on less investigated spatial properties.

(S10-16034 Plenary)

Species distribution modeling for pelagic fishes in the California Current System: Ecological insights, challenges, and future directions

Barbara **Muhling**[1,2], James Smith[1,2], Toby Auth[3], Barbara Block[4], Richard Brodeur[5], Stephanie Brodie[1,6], Heidi Dewar[2], Jerome Fiechter[7], Carlos Gaitan[8], Elliott Hazen[6], Michael Jacox[1,6,9], Jong-Yeon Park[10], Mercedes Pozo Buil[1,6], Charles Stock[11], Desiree Tommasi[1,2] and Rebecca Whitlock[12]

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Climate change is driving shifts in the spatial distributions of marine species, leading to novel trophic interactions, losses and gains in fishing opportunities, and challenges for fisheries management. Statistical models of species distributions are widely used to explain past

distribution shifts, and forecast potential future responses of mobile marine species. However, these models can have limitations in terms of how they represent important ecological processes, and how they respond when applied to environmental conditions beyond the range of historical training data. In this presentation, we use the exceptionally well-observed California Current Large Marine Ecosystem as a test case. We show how statistical distribution models have been used to predict the spatial distributions of pelagic fishes such as Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and North Pacific albacore (*Thunnus alalunga*), and how these models have been used within end-to-end modeling frameworks. We then examine key points of uncertainty and potential failure within statistical distribution models, highlighting choices made within model development that can strongly influence their predictions when applied to future climate projections. Lastly, we use some recent examples of mechanistic models developed for similar species to suggest how the robustness of statistical projection frameworks could be improved in the future.

(S10-16278 Invited)

Accounting for climate change impacts on the spatial dynamics of marine species in fisheries management

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Climate change is impacting the productivity of fish populations and resulting in species moving out of traditional management zones into new areas, and these distribution shifts are expected to increase in the future. A key assumption in stock assessment is that the indices of abundance are proportional to population abundance and that catchability is stationary over time. Persistent directional changes in temperature associated with climate change can impact catchability and confound our interpretation of indices and our understanding of stock status. For example, ocean warming can influence spatial distribution (e.g., shifting species northward or deeper) and density within survey areas. Interpretation of apparent shifts in distribution is more challenging for species with multiple populations which may exhibit differential responses to warming and shifts in the relative abundance of populations along a spatial gradient. Changes in species distribution can be accounted for outside of stock assessments via standardization methods that explicitly incorporate the influence of temperature or depth on spatial-temporal variation in catch rates or within the stock assessment through the integration of environmental covariates to modulate catchability. We will describe the exploration, evaluation, and challenges of these approaches for three species:1) the demersal American plaice (one population), which have shifted deeper in response to warming water temperatures, 2) the highly migratory Atlantic bluefin tuna (two populations), which have shifted northward in distribution, and 3) Atlantic cod (five populations) which has demonstrated spatial shifts. These case studies illustrate how spatial shifts can be accounted for in stock assessment and fishery management.

(S10-15842 Oral)

Assessing the effects of climate change on pelagic fish distribution and abundance in the South-West Atlantic fishery of Sierra Leone

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Coastal Sierra Leone is among the West African countries with high vulnerability to climate change. Recent increases and shifts in climatic regime are negatively impacting important fishery resources in the country. An analysis of temperature distribution and fish abundance, using hydrographic and acoustic surveys reveals direct relationships between temperature increases and reductions in pelagic fish abundances. The spatial distribution of pelagic fish resources of the clupeids and the carangids in Sierra Leone continental shelf suggests marked decreases in fish abundances as surface temperatures increases. Consistent fluctuations of sea surface temperature and variations in fish abundance were pronounced in the southern shelf around Sherbro Island of the Southern Coast of Sierra Leone. The study further shows that within the shallow zone of a major fishing ground of Banana Island, a warm mixed water mass of temperatures around 31°C occupied up to 10m from the surface. This caused convectional forcing and mixing in carangid fish communities. The presence of a 25°C isotherm at deeper layers of 20m coincided with nearshore and offshore salinity increases and decreasing pelagic fish abundance. These temperature variations are critical for the sustainability of the shared Sardinella and Horse Mackerel fish stocks in the West African region. These fish stocks are already fully exploited in Sierra Leone waters and are listed on the IUCN red list of threatened species. This study confirms that wind induced mixing creates isothermal temperatures and sea surface warmings, which accounts for alterations in fish aggregations and abundance in the Southwest Atlantic waters of Sierra Leone.

(S10-15847 Oral)

Implications of climate overshoot for marine biodiversity

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The growing global impetus toward achieving net-zero carbon emissions by 2050 aligns with the overall aim of the Paris Agreement by restricting end-of-century warming to 2°C, relative to the pre-industrial. Yet governments continue to defer implementation of climate action into the future in the hope that technological advances will ease financial and political costs. Emissions pathways associated with delayed action involve ongoing emissions for the next decades, before steep emission cuts after 2040. Such pathways increase the risk of "overshoot" beyond the 2°C target, even though temperature levels drop back below this target before 2100. "Overshoot"

periods lasting a decade or more could be particularly detrimental to marine systems because they absorb and release heat more slowly than the atmosphere does. Here, we use CMIP6 model projections to explore potential implications for marine biodiversity of an overshoot pathway, relative to more conventional pathways that result in 1.5°C, 2°C, 2.7°C and 4.5°C by 2100, without overshoot. Under each emission scenario, we use climate-velocity tracers to quantify potential range shifts for mobile species, and metrics of marine heatwaves to quantify potential risks for sessile species. Results indicate that we cannot infer impacts of overshoot scenarios by intuitive interpolation between the more conventional scenarios employed by the IPCC. Since overshoot is becoming an increasingly likely consequence of delayed global climate action, a greater range of overshoot scenarios will need to be considered by the modelling community and taken up by the ecological community ahead of the next round of IPCC assessments.

(S10-15877 Oral)

Response of snow crab to ocean warming on the Grand Banks, Newfoundland, Canada

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The Grand Banks of Newfoundland are one of the most important fishing grounds in the world. The collapse of northern cod and the associated fishing moratorium in the 1990s resulted in a shift to an ecosystem structure dominated by crustaceans. Currently, snow crab is the most valued species in the region, with high importance for fishing communities. This cold water species is likely to be affected by the impact of climate change. To understand how snow crab will respond to ocean warming, we used a Bayesian species distribution model to evaluate spatial and temporal changes in snow crab biomass and distribution using 22 years of bottom trawl biomass data, bathymetry, and bottom temperature. Our findings indicate that the primary snow crab biomass hotspot is in the northeastern part of the Grand Banks, where its distribution has been persistent through time. We used simulations to project how snow crab will respond to increases in bottom temperature to understand future responses to climate change. This analysis provides fine-scale resolution of the snow crab distributional patterns on the Grand Banks and how they are expected to change in the future. Because the Grand Banks are home to a variety of economic activities (such as fishing, and oil and gas drilling), knowledge of the spatio-temporal distribution of species can be used to inform spatial management.

(S10-15887 Oral)

Application of Bayesian additive regression trees (BART) to global-scale species distribution models (SDMs)

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Marine Ecosystem Models (MEMs) have been developed to analyse the past and future dynamics of the oceans to better understand how marine ecosystems and derived ecosystem services are likely to change. One of such efforts is EcoOcean, a complex, mechanistic and spatiotemporal explicit MEM of the global oceans based on a trophodynamic core. To predict species distributions, EcoOcean requires as inputs the species native ranges, and for key environmental variables, species' functional responses and time-varying maps delivered by Earth System Models (ESMs). The different sources of uncertainty in these inputs may influence the validity and precision of EcoOcean results. In this study, we explore the use of global Species Distribution Models (SDMs) to optimize these inputs. SDMs have been widely applied in ecology to predict or analyse the distribution of target species. Bayesian additive regression trees (BART) are a promising new alternative to traditional SDM classification tree methods. Our goal is to assess the usability of the SDM-BART on a global scale, and to improve the estimation and prediction of some inputs used to inform EcoOcean. We apply SDM-BART to a functional group of sea turtles as well as the commercially important Atlantic cod (*Gadus Morhua*). We used global time series of varying environmental conditions from ESMs GFDL-ESM4 and IPSL-CM6A-LR, as independent environmental variables to predict native ranges, predict present and future habitat suitability, and functional responses of species to environmental variables on a global scale.

(S10-15900 Oral)

Poleward range shifts coincide with population decline in marine fish

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Climate change drives species range shifts and changes in population dynamics. On the one hand, a considerable number of marine species display poleward range shifts. On the other hand, climate-related abundance changes are pervasive, with leading-edge populations (poleward facing edge of distribution) tending to increase and trailing-edge populations (equator facing edge of distribution) tending to decline. However, it remains unclear how species abundances are changing with respect to their range shift velocities (i.e. slow shifters versus fast shifters). Elucidating the relationship between range shifts and abundance change may aid in predicting how species respond to further warming. We used species-specific estimates of changes in abundance from time series extracted from BioTime and relate

these to range shift velocities estimated from BioShifts. Our analyses relied on data for 146 marine fish species comprising 2,572 unique abundance time series across the Atlantic, Pacific, and Indian oceans. We show that population trends are negatively related to range shift velocities, meaning that species rapidly migrating poleward exhibited the strongest decline in local abundance. This pattern was mainly driven by leading-edge populations, while trailing-edge populations generally increased in abundance. These findings challenge the current paradigm in climate change biology, which posits that trailing-edge populations are more prone to extirpation and population decline whereas leading-edge populations experience population growth. Our results suggest that for leading-edge populations, poleward shifts may not compensate for the potential adverse warming conditions, emphasizing that leading-edge populations may become increasingly threatened by climate change.

(S10-15918 Oral)

Model complexity has contrasting benefits for hindcasting and forecasting species responses to climate change

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Identifying and predicting species responses to climate change is a high priority in ecology. Species distribution models (SDMs) are commonly used to quantify environmental drivers of distributions and densities; however, we lack information about how well these models predict fine-scale population metrics under novel conditions. We compared the performance of a suite of SDMs when hindcasting species-habitat associations and forecasting responses to changing climates. We present two case studies from the Bering Sea, a system that has recently undergone considerable warming. Conventional statistics (R^2, % Deviance Explained, UBRE or GCV) were used to assess the performance of in-sample predictions (*i.e.,* hindcasts) for Arrowtooth Flounder (*Atheresthes stomias*) and Walleye Pollock (*Gadus chalcogrammus*). Retrospective skill testing was used to compare out-of-sample predictions (*i.e.,* forecasts) with observed distributions or densities. The most complex models, which accounted for spatial, temporal, and spatiotemporal variation in addition to static and dynamic habitat covariates, outperformed all other models when hindcasting population metrics. Static models that relied on long-term mean environmental conditions, however, exhibited greater forecast skill. Decreased forecast skill for dynamic models likely resulted from predicting species responses to temperatures outside the range of those used in model fitting. Thus, dynamic SDMs better reflect the amount of spatiotemporal variation in natural systems, but static SDMs may prove more skillful when forecasting responses to novel environmental conditions. We also found that model performance and forecast skill were dependent upon the species and population metric of interest, suggesting a negative relationship with niche breadth. Expanding environment-only SDMs to include spatiotemporal variation in fishing pressure, trophic interactions, and other important context-specific drivers would likely improve forecast skill. Nonetheless, our results demonstrate support for the use of retrospective skill testing in model selection rather than identifying forecast models *a priori* based on their ability to quantify species-habitat associations from the past.

(S10-15932 Oral)

Recommendations for quantifying and reducing uncertainty in climate projections of species distributions

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Projecting the future distributions of commercially and ecologically important species helps stakeholders strategically anticipate change, but uncertainties in projections limit climate adaptation planning. Understanding when models can perform well and what factors impact SDM performance under novel conditions is increasingly important. Here, we use a series of simulated species distributions, an ensemble of 252 species distribution models, and an ensemble of three regional ocean climate projections, to isolate the influences of uncertainty from earth system model spread and from ecological modeling. The simulations encompass marine species with different functional traits and ecological preferences to more broadly address resource manager and fishery stakeholder needs and provide a simulated true state with which to evaluate projections. We found uncertainty associated with species distribution models can exceed uncertainty generated from diverging earth system models (up to 70% of total uncertainty by 2100), and that this result was consistent across species traits. We further examine biases and uncertainty that arises from simulated fishery-dependent data. Such data are critical to management, but concerns persist that fishing locations are not independent of the underlying species abundance, potentially biasing predictions of species distributions. Species distribution model uncertainty increased through time and was primarily related to the degree to which models extrapolated into novel environmental conditions but moderated by how well models captured the underlying dynamics driving species distributions. By understanding sources of uncertainty including across data types, and how they change at different forecast horizons, we provide recommendations for projecting species distribution models into the future.

(S10-15964 Oral)

Hotspots of Cenozoic tropical marine biodiversity

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Hotspots of tropical marine biodiversity are places that harbour disproportionately large numbers of species or species richness compared to the rest of the tropics. Richness and location of these hotspots have changed throughout the Cenozoic era. Here we review the global dynamics of Cenozoic tropical marine biodiversity hotspots, including the four major hotspots of the Indo-Australian Archipelago (IAA), western Tethys (present Mediterranean), Arabian Sea and Caribbean Sea. Our review supports the 'Hopping Hotspots' model, which proposes that locations of peak biodiversity are related to Tethyan faunal elements and track broad-scale shallow-marine habitats and high coastal complexity created by the collision of tectonic plates. A null hypothesis is the 'Whack-A-Mole' model, which proposes that hotspots occur in habitats suitable for high diversity regardless of taxonomic identity or faunal elements. Earlier 'Centre-of' theories (e.g. centres of origin with diversity decreasing with distance from supposed areas of exceptionally high rates of speciation, for which easy connection to adjacent regions to the east and west is important) were based on the analysis of recent biotas with no palaeontological foundation and may better explain diversity dynamics within a hotspot rather than those between hotspots. More recently, however, human disturbance is massively disrupting these natural patterns.

(S10-15968 Oral)

Global changes in species richness and community composition of ecosystem-structuring marine species under projected climate change

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Future climate change poses a major threat to global marine biodiversity. For species that structure essential habitats, climate change effects can be magnified into losses of ecosystem functioning, with direct consequences for the numerous ecological and economical services provided. Projections of direction and intensity of net changes in biodiversity patterns of ecosystem structuring marine species are lacking, precluding well-informed management strategies. Here, we use machine learning in species distribution modelling to forecast global changes in richness and community composition (i.e., persistence, extinction, and turnover) of approx. 1500 species of macroalgae, seagrasses and cold-water corals, under contrasting Shared Socioeconomic Pathway (SSP; decade 2090-2100) scenarios: one aligned with the Paris Agreement (SSP1-1.9) and another of substantially higher emissions (SSP5-8.5). Models anticipate a generalized trend of poleward and depth-related shifts at the species level, particularly pronounced under SSP5-8.5, which translated into significant net changes in global patterns of biodiversity. The largest changes in community composition were projected for the Arctic due to poleward expansions, and for the temperate regions of the North Atlantic and Northwest Pacific, the Mediterranean Sea and along Australian and New Zealand coastlines, due to equatorial range losses as habitats become unsuitable. We show that climate change may strongly restructure the distribution of marine biodiversity, with potential negative consequences for the productivity and functioning of temperate environments, particularly if climate forcing surpasses the Paris Agreement expectations. The projected patterns pinpoint key refugial areas for marine conservation, which serve as baselines for well-informed management strategies in the face of climate change.

(S10-15984 Oral)

Potential changes of finfish thermal habitat under negative emissions

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The Paris Agreement has set out the aim to limit global warming to 1.5°C to reduce the risks of climate change. Yet, global carbon emissions continuously increase, such that the option of "negative emissions" – removing CO_2 from the atmosphere and storing it on land, underground or in the oceans - is discussed to delay the transition to a zero-carbon society. Among the options discussed are pathways where the 1.5°C temperature goal is temporarily overshot, while negative emissions are subsequently applied to return to a "safe" climate state.

However, such overshoot strategies might have adverse effects. A previous study showed that a delayed removal of CO_2 does not simply lead to a warming while CO_2 is increasing, a cooling while CO_2 is decreasing and a subsequent steady atmospheric temperature but to a trajectory of warming-cooling-warming. As this response is related to the model´s sensitivity of the Atlantic large-scale ocean circulation, the amplitude of the warming-cooling-warming is most pronounced in the North Atlantic. Here, we extend this study to analyse the impact of the warming-cooling-warming trajectory on Finfish species that are commonly used for Aquaculture, that is Atlantic salmon, gilthead seabream and cobia. Via thermal windows of potential growth ranging from optimal to lethal conditions, we identify temporal fluctuations in the extent of optimal habitats. We anticipate that a more pronounced warming-cooling-warming amplitude exacerbates challenges for the considered species, such that northern habitats are threatened more than southern habitats. We analyse this potential north-south divide in terms of economic and ecological consequences.

(S10-15985 Oral)

Joint modeling in marine systems: three case studies from the Northwest Atlantic.

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Understanding the distribution and abundance of marine organisms is a fundamental question in ecology and essential for effective management of marine species. Single species models are typically used to understand and predict the distribution and abundance of marine species by fitting models for each species independently to a combination of abiotic environmental variables. However, species abundances and distributions are influenced by abiotic environmental preferences as well as biotic interactions such as interspecific competition and predation. Joint species distribution models can help to better inform the inter-specific interactions that shape a species' distribution. By modeling species jointly, we can account for the influence of one species on the occurrence of another, in addition to environmental responses, thus allowing managers to more accurately model current species distributions and evaluate the effects of future environmental change on a more community-oriented level. We apply a hierarchical Bayesian joint model, GJAM, to three case-studies and show that incorporating species dependencies improves predictions and captures more biological reality than single species approaches. Spatial predictions improve for Atlantic cod when utilizing the residual correlation of other functionally similar species such as Haddock in addition to the environment. Bottlenose dolphin density estimates reveal a tight coupling between this top predator and drumming prey, which is essential for predicting dolphin responses to ocean change. Finally, modeling fishing boats as a species using global fishing watch data in a joint modeling framework reveals potential shifts in fishing effort that are dependent on environmental change and the species that are targeted.

(S10-15986 Oral)

Coral reef diversity forecasts for warmer, more acidic seas

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Coral reef ecosystems are expected to undergo significant changes over the coming decades as seas become warmer and more acidic. We investigate the environmental tolerances of nearly 700 Scleractinian coral species based on the conditions found within their present-day ranges and in areas where they are currently absent but could potentially reach as larvae via oceanic currents. These "environmental envelopes" and larval connectivity constraints are then used to develop global forecasts for potential coral species richness under two emission scenarios, representing the Paris Agreement target ("SSP1-2.6") and high levels of emissions ("SSP5-8.5"). The projected changes to environmental suitability suggest significant future declines in coral species richness for the majority of the world's coral reefs, with a net loss in average local richness of 73% (Paris Agreement) to 92% (High Emissions) by 2080-2090 and particularly large declines across sites in the Great Barrier Reef, Coral Sea and Western Indian Ocean. However, at the regional scale we find that environmental suitability for a majority of coral species can be largely maintained under the Paris Agreement target, with 0-30% potential net species lost in most regions (increasing to 50% for the Great Barrier Reef) as opposed to 45-90% losses under High Emissions. Our analyses also indicate that such losses in species richness would have significant implications for the functional diversity of the future coral reef ecosystems, both globally and regionally. This highlights the critical importance of mitigating climate change to avoid potentially massive losses of coral species and the functions they provide.

(S10-15987 Oral)

Changes to the odontocete community and implications for predator-prey distributions in the rapidly warming waters of the Northeast US

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Cetaceans are important consumers in marine ecosystems and climate-driven changes to cetacean distributions relative to their prey have important implications for predator-prey dynamics and food web structure. However, distributional changes are difficult to quantify in cetaceans due to limited survey effort and low at-sea sightings rates, and few studies have conclusively demonstrated climate impacts. Stranding events can provide important data for assessing changes to cetacean distribution and species composition. We examined changes to the distribution and relative abundance of odontocete species using strandings data from 1996-2020 in the Northeast US, where rapid, directional warming is occurring. We conducted simulations to determine the number of stranding events needed to detect a distributional shift. Further, we compared distributional shifts of odontocetes to that of their prey species, assessed using data from bottom trawl surveys. We observed poleward shifts in all odontocete species with sufficient data and found that shifts were faster than that of prey species. The relative abundance of warm water species in the stranding record increased significantly with sea surface temperature, while that of cool water species declined significantly. The center of distribution of trailing edge species approached the northern US border and the relative abundance of these species declined through time, suggesting a shift north out of US waters. Our findings suggest marked changes to the distribution of highly mobile consumers in marine systems under continued warming. Observed differences in the climate responses of odontocetes and their prey could decouple predator-prey relationships and alter food webs in marine ecosystems.

(S10-16024 Oral)

Potential shifts in the distribution of herbivorous Atlantic reef fishes in face of climate change

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Reef fishes are essential for coral reefs functioning and a key indicator of ecosystem health. Herbivorous fishes control the overgrowth of macroalgae that could, in turn, reduce coral growth, leading to phase-shifts to less diverse states. Yet, there is still a gap in the understanding of potential impacts of climate change on the distribution of key species of Atlantic reef fishes. Here we employed an integrated species distribution model under a point-process framework, which enable the use of multiple data types (presence-only and presence-absence), to forecast long-term (2100) shifts in the distribution of three herbivorous reef fishes (*Acanthurus chirurgus*, *Scarus zelindae* and *Sparisoma amplum*) according to CMIP6 climate scenarios. Models were run using a Bayesian approach through INLA (Integrated Nested Laplace Approximation). *Acanthurus chirurgus*, a widely distributed species, will in general maintain its current distribution. For *S. zelindae* and *S. amplum*, species endemic to Brazilian reefs, there are distinct projections. *Scarus zelindae* shows a clear pattern of range expansion, both poleward and equatorward. Differently, *S. amplum* is predicted to have a relatively stable distribution. For this species, there is a small increase in suitability in the southern portion of

its distribution. These results show that key species may exhibit distinct responses to climate change and that ecosystem functioning may be altered in future conditions, which calls for active monitoring and management.

(S10-16038 Oral)

The influence of ontogeny and size on the distribution of pelagic young-of-the-year fishes

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Marine fishes undergo rapid changes in body size and habitat use during their early life stages. Fish species exhibit diverse life histories that may impact the way they respond to climate change and how we, in turn, model their distributions. Many species demonstrate variability in how restricted they are to spawning in specific locations or to what time of year they can spawn. Two life-history strategies are often evident: (1) species that exhibit punctuated spawning phenology and geography, fast growth, and long, often offshore, pelagic duration, and (2) species that have protracted spawning phenology, reproduce in coastal areas, and have slower growth. When modeling species distributions, size-specific models can be more accurate than unstructured or size-aggregated models, but are also more demanding of data for parameter estimation. In this work we aim to determine what modeling approach is most appropriate for projecting future distributions of species with differing life-history strategies by comparing the performance of size-structured and size-aggregated species distribution models. To explore the benefits of using size-structured models, we fit models to abundance data for pelagic young-of-the-year fishes in the California Current System. We found that change in size was linked to a change in distribution for most species. However, size-structured models were not always best suited to modeling species distributions, suggesting that size-aggregated models may be sufficient in certain conditions. Determining when to use structured or unstructured marine species distribution models will allow us to better understand how species will respond to climate change.

(S10-16064 Oral)

Identifying climate refugia through scenario analysis of marine megafauna functional diversity in the Northeastern Pacific

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In the face of escalating pressures from climate change, we need to properly understand how marine organisms are responding. Current approaches in ocean management and conservation planning typically aim to identify and protect climate refugia defined as i) areas with persistent species taxonomic diversity over space and time, and/or ii) areas with stable climatic conditions (i.e., climate analogs). However, this approach critically overlooks complex shifts in functional diversity of community assemblages to multiple climate change stressors. Here, we innovatively define climate refugia as areas where functional diversity persists over space and time, independent from persistence in species taxonomic diversity and/or climate analogs. We performed a scenario analysis by modelling the functional space of marine megafauna in the Northeastern Pacific using 19 functional traits. Although moving northwards, some ecoregions' functional diversity changed at lower rate than taxonomic diversity, meaning that the turnover of species did not correspond to a similar functional diversity shift. With the combined analysis of taxonomic and functional diversity patterns we also identified areas where their relative change will place to new systems, including areas with increased functional diversity. This novel definition of climate refugia will help shape future protection and goals of conservation while considering the capacity of these new systems to provide functions and related ecosystem services in the future.

(S10-16072 Oral)

The role of continental shelf bathymetry in shaping marine range shifts in the face of climate change

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As a consequence of anthropogenic climate change, marine species on continental shelves around the world are rapidly shifting deeper and poleward. However, whether these shifts deeper and poleward will allow species to access more, less, or equivalent amounts of continental shelf area and associated critical habitats remains unclear. By examining the proportion of seabed area at a range of depths for each large marine ecosystem (LME), we found that shelf area declined monotonically for 19% of LMEs examined. However, the majority exhibited a greater proportion of shelf area in mid-depths or across several depth ranges. By comparing

continental shelf area across 2° latitudinal bands, we found that all coastlines exhibit multiple instances of shelf area expansion and contraction, which have the potential to promote or restrict poleward movement of marine species. Along most coastlines, overall shelf habitat increases or exhibits no significant change moving towards the poles. The exception is the Southern West Pacific, which experiences an overall loss of area with increasing latitude. Changes in continental shelf area availability across latitudes and depths are likely to affect the number of species local ecosystems can support. These geometric analyses help identify regions of conservation priority and ecological communities most likely to face attrition or expansion due to variations in available area.

(S10-16077 Oral)

Bergman patterns in a warming ocean, their mechanistic basis, and implications for projecting responses to climate change

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Bergman patterns; the tendency of organisms to be larger at higher latitudes and lower temperatures, are one of the most well-studied biogeographic patterns. Thermoregulation in terrestrial endotherms along latitudinal temperature gradients was the originally proposed driver, but it has become increasingly clear that similar patterns hold for ectotherms and aquatic organisms, suggesting a single driver or mechanism is unlikely. The link between climate change and recent body-size reductions has revived interest in Bergman patterns to predict future community-level and ecosystem effects. Here is a catch: if we do not understand the mechanism behind observed patterns, we cannot make reliable predictions about the future. We use a model that incorporates explicit mechanisms for vision-based feeding and temperature-dependent physiology of a planktivorous fish to explore how intrinsic and extrinsic constraints affect optimal body size across a latitudinal gradient in a seasonal system, now and in a warmer future. The expected latitudinal body size cline emerges from the interaction between temperature and light availability, whereby small planktivores benefit from warmer temperatures at lower latitudes and large planktivores from colder temperatures and more daylight hours for feeding at higher latitudes. Moreover, warming benefits smaller individuals as digestion becomes faster and alleviates the bottleneck for energy processing, while larger individuals suffer from higher metabolic losses in a situation where daylight is already maximally exploited. This suggests that individuals of different sizes may respond differently to warmer temperatures and hence that the size- and demographic- structure, and collective behaviour of a population may influence its spatio-temporal responses.

S10-16082 Oral

Changes in species distribution and biodiversity patterns in response to projected climate change off South Africa

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Climate change is projected to have a wide range of effects on marine organisms. Such changes, including climate-induced shifts in species distribution, range or area inhabited, changes to phenology, or other biodiversity changes, can all affect ecosystem structure and function. In this study, occurrence data from fishes, benthos, and zooplankton in South Africa's EEZ were utilized to model their current distributions, following which, models trained on the current distributions were projected to estimate the distribution of marine species over the next 30 and 80 years, based on expected climatic conditions under RCP-2.6 and RCP-8.5. Under RCP-8.5 and for the 2100 period, the impact of projected climate-driven change appears to be stronger and more consistent across taxonomic groups. Overall, substantial reductions in species richness, under RCP-8.5, for both fish and benthos, were projected for historically species-rich locations, with an increase in species richness projected for the northern Benguela. Although projected climate change impacts based on correlative distribution models do not account for short to medium term physiological adaptive capacity, the results are largely consistent with studies conducted elsewhere at local or regional scales, as well as global studies. In particular: range contractions for some species while there were range extensions for others, and increases in species richness in some regions while there were declines in others. Potential implications of these modelled changes on ecosystem structure and functioning, and implications for conservation and socioeconomics, are discussed.

(S10-16090 Oral)

Model evidence for photic barriers to poleward range shifts

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Globally, species are shifting their distribution in response to a changing climate, typically poleward. Consequently, the highest species turnover, invasion intensities and increases in maximum fisheries catch potential are predicted for high-latitude oceans (>60°N/60°S). Current state-of-the-art statistical approaches to species distribution modelling focus on temperature and habitat, but temperature is not the only factor that restricts species' distributions. Light is a crucial but often neglected factor that exerts both bottom-up and top-down control on marine ecosystems. Seasonality in light becomes progressively extreme at high latitudes, in terms of the diel light dark cycle and the duration of light summers and dark winters. In contrast to temperature, this latitudinal gradient in light seasonality is not affected by climate change. To survive in these extremely seasonal environments, organism require different physiological,

morphological, and behavioral adaptations, which include the seasonal timing of important life history events, seasonal migration, energy reserves and reduced activity during the annual cycle. Here, we use two mechanistic models that explicitly link light-dependent encounters and temperature-dependent physiology for two widespread planktivorous fish types, along a latitudinal gradient in the North Atlantic to predict where populations survive and acquire resources to reproduce, and where they demise. We find that not only does seasonality in light constitute a stronger barrier to poleward distribution than cold temperatures, but counterintuitively we identify two processes that at high-latitudes could lead to equatorward distribution shifts under climate warming: faster depletion of energy stores in winter and higher foraging-related predation mortality in summer.

S10-16106 Oral

Gray whale and harbor porpoise spatiotemporal distribution patterns reveal different responses to environmental variability over three decades in the Northern California Current

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Despite their ecological and economic importance, nearshore habitats (<5km from land) remain understudied, particularly in the context of climate change. The Northern California Current (NCC) is a prominent upwelling system, but the nearshore realm of the NCC appears decoupled from coastal upwelling processes. Using standardized vessel-based surveys, we examine spatiotemporal distribution of harbor porpoises and gray whales relative to upwelling, ocean basin-scale climate indices, and static habitat features. These focal species allow examination of impacts of environmental variability on species with differing life histories and prey requirements over a long sampling period (1992-2022) and broad latitudinal range (38-46N). Sightings per unit effort (SPUE) showed stable hotspots for gray whales. General linear models testing for an interactive effect between latitude and year were used to examine directional shifts in SPUE. No significant relationship was detected for gray whales (F=0.49, p=0.48). For harbor porpoise, a significant positive interactive effect revealed higher SPUE at northerly latitudes in later years (F=9.01, p=0.002). These results indicate that migratory gray whales return to same sites over decadal scales, while harbor porpoises may have a narrower ecological niche that is shifting northward. Boosted regression tree models revealed the importance of static habitat features compared to upwelling or climate oscillation indices, for both gray whales (cross-validated deviance explained=40%) and harbor porpoises (cross-validated deviance explained=23%). Density surface models will further elucidate spatiotemporal patterns. Taken together, these findings shed light on how interactions between static habitat features and dynamic ocean processes will impact nearshore marine predators under changing ocean conditions.

(S10-16110 Oral)

CNA – the Cumulative Niche Approach: a novel correlative framework to assess the risk of spread of alien species in climate change scenarios

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Alien species threaten natural ecosystems and cause major ecological and economic damage. Since the opening of the Suez Canal, in 1869, hundreds of species have migrated from the Red to the Mediterranean Sea, establishing alien populations. Understanding the climate niche of alien species is crucial to predict and prevent future introductions and further spread. Ecological Niche Models (ENMs) are often used to predict species distributions. However, this approach tends to be inaccurate when applied to biological invasions because alien species' realised niches can differ between the colonised and native range. Similarly, ENMs show reduced predictive power when extrapolated to future climatic scenarios. Here, we present a novel solution, the cumulative niche approach (CNA), that will recast our ability to predict and prevent future biological invasions. This framework relies on species distribution data and on environmental variable layers to quantify species' realised niches in the alien range and to compare this to their native range. Here, we demonstrate the CNA with species of naturalised amphibians, birds, mammals, and marine fish as study cases. For each species, we assessed whether the relationship between climate niche extent and occupancy data have reached an asymptote, indicating we have a good understanding of the climate niche that can be used for future risk assessments. Our results point that it is possible to verify whether we can infer each species' fundamental niche through our approach. These advancements provide a guideline and powerful tool in invasion biology research and management.

(S10-16113 Oral)

Quantifying patterns and trends in the environmental niches of groundfish species in the NE Pacific

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Rapidly changing climates around the globe have generated increased challenges for understanding mechanisms affecting population distribution and growth. Adding to this challenge is the fact that linkages between climate and biology may often also be non-stationary in space or time. These challenges have necessitated advances in approaches used to model spatiotemporal variability of species distributions, and methods used to quantify environmental drivers on distribution. Quantifying the tolerance of a species to the environment across its range may be useful for prioritizing species in risk assessments, or for making future predictions to novel environments. A range of model-based approaches have been developed for estimating environmental niches of species (however, generally with presence-only data). In this talk, we

demonstrate how realized environmental niches may be summarized and tracked through time with our recently developed R package sdmTMB, which makes complicated spatiotemporal models more accessible to users familiar with common statistical packages (glmmTMB, mgcv, brms). As a case study, we demonstrate an application to understanding the temperature niches of groundfish species in the Northeast Pacific Ocean (California to the Gulf of Alaska). We demonstrate that combining survey datasets across a species' range can be beneficial to disentangling correlated features, such as depth with environmental variables. We contrast species that appear robust to fluctuations in conditions (Dover sole, longnose skate) with those that more closely track recent increases in temperature associated with the 'Warm Blob' of 2013–2015 (arrowtooth flounder, N. Pacific spiny dogfish).

(S10-16120 Oral)

Will mismatches in predator and prey distribution and abundance disrupt food webs?

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As climate change redistributes biodiversity globally, anticipating the relative rates of redistribution of trophically-linked species is a major challenge. Mismatches in distributional shifts and productivity of predators and prey may have cascading effects throughout the food web. In particular, migratory predators link disparate ecosystems and may contribute disproportionately to the productivity, stability, and resilience of food webs. We explored potential mismatches between marine endothermic and ectothermic migratory predators in the Northeast US Large Marine Ecosystem. In this region, large specialist predators, like the endangered North Atlantic right whale, appear to be shifting their distribution along with their prey, but large generalist endothermic predators appear to be shifting faster than their smaller ectothermic prey. Large ectothermic predators, like sharks, appear to be shifting their distribution and/or changing the timing of their seasonal migrations, but whether this is related to temperature or resource availability is unclear. We used a food web model to explore the implications of changing biomass versus changes in migration timing of sharks on their prey. The effect of migration timing was not as strong as a similar change in shark biomass, but nevertheless when migration or biomass changed more quickly than their prey the food web impacts were not intuitive.

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(S10-16133 Oral)

Interacting effects of fishing and warming on functional traits in Mediterranean and Atlantic demersal communities

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Many studies have focused on the functional response of marine communities to either fishing or climate change, but few have studied how both impacts combined can alter ecosystems. In this work, we compiled eight life-history traits expected to condition species responses to climate change and fishing impacts for 250 species of the demersal communities. The weighted mean traits were calculated by weighting the trait values by the relative abundance of each of the species in the community, using datasets of species abundances obtained from International Bottom Trawl Surveys in the North-Atlantic Iberian Shelf (ATL_{IS}) and the Mediterranean Iberian Shelf (MED_{IS}). Warming was estimated through sea surface temperature data, while fishing pressure was estimated from VMS data. We explored the effects using linear models and fitting an interaction term between both stressors.

Generally, the response to both stressors was stronger in ATL_{IS} than in MED_{IS}, indicating the higher resilience of the heavily impacted Mediterranean ecosystems. These responses, however, differed between the MED_{IS} and the ATL_{IS}, not conforming to the expectations we had based on the literature. Interaction terms did only emerge for some community weighted traits such as body size, longevity or size at maturity, and in some cases seemed to depend on reaching an impact threshold value. Our results suggest that the effect of these stressors on the ecosystem strongly depends on its previous ecological state, exploitation and recovery history, and pleads for the development of sensitivity indices that incorporate this differential response of communities to the same stressors.

(S10-16168 Oral)

NOAA Fisheries Distribution Mapping and Analysis Portal (DisMAP): Visualizing changing distributions

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The impacts of changing species distributions reach far beyond the individual species experiencing the shift, to affect entire ecosystems, fisheries interactions, and coastal economies. Robust information on past, current, and expected future distributions of marine species is critical for effective ecosystem-based management and decision-making in sectors ranging from fisheries to offshore energy. In general, information on species distributions is dispersed across multiple sources and regions and therefore not easily accessible across fisheries governance boundaries. In response to this need, in 2022 NOAA Fisheries launched a new state-of-the-art mapping portal to consolidate information on species distributions into one easily accessible, interactive portal called the Distribution Mapping and Analysis Portal (DisMAP). In this presentation we will describe and demonstrate the capabilities of this Portal and discuss plans for future development. The current version of the portal displays data from fishery-independent surveys for six US regions (Northeast, Southeast, Gulf of Mexico, West Coast, Hawaii, and Alaska) and includes a map viewer and graphing capabilities to explore the distributions of over 900 marine fish and invertebrate species caught during the surveys. The portal is being developed in phases, with plans for future releases to include additional data types, model outputs, and functionalities. The interactive website will improve data sharing and collaboration, facilitate decision-making about fishery management and other ocean use planning, and increase overall knowledge of species distributions. User-friendly tools like this play a critical role in decision-making for a climate-ready future.

(S10-16201 Oral)

Can an spatial trophic ecosystem model represent observed changes in functional groups distribution due to environmental changes in the Barents Sea Large Marine Ecosystem?

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In the Barents Sea Large Marine Ecosystem, water and air temperatures vary over time with alternating warm and cold periods. Changes in temperatures and other environmental drivers can dramatically impact the whole ecosystem. Dynamic spatial models like Ecospace can represent an area's biological community and help predict future impacts of environmental change on populations and communities by considering species' habitat requirements and ecological interactions. We tested the ability of a Barents Sea 108 Functional Groups (FGs) Ecospace model to model shifts in spatial distributions due to warming. We compared model predicted and field surveyed spatial distributions in relatively cold and warm years. We created two plausible scenarios, one representing a relatively cold year (2004) and another representing a warm year (2013) with differences of ca. 0.3ºC in bottom and 0.6ºC in surface temperatures, and 7% less ice coverage between them. Using the scenario-specific environmental drivers, we evaluated the impact on distributions of functional groups. Comparison of the center of gravity, inertia, and spatial overlap of the modelled and surveyed spatial distributions in warm and cold years showed that the model satisfactorily represented the distributions of the functional groups. The model predicted a polewards shift in distribution with increasing temperature for most FG, including many benthic and pelagic invertebrates. Modelled and survey-observed distributions were similar. We conclude that Ecospace represents past observed species distributions in the Barents Sea well and may predict temperature-driven changes in spatial distributions.

(S10-16225 Oral)

Climate velocity in the vertical – slower speeds add a new dimension to species shifts

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As the oceans warm many organisms are shifting poleward at rates that can be understood by horizontal climate velocity, while others are not moving as expected and may instead shift deeper in the water column. In this study we use GLORYS12 reanalysis to investigate the poorly resolved vertical dimension of climate velocity. We examine this variable across the top 200 m of each of the 66 ecologically important large marine ecosystems (LMEs). By dividing the temporal trend by the time mean vertical spatial gradient we get a temperature speed in m/yr. Across all LMEs 80% of lat-lon-depth bins contain negative climate velocity values, indicating a deepening of isotherms. The mean value of vertical climate velocity is -0.5 m/yr whereas the mean value for horizontal climate velocity in the surface layer is 10 km/yr. The much smaller values for vertical climate velocity indicate that many organisms may only have to migrate a tiny fraction of the horizontal distance in the vertical direction to maintain a constant temperature. Comparisons are made across tropical, subtropical, temperate, subpolar and polar regions. Preliminary results suggest subtropical regions have the smallest range in both vertical and horizontal climate velocities. Some LMEs have both low mean vertical and horizontal climate velocities. Organisms in LMEs with both high mean vertical and high mean horizontal velocities may be increasingly threatened by warming as they must move large distances in either dimension to maintain a suitable thermal habitat.

(S10-16226 Oral)

Can physiology and spatial models improve species distribution modeling and forecasting?

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The rapid pace of climate change and its effects on marine ecosystems pose severe challenges to resource management systems. To date, climate impacts research has made advances detecting or predicting consequences for fisheries productivity, documenting range shifts, and their consequences for fisheries governance. While allocation issues are at the forefront of concerns about species distribution shifts, the threat of changes in species overlap, and the potential consequences for mixed-species fisheries e.g., “choke species” that restrict fishing opportunities, are less well known. Here we describe our approach to forecast future species overlap using physiologically informed metrics that consider the joint effect of temperature on oxygen sensitivity. We show that a geostatistical model that accounts for latent spatial processes can detect the fingerprint of oxygen on groundfish distributions across a range of ecosystems in North America. Moreover, we can inform these projections with a hierarchical analysis of laboratory-based experiments to estimate species’ sensitivity to oxygen and how that depends on temperature. By combining these with projections of oxygen and temperature, we can anticipate species overlap in the future and evaluate the threat that changes in overlap will restrict fishing opportunities.

(S10-16236 Oral)

A multi-model approach to improve understanding of species interactions and sensitivity to climate change for Pacific salmon in the California Current

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Management actions to reduce extinction risk due to climate change for threatened marine species is a crucial need for 21st-century science. Salmon marine survival in some populations strongly correlates with sea surface temperature, suggesting climate change is a severe threat. Yet, temperature affects much of the food web simultaneously, and the complexities of interspecific dynamics obscure the mechanisms underlying this correlation. These complexities reduce our ability to identify actions that could improve conservation outcomes. To better understand these dynamics, we developed a multi-model approach to characterize the network links that are most sensitive to climate and evaluated the influence of potential management actions. We present the results from one modeling approach. We used a qualitative network model to conceptualize important network characteristics driving salmon outcomes, and how management actions (including habitat, hydrosystem, predator culling, fisheries) intersect the network. This model helped eliminate unlikely network connections and highlighted non-intuitive dynamics that may drive the system. It also identified the parameter space in which management approaches would be most effective at improving outcomes for salmon. We then describe our second modeling approach using structural equation models to quantify support for various networks and prioritize data needs for management decisions. In a paired talk, we describe our third modeling approach, an end-to-end ecosystem model to capture energy flux and salmon sensitivities at the scale of the Northern California Current. Using this multi-model approach, we have progressed our understanding of data needs and management opportunities for this threatened species in a warming ocean.

(S10-16239 Oral) REVISED: Co-authors

Testing the ability of a metabolic index integrating temperature and oxygen to explain the spatial distribution of juvenile and adult Baltic Sea cod over three decades

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The rapid warming and deoxygenation of our oceans is affecting the spatial distribution of organisms, but to predict responses across taxa we need general approaches based on individual-level physiology. Metabolic indices based on the balance between oxygen supply from the environment and the demands from aerobic metabolism have been able to predict macro-ecological patterns through time. A recent studie, however, found that the metabolic index was not a parsimonious predictor for the distribution of a demersal fish. In this study, we ask whether the metabolic index can explain variation in spatiotemporal distribution of juvenile and adult Atlantic cod in the Baltic Sea—the largest anthropogenically induced hypoxic area and one of the most rapid warming seas in the world. Using generalized linear mixed effects models with Gaussian random fields to account for latent spatial trends, as well as temperature, oxygen, and the metabolic index as fixed effects, we explore which covariates and with what functional relationship can parsimoniously explain variation in biomass density over 3 decades. We find that a smooth function of the metabolic index is the best fitting model, and we do not find large differences in peak the metabolic index between juveniles and adults. Moreover, juveniles occupy habitats with higher metabolic index values, and for both life stages, the weighted average experienced metabolic index has fallen from approximately 5 to 4 in the last 5 years. These findings show physiologically derived covariates can improve model fit and aid the incorporation of mechanistic processes in species distribution modelling.

(S10-16254 Oral)

Improving selection of fish habitat models for climate studies

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Climate-induced shifts in fish distribution have been documented to trigger changes in marine ecosystems and ecosystem services. Species distribution model (SDM) is a widely used tool to study past and future species distribution required by marine spatial plannings as they provide predictions of species distribution and let developing adaptive strategies to promote sustainable use of marine ecosystems. Traditional SDMs relies on cross-validation (CV) techniques to evaluate model performance but rarely consider 1) model transferability, i.e. the ability to extrapolate to future conditions or area with no observations and 2) the ability of these techniques to effectively choose ecological meaningful models. To address this issues, we tested different types of abundance-environment relationships in a framework of generalized modeling applied to 12 commercial fish species. We designed three CV routines to ensure a correct isolation of the long-term climate signal from the sub-scale noise and model an accurate transferability: 1) block-CV, i.e. the traditional approach 2) sampling-CV, to control for sampling design and 3) niche-CV, model fitting with optimal environmental conditions. Finally, we validated partial effects of temperature between models. Our results indicate that, most widely used CV routine (block-CV) often fails to choose a model with the best transferability and, instead, identifies as best models unrealistic ones, unsuitable for extrapolations. Therefore, to avoid misleading predictions, we suggest verifying that the functional form of temperature partial effect is ecological meaningful. This is crucial because of the potential impact on the precision of ecosystem models and consequent policy advises.

(S10-16257 Oral)

Climate change creates regional heterogeneity in projected resource availability and potential adaptation pathways of U.S. West Coast fisheries

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To develop climate-ready fisheries we need to understand how shifts in species distributions can cascade through social-ecological systems to influence management outcomes. Previous research has investigated climate-driven species distribution shifts, but these studies are often performed on coarse spatial scales, ignoring how regional heterogeneity in climate change may affect local, multispecies fisheries. In this study, we investigated future distribution shifts, driven by warming and deoxygenation, within a multi-species commercially-valuable complex on the U.S. West Coast. We show that the most valuable species is highly certain to decline in availability coastwide, while the most abundant species will remain steady or may increase. However, these responses will be regionally heterogeneous, and fishers will need to adapt to fish in deeper waters for the most valuable species or contend with challenges to their ability to target preferred species. Fisheries management under future ocean conditions will increasingly require analyses that draw explicit links between physical changes in the ocean, the distribution and abundance of species, and the implications of regionally divergent adaptation pathways for fishery-dependent human communities.

(S10-16437 Oral)

Future climate-induced distribution shifts in a sexually dimorphic key predator of the Southern Ocean

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Predicting the consequences of global warming in the distribution of sexually dimorphic species is particularly challenging, because males and females may differ in their patterns of habitat use. The Antarctic fur seal *Arctocephalus gazella* is a highly dimorphic species and a major predator of Antarctic krill off West Antarctica, and nothing is known about its response to future global warming scenarios. Here, we combined satellite tracking data with outputs from four Earth System Models to develop species distribution models and predict changes in habitat suitability for both sexes under two climate forcing scenarios (SSP1-2.6 and SSP5-8.5) up to 2100. Our results indicate that habitat suitability for both sexes will be displaced southward during the non-breeding period (i.e. winter months) and reduced in a more extensive way in the SSP5-8.5 scenario. However, the extent of habitat loss will be smaller for males as they will find new suitable patches close to the sea ice limit in the Bellingshausen and Weddell Sea. Conversely, female distribution will not change during the breeding season, as they behave as central place foragers at that time of the year and distance to the colony constitutes their main driver. Complex processes such as food availability, capability to colonize new ice-free areas and high philopatry of females may play a key role in the adaptability of the Antarctic fur seal to new environmental conditions.

POSTER BOARD ID: S10-P1
(S10-15866 Poster)

Is ocean warming affecting fisheries catches in the Northwest Atlantic Ocean?

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Climate change is already affecting marine ecosystems and shifting species from their historical ranges into previously unsuitable and sometimes poorly protected environments. Because of its rapid rate of warming, the Northwest (NW) Atlantic is an ideal region to study the impact of rising water temperatures on species distributions and fisheries catches. A well-established approach that has been used to assess climate-induced changes is the mean temperature of the catch (MTC) index that can identify the signature of ocean warming in the most widely available dataset for fisheries, i.e., fisheries catches. Here, we used up-to-date catch datasets from global and regional sources to detect MTC trends along a latitudinal gradient on the east coasts of the US and Canada. We found variability in the estimated MTC trends among the different datasets, owing to differences in the spatial and temporal resolution of the data. Nevertheless, results indicate that, overall, the MTC has been increasing in the NW Atlantic for the past few decades due to a considerable decline in catches of cold-water species like cod and halibut, and a more gradual increase in catches of warmer-water species such as lobster and mackerel. The observed patterns of MTC change over time were in line with observed increases in sea surface temperature across the region. Revealing patterns of shifting fish stocks and community composition, which have consequences for seafood supply, fisheries revenues, and livelihoods, may help project future conditions and inform national and transboundary management policies in a changing climate.

POSTER BOARD ID: S10-P2
(S10-15913 Poster)

The universal evolutionary and ecological significance of 20 °C

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This talk connects evidence that 20 °C is the most stable temperature for cellular processes across all domains of life with macroecological observations. It provides examples of where temperatures above 20 °C result in decreases in: aquatic species' tolerance to low oxygen; marine pelagic and benthic algal productivity; pelagic and benthic predation rates; and global species richness in pelagic fishes, plankton and benthic invertebrates. In addition, the realised thermal niche breadth occupied by guilds of reef fishes and invertebrates surveyed globally is narrowest among species with distributions centred on 20 °C, matching a pattern also seen in microbes. While many species have evolved to live at warmer and colder temperatures, most species can live at 20 °C. A mathematical model, using a single rate limiting process located within the cell, has predicted that thermal breadth should be minimized and species richness maximised at 20 °C. A systematic literature search of species richness versus temperature (7,618 samples) provided evidence that species richness is maximised at ~20 °C across life in air and water, including animals, plants and microbes. That life seems centred around ~20 °C, implies fundamental constraints, including biochemical ones, that compromise the ability of extant tropical species to adapt to higher temperatures.

POSTER BOARD ID: S10-P3
(S10-15938 Poster)

Disentangling the future distribution of economically important commercial fish species in the Argentine continental shelf

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The South-Western Atlantic Ocean is inhabited by two species of hake: the Argentine hake and the Southern hake, both supporting important commercial fisheries off Argentina. The Southern hake is tightly linked to the cold Malvinas current, whereas the Argentine hake prevails on warmer waters over the continental shelf. Furthermore, the abundance of Argentine hake declines sharply south of 52°S and coastal summer spawning aggregations do not exist south of 47°S, where annual average Sea Surface Temperature (SST) is 11°C. However, zooarchaelogical studies have revealed that during a warmer phase of the Middle Holocene both the Argentine hake and snoek thrived south to 47ºS. Accordingly, increasing SST as a result of global warming could result into the southward expansion of Argentine hake onshore Tierra del Fuego, and the recolonization of this area by snoek from the South-Eastern Pacific Ocean, with a potential impact on the landings of the Argentine and Southern hake. In order to assess these hypotheses, we conducted species distribution modeling (SDM) using Boosted Regression Trees (BRTs) to identify the environmental variables (SST, primary productivity, salinity and depth) linked to the present occurrence of these three species and their main preys (Fuegian sprat, Argentine anchovy and squat lobster). We then used the models to predict species distribution all the way to 2100 in two climate forcing scenarios (SSP1-2.6 and SSP5-8.5) by using outputs from four Earth System Models. The results from this study could contribute to a proactive future fisheries management in the region.

POSTER BOARD ID: S10-P4
(S10-15951 Poster)

Assessing baleen whale incidents relative to human pressures in the Northwest Atlantic Ocean

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Baleen whales in the Northwest Atlantic Ocean (NWA) are becoming increasingly affected by human pressures related to vessel activity, entanglement, and climate change. Interaction with vessels and entanglement in fishing gear, in particular, often result in distress, injury, or death of these animals. These negative interactions or 'incidents' are consistently reported to marine animal response organizations throughout Atlantic Canada but have not yet been analyzed for scientific publication. Here we are using data from 1359 incidents reported between 2004-2019 to determine areas in the NWA where incident risk is high for all species of baleen whale now, and where it might be high in the future given changing environmental conditions. Using outputs from ensemble species distribution models that have been forced with climate models under both high and low emission scenarios, current and future and incident risk will be determined. A secondary objective is to determine the effectiveness of current incident mitigation strategies and how their impacts might change with the effects of climate change. Current incident management strategies will be reviewed, and their present and future success will be assessed based on our findings. Preliminary results suggest that areas of current high incident risk for baleen whales occur around major shipping channels and fishing areas. While some of these high-risk areas have mitigation efforts underway, others require new measures to ensure the safety of whales there now and in the future.

POSTER BOARD ID: S10-P5
(S10-15974 Poster)

Near-time prediction of Atlantic tuna

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Climate prediction models can successfully predict ocean hydrography several years ahead. Less is known to what extent this predictability of ocean physics translate into marine ecosystems. Here, we explore predictability of interannual-to-decadal variations in various Atlantic tuna species, by using Climate Prediction Models in combination with statistical and numerical ecosystem models, as well as a suitable habitat approach. The results are linked to physical and ecological mechanisms giving rise to potential predictability.

POSTER BOARD ID: S10-P6
(S10-15975 Poster)

Modeling climate analogs to determine the effects of climate change on aquaculture species

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Aquaculture has become the fastest-growing food production industry, accounting for more than half of current global seafood production. However, production security is still largely dependent on favourable species-specific environmental conditions. As oceans warm species are projected to move polewards, potentially negatively impacting equatorial farming regions while temperate regions may benefit from an increase in growth rates and a localised diversification of species. The current and projected development of the industry highlights a growing need to assess future aquaculture suitability in a changing climate. Modeling species distributions under contrasting scenarios of climate change can inform on the regions that are more or less suited for aquaculture production in future. To achieve this, climate analog models are utilised to match areas with corresponding climatic conditions, across space and time. This approach can identify countries or regions best suited for marine aquaculture in future by estimating how aquaculture species may shift distributions in response to changing conditions. Contrasting future range shifts across species can further identify those that are more resilient to changing environmental conditions and will be suited for aquaculture in regions vulnerable to climate change, and those less tolerant. Overall, these results will aid governments and industry in establishing adaptive management strategies to mitigate the impacts of climate change, to facilitate the continued growth and sustainability of the aquaculture industry.

POSTER BOARD ID: S10-P7
(S10-16031 Poster)

Predicting Pacific cod spawning habitat in a changing climate

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Warming temperatures elicit shifts in habitat use and geographic distributions of fishes, with uneven effects across life stages. Spawners and embryos are directly linked to fisheries harvest and recruitment but are particularly sensitive to environmental conditions, often having narrower thermal tolerances compared to other life stages. Here, we examine the spatiotemporal variability of thermally-suitable spawning habitat for Pacific cod in the eastern Bering Sea. Specifically, we use bottom temperatures from regionally downscaled global climate models coupled with an experimentally-derived relationship between hatch success and temperature to predict how the spatial extent, mean latitude, and consistency of suitable spawning habitat has varied in the past and may change into the future. We find that although the availability of suitable spawning habitat has not increased in the past, it is predicted to increase and shift northward in the future, particularly if no climate change mitigation occurs. Hotspots of suitable spawning habitat are consistent across shorter time periods but shift across the Bering Sea shelf by the end of the century such that historical and contemporary areas with high suitability are predicted to be unsuitable in the future. Finally, we find no correlation between the availability of suitable spawning habitat and annual estimates of recruitment, suggesting that spawning habitat has not been constraining during the historical period, nor is likely to be in the future. By coupling experimental data with climate models, this work offers a pathway for examining life stage- and season-specific changes in habitat use and distribution with continued climate change.

POSTER BOARD ID: S10-P8
(S10-16086 Poster)

Fish spawning and migration timing match local phytoplankton phenology beyond thermal drivers

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Increasing temperature will speed up physiological rates of ectotherms. In fish, this is suggested to speed up oocyte growth rates and cause earlier spawning. With climate warming, a general expectation is a decoupling between spawning time and the timing of the offspring's food resources. Here, we combine oocyte growth rates of Atlantic cod from temperature-controlled experiments with gonad development stages from 130 000 wild-caught individuals between 1980 and 2019. We find that cod can delay or advance spawning time by up to 23 days - largely independent of their thermal history, but fine-tuned to their choice of spawning location and the local phytoplankton spring bloom phenology. The ability to overcome thermal drivers thus enable individuals to regulate their spawning time to maximize fitness. This finding highlights a new dimension for trophic match-mismatch and should be an important consideration in models used to predict phenology dynamics in a warmer climate.

POSTER BOARD ID: S10-P9
(S10-16101 Poster)

The environment of fish is more than temperature: how food and safety for larvae determine spawning time and location in bluefin tuna

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Atlantic bluefin tuna are large apex predators roaming the Atlantic Ocean from east to west in search for energy dense prey. They swim at large speeds and could potentially spawn in any location in the Northern Atlantic. However, a key spawning ground is found in an ocean desert in the Mediterranean Sea. Why do Atlantic bluefin tuna select just these areas for their offspring? We present a theoretical argument of why this place and time for spawning has evolved. First, the water here is warm enough for eggs to hatch and larvae to grow, but not so warm that they face a metabolic meltdown where energy needs exceed their feeding rates. Second, there is just enough food available in the warm surface layer to sustain the high growth of the first feeding larvae, allowing for short planktivore stage durations. Third, there are few predators around – and tuna also spawn at a certain time in the lunar cycle to reduce the predation risk of larvae even further. We learn from this that predictions of spatial and temporal shifts due to climate change must include the wider ecology of species, not only physiology or temperature. For bluefin tuna, higher temperatures can be beneficial if prey abundance is high, but critical if not. We need a combination of mechanistic process understanding and evolutionary reasoning to predict spawning phenology under long-term seasonal shifts in temperature or other environmental drivers, including prey or predator abundance and their seasonal cycles.

POSTER BOARD ID: S10-P10
(S10-16118 Poster)

Vulnerability to climate change of essential habitats for fishery resources of economic importance in Chile

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The distribution of eggs, landings, fishing effort and CPUE abundance index, sea surface temperature, chlorophyll concentration, winds and sea height are analyzed. The description of the essential habitat is based on bibliographic references along with fisheries and satellite information, generating information matrices with suitability ranges. These matrices are used to generate conceptual maps of the essential habitat for the resources. The importance of the habitat is categorized based on the matrices and conceptual maps, with environmental variables categorized in ranges from 1 to 5. Then conceptual models are elaborated and predictive models associated with regionalized climate change are developed.

For jack mackerel (*Trachurus murphyi*), a Maxent model was developed that shows losses in the area of the most suitable habitat in summer and gains during the rest of the year, around 2055. Neural networks estimate a 92% increase in landings by 2056-2065, which would be due more to a change in availability than abundance. Swordfish (*Xiphias gladius*) would move further south as climate change develops. For anchovy (*Engraulis ringens*) the model shows loss of area of the most suitable egg habitat of 30%, 93% and 95% by August, September and October 2055; and a 97% annual loss of desirable habitat for adults in that year, as would be the case for common sardine (*Strangomera bentinki*). It is necessary to refine the regionalization of climate change, consider its effect on the entire life cycle of the species and develop a regional transdisciplinary research program.

POSTER BOARD ID: S10-P11
(S10-16132 Poster)

Changes in the life-history strategy of fish communities from the Barents Sea in a warming environment

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Life history traits, and their environmental associations, can help understanding spatial and temporal changes in the distribution and abundance of fish communities. In the Barents Sea, the past decade has been the warmest on record, resulting in a decrease in ice coverage and an increase in water temperature. As a response, many Boreal species have expanded their spatial distribution poleward, impacting the Arctic marine ecosystem. Life history strategy framework was used here to obtain a more mechanistic understanding of the recent (2004 to 2017) spatial and temporal changes in the Barents Sea fish community. There was utilized a trait dataset to classify fish species in the Barents Sea according to three strategies: equilibrium, opportunistic and periodic.The Norwegian-Russian Barents Sea ecosystem survey data was used to calculate changes in the strategies proportion within the fish communities in space and time. Spatially, our results revealed that higher proportion of periodic strategy fish

(Boreal species) occurred in the southern and central areas. In contrast, the opportunistic fish (Arctic species) showed a proportion increase in northern areas, while the equilibrium fish strategists exhibited an increase from Northwest to Southwest. Temporally, periodic species increased in proportion in the central area, while opportunistic species significantly decreased in the same region, and the proportion of equilibrium strategists increased from the Southeast to Northeast areas of the Barents Sea. One possible implication of the warming in the Barents Sea is an abundance reduction of opportunistic Arctic fish species, enhancing top-down regulation and, ultimately, modifying ecosystem functioning.

POSTER BOARD ID: S10-P12

(S10-16174 Poster)

Past and future range shifts of Western Baltic fish – how did we get there and where do we go now?

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Climate-driven poleward distribution shifts of fish have been observed worldwide with implications on ecosystem structure and functioning, and ultimately the services they provide for humans. While understanding species moving towards the poles is straightforward in the open ocean without land barriers, detecting species distribution changes in semi-enclosed systems such as the Baltic Sea is a greater challenge. To understand the main drivers of climate change behind past and potentially future distribution shifts of fish species in the Western Baltic Sea, we applied the Integrated Nested Laplace Approximation (INLA) approach. Subsequently, we projected future range shifts under two different climate change scenarios (RCP 4.5, RCP 8.5) combined with status quo and mitigation eutrophication scenarios. While distribution models have already been used for some fish species in the Baltic Sea, we present herein important results for multiple pelagic, benthopelagic and benthic species of present and potentially future commercial and ecological relevance in an advanced distribution modelling framework. These species could easily become the main fish resources in the area but are also likely to play important roles in the structural and functional aspects of the investigated ecosystem.

POSTER BOARD ID: S10-P13
(S10-16193 Poster)

Juvenile Pacific Cod nursery growth and foraging in response to marine heatwaves in the Gulf of Alaska

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Pacific Cod (*Gadus macrocephalus*) declined dramatically following recent anomalous marine heatwaves (MHWs) in the Gulf of Alaska. Early life stages of Pacific Cod may be particularly susceptible to MHWs, including age-0 juveniles during periods of rapid summer growth in coastal nursery habitats. We assessed the recent growth and diet composition of post-settled age-0 juveniles collected from Kodiak Island, AK in July and August before (2006-2013), during (2014-2016, 2019), and between (2017-2018) MHWs to evaluate potential consequences of this extreme thermal variability. We observed a three-way interaction of size, temperature, and heatwave status on relative growth during July. While overall growth was higher in years since 2014, juvenile cod grew faster at smaller sizes before the MHWs. During and after the MHWs, individuals maintained relatively high growth across all observed sizes, which may suggest selection for larger sizes or shifts in age structure during MHWs. Similar growth patterns were observed in August. NMS ordinations of juvenile cod diet composition explained 86% of overall variability in July and 76% of variability in August. Body size was correlated with axis 1 of the ordination in both July and August. Smaller prey items were more common in years prior to the MHWs, and larger prey items were more common during and between the MHWs. Larger, faster growing, and older juvenile Pacific Cod appear to have exploited new foraging opportunities in the nursery during MHWs, suggesting that the dramatic declines in abundance observed during the MHWs primarily occurred during earlier life stages.

POSTER BOARD ID: S10-P14
(S10-16219 Poster)

Climate change affects the distribution of diversity across marine food webs

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Many studies predict shifts in species distributions and community size composition in response to climate change, yet few have demonstrated how these changes will be distributed across marine food webs. We model how climate change will affect the habitat suitability of marine fish species across a range of body sizes and belonging to different feeding guilds, each with different habitat and feeding requirements, in the northeast Atlantic shelf seas. Contrasting effects of climate change are predicted for feeding guilds, with spatially extensive decreases in the species richness of consumers lower in the food web (planktivores) but increases for those higher up (piscivores). Changing spatial patterns in predator-prey mass ratios and the mean maximum length of species are also predicted, both within and between feeding guilds. In combination, these changes could influence nutrient uptake and transformation, transfer efficiency and food web stability, and thus profoundly alter ecosystem structure and functioning.

POSTER BOARD ID: S10-P15
(S10-16227 Poster)

What is the superpower of organic particles to reduce the impact of their northward shift distribution on dependent benthic organisms in the North Water Polynya?

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The North Water Polynya, in northern Baffin Bay, Canada, is one of the most productive ecosystems of the Arctic. Change in the sea ice dynamics in the region over the last decades led to a northward spread of the primary production while a growth analysis of benthic organisms found in the center of the polynya suggests a higher downward export of pelagic microalgae. This work examines the possibility that the primary production responsible for the subsistence of those bivalves has an allochthonous origin due to the coagulation and fragmentation capacities of the organic particles. It investigates through a modeling approach the properties of the particles favoring their rapid export (during the same season) towards the center of the polynya, the drift time and distance necessary for the export of a surface production. Simulations allow us to estimate the time required for a specific distribution of surface phytoplankton particles to coagulate and create aggregates of determined sizes. Our simulations confirm the allochthonous origin of the phytoplankton cells that could have been filtered by the bivalves harvested and highlight the utility of the model to investigate benthic-pelagic coupling responses in a variety of environments.

POSTER BOARD ID: S10-P16
(S10-16229 Poster)

Potential bottom temperature-associated range shifts of snapper-grouper species along the US Atlantic Coast

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Future warming ocean conditions due to increasing greenhouse gasses may alter the suitability of habitat for many species resulting in potential range shifts. Climate models have been developed to estimate environmental conditions under various climate scenarios and thus are a tool to forecast these changes. Here, we use ocean bottom temperature from a multi-model ensemble mean of six Coupled Model Intercomparison Project (CMIP6) models for "low", "medium", and "high" socioeconomic climate scenarios (SSPs 2-4.5, 3-7.0, 5-8.5) to estimate changes to thermal habitat availability for seven species in the snapper-grouper complex along the US Atlantic coast from 2015 to 2100. Thermal limits were used to estimate where a species could inhabit based on bottom temperature. Suitable habitat area was projected to decrease for Gag Grouper, Scamp Grouper, and Vermillion Snapper, and increase for Red Grouper, Greater Amberjack, and Cobia, with Red Snapper not expected to change overall. Poleward shifts in suitable habitat were projected for all species ranging from 0.1 to 5.41 degrees from 2070-2100. Shifts in species' distributions will require neighboring fisheries management councils to co-develop management strategies that address reorganization of marine ecosystems due to climate change. Interestingly, results are similar between mid- and high-emission scenarios suggesting that if the low socioeconomic pathway is not achieved, as is likely, a tipping point may be reached where more severe impacts occur. Many environmental factors coalesce to influence habitat suitability and future studies will consider non-thermal factors including productivity and plankton biomass to expand current work.

POSTER BOARD ID: S10-P17
(S10-16256 Poster)

Demersal fish community biomass declines with temperature across productive shelf regions

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The observed and predicted effects of temperature change on the spatial biomass distribution of individual fish species is increasingly documented. However, the effect of temperature change on the spatial biomass distribution of fish communities is less well understood. Here we examine variation in demersal fish community biomass across and within 21 productive shelf regions. We find that biomass per km^2 varies 40-fold across regions and is highest in cold waters and areas with low fishing exploitation. We find no evidence that temperature change has impacted biomass within marine regions over time, however, the cross-regional patterns indicate that the long-term impacts of climate warming on community biomass will be negative. These results provide an empirical basis for predicting future changes in the upper trophic levels of marine ecosystems.

POSTER BOARD ID: S10-P18
(S10-16289 Poster)

Latitude- and depth-dependent size structure shifts of Atlantic sea scallop (*Placopecten magellanicus*) in response to warming and fishing

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Unlike mobile fish species in the ocean, many benthic bivalve species, such as Atlantic sea scallop (*Placopecten magellanicus*), are sedentary and less capable of avoiding localized stress such as warming and fishing. Disentangling the relative contribution of different stressors is challenging, but important for projecting population changes and designing effective management strategies. In this study, we constructed time series of sea scallop size structures in three rotationally closed areas on the Northeast US shelf using a self-organizing map algorithm and decomposed their total variances based on the variance partitioning method. The results suggested that the interannual scallop size variances are associated more with changes in bottom temperature in shallow regions (≤ 60 m), but more with fishing mortality in deeper regions (> 60 m). The proportion of small (large) size groups increase (decrease) in response to increased thermal stress and fishing pressure, while the proportion of middle size group is less affected. The results of our sea scallop scope for growth model show the gradual decrease of maximum shell height under future warming and associated offshore and poleward contraction of sea scallop habitats.

POSTER BOARD ID: S10-P19
(S10-16319 Poster)

Exploring environmental effects on small pelagic fish community composition in the open ocean using environmental DNA

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Small pelagic fishes are abundant, and their stocks fluctuate in response to climate change. Species alternation within small pelagic fishes is one of the distinctive phenomena in many large marine ecosystems. Environmental factors including habitat temperature have been investigated in each species separately. However, studies on small pelagic fish community composition and its relationship to the environments were limited. We aimed to compare their community composition with environmental factors including water temperature, salinity, dissolved oxygen. The fish community composition was derived using a multiplex real-time PCR method that can efficiently quantify the eDNA of six species of small pelagic fishes including chub mackerel (*Scomber japonicus*), blue mackerel (*Scomber australasicus*), Japanese anchovy *(Engraulis japonicus*), Japanese sardine (*Sardinops melanostictus*), Japanese jack mackerel (*Trachurus japonicus*) and Pacific saury (*Cololabis saira*). Nonmetric multidimensional scaling (NMDS) was conducted to investigate the fish community composition, and distance-based redundancy analysis (db-RDA) was used to analyze environmental effects on the fish community structure. Samples from the Sea of Japan in 2020 summer were used. Whereas Japanese anchovy dominated the eDNA composition and Pacific saury were not detected, the NMDS analysis revealed the distributional similarity between the chub mackerel and Japanese jack mackerel, suggesting they may share the same ecological niche. The db-RDA indicates the strong influence of dissolved oxygen on Japanese sardine and temperature influence on blue mackerel, which could be the major factors that determine the distributions between the two species. This information could improve our understanding on the fish community responding to future climate change.

POSTER BOARD ID: S10-P20
(S10-16347 Poster)

Migration timing of commercially important fishes in the New York Bight since 2016

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Understanding both broad-scale and local migratory behavior of fishes is important for effectively managing coastal fisheries in a changing climate. This study investigates these behaviors by utilizing six years of acoustic data from arrays located in the New York Bight along the South Shore of Long Island, NY. Seasonal habitat uses and coastal migrations were tracked in a series of arrays consisting of 124 receivers in the New York Bight. Using these data, coastal movement and migration timing was evaluated for two acoustically tagged diadromous species, Atlantic sturgeon, and striped bass. Movements were explored with environmental covariates to investigate how a changing climate may impact the migration movement and preferred habitat space of these diadromous species. Over the six years of data, we found the peak of fall migration for Atlantic sturgeon shifted earlier in the year. And there is more overlap between the spring and the fall movements in more recent years. For striped bass, there is a less determinate trend in the timing of peak migration, but, similarly to Atlantic sturgeon, the migration timing is spread over a longer period of days in more recent years. In the future, it may be possible to investigate the movements of these species on finer scales with the installation of fine-scale acoustic arrays on the South Shore of Long Island. As well as expand to investigate other commercially important species as acoustic data time-series grow.

POSTER BOARD ID: S10-P21
(S10-16429 Poster)

Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of Southern Ocean ecosystems

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The first Marine Ecosystem Assessment for the Southern Ocean (MEASO, 2021) has completed a synthesis of the status and trends in habitats, species and food webs to identify how climate change and local impacts will affect Southern Ocean ecosystems and their services. The MEASO has shown that Antarctic ecosystems are under increasing pressure from global climate change and direct human impacts, which are causing significant changes in socio-ecological systems at the circumpolar scale. At the same time, the MEASO addressed local and regional scale questions concerning important taxa such Antarctic krill, penguins, marine mammals, benthos and ice-associated species. The studies found that changes to biota and habitats are not uniform in direction or magnitude, highlighting the complexity of the Southern Ocean ecosystem. Regardless, global reductions in greenhouse gas emissions and climate recovery are required to avoid irreversible deterioration of Southern Ocean ecosystems and associated loss of their wide-ranging societal benefits. Only by mitigating global climate change, alongside effective local conservation and management, can we safeguard these vulnerable polar oceans and their societal benefits now and into the future. It is envisaged that this assessment will be repeated at regular time intervals to assess and quantify ongoing changes in the system and underpin effective decision-making around climate change mitigation, and conservation of this climate-sensitive region. The MEASO represents a truly international collaboration of over 200 researchers from 19 countries, with a strong engagement from Early Career Researchers (one third of the authors; 11 of the 25 papers were led by ECRs).

POSTER BOARD ID: S10-P22
(S10-16430 Poster)

Movements of highly migratory elasmobranch species under a changing climate

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Climate change is expected to alter marine fish habitat use and migration patterns. Due to increased anthropogenic pressures coupled with slow life history strategies, many global elasmobranch species are vulnerable to substantial population declines. Thus, climate-driven changes in movement behavior and variability in habitat use are critical information to support successful conservation efforts. Further, sensitivity to climate-driven changes in habitat use is species-specific. Thus, identifying species more responsive to climate change will provide valuable insight into future changes in community dynamics. We coupled movement data with environmental data to investigate species-specific drivers of habitat use and migratory patterns of sandbar (*Carcharhinus plumbeus*), sandtiger (*Carcharias taurus*), dusky (*Carcharhinus obscurus*), and thresher (*Alopias vulpinus*) sharks, and winter (*Leucoraja ocellata*), little (*Leucoraja erinacea*), and clearnose (*Raja eglanteria*) skates using generalized additive models. Long-term movement data was derived from an extensive acoustic telemetry network encompassing the entire US east coast from 2018-2022. These species are highly migratory and commonly caught as bycatch and subjected to future habitat alterations via climate change and increased anthropogenic activity. Consequently, the IUCN has listed all of these species, except *L. erinacea* and *R. eglanteria,* on their Red List for Threatened species as vulnerable, endangered, or critically endangered. Modeling techniques allowed for predictions of habitat use under future climate scenarios providing valuable insight into species-specific responses to climate change. Additionally, this work provides baseline information to investigate the impacts of future additional habitat changes such as the development of offshore wind farms.

POSTER BOARD ID: S10-P23
(S10-16440 Poster)

The future projection for chub mackerel (*Scomber japonicus*) catch distributions in Korean waters under CMIP6 forcing scenarios

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Changes in the spatiotemporal catch distributions of fisheries resources in marine ecosystems around the world are directly or indirectly affected by changes in the aquatic environments caused by global warming and climate change. Understanding species-specific responses to environmental variability is important for managing commercially important fish stocks. Chub mackerel (*Scomber japonicus*) is a commercially and ecologically important pelagic fish species in Korea waters. In this study, we examine the effects of environmental factors on

changes in the catch distributions of chub mackerel using generalized additive models and then project future changes in their catch distributions in the Korean waters in the 2050s under CMIP6 forcing scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5). Results from our research show that there are seasonal variations of chub mackerel catch in current (2000-2015) and future projections.

POSTER BOARD ID: S10-P24
(S10-16441 Poster)

Changes in ocean stratification and seabird productivity across northern hemisphere marine ecosystems

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Ocean thermal stratification is an important factor determining vertical mixing, nutrient availability, and productivity in epipelagic zones of the world's oceans. Model predictions and empirical observations have demonstrated increasing ocean thermal stratification with global warming, raising concerns about potential impacts on upper ocean productivity. A recent meta-analysis of changes in seabird productivity showed decreasing productivity for numerous species foraging in the epipelagic zones of northern hemisphere marine ecosystems, suggesting impacts of thermal stratification on upper ocean 'prey availability', though mechanisms of response remain uncertain. Here, we provide an overview of a new project to assess stratification impacts on the role seabirds can play as indictors of epipelagic 'prey availability' in northern hemisphere large marine ecosystems relative to climate change. To examine these ideas, we present metadata associated with an updated global database on seabird productivity, and examine relationships between seabird breeding success and high-resolution thermal stratification data (European GLORYS model), as well as NASA satellite data on primary productivity (chl-a). A comparative approach with analyses yields results about how seabird breeding success varies between ecosystems, as well as by seabird life history traits, i.e. trait-mediated impacts. Results apply to which seabird species may be best suited as ecological sentinels of change in the upper oceans. In coastal pelagic ecosystems where stratification appears to be increasing the most, obtaining a better understanding of seabirds as indicators of changes in epipelagic productivity is an important research topic with significant cultural, economic, and food security implications.

POSTER BOARD ID: S10-P25
(S10-16454 Poster)

Climate-warming induced changes in fish biodiversity and ecosystem functioning in the Norwegian and Barents Sea

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Range shifts of marine species are a widespread response to climate warming. In the Arctic, one of the oceanic regions warming fastest on earth, these shifts lead to a borealisation of the community in recent years, inducing changes in the food web structure and an enrichment of the ecosystem functionality. However, the factors that determine the magnitude and direction of species shifts remain unclear, and how these changes affect the ecosystem functioning and biodiversity of Arctic and subarctic ecosystems has been rarely studied. We used standardised scientific research trawl surveys from the North Sea to the Arctic Ocean collected from 1995 to 2020, and including 173 fish species, to investigate how species shifted across the study area in the last decades, and the effect of these shifts in the community functional traits. Our results suggest more widespread shifts in the Barents than in the Norwegian Sea, higher functional changes around the polar front, and an overall increase in species richness and fish biomass parallel to the increase in sea bottom temperature in the area. These changes were mainly driven by increasing abundance of boreal and temperate species over years, and several but not all Arctic species declining.

POSTER BOARD ID: S10-P26

(S10-16462 Poster)

A decadal nationwide assessment of climate-driven species redistribution using citizen science data

Barrett W. Wolfe[1], Joshua Brown[2], Curtis Champion[3], Melinda Coleman[3], Sven Frijlink[4], Troy Gaston[5], Freddie Heather[1], Shannon Kjeldsen[6], Thomas Hatley[7], Gary Jackson[2], John Keane[1], Mark McGrouther[8], Natalie Moltschaniwskyj[3], Glenn Moore[9], Rod Pearn[4], Kate Rodda[10], Jan Strugnell[6], Jemina Stuart-Smith[1], Rick Stuart-Smith[1], Sue-Ann Watson[11], Gretta T. **Pecl**[1]

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Climate-driven changes in species' distributions can affect ecosystem function, fisheries and conservation, presenting challenges for management. Over the past decade, several citizen science programs in Australia have collected large amounts of species observations that could address gaps in our understanding of redistribution along our coasts, but these databases have not yet been systematically searched and analysed to characterise species redistributions. We used a qualitative decision tree analysis to assess potential extensions of marine species around Australia, with data from three citizen science projects: the Range Extension Database and Mapping Project (Redmap Australia); iNaturalist Australasian Fishes; and Reef Life Survey. This analysis considered historical distribution limits (as of 2012), along with species traits (e.g., migratory behaviour, detectability) and evidence provided by citizen scientists' data (e.g., possible overwintering and/or multi-year observations) to assess confidence in redistributions occurring among a list of 200 species tracked by Redmap over the past decade. We identified dozens of previously undocumented shifts (with a mean extent of 316km (max.1474km), and our findings suggest priority species and regions where targeted scientific research may be appropriate. Further, results of the assessment have been incorporated into detailed regional state-based report cards, and an A1 poster summarizing the results across the whole Australian marine estate. The report cards provide communication tools for dissemination to demonstrate the scientific value of citizen science and engage with the broader public on climate change, using their own observations.

S11: Ocean Deoxygenation: Physical, Biogeochemical and Ecological Research Advances and Future Needs

Convenors:
Natalya Gallo (Corresponding), (Department of Biological Sciences, University of Bergen and Bjerknes Center for Climate Research, Norway)
Yassir Eddebbar, (Scripps Institution of Oceanography, University of California San Diego, USA)
Marilaure Gregoire, (University of Liege, GO2NE Co-chair)
Kirsten Isensee, (IOC-UNESCO)

Plenary Speaker:
Laure Resplandy, (The Resplandy Research Group, Princeton University, USA)

Invited Speaker:
Maggie Johnson, (King Abdullah University of Science and Technology (KAUST), Saudi Arabia)

The oceanic oxygen content continues to decline due to ocean warming and coastal eutrophication, with consequences for marine species, ecosystems, fisheries and biogeochemical cycles. Research investigating this has expanded rapidly in recent years, yielding major advances in identifying the drivers and consequences of ocean deoxygenation. This session will highlight recent progress in understanding the physical and biogeochemical mechanisms of ocean deoxygenation and its ecological and economic consequences in the coastal and open ocean. It aims at identifying knowledge gaps and stimulating cross-disciplinary discussions including with social sciences. This session provides a platform to highlight recent research and activities contributing to the Global Ocean Oxygen Decade, The United Nations Decade of Ocean Science for Sustainable Development Programme, a roadmap of future ocean oxygen research needs and possible solution-based actions for the coming decade.

(S11-15991 Plenary)

Climate controls on ocean deoxygenation: compounding effects of hydrological cycle amplification and natural variability

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The ocean is unambiguously losing oxygen in response to warming. Yet, observations show an unexplained increase in oxygen concentrations in Atlantic Ocean subsurface waters, and contradictory changes in the largest oxygen minimum zones (OMZ) in the Pacific Ocean. Combining observations with ocean and Earth system models, we show that the amplification of the hydrological cycle, a response to global warming that results in a 'salty-get-saltier, fresh-get-fresher' pattern at the ocean surface, explain the observed oxygenation in the Atlantic, yielding an oxygen gain five times larger than the oxygen loss associated with other climate effects (e.g. warming, sea ice melt). In the Pacific, we show that models project a robust expansion of the OMZ in response to human activities, but a contraction of its core where oxygen levels are the lowest. We find that these changes are, however, obscured in past observations by the Pacific Decadal Oscillation, which yields natural variations in tropical Pacific oxygen content similar in magnitude to the anthropogenic trend. The tighter constraints on regional changes provided here and the attribution to anthropogenic forcing and natural variability are critical steps to improve the monitoring, forecast and mitigation of deoxygenation impacts on ecosystems and ecosystem services.

(S11-16420 Invited)

Recognizing deoxygenation as an emerging stressor on coral reefs

Maggie D. **Johnson**

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Local and global environmental change has led to the continued decline of coral reef ecosystems worldwide. The majority of global change research on reef corals has focused on the effects of warming and ocean acidification, however, emerging research indicates that deoxygenation poses an imminent threat to coral reefs. Eutrophication and climate change are leading to increasing occurrences of coastal deoxygenation events, and the resulting mass mortality of marine life threatens the persistence of these ecologically and economically valuable ecosystems. Acute deoxygenation events (also referred to as hypoxic events) have long been recognized to cause ecosystem collapse in temperate environments, but similar consequences have only recently been identified in the tropics, where the effects on coral reef ecosystems remain poorly understood. In this talk, I will present an account of an unfolding hypoxic event on a coral reef in Caribbean Panama, and detail the effects on resident organisms- including bleaching and tissue loss in virtually all corals and mass mortality of invertebrates below the hypoxic depth horizon. I will also discuss results from targeted laboratory experiments designed to identify effects of prolonged exposure to deoxygenation on key species of Caribbean reef-building corals. Although observations from the acute event in Panama provide a grim outcome for coral reefs in deoxygenated waters, results from laboratory experiments illustrate the dynamic capacity of corals to respond to oxygen depletion and the potential for coral resistance to deoxygenation.

(S11-15911 Oral)

In situ and laboratory observations of zooplankton show avoidance and changes in swimming speed in response to chemical stress

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Zooplankton, which play major roles in marine food webs and biogeochemical cycling, are increasingly impacted by hypoxia and acidification. Understanding past, present and future dynamics of zooplankton populations is challenging, in large part because traditional methods for quantifying zooplankton distributions such as ship-board net tows are costly, limited in scope, and require extended analysis by trained investigators. A combination of two rapidly-developing technologies—remotely deployed profiling camera systems and Artificial Intelligence-based identification of individual zooplankton from *in situ* imaging—promises to change the type and amount of data available to quantify zooplankton populations. To explore copepod responses to chemical stress, we used a camera system deployed in a seasonally hypoxic fjord in conjunction with detailed laboratory observations of swimming behaviors. In our laboratory experiments, copepods showed strong behavioral responses to hypoxia, and weaker but significant responses to acidification. When exposed to hypoxic (0.65 mg O^2/l) bottom waters, copepods were 20% closer to the surface, avoiding stressful conditions. Additionally, we observed a 46% decrease in swimming speed within hypoxic water and a 12% increase above hypoxic waters, potentially highlighting the mechanisms used by copepods to survive and ultimately avoid lethal oxygen conditions. When exposed to acidic (7.48 pH) bottom waters, copepods swam slower but did not move vertically to avoid them. Preliminary analysis of *in situ* behaviors indicate observable changes in swimming when exposed to simultaneous hypoxia and acidification. With advances in ocean technology, *in situ* behaviors may become useful proxies in monitoring impacts of climate change on coastal ecosystems.

(S11-15930 Oral)

Widespread hypoxia off the Pacific Northwest coast of North America: The role of shelf and shelf-deep ocean exchange processes and climate change

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Widespread, near-bottom hypoxia has become the norm over the continental shelf off the Pacific Northwest coast of North America, appearing mid to late in the summer upwelling season. Low-oxygen water is upwelled from the California Current eastern boundary current that, in turn, is connected to basin scale processes affecting the oxygen content of subsurface waters. Biological and physical processes on the continental shelf further drive near-bottom oxygen levels hypoxic and influence the spatial distribution of hypoxia. We use a variety of observational platforms, including ship-based measurements, ocean observing moorings, underwater gliders, and a novel, crab-pot based sensor deployed in collaboration with fishing partners to map, monitor and explore hypoxia off the Pacific Northwest. In summer 2021 when the summer upwelling season started unusually early and was long-lasting, these observations revealed the early onset and widespread distribution of near-bottom (within 10 m of the bottom), low-oxygen waters. Hypoxia, dissolved oxygen less than 1.4 ml/l (64 micromoles/kg), was observed over nearly 70% of the continental shelf inshore of the 200-m along nearly 900 km of coastline from 41-49°N. We describe robust spatial patterns in near-bottom hypoxic and normoxic waters relative to the continental shelf width and other prominent features of the region like the Columbia River plume and flow-topography interaction at submarine banks and capes. We explore both the seasonal evolution and the multidecadal variability of near-bottom dissolved oxygen relative to physical forcing influenced by changing climate.

(S11-15941 Oral)

Updated decadal and long term patterns of global Ocean oxygen decline using Argo data

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Recent studies suggest an ocean global long term deoxygenation likely explained by anthropogenic warming. This tendency is also observed in the climate projection, however with a large uncertainties. Ocean deoxygenation is a major concern for marine life and human resources since it manifests notoriously by expansion of hypoxic zones and displacement of habitat for major pelagic species. Yet, lack of sustained and consistently sampled dissolved oxygen measurements put a large uncertainty on global and regional ocean oxygen change, and knowledge gap are still pending on physical and biogeochemical regional oxygen variability processes. Since 2005 increasing Argo floats equipped with dissolved oxygen sensor have been deployed over the global ocean progressively populating regional basins over the last decades mainly in ocean ventilation zones of North Atlantic and Southern Ocean. This new Argo dissolved oxygen network, as part of the BGC Argo mission, provides us for the first time a regional and decadal insight over (quasi) global ocean within the first 2000 m depth. Using ISAS optimal interpolation tools, we provide updated Argo oxygen global climatologies over the last decade. Over this period, highly variable regional patterns of oxygen change are revealed at interannual scale, contrasting with the general oxygen decline over the long term. For instance, during Argo period, Southern Ocean region appears to have loss oxygen, while North Atlantic subpolar region has gain oxygen. Insight in regional variability and associated physical and biogeochemical processes will be discussed.

(S11-15976 Oral)

High-resolution, basin-scale simulations reveal the impact of intermediate zonal jets on the Atlantic oxygen minimum zones

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Intermediate, eastward zonal jets connect the oxygen-rich western boundary of the Atlantic basin with the oxygen minimum zones (OMZs) on the eastern boundary. They are not well represented in climate models because the low horizontal resolution of these models yields excessive viscosity. We use two physical-biogeochemical model configurations of the Tropical Atlantic to show that the increase in resolution results in more robust intermediate zonal jets and a better representation of the OMZs. The OMZ structure is distorted at low-resolution as surface, westward jets advect low-oxygen waters from the eastern boundary much further west than in the climatology. The emergence of robust eastward jets in the high-resolution run alleviate this problem and reproduce the Atlantic OMZs more accurately. The asymmetry between westward and eastward jets occurs because the former are associated with homogenous potential vorticity regions originating in the eastern boundary while the latter are associated with potential vorticity gradients. Intermediate, eastward jets constrain the westward expansion of the OMZs by supplying oxygen to their western edge. Within the more isotropic OMZs, higher resolution allows a better representation of the boundary current system and eddying processes at depth which redistribute of low oxygen values from the productive eastern boundary. Basin-scale, high-resolution simulations reproduce more accurately the transfer of energy across scales that results in robust zonal jets as well as their impact on the ocean biogeochemistry . Accurate model predictions provide a pathway to disentangle natural and anthropogenic causes of ocean deoxygenation.

(S11-15997 Oral)

Temperature elasticity of fish biomass: A gill oxygen limitation theory-based analysis

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Increasing water temperatures lead to tangible changes in fish biomass. Recent studies have linked these changes to deoxygenation of the waters, resulting in significant disruption of the natural habitat of all species. As a consequence, the maturation ages of fish species have shifted, bringing about earlier maturation of juveniles. This paper addresses this issue from a multidisciplinary perspective, linking biology, economics and game theory. Based on Gill-Oxygen limitation (GOTL) theory, we define the “Temperature Elasticity of Biomass”, a quantitative measure that characterizes changes in the overall biomass of a fish species with water temperature. In addition, we apply our findings to bluefin tuna, a key international species. We estimate the impact of a one degree Celsius increase in water temperature on the weight of the global catch and the associated financial loss to suppliers. Finally, as the world’s largest bluefin tuna market, we examine the implications in terms of prices and quantities traded in the local Japanese markets.

(S11-16027 Oral)

Can oxygen utilization rate be used to track long-term change of aerobic respiration in the mesopelagic zone?

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The ocean is losing oxygen due to an imbalance in oxygen supply and aerobic respiration. Therefore, monitoring the temporal changes in the aerobic respiration is essential to quantitatively understand the contribution of biogeochemical processes to oceanic oxygen change. By analyzing results from simulations of an Earth system model, we investigate whether the classical OUR (oxygen utilization rate) approach can be used to reliably diagnose changes of the respiration rate in the mesopelagic zone. OUR is calculated as the ratio of the gradients of the apparent oxygen utilization (AOU, saturated oxygen concentration minus local oxygen concentration) and seawater age that can be computed from transient abiotic tracers. Results show that in intermediate waters of the North Atlantic Subtropical Gyre (200m-1000m), vertically integrated OUR shows the same trend (decrease by around 0.2 mol $O_2/m^2/y$) as the model's vertically integrated true respiration for the time period 1850 to 2100 at a 95% confidence level. However, in our second study region, the mesopelagic Tropical South Atlantic, integrated OUR increases by 0.2 mol $O_2/m^2/y$, while the local true respiration decreases by 0.3 mol $O_2/m^2/y$, i.e. the trend in OUR is significantly different from that of true respiration (p-value << 0.0001). We identify changes in water mass mixing over time, affecting AOU and age in different ways, as one explanation for the divergence of changes in OUR and true respiration in this region. Quantitatively assessing changes in aerobic respiration from tracer measurements in a changing ocean requires accurate knowledge of changes in mixing processes.

(S11-16046 Oral)

Global impacts of warming and deoxygenation on marine species in the 21st century

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Global warming and deoxygenation have occurred over the past few decades and are projected to intensify with global warming. In addition, marine heatwaves and low O2 extremes are expected to change disproportionately. Both these mean changes and extremes have shown to have a large potential for ecological and socioeconomic impacts. The Aerobic Growth Index (AGI; Clarke et al., 2021) provides the opportunity to assess in one metric the combined impact of deoxygenation and warming on marine species at a global level. AGI is species-specific and depends on ocean temperature and partial pressure of O2. AGI quantifies habitat viability, i.e., whether the environmental state allows for the species to sustain its population and is considered detrimental whenever AGI decreases beneath its species-specific critical level (AGIcrit). We calculate habitat viability (i.e., AGI) for a total of 47 globally representative species in the epipelagic, mesopelagic and demersal realms using output from six CMIP6 Earth system models. We hereby assess the impact of mean changes on habitat volume as well as deriving driving mechanisms. We find loss of habitat viability at all depths in the ocean. Species living in a habitat with a narrow range of O2 and temperature are most vulnerable to AGI changes and experience loss of contemporary habitat of >5% at 2ºC global warming. Notably, warming explains the loss of contemporary habitat for most of the species studied. Our results show that the projected 21st century warming and deoxygenation causes local extinction in particular for vulnerable marine species.

(S11-16058 Oral)

Coastal hypoxic upwelling partly mitigates summer heat stress in a temperate benthic community

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Global change impacts marine ecosystems mainly through warming, acidification, deoxygenation, and changes in ocean nutrients. The magnitude of the impact of these stressors, however, will vary seasonally. Warming may impose the strongest threat in summer when temperatures exceed physiological optima of species. Upwelling of cooler deep water may alleviate thermal stress, although this mitigation may be modulated by associated shifts in other parameters such as late-summer hypoxia. In indoor (mechanistic) and outdoor (most-natural) mesocosm studies, we investigated the differential effects of simulated coastal upwelling events coupled with preceding marine heatwave and warming scenarios on a temperate benthic community in the Western Baltic Sea. Findings corroborated ocean warming to be beneficial in early- but most detrimental during peak summer. Yet, overall individual performance strongly depended on the intensity and duration of the heat stress experienced. The effects of early-summer upwelling in the absence of warming were generally weakly beneficial, while this effect vanished with intensifying heat stress. Hypoxia associated with the late-summer upwelling did not impair macrophytes but impacted key grazers and predators in the system. Interestingly, prior exposure to heat stress partly alleviated upwelling-induced stress effects. Thus, to assess the ecological impacts of global change, the effects of multiple interacting environmental drivers, including their fluctuations and seasonal shifts, must be tested at different levels of biological organization. We conclude that in coastal temperate communities, ocean warming is the predominant stressor that may partially be buffered by upwelling. Finally, our findings indicate a positive ecological memory imposed by successive stress events.

(S11-16098 Oral)

Association between coastal water darkening and hypoxia

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One of Earth's largest movements of biomass occurs in the oceans when small fish and crustaceans undertake diel vertical migrations (DVM) in response to daily variations in sunlight. The migration leads to active vertical transport of organic matter between surface waters and the deep sea and is a relevant component of the biological carbon pump. DVM organisms typically stay deep during the day (mesopelagic zone: 200 – 1000 m), and their daytime depth is associated with water mass light penetration (i.e., daytime depth is shallower in murky water compared to clear water). In addition, shallow daytime depths have been found to concur with hypoxia. Some suggest that DVM organisms stay shallower to avoid hypoxic water masses, while others have found that hypoxic water tends to have higher light attenuation than oxygen-rich water. Here we find, using *in situ* light and oxygen measurements in a 120 m deep west Norwegian fjord with hypoxic and anoxic water masses, that low-oxygen water has reduced light penetration compared to well- oxygenated water. Our data supports the hypothesis that there is an association between optical properties and dissolved oxygen conditions in marine waters. If our findings also apply to the oceanic oxygen minimum zones, we should expect shallower daytime depths by DVM organisms and reduced active carbon flux in these regions due to the elevated light attenuation.

(S11-16111 Oral)

Hypoxia's toxic impact: Deoxygenation tracked by total mercury concentrations in fish flesh and eye lenses

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Mercury is an environmental contaminant of concern due to health impacts on wildlife and people. Hypoxic/anoxic zones in aquatic ecosystems promote formation of methylmercury (MeHg), a potent neurotoxicant, by methylating microbial communities present there. Once formed, MeHg persists in hypoxic waters and can enter food webs. We propose that hypoxic ecosystems are thus particularly prone to accumulate MeHg. We surveyed a range of fish taxa in a system of Norwegian fjords as part of a larger study focusing on ecological effects of hypoxia. A focal deoxygenating system, Masfjorden, was compared to local normoxic fjords. Total mercury (THg) was quantified both in muscle tissue, a conventional measure of fish exposure, as well as in eye lenses, a novel tool that produces a record of lifetime mercury uptake. Fishes displayed differences in THg due to size/age and ecological position. Roundnose grenadier (*Coryphaenoides rupestris*), a benthic species of conservation concern, showed clear muscle tissue differences as predicted (Masfjord 0.44 ± 0.25 mg/kg wet weight, Sørfjord 0.12 ± 0.06 mg/kg). On the other hand, tusk (*Brosme brosme*) did not (Masfjord 0.81 ± 0.31 mg/kg vs. Fensfjord 0.91 ± 0.17 mg/kg). Lens THg was low in the interior and generally elevated in more recent layers, often showing maximum values prior to the end of life. In some taxa lens core THg was slightly elevated, suggesting maternal transfer of Hg. This study helps elucidate how deoxygenation may increase the susceptibility of vulnerable benthic and deep sea taxa to a potent pollutant.

(S11-16125 Oral)

Temporal trends and causes of deoxygenation: a comparison of the Northwest Atlantic Shelf and Atlantic Basin

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Oxygen concentrations are of fundamental importance for organisms as well as geochemical cycling in oceans. Since the middle of the 20th century, oxygen concentrations have been declining in the open ocean and the coastal ocean. Located near the crossroads of the subtropical and subpolar circulations, the northwest Atlantic Shelf is sensitive to climate variability, which has been shown to be important for oxygen variability in the region (Claret et al. year; Nguyen et al. in prep). The relative contribution of biological and physical drivers to the decline of oxygen varies regionally and with time, making it challenging to diagnose drivers of recent oxygen trends with available historical observations (Nguyen et al. in prep). Numerical models complete with biogeochemical processes that drive oxygen concentration variation can help but only if they skillfully simulate the regional variability. Here, a regional model equipped with COBALT for the Northwest Atlantic (NWA) is used to simulate the decadal trend and spatial pattern in dissolved oxygen concentrations over the shelf off the east coast of the US. Using in situ measurements from World Ocean Database (WOD), we evaluate the spatial and temporal trends in the regional model and contributors of the deoxygenation in the region on the shelf and compare them to the published rates from the Atlantic basin. Our results from *in situ* dissolved oxygen observations on the NWA Shelf, indicate oxygen is declining by 1.386±0.305 µmol/kg/year from 1988 to 2019, which is much larger than documented in the

Atlantic basin. The observed oxygen trends on the Scotian Shelf, in the Gulf of St Lawrence and on the Newfoundland Shelf are driven by changes in Apparent Oxygen Utilization, which is consistent with previously documented changes in the same water masses found in the Atlantic Basin despite the increased magnitude of the trends on the shelf quantified here. Model biases and performance will be discussed and implications for future projections presented.

S11-16234 Oral

Oxygen dynamics and predictability in the tropical and northern Pacific Ocean in CMIP6 models

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Ocean deoxygenation, i.e. the loss of oxygen from the ocean, is a direct consequence of ocean warming, with increasing water temperature reducing dissolved oxygen solubility. While the foundational processes controlling the dynamics of oxygen content in the upper Ocean are understood, how climate variability, ocean circulation and dynamical properties modulate the regional differences over decadal timescales is still under debate. Direct measurements of ocean oxygen content at high spatio-temporal resolution (i.e. monthly or higher) over decades are still lacking over extended basins with uniform coverage. This makes the unraveling of its dynamics challenging at large scales. Our work revolves around the hypothesis that the upper-ocean stratification, as measured by the isopycnic potential vorticity inventory (IPV), is a major driver of multi-decadal variability of the upper-ocean oxygen inventory of the northern Pacific Ocean because it modulates water masses distributions and ocean ventilation. Unveiling the physical linkages between oxygen and stratification dynamics opens new chances, as IPV can be easily computed by high-resolution reanalysis or physical-only models products. Using traditional statistical analysis and complexity assessment tools augmented by a dimensionality reduction and network-inference algorithm, we quantify the spatio-temporal connections between IPV and oxygen variability in the tropical and northern Pacific Ocean, in a set of CMIP6 earth-system models (EaSMs) over a 65-year period and in a reanalysis. Our results suggest that IPV exerts local and non-local modulations on oxygen predictability and dynamics, while tropical and extra-tropical relationships with the main modes of climate variability and their representation is state-of-the-art EaSMs are discussed.

(S11-16243 Oral)

Sensitivity of sill fjord basin water dissolved oxygen concentrations to freshwater nutrient loading

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Fjords are hotspots of ocean deoxygenation due to the surface waters' high productivity and reduced basin water ventilation rate. During renewal events, oxygen-rich coastal water replaces the oxygen-poor basin water. In the stagnant periods between renewals, the dissolved oxygen concentration in the basin decreases due to the remineralization of organic matter that sinks from the productive upper water column. In this work, we study the impact of varying nutrient loading due to freshwater runoff on the primary production of the fjord and the remineralization and oxygen consumption rate in the fjord basin. We use a physical-biogeochemical water column model of Masfjorden, a sill fjord in Western Norway subject to intermittent hypoxia, and realistic nutrient runoff data to explore the role of nutrients in freshwater runoff in decreasing dissolved oxygen concentrations during stagnant periods.

(S11-16253 Oral)

Increased ventilation of the Indian Ocean oxygen minimum zone sheds light on global oxygen dynamics under climate change

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Observations and Earth System Models (ESMs) agree that anthropogenic climate change is driving the global loss of oceanic oxygen via reduced oxygen solubility and ventilation. However, ESMs project that poorly ventilated regions of the ocean, where there exist oxygen minimum zones (OMZs), become better ventilated over the twenty-first century. In turn, ESMs project that the volume of lowest oxygen (suboxic; <10umol/kg) waters contracts even while the volume of hypoxic waters expands. Are the mechanisms driving increased ventilation of OMZs with global warming intrinsically tied to regions where ventilation is lowest (ie OMZ cores)? Studies of OMZ evolution in the Pacific Ocean, which dominates global trends in OMZ volume, seem to suggest that this is the case. Here, we examine this phenomenon for the unique and understudied case of the Indian Ocean OMZ, which is regulated by different regional dynamics than the Pacific Ocean OMZ (shadow zone geometry, Asian monsoon, Indian Ocean Dipole, etc). Using an ensemble of ESMs from the Coupled Model Intercomparison Project (CMIP6), we diagnose simulated twenty-first century trends in subsurface (100-1000 m) dissolved oxygen and ventilation in the Indian Ocean under a high emissions scenario (SSP5-8.5). We find that ESMs indeed project strong oxygenation within regions of the Indian Ocean OMZ. However, oxygenation is strongest in waters with much higher historical oxygen concentrations than expected (100-150 umol/kg), rather than in the OMZ core. We discuss possible regional mechanisms driving this oxygenation and implications for understanding global dissolved oxygen dynamics in a warming world.

(S11-16296 Oral)

Ocean deoxygenation may drastically constraint planktonic assemblies in highly productive coastal upwelling zones

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Ongoing ocean deoxygenation is a critical for marine organisms globally. In eastern boundary upwelling systems (EBUS), planktonic copepods dominate the zooplankton biomass, and they are crucial for the food webs. Copepods must cope with increasing hypoxia in the photic zone caused by shoaling of a shallow oxygen minimum zone (OMZ). We tested the effect of hypoxia on three abundant copepod species from the EBUS of central-southern Chile, *Calanoides patagoniensis*, *Paracalanus* cf. *indicus* and *Acartia tonsa*. The metabolic rate (MR) and the critical oxygen tension (P_{crit}) were estimated for the three species at different seasonal conditions (2019-2020). For all species and conditions, MR was in the range of 11.2-44.4 µmol O_2 µg C^{-1} h^{-1}, while P_{crit} ranged between 2.2 Kpa and 5.5 Kpa. MR and P_{crit} significantly increased during the upwelling season (spring-summer), whereas MR differed among species, but P_{crit} did not. P_{crit}'s were contrasted with oxygen conditions of the water column during 2002-2020 at Station 18 over the continental shelf. Oxygen levels equal or lower than P_{crit} appeared as a common condition (ca. 70% of occurrence) that copepods encounter during the year in the photic zone. Increasing P_{crit} during the upwelling season, under a shallower OMZ, reflects a lack of metabolic adjustment or adaptation to hypoxia, suggesting that ocean deoxygenation and increased upwelling can have a strong impact on copepod mortality and their population dynamics in EBUS.

(S11-16352 Oral)

Canaries in the Baltic Sea "coal mine": Fish otoliths document accelerating climate impacts

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Spreading global deoxygenation affects marine environments with potentially detrimental consequences for fish and other aquatic organisms. In the Baltic Sea, accelerating climate change and anthropogenic hypoxia have resulted in major declines in aquatic habitat quality, negatively impacting biodiversity and ecosystem services. Here, demersal Baltic cod (*Gadus morhua*) serve as "canaries in the coal mine." We used microchemical tracers in cod otoliths to provide a historical perspective and track changes in hypoxia, salinity, fish metabolic status and growth, comparing Stone Age baseline conditions to the period 1927-2018. The chemical proxy for hypoxia exposure (Mn:Mg) increased with intensifying anoxia and hypoxia and decreased during major Baltic inflows. Changes in migration behavior over time was documented by Sr:Ca. The proxy for metabolic status (Mg:Ca) increased with higher dissolved oxygen percent saturation and peaked during the 1980s and 1990s, but declined severely from 2010. The predicted mean length at age showed highest growth in the 1990s and thereafter a dramatic decline in the 2010s. This historic record provides further evidence of a profound state change in dissolved oxygen in the Baltic Sea, creating the largest dead zone in the world and affecting the biology of the Baltic cod over time. Otolith chemical proxies provide detailed life history information for individual fish, reflecting biogeochemical processes and physiological responses. These useful biomarkers are important tools to reconstruct marine environmental changes and forecast future impacts on threatened fish populations.

(S11-16364 Oral)

On the evolution of stratification and oxygen conditions along the west African continental shelf during the last three decades.

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Climate change is expected to result in a reduction of oceanic oxygen concentration and increased stratification in the tropical ocean. In West Africa rich fisheries are essential for supporting the livelihood of coastal populations. Anticipating and mitigating effects of expanding hypoxic conditions and stronger stratification (hence less upwelling) in the fishable coastal shelf waters is a societal necessity. Here, we present an evolution of stratification and oxygen conditions in the coastal fringe off West Africa between 25°N and 25°S using collected during regular fisheries monitoring surveys on board the RV Dr Fridtjof Nansen since 1980s, through the

EAF Nansen Program (FAO and Norway). During these surveys, environmental scientists representing regional research fisheries institutes carried out oceanographic observations within their respective exclusive economic zones (EEZ). In this presentation, we show a summary from these observations - the evolution of the mean and extreme stratification and oxygen conditions in the coastal fringe along West African continental boundary and discuss potential impacts of the observed trends on local ecosystems and fisheries.

(S11-16379 Oral)

Hypoxia-induced trophic decoupling across multiple habitats and consumers within a large, coastal ecosystem

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Chesapeake Bay is a large, highly productive estuary that supports a range of critical ecosystem services. In part because of this productivity, many deeper areas in Chesapeake Bay experience seasonal hypoxia or anoxia. Like many coastal ecosystems, Chesapeake Bay food webs are highly reliant on pelagic and benthic sources of organic matter and the trophic linkages that serve as pathways integrating these disparate sources within the larger food web. Here, I present results from two recent studies aimed at understanding if and how hypoxia disrupts these trophic linkages in different habitats and for ecologically and taxonomically dissimilar consumers. The first study focused on white perch (*Morone americana*) inhabiting a network of subestuaries within the highly urbanized cityscape of Baltimore, MD, part of the Patapsco River tributary. The second study was focused on a species of mysid (*Neomysis americana*) collected in the Patuxent and Choptank rivers, two tributaries with watersheds dominated by suburban and rural land uses. In both studies, our research teams found reduced contribution of benthic trophic pathways in the presence of hypoxia, regardless of taxon or habitat. In the urbanized Patapsco River, biomarkers of benthic contribution and a proxy for trophic niche width both declined in hypoxia-prone subestuaries. In the second study, estimates of benthic contribution and a tissue proxy for lipid content again declined for mysids in the Patuxent River which experiences recurring seasonal hypoxia. Together, these studies provide empirical evidence for the pervasive, sub-lethal impacts of hypoxia on the trophic linkages supporting productivity in coastal ecosystems.

(S11-16422 Oral)

Using Argo data to improve oxygen projections in ecosystem models

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Biological processes are a key factor affecting the oxygen budget in marine environments and consequently, its representation in models is vital for better understanding and predicting future changes. Here, we present a framework that links in situ observations from the biogeochemical-Argo array to biogeochemical models. With this framework, we utilize the physical and biogeochemical dataset from the Argo array to identify potential sources of model errors and to improve and validate model configurations. Improved model configurations can then be employed in 3D models with a range of applications from regional to global operational and climate scale models. With this framework, we build simulations along the biogeochemical-Argo trajectories, imitating the observed physical conditions along the track. This approach enables us to focus on the biogeochemical model formulations and parameterizations. In this presentation, we will focus on a range of biogeochemical Argo floats in the Nordic Seas and describe how we can utilize the Argo data to assess and improve the configuration of biological processes affecting modelled oxygen concentrations. We will showcase how effective the Argo array can be for model improvement and validation. The framework we present is built in a water-column (1D) structure and our ultimate goal is to improve the 3D model configurations that are currently underestimating the oxygen decline trend in the oceans.

(S11-16443 Oral)

Sources and variability of oxygen supply in the upper equatorial Pacific: insights from high resolution models

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The structure and volume of the Oxygen Minimum Zones (OMZ) exert major controls on the ecology and biogeochemistry of the tropical Pacific. These OMZs are subject to large variability from subseasonal to multidecadal timescales, challenging the attribution and detection of ocean deoxygenation in the tropics, particularly in the upper equatorial Pacific where ocean circulation is highly energetic and air-sea interactions and variability are pronounced. This variability, in turn, offers a unique and observable opportunity for identifying processes governing the OMZ structure and testing model performance. Using an eddy resolving simulation of the Community Earth System Model (CESM) and an ocean state estimate of the Tropical Pacific (TPOSE), we examine processes governing the variability of oxygen supply into the upper equatorial Pacific from seasonal to interannual timescales. An analysis of the simulated oxygen budget reveals complex and seasonally varying roles of advection and mixing in balancing oxygen consumption in the thermocline. Variability in advection by the Equatorial Undercurrent and Tsuchiya jets dominate the seasonal supply of oxygen in this region, with important contributions from seasonally-dependent eddy-induced advection and turbulent mixing from the mixed layer. These advective and mixing processes are further explored in the context of interannual variability and ENSO effects on oxygen distribution and supply.

(S11-16463 Oral)

Drivers of regional deoxygenation periods in the Northern Humboldt Current System during the late nineteenth century

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In the Northern Humboldt Current System (NHCS), at interannual time-scales, the subsurface oxygen content decreases mainly due to the shoaling of the thermocline depth along the Equatorial Pacific and reduced oxygen supply to the region by the eastward equatorial currents, e.g. La Niña conditions. Nevertheless, on a year basis, enhanced subsurface oxygen depletion nearshore occurs in summer, when alongshore winds are weaker and primary productivity is higher, but also in spring, when coastal upwelling is stronger. Sedimentary multiproxy studies from the NHCS have evidenced a 20 to 30-year period around the 1870s characterized by the occurrence of prolonged periods of strong water column deoxygenation and bottom anoxia. These regional events were associated with massive diatom-rich fluxes, suggesting that they were associated to the decay of phytodetrital organic matter. In order to elucidate the drivers and mechanisms involved, we compared the proxy records with re-analysis data of SST (HadISST) and winds in the Tropical Pacific (NOAA/CIRES/DOE 20th Century Reanalysis) and other climatic records and indices. Predominant La Niña conditions characterized the Central Equatorial Pacific until the very strong 1877-1878 El Niño, but in the same period warmer SSTs were observed in the Tropical South Eastern Pacific (TSEP), especially between 10 and 25 °S. In addition, the warmer conditions in the TSEP, which prevailed until the early 1890s, occurred along weaker than normal alongshore winds in the same region. Thus, regionally-forced water thermal stratification, followed by algal blooms and enhanced oxygen consumption, likely played a major role in driving the deoxygenation periods.

While La Niña conditions promote thermocline shoaling in the region (recorded as cooling U^{K}_{37}-NSTs), warmer SSTs could be explained by weaker alongshore winds, thus implying a decoupling between Walker circulation and Southeast trade winds in the NHCS. However, with a shallow thermocline, moderate winds in spring would be enough to force upwelling and related diatom blooms. Under warmer mean conditions, such as after the 1870s off central Peru, blooms of oceanic microflora would be favored, as were observed in diatom composition.

POSTER BOARD ID: S11-P1

(S11-15803 Poster)

Elevated air-sea exchanges of biogenic volatile organic compounds (BVOCs) over the Arabian Sea (OMZ) in pre-monsoon season: Role of biogeochemical cycle

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The northern Indian Ocean is one of the most biologically productive ocean regimes and possesses a perennially intense oxygen minimum zone (OMZ). High biological productivity can potentially modify the production and sea-air exchange of trace gases including volatile organic compounds (VOCs). We measured concentrations of isoprene, ethane, ethene, propane, propene, 1-butene, cis-2-butene, and 1-pentene in the marine air and characterized phytoplankton species in seawater of the Arabian Sea during a cruise campaign onboard *Sagar Sampada*#19 from April-May 2017. Northern tropical Indian Ocean is expected to be a strong source of many BVOCs due to relatively high productivity (phytoplankton) where studies of air-sea exchanges are scarce. The concentrations of BVOCs were measured using a thermal desorption-gas chromatography with a flame ionization detector (TD-GC-FID) instrument. The major enhancements of isoprene (>0.6 ppbv) over the Arabian Sea were associated with the blooms of *Trichodesmium* and *Thalassiosira* in oligotrophic conditions. The large gradient and heterogeneity in fluxes of BVOCs could be mainly controlled by the distribution of DOCs in the pre-monsoon season. Consistent with the distribution of isoprene concentration, the satellite-based ocean color map (chlorophyll concentration) shows much higher productivity in coastal regions than in open oceanic regions. Spatio-temporal variation of BVOC is consistent with the high primary production, which could cause low surface pCO_2 and higher DOCs observed over the Arabian Sea. This result is important for further understanding different processes controlling the oceanic emissions of BVOCs from the OMZ of the tropical Indian Ocean.

POSTER BOARD ID: S11-P2

(S11-15846 Poster)

Hypoxia in a tropical estuary

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Climate change-driven hypoxia is an increasing phenomenon occurring in coastal and estuarine waters with a great impact on broad socioeconomic and environmental spheres such as marine and coastal ecosystems, fisheries, tourism, food safety and even human health, among many others. However, this is poorly documented in estuaries of Colombia due to the lack of systematic data collection and the availability of observed data to establish historical changes in dissolved oxygen. Here we used 10 years of observed data (2001-2011) to report for the first time the unprecedented occurrence of hypoxia in the widespread estuaries (i,e Gulf of Urabá) located in the southwest Caribbean Sea, Colombia (South America). We believe that it is urgent to continue making measurements in this field and help take action measures for future years in a changing world.

POSTER BOARD ID: S11-P3

(S11-15880 Poster)

Deoxygenation of the southwestern margin of Baja California Peninsula: A foraminiferal-based record of last 5 kyr

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The zones of minimum oxygen (OMZ) are characterized by a concentration of dissolved oxygen (DO) <0.5 ml L^{-1}. In situ measurements of DO concentration suggest that the upper boundary of the OMZ is shallower than it was 60 years ago on a global scale, due to global warming. Numerous investigations have allowed us to understand how global warming can cause changes in the OMZ in the future. However, predictions of future changes in the OMZ require understanding of its past spatial and temporal variability. Benthic Foraminifera (BF) associations have been widely used in paleoceanographic investigations because these microorganisms have an extensive global distribution. Based on BF associations, a classification of oxygenation levels in the benthic environment has been established throughout the Northeast Pacific. The present research aims to analyze the diversity indices of BFs to infer the concentration of DO in the southwestern margin of Baja California Sur during the last 5000 years. The following methodology will be used: quantification of the percentages of disoxic, hypoxic and oxic foraminifera; calculate the FB association index and estimate the OD concentration, under the assumption that in the warm periods of the Holocene would expect to find FB associations indicative of severe hypoxic conditions and in the cold periods FB associations that suggest oxic conditions. These expected results will be contrasted with geochemical tracers, trace elements that corroborate severe hypoxic conditions in the Holocene Climatic Optimum and Medieval Warming, and oxic conditions in the Dark Age and Little Ice Age.

POSTER BOARD ID: S11-P4

(S11-15885 Poster)

Climate change and the de-oxygenation of Norwegian sill fjords

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How often the basin water is renewed, the renewal frequency, depends on how fast diffusion and mixing cause the density in the basin to decrease and on the variability of the density in the ambient ocean. Here we use 1) a statistical approach and b) idealized modelling to show that the negative trend in density anomalies that is observed along most of the Norwegian coast since 1990 is likely to have reduced the renewal frequency and increased the length of the stagnation periods in many Norwegian fjords.

Using the well-visited Masjorden in western Norway as a case study, we show that the reduced renewals frequency leads to a negative trend in the oxygenation of the basin water.

POSTER BOARD ID: S11-P5
(S11-15924 Poster)

Hypoxia and ocean acidification alter organic carbon fluxes in marine soft sediments

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Anthropogenic stressors, such as hypoxia and ocean acidification (OA), can alter the structure and functioning of infaunal communities, which are key drivers of the carbon cycle in marine soft sediments. Nonetheless, the compounded effects of anthropogenic stressors on carbon fluxes in soft benthic systems remain largely unknown. Here, we investigated the cumulative effects of seabed hypoxia and OA on the organic carbon fate in marine sediments, through a mesocosm experiment. Isotopically labelled macroalgal detritus (^{13}C) was used as a tracer to assess carbon incorporation in faunal tissue and in sediments under different experimental conditions. In addition, labelled macroalgae (^{13}C), previously exposed to elevated CO_2, were also used to assess the organic carbon uptake by fauna and sediments, when both sources and consumers were exposed to elevated CO_2. At elevated CO_2, infauna increased the uptake of carbon, likely as compensatory response to the higher energetic costs faced under adverse environmental conditions. By contrast, there was no increase in carbon uptake by fauna exposed to both stressors in combination, indicating that even a short-term hypoxia may weaken the ability of marine invertebrates to withstand other stressors, such as OA. In addition, both hypoxia and OA increased organic carbon burial in the sediment, potentially affecting sediment biogeochemical processes. Since oceanic hypoxic events and OA are predicted to increase under climate change, our results suggest that local reduction of hypoxic events may mitigate the impacts of global climate change on marine soft-sediment systems.

POSTER BOARD ID: S11-P6
(S11-15943 Poster)

Mediterranean Sea marine ecosystems during the 21st century: a first-of-its-kind study using eddy resolving projections under RCP4.5 and RCP8.5 emission scenarios

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The temporal evolution of several essential ocean/ecosystem variables of the Mediterranean Sea in the middle and at the end of 21st century is assessed by using eddy resolving projections of the biogeochemical state of the basin under the Representative Concentration Pathways (RCP) 4.5 and 8.5. The projections have been produced using an offline coupling between a physical model (MFS16) and a transport-reaction model (OGSTM-BFM). Scenario projections show significant changes of the dissolved nutrient content in the euphotic and intermediate layers as well as in net primary production, phytoplankton respiration and carbon stock. Moreover, an almost spatially uniform surface and subsurface reduction of the oxygen concentration and an increase of acidification occurs as a response to the warming of the seawater and the increase in ecosystem respiration and CO_2 absorption from the atmosphere. The magnitude of projected changes is found to be stronger under RCP8.5 (worst-case) scenario and in the

Eastern Mediterranean due to the limited influence of the exchanges at the Strait of Gibraltar Moreover, the use of an eddy resolving resolution allows to detect different responses between the coastal and open ocean areas with the latter showing the largest impacts. Projections under RCP4.5 emission scenario shows, after the first half of the 21st century, a tendency for several variables to recover the levels observed at the beginning of the century. This result supports the idea that significant reduction of CO_2 emission could be, indeed, effective and could contribute to the foundation of ocean sustainability science and policies.

POSTER BOARD ID: S11-P7

(S11-15969 Poster)

In-situ datasets of important physical and bio-chemical parameters in the continental shelf of the northern Bay of Bengal

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Data equipped with this article were collected from Northern Bay of Bengal (NBoB) wrapping both the eastern and western coast for CTD and sediment samples and only the eastern coast for water sampling. In-situ data of physical parameters, heavy metals, elements, Total Organic Carbon (TOC), nutrients, chlorophyll-a and phaeopigment were sampled across the shallow continental shelf. These data were assembled from 15 CTD points, 76 water samples, and 10 surface sediment samples adjacent to Bangladesh coast. Vertical CTD profiles were collected for Temperature (°C), Salinity (PSU), Density (kg^{-3}), Turbidity (NTU), Fluorescence (mg m^{-3}), and Dissolved Oxygen (DO, mg/l). Heavy metals (mg/l) of water column enlisted as Calcium (Ca), Cadmium (Cd), Copper (Cu), Cobalt (Co), Iron (Fe), Manganese (Mn), Magnesium (Mg), Nickel (Ni), Lead (Pb), and Zinc (Zn). Total Organic Carbon (TOC) was measured as Non-Purgeable Organic Carbon (NPOC) in ppm. Measurements of Chlorophyll-a, Nitrate, Nitrite, Phosphate, Ammonia, Silica and Phaeopigment were taken from 76 water sampling points. The survey was conducted with the assistance of a fishing vessel 'Agro food-4 'of 'Sea Resource Ltd.' lengthening a fishing period from January to February (in winter), 2016. SBE 19 plus V2 CTD machine was deployed for sampling of vertical physical features, Niskin sampler of HYDRO-BIOS consisting of a non-metallic interior was used to collect water sample. Sediment was collected by Van Veen Grab sampler with built-in messenger. Water samples were analyzed following the standard procedure in the laboratory to access in-situ data. The shallow coastal and offshore regions of Bangladesh support for vast biological resources to its adjacent inhabitants. Therefore, understanding the influence of physico-chemical properties on other biological resources in coastal ecosystem is a crucial one to investigate. However, the shelf region of the BoB has a lack of in-situ baseline or reference data to compare with in terms of ocean biogeochemistry. Thus, these datasets can be utilized for further reference and also in validating other remotely-sensed physico-chemical parameters in this region.

POSTER BOARD ID: S11-P8
(S11-16126 Poster)

Mapping of deoxygenation trend in the subsurface waters of the East China Sea

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Several studies have reported a deoxygenation trend in the East China Sea (ECS), but most of the deoxygenation signal was detected in the continental shelf areas along the Chinese coasts. Ono [2021], however, detected a rapid decrease of oxygen in the Tsushima Strait, the eastern area of the ECS, suggesting that deoxygenation had actually been occurring in a wide area within this sea. To capture the exact distribution of deoxygenated area in the ECS, historical oxygen data recorded after 1950 in World Ocean Database 2018 were extracted from the whole area of the ECS. The ECS was then divided to 29 subareas, and temporal variation of oxygen as well as related hydrographic properties were investigated in each subarea. A significant decreasing trend in oxygen was detected in the latitudinal bands from 30° N to 34.5°N in summer time, which roughly corresponds to the area of the seasonal occupation of low-salinity Changjiang diluted water. Vertically, the deoxygenation signal showed two peaks, one located just above the seafloor while the other peak was located at 30m - 50m. Detailed analyses indicated that the lower deoxygenation peak was constructed by the enhanced decomposition of organic materials that was provided by the increased primary production along the Chinese coast (Ning et al., 2011), while the shallower peak has been generated by the upward shift of the pycnocline caused by the ocean warming. The present study suggests that the ECS is now facing a hybrid effect of “ocean deoxygenation” and “coastal deoxygenation,” and hence international cooperation is needed to cope with socio-economic problems arising from this phenomenon.

POSTER BOARD ID: S11-P9
(S11-16208 Poster)

REVISION: Authors: Helmut Maske, Andreas M. Thurnherr, Aurelien Paulmier, Chris Langdon and Cesar O. Almeda

Below mesopelagic oxygen deficit layers: gradients of particle acoustic backscattering and oxygen.

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We compared acoustic backscatter profiles obtained by lowered ADCPs below mesopelagic oxygen deficit layers (ODL) in different regions. Assuming that the acoustic volume backscatter is proportional to live zooplankton concentration, we find recurrent patterns. The zooplankton shows a well-defined peak below the lower oxycline of the ODL. In part of the profiles, the population is reaching a maximum at oxygen concentrations of a few mmol/L, whereas in other profiles, the maximum backscatter is found at higher concentration but still less than 10 mmol/L. Below the backscatter maximum, the profile exponentially decreases. We assume the zooplankton biomass is maintained by organic particle flux if there is no vertical migration of zooplankton. Thus, there should be proportionality between acoustic backscatter and the organic particle flux at a given depth. We expect that the attenuation length of the backscatter profiles should be comparable to the remineralization length of the organic particle flux. In particular, we found shorter remineralization length below the ODL than in oxic water columns in similar ecoregions.

POSTER BOARD ID: S11-P10
(S11-16216 Poster)

Potential distribution of *Lutjanus guttatus* (Steindachner, 1869) under climate change scenarios in the Eastern Tropical Pacific

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Lutjanus guttatus represents an important resource for the economic and gastronomic value in the Eastern Tropical Pacific. Our study aims to analyze the potential distribution of *L. guttatus*, under the effect of different climate change scenarios in the ETP. The occurrences of *L. guttatus* was obtained from field data and open access sources, following by the oceanographic variables according to CMIP6. Our analyses were carried out using Boosted Regression Trees (BRT). Future projections were analyzed for mid-century (2040-2069) and end-of-century (2070-2099) under the scenarios of SSP2-4.5 and SSP5-8.5. Distribution models were executed for the dry season (January-April) and rainy season (June-September). The results suggest suitable habitat for *L. guttatus* includes areas with medium roughness (> 200cm), SST between 25°C-30°C, and depths lower than 50 meters. As for the results of the historical modelling (1981-2010), temporal differences are observed between dry and rainy season, with greater occurrence between latitudes 0°N to 20°N during dry season, and the expansion in its distribution pattern to the north during rainy season. Potential distribution models suggest the specie will move to higher latitudes in response to optimal temperature conditions. The change in distribution suggests greater negative impacts under the SPP5-8.5 scenario at the end of the century compared to the SSP2-4.5 model.

POSTER BOARD ID: S11-P11
(S11-16260 Poster)

Behavioural response to hypoxia in Trinidadian guppy (*Poecilia reticulata*)

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In densely vegetated aquatic environments oxygen availability can fluctuate daily, reaching low levels towards dawn. It is hypothesized that this creates an important ecological trade-off for its inhabitants, as habitats like these can provide shelter and serve as nursery grounds. The effect of hypoxia on fish may include neurological and physiological disruptions which could be reflected behaviourally. Here we investigated whether hypoxia impairs the senses of fish, and how hypoxia may affect energetically costly processes such as activity. Using the Trinidadian guppy (*Poecilia reticulata*) as a model organism, 96 individuals were tagged and distributed amongst 12 tanks. Half the tanks experienced daily hypoxic fluctuations, mimicking conditions the fish experience in the wild. The other six served as control tanks which were held under normoxic conditions. After two weeks of acclimation to these conditions we measured activity, and startle response in all fish under normoxia, acute hypoxia and during recovery from hypoxia. We predicted a reduced activity and longer response times when fish were subjected to acute stimuli due to reduced energy available and impaired senses. Lastly, previous acclimation to hypoxia may result in physiological adjustments which lead to improved performance such as higher activity and shorter response times.

POSTER BOARD ID: S11-P12
(S11-16274 Poster)

Multiyear oxygen variability in source water contributions to the California Current System

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The California Current System represents a confluence of different water masses originating in the subarctic, subtropical, and tropical eastern Pacific. Variations in their relative influence can alter regional biogeochemistry and ecosystem structure. Here, we use global physical and biogeochemical ocean hindcast products to perform an Optimum Multiparameter (OMP) analysis, which quantifies the spatiotemporal variability of water mass contributions to the California Current (CC). Within the CC domain, we focus on spatial and temporal variability of three source waters: the Pacific Subarctic Upper Water (PSUW), Eastern North Pacific Central Water (ENPCW), and the Pacific Equatorial Water (PEW) and their effect on the oxygen spatiotemporal variability. We will explore the drivers and pathways of oxygen variability in this region and quantify regionally heterogeneous impacts driven by oceanic changes occurring far afield.

POSTER BOARD ID: S11-P13 Revision: Poster **CANCELLED**
(S11-16334 Poster)

Environmental drivers of mesopelagic fish assemblages in the Benguela and Canary Current Upwelling Systems

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Mesopelagic fishes play a vital role in the transport of organic matter between the epipelagic and mesopelagic layer when performing diel vertical migrations. The mesopelagic realm, between 200-100 m, is often low in oxygen due to low primary productivity but high rates of respiration, especially in eastern boundary upwelling systems. We examined the assemblage structure of mesopelagic fishes in the northern (nBUS) and southern (SBUS) subsystems Benguela Upwelling Systems and the Mauritanian-Senegalese subregion (MS) of the Canary Current as well as the environmental factors that drove species composition. While the sBUS is high in oxygen concentration throughout the water column, Both the nBUS and MS are known for their oxygen minimum zones. Community composition differed between the nBUS and sBUS as well as between stations on the shelf and offshore. The dominant species in the MS was *Cyclothone* spp. which is known to be well adapted to low oxygen concentrations. Environmental factors that were responsible for community composition were mixed layer

depth and oxygen concentration at 600 m and near the surface in MS and water mass, oxygen concentration at the surface and chlorophyll concentration between 50 and 100 m in the Benguela. Because oxygen was a main driver in both systems and the oxygen minimum zones are expanding in the world's oceans, it is of high importance to gather baseline data on understudied mesopelagic fish assemblages, before these resources become exploited.

POSTER BOARD ID: S11-P14

(S11-16339 Poster)

Oxygen variability from a reanalysis of the Mediterranean Sea biogeochemistry: is there evidence for deoxygenation?

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Oxygen dynamics in the semi-permanently stratified Mediterranean Sea include a summer subsurface oxygen maximum (SOM), an oxygen minimum layer between 300 and 1000 m, shallowing westward, and winter deep maxima in the areas characterized by deep water formation. The Copernicus reanalysis of the Mediterranean Sea biogeochemistry provides an overview of oxygen variability in the last two decades, together with a valuable insight on interconnected physical-biogeochemical processes at a relatively high horizontal resolution (1/24°) and at the sub-weekly frequency. On the long-term scale, the reanalysis shows a small but significant deoxygenation at surface in large part of the basin. The estimated value of such a trend is within the range -0.05 ÷ -0.1 mmolO_2 m^{-3} y^{-1}, which is compatible with the oxygen solubility decrease due to the observed increase in sea surface temperature. On the other hand, in the subsurface layers we do not observe a clear signal of decreasing oxygen. In particular, the SOM shows a mesoscale spatial variability with concentration and depth in the range 230 ÷ 250 mmolO_2 m^{-3} and 30 ÷ 100 m, respectively, but negligible interannual variability and trends. Finally, a study conducted by integrating BGC-Argo profiles with the reanalysis in a winter deep convection area (i.e., southern Adriatic Sea) highlighted that the oxygen long-term variability is affected by shorter term signals. For instance, lower oxygen concentrations along the water column were detected in the area after 2019 and associated with modifications in water mass formation and transport.

POSTER BOARD ID: S11-P15

(S11-16342 Poster)

Scaling deoxygenation impacts from individual fish activity and metabolism

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Projections place the decline in the global ocean dissolved oxygen inventory at 1 to 7% by 2100, threatening marine community structure, species distributions, and nutrient cycling. Previous studies have used species assemblages to mechanistically predict the physiological and biogeographical effects of ocean deoxygenation. However, this limits predictions to species whose hypoxic tolerance has been characterized in relation to temperature and oxygen concentration. Our study establishes a systematic metabolic relationship between oxygen demand and traits associated with functional fish guilds across species. This will allow us to assess size-at-age, reproduction, and activity in a warming, deoxygenating seascape. We aim to scale these individual oxygen budgets to a global size- and trait-based fish community model to resolve the emergent biogeography and community structure under ocean deoxygenation projections. We expect the results to show ocean deoxygenation reduces average individual size and compresses available habitat in the global upper ocean and polar regions.

POSTER BOARD ID: S11-P16

(S11-16349 Poster)

Regional variations of myctophids in the Western Indian Ocean with oxygen concentrations

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The oxygen minimum zones in the Western Indian Ocean (WIO) experiences three dominant seasons, the summer monsoon (SM) from June to October Fall inter monsoon (FIM) in October is also considered as SM, Winter Monsoon (WM) season from November to end of February, interspaced by Spring Inter monsoon from March to end MAY. Myctophid species assemblages of eco-region in the present study are best explained by tolerance range of species to low oxygen levels. According to the assemblages the WIO is divided in to North Eastern Arabian Sea (NEAS), South Eastern Arabian Sea and Western Equatorial Indian Ocean (WEIO). WEIO assemblages are characterised by species assemblage that need higher DO, whereas the assemblage of SEAS is dominated by species that can tolerate intermediate levels of Dissolve Oxygen (DO) as compared to WEIO & NEAS. NEAS on the other hand is occupied by species that tolerates very low DO levels. Dissolve Oxygen levels in the 500m depths of WEIO was higher than Oxygen minimum zone during all seasons, whereas in the SEAS suboxic conditions occur during the SM & FIM seasons. Intermediate depths of NEAS have perennial suboxic conditions. Data collected in the course of the present study clearly depict seasonal and regional variations in the environmental variables especially the DO and density. Sub surface DO levels are high in the WEIO and show a decreasing trend towards north.

POSTER BOARD ID: S11-P17
(S11-16369 Poster)

Life in a swiftly-changing world: growth and life history of the glacier lanternfish (*Benthosema glaciale*) and Mueller's pearlside (*Maurolicus muelleri*) in West Norwegian fjords

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Worldwide, hypoxia has been linked to shifts in the composition of ecological communities, change of migration patterns, life-cycle disruptions and reduced growth. Increased stratification due to multidecadal warming of the North Atlantic Ocean has caused reduced ventilation – and subsequent deoxygenation – of the mesopelagic zone in Masfjorden, a fjord in western Norway. Despite its ecological importance, the mesopelagic domain is one of the most understudied marine regions in the world. Using Norwegian fjords as natural infrastructure this work aims to assess whether low-oxygen conditions affect growth, recruitment and distribution of two of the most abundant mesopelagic fish species in the North Atlantic, *Benthosema glaciale* and *Maurolicus muelleri*. Environmental data and biological samples were collected at fixed depth intervals over several years in Masfjorden (before, during, and after hypoxia) and in other fjords with different oxygen levels. Growth differences between areas will be tested by comparing von Bertalanffy growth models, and otolith increments will be modelled as a function of environmental variables such as oxygen, temperature, salinity, and food availability. Recruitment, based on cohort analysis, will be estimated separately for each fjord. Ocean warming and oxygen loss are pressing concerns in coastal areas. Fjords, as semi-enclosed systems prone to rapid and intense oscillations in their physical parameters, provide a unique environment to study the effect of climate change on biological populations. Although highly abundant mesopelagic fish are regarded as a potential food resource for the future, their susceptibility to global change is yet to be assessed.

POSTER BOARD ID: S11-P18
(S11-16432 Poster)

Analysis of climate-driven physical-biogeochemical processes in key regions of the tropical and south Atlantic using the NorCPM

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Climate-induced changes in oceanic biogeochemical variables in the tropical and southern Atlantic (TSA) are analyzed using numerical-modeling simulations from the Norwegian Climate Prediction Model (NorCPM) which includes a coupled version of the Hamburg Ocean Carbon Cycle Model (HAMOCC). Key areas within the TSA, characterized by enhanced biological productivity, are analyzed individually to understand what physical-biogeochemical processes are primarily responsible for such enhanced biological levels, from observation-based datasets. The existence of the identified leading processes is corroborated in the NorCPM simulations, as well as their corresponding role in the local modeled biogeochemical variables, in order to determine the model's capability to reproduce the frequency and biological importance of those processes, even if their time of occurrence is not reproduced accurately. These results provide better criteria for climate-change projections of the biogeochemical conditions in the study area.

POSTER BOARD ID: S11-P19
(S11-16294 Poster)

Changing marine habitat viability under warming and deoxygenation

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Ocean warming is shifting the boundaries of species distributions, causing contractions of the warm range limits, and expansions of the cool range limits. The Aerobic Growth Index (AGI) projects habitat loss along the warm boundary of a species' distribution by integrating metabolic theory, growth theory and biogeography. Specifically, AGI represents the process by which ocean warming can increase a species metabolic oxygen demand above what is supplied in the environment, rendering the habitat unviable. Here, we present a new iteration of the AGI that is also able to model habitat expansions, by representing elevated rates of protein denaturation in both extreme cold and warm waters. Specifically, we assume that protein denaturation causes higher catabolic rates at both cooler and warmer temperatures, thereby increasing the metabolic rate required for body maintenance above what may be supplied in the environment. Using the original and new iteration of the Aerobic Growth Index, we project habitat losses and habitat expansions for 880 species of commercial fisheries importance, under a 1.5 ºC, 2.6 ºC, 3.5 ºC warmer world. We expect the utility of this new iteration of the AGI to be two-fold: 1) it may be used to gain insights into the mechanisms limiting marine ectothermic species distributions, 2) it may be used to support climate mitigation and adaptation in data poor contexts.

S12: Improving pathways for delivery of multi-disciplinary ocean observations into marine assessments across multiple scales

Convenors:
Karen Evans (Corresponding), (Commonwealth Scientific Industrial Research Organisation (CSIRO))
Gabrielle Canonico, (NOAA,USA)
Indiah Hodgson-Johnston, (Australia)
Jörn Schmidt, (ICES)

Invited Speakers:
Michelle Heupel, (Integrated Marine Observing System (IMOS), Australia)
Adam Martiny, (Earth System Science & Ecology and Evolutionary Biology, University of California, USA)
Patricia Miloslavich, (Scientific Committee on Oceanic Research (SCOR))

Central to being able to provide comprehensive assessments of change in the marine environment are two components. First, is the utilisation of multidisciplinary ocean observations for assessing marine environments comprehensively to establish their state and responses, including ongoing trends. Second, is the interpretation of multidisciplinary observations and associated products to provide information that can be utilised and applied to address management and policy needs. This session will discuss current and developing pathways, priority needs and future work for improving linkages between observation systems and decision making through the delivery of multidisciplinary ocean observations into marine assessments at multiple scales. Strategic topics addressed:

- Indicator-based frameworks for detecting and responding to climate impacts on ocean ecosystems
- Valuation and non-economic assessment of ecosystem services
- Data mobilisation and accessibility challenges and solutions

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(S12-15915 Invited)

From data to decisions: applying ocean observing to deliver benefit

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Global populations rely on our oceans for a range of goods and services, and this dependence will increase as the blue economy continues to grow. In addition, climate change is altering our ocean ecosystems at rates not previously experienced. To sustainably manage, understand and protect the incredible resources provided by our oceans we need observations that underpin policy. Ocean observations support decision-making in a wide range of fields, including fishing, aquaculture, shipping, oil and gas, offshore energy, maritime safety, defence and resource management. Long-term, sustained ocean observing underpins decision-making by natural resource managers, such as understanding how climate change is affecting critical ecosystems and species. Therefore, there is an integral link between ocean observing and effective decision-making to improve ocean management and sustainable use. Strong engagement amongst scientific and stakeholder communities is needed to identify new and evolving observation needs, and develop products that translate raw observation data into information useable by non-experts and decision-makers. Strong user-focused ocean observation systems are delivering significant benefits through understanding the state of, and changes to, our oceans. Ongoing development, international collaboration and the deployment of new technology, will allow ocean observing systems to continue to provide relevant and timely information to maintain healthy oceans into the future.

(S12-16040 Invited)

Bio-GO-SHIP: A global analysis of changes to ocean plankton systems

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Ocean biology is largely under-sampled in time and space compared to physical and chemical properties. However, marine biodiversity is highly sensitive to environmental changes while at the same time playing a key role in regulating marine ecosystem functions. Bio-GO-SHIP is a new program to produce systematic and consistent biological observations during global ocean repeat hydrographic surveys, with a particular focus on the planktonic ecosystem. In the last two decades, new technologies including cell imaging, bio-optical sensors and 'omic tools have been developed and matured, making it possible to greatly expand our biological ocean observing capacity. Here we outline how Bio-GO-SHIP leverages these technological advances to greatly expand our knowledge and understanding of the constituents and function of the global ocean plankton ecosystem. We will provide an example of how shifts in plankton molecular biodiversity can be a powerful 'biosensor' of large-scale ocean changes. Finally, new developments in data management and open sharing can facilitate meaningful synthesis and integration with concurrent physical and chemical data.

(S12-16470 Invited)

Building a global multidisciplinary observing system

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Globally sustained and coordinated observations of physical, biogeochemical, and biological parameters are urgently needed to systematically assess their status, and to understand how the ocean is responding to increased human use and climate change. These multidisciplinary observations are required for the global community to predict, mitigate, and manage our ocean.

The Global Ocean Observing System uses the framework of essential ocean variables (EOVs) to document global trends across ocean parameters including the diversity, distribution, and abundance of marine life. The observing networks of EOVs are the building blocks of a comprehensive observing system.

SCOR supports a portfolio of large-scale projects and working groups informing the EOVs and addressing the UN Ocean Decade challenges. These projects include GEOTRACES which is establishing a baseline of marine trace elements and their isotope, the International Quiet Ocean Experiment (IQOE) which facilitates access to passive acoustic data from national systems worldwide, the International Ocean Carbon Coordination Project (IOCCP) which coordinates a global network of ocean carbon observations, and the Southern Ocean Observing System (SOOS) which supports the development of systems that maximise the discoverability, access, and impact of Southern Ocean observations.

SCOR working groups are developing novel experimental designs, tools, and databases to improve our observation and understanding of physical, chemical, biogeochemical, and

biological processes in the ocean. SCOR also promotes and supports networking and training activities across all ocean science disciplines through its capacity development programs. SCOR will continue to be a major global building block for generating and facilitating data to help the global community to detect and respond to climate impacts on ocean ecosystems.

(S12-15817 Oral)

Integrating low cost – open source technology with citizen science approach for coastal ecosystem monitoring in Bangladesh

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Coastal ecosystem monitoring is important to understand the continuous global climate change. However due to high cost involved with monitoring, continuous observation of coastal ecosystem in developing countries is difficult. Therefore, this study integrated low cost – open source technology with citizen science approach for coastal ecosystem monitoring in Bangladesh. We involved 10 artisanal fishing boats and 30 fishermen for this approach. Low cost OpenCTDs were installed in the fishing boats to monitor temperature and salinity data. Fishermen were trained to operate OpenCTD and to collect the data. In addition, fishermen were also trained to collect the data on their fish catch. This approach was experimentally conducted for one year period during July 2021 to June 2022. Our study found that fishermen are able to collect temperature and salinity data from the coastal ecosystem of Bangladesh utilizing facilities of artisanal fishing boats and OpenCTD. In addition, fishermen are also able to provide spatial data on their fish catch. Analysis of collected temperature and salinity data by fishermen showed both spatial and temporal variability. Similar spatial and temporal variability was also observed in fish catch data provided by fishermen. Collected data by fishermen showed a good agreement with the data collected by researchers. This suggests that citizen science approach can be applied for the coastal ecosystem monitoring in developing countries.

(S12-15822 Oral)

Enhanced observations for integrated modeling and climate decision-support system

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Warming waters, changing currents and productivity are affecting the distribution and abundance of living marine resources, and the frequency, and magnitude of impacts are expected to increase. There is much at stake, and action is needed now to enable integrated modeling and decision support needed to deliver the climate information to reduce risks and increase resilience. However, integrated models require enhanced observations and many of the observational tools in use today are limited and less cost-efficient for scalable deployment. There is also limitation in shared-data standards and data dissemination that impedes the model's updates and especially the development of ecological fisheries forecasting models that are deadly needed for rapid management-risk assessment. While modern systems capture a wealth of information; i.e., satellites providing constant high-resolution coverage at the surface but unable to penetrate depths, the uncrewed systems network and other technologies such as eDNA, acoustic provide today high-resolution data streams and capture over increasing scales. Improved scientific understanding and technological innovation offer opportunities to deliver quality observations, analyze them at scale using AI/ML techniques, and apply the resulting insights to inform timely management. Here, we first provide the needs for the development of short-and medium-term ecological forecasting products to support rapid management-risk assessment, we then review emerging observing technologies, data standards and processing

and analysis techniques for selected ecological variables, and finally we identify transformative directions for future development to meet the needs for integrated modeling and decision making.

(S12-15998 Oral)

Playing it SAFE: Stock Assessment and Fishery Evaluation indicators for climate-ready sustainable fisheries

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The Western Pacific Regional Fishery Management Council is working to enhance awareness of the relationships between climate and fisheries. To this end, their annual Stock Assessment and Fishery Evaluation (SAFE) reports include a now standard chapter on ocean and climate indicators. These indicators were developed collaboratively by Council staff and NOAA Fisheries scientists. The indicators capture the state of regionally relevant modes of interannual variability as well as the local effects of long-term climate change. They include both physical variables such as ocean temperature and pH, and biological variables such as fish size structure and catch rates. The Council has been iteratively updating their public access to these indicators with the aim of making them easier to access and interpret. Currently, these indicators are used by the Council, NOAA Fisheries, and third parties to inform management decisions. We are working to broaden the reach and accessibility of the indicators by making them available through a data app. Our long-term goal is that the SAFE indicators will be a 'one stop shop' for managers and decision makers who want to understand fisheries trends and the state of the ocean, and that the indicators can provide a base for identifying thresholds and informing ecological forecasts. This presentation will present representative indicators and discuss avenues for better linking them to management and decision-making processes.

(S12-16032 Oral)

Understanding the effects of climate change on marine ecosystems using long-term, integrated ocean observations: An exploration of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) in the California Current System

Erin V. **Satterthwaite**[1], Brice Semmens[2], Ralf Goericke[2], Rasmus Swalethorp[2], Julia Coates[3], Noelle Bowlin[4], Andrew Thompson[4], Natalya Gallo[5], Zachary Gold[2], Steven Bograd[4], Elliott L. Hazen[4], Todd Martz[2], Wiley Wolfe[2], Moira Decima[2], Simone Baumann-Pickering[2], William Sydeman[6] and Brian Hoover[6]

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Human activities and changes in climate are affecting ocean ecosystems and human well-being. Managing these complex social-ecological systems requires an adaptive, holistic, integrated approach rooted in robust, evidence-based decision making. Integrated ocean observing programs provide essential information for understanding and monitoring the effects of climate change on marine ecosystems. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) is a marine ecosystem research program off the coast of California that was started in 1949 and studies the physics, biogeochemistry, and biology of the marine environment.

CalCOFI is one of the world's longest- running, integrated ocean ecosystem sampling programs that simultaneously collects biological, chemical, and physical observations and specimens across the California Current System (CCS) to inform research and management. This talk will provide a case study exploring how CalCOFI has been working to understand climate impacts on ocean ecosystems. It will highlight a few key CalCOFI scientific advances in understanding climate impacts on the California Current Ecosystem, demonstrate the utility of long time series, and explore the connection to marine resource and ecosystem-based management.

(S12-16057 Oral)

Delivering climate, ecosystem, and socioeconomic observations to fishery managers: integrated ecosystem reporting and risk assessment for the U.S. Mid-Atlantic Fishery Management Council

Sarah K. **Gaichas**[1], Brandon Muffley[2], Geret DePiper[1], Kimberly Bastille[1,3], Kimberly J.W. Hyde[4], Scott Large[1], Sean M. Lucey[1] and Laurel Smith[1]

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Fisheries managers use technical and diverse information to make informed decisions. As ecosystem approaches to management are implemented, the complexity and volume of information needed by managers is increasing, but the time to receive, digest, and act on information is not. We demonstrate how ecosystem observations are integrated into annual reporting for fisheries management in the Northeast U.S., and how these observations translate into a risk assessment framework developed by the Mid-Atlantic Fishery Management Council (MAFMC). The MAFMC developed its Ecosystem Approach to Fisheries Management (EAFM) structured decision process to integrate and make better use of climate, ecosystem, social, and economic information within current operational fisheries management. The EAFM process begins with risk assessment to characterize climate and other risks to managed species and fisheries, and to identify high priority fisheries for further analysis. As MAFMC has developed and implemented EAFM, annual ecosystem reporting has evolved to more clearly link fishery management objectives with social, economic, and ecosystem indicators, and to link climate indicators with risks to managed species and fisheries. With continued MAFMC feedback and input, brief and plain-language State of the Ecosystem reports now include updates on both general climate conditions and linkages to managed species and their habitats. More focused ecosystem reports can be used to update the EAFM risk assessment climate indicators and criteria to make best use of the most recent science. The success of the EAFM process and continued use of ecosystem information in management hinges on scientist-manager collaboration with stakeholder engagement throughout.

(S12-16136 Oral)

The Integrated Ecosystem Programme: Southern Benguela, a South African multidisciplinary flagship on ocean observations for assessing the marine environment

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The South African government has been sampling the west coast of the country for decades. While long-term datasets are extremely valuable these operations were based on specific research questions therefore sampling was not consistent in space and time which is a requirement for long-term monitoring. In 2013, the Integrated Ecosystem Programme: Southern Benguela (IEP:SB) was initiated to consolidate all this existing data under one umbrella. The core of the IEP:SB was the 70 year sample record of monitoring mesozooplankton and from this an ecosystem monitoring programme was created. The IEP:SB aimed to develop essential ocean variables (EOVs) for long-term monitoring and assessment of the environment, assess gaps to initiate new data types required to address current climate priorities, introduce innovative methods to reduce cost and time of the monitoring initiative, create a platform for government-led multi-disciplinary, multi-institutional work ensuring capacity building and contribute decadal data in an open source format to the public. Under the IEP:SB spatio-temporal sampling has been standardized and consolidated into 15 projects that can stand alone and be integrated together resulting in the creation of 22 EOVs, some of which are new data types to assess growing climate concerns. For existing data types both at-sea and laboratory methods were standardized and modernized increasing the turnaround time from data to useful information. All data are accessible online from www.ocean.gov.za. Presented here is the journey from a single variable sole-institutional project to an ecosystem-driven multi-disciplinary, multi-institutional programme fulfilling the needs of government and its academic partners.

(S12-16195 Oral)

Surface ocean CO_2 monitoring strategy

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The society's needs for ocean carbon cycle information are ever-increasing both in resolution and accuracy. Hundreds of ocean carbon scientists from more than 30 countries collaborate under the IOCCP umbrella to design and implement the observing and system required to deliver on these needs.

In terms of the surface ocean carbon, we developed a pilot Surface Ocean CO_2 Reference Observing Network (SOCONET), focusing on providing high-quality surface water and atmospheric CO_2 measurements from multiple platforms. These in situ surface ocean carbon measurements are being collated into the Surface Ocean CO_2 Atlas (SOCAT). These data serve as the global basis for quantification of ocean CO2 uptake and its variations in time and space, as part of the Surface Ocean

pCO$_2$ Mapping Intercomparison project (SOCOM). Finally, the Global Carbon Project, combines the ocean carbon information with the information from land and atmosphere carbon fluxes to produce the annual Global Carbon Budget.

These community-led elements of the value chain have been operating for several years supported by short-term research funding, which makes them fragile, and hinders progress. We have initiated a program to transition these pilot activities into an operational system. In close partnership with G7 FSOI, ICOS-OTC, US NOAA, JPI-Oceans and individual champions across our global network, we are working to develop an internationally-agreed strategy and implementation roadmap that can be used by governments to enable integration into a consolidated global system allowing for timely delivery of critical information for decision making. We would like to present the progress of these efforts.

(S12-16247 Oral)

Integrating information into end-to-end ecosystem models: data accessibility challenges and solutions

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End-to-end ecosystem models are useful tools for incorporating multiple, disparate data sources into one cohesive ecosystem-based fisheries management framework. Collectively, humans have incredible datasets on mostly individual components of marine ecosystems. Yet, there are crucial barriers in our ability to collate this information. I first offer a case study in building an end-to-end ecosystem model of the Northern California Current with long-term datasets that have not previously been incorporated into an ecosystem model of the region. I highlight the advantages of building models with such information, the challenges faced in trying to bring this information together, and some solutions to these challenges. I then discuss, more generally, data accessibility issues, barriers that researchers face in openly sharing their datasets, and solutions to help us overcome these gaps. I highlight examples from areas in which open science has thrived and others that could use improvement. Ultimately, if we wish our science to make the largest impact possible, we must join forces and help each other, openly collaborate, and freely work together.

POSTER BOARD ID: S12-P1
(S12-16035 Poster)

The CLIOTOP science programme: building collaborations to develop understanding of dynamic marine ecosystems and the pathways for sustainable practices needed

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Marine ecosystems are dynamic and constantly changing through both natural and anthropogenic processes. Effective management requires sufficient understanding of such dynamic systems, including the pressures impacting them and associated risks, and the implementation of adaptive frameworks for management of those risks. At the same time, pathways for sustainable practices that meet stakeholder and public expectations and are resilient to change are also required. Delivering ocean management that addresses these key components requires multi-disciplinary approaches that incorporate physical, ecological, and socio-economic aspects. The CLimate Impacts on TOp Predators (CLIOTOP) science programme is a regional programme of the Integrated Marine Biosphere Research (IMBeR) project. CLIOTOP's overarching goal is to facilitate broad-scale comparisons (e.g. over time, space, and taxa) that better identify the impacts of climate and fishing on top predators and the functioning of pelagic ecosystems, with the ultimate goal of developing predictive capabilities. Activities such as collaboration-promoting workshops, open science symposia, and dedicated task teams addressing specific topics are open to any interested individuals, and have yielded valuable studies and results to meet CLIOTOP's objectives and contribute to IMBeR's research goals. Moving forward, CLIOTOP is looking to expand these collaborations to facilitate large-scale comparative efforts elucidating key processes structuring interactions between climate drivers, pelagic ecosystems, and human uses of the ocean. Outcomes from these projects will provide information, products and tools for better resource and conservation management. This presentation will briefly summarize the history of CLIOTOP, and highlight upcoming opportunities for researchers to get involved with the programme.

POSTER BOARD ID: S12-P2
(S12-16091 Poster)

Integrating stakeholder knowledge and observations to assess key vulnerabilities in the southern Benguela system, South Africa

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The analysis of risks posed by anthropogenic drivers, including climate change, is key to the sustainable management of marine ecosystems. However, ecosystem assessments are usually confounded by different uncertainty sources such as natural variability, impacts of multiple drivers and limited knowledge of a system. Bayesian Belief Networks (BBNs) are decision-support tools that represent the uncertainty related to predictions. It makes them a useful tool for addressing complex problems and they havebeen applied in several fields, including climate change research. Here, we used a BBN integrating qualitative (stakeholder knowledge) and quantitative data to conduct a risk assessment of key vulnerabilities in the southern Benguela system. Key vulnerabilities were identified using the Options for Delivering Ecosystem-Based Marine Management (ODEMM) approach through a review of available literature and stakeholder consultations. We investigate changes in risk levels from key sectors (e.g. fishing, shipping) on ecological components and ecosystem services provided by this system. Climate scenarios and potential management strategies are also be evaluated, while accounting for the uncertainty in predictions for the southern Benguela system. The probability of minimising the risk level from the key sectors while achieving socio-ecological objectives is estimated.

POSTER BOARD ID: S12-P3
(S12-16214 Poster)

Science RoCS: Integrated interdisciplinary platforms for the future

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Repeat integrated interdisciplinary observations transecting strong currents, crossing the interface between open ocean and shelf regions, and sampling the broad interiors of ocean basins are imperative to understanding how oceans are changing in a changing climate. However, such observations are difficult and expensive to obtain and maintain. Science RoCS (Science Research on Commercial Ships, https://sciencerocs.org/) is being developed with the vision that the 50,000 commercial vessels in operation around the world represent a viable underutilized platform - an opportunity to obtain repeat direct observations of velocity and other parameters in under-observed regions on a scale unapproachable by research vessels. Science RoCS is developing relationships with shipping company CEOs, working with the meteorological and modeling communities already making broad use of commercial ships, and collaborating with the pCO_2, XBT, drifter, and profiling float programs seeking deployment platforms. While still in its infancy, Science RoCS looks to build on existing individual ship-of-opportunity based projects to utilize fleets of large bulk carriers.

MV Bulk Xaymaca is our pilot vessel, running a 17-day Jamaica-Louisiana repeat route sampling the western Caribbean, Yucatan Strait, and Gulf of Mexico Loop Current System. She has recently begun sending ocean velocity profiles and meteorological data to shore in Near Real Time. We aim to expand the suite of observations being made from the Xaymaca, outfit more ships with scientific sensor suites, develop a system that enables others to find appropriate ships of opportunity, create data products for scientific investigation and submit the underway data to appropriate data repositories.

POSTER BOARD ID: S12-P4
(S12-16358 Poster)

Tropical and South Atlantic Climate-Based Marine Ecosystem Prediction for Sustainable Management (TRIATLAS)

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Marine ecosystems in the tropical Atlantic and South Atlantic have been influenced by climatic changes and other human pressures. The EU TRIATLAS project takes an integrated approach to better understand such influences and to develop approaches needed to enable sustainable management of human activities. It brings together climate researcher, physical and biogeochemical oceanographers, and ecological and social scientists from across the Atlantic, together with multisectoral and regional stakeholders. The aim of this presentation is to illustrate the necessity and power of the interdisciplinary and integrated approach to address the challenges facing marine ecosystems globally. I will showcase novel new data sets of combined physical, biogeochemical, and biological parameters that are giving insights into physical ocean processes and their impact on marine ecosystems. Together with climatic data and model simulations, these are providing deeper understanding of changes in physical, biogeochemical, and biological systems. For example, we have linked climatic phenomena to variations in dissolved oxygen, primary productivity, tuna, northeast Brazil shrimp and southeastern Atlantic sardinella and horse mackerel. We have developed the first ever climate-based marine ecosystem prediction system for seasonal to decadal timescale. Considering both environmental and anthropogenic influences, this system provides a unique and timely tool to sustainably manage human activities (e.g., fisheries). In addition, to deliver societal and policy relevant information, we are analysing the complex interrelationships with human social drivers, considering large-scale and artisanal fisheries and the vulnerability of fishing communities.

POSTER BOARD ID: S12-P5
(S12-16417 Poster)

Towards a High Arctic Ocean Observation System

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Sustained in situ observations of the interior of the ocean lacks in the ice-covered Arctic Ocean. This limits the possibility to advance research within climate, weather, ice-ocean processes, and geophysical hazard. A roadmap for sustained ocean observations was established in the EU project Integrated Arctic Observing System - INTAROS. The roadmap includes recommendations for new observing technologies including network of multipurpose mooring providing ocean observations and facilitating for under water geo-positioning systems as well as support for the vision of SMART cables in the Arctic. As part of the Coordinated Arctic Acoustic Thermometry Experiment (CAATEX) a basin wide mooring system was operated for one year. The six moorings were installed in 2019 extending from north of Svalbard to the Beaufort Sea north of Alaska in the west. Two of the moorings were equipped with low-frequency acoustic source (35 Hz). Each mooring was equipped with 50–75 acoustic and oceanographic instruments providing oceanographic point measurements and acoustic thermometry measurements. The acoustic signals were successfully transmitted and received at ranges from 100 to 2700 km. The CAATEX observations increases our knowledge about the interior of the Arctic Ocean. In particular, the experiment shows that the signals from the low frequency acoustic sources are received at all depths at all the considered ranges which is an important result for establishing an underwater geo-positioning (UW-GPS) system in the central Arctic.

S13: Detectability of non-linearities, abrupt shifts and tipping points in marine ecosystems

Convenors:
Friederike Fröb (Corresponding), (Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway)
Thorsten Blenckner, (Stockholm Resilience Centre, University of Stockholm, Sweden)
Camilla Sguotti, (Department of Biology, University of Padova, Italy)

Invited Speaker:
Mary Hunsicker, (Northwest Fisheries Science Center, NMFS, NOAA, USA)

Regime shifts of marine ecosystems are increasingly observed in response to food production, coastal development and climate change, and abrupt changes are expected to occur even more frequently, if the anthropogenic perturbation remains unabated. Such abrupt shifts, associated with a substantial reorganisation between different states of ecosystem structure and functioning, may even be irreversible. Gradual, but also nonlinear changes, crossings of thresholds, and cascading effects associated with multiple stressors such as ocean warming, deoxygenation, or ocean acidification, but also other anthropogenic stressors such as overfishing, plastic contamination, pollution or eutrophication, can trigger abrupt changes and ecosystem-wide tipping points. The detectability of these abrupt shifts or tipping points is, however, limited due to nonlinear dynamics of ecological systems, complex interactions between the physical-chemical environments and biota, and species-dependent physiological tolerances to change. Moreover, the large natural variability of the system may obscure gradual changes from abrupt shifts. Yet, particularly for ecosystem management and governance, a better understanding of the likelihood of abrupt change is crucial.

In this session we invite contributions on all topics relating to interactions between multiple stressors that may lead to tipping points, abrupt shifts and cascading effects in marine ecosystems. We are particularly interested in various methodological approaches to detect nonlinearities, identify early warning signals for abrupt change, and define safe operating spaces to avoid critical tipping points in marine ecosystems, using both observational data and Earth System Models.

(S13-16471 Invited)

Tracking climate-driven changes in ecosystem state in the northeast Pacific Ocean

Mary **Hunsicker**[1], Jennifer Boldt[2], Brendan Connors[3], Bridget Ferriss[4], Michael Jaccox[5,6], Jacquelynne King[2], Michael Litzow[7], Eric Ward[8] and Samantha Zeman[9]

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Ocean ecosystems are vulnerable to climate-driven perturbations, which are increasing in frequency and can have profound impacts on marine social-ecological systems. Detecting or anticipating the impacts of such perturbations as early as possible can help managers and stakeholders better mitigate and adapt to the impacts. We are generating ecosystem state indicators for northeast Pacific large marine ecosystems, including the California Current, Gulf of Alaska and Bering Sea, to detect potentially large-scale shifts in these systems in response

to changing environmental conditions. We are also creating one-year lead-time forecasts of species responses and ecosystem state based on regional ocean variables. Here, we present a comparison of climate-driven changes in ecosystem state across the study ecosystems. We also assess evidence of nonstationary dynamics in these systems. A growing number of analyses have revealed nonstationary relationships among climate and individual species, or community-level variables and they are important consideration for producing reliable ecological forecasts. The work discussed in this presentation is widely applicable to other ecosystems where scientists and managers are faced with the challenge of managing and protecting ocean resources in a rapidly changing climate.

(S13-15890 Oral)

Detection timescales of environmental drivers in the interior ocean

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In this study, we analyze outputs from the latest IPCC-class Earth system model projections to estimate the detection timescale of anthropogenic signals in the global ocean under two future climate change scenarios: SSP2-4.5 (Shared Socioeconomic Pathway) and SSP5-8.5 over the 2015-2100 period. The slow inertia of the deep ocean leaves the perception that it is less prone to anthropogenic-induced changes than the surface. Here, we show that detectable changes in the interior ocean for temperature, salinity, oxygen, and pH can occur earlier than on the surface, primarily due to the low background natural variability at depths. Acidification signals will occur earliest, followed by warming and oxygen changes. Consistent with the global overturning circulation pathway, the interior of the Atlantic basin is projected to experience earlier detectable signals than the neighbouring basins. The model ensemble projects the subsurface tropical Atlantic and Pacific as the domains most and least susceptible, respectively, to exposure of anthropogenic climate change. We show that even under mitigated scenario, the detection timescales for all variables are remarkable similar to the non-mitigated future scenario, suggesting that anthropogenic signal in the interior have already manifested today. In addition to the tropical Atlantic, our study calls for long-term interior monitoring system to be established in the Southern Ocean and North Atlantic in order to advance our understanding of early exposure of anthropogenic change on multiple environmental drivers.

(S13-15891 Oral)

Resilience or regime shift in the Gulf of Maine food web during rapid warming?

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Resilience buffers systems against regime shifts, but what properties of trophic networks confer resilience – in particular, redundancy amongst trophic flow pathways? To explore this question, we modeled the Gulf of Maine (GoM) food web using mass balance approaches. In recent decades, the GoM has experienced dramatic warming, with major changes in species composition and abundance both expected and observed. We do not know if this ecosystem's emergent properties, including its resilience, have altered during this period. Although there have been many changes in abundance of specific species – steep declines in cod populations,

the collapse of the northern shrimp fishery, increases in once-rare black sea bass, among others – it remains unclear whether the GoM has undergone a regime shift and entered a new stable state. We explore connections between resilience and possible states of the GoM food web by modeling the food web in 1980-85 (prior to contemporary warming) as well as over time. We rely on ecological network analysis to derive metrics of ecological resilience, and use uncertainty-based approaches to probabilistically describe the system's components and flows. While this work is focused on the GoM, our broader goal is to advance methods for understanding food web resilience and regime shifts to inform management decisions.

(S13-16025 Oral)

Assessing possible futures of a complex fisheries social-ecological system in the southern North Sea with a spatially explicit Bayesian Belief Network

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The southern North Sea is a notoriously busy marine area with increasingly less space for viable social-ecological systems (SES) centered around fisheries resources. SES face an increasing number of risks and threats related to climate change, the rapid expansion of offshore renewables, and marine conservation. To support the functioning and adaptations of SES it is, therefore, a matter of urgency to develop spatial explicit and transparent tools describing key SES components, their dependencies, and spatio-temporal dynamics. We developed a Bayesian Belief Network incorporating socio-ecological, socio-economical, and, as a first, also socio-cultural subsystems of the SES describing the German place-related fishery. The evaluation of different future scenarios revealed that the loss of space due to the installation of wind farms or marine protected areas is the most decisive factor for the spatio-temporal dynamics of the SES overriding effects of climate change and economic fluctuations. With our Bayesian Network, we will present a promising tool for embedding SES and their vulnerabilities in management decision-making as well as assessing spatial use conflicts among sectors and the wider impact of spatial planning.

(S13-16051 Oral)

Assessing long-term temporal trends in abundance and composition of demersal fish and zooplankton communities

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Understanding the effects of environmental variability on marine communities over the long temporal term offers an improved understanding of the processes driving biological change. Such trends are key to predicting the future impacts of climate change and responses to conservation and management measurements at community level. We assessed the long-term temporal trends in the demersal (31 fish taxa and one squid species, from summer trawl surveys) and zooplankton (55 taxa from spring and fall surveys) communities on the Scotian Slope, off Nova Scotia, Canada, during the last four decades. Temporal trends were identified in community abundances using dynamic factor analysis. While a slight but steady decrease was observed in the zooplankton, two periods of significant and abrupt change were identified in the abundances of fish and squid. Trajectory analysis and multivariate regression trees further revealed temporal changes and break points in the composition of both communities. The complex oceanographic interactions in the study area between warmer, north-eastward flowing waters derived from the Gulf Stream and colder, south-westward flowing waters from the Labrador Current and Gulf of St. Lawrence, appeared to influence the biological shifts in both ecological communities. More detailed outputs from regional oceanographic models and functional traits are currently under further investigation.

(S13-16134 Oral)

Detecting abrupt shift of the Arctic Ocean pelagic ecosystem in 21st century with dynamic ecoregions

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The concept of ecoregions is based on the observation that large extent of geographical region is characterized by coherent environmental conditions, which are responsible in shaping ecosystem structure and functions. In this study, past and future surface pelagic ecoregions of the Arctic Ocean are defined based on classification of abiotic drivers from a CMIP6 earth system model output. The Arctic Ocean ecoregions at each decade over the 150 years (1950s-2090s) of period are mapped using outputs from one of the CMIP6 NorESM2-MM, with historical and SSP585 experiments and their dynamical transitions are tracked over the period. Extraction of ecoregions is conducted by the self-organizing maps classification method and dynamical tracking of ecoregions is achieved by extending the analysis period over the fifteen decades rather than assuming ecoregions as static entities. This approach is especially useful for the Arctic Ocean where drastic abiotic environmental changes are happening and predicted to be continued throughout the 21st century. Spatial structure of the Arctic Ocean ecoregions during the 20th century (1950s-2000s) resembles to the one identified in the past study derived subjectively based on observed abiotic drivers. It was found that state of the Arctic Ocean ecoregions, area fractions and positions of identified provinces, are relatively stable during the first 100 years (1960s-2050s), but its composition starts to shift rapidly crossing mid-21st century. Among identified 10 ecoregions, the ones that occupy the western Barents Sea and the deep basin of the central Arctic Ocean are the most stable provinces throughout the analysis period.

(S13-16148 Oral)

Ocean regime shift and biodiversity turnover in the Bay of Biscay

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Global ocean warming, extreme events, and accelerating sea-level rise are challenges that coastal communities must address to anticipate damages in coming decades. The aim of this research is to present the new steps of the recently built marine observatory of climate change of the Bay of Biscay, including the Basque coast. We selected 19 climate change indicators (marine physics, chemistry, atmosphere, hydrology, geomorphology, biodiversity, and commercial species) and used mixed GAMs to detect trends. Results of 90 long-term time series of the last four decades indicate regime shifts associated with climate change: 1) An increase in air temperature and insolation and a gradual warming of sea surface down to 100 m depth in the bay (0.10-0.25 °C per decade) starting in the 1980s. This warming may have impacted benthic assemblages and fish spawning and weight. Benthic community shifted, favouring warm-water species relative to cold-water species. Weight-at-age for anchovy and sardine decreased since 2000. Over northeast Atlantic, horse mackerel spawned earlier (11.7 days / ºC of warming), whilst Atlantic mackerel shifted northward (367 km / ºC of warming) through 1992-2019. 2) A continuous pH decline of 0.11-0.13 units per decade on the shelf during the last two decades, which is slightly higher than the rate over larger periods at global scale (0.020 units per decade in 1961-2015). 3) Sea-level rise (1.5-3.5 cm per decade since 1990s). Estimating accurate rates of sea warming, ocean acidification, sea-level rise, and biodiversity consequences are key to define the best adaptation measures to minimize local impacts.

(S13-16151 Oral)

Critical transitions, spurious or not spurious?

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Multiple methods are available to detect past critical transition from observational data. Among these, Integrated Resilience Analysis (IRA) is a multivariate approach based on the detection of folded response curves, tipping points and alternate attractors. IRA relies on the detection of abrupt transitions in the ecosystem state-space (the space defined by abiotic-control and biotic-response variables), using a suite of tools that include dimension reduction, generalised linear modelling, and mapping of the stability landscape. Evaluating the performance of IRA on empirical observations of marine ecosystems is challenging because of the complexity of the method combined with observational time-series that are typically short (few decades) and uncertain. We present a simulation-based approach to evaluate method performance. The method uses surrogate time-series that have the same mean, variance, and temporal autocorrelation as the original time-series but with random values in the time-domain. Because the time-series are generated independently from each other, relationships between time-series, and therefore critical transitions, can only emerge by chance. As such, the simulated datasets are analogues to experimental 'controls'. We test IRA on datasets from five ecosystems: Barents Sea, Bay of Biscay, Central Baltic Sea, Norwegian Sea and North Sea/ Skagerrak. Our results show that IRA outputs from the surrogate datasets are similar to those from the original datasets and that, contrary to expectations, fold bifurcation patterns are not more pronounced in the observational time-series. This analysis highlights the challenge of unambiguously interpreting the results of IRA for the detection of critical transitions in marine systems.

(S13-16154 Oral)

Regime shifts in the Norwegian Sea: what is the evidence?

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Regime shifts have been reported in many marine ecological systems and appear to be ubiquitous features in world oceans. Most regime shift detection methods rely on long time-series (>100-1000 observations) of precise observations and their performance is rarely evaluated. Because time-series for marine ecological systems are often short (few decades) and uncertain, the supporting evidence for regime shifts may be weak. In the Norwegian Sea (NOS), it has been argued that a regime shift occurred in the mid-2000, resulting in simultaneous changes in oceanography, plankton, and fish. Here, we evaluate the evidence for the NOS regime shift by employing several detection methods and measuring their performance. The methods tested focus on two aspects of regime shift: 1) step-change in general mean and 2) increase in instability at the vicinity of a critical transition. We use 47 annual time-series that describe the main components of the NOS ecosystem, from hydrography, primary production, up to marine mammals, from 1994 to 2021. The performance is tested simulating surrogate time-series that share mean, variance, and autocorrelation with the original time-series, but with random values. The surrogate time-series serve as a null model for the absence of regime shift. We apply regime shift detection on 1000 surrogate time series and report the probability of reporting a regime shift under the null hypothesis (type-1 error) as a measure of the performance of the regime shift detection method. We show that there is a significant probability for false detection of regime shifts in the Norwegian Sea ecosystem.

(S13-16161 Oral)

A null hypothesis for abrupt shifts in marine populations forced by multiple stressors

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Long-term time series of marine ecological indicators often are characterized by large-amplitude state transitions that can persist for decades. Understanding the causality of these variations depends critically on the underlying hypotheses characterizing expected natural variability.

There has been a propensity to interpret time series in terms of nonlinear 'regime shifts' when a simpler null hypothesis may be a more parsimonious explanation. Previous work examining the ecosystem response to individual stressors shows that double integrations of white noise atmospheric forcing by the ocean (1x integration) and subsequently by biological processes (2x integration) can explain the emergence of strong transitions and prolonged apparent 'state changes' in marine populations. While this 'Double Integration' model provides a baseline hypothesis for explaining ecosystem variability and for interpreting the significance of abrupt responses and climate change signatures in marine ecosystems, it does not account for the role of multiple stressors, which are particularly relevant for species in higher trophic levels. In this work, we expand the Double Integration model to simulate fish species in different ocean provinces that are sensitive to multiple regional and basin-scale forcing functions. We show that if the different forcing functions have even a small imprint (e.g., 5-10%) from global-scale climate variability or climate change signal, Double Integration acts as a powerful filter that amplifies the shared climate signal. This effect can lead to an apparent synchrony in the collapses and recovery across fish populations in widely separated geographic regions. This model can serve as a null hypothesis to test, and possibly explain, the observed synchrony in the abrupt transitions of pelagic species like sardine and anchovies.

(S13-16163 Oral)

Empirical evidence of non-linearity in the interaction between fish stocks in the Barents Sea

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The strength of species interactions can have a significant impact on population dynamics. Empirical estimates of interaction strength are often based on the assumption that the interaction strength is constant. Several fish species interact in the Barents Sea and their population dynamics are typically modelled under the assumption of constant interaction strength. However, interactions between species are often non-linear in marine ecosystems and this could fundamentally change our understanding of food webs' functioning. Here, we present two examples of such nonlinear interactions in the Barents Sea, between cod *Gadus morhua* and capelin *Mallotus villosus*, and between cod and haddock *Melanogrammus aeglefinus*. Analysis of long survey time series in the Arcto-boreal Barents Sea within a state-space modelling framework showed that the effect of capelin on cod is not linear but varies with capelin abundance. Similarly, interactions between cod and haddock have changed over the past two decades due to rising ocean temperatures, altering the equilibrium abundances and the dynamics of the system. Our analyses demonstrate that long-term climate change in the Arcto-boreal system leads to differences in equilibrium conditions for species communities and demonstrates the importance of investigating nonlinearities in species interactions, leading to a better understanding of species communities and species assemblages.

(S13-16173 Oral)

Changes in the shallow-water fish community in relation to a temperature induced regime shift along the Norwegian Skagerrak coast in 2002

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In 2002, a regime shift occurred along the Norwegian Skagerrak coast in relation to increasing sea temperatures. The regime shift caused substantial reduction in recruitment of 0-group gadoids, reduction in copepod biomass and changes in phytoplankton. Prior to the regime shift, recruitment in cod (*Gadus morhua*) was mainly determined at the 0-group stage (mid-August), whereas after the regimes shift survival through the first autumn and winter has been severely reduced and thus effected recruitment. From mid-August onwards, 0-group cod mainly feed on hyperbenthic prey like small gobies and shrimps. Here, we investigate changes in the fish community before (1997-1999) and after (2016-2019) the regime by biweekly sampling from May-December using a fine-meshed beach seine, with particular focus on prey of 0-group cod. These hyperbenthic organisms have a life cycle of one year. They spawn in summer, and before the regime shift the abundance of the new generations reached a peak in September, varying interannually between 12 000 and 50 000 individuals per beach seine haul. After the regimes shift, total abundance in September dropped substantially and varied between 400 and 1 8000 individuals per beach seine haul. Furthermore, there was no peak September, but the abundance increased gradually to November thus indicating a delay in recruitment by approximately two months. In contrast, peak settlement in 0-group cod appeared 1-1.5 months earlier after the regime shift. This suggest that earlier settlement in cod and delayed recruitment of their main prey have resulted in a mismatch in early autumn when 0-group cod shift to a diet of hyperbenthic prey and may thus explain the low survival in cod from age 0 to age 1.

(S13-16175 Oral)

A regime shift in the Southeast Greenland marine ecosystem

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Two major oceanographic changes have recently propagated through several trophic levels in coastal areas of Southeast Greenland (SEG). Firstly, the amount of drift-ice exported from Fram Strait and transported with the East Greenland Current (EGC) has decreased significantly over the past two decades. This has led to the virtual disappearance of a main tipping element (summer sea ice) with a transition to a new regime after 2003. The 20-year period with low or no coastal sea ice is unique in the 200-year history of SEG ice observations; the temperature of the EGC south of 73.5N has increased significantly (>2°C) since 1980. Secondly, the warm Irminger Current, that advects warm, saline Atlantic Water into the region, has become warmer since 1990. The lack of summer pack ice together with a warming ocean has had cascading ecosystem effects. The fish fauna is changing due to an influx of boreal species in the south and the subarctic capelin further north. At higher trophic levels, there has been an increase in abundance of several boreal cetaceans (humpback, fin, killer and pilot whales and dolphins) that are new to this area or occur in historically large numbers. New cetacean species in SEG are estimated to consume annually 700,000 and 1,500,000 tonnes of fish and krill respectively. Simultaneously there has been a reduction in abundance and catches of ice-adapted or -dependent species such as narwhals and walrus in SEG, likely due to climate-induced habitat changes. These tipping point effects will likely persist with climate change.

(S13-16209 Oral)

Local adaptation mediates shifts in thermal performance curves under multiple drivers

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Climate change is a multidimensional challenge; temperature is rising at an unprecedented rate, accompanied by a multitude of other drivers that can drive fundamental changes to the structure and function of ecosystems. Further, the response of species to anthropogenic change is not invariant among populations, as species may locally adapt to their unique environmental regime. To predict how species will respond to future abiotic change, we need to understand how key thermal traits are altered with multiple drivers, and if these shifts are contingent on population. Here, we measured the thermal performance of germination and growth rates in the intertidal fucoid, *Fucus distichus*, under three levels of salinity (5, 15, 30 psu) and in populations originating from an area of high salinity or seasonally low salinity. We used Sharpe-Schoolfield model fits to estimate how salinity alters the thermal optima (Topt) and critical thermal maxima (CTmax) of each population. We found the population originating from a higher salinity region had a considerable suppression of performance at Topt in the lower salinity treatments,

as well as a larger shift in the position of Topt and CTmax towards cooler temperatures. In comparison, the population originating from seasonally hyposaline waters had a more stable thermal performance curve across salinity treatments, only experiencing shifts of Topt and CTmax under the most stressful salinity treatment. Our work highlights the importance of both considering how multiple drivers will alter thermal performance, as well as the role local adaptation may play in mediating shifts in key physiological thresholds.

(S13-16217 Oral)

Detecting and forecasting non-linear dynamics for copepods in North Atlantic Ocean

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Copepods are believed to be the most abundant metazoans in the North Atlantic Ocean for their large number of species, high quantity and wide distribution and they generally dominate the zooplankton biomass in oceans. Copepods are an intermediate link in the food web and are controlled by both bottom-up and top-down forcing. Copepods are characterized by fast dynamics and short generation times, the changes in their populations are related to the dynamic process of marine ecosystems and they play an important role in regulating fishery resources. We use empirical dynamic modelling (EDM), a non-linear forecasting method in ecology, to forecast the population size of copepods in four Northwest Atlantic ecosystems. We implement EDM via Gaussian process (GP) regression. First, we determine the complexity of the copepod's dynamics then we detect and quantify the nonlinearities in dynamics, and finally, we forecast the abundance and biomass of copepods. Given that copepod time series are very short, we also incorporate spatial information in forecasting to improve prediction accuracy.

(S13-16297 Oral)

Phenological change detection from fisheries-independent surveys

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Changing phenology can lead to abrupt, non-linear shifts in food webs if interacting species no longer co-occur seasonally due to asynchronous responses to climate change. Understanding and projecting phenological changes require long time series, such as those from fisheries-independent surveys. However, many surveys do not sample frequently enough to detect potential phenological changes. Using surveys with suboptimal sampling timing or frequency can bias estimates of phenology, while variability in fish abundance can obscure phenological trend detection. We address this using Monte Carlo simulations to model changes in seasonal occurrence of early life history stages of Pacific sardine and northern anchovy from three surveys in the California Current System (CCS). Phenological shifts of 1-15 days decade^{-1} were simulated and resulting distributions were sampled mimicking existing survey designs. Across the CCS, estimated changes were most precise for the seasonal centroid and least precise for season duration. In southern California, changes in sardine could be accurately assessed, but with half the precision as anchovy. Biases in detecting phenological changes occurred among anchovy when assessing rapid changes (>9 days decade^{-1}). In Baja California, two sardine stocks overlap, but exhibit different phenology. Phenological change for the summer-spawning

stock can be under- or over-estimated based on survey timing, which can lead to misestimation of stock size. In the northern CCS, the 2015-2016 marine heat wave led to large and abrupt changes in phenology and species abundance. In this region, variations in abundance obscured detectability of phenology trends to a greater extent than in the southern CCS.

(S13-16365 Oral)

Non-additive and non-linear responses of a sub-Arctic ecosystem to combined impact of fisheries and climate

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Global models project loss of biomass and diversity across the world's ocean under climate change. A frequent exception is the Arctic region, where biomass and biodiversity are expected to increase owing to an extended productive season and northward shift of mobile species. Regional studies highlight that there are large uncertainties around these predictions. To investigate the combined effects of climate, fisheries, and primary productivity on the biomass of the main functional groups and ecosystem processes, we tested twenty-seven scenarios of contrasted forcings with an end-to-end ecosystem model of the Nordic and Barents Seas. Climate and primary productivity impacted the lower trophic levels, while fisheries affected mostly the fished stocks, their preys and their predators. Changes in biomass in response to combined impacts from the drivers were non-additive - and thus harder to predict - in 79% of the simulations. In about half of the cases, changes in biomass were dampened (i.e., lower absolute effect than expected from the sum of singular effect of each driver). Adverse synergism increased steadily with warming. These non-additive responses originated from interactions between the three drivers on food-web processes, and non-linear responses in the response of recruitment to warming. Overall, high uncertainties are surrounding the direction and magnitude of change of biomass under climate change in the Barents Sea, but decreasing biomasses were more frequent under warmer climate.

POSTER BOARD ID: S13-P1
(S13-15871 Poster)

Fishing past a tipping point – Climatic changes and medieval overfishing depleted Baltic herring in the 16th century

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In the late Medieval, salted herring became one of the most important commodities in northern Europe. The herring fishery played a central role in ecological, economic, and social interactions, as herring was not only important as food, but also provided livelihoods, and was the basis for welfare, and political power. Analysing a multitude of historic sources, e.g. on toll-books, demographics, money-supply, prices, salt production, and market-volume, we

construct a 450 years time-series of western Baltic herring catches (years 1200-1650). Here we show that by the year 1580 medieval overfishing in combination with climate change caused a sudden collapse of one at that time most important fisheries, constituting a major marine tipping point with strong and partly still lasting ecological, economic, and social consequences. Today, the same combination of climate forcing on fish stocks and overuse can be detected in the Baltic, although stock dynamics back in 1580 were challenged by decreasing temperature, not climate warming as today. Large scale dislocations in trade occurred, with major social and political consequences. The biological basis of the fishery, the autumn spawning western Baltic herring stock, did never recover to its historic size. Catches stayed low, and today the stock is that small and economically unimportant. We reveal a marine example that overstraining of natural resources in combination with environmental change might lead to tipping points with huge and lasting consequences. It highlights the importance for today's management of marine resources.

History never repeats itself, but it does often rhyme" (Mark Twain).

POSTER BOARD ID: S13-P2
(S13-15972 Poster)

Warmer winters advance clam phenology on the temperate East Asian marginal sea coast

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As seasonally asymmetric warming of the sea is being projected by different trends among geographical regions, strong winter warming has been established as a unique trend in the East Asian marginal seas. Given that winter conditions can affect the entire life-history stage of ectotherms, an understanding of the current biological consequences of rising winter-sea temperatures remains one of the new challenges for more accurate predictions of the impacts of climate change. We combined existing data of long-term daily sea surface temperatures (1963–2018) and the period of spawning of native clams on the East Asian marginal sea coast to highlight winter warming-induced phenology changes. We show that an improved energetic balance (i.e., the positive scope for growth) in overwintering clams under physiologically favorable thermal conditions in warmer winters ensures the replenishment of nutrient reserves and the fast gamete development, consequently advancing the timing of spawning. Such phenological shifts disturb the evolved reproductive cycle to adjust spawning to summer phytoplankton bloom, preventing the long-term success of recruitment. Moreover, the summer maximum temperature elevations result in a physiological disturbance in clams (i.e., the negative scope for growth) due to heat stress. Our results reveal mechanistic species-level consequences of winter warming of the sea. Despite physiological benefits from warmer winter temperatures, the resulting phenological shifts may make the clam populations more vulnerable to collapse as a result of a mismatch with seasonal food availability.

POSTER BOARD ID: S13-P3
(S13-16185 Poster)

Analysis of environmental changes and regime shift in the southern Benguela using outputs from earth system models

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It is anticipated that as the climate changes, the marine environment will become more variable, and extreme events and regime shifts will likely be more intense and occur more frequently. Determining future changes in ocean variables driving changes in marine ecosystem structure and functioning can inform ecosystem-based management to contribute to the sustainability of social-ecological systems. This study uses statistical analyses of two earth system model (ESM) outputs: (1) The Geophysical Fluid Dynamics Laboratory and (2) the Institut Pierre Simon Laplace from 1981 to 2100. First, the outputs are analysed for the historic period in the southern Benguela to examine oceanographic changes over time. In particular, the study explores whether regime shifts detected in in situ and remotely sensed data for the region, are also detected in ESM outputs. In a second step, future trajectories of climate change impacts on environmental and biogeochemical variables are analysed to determine long-term future trends under contrasting Shared Socioeconomic Pathways (SSP1: 'Sustainability' and SSP5: 'Fossil-fuelled Development') of the Sixth Coupled Model Intercomparison Project. This study could form a foundation to explore future scenarios impacting the southern Benguela ecosystem, and will contribute to the growing oceanographic knowledge for climate change adaptation in the southern Benguela.

POSTER BOARD ID: S13-P4
(S13-16224 Poster)

Complications of detecting ecological regime shifts associated with tipping points

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The latest Intergovernmental Panel on Climate Change report has provided some concerning facts and predictions about the health of oceans. It is highly likely that temperatures will continue to increase over the remainder of the 21st Century; competing stable state predictions of the IPCC report a mean global sea surface temperature increase of between 0.86 and 2.89 °C before 2100. Tipping points are defined as rapid and irreversible changes to temperature, acidification, and deoxygenation. One of the issues associated with tipping points in the ocean is the potential for ecological regime shifts to occur. A regime shift has been defined as an ecosystem abruptly, sometimes catastrophically, changing to an opposing alternative dynamic regime. In practice, regime shifts are typically difficult to identify and have in the past required many statistical methods to confirm. In addition, after they have been identified they can be subject to controversy due to the need for evidence of abrupt change to a contrasting dynamic regime across several trophic levels. This poster will address these concerns and present a machine learning method using publicly available plankton time series data, to show like occurrences of ecological regime shifts in the North Sea. We will also present the potential to use this methodology to detect ecological regime shifts in the wider Atlantic and Pacific Oceans, and in future scenarios. In this we will discuss the impacts of climate change and correlated issues such as stratification changes, likely to become increasingly problematic in the Anthropocene.

POSTER BOARD ID: S13-P5

(S13-16343 Poster)

The impact of 20th century warming on marine ectotherms

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Climate change-related ocean warming is expected to co-occur with deoxygenation in most parts of the deep ocean, posing a threat to marine ectotherms. Marine ectotherms have a higher metabolic oxygen demand at higher temperatures. In the surface ocean, warming poses a greater threat to marine ectotherms than oxygen since the near-surface ocean is near-equilibrium with atmospheric oxygen. This study leverages a compilation of physiological data quantifying the temperature sensitivity and oxygen requirements of metabolic rates for a range of marine species adapted to specific conditions to investigate the impact of climate warming on the surface ocean ectotherms between 1870 – 2021. Preliminary results show that the tropical and Southern oceans may already be showing habitat loss due to climate warming. On the other hand, intrinsic variability is still larger than the climate signal in the North Pacific and Atlantic basins.

POSTER BOARD ID: S13-P6

(S13-16357 Poster)

Detecting abrupt aerobic habitat loss in NorESM2

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The impact of ocean warming and deoxygenation on marine ecosystems can be jointly evaluated using a single metric: the metabolic index. The metabolic index describes the ratio of oxygen supply over the organisms resting oxygen demand (Heinze et al., 2020). Changes therein characterize a changing aerobic habitat tailored to species-specific thermal and hypoxia sensitivity traits. If the geographical limits of marine species as indicated by critical thresholds of the metabolic index shift abruptly in response to continued ocean warming and deoxygenation (Deutsch et al., 2020), aerobic habitat could potentially be lost abruptly as active aerobic metabolism would no longer be supported. Here, a conceptual framework of 9 ecophysiotypes is constructed that represent various levels of resting vulnerability to hypoxia, sensitivity of hypoxia vulnerability to temperature, and critical thresholds of the metabolic index to quantify the abrupt loss in potential aerobic habitat. We analyse the number and timing of these abrupt changes in the Shared Socioeconomic Pathway 5-85 (SSP5-85) scenario run with the fully coupled Norwegian Earth System Model version 2 (NorESM2) using an environmental time series change point detection routine (Beaulieu and Killick, 2018). For all ecophysiotypes with positive temperature sensitivity to hypoxia, the volume of non-viable habitat expands from 1850 to 2100. The overall potential for loss is evident in all mayor ocean basins across all depth levels. Ecophysiotypes with a negative temperature sensitivity to hypoxia experience only small changes in habitat volume in the surface ocean and even a small expansion of their potential habitat at depth. Within the fraction of volume that eventually becomes non-viable, changepoints in the metabolic index are detected for all ecophysiotypes over the course of the 21st century. These abrupt changes occur mainly in response to warming, close to the surface, while at depth, the abrupt shift from potentially viable to non-viable is mainly dominated by changes in oxygen partial pressure.

POSTER BOARD ID: S13-P7
(S13-16399 Poster)

Can zooplankton metabarcoding be used to track Atlantification of the Arctic?

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The Arctic is warming at an unprecedented rate and all available climatic models predict that this trend will continue. Additionally, relatively warm Atlantic waters and associated planktonic biota, which are transported northwards with the West Spitsbergen Current (WSC), penetrate more northern parts of the European Arctic, what intensifies changes observed in the environment, and causes shifts in species distribution ranges as well as the inflow of new species to the Arctic. All these processes, which are referred to as Atlantification of the Arctic, may boost local biodiversity, but simultaneously pose threat to naturally occurring communities. Recently, the development of molecular techniques facilitates for faster and more accurate species identification than traditional optical techniques based on morphology, what may allow for the complete characterization of biodiversity, including species that are difficult to identify. Therefore, we aimed to study the influence of Atlantification on zooplankton diversity, with the combination of morphology-based taxonomy and metabarcoding, which enables for analyses of the entire plankton sample at the same time. As a study area, we selected oceanic area influenced by WSC and three Svalbard fjords with contrasting hydrological characteristics, where zooplankton was sampled from the epipelagic zone, and water physico-chemical properties were measured simultaneously. Thanks to the metabarcoding approach, it was possible to investigate hidden diversity, identify meroplanktonic larvae, and species that were too small or too difficult to be recognized morphologically, what proves that metabarcoding can be used for the qualitative analysis of zooplankton, and studying processes connected to climate change in different regions.

S14: Cumulative anthropogenic impacts on key Arctic species

Convenors:
Frode B. Vikebø (Corresponding), Institute of Marine Research, Norway)
Ben Laurel, (Hatfield Marine Science Center, USA)
Mette Skern-Mauritzen, (Institute of Marine Research, Norway)
Franz Mueter, (University of Alaska Fairbanks, USA)

Plenary Speaker:
Katrine Borgå, (Department of Biosciences, Aquatic biology and Toxicology, University of Oslo, Norway)

Invited Speaker:
Nadja Steiner, (Fisheries and Oceans Canada)

Warmer waters and retreating sea ice allows marine populations and human activities to extend northwards, introducing multiple pressures acting in synergy on Arctic coastal and oceanic ecosystems. This comes in addition to the long-range transport of contaminants bioaccumulated and biomagnified in the food chain. It is imperative to develop risk assessments that take into account not only changes in the structure and function of marine ecosystems induced by climate change, but also new initiatives to utilize Arctic marine ecosystem services, including living and non-living marine resource, shipping and tourism. A prerequisite for assessing risks is to understand processes linking drivers to effects and to combine experiments, in situ and remote data collection and numerical ecosystem models to link effects at the individual level to impacts on populations and ecosystems. The session invites contributions focusing broadly on impacts of multiple pressures, including climate change, on key Arctic marine species, ecosystems and ecosystem services.

(S14-16468 Plenary)

The influence of climate change on accumulation and toxicity of pollutants in arctic marine food webs

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As global climate change affects physical, biological, and ecological processes in the environment, it has the potential to influence the uptake, fate and effects of persistent organic pollutants (POPs) and contaminants of emerging Arctic concern (CEACs) in biota and food webs through multiple mechanisms. We have summarized the current understanding of how climate change-driven physical and ecological processes influence the levels of persistent organic pollutants (POPs) and contaminants of emerging Arctic concern (CEACs) in biota and food webs.

In summary, climate change will impact the long-range transport of pollutants to the Arctic and within the Arctic by altering atmospheric, environmental, and ecological processes, and thus will influence the exposure, accumulation and toxicity of POPs in Arctic wildlife. In detail; i) physical climate parameters, including climate oscillation indices, precipitation, water salinity, sea ice age, and sea ice quality, show statistical associations with POPs concentrations in multiple Arctic biota. ii) Northward range-shifting species can act as biovectors for POPs and CEACs into Arctic marine food webs. iii) Shifts in trophic position can alter POPs concentrations in populations of Arctic species. iv) Reductions in body condition are associated with increased in levels of POPs in some biota. v) Models are useful for predicting the net result of various contrasting climate-driven processes on POP and CEAC exposures; however, for some parameters, especially food web changes, insufficient data exists with which to populate such models. In addition to the impact of global regulations on POP levels in Arctic biota, we demonstrate that there are various direct and indirect mechanisms by which climate change can influence contaminant exposure, accumulation, and effects. Recent data from the Nansen legacy programme in the Barents Sea will be presented showing both effect of borealisation pollutant accumulation, seasonality and food web accumulation, as well as climate dependent toxicity by contrasting present and future climatic conditions and the resulting pollutant effect in calanoid copepods.

(S14-16469 Invited)

Climate change impacts on marine ecosystems and ecosystem services in the Arctic

Nadja S. **Steiner**[1,2,3], Cathy Reader[2], Patrick Farnole[3] and BEPSII[4] community

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Environmental changes impact marine ecosystem functioning, and through this good quality of life for Arctic communities. The ecosystem services concept guides environmental decision-making by highlighting how ecosystems support human well-being, and how biophysical changes can affect humans. Arctic marine and sea-ice ecosystems support all four ecosystem service categories: supporting, provisioning, cultural, and regulating, where provisioning and cultural services are intricately linked in the Arctic. Changing temperatures, sea-ice, nutrient supply, oxygen decline, and ocean acidification are key stressors to those ecosystems. To understand if ecosystem health can be maintained in future climates, we need to understand how these stressors evolve. This can be addressed through climate model projections. To assess impacts on communities, ecosystems and stressors need to be linked with traditional knowledge.

We will present a sub-regional analysis of changing marine ecosystem stressors in CMIP6 models, detail the impact on Arctic sea-ice ecosystem services and introduce a collaborative project with Inuit to link environmental changes with the seasonal cycle of subsistence and harvesting activities. Our results indicate that marine stressors intensify with different timing, pace and seasonality across the Arctic. The changes cause ripples in the Inuit circle of seasons which propagate into the Inuit circle of life. While responses of sea-ice associated primary production to environmental change are regionally variable, effects on ice-associated mammals and birds are predominantly negative, subsequently impacting human harvesting. Conservation can help protect some species/functions. However, the key mitigation measure that can slow the loss of sea-ice ecosystem services, is a reduction in carbon emissions.

(S14-15925 Oral)

Physical drivers of biogeographical shifts in the Northeastern Atlantic – and adjacent shelves

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The subpolar North Atlantic Ocean is characterized by its rich ecosystems – rapid spring blooms, vast energy-rich zooplankton stocks, huge migratory pelagic fish stocks, large seabird colonies and highly productive demersal fish stocks on the shelves surrounding the oceanic basins. A multidisciplinary Research Topic in Frontiers in Marine Science has brought together 20 research articles under themes related to physical drivers of biogeographical shifts in the northeastern Atlantic and adjacent shelves. The main results from this Research Topic are summarized in an Editorial, which binds together this collection of papers into an eBook. In this talk, I will present highlights from the Editorial.

(S14-15952 Oral)

Changes in overwintering success for juvenile cod species in the Arctic

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Cumulative environmental stressors in the first year of life of fish will likely alter their mortality schedules and recruitment to the adult population. Such processes are particularly important in rapidly changing Arctic environments where fish must accumulate sufficient size and energy during the open ice period to survive long winters of low productivity. We present several recent studies demonstrating how responses to stressors in the spring (e.g., temperature, oil) can initiate size- and lipid-dependent winter survival trajectories as early as the egg stage. We then experimentally show how temperature and food availability in fall can dampen or amplify these survival trajectories, which in turn further interact with variable metabolic demands in the winter. Two surprising results from these experiments were that: 1) lipid-content (not fish size) is a better metric for predicting future winter survival, and 2) winter warming will still be a major source of mortality even when pre-winter environments are optimal for growth. Collectively, these results suggest survival to age 1 will become increasingly difficult to predict from earlier life stages. It is also likely that heatwave events that contribute to warm falls and winters will magnify overwintering mortality for age-0 juvenile cod and potentially lead to new population bottlenecks in regions already experiencing high rates of warming.

(S14-16005 Oral)

Influence of historical climate drivers on the Beaufort Sea Shelf marine food web

Kristen J. **Sora**[1], Colette C.C. Wabnitz[1,2], Nadja S. Steiner[3], U. Rashid Sumaila[1,4], Carie Hoover[5,6], Andrea Niemi[5], Lisa L. Loseto[5], Mi-Ling Li[1,7], Amanda Giang[8], Emma Gillies[8], Gabriel Reygondeau[1] and William W.L. Cheung[1]

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Climate change is affecting the world's ocean, causing sea surface warming, loss of sea ice, decreases in dissolved oxygen, and changing salinity associated with changes in atmospheric and oceanographic mixing, with contrasting impacts on nutrient supply and productivity. Climate change impacts on marine ecosystems are particularly acute in the Arctic, where the rate of change in recent decades is amongst the fastest in the ocean, raising concerns on the conservation of key ecologically and culturally significant species (e.g. beluga whales, Arctic cod). Here, we develop and apply an Ecopath with Ecosim (EwE) food web model for the Canadian Beaufort Sea Shelf (BSS) to examine historical (1970-2020) changes in ecological dynamics and long-term health of key species under climate change. We compare and contrast the effects of (i) increased sea surface temperature; (ii) reduced sea ice extent; (iii) ocean deoxygenation; and (iv) changing ocean salinity as both individual and synergistic drivers. We expect to find a decrease in biomass of cold-water species (e.g. Arctic cod) attributed to reduced availability of preferred prey species and productivity. Biomass decreases of these species as a result of climate change can negatively impact beluga whales – a flagship species for the region – and contribute to overall declines in ecosystem health. The models developed in this study provide a useful baseline for future projections of the BSS ecosystem. The findings reveal valuable insights into the attribution of climate change effects on Arctic ecosystems and how existing conservation measures (e.g. protected areas) can help adapt climate change impacts.

(S14-16135 Oral)

Spawning stock age structure and climate combined cause long-term fluctuations in recruitment – demonstrated for the Norwegian spring-spawning herring stock

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Climate and fishing are often the dominating external pressures on population dynamics of harvested fish stocks. These two pressures may interact, causing complex impact-response patterns. Norwegian spring-spawning herring (NSSH; *Clupea harengus*), is one of the world's largest herring stocks with an estimated peak spawning stock biomass of 16 million metric tonnes. The stock size has fluctuated extensively – linked to variations in fishing pressure and climate-driven conditions, especially sea temperature. Like for many fish populations, NSSH spawn a vast number of offspring, while only a small and highly variable fraction survives long enough to recruit into the fishery. It is intuitive that the size and state of the spawning stock

is important for recruitment. Additionally, environmental conditions can greatly influence survival, especially through vulnerable early life stages. To understand what regulates recruitment it is thus necessary to explain the impact of fluctuations in both spawning stock and environment, including interactions. Here we investigate how the connection between the environment and recruitment is affected by spawning stock biomass and age structure. Specifically, we examine if recruitment from a spawning stock dominated by young fish and few age classes is more vulnerable to year-to-year environmental fluctuations. Our analysis is based upon a 100 years of data from existing NSSH virtual population analysis output, sea temperature, and the North Atlantic Oscillation index. A better understanding of the spawning stock structure-sea temperature-recruitment relations should provide valuable input towards long-term management tools like Harvest Control Rules and projecting population responses to (IPCC type) future climate scenarios.

(S14-16159 Oral)

Assessing the impacts of past environmental changes on Arctic biodiversity using sedimentary ancient DNA

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Arctic marine ecosystems are highly sensitive to climate change and are currently being altered by increasing water temperatures, changes in sea ice conditions and anthropogenic stressors. These rapid changes will inevitably have profound effects on biodiversity and productivity. However, so far, our knowledge on the cumulative impact of these changes on benthic and planktic communities remains limited, despite their important roles in food webs and nutrient cycling. In order to understand ongoing and future changes in Arctic ecosystems and the resilience of marine communities, it is essential to assess their response to past changes in environmental conditions. To date, such studies are limited to lineages with a fossil record, leaving an incomplete picture of the remaining diversity. We are applying sedimentary ancient DNA sequencing as a new tool for reconstructing past changes in entire marine communities in relation with past environmental changes. We are focusing on marine sediment cores from the shelf areas of the Nordic Seas and assess environmental and biodiversity changes throughout the last 10,000 years. Here, we present the first results from a sediment record from a coastal area of northern Svalbard. We extracted ancient DNA and trace a wide range of eukaryotic taxa through time to estimate past changes in diversity and productivity. These paleogenomic data are compared to other paleo-proxies, changes in sea ice cover and water temperature to identify drivers of biodiversity change.

(S14-16165 Oral)

Deciphering climate change impacts on Arctic marine mammals using sedimentary ancient DNA

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The Arctic Ocean is one of Earth's most fragile ecosystems and the scale of change taking place due to rises in temperature and loss of sea ice cover is overwhelming. Reliable data are imperative to making informed predictions and decisions concerning the conservation of Arctic marine mammal species, but no long-term data on the response of these species to abrupt climatic perturbations yet exists. Palaeo-archives such as sediment cores are invaluable for the reconstruction of past environmental changes and biological processes. However, most research has focused on resolving dynamics of physical parameters and obtaining proxy time-series from organisms at the base of the food web, whereas higher trophic levels are so far neglected. Our project aims at leveraging recent advances in the development of molecular tools for the analyses of ancient genetic material to characterize the histories of marine mammals in the Arctic region. For this purpose sedimentary ancient DNA extracted from Holocene marine sediment cores from around Greenland will be analysed. Specifically, shotgun metagenomic sequencing is used to comprehensively describe DNA from all organisms present, targeted assays for the quantification of Arctic marine mammal DNA (ddPCR) are used and past populations are characterized based on mitogenomes retrieved by hybridization capture. We integrate our findings with proxy data that document the timing and magnitude of environmental changes, as well as community structure and abundance of lower trophic levels. This allows for a holistic perspective on the processes that cause spatial and temporal variability in marine mammals, which will also aid answering the question whether demographic changes in marine mammals were driven by bottom-up ecosystem processes or anthropogenic pressure such as whaling.

(S14-16189 Oral)

Arctic ecosystem impact assessment of oil in ice under climate change

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The Arctic amplification of global warming is causing the Arctic-Atlantic ice edge to retreat at unprecedented rates. While pockets of Arctic water masses remains in the Barents Sea (the largest shelf sea of the Arctic) still allowing spawning of key Arctic species, the retreating ice cover presents opportunities for resource exploitation in ice free areas. In multidisciplinary project ACTION we investigate how multiple direct and indirect human stressors, here represented by oil spill scenarios and climate change, might impact the recruitment of key arctic species Polar cod (*Boreogadus saida*). We assemble a multi-level biophysical model representing seasonal sea ice cover, under ice primary production, zooplankton phenology, and individual based model of early life stages of Polar cod; to quantify the potential for spatio-temporal overlap with oil spills and important biological processes for recruitment for Polar cod. Preliminary results show a high degree of robustness of an early spawning time with regards to overlap in timing of initiation of spring bloom dynamics with first feeding of Polar cod–but with a contradictory result that only late spawning would resemble the observed juvenile spatial distribution. And although oil-spill scenarios remains to be modelled within the framework of the project, general knowledge of the dominant current regimes suggests that a potential oil spill from northern-most areas of interest for petroleum extraction may intersect with the marginal ice zone in the central Barents Sea–however core Arctic areas in the northern Barents Sea are unlikely to be affected.

(S14-16221 Oral)

Investigating combined effects of climate change and fisheries on the Barents Sea ecosystem dynamics using Chance and Necessity modelling

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Marine ecosystems displayed large fluctuations in species biomass over time. These fluctuations can result from internal processes, stochasticity, external drivers, or the combination of these three elements. Thus, it is necessary to study variability resulting from the first ones to assess the contribution of external drivers, such as climate change and fisheries, to ecosystem dynamics and better inform future management policies. Temporal stability is a measure of temporal variability and corresponds to the inverse of the coefficient of variation for individual species biomass. How temporal stability is affected by climate change and fisheries is still debated. Chance and Necessity (CaN), and associated models, simulate possible food-web dynamics accounting for stochastic biomass variations. Thus, CaN models explore stochastically (chance) the possible trajectories of the modelled food-web complying with physical and biological constraints (necessity). Using the Non-Deterministic Network Dynamics (NDND) model, we simulated biomass dynamics for the Barents Sea food-web for multiple scenarios of temperature and fishing mortality. Our results identify the individual potential effects of increasing and decreasing temperature and fishing mortality on the dynamics of individual species while accounting for possible stochastic biomass variations. The conclusion of this study advocates for the importance of using approaches accounting for possible combined effects of multiple external drivers to define future management policies.

(S14-16228 Oral)

Key uncertainties and modeling needs to anticipate cumulative impacts on future Arctic fisheries

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In the rapidly-warming Arctic Ocean, shifting fish distributions have challenged transboundary management, resulting in overexploitation that compounds the effects of warming waters. These trends are projected to continue, with particular concerns for the high seas Central Arctic Ocean as melting ice could open opportunities for multiple resource extraction activities, creating risks of geopolitical conflict as well as multiple stressors on marine ecosystems. Key to informing proactive and holistic management of Arctic high seas ecosystems would be predictive models to anticipate future distribution of fish biomass, ecosystem impacts of shifting stocks, and potential spatial overlap between fishing activity and other emerging human activities. However, the Arctic Ocean has been identified as one of the regions where current models perform the poorest. Fortunately, a sixteen-year moratorium on commercial fishing in the Arctic high seas provides a critical window for improving modeling capacity. Given the magnitude of knowledge gaps, a key first step is mapping the uncertainties and data needs for improved marine ecosystem modeling performance specific to the Central Arctic Ocean. Here we describe the current state of marine ecosystem models for the Central Arctic Ocean region, focusing on the Fisheries and Marine Ecosystem Intercomparison Project (FishMIP). We characterize the areas of highest uncertainty and discuss the ecological and governance implications of that uncertainty. We outline priorities for data collection and further modeling work for the remainder of the moratorium to inform proactive management that can reduce cumulative impacts on marine ecosystems and future Arctic fisheries.

(S14-16249 Oral)

Survival of adult polar cod (*Boreogadus saida*) in the context of "borealization" of the Barents Sea

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The Arctic part of the Barents Sea is facing a change in the fish community, i.e. "borealization", characterized by a northward expansion of sub-Arctic piscivorous species. The phenomenon is associated with changes in environmental conditions notably decreasing sea-ice cover. Sea-ice has been positively associated with the survival of young polar cod (*Boreogadus saida*), an Arctic key species, but not with the adult population survival which was negatively associated with predation pressure exerted by its main predators: Atlantic cod (*Gadus morhua*) and harp seal (*Pagophilus groenlandicus*). However, the northward expansion of Atlantic cod in relation to the decrease of sea-ice cover suggests a potential increase in predation on polar cod in the Arctic part of the Barents Sea. We tested that hypothesis by predicting observed time series of the abundance of adult polar cod using a multilinear regression model allowing for different predation effects based on threshold value of varying environmental conditions. Our results showed increased predation effects of Atlantic cod in years of low sea-ice cover. Furthermore, predictions from the regression model suggested that predation mediated by sea-ice cover and predator biomass was associated with long term decrease in adult polar cod abundance in the Barents Sea. Our results suggested that the "borealization" of the Barents Sea is associated with a reduced survival of the adult population of polar cod due to increased predation in years of reduced sea-ice which adds environmental pressure to a population already fragilized by decreased survival of young individuals associated with reduced sea-ice.

(S14-16298 Oral)

Risk of cumulative human impact on scientific-based valuable and vulnerable areas in Norwegian waters

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Recent work defines 60% of Norwegian marine waters as particularly valuable and vulnerable, based on biologically and ecologically important habitats, and ecosystem processes that are present (e.g. fish spawning habitats, coral reefs, nesting habitats for sea birds). Here, we used the ODEMM (Options for Delivering Ecosystem based marine management) approach to assess the cumulative risk from human activities in each of these areas (19 in total). The assessment was based on identified vulnerability and exposure (time and space) for each ecosystem component towards pressures from sectors that are operating in the area. Cumulative risk of human impact varied greatly between the areas. Coastal areas were in general associated with higher impact risk than more offshore and remote areas, and a north-south gradient was also evident in the region. Overall, four main sectors were associated with the highest risk of impact: shipping, fisheries, oil and gas and tourism. However, in coastal areas also land based sectors and nearshore activities added to the cumulative impact risk. One of the reasons for doing an ODEMM assessment for each of the 19 areas was that for management purposes, an assessment on regional scale (e.g. Norwegian Sea) has been considered to be too coarse and not providing detailed enough information. This is supported by the findings in the current study, showing significant differences in risk of cumulative human impact between areas within the same region.

(S14-16340 Oral)

Climate change dynamics and mercury trends in Northeast Arctic cod from the Barents Sea ecosystem

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The Northeast Arctic cod (NEAC - *Gadus morhua*) is a large fish stock of considerable ecological and economic importance. NEAC are widely distributed in the Barents Sea (BS), an environment that supports a high degree of ecosystem resiliency and food web complexity. Here using 120 years of ocean temperature data (1900-2020), 41 years of sea ice extent information (1979-2020) and 27 years of total mercury (Hg) fillet concentration data (1994-2021, n=1999, >71% MeHg, n=20) from BS, we evaluate the effects of climate change on Hg trends in NEAC. Over time we observed a significant increase in ocean temperature (>1.5°C), a strong decrease in sea ice extent, and consistently low and stable NEAC Hg concentrations in length-normalized individuals. Overall, our data suggest that recent Arctic amplification of ocean temperature, "Atlantification" of BS water masses, and rapidly declining sea ice extent over the last ~30 years in the BS ecosystem did not translate into higher or lower Hg in NEAC. Our findings are consistent with similar temporal assessments studies for cod from Oslofjord, Norway, and with recent empirical data for other marine apex predators, demonstrating that Hg bioaccumulation in some species may not be as sensitive to climate change as currently thought. Our findings suggest that the relationships between climate change and Hg trends in marine apex predators can vary substantially within and among species, are highly nuanced, and likely driven by global environmental change factors and inputs from anthropogenic activities at local, regional, and global scales.

(S14-16341 Oral)

Climate driven ecosystem reorganization and cumulative risk in the High North

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Marine ecosystems in the High North are undergoing rapid climate-driven reorganization fueled by species redistributions. The impact of climate warming on biodiversity and ecosystem organization affects exposure and vulnerability to multiple stressors, ultimately determining cumulative risk. The changes in biodiversity and food web structure observed during the last twenty years in the Barents Sea and along the North Norwegian coast help illustrate the pace and magnitude of the ongoing ecosystem reorganization in the High North. The rapid borealization of these Arctic marine communities, driven by poleward distributional shifts, has changed the functional character of species and the configuration of feeding relationships. The ecological changes are concomitant with the northward expansion of human activities such as fisheries, aquaculture and oil and gas extraction. The redistribution of species and human activities changes the character of exposure to multiple stressors in these High North ecosystems. In turn, the ecological reorganization affects the ecosystem internal stability, or robustness to perturbations, and its invasibility by new incoming species. The documented changes in ecosystem organization and exposure to multiple stressors provide the context for considerations of the ensuing cumulative risk and of its adaptive management.

(S14-16403 Oral)

Predicting epibenthic functional distribution on changing Arctic shelves

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Oceanographic changes in the Pacific Arctic affect habitat suitability of current Arctic marine species. Understanding habitat suitability and its changes is an essential part of predicting and adapting to changes in ecosystem functioning. Here, we used Northern Bering and Chukchi Sea shelf epibenthic communities to explore past and future habitat suitability using functional trait–environment relationships. These regions of historically cold, stable, and relatively undisturbed benthic habitats may be changing due to shifting oceanographic conditions resulting in an increasing poleward migration of boreal benthic taxa. We investigated past (2009-2019) benthic functional shifts using hindcast temperatures and salinities from the Pan-Arctic Regional Ocean Model System. Future functional composition was based on predicted regional conditions based on the high-carbon emission, low mitigation effort (i.e., "worst case scenario). Northern Bering and Chukchi Sea epibenthic communities exhibited a longitudinal (coastal to offshore) and latitudinal (south to north) functional shift over time, respectively. These patterns followed past and predicted shifts in hydrographic conditions for these Arctic inflow shelves (i.e., generally increased temperatures and decreased salinities). Large functional shifts were predicted to occur in future time periods in the most southern region and between the earliest and most recent time periods in the most northern regions, driven by changes in larval development and skeleton. Large functional shifts between earlier time periods, along with relatively small functional changes between the most recent and mid-century periods, suggests these northern Arctic inflow benthic communities may have already undergone a larger functional transformation due to oceanographic changes.

(S14-16407 Oral)

Pollution in the Arctic Ocean: An overview of multiple pressures and implications for ecosystem services

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The Arctic is undergoing unprecedented change. Observations and models demonstrate significant perturbations to the physical and biological systems. Arctic species and ecosystems, particularly in the marine environment, are subject to a wide range of pressures from human activities, including exposure to a complex mixture of pollutants, climate change and fishing activity. These pressures affect the ecosystem services that the Arctic provides. Current international policies are attempting to support sustainable exploitation of Arctic resources with a view to balancing human wellbeing and environmental protection. However, assessments of the potential combined impacts of human activities are limited by data, particularly related to pollutants, a limited understanding of physical and biological processes, and single policies

that are limited to ecosystem-level actions. This work considers how, when combined, a suite of existing tools can be used to assess the impacts of pollutants in combination with other anthropogenic pressures on Arctic ecosystems, and on the services that these ecosystems provide. Recommendations are made for the advancement of targeted Arctic research to inform environmental practices and regulatory decisions.

(S14-16453 Oral)

Natural Analogues of an Arctic in Rapid Transition (AnalogueART working group)

Samuel S.P. **Rastrick**[1], Antonio Aguera[1], Kumiko Azetsu-Scott[2], Allison Bailey[3], Melissa Chierici[4], Jorge Corrales Guerrero[1], Agneta Fransson[3], Jason Hall-Spencer[5], Haakon Hop[3], Elizabeth Jones[4], Tina Kutti[1]. Marco Milazzo[6], Helen E Rastrick[7] and Daniel Small[8]

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Northern oceans are in a state of rapid transition, however, our knowledge of the likely effects of climate change and ocean acidification on key species in the food web, functionally important habitats and the structure of Arctic and sub-Arctic ecosystems is limited and based mainly on short-term laboratory studies on single species. In tropical and temperate systems natural analogues (Gradients and Mosaics) of carbonate chemistry drivers have been used to further our knowledge of the sensitivity of biological systems to predicted climate change, and thus assess the capacity of different species to show long-term acclimation and adaptation to changes in carbonate chemistry. Natural analogues have also provided the means to scale-up from single-species responses to community and ecosystem level responses. However, to date the application of such approaches is limited in high latitude systems. Here we present an overview of work within the Analogues of an Arctic in Rapid Transition Working Group (AnalogueART) (ESSAS hokudai.ac.jp/working groups/). Presenting a range of Arctic and sub-Arctic case studies where environmental gradients and mosaics in Carbonate Chemistry (including, CO2 and methane cold seeps, fjords, up-welling areas, and mixing of Arctic and Atlantic water) are being used to elucidate how future climate change may effect vulnerable systems (including, cold water coral reefs, intertidal invertebrates, and shellfish important to aquaculture). We will also discuss the need for the standardisation of methods across natural analogue research and the method development necessary to move from single-stressor gradient studies to more complex multi-stressor Mosaic studies.

POSTER BOARD ID: S14-P1
(S14-15988 Poster)

Climate change signals in sub-Arctic fjord zooplankton from 1983 to 2021

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As global climate change impacts continue to be evaluated and understood, long duration time series datasets are being recognized as key sources to examine ecosystem trends over time. Shifts in species distribution and abundance caused by climate change are evident globally, and the Arctic region is warming four times faster than the global average. Population changes include a doubling of fish species in northern Norway since the 1980s, and other communities bear similarly dynamic patterns. Zooplankton community data provide an opportunity to rigorously examine mechanisms shaping ecosystem level changes, particularly because zooplankton species are not directly affected by fishing pressures. Long term datasets focused on zooplankton species richness and diversity are rare, so those that do exist infer a significant statistical power with their analyses. Here, we analyze for climate change effects from a bi-annual sampling of two distinct sub-Arctic Norwegian fjords since the 1980s for zooplankton species diversity, richness and abundance with depth profiles of salinity, temperature and oxygen conditions.

POSTER BOARD ID: S14-P2
(S14-16059 Poster)

Asymmetric Atlantification in the Barents Sea and its effect on the ecosystem

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The Barents Sea forms an important gateway and interface between the Atlantic Ocean regime and the Arctic Ocean. Here, Atlantic Water loses heat to the atmosphere and is freshened by and subducted under cold, fresh polar water as it encounters the sea ice edge. The Barents Sea has undergone large physical changes in recent decades differing from east to west. Part of the main circulation pathway, the eastern Barents Sea has experienced rapid Atlantification becoming ice-free in winter, warming, and losing stratification. In the more isolated northwest the cold and fresh Arctic Water has also warmed and become more saline, but has retained the layer structure and stratification associated with the Arctic water column. The asymmetry in the response of the physical ocean is reflected in the ecosystem by the retention of a polar species assemblage in the northwest and the expansion of boreal fish species into the eastern Barents Sea. The underlying response of species may be heterogeneous. Some species followed the retreating sea ice northeast, possibly carried by advection, e.g., zooplankton or fish larvae. More mobile species migrated towards the Arctic refugium of the northwest, potentially a migration dead end for species not adapted to the greater depths of the Arctic Basin. Joint Russian-Norwegian surveys of the Barents Sea have included a comprehensive ecosystem survey since 2004 allowing us to investigate changes in the system between recent and previous decades and to explore the heterogeneity in the ecosystem response to the asymmetric physical changes in more detail.

POSTER BOARD ID: S14-P3

(S14-16084 Poster)

Evolution of Northeast Arctic cod (*Gadus morhua*) in response to concurrent fisheries and climate stressors

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Fish life-histories are known to evolve in response to anthropogenic stressors. If not accounted for, this can lead to sub-optimal fisheries management, and in the worst cases even stock collapses. Two major anthropogenic stressors affecting fish stocks are climate warming and human exploitation. While evolutionary responses to both have been studied both empirically and theoretically, they have so far been kept separate, leading to poor understanding of the potential interactions. For temperate fishes, both fishing and warming has been shown to select for faster life histories, such as early maturation and smaller body sizes. We present here an individual-based, mechanistic model parametrized for the commercially important Northeast Arctic Cod stock, which allows us to simultaneously consider the effects of fishing and warming and apply this to an arctic species, accounting for density dependence. We find that for the Northeast Arctic Cod, growth rates can be expected to increase with increasing temperatures, allowing for higher fishing pressures before faster life-histories and smaller sizes are selected for. Combined with the lessening sea ice extent increasing available habitat area, this stock has the potential to provide even more value within sustainable limits in the coming decades, which is an interesting avenue for further research. These results not only highlight the importance of considering multiple stressors in unison, but also supports the theory that species living in the coldest ranges of their thermal niches may benefit from moderate warming.

POSTER BOARD ID: S14-P4

(S14-16115 Poster)

Effects of environmental change on planktonic associations in the Northern Bering and Chukchi seas

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The Northern Bering and Chukchi Seas have been undergoing dramatic oceanographic changes associated with increasing temperatures and shortening of the sea-ice covered season. Changes in the environment impact planktonic communities, including phytoplankton, microzooplankton, and mesozooplankton which are important prey items for key Arctic fish. Decreasing trends in phytoplankton size and increased abundances of smaller zooplankton of Pacific origin have been reported for the Northern Bering and Chukchi Seas as a response to warming and sea ice loss. Changes in composition and size structure of planktonic communities can affect trophic interactions, energy pathways, and benthic-pelagic coupling altering the entire structure of Arctic marine ecosystems and the services it provides to human communities. A set of integrated ecosystem surveys were conducted in spring of 2017 and 2018 and in late summer/early fall of 2017 and 2019 in the Northern Bering and Chukchi seas as part of the Arctic Integrated Ecosystem Research Program (Arctic IERP). We used concurrent samples on phytoplankton, microzooplankton, mesozooplankton, and oceanographic conditions

from these surveys and a Structural Equation Modeling approach to understand mechanistic associations among planktonic communities and the environment. In general, differences in water column stratification and nutrient availability influenced phytoplankton abundance and size composition, affecting the size structure of mesozooplankton communities. The type, direction, and strength of correlative interactions within the planktonic food web varied by season and year. Our study provides insight into the mechanisms structuring planktonic communities and increases our understanding of ecosystem level responses to climate change and other anthropogenic impacts.

POSTER BOARD ID: S14-P5

(S14-16318 Poster)

Tracing Holocene marine ecosystem changes off West Greenland with ancient DNA

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The West Greenland shelf is a unique ecoregion harboring marine areas of international value like the North Water polynya and the Melville Bay Wildlife Sanctuary, yet it is among one of the most vulnerable regions to climate change. According to model projections, this region will be increasingly affected by sea-ice loss and freshwater discharge from the Greenland Ice Sheet. Large uncertainties prevail on how diversity and ecosystem structure will change, due to the complexity of ecological responses and the fact that modern observations cover mostly timeframes already affected by climate change. This is raising questions on how to define baselines for evaluating observed changes, and on how to disentangle the effects of human impact and natural climate variability. Ocean sediments are archives of the past and provide invaluable insights into long-term ecosystem responses. Here, we use sedimentary ancient DNA to explore past marine ecosystem dynamics to climate variability off West Greenland over the past 8,500 years. We applied DNA metabarcoding using a eukaryotic (18S) and a diatom-specific marker (rbcL) to a well-dated marine sediment core retrieved on the shelf off the Upernavik Ice Stream (AMD14-204C; Lat. 73.261, Long. -57.899, 987 m water depth). We uncovered a high taxonomic diversity (251 families in 31 phyla), including many taxa whose body parts are usually not preserved in sediments, such as copepods, polychaetes or jellyfish. We will discuss the unique potential of ancient DNA to improve predictions of marine productivity and biodiversity, and to support ocean and cryosphere risk assessment and conservation efforts.

S15: Using Management Strategy Evaluation to establish robust fishery management in a changing ocean

Convenors:
Desiree Tommasi (Corresponding), (UCSC/NOAA SWFSC)
Caren Barceló, (Oregon State University, USA)
Beth Fulton, (CSIRO)
Isaac Kaplan, (NOAA NWFSC)
Lisa Kerr, (GMRI)
Sonia Sánchez-Maroño, (AZTI)
Robert Thorpe, (CEFEAS)
Cassidy Peterson, (NOAA SEFSC)
Alfonso Perez-Rodriguez, (Spanish Institute of Oceanography, Spain)

Plenary Speaker:
Laura Blamey, (CSIRO, Brisbane, Australia)

Invited Speaker:
Jose De Oliveira, (Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK)

To maintain resilience of fish populations under climate change and limit sociological and economic impacts, future fishery management advice needs to be robust to uncertainty in climate-driven fisheries responses. The focus of this session will be on the use of management strategy evaluation (MSE) to assess robustness of current and novel, climate-ready fishery management strategies in a changing ocean. In addition to MSEs, we welcome contributions on methodological advances in stock assessment and operating models to simulate climate-driven changes in distribution, fleet dynamics, productivity, and food-web interactions, including but not limited to, spatially explicit models, multi-species models, and environmentally-enhanced stock assessments. We also encourage presentations highlighting the use of ecosystem indicators to directly inform harvest control rules and dynamic spatial management strategies.

(S15-16466 Plenary)

Disrupting 'business as usual': how to future-proof fish stocks in oceans of extremes

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Fisheries management needs to ensure that key resources and associated ecosystems remain resilient, particularly in the face of changing climate. Uncertainties in the exact relationships between the environment and the resource have meant that environmental extremes and climate have been difficult to integrate directly into fisheries decision-making frameworks. Australia is a land of climate extremes and improving climate preparedness will help safeguard fish stocks and industries in the future. Using case studies from northern Australia, we show that a combination of novel modelling approaches to help guide decision makers, such as management strategy evaluation, and novel design of harvest strategies can be used to test and increase robustness of fisheries management approaches to extreme environmental variability. We find that 'business as usual' fisheries management may increase risk to stocks under future climate uncertainty. Novel climate-proofed solutions are needed to account for this uncertainty and help safeguard stocks. We show that the inclusion of hypothesised environmental relationships in a model may not necessarily improve model performance or may be too uncertain to warrant inclusion in stock assessment models. Often, it's preferable to instead account for these relationships in a harvest strategy or its component harvest control rules. Hence even if environmental relationships are not fully understood, we show that it may be possible to adjust the harvest strategy to allow for greater precaution in managing the stock under future environmental uncertainty.

(S15-16475 Invited)

When is an "MSE" an MSE, and when is it not?

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ICES prides itself in its tradition of conducting Management Strategy Evaluations (MSEs). In fact, ICES will base its headline catch advice on outcomes of management plans if evaluated to be consistent with the precautionary approach, and if agreed by all relevant management bodies. MSEs are typically used for such evaluations. Furthermore, ICES has been doing it for a long time, with an average of 4-5 per year since 2008. Usually, these MSEs are initiated through special requests to ICES by management bodies, which tend to be top-down in nature and often prescribe the form of the harvest control rules (HCRs) to be tested, along with the types of stability mechanisms to consider, and the outputs to expect (e.g. a minimum set of performance statistics). But is what ICES does *really* MSE, or as some would argue, mostly just HCR evaluation? And how does the nature of the process by which MSEs are initiated impact their effectiveness? In this talk, I will explore these questions, and offer some potential ways forward for ICES and management bodies.

(S15-15878 Oral)

Testing models of increasing complexity to provide ecosystem-informed fisheries management advice

Matthew D. Robertson[1], Noel Cadigan[1], Paul M. Regular[2], Mariano Koen-Alonso[2], David Bélanger[2], Frédéric Cyr[2], Fan Zhang[1,3] and Tyler D. Eddy[1]

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Despite continued calls for the application of ecosystem-based fisheries management, tactical fisheries management continues to be heavily based on single-species stock assessments that rarely quantitatively assess the effects of ecosystem processes on fish stock productivity. Examining models with varying assumptions can help identify sources of uncertainty and their relative importance. Testing and comparing models of increasing complexity may present a transparent hypothesis testing method that underscores the importance of incorporating various population and ecosystem processes. Here, we compare population dynamics models of increasing complexity to assess the population and ecosystem processes that most likely affected the differential recovery of two flatfish populations (American plaice and yellowtail flounder) on the Newfoundland Grand Bank over the past three decades. We observed that the population dynamics of yellowtail flounder were primarily driven by recruitment variability, which was negatively affected by bottom water temperatures. Meanwhile, the population dynamics of American plaice were affected by a combination of temporal variability in recruitment and natural mortality, where recruitment was negatively affected by the area of the cold intermediate layer. Furthermore, despite both species sharing similar life-history traits, habitat, and prey we did not observe any indication that direct competition between yellowtail flounder and American plaice is influencing either of their population dynamics. Overall, the framework explored here may provide a transparent hypothesis testing method for exploring plausible population and ecosystem processes that have influenced stock productivity over time.

(S15-15912 Oral)

A flexible approach for projecting fish stocks under assessment uncertainty and climate change

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New modeling tools are needed to project stock dynamics to understand the possible impacts of climate variation on fish productivity, population dynamics, and fisheries. In common with most stock projection models globally, that currently being used to evaluate alternative harvest recommendations for groundfish in the North Pacific has limited capabilities for including environmental forcing and accounting of stock assessment uncertainty. Moreover, despite the growing need to produce long-term quantitative forecasts of climate change effects on exploited fish populations, the current projection model remains mainly designed for short-term tactical projections. Here we developed a flexible projection modeling tool that corrects these shortcomings, and which is sufficiently generic to enable application in jurisdictions for which assessments are based on sex- and age-structured population dynamics models. The framework can be used to provide not only near-term tactical advice, but also primarily, longer term environmentally-driven projections enabling evaluation of strategic management advice under alternative climate change scenarios, including as the basis for operating models to evaluate candidate management strategies. The approach therefore provides assessment scientists with tools for evaluating climate change impacts. The projection model complements a growing suite of approaches including Regional Oceanographic Modelling System environmental projections and, demonstrates how the model supports the move towards Ecosystem Based Fisheries Management.

(S15-15948 Oral)

Exploring climate-readiness of fisheries management procedures in the southeast U.S. Atlantic

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The impact of global climate change on fish stocks and associated fisheries is threatening the assumption of stationarity inherent in many fisheries management decisions. This heightens the importance of developing and applying management strategies that are robust to future uncertainty. Management strategy evaluation (MSE) is a framework in which various management procedures (MPs) can be developed and tested using closed-loop simulation. MSE serves to test MPs across a suite of plausible current and future simulated scenarios, indicating whether the candidate MPs are robust to the uncertainties tested. As such, MSE provides an optimal testing ground for MPs in the face of rapid climate change. We explored the performance of various MPs with nonstationary future projections for three commercially and recreationally important fish stocks in the southeast U.S. Atlantic using a "desk MSE" (i.e., with no stakeholder input). Candidate MPs tested include traditional model-based (statistical-catch-at-age stock assessment) and less conventional empirical (non-model, indicator-based) MPs. Using the openMSE package suite (DLMtool, MSEtool, SAMtool), we tested candidate

MP performance across nonstationary future projections designed to emulate plausible future conditions, including: episodic mortality, recruitment- and young-of-year mortality-based regime shifts, nonstationary recruitment, and biases in perceived reference points. Candidate MP performance was measured based on ability to maintain a healthy stock biomass, high catches, and stability in fishery catches. Results of this MSE exercise demonstrate that empirical MPs are more flexible, their performance is species-specific, and they may be better able to adapt to nonstationarity than traditional model-based MPs.

(S15-15995 Oral)

Evaluating robustness of harvest control rules to variability in Pacific sardine recruitment

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Climate change may disrupt or alter pelagic forage fish recruitment dynamics driven by ocean temperatures, currents, or plankton dynamics. Being responsive to such climate impacts enables fisheries management to ensure continued sustainable harvest of forage species. We conducted a management strategy evaluation to assess the robustness of current and alternative Pacific sardine harvest control rules under a variety of recruitment scenarios representing projections of future climate conditions. The current control rule modifies catch limits for the northern subpopulation based on average sea surface temperatures measured during field cruises of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program. This rule prioritizes catch at intermediate biomass levels but may increase variability in catch and closure frequency compared to alternative control rules, especially if recruitment is unrelated to ocean temperatures. Fishing at maximum sustainable yield and using dynamically estimated reference points improved fishery-related performance measures, while using survey index-based biomass estimates resulted in higher risk of failure to close the fishery during stock declines than assessment-based estimates. Our study explores the possibilities and potential impediments to sustainably harvesting highly variable forage fish stocks in an increasingly dynamic ocean.

(S15-16061 Oral)

Accounting for climate-driven changes in the availability of pollock to assessment surveys in the Gulf of Alaska

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Climate-driven changes in the timing of spawning or migration can affect the availability of fish to surveys designed to monitor their abundance, complicating efforts to assess stock status and sustainably manage fisheries. In recent years, the trends in biomass estimates from four surveys used to monitor Gulf of Alaska pollock (*Gadus chalcogrammus*) have diverged. These conflicting trends increased uncertainty in the stock assessment and occurred during a time of rapid environmental change. Following recent evidence of shifting spawn timing in Gulf of Alaska pollock, we hypothesized that changes in spawn timing relative to survey timing affected availability of pollock to a winter acoustic-trawl survey that targets pre-spawning aggregations. To test this, we reconstructed two independent time-series of relative spawn timing using (1) estimated hatch dates of larvae collected during spring larval surveys and (2) observations of spawning state in mature female pollock collected during winter acoustic-trawl surveys. We then incorporated these time-series of spawn timing/survey timing mismatch as catchability covariates in an enhanced state-space stock assessment model. Models with spawn timing-based catchability covariates significantly improved the model fit to survey data and provided a mechanistic explanation for recent survey discrepancies, increasing confidence in model estimates. As climate change accelerates, changes in phenology and distribution will create challenges for monitoring and assessing fish stocks. We show that knowledge of underlying processes can guide approaches to account for these changes in assessment frameworks, expanding our toolkit for climate-ready fisheries management.

(S15-16071 Oral)

Evaluating management procedures for the Pacific halibut (*Hippoglosssus stenolepis*) fishery while considering historical and future changes in the environment

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Pacific halibut (*Hippoglossus stenolepis*) is a large flatfish that can migrate long distances throughout the northeast Pacific Ocean. The International Pacific Halibut Commission (IPHC) has managed Pacific halibut fisheries in U.S. and Canadian waters for nearly 100 years. Throughout this time, variable productivity of this stock has been observed, including periods of high and low weight-at-age, average recruitment, movement rates-at-age, and changes in the distribution of age-0 recruits. Some of these processes have been linked to the Pacific Decadal Oscillation (PDO). Management of Pacific halibut in recent decades has distributed fishing mortality throughout eight IPHC Regulatory Areas based on annually observed biomass along with a shift to eastern areas that benefit from ontogenetic migration. This dynamic allocation approach adapts to changes in distribution. To test how robust this harvest strategy is to potential environmental change, and contrast it with alternative management procedures, an MSE framework for Pacific halibut has been developed. This framework integrates multiple operating models with both parameter and structural uncertainty and allows for testing projections with alternative PDO regimes. Results are evaluated against coastwide and spatial conservation and fishery objectives. Across various fishing intensities most management procedures are robust

to changes in the environment, conserving the spatial distribution of spawning biomass across biological regions. Departures from using observed annual stock distribution to distribute fishing mortality has the largest effect on the long-term distribution of spawning biomass. Furthermore, potential yield is highly variable, uncertain, and dependent on stock conditions, especially when considering size-limits and assessment frequency.

(S15-16177 Oral)

Evaluating the performance of climate-informed state-space stock assessments using the Woods Hole Assessment Model

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Climate-integrated stock assessments provide a path to more explicitly consider environmental drivers of marine fish populations in fisheries management, but their operational applications have been limited. The Woods Hole Assessment Model (WHAM) is a state-space age-structured integrated analysis model that includes features to implicitly and explicitly link climate drivers to stock dynamics, but these features have not yet been fully leveraged in the growing list of operational stock assessments that use this model in the Northeast US. We developed a simulation framework to explore the estimation performance of WHAM models with alternative configurations of environmental effects for a stock with a cod-like life-history. Simulations assessed model configurations with explicit environmental linkages to recruitment, natural mortality, growth, and survey catchability and compared their performance to models that implicitly considered time-varying processes via random effects or did not include any environmental drivers (i.e. status quo). Model performance was assessed against the ability to reliably estimate model parameters, the environmental effect, and other important derived stock quantities such as recruitment, spawning stock biomass, and fishing mortality. Our results highlight the range of model outcomes when climate drivers are linked to different stock dynamics within state-space stock assessments and provide guidance for incorporating these linkages into management settings.

S15-16179 Oral)

Does climate-integrated stock assessment improve management? An American plaice example

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Climate impacts on marine species are widely acknowledged, but are rarely incorporated directly into management advice. Climate-integrated stock assessment models may reduce this disconnect by linking broad climate and oceanographic drivers to population dynamics. However, the proposed benefits of this approach have not always been realized. We used the Woods Hole Assessment Model (WHAM) to develop assessment models with and without environmental covariates influencing aspects of stock dynamics and tested their performance using Management Strategy Evaluation. American plaice were used as a case study because they have known changes in productivity and a demonstrated shift in distribution in response to ocean warming that are not explicitly accounted for in the current stock assessment. The strength of environmental drivers on recruitment and catchability were varied across simulations to identify possible thresholds for environmental change, past which climate-integrated assessment models are more likely to result in differential management advice. Our results explore methods to incorporate physical-biological links in single-species stock assessments and explore the long-term consequences for management under climate change.

(S15-16231 Oral)

Performance of single- and multi-species management strategies under climate change

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Despite the large body of research suggesting that the population dynamics of fishes are affected by climate and species interactions, the majority of tactical fisheries management use single-species population dynamics models that assume individual populations are independent of one another and their environment. Multi-species harvest control rules that account for shifting productivity due to climate variability and species interactions have been proposed as an alternative to single-species approaches. However, research is needed to evaluate the performance of multi-species harvest control rules relative to single-species approaches while accounting for the feedback between management and fish populations through continued data collection and assessment. Here we conduct a management strategy evaluation using a climate-linked multi-species statistical catch-at-age models developed for the Gulf of Alaska as an operating model to assess the performance of single- and multi-species harvest control rules under alternative climate and predation scenarios. We evaluate the ability of management strategies to achieve single- and multi-species reference points, maximize catch, minimize catch variability, and reduce model bias. Our work addresses key questions regarding the performance of ecosystem based management compared to traditional single species management under climate change and the utility of management strategies that include ecosystem considerations such as multispecies interactions.

(S15-16246 Oral)

Consequences of ignoring climate impacts on New England groundfish stock assessment and management

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The impact of warming on fisheries resources on the Northeast U.S. Shelf is increasingly apparent through shifts in species distribution and productivity changes of economically and culturally important stocks, such as groundfish. Ignoring such impacts can potentially lead to problems with stock assessment performance and effectiveness of fisheries management decisions. Retrospective patterns (i.e., inconsistency of recent estimates after adding another year of data) currently present a large source of uncertainty in the classification of stock status and determination of catch advice for New England groundfish. We evaluated the impact of ignoring climate impacts on assessment performance and the resulting management for New England groundfish. We utilized a management strategy evaluation framework to simulate the impacts of climate change on recruitment, natural mortality, and growth for New England groundfish, emulate stock assessment misspecifications, and evaluate the performance of harvest control rules. Results suggest tradeoffs among control rules, but addressing stock assessment bias resulting from misspecifications may be more important than identifying an optimal harvest control rule for meeting management objectives. Failure to account for changes in stock dynamics from climate change resulted in adverse effects on the performance of New England groundfish assessment and management, but the magnitude of impact varied by harvest control rule. Retrospective patterns caused unintended overfishing because of management actions derived from misperceptions of stock status. Our research shows how management strategy evaluation can be used to test the robustness of harvest control rules to climate change impacts on stock dynamics.

(S15-16284 Oral)

Climate risk planning and decision-making in transboundary fisheries: environmentally-driven recruitment forecasts and projections for Pacific Hake

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Novel analytical approaches and forward-looking management solutions are needed as climate change threatens to increase conflicts in fisheries. Improved understanding of environmentally-driven recruitment variability would greatly reduce prediction uncertainty and improve advice for managers in tactical decision-making and long-term climate risk planning. Pacific Hake (*Merluccius productus*) is the most abundant groundfish on the U.S. West Coast and the target of the largest groundfish fishery by volume in the region. Pacific Hake population dynamics are strongly influenced by environmentally-driven recruitment variability, with infrequent large cohorts supporting the fishery. Recent analyses have identified several potential environmental

drivers of recruitment from Regional Ocean Modeling System output over the historic period 1980-2010. Here, we extend those analyses to the present decade and explore empirical survey data on larval and juvenile fish on the U.S. West Coast to inform indices of operational forecasts of recruitment for use in setting catch advice and long-term risk planning using management strategy evaluation. We found high forecast performance skill for recruitment indices using surveys of juvenile abundance. Importantly, models with the best forecast skill were obtained by fitting models that included other species, not data on early life stages of Pacific Hake themselves, which collectively appear to be indicators of favorable ocean conditions linked to strong cohorts of Pacific Hake. Recruitment projections suggest that shifting ocean conditions can shift the scale and frequency of strong cohorts of Pacific Hake, with implications for meeting sustainability objectives. We will discuss the opportunities and challenges these approaches and results present for management of the Pacific Hake fishery, and transboundary fisheries more broadly.

(S15-16304 Oral)

Exploring the impact of fishing and climate scenarios on the South African sardine and anchovy fishery

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This study explores the possible future impacts of environmental variability and climate change on the biomass and distribution of anchovy and sardine, and the associated implications for the small pelagics fishery using a Model of Intermediate Complexity for Ecosystems (MICE). This model includes biomass-based age- and area-structured population dynamics for sardine and anchovy to account for the major life history migrations of these species and includes links between environmental variables and fish movement. In addition to movement, the model accounts for growth, recruitment, natural and fishing mortality, with the latter taking explicit consideration of the impact of juvenile sardine bycatch with directed anchovy fishing on future directed sardine catches. The model parameters were estimated by fitting to the hydro-acoustic survey recruit and total biomass data for the years 1987-2014, together with observed catches, and sea surface temperature and primary production data from 1987-2014. Projections were run from 2015–2050 under scenario Shared Socioeconomic Pathway 5-8.5.

This MICE model provides an opportunity to consider forecasts of the impacts of predicted climate change, specifically sea surface temperature and primary production, on the southern Benguela anchovy and sardine. Such forecasts could assist the small pelagic fishery to improve their resilience and reduce their vulnerability to future environmental changes.

(S15-16316 Oral)

Climate-informed ecosystem management strategy evaluation in the California Current: Investigating the robustness of pelagic fisheries management to productivity changes, distribution shifts and recruitment fluctuations

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In the California Current Large Marine Ecosystem (CCLME), coastal pelagic species (CPS) such as sardine, anchovy, or market squid support a large community of predators, including protected species. CPS are also targeted by commercial fisheries, triggering the need to reconcile their ecological role and their exploitation through ecosystem-based fisheries management. Such an approach is all the more challenging in a changing climate, where ecosystem and species productivity and species assemblages are expected to change. We present an application of the end-to-end Atlantis ecosystem model to implement a climate-informed ecosystem management strategy evaluation of the CPS fisheries in the CCLME. The Atlantis model represents oceanography, biogeochemistry, food-web and fisheries dynamics, and is designed to perform management strategy evaluation through a built-in module. Here we use this module to simulate alternative harvest strategies and test the robustness of management to future climate change, through to 2100 with respect to both economic and conservation objectives. Atlantis was driven by (i) projections from regionally downscaled biophysical models to predict changes in biological production fueling the food web, (ii) outputs of species distribution models estimating the distribution of CPS and their predators, and (iii) projections of anchovy and sardine recruitment anomalies derived from other ecological models or multivariate analyses. Our new framework also realistically represents the spatial footprint, behavior and métier resolution of the CPS fleets, enabling simulation of CPS fisheries' response to climate in terms of production, fishing portfolio and stability and allowing for a system-level evaluation of adaptive management options for the future.

(S15-16333 Oral)

Incorporating Dynamic Range Models for adaptive management of commercially important fish species undergoing rapid range shifts

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One of the most well documented responses to climate change in marine ecosystems is shifts in the spatial distribution of fish and invertebrate species. Such spatial shifts can result from adults moving from less- to more-suitable habitat but can also result from spatial differences in survival or recruitment. The impacts of climate-driven changes in spatial distributions and productivity on meeting fisheries management objectives is an ongoing and important area of research. Here we present a framework that incorporates a dynamic range model (DRM) to estimate stock parameters which will then be used to simulate management outcomes under different climate and fishing scenarios. Our model is parameterized for black sea bass (*Centropristis striata*), an important fish species whose range has shifted dramatically in the Mid-Atlantic Bight, a region undergoing rapid warming. The DRM is governed by a spatially

explicit process-based operating model that incorporates temperature-driven impacts on adult natural mortality, recruitment, and on the movement of fish between spatial units (dispersal) as well as fishing pressure. In addition to the traditional process model outputs such as spawning stock biomass and recruitment, we also get estimates on the spatial distribution of the stock and where they are moving through space and time. We then simulate management outcomes of different harvest control rules under a range of future climate change scenarios. We believe that the application of robust process models will be useful in developing adaptable management frameworks that can be applied for a wide variety of species.

(S15-16354 Oral)

Climate-resilient management of North Sea cod under deep uncertainty

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Fisheries worldwide face uncertain futures as climate change manifests in environmental effects of hitherto unseen strengths. Developing climate-resilient management strategies requires reliable projections of how fish stocks respond to the effects of climate change under different degrees of exploitation. Unfortunately, models used in management strategy evaluation bear large uncertainties in key processes such as offspring production, because the required environmentally-sensitive stock-recruitment relationship is usually not well represented and can cause uncertainty in stock projections to a level that reduces the usefulness of probabilistic assessments. An alternative approach to evaluation of management strategies is to shift focus from improving predictive skill of models to improving the decision-making process postulated by the Decision-Making under Deep Uncertainty (DMDU) framework. Robust Decision Making (RDM) is a key DMDU concept and aims at identifying management decisions that are robust to a vast range of future scenarios and model uncertainties. Here we employ RDM to investigate the capability of North Sea cod to support a sustainable and economically viable fishery under future climate change. We projected the stock under multiple combinations of exploitation levels, emission scenarios and stock-recruitment parameterizations and found that model uncertainties have a similarly strong effect on simulation outcomes than exploitation level. Our study furthermore revealed that no management strategy exists that is fully robust to the uncertainty in relation to model parameterization and future climate change. We instead propose a risk assessment that accounts for the trade-offs between stock protection and profitability of the fishery under deep uncertainty.

(S15-16419 Oral)

An efficient MSE framework for exploring multispecies management strategies of pelagic stocks in the Norwegian Sea

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Multispecies interactions may inhibit robust single-stock management. Examining the implications of these interactions is increasingly done through Management Strategy Evaluation (MSE) using ecosystem models such as Atlantis or Ecopath with Ecosim. Using these models in MSE is often computationally intensive and cannot sufficiently quantify uncertainty, particularly model uncertainty. In this talk, I present an efficient stochastic multispecies MSE framework applied to the major pelagic stocks and fisheries in the Norwegian Sea; Northeast Atlantic Mackerel, Blue Whiting, and Norwegian Spring-spawning herring. We model two potentially consequential interactions between these stocks: 1) inter- and intraspecific competition via density dependent growth and 2) mackerel predation on herring larvae. Alternative models of the mackerel-herring larvae linkage are also explored. We first test single stock harvest control rules (HCR) from the ICES framework to identify management tradeoffs. Exploratory simulations shown negligible 'knock-on' effects of other stocks' HCR's on the management performance on any one stock under density dependent growth. The mackerel-herring linkage produced asymmetric management tradeoffs between these two stocks, where a potentially unique mackerel HCR parameterization may maximize herring yield and biomass with small reductions in mackerel biomass in the long-term. These tradeoffs were consistent across several alternative models of the mackerel-herring linkage. Continuing work will explore the use of ecological indicators to adjust the target F in the single-stock HCR's, and more alternative operating models. This multispecies MSE framework offers another valuable tool to be used along with more comprehensive ecosystem models to test strategies amidst a broader range of uncertainties.

POSTER BOARD ID: S15-P1
(S15-15865 Poster)

Barriers to implementation of dynamic approaches in fisheries management

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Fish populations are dynamic; their productivity is dependent on fisheries harvest rates, their environment, and feeding and non-feeding interactions with other species. Failure to account for these factors in fisheries science and management can lead to a misestimation of stock dynamics and productivity or natural mortality, resulting in overexploitation or forgone yield. Climate change impacts on ecosystem structure and function adds an additional challenge for fisheries management. Fisheries science that accounts for ecosystem interactions of fish stocks that is used to implement dynamic reference points may lead to better management performance outcomes. Using an online survey, we asked fisheries scientists, industry and Indigenous stakeholders, and NGOs if changing ecosystem productivity was a problem in their experience, and how often dynamic approaches to fisheries reference points have been adopted. Survey respondents had up to 20 years of experience providing reference points for fisheries in 51 countries. We found that changing fisheries or ecosystem productivity had been reported as being an issue by 93% of respondents, however 74% of respondents said they had never seen dynamic reference points implemented, 16% said in very few instances, while 10% said frequently. When asked to identify barriers to implementation of dynamic approaches in fisheries management, institutional inertia and uncertainty about whether a change is lasting were the most common responses, followed by difficulty to operationalize, and a lack of consistent methods. We summarize dynamic reference point approaches and the fisheries that they have been applied to. We conclude by discussing trade-offs between fisheries management stability and performance and incentives for change.

POSTER BOARD ID: S15-P2
(S15-16271 Poster)

Growth response of juvenile Sockeye salmon populations under climate change

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Salmon stocks have unique life cycles that alternate between freshwater and marine environment. Climate- induced changes in fish population status are widely expected, but the responses to climate impacts in early life stages and carry-over effects to adult life stages are poorly understood. Laboratory studies demonstrate that fish growth exhibits a 'thermal window', increasing with temperature to species-specific thermal optima, outside which temperature is considered thermal extremes. Slower growth can result in lower survival, leading to reduced stock productivity. In this study, we reconstruct stock-specific long-term time series (1970-now) of annual growth rates of juvenile Sockeye Salmon in freshwater in relation to their thermal environments and other climate factors. We then estimate the common trend in the growth of Sockeye in multiple locations and subsequent effects on population to detect extreme events. This represents a key area measuring the effects of climate change and other factors on stock outcomes (i.e. productivity), that are not accounted for under current fisheries management.

S16: Emerging challenges in socio-ecological systems brought about by climate-related ecosystem changes and how to equitably manage them

Convenors:

Rachel Seary (Corresponding), (University of California, Santa Cruz and NOAA Southwest Fisheries Science Center, USA)
Tim Frawley, (University of California, Santa Cruz and NOAA Southwest Fisheries Science Center, USA)
Felipe Quezada, (University of California, Santa Cruz and NOAA Southwest Fisheries Science Center, USA)

Invited Speaker:
Samiya Selim, (University of Liberal Arts Bangladesh)

Climate change is restructuring ocean ecosystems and creating new challenges and opportunities for marine resource dependent individuals, communities, and industries. Novel environmental conditions increasingly necessitate management intervention in order to protect essential habitat, ensure resources sustainability, and reduce bycatch and other human wildlife conflicts. Critical in ensuring effective climate adaptation and the equitable distribution of associated costs and benefits will be measuring the response of individuals, communities, and industries to ecosystem changes and the policies enacted to manage them. This session will discuss how socio-economic impacts can be measured and effectively communicated and how policies and interventions can be designed with equity across different resource user and stakeholder groups in mind. It will highlight the ever-expanding suite of tools available to fisheries managers and practitioners and discuss their relative suitability and success with addressing different objectives in diverse human and ecological contexts, and evaluate the implications of their use for different resource user and stakeholder groups.

(S16-16018 Invited)

Reflections on participatory and transdisciplinary research approaches in addressing challenges around climate change and sustainable development

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Coastal communities in low-lying areas already live with the impacts of sea-level rise, and developing coordinated mitigation and adaptation strategies for such communities is key to collective global sustainability goals. Our research is focused on Bangladesh Bay of Bengal communities where storm surges, salinity intrusion and river erosion have already displaced people. The structural, functional, relational and cognitive dimensions of the associated coastal transformation impact multiple levels of coastal social-ecological systems. Mapping these changes requires communities and civil society to participate in monitoring, quantifying and describing impacts. In the face of serious equity challenges, both in blue growth development and in the impacts of climate change, innovative approaches that provide novel sustainable livelihoods for the poorest, most nature-dependent and salinity-affected coastal women and men are needed. To propel the complex coastal social-ecological-technical settings of coastal livelihoods into viable directions that benefit the poor we need to address a range of important new tasks in transdisciplinary and collaborative ways. This paper explores how one can be successful in creating more inclusive and equitable research pathways by taking the time to listen to the voices of the communities we work with. This includes both the community and the grassroots and community based organized who are best connected to the communities. We present here our work over the past three years in working with coastal communities on building resilience, exploring and capturing their experiential learning around governance, adaption and the changes in the ecological and social ecosystem.

(S16-15895 Oral)

Integrating local and scientific knowledge in the assessment of traditional fisheries vulnerability to climate change in French Polynesia

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In many southern regions, fishing communities are facing the cumulative effects of climate change and ciguatera poisoning which threaten local livelihood, food security, human health and the already limited economic opportunities. This ichthyosarcotoxism is endemic in tropical areas spreading from 358N to 358S latitudes with French Polynesia being one of the world's highly affected areas. Thus, to adequately assess the vulnerability of such communities to climate change, it is essential to understand how Ciguatera fish poisoning (CFP) will evolve with the future climatic conditions. This study integrates local knowledge and scientific knowledge to identify relevant criteria and indicators of exposition, sensitivity and adaptive capacity of local fisheries to climate change and to expected increase of CFP. The first step is to characterize local fisheries in terms of techniques, type of fish and shellfish and the associated social and cultural value. The second step consists to understand how functional traits of those species have changed (local knowledge) and will change (experts' knowledge) under different IPCC climate change scenarios. The third step integrates predictions about the changes in Ciguatera abundance and distribution under the future climatic conditions and how people will adapt to such changes. This study wants to highlight the need to assess climate change vulnerability at local scale by integrating the valuable information that comes from traditional indigenous fisheries and their capacity to observe changes in environmental conditions.

(S16-16039 Oral)

Interventions towards sustainability transformations in coastal social-ecological systems in New Caledonia

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Coastal social-ecological systems in Pacific Island States are facing severe sustainability challenges. These include destructive human practices, climate change and associated ecosystem changes, but also issues concerning equality, and marginalization of indigenous life and knowledge. Addressing these challenges and moving toward more sustainable trajectories will require system transformations that may be induced through well-placed interventions. Based on a systematic literature review and expert interviews on sustainability interventions in New Caledonia and Fiji we classify efforts by their transformative potential. This classification is built on the leverage points perspective as based on Meadows (1999) and Abson et al. (2017). We focus on two specific case studies to test our lessons learnt through the literature review within expert interviews. Ouvea, a small, low-lying island northeast of the main island of New Caledonia, and Touho, a municipality on the east coast of the main island, were chosen as case studies.

Preliminary results show that most interventions are concerned with shallower leverage points, while deeper leverage points, which have a higher transformation potential are scarcely addressed due to limited agency to act on deeper leverage points (halt carbon emission, relocation). Moreover, many interventions are reactive instead of proactive and get proposed but not implemented, thus the transformational capacity is restricted. The insights of the experts can help to close gaps between interventions proposed by scientific literature and the reality in places like Ouvea and Touho. In this way, new interventions that pursue deep leverage points can be found possibly leading to more sustainable trajectories.

(S16-16062 Oral)

Human dimension indicator based-assessment of change in coastal ecosystem services delivery in Mumbai, India

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We attempted to comprehend the current state of the ecosystem as well as the shift in the delivery level of ecosystem services (ES) and its implications for the Mahim Koliwada fishing community in Mumbai. For understanding the shift in coastal ES and its consequences, a set of Human dimension indicators was used. These indicators are essentially proxies for the perceived state of ecosystems in a specific socio-ecological system that is subject to both environmental and climate change stressors. To do this, an in-depth socio-ecological assessment was conducted in Mahim, focusing solely on the fishing population because they rely on the coastal ES for their livelihood and well-being. Three ecosystem services have been chosen: "fish and other sea food production," "flood and storm regulation," and "cultural services." A collection of indicators (total of 13 indicators) was chosen to understand the change in ES deliverance level. The hypothesis here is that "the change in ES delivery level is proportional to the health of the ecosystem." The fishing community's view of these indicators has been recorded and analyzed. This reflected on the current level of ecosystem health and aided in understanding how the community is experiencing the shift in ES. It also emphasized the consequences for their livelihood and well-being.

(S16-16184 Oral)

Tracking the social dimension of ongoing fish distributional range shift in marine recreational fishing

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One of the most important ecological impacts of climate change on marine ecosystems is the distributional range shift of species. Understanding the social implications of this phenomenon is crucial for managers and policymakers for developing effective and proactive adaptive management. Here, we characterize the social dimension of recreational fishing by mining data on YouTube about recreational anglers and spearfishers targeting the white grouper (*Epinephelus aeneus*), which is expanding northwards in the North-Western Mediterranean Sea. Results showed that social engagement in Italian videos is higher for spearfishers than anglers. We also found a higher positive polarity and positive emotions in spearfishing comments compared to angling comments. Most importantly, we detected a geographical gradient of emotions showing a positive correlation between the emotion "joy" and latitude. This result suggests that videos from higher latitudes, where the white grouper is still a rare species, triggered more joy than at lower latitudes where this species is more common. We demonstrated the potential of social media data for quantifying socio-ecological dynamics across a geographical gradient and, above all, the possibility for real-time monitoring of the social dimension associated with biodiversity redistribution in response to climate change.

(S16-16222 Oral)

Substitution between coastal pelagic species under shifting target species distributions and policy constraints

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Fishers often target diverse species. More diverse portfolios may reduce income risk, increasing fisher resilience to climate-driven changes in target species' spatial distributions and availability. Therefore, evaluations of climate risk to a particular fishery need to consider climate impacts on the availability of multiple target species and how such changes may impact substitution behavior. Regulations and other constraints (e.g., port infrastructure constraints on where landings of a particular species may occur) may also reduce the degree of substitution we observe. Here we explore how climate-driven changes in target species distribution interacts with other constraints to affect changes in substitution behavior. In this study, we analyze how historical changes in forage species distribution and the closure of the Pacific sardine fishery affected landings of three coastal pelagic species: Pacific sardine (*Sardinops sagax*), market squid (*Doryteuthis opalescens*), and Northern anchovy (*Engraulis mordax*) that are targeted by the US West Coast Coastal Pelagic Fleet during the period 2005-2020. Using cluster analysis results, we group vessels in different fleets and estimate heterogeneous responses by fleet and port areas.

(S16-16287 Oral)

Climate change exacerbates nutrient disparities from seafood

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Seafood is an important source of bioavailable micronutrients supporting human health, yet it is unclear how climate change will influence its availability. Here, combining observational databases and predictive models, we assess nutrient availability from fisheries and mariculture in the past, and project their future under climate change. Since the 1990s, availability of iron, calcium, omega-3 and protein from seafood has declined, with increasing contributions of invertebrates and mariculture failing to compensate for these loses. Nutrient availability is projected to decrease at a rate of 10 - 12% per degree Celsius of warming in low-income countries where they are already highly dependent on seafood-derived nutrients. Our results highlight that these low-income countries will face much bigger challenges to food security if the world fails to achieve the international agreement to keep global warming well below 2 °C and preferably at 1.5 °C relative to pre-industrial levels. We demonstrate the importance of achieving the Paris Agreement to supporting nutritional security and global health equity, particularly for low-income nations. Our results highlight the need for nutrition- and climate-sensitive fisheries management, with food-based trade policies developed to prevent the changes we predict in nutrients from seafood translating to substantial malnutrition and declines in public health.

(S16-16290 Oral)

Managing fisheries using the Resist-Accept-Direct (RAD) framework: Strategies to account for ecological and social considerations

Abigail Lynch[1], Frank Rahel[2], Doug Limpinsel[3], Suresh Sethi[4], Augustin Engman[5], David Lawrence[6], Katherine Mills[7], Wendy Morrison[8], Jay **Peterson**[9] and Mark Porath[10]

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Marine ecosystems impacted by climate change and other anthropogenic stressors are, in some cases, transforming to systems that have a structure and function different than in the past. Managing fisheries and other marine resources under the high uncertainty and variability associated with ecosystem transformation may require a portfolio of strategies to successfully navigate changes. The Resist-Accept-Direct (RAD) framework provides a set of pathways that spans the range of ecosystem management response options. This talk will present RAD framework strategies to address ecological and social goals for ecosystems and fisheries and explore the feasibility of various management options based on the ecological responsiveness of the system and the social receptivity to change.

(S16-16346 Oral)

Understanding drivers of fishing pressure in South Africa's Western Cape: insights from the development of a synthetic set of social indicators

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Fishers and the communities they support face various challenges brought on by changes in their marine social-ecological systems (SES). The resulting complexity and uncertainty hamper their ability to achieve sustainability while holding implications for decision-making at various scales. Fishers must respond proactively to change at the level of their fishing operation. Managers, however, must apply the principles of ecosystem-based management on larger scales. Despite many anthropogenic drivers of change, fishing pressure remains the most impactful on the southern Benguela marine ecosystem. As such, understanding the drivers of fishing pressure is crucial to implementing ecosystem-based fisheries management. Social well-being and vulnerability indicators for fishing communities provide an essential tool for understanding these drivers and can thereby aid managers' decision-making. As a first step in creating such indicators for South African fisheries in the southern Benguela, we have adapted the methodology developed in the U.S. by NOAA Fisheries to construct an initial set of indices for communities of fishers residing on the west and south coast of South Africa's Western Cape. Using Census data, we developed six quantitative indices related to population composition, personal disruption, and poverty to describe social vulnerability, whilst gentrification pressure

is defined by labour market status, housing characteristics, and retiree migration. Additionally, two qualitative indices represent fishing engagement and reliance related to economic and social/cultural importance. We provide an overview of how we implemented the methodology before making recommendations for future work.

(S16-16368 Oral)

Diverse pathways for climate resilience in fishery systems

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Fisheries are complex social-ecological systems with climate change affecting both the natural and human dimensions. As a result, managers and fishing communities are seeking guidance on how best to holistically build and operationalize resilience to climate change. Although attributes of resilience in fisheries literature are articulated with hypothetical mechanisms, concrete fishery system examples that explicitly link attributes to resilience outcomes are lacking. Such empirical examples could demonstrate how these attributes are developed, maintained, and managed in practice; which attributes and combinations thereof, are relevant for different fishery contexts and stressors; and how attributes interact. To better understand and visualize climate resilience in practice and in different settings, we assembled 18 case studies spanning broad ecological, social and economic, governance, and geographic contexts. Using a novel template for evaluating attributes, the case studies were systematically assessed to understand external stressors and attributes that enhanced the ability to resist, cope with and/or adapt to climate stressors. We used these responses to: (a) derive insights on the strength of these attributes across contexts, including which are consistently important across case studies, and (b) examine interactions among attributes. From this, we created a typology of attributes based on scoring strength and variability, identified fishery archetypes for analyzing resilience, and derived a framework of attribute linkages with shared resilience pathways. We provide managers with a framework that can help identify climate impacts, attributes of resilience and contextual factors that are influencing the resilience of their fisheries to climate change, and actionable levers for building resilience.

(S16-16431 Oral)

Whose fish they are? Opportunities and challenges arising from the range expansion of northern hake (*Merluccius merluccius*)

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Climate change can trigger poleward shifts in species' distributions. Hake is often seen as a climate winner in the North Sea and the Norwegian waters. New spawning areas have emerged in the northern North Sea, and intensified spawning is occurring along the coast of mid-Norway. This has created new fishing opportunities, but also new management challenges: while hake has been present in the Norwegian coast for a long time, it has been a minimally regulated minor species. The North Sea component is quota-regulated by the EU and UK, with no quota granted to Norway. This raises the question (1) what is the relationship between hake in the North Sea and the Norwegian coast, and (2) how fishers have been responding to the expanding fishing opportunities of hake? Here we use trip-level sales slip data from the Norwegian fisheries 2005–2020. Spatial correlations of commercial CPUE suggest that the North Sea component is relatively homogenous, whereas the Norwegian coastal hake are very heterogeneous. Correlations across the Norwegian Trench suggest a moderate connectivity between the coast and the North Sea. Finite mixture models suggests that there are three fishing patterns: hake as a target species, hake as a valuable bycatch, and hake as a minor bycatch. Targeted hake fishing occurs primarily in the North Sea and off the coast of mid-Norway. The fleet group that has expanded its hake catching most are the largest vessels (≥21 m). Management has yet to adapt to the new reality of Norwegian hake fishery.

(S16-16459 Oral)

Future Seas: What could the ocean look like by 2030 if we shared it equitably, and used the knowledge we already have available?

Gretta T. **Pecl**[1,2], Karen A. Alexander[1,2], Kirsty L. Nash[1,2], Camilla Novaglio[1,3], Jessica Melbourne-Thomas[1,3], plus 100+ collaborators

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Major transformations are needed to create a sustainable future for our oceans, and these transformations are reliant on more than 'just' additional data and knowledge. "The ocean we need for the future we want" requires scientists and decision-makers to facilitate the use of available science and encourage the uptake of sustainable behaviors at individual, local and global scales, that will leverage greater environmental benefit. Yet the complex and uncertain nature of many key challenges facing the oceans can lead to inertia and paralysis. The Future Seas project (www.FutureSeas2030.org) involves 120+ ecologists, philosophers, economists, Indigenous scholars and Elders, engineers, social scientists, psychologists, governance experts and more, in taking a broad interdisciplinary approach to developing positive but realistic 'mobilising narratives' of the future. Teams addressing 12 different key challenges, like food security, pollution and climate change for example, used 'foresighting' to create two alternative plausible, evidence-informed, and defensible futures - one that continues on a Business-as-Usual trajectory, and a second that pushes as far towards achieving the SDGs as technically possible. We then use 'backcasting' to derive credible pathways to action to achieve the more sustainable future. The Future Seas project aims to leverage interdisciplinary knowledge to improve society's capacity to purposefully shape the direction of marine social-ecological systems over the course of the UN Oceans Decade.

POSTER BOARD ID: S16-P1

(S16-15825 Poster)

Witnessing the Effects of Sea Level Rise on the Chilka Lake in India

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Chilka Lake, spreading over an area of about 3500 km^2 situated in the State of Orissa in eastern India, is a shallow gulf that was till now practically cut off from the Bay of Bengal sea by a sandy bar. It is also the largest brackish water lagoon in Asia and the famous winter home for lakhs of overseas avian guests - but now facing the danger of getting submerged in the Bay of Bengal is believed to be an impact of global warming and rising sea level that has resulted in frequent high tides on the coast. It has now become the greatest threat to over ten nearby villages also which are anticipating quick submergence of their villages in the Bay of Bengal. Sea levels along almost the entire Indian coast are rising faster than the global average, according to the World Meteorological Organization's (WMO) State of the Global Climate in 2021 report released May 18, 2022. Globally, the rate of sea-level rise was 4.5 mm per year between 2013 and 2021. Be it a submergence of the lake or an increase in salinity level of Chilka water, the fishing communities are suffering the worst as their main source of living wouldn't remain reliable. The threat posed to Chilka must be taken seriously and quick action must be initiated to save the valuable gift of nature from submergence. The existing sandy bar be strengthened with strong rock slab thatching. Plantation of mangroves be encouraged as additional protection against coastal erosion and to conserve the lake in a more meaningful way.

POSTER BOARD ID: S16-P2

(S16-15996 Poster)

Climate change and marine litter: inextricably connected threats to the world's oceans

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The global issues of climate change and marine litter are interlinked, and understanding these connections is key to managing their combined risks to marine biodiversity and ultimately society. On the one hand, marine litter is an acknowledged threat multiplier, acting with other stressors including climate change to cause far greater damage than if these occurred in isolation. For example, fossil fuel-based plastics cause direct emissions of greenhouse gases and therefore are an important contributing factor to climate change, while other impacts of plastics can manifest as alterations in key species and habitats in coastal and marine environments. On the other hand, climate change can exacerbate the issue of marine litter, e.g. through increased coastal erosion or storminess leading to higher inputs of litter into the marine environment. Marine litter can also degrade coastal ecosystems such as mangroves that are important for climate resilience. These examples illustrate that climate change and marine litter are linked in multiple ways, although the interactions and the resulting effects vary widely across oceanic regions and depend on the characteristics of specific marine environments. Ecosystem resilience approaches that integrate climate change with other local stressors, offer a suitable framework to incorporate the consideration of marine litter where that is deemed to be a risk. Such approaches can help steer, coordinate and prioritise research and monitoring, as well as management, policy, planning and action to effectively tackle the combined risks and impacts from climate change and marine litter.

S17: Coupling social science and economics in integrated marine climate modeling efforts

Convenors:
Mitsutaku Makino (Corresponding), (University of Tokyo, Japan)
Alan Haynie, (ICES)
Katell Hamon,(Netherlands, Wageningen Economic Research)
Kanae Tokunaga, (United States, Gulf of Maine Research Institute)

The scientific community has recognized that the marine environment is a social-ecological system and that climate change alters human relationships with the biophysical environment. Social scientists have increasingly focused on understanding how climate change impacts human communities and their resource use so that local, national, and global adaptation and mitigation efforts can effectively address the needs of diverse stakeholders. We invite quantitative and qualitative presentations that couple social and economic modeling and research with integrated biophysical climate modeling efforts. We especially welcome work about when global approaches such as shared socioeconomic pathways (SSPs) are appropriate versus when local approaches are necessary or effective.

(S17-15879 Oral)

Blue natural capital in a cost-benefit integrated assessment model of climate change

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Marine ecosystems will be substantially and permanently damaged by climate change. This threatens the unique and diverse values that people draw from the oceans globally. Nevertheless, models that aim to integrate climate and socio-economic systems largely ignore many marine ecosystemic losses as they cannot be framed through a market logic. Therefore, policy-relevant estimates that result from these models, like the social cost of carbon which informs optimal carbon tax, have been historically underestimated. Here we give the first step to expand a cost-benefit integrated assessment model of climate change to account for blue natural capital worldwide, which refers to the latent benefits societies get from the oceans. We start by examining the role of fish populations in providing use and non-use values to coastal communities worldwide. We retrieve fisheries projections under warming scenarios from process-based marine ecological models to estimate country-level changes in fish catch. Using an extended Cobb-Douglas production function to account for blue natural capital – in addition to labor and manufactured capital, we estimate future changes in gross domestic product and non-market services from fisheries. We show the importance of implementing blue natural capital into these models by contrasting policy-relevant variables, such as the social cost of carbon, with and without considering the role of blue natural capital in our society.

(S17-15888 Oral)

How climate change and climate variability affected trip distance of a commercial fishery

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Changes in climate factors affect the distribution of various tuna species differently due to their unique physiological adaptations and preferred habitats. As the resulting spatial distribution of tunas alters in response to climate change and climate variability, the distribution of fishing effort will, in turn, be affected. This study uses a quantitative model to estimate the impacts of SST and ENSO events on trip distance of the Hawaii deep-set longline fleet between 1991 and 2020. The results show that the higher the SST of the fishing grounds of the Hawaii longline fleet, the longer trip distance; and the fishing location shifted toward higher latitude and eastward from the Honolulu fishing port. This is consistent with the poleward shift in tuna habitat that occurred in the North Pacific Ocean during the period of warming ocean and the increasing trend of longline catches of tropical tuna in the subtropical areas of the western Pacific Ocean in the past four decades. Alternatively, ENSO events could result in shorter trip distance, possibly due to changes in catch rates of different tuna species through spatial redistribution during El Niño and La Niña events. This result suggests that the Hawaii longline fleet took advantage of the changes in spatial distribution of different tuna species during ENSO events, and utilized its locational advantage to travel in different directions in the Pacific Ocean to achieve higher CPUE that occurred closer to the Honolulu port, thereby shortening their travel distance.

(S17-15923 Oral)

Stakeholder engagement for the co-construction of plausible futures for French fisheries: societal and environmental consequences of global change

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Policy makers and industry managers need projections of the evolution of human societies and natural ecosystems in order to develop adaptation and mitigation strategies and cope with the consequences of global change. We aimed to construct projections of the consequences of climate change and contrasted socio-economic orientations for the French fisheries of the North Sea and the Mediterranean. Our approach consisted of a regional downscaling of global scenarios combining IPCC Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) for the 2050-2100 horizon. To co-construct policy-relevant downscaled scenarios, we engaged with fisheries managers, policy makers, scientific experts, and NGOs. We co-constructed four contrasted scenarios by mobilizing their knowledge and perceptions through an interdisciplinary framework implemented in a suite of participatory workshops. We then integrated the co-constructed scenarios into semi-quantitative models of fisheries socio-ecosystems and assessed the impacts of climate change and socio-economic mutations on marine ecosystems and fishing communities. We were thus able to identify some of the key factors regulating these fisheries in a context of global change, as well as some interdependencies and feedback loops between the components of the two French social-ecological systems. This method represents an innovative and promising approach to provide projections of marine social-ecological systems. It could complement the development of quantitative models and be useful for regional policy making. In addition, the contrasted projections we obtained are proving useful to stakeholders in developing adaptation strategies.

(S17-16067 Oral)

Livelihood resilience in the Subtropical coasts of Kerala, India using a structural equation modelling approach

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Livelihood resilience is one of the social-ecological concepts with importance for development, policy and research as crises from human-environment interactions are becoming intense and widespread. Kerala, being a State with nine coastal districts, Government have taken up a project that support the fisherfolks for their sustainability and poverty reduction named Theeramythri. This study deals with testing of various hypotheses formulated and development of Co-variance Based Structural Equation Modelling which measures effects of Theermythri project on reducing vulnerability and livelihood diversification of fisherfolks and enhancing the empowerment of fisherwomen in Kerala. It contains an overview of CB-CFA and SEM method and developing Theeramythri model for Kerala. The study carried out in three districts of Kerala. Primary data collected from a total of 474 respondents i.e., 158 respondents each from three districts, have been considered for the analysis. Based on the standardised beta coefficient, Sustainable livelihood (0.80) is the most influencing factor to Theeramythri Project – Financial Stability factor among fisherfolks in Kerala followed by accelerating the income level by alternate livelihood (0.79), improves the living standards (0.77) and develop saving habits (0.69). The result summary of hypotheses testing are also explained. In this chapter, various hypotheses were tested and a Theeramythri model for Kerala was developed based on the results of these hypotheses testing. All hypotheses are supported except the hypothesis that effects of Theeramythri project on livelihood diversification. Fit indices of this model show that both all CFA models and SEM model are with a good fit.

(S17-16242 Oral)

Socio-economic and ecological drivers of demersal fish community catch across productive shelf regions

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Demersal fish are a globally important marine resource accounting for 35% of global fisheries catches. Climate projections out to 2100 indicate that community-level demersal biomass and potential sustainable catch will decline in most continental shelf regions. Yet, the ramifications for demersal fisheries are unclear since fisheries catch are both controlled by the productive capacity of ecosystems as well as socio-economic drivers. Here we conduct a comparative ecosystem analysis to examine the relative importance of socio-economic and ecological drivers on demersal catch. This analysis is done across productive shelf regions in the North Atlantic and Northeast Pacific. Using bottom trawl survey data, we find highest community exploitation rates in the Northeast Atlantic ecosystems. Ecosystem modeling further shows that the demersal communities in these ecosystems are exploited close to their sustainable potential. In most other ecosystems, exploitation rates are lower, which indicates that total catch is predominantly limited by socio-economic drivers. To understand the differences between regions, we review fisheries management strategies, opportunities, and economic performances. We propose that ecological effects of climate change may lead to a decline in total catch in regions that are currently limited by the productive capacity. For most other regions, changes in the fish productive capacity with climate change may drive a change in fisheries economic performance but not necessarily total catch. Our findings highlight the importance of socio-economic drivers in determining the level of exploitation of marine ecosystems and support the development of future exploitation rate scenarios in line with the Shared Socioeconomic Pathways.

(S17-16331 Oral)

The impact of ocean warming on commercial fisheries in New Zealand

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The increase in ocean temperature impacts the growth, reproduction, and survival of fish. Using a bioeconomic framework pioneered by Barbier and Strand (1988), we estimate the relationship between sea surface temperature (SST) and the catch of *de facto* open-access commercial fisheries of flatfish, trevally, and jack mackerel within Aotearoa New Zealand's exclusive economic zone. We assume either a logarithmic or quadratic relationship between the SST and the carrying capacity of the fishery. We consider three fishing methods (bottom trawl, set net, and midwater trawl) and two measures of effort (count and duration). We show that ocean warming results in an increase in catch of all three fish species if we assume a logarithmic relationship, with the highest increase projected for jack mackerel caught using midwater trawl. The marginal products of SST at means () are positive for all species and gears if we assume a logarithmic relationship between SST and carrying capacity. We also show that there is a threshold above which catch starts to decrease as SST increases. If we assume a quadratic relationship, the for jack mackerel using bottom trawl is -2.89 g/ha. The maximum catch for this method and species is at 12.17°C, which means the is positive for values below 12.17°C and negative thereafter. These results are relevant in the review of the fisheries management system to respond to ocean warming and are also potentially informative about the likely re-distribution of fishes across different countries' exclusive economic zones.

S18: Beyond blue carbon: Ocean-based carbon dioxide removal (CDR) approaches

Convenors:
Darren Pilcher (Corresponding), (Cooperative Institute for Climate, Ocean, and Ecosystem Studies, University of Washington, USA)
Brendan Carter, (Cooperative Institute for Climate, Ocean, and Ecosystem Studies, University of Washington, USA)
Tiziana Luisetti, (Cefas – Centre for Environment, Fisheries & Aquaculture Science, UK)
Prateep Nayak, (Faculty of Environment, V2V Global Partnership, University of Waterloo, Canada)

Invited Speaker:
Sarah Cooley, (Ocean Conservancy, USA)

Recent reports suggest that carbon dioxide removal (CDR) is required to stabilize global temperatures following the Paris Climate Accords. The oceans, as one of the largest natural carbon sinks, are an ideal option for this removal, however, there are significant hurdles to overcome. This session will discuss the current natural science gaps in ocean CDR techniques (e.g., alkalinity enhancement, ocean fertilization), in addition to the economic, social science and governance knowledge required to ensure efficiency and effectiveness of CDR approaches (including blue carbon) and cooperation between diverse stakeholders and sectors in providing ocean-based solutions to tackle climate change.

(S18-15949 Invited)

Transdisciplinary ocean carbon dioxide removal research and evidence-based decision making

Sarah R. **Cooley**

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Ocean carbon dioxide removal (OCDR) is capturing the imaginations of many researchers and investors, given the ocean's vast size, its existing role as an anthropogenic carbon dioxide sink, and the urgent need to mitigate climate change. Research projects are beginning to consider the carbon storage potential of several OCDR techniques, costs associated with them, and even the regulatory policies that might apply to particular techniques. Policymakers are increasingly interested in whether OCDR can help governments reach their emissions-reduction commitments. Research on the likely effects of OCDR techniques on nearby ecosystems or neighboring marine activities is in the early stages of planning. Meanwhile, most people with ocean interests haven't heard about OCDR at all. This talk will discuss what information and activities are needed to enable equitable, evidence-based decision making about OCDR, and what advances have been made towards that outcome.

(S18-15840 Oral)

Predictable patterns within the kelp forest can indirectly create temporary spatial refugia for ocean acidification

Nina **Bednaršek**[1,2], Greg Pelletier[3], Marcus Beck[4], Richard Feely[5], Zach Siegrist[6], Dale Kiefer[7], Joth Davis[8] and Betsy Peabody[9]

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Seaweeds are gaining recognition as a significant CO_2 sink with a role in active mitigation and climate change adaptation, and specifically so in the application of an innovative coastal CO_2 removal belt, effectively utilizing seaweed habitats to mitigate the adverse effects of ocean acidification (OA). However, assessing OA modification strength requires an understanding of the multiple parameters' potential buffering effects, especially in highly dynamic systems. Exactly how kelp might generate more favorable conditions for marine calcifiers, has not been taken into account in previous studies to date. We studied the effects of sugar kelp (*Saccharina latissima*) on an experimental farm at the north end of Hood Canal, Washington—a low retentive coastal system. This study can serve as a natural analogue for many coastal bay habitats where prevailing physical forcing drives chemical changes. In this field mesocosm study, pelagic and benthic calcifiers were exposed with or without the kelp's putatively protective proximity at locations in the middle, on the edge, and outside the kelp array. Model outputs were used to identify dominating factors in spatial and temporal kelp dynamics, while wavelet spectrum analyses helped in understanding predictability patterns. We linked these results to biological assessments, including biomineralization, growth, and trophic connectivity of the examined species. We found our studied kelp array system did not modify carbonate chemistry parameters, but changed pH autocorrelation patterns towards higher predictability that was more favorable for marine calcifiers. Kelp also improved habitat provisioning through kelp-derived particulate organic resource utilization. Because of this, the co-culture of bivalves and seaweed can protect the calcifiers from negative effects of projected near-future OA. However, our study shows that a complex combination of physical, chemical and biological processes determines the efficiency of the kelp farms for creating more favorable habitats with respect to OA. Future macrophyte studies should focus significantly on the importance of predictability patterns, which can additionally improve the conditions for marine calcifiers as well as ecosystem services, with important implications for the aquaculture industry.

(S18-16021 Oral)

Ocean carbon cycle feedbacks and the seasonal cycle of the carbonate system under ocean alkalinization

Jörg **Schwinger**

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Ocean Alkalinization deliberately modifies the chemistry of the surface ocean to enhance the uptake of atmospheric CO_2. Here I quantify, using idealized Earth system model (ESM) simulations, changes in carbon cycle feedbacks and in the seasonal cycle of the surface ocean carbonate system due to ocean alkalinization. We find that both, the sensitivity to changes in atmospheric CO_2 concentration (carbon-concentration feedback) as well as the sensitivity to temperature changes (carbon-climate feedback) are enhanced. While the temperature effect, which decreases ocean carbon uptake, remains small in our model, the carbon-concentration feedback enhances the uptake of carbon due to alkalinization by more than 20% compared to the carbon sequestration that alkalinity addition would facilitate at constant CO_2 levels. This effect depends on the trajectory of atmospheric CO_2 concentration. The seasonal cycle of air-sea CO_2 fluxes is strongly enhanced due to an increased buffer capacity in an alkalinized ocean. This happens largely independently of the seasonal cycle of *p*CO2, which is only slightly enhanced. The most significant change in the seasonality of the surface ocean carbonate system is an increased seasonal cycle of the aragonite saturation state in some regions, which has the potential to adversely affect ecosystem health.

(S18-16114 Oral)

Why planting trees and seagrasses cannot offset fossil fuel emissions

Sophia C. **Johannessen** and James R. Christian

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Climate change mitigation science has a communication problem. There is a widespread idea – in both the blue carbon literature and the popular media – that restoring vegetated ecosystems can offset fossil fuel emissions. The implication is that if we restore enough seagrass, mangroves, salt marshes and trees, then fossil fuel emissions can continue without causing further climate change. Nature-based solutions cannot truly offset fossil fuel emissions, because of the difference in timescale. Nature-based solutions operate on the modern carbon cycle: air, water, vegetation, surface sediment and soil, which exchange on timescales of days to centuries. In contrast, fossil fuels have been isolated for hundreds of millions of years. So long as fossil carbon emissions continue, the total amount of carbon in the modern cycle will continue to increase. Short- or medium-term nature-based solutions can remove CO_2 from the atmosphere and thereby buy time until longer-term solutions can be implemented. Ending fossil fuel emissions would limit the total amount of carbon in the modern cycle. Developing technology to remove carbon from the modern cycle and store it for the long term (> 100,000 years) could potentially reverse some of the effects of climate change, although with unknown effectiveness and risks. To support informed decision-making, science communication about these options and what they can achieve must be clear and unambiguous.

(S18-16152 Oral) REVISION: New authors and title.

~~**Solutions road maps for ocean CDR: advances on seaweed cultivation and sinking**~~
Solutions road maps for ocean CDR: Advances, challenges, and opportunities

~~David Koweek[1], James Barry[2], Brad Ack[1] and Emanuele **Di Lorenzo**[1,3]~~
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During 2020, Ocean Visions convened experts from multiple disciplines, sectors, and geographies to co-develop a set of road maps to advance solutions for ocean carbon dioxide removal (CDR) in three domains: ocean alkalinity enhancement, electrochemical removal of carbon dioxide, and macroalgal cultivation and carbon sequestration. Numerous workshops helped to identify technology readiness, scaling potential, uncertainties, obstacles, opportunities, and first-order priorities. In this talk, we will discuss recent advances in the priorities identified in the macroalgal CDR road map. Specifically, we will introduce a framework for a coordinated global research effort dedicated to investigating the efficacy of carbon sequestration and environmental impacts of growing and sinking macroalgae into the deep ocean as CDR strategy. This framework, published in a 2022 report co-produced by Ocean Visions and the Monterey Bay Aquarium Research Institute, incudes 23 fundamental scientific questions spanning physical and biological sciences, detailed guidance on the design and execution of controlled field trials, estimates of the cost of a single controlled field trial, and a compilation of global oceanographic assets that can be used to facilitate the research activities described in the framework, alongside a list of pilot projects underway or in the planning stages. Adherence to the guidance in this report is intended to accelerate the production of actionable information for policy about efficacy, costs, and benefits of sinking macroalgae into the deep sea as a carbon dioxide removal strategy, and more broadly, as part of the set of solutions for solving the climate crisis.

(S18-16156 Oral)

Biogeophysical constraints of macroalgae carbon dioxide removal identified with a high-resolution ocean biogeochemical model

Manon **Berger**[1], Lester Kwiatkowski[2], David T. Ho[3] and Laurent Bopp[1]

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Using a high-resolution global ocean biogeochemical model, we simulated idealised macroalgal cultivation as a uniform and unconstrained carbon sink in the upper 100 m of coastal regions to evaluate the extent to which macroalgal cultivation could enhance regional and global ocean carbon uptake. We demonstrate that physicochemical and biological constraints limit the carbon dioxide removal (CDR) efficiency, with efficiencies varying from 85% to –5% regionally. Nutrient constraints on macroalgae production and phytoplankton feedbacks caused by macroalgal nutrient reallocation further reduced CDR efficiency in most regions (73% of the total cultivated area). This decrease in CDR efficiency is mainly caused by a deepening of the optimum depth of macroalgal production. In some regions (17% of the total cultivated area), nutrient constraints and feedbacks can even lead to a reduction in the unperturbed oceanic carbon sink, highlighting the critical choice of cultivation location. The macroalgae driven suppression of phytoplankton primary production is highest in the eastern tropical Pacific where it reaches -40 gC m^{-2} yr^{-1}, indicating the potential to significantly impact wild food webs. Our analysis further demonstrates that half of macroalgae CDR occurs outside the cultivated area, potentially hindering the monitoring and verification of carbon removal that any real-world deployment is likely to require.

(S18-16158 Oral)

Storing captured and intentionally sequestered CO_2 in the deep ocean

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The large capacity of the ocean to store CO_2 makes it a very important factor in the efforts to control and reduce the CO_2 concentration in the atmosphere. When sequestering CO_2 in the deep by engineering methods, most of it is expected to remain isolated from the atmosphere for centuries. Such sequestration can be as direct injection of captured gas from point sources or from the air, or indirectly, via enhancing the natural carbon pump. The two latter methods are usually termed negative emissions. Numerous initiatives were made to study ocean CO_2 storage over the last decades. Many projects have been met with scepticism and opposition, and some research has been prematurely terminated of such reasons. Concerns have been raised about environmental impacts of the introduced CO_2 and about legal, political, economic, and ethical issues. The legality of injecting CO_2 into the ocean is still unclear. Captured CO_2 tends to be labelled as an industrial waste and thus "dumping" of it in the ocean is dubious. The practices are easily termed Geoengineering by oponents. The ethics of ocean storage of CO_2 revolves around society's perception of the risks and benefits of such an activity. This paper reviews experiences made in this field, from direct injection modelling and field experiments to proposed negative emissions methods like ocean fertilization and ocean liming. Lessons learned and suggestions for the future are provided.

S19: Ocean Acidification Research for Sustainability

Convenors:
Katherina Schoo (Corresponding), (IOC-UNESCO)
Jan Newton, (GOA-ON co-chair and University of Washington, USA)
Steve Widdicombe, (GOA-ON co-chair and Plymouth Marine Laboratory, UK)

Plenary Speaker:
Punyasloke Bhadury, (Indian Institute of Science Education and Research Kolkata, West Bengal, India)

Invited Speaker:
Samantha Siedlecki, (University of Connecticut, USA)

The United Nations Decade of Ocean Science for Sustainable Development Programme "Ocean Acidification Research for Sustainability (OARS)" will provide ocean acidification (OA) data and evidence, identify data and evidence needs for mitigation and adaptation, co-design and implement observation strategies, and increase understanding of OA impacts to protect marine life, by 2030. To ensure its success, OARS will require collaboration across the global OA community, spearheaded by OARS "co-champions" to coordinate these efforts. This session invites contributions that highlight activities addressing the 7 outcomes of OARS, such as OA biogeochemical and biological observations, data management, projections, capacity development and science-policy efforts. More about OARS

(S19-16350 Plenary)

Ocean acidification research for sustainable ocean- nexus between science, local knowledge and policy framework

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The coastal and marine ecosystems across South and South-east Asia have emerged as a key space today. More than 1.5 billion people co-exist along the coastlines with biotopes such as estuaries, mangroves, saltmarshes, lagoons and coral reefs. The rich local, indigenous and cultural knowledges of the people are influenced by ocean on a daily basis. With more than 25% of global population inhabiting the coastlines of South and South-east Asia, the rich marine bioresources serve as a source of livelihood, drive blue economy and contribute to regional GDPs. However, a number of stressors of anthropogenic origin are leading to ocean acidification which is adversely affecting sustainability of coastal and marine ecosystems across South Asia and wider Indo-Pacific. There are a number of challenges being faced in the region including limited data on changing ocean carbonate chemistry, lack of atlas of coastal ocean acidification such as in the Northern Indian Ocean and very limited blue financing initiatives that can support monitoring of regional seas and ocean. The establishment of South Asia Regional Hub on Ocean Acidification (SAROA), part of the Global Ocean Acidification Observing Network (GOA-ON) offers to bridge the gaps in knowledge linking ocean acidification with ocean sustainability. The existing regional and pan-regional frameworks such as South Asia Association for Regional Cooperation (SAARC), Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), ASEAN-India and QUAD offers opportunity to mainstream ocean acidification research within policy frameworks as well as from polycentric governance approaches. The rich knowledge of the people and their role as citizen scientists towards achieving ocean sustainability from ocean acidification perspective can offer opportunities for bridging gap and disparities in development indicators in South

Asia and broader Indo-Pacific context. The synergy between the science of ocean acidification, integration of local knowledge and policies can form the basis for promotion of ocean-based enterprises through ocean financing to ultimately achieve sustainable ocean economy.

(S19-16480 Invited)

Can seasonal forecasts of ocean conditions including ocean acidification variables aid fishery managers?: Experiences from 10 years of J-SCOPE

S.A. **Siedlecki**[1], I. Kaplan, E. Norton, A. Hermann, S. Alin, R. Feely, N. Bond, S. Ray, M. Malick, M. Hunsicker, F. Soares, E.J. Schumacker, D. Ayres, K. Corbett, M. Alexander, G. Hervieux, G. Williams, N. Bednarsek, J. Fisher, C. Morgan, and J. Newton

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Multiple stressors including ocean acidification of coastal waters is of increasing concern to local fisheries. Many economically, culturally, or ecologically important species (oysters, crabs, etc.) in the Pacific Northwest already experience direct effects of ocean acidification, warming, and hypoxia. Additional indirect economic impacts are possible on the finfish industry due to a loss of prey species. The ability to predict the degree of acidification and hypoxia as well as relevant indices of impact for species of interest could be of considerable benefit to managers. Over the past 10 years, we have developed a seasonal ocean prediction system, JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE) for the coastal waters of the Pacific Northwest (Siedlecki et al. 2016; Kaplan et al. 2016). The goal has been to provide seasonal (six month) predictions of ocean conditions that are testable and relevant to management decisions for fisheries, protected species, and ecosystem health components. The results (http://www.nanoos.org/products/j-scope/home.php/) include publicly available seasonal forecasts of OA variables, hypoxia, temperature, and ecological indicators. Additionally, results are tailored for decision makers involved in the federal, international, and tribal fisheries. Federal managers at the Pacific Fishery Management Council now receive J-SCOPE forecasts of OA and hypoxia within annual Ecosystem Status Reports. US and Canadian managers of Pacific hake (*Merluccius productus*) are now briefed on J-SCOPE forecasts of hake distribution. Most recently, new ocean acidification indices specific to Dungeness crab (*Metacarcinus magister*) have been co-produced with state and tribal managers. In each of these cases, the team has also investigated the sources of skill in the ocean conditions to assess applicability of the forecasts to the variables, depths, and seasons relevant to these high value fishery species. Finally, we will look back on the past 10 years of forecasting and discuss our successes and failures, and potential global applicability of seasonal forecasting to inform flexible management responses to grapple with global change.

(S19-15922 Oral)

Consumer-resource interactions of calcifying marine organisms under ocean acidification and warming

Laura J. **Falkenberg**, Alissa V. Bass, Shu Him Lam and Patrick W.S. Joyce

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Consumer-resource interactions play an important role in shaping ecosystem structure and function. As oceans change, undergoing acidification and becoming warmer (both over the long term and under short-term marine heatwaves), these interactions may be altered. Feeding rates may be adjusted as ocean acidification and warming can both affect related physiological (e.g., metabolic rate) as well behavioral traits (e.g., foraging, feeding preference). The consequences of these adjustments will be particularly notable where the consumer affected links different

trophic levels, as is the case for marine invertebrate herbivores. Given the importance of these organisms, there is an emerging body of literature considering the responses of invertebrate herbivores to ocean acidification and warming (both long- and short-term), which I will review here and synthesize into more general statements about the anticipated response directions and proposed underlying mechanisms. I will also discuss a manipulative experiment conducted in Hong Kong which quantified the responses of herbivores to moderate ocean acidification and warming, both in isolation and combination. The results of this experimental study will then be considered in the context of the general patterns identified in the review. Together, the literature review and experimental outcomes highlight that while we can try to draw generalizations, the exact responses observed will likely be context-specific (e.g., to a particular location, feeding group, combination of environmental conditions altered). Despite these moderating factors, our results indicate that there could be important changes to ecosystem structuring consumer-resource interactions under a future climate.

(S19-16010 Oral)

The Olympic Coast as a sentinel: An integrated social-ecological regional vulnerability assessment to ocean acidification

Jan A. **Newton**[1], Melissa Poe[1], Samantha Siedlecki[2], Simone R. Alin[3], Richard A. Feely[3], Halle Berger[2], Roxanne Carini[1], Steven Fradkin[4], Tommy Moore[5], Joe Schumacker[6], Russel Svec[7], Julie Ann Koehlinger[8], Jennifer Hagen[9], Jenny Waddell[10], Meg Chadsey[1] and Adrienne Sutton[3]

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We present results of a NOAA-funded Regional Vulnerability Assessment (RVA), a place-based collaborative effort to understand, anticipate, and prepare for ocean changes affecting natural and human systems. The study was located at the Olympic Coast of the northwest corner of Washington state, USA, home to four coastal treaty tribes: the Hoh, Makah and Quileute Tribes and the Quinault Indian Nation who have stewarded and depended on the ocean for thousands of years. We used a stepwise approach, integrating new social science, a synthesis of existing data, and forecast model projections relevant to Olympic Coast biological resources to provide an assessment of coupled social-ecological vulnerability to effects from ocean acidification (OA) and other climate-change related stressors. Tribal community partners and collaborating institutions co-designed, co-produced, and actively collaborated on the project, driven by their priorities, needs, and capacities, and bringing together multiple streams of knowledge to address intersecting issues in a coupled social-ecological context. I will cover the overall approach with a specific focus on results from the oceanographic data synthesis and model projections that enabled us to estimate the risk of OA impacts to key biological resources important to the tribal community partners. We focused on four target species (Dungeness crab, Pacific halibut, razor clams, olive snails), assessing the stressors of highest relevance while incorporating temporal aspects of their life history patterns indicating highest vulnerability. This was interpreted across the spatial context of the Olympic region to identify and assess risk potential. Our approach, while place-based, is easily transferrable to other locations.

(S19-16047 Oral)

Role of ocean acidification in changing characteristics of coastal ocean system in Bay of Bengal and Arabian Sea – Evidence from pre- and post- Covid'19 lockdown conditions

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Ocean acidification or reduction in the magnitude of *p*H of the sea water is not new. What is new is the alarming threat of changing physico-chemical characteristics of coastal sea water that has the multitude potentials for altering the climate that generates from natural ocean system since the time immemorial. This paper shows how the coastal sea water is influenced by release and non-release of CO_2 during normal operation of various industries nearby coastal areas of Bay of Bengal and Arabian Sea and during cessation of industrial release of CO_2 during Covid'19 lockdown period. It is very interesting to note that such influence of land based CO_2 falling onto the sea surface, and its subsequent dissolution leading to reduction, from the normal *p*H scale of the coastal sea water while commenced readily but the overall alteration in changing characteristics of the sea water appears late in the time frame on an average of 1 year. The renewability and continuous flushing of landward high tidal seawater intrusion to the coastal zone appears to be the reason for delaying the stagnation signature of reduction of *p*H in the coastal sea water examined, and a model has been suggested based on the time series data generated mostly on *in situ* experimentation.

(S19-16103 Oral)

Feedbacks between the carbonate pump and future ocean acidification in Earth system and ocean biogeochemical model simulations

Alban **Planchat**[1], Laurent Bopp[1] and Lester Kwiatkowski[2]

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Ocean acidification is likely to impact the ocean carbonate pump, specifically the production, export, dissolution and burial of biogenic $CaCO_3$. However, the feedbacks of this on anthropogenic carbon uptake and ocean acidification have received little attention. It has previously been shown that Earth system model (ESM) carbonate pump parameterizations can affect the representation of ocean alkalinity, which is critical to the uptake of atmospheric carbon and provides buffering capacity towards associated acidification. We show that Coupled Model Intercomparison Project Phase 6 (CMIP6) projections of $CaCO_3$ export at 100 m diverge this century, with 2100 anomalies ranging from -72 % to +23 % under a high-emissions scenario. Interestingly, the greatest export declines are projected by ESMs that consider pelagic $CaCO_3$ production to depend on the local calcite/aragonite saturation state. Despite the potential effects of other processes on alkalinity, there is a correlation between anomalies in $CaCO_3$ export and salinity-normalized surface alkalinity across the CMIP6 ensemble. Motivated by this relationship and the uncertainty in $CaCO_3$ export projections across ESMs, we perform idealized simulations with an ocean biogeochemical model to assess the extent to which changing $CaCO_3$ export can influence ocean carbon uptake and acidification. Our simulations suggest that under high emissions, the magnitude and response of the carbonate pump have limited impact on ocean carbon fluxes by 2300 but can have a notable impact on ocean acidification.

(S19-16119 Oral)

Around the bend and back again: Crossing buffering capacity minima in northwest US coastal and estuarine waters and implications for future regional ocean acidification trends and patterns

Simone R. **Alin**[1], Richard A. Feely[1], Samantha Siedlecki[2], Brendan Carter[1,3], Jan Newton[3] and Jenny Waddell[4]

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Northeast Pacific marine ecosystems experience naturally high CO_2 conditions as a result of subsurface respiratory CO_2 accumulation during global ocean circulation. Subsurface water masses upwelled into coastal and estuarine environments thus have naturally low buffering capacities, which are eroded further by local respiration processes and global ocean acidification. Here we present estimates of how buffering capacity and carbonate chemistry in Washington state's marine waters have changed from pre-industrial to present (indexed to 2013) times, compared to local data-based projections of near-future (2030–2040) acidification and ROMS (J-SCOPE) simulation of end-of-century conditions. Bottom-water residence times vary across the Washington shelf (northern California Current System) and Puget Sound basins to create a mosaic of biogeochemical conditions in the present-day. Acidification anomalies during recent extreme events consequently manifested in a spatially complex way. Projected rates of acidification are also expected to vary by water depth and carbonate system parameter as a result of spatial heterogeneity in residual buffering capacity. Some regional habitats are projected to see equal or greater change by 2030–2040 in saturation states, partial pressures of CO_2, and pH as we estimated between the pre-industrial and present. In contrast, the habitats currently most acidified may see less change in saturation states over the near future but an acceleration of pCO_2 increase as the carbonate system is depleted of carbonate ions. Differential rates of change across ocean acidification metrics have implications for how the multi-stressor seascape will evolve over the coming decades, and its relevance to potential biological impacts.

(S19-16157 Oral)

Ocean acidification state variability of the North-West Africa Atlantic ocean waters

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The Canary Current Large Marine Ecosystem (CCLME) region supply very significant local and international fish resources, based largely on small pelagic fish and artisanal fisheries. Especially on the North West Africa Atlantic Sea, the fishery market contributes to economy

of the region bordering this sea and provide an important food and employment to coastal communities. In 2017, the 30-year long EAF Nansen Program (FAO and Norway), began with studies on ocean acidification along this region. Here, we show the first results on the ocean acidification state from this new research theme focusing on the North West Africa waters (from Morocco (35°N) to Senegal (12°N). In May-July 2017 and October-December 2019, samples were measured, in this region, onboard the R/V Dr. Fridtjof Nansen for total alkalinity and pH using potentiometric titration and spectrophotometric pH measurements, respectively. The other parameters describing the carbonate chemistry and ocean acidification state were derived from salinity, temperature and pressure combined with AT and pH, using the CO2SYS calculation program. The survey performed at twenty-seven sections perpendicular from the coast with a total of 110 stations in the full water column. We found large variability along the coast, connected to upwelling/mixing of water masses, primary production, temperature and biological processes. In this presentation, we present the first ocean acidification data from the North West Africa waters and discuss the variability in context of deep-water intrusions, upwelling, temperature, and phytoplankton production.

(S19-16162 Oral)

Assessing vulnerability of the U.S. Atlantic sea scallop to ocean acidification and warming: A dynamic energy budget modeling approach

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The U.S. Atlantic sea scallop (*Placopecten magellanicus*) fishery is valued at more than $500 million per year, making it the second highest valued fishery in the country and the largest wild scallop fishery in the world. While the fishery is currently considered to be well-managed, managers and industry stakeholders are concerned that changing ocean conditions driven by climate change will cause declines in scallop availability, harvest, and revenue. Subsurface scallop habitats in the Northeast and Mid-Atlantic already experience suboptimal temperature and carbonate chemistry conditions episodically. Regional ocean model projections indicate that conditions in the Gulf of Maine will begin to surpass suboptimal thresholds persistently by the year 2050. Here, we project the effects of ocean acidification (OA) and warming on sea scallop growth and reproduction historically and over the next 100 years using a dynamic energy budget (DEB) model forced by a regional ocean model. Preliminary results suggest that end-of-century OA and warming, together, will cause sea scallops to grow faster but reach a smaller maximum size. Our future work will couple the DEB model to a larval transport model. This novel combination of approaches will allow us to quantitatively relate changing ocean conditions to changes in the sea scallop population vulnerability and inform fisheries management by estimating changes in time to reach harvest size and identifying areas that are candidates for future fishing zones.

(S19-16167 Oral) **REVISION: Presentation CANCELLED**

Warming and acidification responses of ionocytes in the skin of early life stage fish

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An important part of understanding how fish survival, growth, and reproduction are affected by ocean acidification and co-occurring stressors is to quantify physiological mechanisms by which fish respond to them early in life. Embryos and larvae have ionocytes, cells that use ATP to transport ions, on the skin surface of the body until gills develop. We hypothesized that early life stages of the estuarine fish *Menidia menidia* respond to elevated carbon dioxide (CO_2) by increasing the density of ionocytes on epithelial surfaces for enhanced acid-base balance. To test our hypotheses, we reared *M. menidia* embryos and larvae in factorial CO_2 and temperature treatments and stained their ionocytes to quantify ionocyte density per unit of skin surface area. A significant interactive effect was found in which embryonic ionocyte abundance increased with temperature at high CO_2 but was unaffected by temperature at ambient CO_2. In addition to highlighting the importance of multistressor experiments, this suggests that warmer temperatures could enhance internal pH regulation, while also increasing energy spent on acid-base balance. In larvae sampled the day of hatching, the temperature and CO_2 interaction remained but ionocytes decreased, rather than increased, with increasing temperature under high CO_2. When larvae reached about 10mm total length, and gill development had progressed, elevated CO_2 slightly increased ionocyte density but temperature had no effect. Interestingly, results varied between experiments conducted at various times throughout the spawning season with different wild-caught parents, suggesting that environmental conditions before spawning may influence acidification tolerance of offspring.

(S19-16186 Oral)

The OSPAR assessment of ocean acidification in the North-East Atlantic

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The OSPAR Convention is the mechanism by which 15 Governments and the EU cooperate to protect the marine environment of the North-East Atlantic (NEA). OSPAR provides a platform where scientists and policy makers enter into a dialogue, assessments of the state of the marine environment are performed, and recommendations are formulated for participating nations to improve or conserve the marine environment. OSPAR's NEA Environment Strategy aims to achieve *clean*, *biologically diverse, productive and sustainably used* seas that are *resilient to climate change and ocean acidification*. For OSPAR's Quality Status Report 2023, an expert group undertook a comprehensive assessment of ocean acidification (OA) for the NEA. OA variability and trends were assessed using multiple approaches including observational data, regional reconstruction synthesis products, and a regional hindcast simulation. Two regional coupled hydrodynamic-biogeochemical models (covering much of the OSPAR area) were used to project OA trends on a mid-century time horizon, for medium and high emission scenarios (RCP 4.5 and 8.5). OA impacts on ecosystems and ecosystem services were reviewed and highlighted with selected case studies, and the assessment features a discussion on adaptation and mitigation. The assessment revealed OA occurring in all OSPAR regions, albeit at differing rates, and that OA is projected to progress in the future. OA contributes to a multi-stressor marine environment exerting pressure on many species and habitats, including those under protection and those of commercial value. With the assessment we present here OSPAR aims to inform the wider public and develop recommendations for policy in OSPAR nations.

(S19-16206 Oral)

Observed and projected impacts of coastal warming, acidification and deoxygenation on Pacific oyster (*Crassostrea gigas*) farming: A case study in the Hinase Area, Okayama Prefecture and Shizugawa Bay, Miyagi Prefecture, Japan

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Coastal warming, acidification and deoxygenation are all progressing primarily due to an increase in anthropogenic CO_2. There is concern about the future combined impacts of these phenomena on shellfish and their farming including Pacific oysters (*Crassostrea gigas*), and the impacts are anticipated to become more severe as climate change progresses. Therefore, it is necessary to elucidate the current and project future impacts to take necessary measures to minimize the impacts on shellfish farming. We deployed continuous monitoring systems for

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coastal warming, acidification and deoxygenation in the Hinase Area in Okayama Prefecture and Shizugawa Bay in Miyagi Prefecture, Japan, which is the first attempt in major oyster farms in Japan coasts. The aragonite saturation state (Ω_{arag}) value was first found to be often lower than the critical level of acidification for Pacific oyster larvae in Hinase, while no impacts of acidification on the larvae were identified by microscopic examination. The oyster larvae are anticipated to be affected more seriously by the combined impacts of coastal warming and acidification, with lower pH and Ω_{arag} values and prolonged spawning period, which may shorten oyster shipping periods and lower oyster quality, and may affect oyster processing industries in future. To minimize impacts of coastal warming and acidification on Pacific oysters and relevant local industries, CO_2 emission cutting measures are mandatory, but adaptation measures such as regulation of freshwater and organic matter inflow from rivers and change of oyster farming form might be required for local implementation.

(S19-16218 Oral)

Drivers of surface ocean acidity extremes under different climates

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It is well known that the uptake of anthropogenic carbon by the ocean causes acidification, a process that describes the gradual increase in [H^+] concentrations and decrease in calcium carbonate mineral saturation states (Ω), which affects a variety of calcifying marine species and has the potential to disrupt entire ecosystems. Especially harmful are ocean acidity extreme (OAX) events, during which [H^+] is much higher than normal. Such OAX events can last for days to months and are projected to strongly increase under elevated atmospheric CO_2 concentrations. However, a global perspective on the local physical and biogeochemical processes driving OAX events is missing. Using a pre-industrial simulation of a fully-coupled Earth system model, we analyze two-hourly output of all processes that influence the surface ocean temperature and carbon budget, and ultimately [H^+], to quantify the driving mechanisms during the onset and decline of OAX events. We show that increases in temperature due to net ocean heat uptake dominate the onset of OAX events, especially in the subtropics. In the high latitudes, decreased downward vertical diffusion and mixing of warm temperature during summer and increased mixing with carbon-rich subsurface waters during winter are the main drivers of OAX event onset, whereas in the tropics, upwelling of carbon often drive the onset of OAX events. These results will be contrasted with the drivers for low Ω extremes. Finally, potential changes in the driving processes under near-stabilized future climates (e.g., 1.5, 2.0° and 3.0°C) will be discussed.

(S19-16240 Oral)

Climate change co-stressors and their effects on the biological, physiological, and genomic responses of juvenile Pacific oysters

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Climate change, driven by increasing anthropogenic greenhouse gas emissions, is leading to increases in global atmospheric and oceanic temperatures with coinciding rises in oceanic carbon dioxide (pCO_2), which is driving ocean acidification (OA). Certain marine animals, including various bivalves (e.g. oysters, mussels, clams), are negatively impacted by the independent impacts of increasing temperature and OA, but the effects of combined stressors on marine organisms can be unpredictable. Here we focused on warming and low pH, two climate change stressors expected to interact, particularly in the northeast Pacific ocean where low-pH-water upwelling events are common. We determined potential independent (one stressor) and cumulative (two stressors) effects on biological (growth), physiological (dissolved oxygen uptake), and genomic (gene expression) responses of juvenile Pacific oysters (*Crassostrea gigas*). Responses were measured over a 16-week experimental duration with two factors (pCO_2 and temperature) and two levels (current summer average and future summer level) in a fully crossed design including six replicate tanks per treatment, with 20–24 oysters per tank. Oysters were sampled at regular intervals (bi-monthly/monthly) over the experimental duration to examine shell length, shell height, shell width, condition index, dissolved oxygen uptake, and gene expression of a suite of genes related to energy budgets and metabolism. Results of condition index, gene expression, and carbonate chemistry of the experiment will be presented and interpreted in the context of mitigations to combat climate impacts on marine life.

(S19-16262 Oral)

The interactions between acidification and deoxygenation along the West Coast of North America

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The continental shelf waters off the west coast of North America are exposed to water with increasing concentrations of anthropogenic CO_2 (C_{anth}) and decreased oxygen from exchanges with the atmosphere and mixing of upwelled water. Based on measurements collected off the west coast of the United States and Canada in 2021, seasonal upwelling drives intense cycling of organic matter that is created through photosynthesis in the surface ocean and degraded through biological respiration in subsurface habitats. We observed reductions in pH and decreases in aragonite saturation state of up to 0.24 and 0.45, respectively, relative to a linear mixing model. These conditions for dissolved oxygen, pH and aragonite saturation state in the subsurface waters were below critical thresholds for several marine species. The results indicate a strong non-linear correlation where respiration processes and C_{anth} input are the major cause of the decreasing aragonite saturation state with increasing depth. Aragonite saturation state drops

below the value of 1.0 at an oxygen concentration of approximately 145 µmol kg^{-1} in 2021 and 93 µmol kg^{-1} in the preindustrial period. While the results for the higher saturation state thresholds follow the same overall trend, the differences are larger when the thresholds occur at higher saturation states. Thus, the impact of the additional amount of C_{anth} added to the subsurface waters in this region is to reduce the amount of respiration required to bring the system down below this critical thermodynamic threshold for calcification. This effect decreases the overall volume of suitable habitat for calcification.

(S19-16305 Oral)

Phytoplankton community dynamics under potential ocean acidification scenarios: a case study from the Indian Sundarbans

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Estuaries are dynamic and thus resident as well as 'specialized' biological communities are subjected to constant changes in environment parameters that could potentially act as a set of'adaptive stressors. The estuaries of Sundarbans mangrove witness diurnal tides that result in sharp changes in salinity and pH in surface water. In addition, there is influx of litterfall that can either aid in the buffering capacity and further tip alkalinity values, resulting in more acidic conditions. High temperature of the tropical regions changes atmospheric dynamicity, altered pCO_2 levels and these are ultimately reflected in mangroves in terms of sink or source of carbon dioxide. It is thus imperative to understand the influence of this estuarine variability in pH in the backdrop of ocean acidification. A mesocosm experiment was set-up to study the influence of coastal pH on the resident phytoplankton communities. The pH levels were altered by ±0.5 units from the *in-situ* value measured during collection. Total phytoplankton abundances were observed to be higher than the control in both pH±0.5 set-ups. However, sharp changes in community structure were only observed till Day 4, after which the relative abundance of phytoplankton taxa appears to remain study. Dissolved nutrients including nitrate and reactive silicate were significantly lower at the end of the experiment indicating uptake by biological communities including phytoplankton. Such intricate mesocosm experiments can provide deep insights into resilience and succession of phytoplankton taxa under ocean acidification scenarios in dynamic coastal biotopes such as mangroves.

(S19-16315 Oral)

Observations in Svalbard fjords as climate change proxies for a changing Arctic: focus on Kongsfjorden, ocean acidification and drivers

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Svalbard fjords in the west-Spitsbergen are influenced by warm and salty Atlantic water in the outer parts contrasted by colder, fresher glacial and sea-ice meltwater in the inner parts. Due to warming, glaciers retreat and add glacial meltwater into the fjords, and sea ice melts. Since 2012, we perform seasonally and yearly observations to monitor the carbonate chemistry, nutrient concentration, and freshwater content in several Svalbard fjords. Here, we present seasonal and interannual variability in the carbonate chemistry, ocean acidification (OA) state and freshwater influence in Kongsfjorden, using measured total alkalinity (AT), total dissolved inorganic carbon (DIC), pH, dissolved inorganic nutrients, salinity, temperature, calculating calcium carbonate saturation state (Ω) for aragonite and calcite and freshwater fractions. Changes in the different water masses and freshwater directly influence Ω, but also indirectly by affecting biological drivers. The lowest Ω and pH values are observed in winters and the highest Ω and pH are found in autumn, mostly due to CO_2 consumption during primary production. In Kongsfjorden, near the glacier front, generally glacial water decreases Ω by the same amount as the biological effect increases Ω. The seasonal increase in temperature only plays a minor role on the increase of Ω. Overall, we conclude that increase in freshwater supply results in decrease in Ω, pH and the buffering potential of acidic CO_2 uptake. Observations of calcite and dolomite crystals in the glacial ice suggest supply of carbonate-rich glacial drainage water to the fjord, partly mitigating ocean acidification.The time series contributes to the GOA-ON network and OARS.

(S19-16434 Oral)

The variable impacts of ocean acidification on the growth and toxigenicity of *Pseudo-nitzschia* diatoms from the California Current Upwelling System

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The decrease in pH due to ocean acidification (OA) and the increase in severity of toxigenic diatom blooms are well known in the coastal waters of the California Current eastern boundary upwelling system. However, since the physiological impacts of OA on diatoms of the genus *Pseudo-nitzschia* have been poorly studied, it is currently very difficult to characterize the toxic risk to marine ecosystems and human health. Here the effects of elevated CO_2 levels were examined as a function of nutrient availability in controlled laboratory studies of *Pseudo-nitzschia australis* and *P. multiseries* - the system's two most impactful diatoms. Non-axenic strains, isolated from Monterey Bay, CA were grown at pH levels ranging from 8.10 to 7.80 - representing present and future coastal ocean conditions under climate change. Our results demonstrate the adaptive capability of both species to produce the potent neurotoxin, domoic acid

(DA), during their nutrient-replete, exponential growth phase where cellular DA concentrations were very low, and their silicate-depleted, stationary growth phase where cellular DA levels were much greater, however the growth response to OA was not consistent between species. Whereas the exponential growth rate of *P. multiseries* did not vary with declining pH, the growth rates of *P. australis* decreased by 30% at the lowest pH tested. Domoic acid production results were more consistent; stationary cells of both species increased DA production with declining pH demonstrating the potential of both species to become increasingly harmful due to OA, and increasing the toxic risk to coastal ecosystems and human health.

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(S19-15893 Poster)

Development of ocean acidification in situ observation over the Indonesian maritime continent

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Indonesian Maritime Continent (IMC) is a tropical archipelago area in which the ocean's the largest and provides the only tropical pathway connecting the Pacific to the Indian Ocean through Indonesian Throughflow Ocean variability and circulation over the Indonesian seas has an impact not only on the local ocean but also the global ocean circulation through teleconnections with the Pacific and the Indian Ocean. In situ observation from the Indonesian seas is essential to understanding regional and global conditions. In this study, we want to brief the development of ocean observation in the IMC area especially ocean acidifications near the estuary with the peatland coast in the western part of IMC and the open ocean area in the eastern IMC. pH for peatland is generally acid conditions (pH is about 3 – 4) and has a strong impact on ocean conditions due to flow from the tidal current. During flood conditions, the pH ocean is about 7.8 while during the ebb conditions, the pH around the ocean is about 6.7. The open area shows that the pH around the ocean is about 8.1. We have 40 locations for pH observations for detected ocean acidification with specific characteristics and conditions.

POSTER BOARD ID: S19-P2

(S19-15896 Poster)

Modified diurnal variability of the global surface ocean CO_2 system

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Our understanding of how climate change influences the marine CO_2 system has increasingly focused on perturbations to carbonate chemistry variability. This variability can affect ocean-climate feedbacks and influence marine ecosystems. The seasonal variability of the ocean CO_2 system has already changed, with enhanced seasonal variations in surface ocean acidity and pCO_2 over recent decades and further amplification projected by models over the 21st century. CO_2 vent sites indicate that diurnal variability is also likely to be altered by climate change. We modified a global ocean biogeochemical model to resolve physically and biologically driven

diurnal variability of the ocean CO_2 system. Forcing the model with 3-hourly atmospheric fields, we explore how surface ocean diurnal variability responds to historical changes and project how it changes under two contrasting 21st century emissions scenarios. Compared to preindustrial values, the global mean diurnal amplitude of pCO_2 increases three-fold in the high-emissions scenario but only 55 % in the high-mitigation scenario. The probability of extreme diurnal amplitudes of pCO_2 and acidity is also dramatically affected, with 30- to 60-fold increases relative to the preindustrial under high emissions. The main driver of heightened pCO_2 diurnal variability is the enhanced sensitivity of pCO_2 to changes in temperature as the ocean absorbs anthropogenic carbon. Our projections suggest that organisms in the future ocean will be exposed to enhanced diurnal variability in pCO_2 and acidity, with likely increases in the associated metabolic cost that such variability imposes.

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(S19-15939 Poster)

Ocean acidification data: Weaves to be tied on European and global scale

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FAIR (Findable, Accessible, Interoperable and Reusable) Ocean Acidification data for knowledge of impacts on marine ecosystems are of increasing importance, as is the consolidating of dialogue between scientists and data scientists with policy makers to achieve the UN goal of Good Environmental Status (GES) for the oceans and seas. Open science can therefore help address the challenges facing our societies. In this contribution, we will describe the validated and aggregated Ocean Acidification dataset provided by EMODnet Chemistry, the long-term European initiative involving a network of organizations working together to collect, process and make marine data freely available as interoperable data layers and data products. Ocean acidification is related to a number of physical and biogeochemical processes involving the carbonate system of seawater. EMODnet Chemistry provides several parameters related to ocean acidification such as pH, Total Alkalinity (TA), Total Dissolved Inorganic Carbon (DIC), partial pressure of CO_2 (pCO_2) and fugacity of CO_2 (fCO_2). EMODnet Chemistry uses standard tools and approaches such as standard metadata, common file formats and common vocabularies based on the BODC Parameter Usage Vocabulary. Climatologies from the latest aggregated EMODnet Chemistry dataset for surface, intermediate and deeper layers, will be shown, and long time series examples will be used to demonstrate the challenges and importance of correct and essential metadata to ensure long-term usability of data. The aim is to contribute to the discussion on data management and how EMODnet Chemistry can contribute on an international and global scale.

POSTER BOARD ID: S19-P4
(S19-15953 Poster)

A global surface ocean acidification indicators product based on the latest CMIP6 Earth System Models and observational data

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Accurate projections of future ocean acidification (OA) conditions are critical to support marine research and guide mitigation and adaptation efforts. In this study, a global surface OA data product covering ten OA indicators is produced based on 14 Earth System Models from the sixth phase of the Coupled Model Intercomparison Project (CMIP6), along with three recent observational data products: (i) the Surface Ocean CO2 Atlas (SOCAT, version 2022), (ii) the Global Ocean Data Analysis Project version 2 (GLODAPv2, version 2022), and (iii) the Coastal Ocean Data Analysis Product in North America (CODAP-NA, version 2021). The indicators are fugacity of carbon dioxide, pH (total scale), total hydrogen ion content, free hydrogen ion content, carbonate ion content, aragonite saturation state, calcite saturation state, Revelle Factor, total dissolved inorganic carbon content, and total alkalinity content. The evolution of these OA indicators is provided on a global surface ocean grid from preindustrial conditions (1750), through historical conditions (1850-2010), and to five future shared socio-economic pathways: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 (2020-2100). These OA trajectories are improved relative to previous OA data products with respect to data quantity, spatial and temporal coverage, diversity of the underlying data and model simulations, and the provided SSPs over the 21st century.

POSTER BOARD ID: S19-P5
(S19-15956 Poster)

The Alaska Ocean Acidification Network: Connecting Alaskans through monitoring, information sharing and the quest for solutions

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With Alaskans heavily reliant on the ocean for their lives and livelihoods, both direct and indirect effects of ocean acidification are expected to have implications on commercial fisheries, subsistence and lives and livelihoods in Alaska. Researchers are working together to better understand the chemical and ecological systems at play so we can anticipate and respond to upcoming changes in the marine environment. In addition, Tribal involvement in community sampling has expanded to 20 communities that are documenting local information on a regional level. In 2016, the Alaska Ocean Observing System (AOOS) initiated the Alaska Ocean Acidification Network to serve as an information clearinghouse and facilitate coordination within and beyond the research community. The primary mission of the network is to engage with researchers and stakeholders to expand the understanding of OA processes and consequences in Alaska, as well as potential adaptation and mitigation strategies. Now in its sixth year, the Alaska Ocean Acidification Network provides and receives relevant information from researchers, the fishing and aquaculture industries, coastal communities, Tribes, policy makers and educators. Among the most frequent questions that arise from stakeholders is "what can we do?", articulating an increased desire for actionable information on both the adaptation and mitigation fronts. This presentation will illustrate the approach of the Alaska Ocean Acidification Network in Alaska, the priorities voiced by Alaska stakeholders and the status of reaching those goals, and challenges and opportunities ahead.

POSTER BOARD ID: S19-P6
(S19-15973 Poster)

Who will be the winners of climate change in Indian waters: edible green mussels or invasive mussels?

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Perna viridis commonly known as Asian green mussel is a potential candidate species for aquaculture, especially along the southwest coast of India. There has been a reported decline of the species along several coastal provinces and the reasons for this are not clearly understood. The ocean acidification induced by anthropogenic climate change is reported to have an adverse impact on marine shellfish organisms. A mesocosm experiment was conducted to examine how *Perna viridis* and invasive *Mytella strigata* respond to future ocean acidification

scenarios. *Mytella strigata* has recently invaded the coastal areas, especially in areas where green mussel is abundant and is rapidly spreading. The study sheds light on how the invasive mussel could take the advantage of the changed conditions by increasing the byssal strength and enhancing the shell morphology and mineralogy. The study provides insight into which species will survive and flourish under future climatic conditions and whether *Mytella strigata* pose a serious threat to *Perna viridis*.

POSTER BOARD ID: S19-P7

(S19-16041 Poster)

Effects of ocean acidification on red king crab larval development

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Ocean acidification, a decrease in oceanic pH from the uptake of anthropogenic CO_2, can be a significant stressor for marine organisms. In this study, we reared red king crab larvae from hatching to the first crab stage in three different pH treatments: current surface ambient, pH 7.8, and pH 7.5. Larvae were monitored throughout development and the average length of each stage was determined. At each of the four zoeal stages, the glaucothoe stage, and the first crab stage, we measured survival, morphometry, dry mass, and carbon, nitrogen, calcium, and magnesium content. Red king crab larvae were highly resilient to ocean acidification. There were no differences among treatments in survival or in average stage length. Although there were ontogenetic trends in size, weight, and elemental composition, most did not vary with pH treatment. Zoeal morphology did not vary among treatments, although glaucothoe and C1 crabs were slightly smaller in pH 7.8 than in the ambient treatment. Ambient larvae had a slightly higher mass than pH 7.8 larvae but not pH 7.5. Further, ambient larvae had slightly higher magnesium contents than pH 7.8 and pH 7.5, but calcium levels were the same. Ambient larvae also had slightly lower carbon and nitrogen content than pH 7.8 and pH 7.5 larvae but only in the 4th zoeal stage. Overall this study suggests that red king crab larvae are adapted to a wide range of pH conditions and are unlikely to be significantly affected by ocean acidification levels projected for the next two centuries.

POSTER BOARD ID: S19-P8

(S19-16076 Poster)

Measuring protons with photons: A hand-held, spectrophotometric pH analyzer for ocean acidification research, community science and education

Kalina C. **Grabb**[1], William Pardis[2,3], Michael DeGrandpre[4,5], Reggie Spaulding[4], James Beck[4], Jonathan Pfeifer[2,3] and David Long[2,6]

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Increasing atmospheric carbon dioxide concentrations has driven a measurable acidification in oceanic pH, a process termed Ocean Acidification (OA). As a controlling variable in

aqueous chemical equilibria, pH also has implications on carbon sequestration and biological processes. Yet, since pH measurements can be challenging, expensive, and/or require scientific training, there are large uncertainties in pH measurements within natural aquatic systems. Wide distribution of accessible, low-cost, and precise instruments is needed to increase pH measurements throughout coastal communities. This study describes the development of a low-cost aquatic pH instrument, the pHyter. The pHyter is based on pH indicator chemistry. The precision and accuracy of the pHyter has been verified through analytical laboratory characterization as well as during field deployments to the South Pacific and in the Caribbean. The pHyter can make pH measurements at a similar precision to high-end pH meters, however it costs a fraction of the price, can be used by the general public with minimal training, and can fit in the palm of your hand. Therefore, the pHyter is an ideal instrument for community-based science, education, and to increase public awareness of OA. Here, we describe the development of pHyter and the vision for the future as a tool that can be deployed around the world and enable communities to sustain measurements of pH within their own waters.

POSTER BOARD ID: S19-P9

(S19-16169 Poster)

Ocean acidification variability in Atlantic and Arctic influenced Norwegian waters

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A decade of monitoring on the state of ocean acidification has revealed variability attributed to oceanographic and anthropogenic processes that influence oceanic pH and calcium carbonate saturation (Ω). Variability in the North Sea (Skagerrak) was driven by mixing of water masses from the Atlantic Ocean and North Sea, fresher water with Baltic origins, and riverine inputs. Observed trends of annual mean pH and Ω in the Atlantic Water were –0.008 yr^{-1} and –0.003 yr^{-1}, respectively, from 2012 to 2020. Variability in pH and Ω in the upper layer of the Norwegian Sea was driven by coastal freshwater inputs, biological production and mixing with Atlantic Water. Observed trends of annual mean pH and Ω in the Atlantic Water were –0.006 yr^{-1} and –0.016 yr^{-1}, respectively, from 2011 to 2021. The saturation horizon for aragonite (Ω = 1) occurred at approximately 2000 m depth. In the Barents Sea, variability in pH and Ω was driven by the presence of Atlantic Water and Arctic waters. Trends of annual mean pH and Ω in the Arctic waters were –0.002 yr^{-1} and –0.004 yr^{-1}, respectively, from 2013 to 2020. Integrated monitoring including measurements or proxies for biological productivity, ocean physics, and land-ocean exchanges, is essential to determine the drivers of ocean acidification and resolve their spatio-temporal variability. This work is part of "Monitoring ocean acidification in Norwegian Seas" funded by the Norwegian Environment Agency.

POSTER BOARD ID: S19-P10
(S19-16180 Poster)

Environmental effects on growth performance of Pacific oyster *Crassostrea gigas* cultured in the Seto Inland Sea, Japan, from 1990 to 2021

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The Pacific oyster (*Crassostrea gigas*) has been widely used as an important marine model organism to understand the impact of elevated pCO_2 on shellfish growth by short-term laboratory experiments. However, the long-term effects of various environmental factors (water temperature, salinity, pH, and food availability) on *C. gigas* growth in the natural ocean environment remain unknown. *Crassostrea gigas* has been cultured in the Seto Inland Sea, western Japan, over the last half century, yet little is known about changes in oyster growth throughout long-term culturing. To effectively manage oyster production under future climate challenges, this study investigated the long-term changes of *C. gigas* growth and its associated environmental factors. Environmental data and oyster biological data were obtained from observations in Hinase waters, Seto Inland Sea, and compared for the two periods 1990 and 2015-2021. Despite changes over the period studied, water temperature was discounted as a primary factor affecting long-term changes in oyster culture. Heavy seasonal rainfalls led to low salinity in July of 2015-2021, which had a significantly negative impact on oyster growth. Meanwhile, pH also dropped abruptly, probably explaining the abnormal larval development from the latest observation. The concentration of chlorophyll-a was fluctuating in 1990, but stable during 2015-2021. Eelgrass restoration in the Seto Inland Sea since 1985 may have improved water quality and facilitated the presence of abundant food material, perhaps offsetting the negative influence of low salinity and contributing to a high growth rate and high meat weight at harvest during the period 2015-2021.

POSTER BOARD ID: S19-P11
(S19-16192 Poster)

The count-down for calcifiers to dissolve in water masses of the Strait of Gibraltar

Silvia **Amaya-Vías**[1], Susana Flecha[1], Fiz F. Pérez[2], Gabriel Navarro[1], Jesús García-Lafuente[3], Ahmed Makaoui[4] and I. Emma Huertas[1]

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The assessment of saturation state (Ω) for calcium carbonate minerals (aragonite and calcite) in the ocean is important to determine if calcifying organisms have favourable or unfavourable conditions to synthesize their carbonated structures. This work examines temporal trends of $\Omega_{Aragonite}$ and $\Omega_{Calcite}$ in three water masses that exchange in the Strait of Gibraltar: North Atlantic Central Water (NACW), Levantine Intermediate Water (LIW) and Western Mediterranean Deep Water (WMDW) using accurate measurements of carbon system parameters collected from 2005-2021. Our analysis shows a gradual temporal decline in Ω in all water masses, with decreasing trends being more and less pronounced in the NACW and LIW, respectively. Estimated long-term changes of Ω for future increases in atmospheric CO_2 under the IPCC

AR6 shared socio economic pathway "fossil-fuel-rich development" (SSP5-8.5) indicate that critical conditions for calcifiers will be reached in the region at all depths before 2100, with a corrosive environment for aragonite (undersaturation of carbonate) expected within the next 130 years.

POSTER BOARD ID: S19-P12

(S19-16198 Poster)

The Rías Baixas (NW Iberian Upwelling System) as experimental sites for studying the impact of marine environment acidification on coastal ecosystems

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The Rías Baixas are four embayments in the western coast of Galicia (NW Spain). They harbor large fishing and shellfish activities, which form the economical foundation of the majority of the population and support the highest mussel production in Europe. Wind-driven upwelling that is common along the eastern boundary of the North Atlantic (10ºN-40ºN, Iberian Upwelling System) determines the response of the microbial plankton community and is responsible for the net autotrophic behavior of this ecosystem throughout the year. Nowadays, Rías Baixas are sensitive to the anthropic pressure generated by industry, aquaculture, tourism and wastewater treatment plants. But also to indirect effects related to climate change such as upwelling intensity and precipitation, which together with the increase in atmospheric CO_2 can affect coastal acidification. CO_2 analysis along longitudinal transects carried out in Ría de Vigo, the southest and more populated embayment, showed that CO_2 concentration decreased from the inner shallow coastal stations to the deeper stations at the mouth, and that CO_2 range was highly dependent on the upwelling intensity. Maximum values of 5429 ppmv and steepest CO_2 gradients were observed during downwelling events while the lowest happened during upwelling. Moreover, both, phytoplankton biomass and photosynthetic efficiency were directly related to the CO_2 gradient during downwelling. CO_2 also explained 34% of the variability in the phytoplankton community composition, which was dominated by the picophytoplankton fraction at the high CO_2 stations. A recently funded project (IP C. Sobrino) will further analyze these CO_2 effects and its environmental and social impact.

POSTER BOARD ID: S19-P13

(S19-16313 Poster)

pH sensor measurements vs pH laboratory measurements

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From January 2021 to March 2022, Sunburst isami pH sensor was deployed on eight occasions for three hours on each day at five selected lagoons around Mauritius. Temperatures and pHs were obtained at every half an hour and in all, thirty-two measurements were taken. On 21 occasions the temperatures recorded by isami were less compared to measured temperatures in the range 0.28 (LC) to 2.7 ^{0}C (MC). Concerning the higher temperatures recorded by isami compared to measure ones, the difference varied from 0.1 (LC) to 2.59 ^{0}C (FF). In both scenarios, the greatest difference in the temperatures occurred when the water was warmer. All the pHs obtained from the sensor were brought at the measured temperatures using CO2SYS. On eleven occasions pHs from the sensor were slightly less compared to calculated ones in the lab; the difference varied from 0.00153 (LC) to 0.03824 (FF). For the other pH measurements,

the difference varied from 0.00421 (LC) to 0.04117 (MC). Surprisingly, it was noted that every time the recorded temperature on the sensor was higher than the measured one, the pH of the latter was lower compared to the measured one in the lab. In addition, there is strong positive correlation between the values of the difference in temperatures vs difference in pHs (R^2= 0.9992). T-test, using the latter data, revealed that the results were significant. Tris buffer certified reference materials were used to check for accuracy and precision of our pH determination in the lab; 0.0152 ± 0.0006 was obtained.

POSTER BOARD ID: S19-P14

(S19-16425 Poster)

Physiological and gene expression responses of the mussel *Mytilus galloprovincialis* to low pH and low dissolved oxygen

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The hypoxia events have increased worldwide over the past decade as a consequence of global climate change and coastal biological oxygen depletions. On the other hand, anthropogenic emissions of CO_2 and consequent accumulation in the sea surface result in a perturbation of the seawater carbonate system, including a decrease in pH, known as ocean acidification. While the effect of decreases in pH and dissolved oxygen (DO) concentration is better understood, their combined effects are still poorly resolved. In the current study we exposed adult mussels (*Mytilus galloprovincialis*) to two pHs (8.27 and 7.63) and DO concentrations (7.65 and 2.75 mg L^{-1}) over 17 days in a full-factorial design. These levels correspond to extremes of the present natural variability and are relevant in the context of ocean acidification and hypoxia. Respiration and excretion rates were not dramatically impacted by low pH and DO, alone or in combination. Low pH alone led to a decrease in all tested physiological parameters. Low DO alone led to a decrease in clearance rate, haemocyte parameters and an increase in carbohydrate content. Both parameters led to up- or down-regulation of most of the selected genes. The combined effect of low pH and low DO could not be predicted by a simple arithmetic additive response at the effect level, highlighting more complex and non-linear effects.

POSTER BOARD ID: S19-P15

(S19-16456 Poster)

REVISION: This poster is now also an S19 Oral Presentation (S19-16484 Oral)

A new laboratory to investigate the impact of multiple drivers on ocean life

Hrönn **Egilsdóttir**, Einar Pétur Jónsson, Ragnar Jóhannsson, Agnar Steinarsson and Tómas Árnason

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Large- and small-scale changes in the ocean environment are impacting ocean life and ecosystems. From a management and conservation perspective it is important to understand how these changes will affect marine organisms and ecosystems. To achieve this goal, we need to use a variety of complementary research methods including experimentation.

We present a new state-of-the-art experimental laboratory that is well equipped to study how different environmental drivers affect a variety of marine organisms. The laboratory is set-up

within the Aquaculture Research Station operated by the Marine and Freshwater Research Institute, Iceland. The station, which is located on the volcanically active Reykjanes peninsula, makes use of fresh groundwater, geothermally heated water (60°C) and borehole seawater that has been naturally filtered through the basalt bedrock.

The laboratory consists of 45 tanks with a diameter of 60 cm, permitting research on a variety of organisms such as fish, invertebrates, and algae. It is possible to alter five temperatures simultaneously (9 tanks per temperature) and manipulate carbon chemistry (CO_2/pH) in each tank separately. First experiments aim to test the impact of temperature and CO_2/pH and the interaction of these drivers on early life stages of fish. Other environmental parameters can be altered in future experiments, such as light, food availability and salinity.

POSTER BOARD ID: S19-P16

(S19-16472 Poster)

Sargasso inundation driven hypoxia and ocean acidification in La Parguera, P.R. Marine Reserve: Spatiotemporal variability

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Since 2011, the seasonal occurrence of extensive blooms of pelagic Sargassum species in the Caribbean and the tropical Atlantic has become a major concern to coastal areas which are inundated by large Sargassum quantities. While excessive accumulation in beaches becomes a deterrent for tourism, Sargassum entrained in coastal mangroves, coral reefs and seagrass beds becomes a threat to these ecosystems.

La Parguera Marine Reserve, off the southwest coast of Puerto Rico, hosts an ecotone extending from a mangrove lined shoreline to inner mangrove islets and coral reef keys further seaward. Two years of observations documenting Sargasso biomass arrival rates, C, T, pH and total alkalinity at discrete stations along said gradient evidence a d decrease in oxygen concentration and increased acidification corresponding to the magnitude of Sargasso inundation but also to the wave and current energy at each location. While observations at stations in inshore mangrove islands, capable of effectively retaining the incoming Sargasso, evidence extrema hypoxia (<1.0 mg. l^{-1}) and acidification (pH <7.2, Ω<2.0) events lasting over 14 days long, mid-shelf keys receiving similar Sargasso biomass input exhibited no detectable impacts.

The inferred role of hydrodynamic processes in modulating the spatiotemporal variability of Sargasso inundation driven impact underlines the need to include parameterization of the former in the development of Sargasso inundation impact forecasting tools.

Workshop Abstracts

W1: A systematic and rapid assessment of climate vulnerability and adaptation in marine and coastal areas

Convenors:
Jon Day (Corresponding), (James Cook University, Australia)
Scott Heron, (James Cook University, Australia)

Duration: 1-day workshop

UPDATED DESCRIPTION (Feb. 7, 2023)

Assessing vulnerability to climate change of cultural and natural heritage within marine and coastal areas (and beyond) begins with a clear definition of the objectives and the desired characteristics and implementation components of the assessment process. This workshop seeks to draw upon applications of climate vulnerability assessment tools and reflections by participants who have undertaken these. By sharing lessons learned, and benefits and limitations of different approaches, the workshop will seek to provide guidance for future applications and practitioners on how to effectively assess climate vulnerability – and how to work out what to do in response to help marine and coastal areas better cope with climate change. Implementing actions to reduce vulnerability can be affected by political and fiscal realities but can also benefit from broader perspectives across practitioner networks, which also require guidance and/or maintenance.

The outcomes of this workshop will be developed for a submission to an intended special issue of the journal Heritage, entitled "Assessing Impacts of Climate Change on Cultural and Natural Heritage". Presenters in Session 3 will be encouraged to submit manuscripts to this special issue.

POSTER BOARD ID: W1-P1
(W1-15917 Poster)

A survey on adaptation strategies in the aquaculture industry facing climate change hazard - a case study in Kaohsiung, Taiwan

Ching-Hsien **Ho***[1], Yi-Hua Hsiao[2], Min-Yin Liao[1] and Jyun-Rong Gong[1]

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In recent years, the aquaculture fisheries have gradually become an important industry and a key role in the seafood supply and demand. Since 2011, the quantity of aquaculture has been maintained at about 310,000 tons with an annual value of about 400 hundred million NT in Taiwan. The main aquaculture species is including milkfish, tilapia, clams and oysters etc. However, aquaculture is closely linked natural environment. It's easy to result in disaster when typhoon or torrential rain occurs. Lead to deterioration of water quality, loss of aquaculture creatures, even though the fish ponds were buried and the dike was collapsed by the mud, resulting in the loss of fish famers. Ultimately, the extreme meteorology caused by the extreme climate will directly or indirectly affects to the aquaculture in Taiwan. In the study, we are analyzed the long-term changes of aquaculture geographical location, area, yield and dominant species in Taiwan from 2000 to 2017. And, we are elected the temperature as the climate factor to explore the impact of historical extreme climate disasters on aquaculture fisheries and determine the extent of harm, vulnerability and potential risks in the current aquaculture areas under the CC. And, when face to the more extreme meteorology event, coming up with relevant measures and methods.

POSTER BOARD ID: W1-P2
(W1-16413 Poster)

Global risk assessment of sharks to climate change

Catarina **Pereira Santos**[1,2,3], Catarina Frazão Santos[1,2,3] and Rui Rosa[1,2,4]

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In what has been referred to as a 'perfect storm', it is now clear that we will be concurrently facing both a biodiversity and climate crisis over the incoming decades. Hence, we propose a broadly applicable IPCC-derived framework to evaluate the climate-associated risk for marine life, at the species-level. We apply this framework to all extant sharks, given their major ecological and socioeconomic importance, alongside their particularly precarious conservation status, performing the analysis at the global scale. Through the integration of expert-assessed information on each risk dimension, we consider the ecosystem dependencies of the targeted species, alongside with their vulnerability to both present (i.e., current extinction risk) and incoming hazards (i.e., climate change). More specifically, we estimate the threat level imposed by different climate change scenarios (SSP1, SSP2, SSP3 and SSP5) across meaningful timeframes (2021-2040, 2041-2060 and 2081-2100). We rank the threat (exposure & cumulative hazard) and risk (threat & vulnerability) incurred by each species, comparing scores across different regions, functional traits and attributes. Our analysis showcases how all shark species should experience the effects of climate change to a certain degree regardless of the emission scenario. Differences between emission scenarios, with the effects to be noticeable over the next two decades. Differences between scenarios escalate considerably over time, with associated changes in the level and type of ecological implications. Distinct lineages, lifestyles and trophic levels are expected to be differently affected, exacerbating the already disproportional risk of functional and phylogenetic loss documented for this key group of marine predators.

POSTER BOARD ID: W1-P3
(W1-16421 Poster)

Impacts of hydrodynamic factors of sea and sea level rise on coastal zone of India using CVI geospatial model

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The degree to which society is potentially vulnerable to the impacts of climate change can be expressed through an assessment of either the biophysical (extemal) or social (intemal) elements at risk.The research work has utilized Remote Sensing and GIS techniques for assessing vulnerability of the Trivandrum coast, India due to predicted sea level rise. Multi-sensor satellite data has been interpreted using on-screen visual interpretation techniques to generate coastal thematic information followed by ground truth data collection and validation. Geospatial models for carrying out regional coastal vulnerability assessment of the entire Trivandrum coast. A new approach of integrating physical variable has been developed and demonstrated in GIS environment. Coastal Vulnerability Index (CVI) has been computed for entire Trivandrum coast based on integration of eight physical variables, those are: relative sea level, coastal geomorphology, regional elevation and coastal slope, rate of shoreline change, coastal accretion and erosion, significant wave height, land use land cover and suspended

sediment concentration in GIS environment. The results show that 42 % of the Trivandrum coast is under high to very high risk category and 54 % of the Trivandrum coast is under Moderate to Low risk categorydue to the threat of predicted sea level rise. Sea level rise is a realistic approach with the coastline geometry.Obviously, sea level change solely affects the configuration of the coastal areas other factors and also play a major role in hammering the west coastal environment of Trivandrum. Therefore, the analysis of coastal vulnerability to sea level rise has many advantageous sights. The vulnerability analysis provides a valuable information that helps to priories major issues which need to be addressed.

W2: The Climate-Fisheries Nexus Within the UN Decade of Ocean Science for Sustainable Development: Co-Designing Actions and Solutions for a Productive, Healthy and Resilient Ocean

Convenors:
Steven Bograd (Corresponding), (NOAA Fisheries, USA)
Claudia Baron-Aguilar, (University of South Florida, USAA)
Hannah Lachance, (NOAA Fisheries, USA)
Jörn Schmidt, (ICES)

Invited Speakers:
Gretta T. Pecl, (Centre for Marine Socioecology & Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Australia)
Ana Queiros, (Marine Life Support Systems, Plymouth Marine Laboratory, UK)

Duration: 1-day workshop

The UN Decade of Ocean Science for Sustainable Development (2021-2030) addresses challenges associated with ecosystem health, food security, and climate change through synergistic programs, including SmartNet (network to advance and share scientific understanding of marine ecosystems); SUPREME (advance ocean forecasts and projections to guide climate-informed resource management); FishSCORE (sustain fisheries, protect ocean ecosystems, and enhance equitable benefits); Marine Life 2030 (coordination to deliver actionable knowledge of ocean life and ecosystem restoration); and ECOP (empower early career ocean professionals and incorporate new thinking into ocean sustainability and stewardship). Workshop participants will learn about these and other Decade programmes, share knowledge and capacity, establish collaborative networks to advance Ocean Decade goals, and co-design transformative actions for the climate-fisheries nexus.

(W2-15850 Invited)

Bright spots as climate-smart marine spatial planning tools for conservation and blue growth

Ana M. **Queirós**[1], Elizabeth Talbot[1], Nicola J. Beaumont[1], Paul J. Somerfield[1], Susan Kay[1], Chris Pascoe[1], Simon Dedman[2], Jose Fernandes[3], Alexander Jueterbock[4], Peter I. Miller[1], Sevrine F. Sailley[1], Ginaluca Sará[5], Liam M. Carr[6], Mel C. Austen[7], Steve Widdicombe[1], Gil Rilov[8], Lisa A Levin[9], Stephen C. Hull[10], Suzannah F. Walmsley[10] and Caitriona Nic Aonghusa[11]

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[6]National University of Ireland Galway, Ireland
[7]Plymouth University, United Kingdom
[8]National Institute of Oceanography, Israel Oceanographic and Limnological Research Institute, Haifa, Israel
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[10]ABPmer, United Kingdom
[11]Marine Institute, Ireland

Marine spatial planning addressing ocean climate change ("climate-smart MSP") is a global aspiration supporting economic growth, food security and ecosystem sustainability. Ocean climate change ("CC") modelling may become a key decision-support tool for MSP, but traditional modelling analysis and communication challenges prevent their broad uptake. We employed MSP-specific ocean climate modelling analyses to inform a real-life MSP process; addressing

how nature conservation and fisheries could be adapted to CC. We found that CC may render the planned distribution of these activities unsustainable during the policy's implementation, leading to a shortfall in its sustainability and blue growth targets. Supporting adaptation, we then identified: CC refugia (areas where the ecosystem remains within the boundaries of its present state); CC hotspots (where climate drives the ecosystem towards a new state, inconsistent with each sectors' present use distribution); and for the first time, identified bright spots (areas where oceanographic processes drive range expansion opportunities that may support sustainable growth in the medium-term). This method allows the identification of where sector-relevant ecosystem change is attributable to CC; resilient delivery of conservation and sustainable ecosystem management through MSP; and harnessing of blue growth opportunities where they may exist. Capturing CC bright spots and refugia within protected areas is an opportunity to meet sustainability targets whilst supporting fisheries under changing climate. By capitalising on the natural distribution of climate resilience within ocean ecosystems, such climate-adaptive spatial management strategies are nature-based solutions limiting the impact of CC on ocean ecosystems and dependent blue economy sectors, delivering climate-smart MSP.

(W2-16460 Invited)

Future Seas: What could the ocean look like by 2030 if we shared it equitably, and used the knowledge we already have available?

Gretta T. **Pecl**[1,2], Karen A. Alexander[1,2], Kirsty L. Nash[1,2], Camilla Novaglio[1,3], Jessica Melbourne-Thomas[1,3], plus 100+ collaborators

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Major transformations are needed to create a sustainable future for our oceans, and these transformations are reliant on more than 'just' additional data and knowledge. "The ocean we need for the future we want" requires scientists and decision-makers to facilitate the use of available science and encourage the uptake of sustainable behaviors at individual, local and global scales, that will leverage greater environmental benefit. Yet the complex and uncertain nature of many key challenges facing the oceans can lead to inertia and paralysis. The Future Seas project (www.FutureSeas2030.org) involves 120+ ecologists, philosophers, economists, Indigenous scholars and Elders, engineers, social scientists, psychologists, governance experts and more, in taking a broad interdisciplinary approach to developing positive but realistic 'mobilising narratives' of the future. Teams addressing 12 different key challenges, like food security, pollution and climate change for example, used 'foresighting' to create two alternative plausible, evidence-informed, and defensible futures - one that continues on a Business-as-Usual trajectory, and a second that pushes as far towards achieving the SDGs as technically possible. We then use 'backcasting' to derive credible pathways to action to achieve the more sustainable future. The Future Seas project aims to leverage interdisciplinary knowledge to improve society's capacity to purposefully shape the direction of marine social-ecological systems over the course of the UN Oceans Decade.

W4: A global ensemble of comparable marine ecosystem models to project climate risk to species and human communities

Convenors:
Isaac Kaplan (Corresponding), (NOAA NWFSC)
Cameron Ainsworth, (University of South Florida, USA)
Gavin Fay, (University of California Santa Cruz, USA)
Elizabeth Fulton, (CSIRO)
Joseph Caracappa, (NOAA)
Cecilie Hansen, (Institute of Marine Research, USA)
Pierre-Yves Hernvann, (University of Massachusetts, Dartmouth, USA)
Owen Liu, (NOAA, USA)
Hem Nalini Morzaria Luna, (Long Live the Kings and NOAA, USA)
Holly Perryman, (University of South Florida, USA)
Alberto Rovellini, (University of Washington, USA)
Rebecca Scott, (University of South Florida, USA)

Invited Speaker:
Juliano Palacios Abrantes, (Institute for the Oceans and Fisheries, UBC, Canada)

Duration: 1-day workshop

Ensembles of coupled climate-marine ecosystem models have great potential to illustrate risks of global change and vulnerabilities of marine species and human communities and industries. These models are expected to inform the Seventh Assessment Report (AR7) of the IPCC and local efforts such as the (US) National Climate Assessment. A grand challenge of such ecological ensembles is grappling with uncertainty, in particular structural uncertainty stemming from alternate ecological parameterization of responses to temperature, oxygen, and pH. In this workshop we will apply a global ensemble of 7+ Atlantis ecosystem models, built on a common modeling framework and code base. We aim to engage the broader ECCWO community to collectively inform ecological parameterization of metabolic and spatial movement responses to climate change. Our goal is to identify future trends in regional ecosystem responses likely to stem from standardized, downscaled ocean projections.

(W4-16478 Invited)

Using coupled climate-marine ecosystem models to inform the management of shared fish stocks

Juliano **Palacios Abrantes**

Changing Oceans Research Unit, Institute for the Oceans and Fisheries, The University of British Columbia, Vancouver, BC, Canada.
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Delineating spatial boundaries is a fundamental approach to marine resource governance and management with examples ranging from small marine reserves to Exclusive Economic Zones. Yet, the effectiveness of spatial management tools is threatened as marine biodiversity worldwide shifts as a response to climate change. The mismatch between species distributions and spatial management tools have contributed to overfishing of important fish stocks, failed conservation goals, and international conflict between nations. Modelling frameworks have been increasingly used to inform ocean governance for better preparing to the effects of climate change in the ocean. Using key examples, this talk centers on how frameworks of coupled Earth-system and ecosystem models can be used to identify and address potential spatial mismatches. While coupled climate-marine ecosystem models have the power to inform overarching policy goals and foster ocean management in a changing world, they encapsule different levels of uncertainty that must be acknowledged and, when possible, included in management plans. Addressing such uncertainty requires the constant development of modelling frameworks, multidisciplinary collaboration, as well as bridging the communication between stakeholders.

(W4-15971 Oral)

Climate-driven habitat shifts of Pacific predators within and beyond national jurisdiction

Bianca S. **Santos**[1], Elliot L. Hazen[2,3], Heather Welch[3,2], Nerea Lezama-Ochoa[3,2] and Larry B. Crowder[4]

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[2] Southwest Fisheries Science Center, National Oceanographic and Atmospheric Administration, Monterey, CA, USA
[3] Institute of Marine Sciences, University of California, Santa Cruz, CA, USA
[4] Hopkins Marine Station, Department of Biology, Stanford University, Stanford, CA, USA

Projections of climate-driven habitat change can reveal if marine species are predicted to be climate 'winners' or 'losers', i.e. gaining or losing habitat in the future. However, political boundaries and differing governance regimes may influence animals' abilities to thrive in new areas, shifting species into waters that leave them more, or less, exposed or protected from stressors. Policies aimed at the conservation and management of marine species can be more easily implemented at the national level, where countries have full rights to manage marine resources within their exclusive economic zones, compared to areas beyond national jurisdiction. In this study, we use projections of climate-drive habitat change to assess habitat redistribution across jurisdictional boundaries for five species from the Tagging of Pacific Predators program (shortfin mako shark, sooty shearwater, bluefin tuna, California sea lion, and elephant seal). We overlaid annual projections of species-specific core habitat from 2001-2100 with jurisdictional boundaries in the Northeast Pacific, to explore how the proportion of core habitat for these species within and beyond national jurisdictions may change. Sooty shearwaters are predicted to be the biggest 'winners,' not only predicted to gain the most habitat, but also experience an increase in the proportion of core habitat found within national boundaries. Overall, our study highlights the importance of considering tradeoffs in magnitude of climate-driven habitat change with attention to where in space these shifts are projected to occur. Understanding these nuances are key in implementing proactive and climate-resilient management approaches.

(W4-16145 Oral)

Bridging climate, biophysical and statistical models to identify key drivers of recruitment variability of fish stocks inhabiting different North-East Atlantic ecoregions

Shuyang **Ma**[1], Geir Huse[1], Tom Clegg[1], Anne Britt Sandø[1], Solfrid Hjøllo[1], Kotaro Ono[1], Richard D.M. Nash[2], Kjell Nedreaas[1], Jon Helge Vølstad[1] and Olav Sigurd Kjesbu[1]

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Recruitment, natural mortality and body growth are traditionally defined as vital parameters of stock productivity, but the former one can be taken as an integrated measure of the latter two. Forecasting recruitment is therefore central in tactical fisheries management, principally for setting the harvest rate and thus the next-year quota. Meta-analyses of observed recruitment strength in view of climate fluctuations and change are, however, generally rare in the literature. In this presentation we examined species located in the ecoregions Greater North Sea, Norwegian Sea and Barents Sea, to encompass i) warm- and cold-temperate as well as

Arctic zones, and ii) local, regional (transboundary) and wide-distributed (straddling) stocks (altogether about 40). Survey and fisheries data sets, local environmental parameters, climate indices (AMO, NAO, AO) along with down-scaled climate (NEMO-NAA10km) and associated biogeochemical models (NORWECOM) provided a suite of spatially and temporally resolved explanatory factors. Forecasting is undertaken over a range of climate scenarios (cf. IPCC) from the Norwegian Earth System Model (NorESM2). The statistical analyses utilized break point analysis, gradient forest and various GAMs. This combined, analytic framework reflected the degree to which recruitment is a function of stock biomass, primary and secondary production, and climate indices. The responses in recruitment strength ranged substantially from one stock to another, depending on the driver and ecoregion in question, and thereby adaptive capacity. Our talk will give stock-specific examples, placed within an ecological context, and indicate ways forward for further advancements in the understanding of climate-induced variation in stock productivity in high-latitude systems.

(W4-16321 Oral)

Portuguese continental shelf ecosystem under the future climate - insights from the spatial-temporal food-web model.

Dorota **Szalaj**[1,2], Alexandra Silva[2,3], Jeroen Steenbeek[4] and Marta Coll[1,4]

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[4]Ecopath International Initiative, Barcelona, Spain

Climate change is affecting spatial distributions of marine species globally. Consequently, marine ecosystems worldwide are expected to undergo significant reorganisations in dominant species, commercial fish resources and biodiversity. In this study, we used mechanistic spatial-temporal food web model (Ecopath with Ecosim and Ecospace) to demonstrate and assess the changes in the Portuguese continental shelf ecosystem (PCSE) under future climate scenarios. PCSE is located in the biogeographic transitional zone between temperate and subtropical waters, where many species occurred at their southern or northern distribution limits. We run future climate projections (RCP45 and RCP85) combined with scenarios simulating alternative marine management measures (MPA, sustainable fishing, and restorations of engineer species) to demonstrate plausible future changes in the ecosystem and to assess if they can be counteracted by the management actions. Results showed that the composition of marine fish communities is expected to shift under the future climate and replacement between species will occur. This will affect the fisheries, ecosystem biodiversity and its stability. Management scenarios showed the potential to counteract some of the negative effects expected to happen in future, while the others are inevitable regardless of the applied measures. This study highlights the need to develop socio-economic adaptation strategies to climate change and emphasise the urgency to implement management actions that have a potential to counteract negative effects of climate change.

(W4-16404 Oral)

How the predicted redistribution of fishing stocks may impact the oceans of tomorrow?

Joana **Boavida-Portugal**[1], François Guilhaumon[4], Miguel B. Araújo[1,5] and Rui Rosa[2,3]

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[6] Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Lisboa, Portugal

Climate change scenarios have predicted drastic changes in oceanic conditions by 2100 and marine species are expected to respond to these changes by shifting their latitudinal range and depth. The projected changes in distribution and abundance of important fish stocks may dictate profound impacts on fisheries and aquaculture. In this talk, we will present the potential impact of climate change on the global patterns of several important taxonomic groups (cephalopods, lobsters and small pelagic fishes). Through an ensemble forecast approach, we used ecological niche models to project changes in terms of richness, catch potential and geographic range size by the end-century, under different scenarios for the different groups. We then predicted the latitudinal shifts that important species might undergo due to climate change and discussed the ecological and economic impacts potentially induced by climatic change, linking the projections with the global trends in landings since 1950. Our results suggest major effects on fisheries worldwide and highlight the need for precautionary management that can easily adapt to projected changes.

W5: S-CCME/SICCME Workshop on integrated modeling to identify climate change tipping points in marine ecosystems

Convenors:
Kirstin K. Holsman (Corresponding), (NOAA Alaska Fisheries Science Center, USA)
Elliott Hazen, (Southwest Fisheries Science Center, USA)
Kathy Mills, (ICES, Gulf of Maine Research Institute, USA)

Invited Speaker:
Christian Möllmann, (Institute for Marine Ecosystem and Fisheries Science, Center for Earth System Research and Sustainability (CEN), University of Hamburg, Germany)

Duration: 1-day workshop

Marine ecosystems are increasingly impacted by multiple climate change and non-climate stressors that are pushing some systems and species towards or past tipping points (critical points where a small change in a pressure or driver can induce a disproportionate change in system dynamics). The goal of this workshop is to draw upon recent PICES and ICES working group efforts to synthesize findings and outputs from recent integrated modeling projects across the globe. In particular, the workshop will review evidence and case studies for historical and future tipping points and thresholds in marine ecosystems to help support climate-informed management advice.

(W5-16482 Invited)

Consequences of ignoring tipping point dynamics in Western Baltic cod

Christian Möllmann

Institute of Marine Ecosystem and Fisheries Science (IMF), Center for Earth System Research and Sustainability (CEN), Hamburg University, Hamburg, Germany.
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Understanding tipping point dynamics in harvested ecosystems is of crucial importance for sustainable resource management because ignoring their existence imperils social-ecological systems that depend on them. Fisheries collapses provide the best known examples for realizing tipping points with catastrophic ecological, economic and social consequences. However, present-day fisheries management systems still largely ignore the potential of their resources to exhibit such abrupt changes towards irreversible low productive states. Here I first report on an empirical study that shows that Western Baltic cod is beyond such a tipping point caused by unsustainable exploitation levels that failed to account for changing environmental conditions. The results of the study demonstrate that climate change stabilizes a novel and likely irreversible low productivity state of this once important fish stock that is not adapted to a fast warming environment. The study eventually shows that ignorance of non-linear resource dynamics has caused the demise of an economically and culturally important social-ecological system. Subsequently, I use a single species, climate-informed population model for Western Baltic cod to show the consequences of the present low productivity regime for future recovery and catch potential of the stock as well as for the adaptation of the fishery to climate change. I will close with an outline of research tasks that may be necessary for identifying tipping point dynamics and their implications in social-ecological fisheries systems.

POSTER BOARD ID: W5-P1
(W5-15851 Poster)

Bright spots as climate-smart marine spatial planning tools for conservation and blue growth

Ana M. **Queirós** [1], Elizabeth Talbot[1], Nicola J. Beaumont[1], Paul J. Somerfield[1], Susan Kay[1], Chris Pascoe[1], Simon Dedman[2], Jose Fernandes[3], Alexander Jueterbock[4], Peter I. Miller[1], Sevrine F. Sailley[1], Ginaluca Sará[5], Liam M. Carr[6], Mel C. Austen[7], Steve Widdicombe[1], Gil Rilov[8], Lisa A. Levin[9], Stephen C. Hull[10] , Suzannah F. Walmsley[10] and Caitriona Nic Aonghusa[11]

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[5]University of Palermo, Department of Earth and Marine Science, Laboratory of Ecology, Italy
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[8]National Institute of Oceanography, Israel Oceanographic and Limnological Research Institute, Haifa, Israel
[9]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, USA
[10]ABPmer, United Kingdom
[11]Marine Institute, Ireland

Marine spatial planning addressing ocean climate change ("climate-smart MSP") is a global aspiration supporting economic growth, food security and ecosystem sustainability. Ocean climate change ("CC") modelling may become a key decision-support tool for MSP, but traditional modelling analysis and communication challenges prevent their broad uptake. We employed MSP-specific ocean climate modelling analyses to inform a real-life MSP process; addressing how nature conservation and fisheries could be adapted to CC. We found that CC may render the planned distribution of these activities unsustainable during the policy's implementation, leading to a shortfall in its sustainability and blue growth targets. Supporting adaptation, we then identified: CC refugia (areas where the ecosystem remains within the boundaries of its present state); CC hotspots (where climate drives the ecosystem towards a new state, inconsistent with each sectors' present use distribution); and for the first time, identified bright spots (areas where oceanographic processes drive range expansion opportunities that may support sustainable growth in the medium-term). This method allows the identification of where sector-relevant ecosystem change is attributable to CC; resilient delivery of conservation and sustainable ecosystem management through MSP; and harnessing of blue growth opportunities where they may exist. Capturing CC bright spots and refugia within protected areas is an opportunity to meet sustainability targets whilst supporting fisheries under changing climate. By capitalising on the natural distribution of climate resilience within ocean ecosystems, such climate-adaptive spatial management strategies are nature-based solutions limiting the impact of CC on ocean ecosystems and dependent blue economy sectors, delivering climate-smart MSP.

General Poster Session Abstracts

POSTER BOARD ID: GP-P1
(GP-15821 Poster)

Cutting greenhouse gas emissions: Role of bivalve mariculture in extenuating climate change

Rasheed O. **Moruf**[1], Mutiat M. Ogunbambo and Aderonke O. Lawal-Are[2]

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Food production is projected to be responsible for 20% to 37% of all greenhouse gas (GHG) emissions annually, which makes it a substantial contributor to climate change. Although there is significant variation within each food type, the GHG emissions from mariculture generally compare favorably to those from most livestock operations and some wild-caught fisheries. Compared to finfish culture, bivalve maricculture is thought to have less dramatic environmental and climatic impacts since it requires less environmental modification. Oyster, clam, scallop and mussel are the main bivalve species that are cultured globally. Bivalve maricculture plays a significant role in reducing drivers of climate change. Given that it emits lower GHG footprints than the equivalent products farmed on land, it could provide a climate-friendly, high-protein food source. The reduced emissions intensity of bivalve mariculture is mainly due to better feed conversion ratios and a lack of direct GHG emissions from land use change. However, during the past few decades, marine bivalve production has been continuously rising on a global scale. Therefore, prudent bivalve mariculture growth is a crucial method to satisfy rising food demand, meet nutritional needs, and attain food security within the confines of the planet. Bivalve mariculture "done right" can aid climate change extenuation by cutting greenhouse gas emissions. The review concluded that sustaining a low GHG footprint as production grows up to meet future demand requires sustainable intensification of low-emissions bivalve mariculture.

POSTER BOARD ID: GP-P2
(GP-15823 Poster)

Gis-based method for assessing the flood vulnerability assessment of the Ayetoro coastal community in Nigeria's Ondo state

Adewale **Busolami,** Olusegun A. Dada, Adewusi Dapo

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Regular floods are part of people's lives in various regions of the world, recurring with varying magnitudes and frequencies to which people have adapted for centuries. These floods are generally expected and welcomed in many parts of the world since they enrich the soil and provide both water and livelihoods. In contrast, flooding resulting from extreme hydro-meteorological events and occurring in unexpected magnitudes and frequencies can cause loss of lives, livelihoods, and infrastructure. They can also damage the environment. Floods have large social consequences for communities and individuals. As most people are well aware, the immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases. The aim of the research was to make an assessment of flood risk vulnerability in the Ayetoro Coastal Community. The study assessed the land use land cover changes (LULC) between 1986 and 2017 using two Landsat series (7 and 8), Slope was also generated using Digital elevation Model 2011, Rainfall data from CHRS, tidal data, and wave data were obtained for four years. Supervised classification, using maximum likelihood algorithm, was employed for LULC, Slope was extracted using spatial analyst tool i.e., Surface in ArcMap 10.5 and other ancillary data like

Tide, wave and rainfall were computed using statistical software (Microsoft Excel). Five classes were identified on LULC which are respectively; thick vegetation, light vegetation, built-up areas, water bodies, and bare land, Slope ranges from 0 (Flat) to 860736 (Very steep), rainfall has the highest value of 8807.61mm in 2019 and 2434.41mm in 2016. Also, tidal value has increased drastically over the years and wave data respectively. LULC resulted in to increase in water (11%) and built up (16%) over the years, Slope generated shows the area has a low relief (flat) which is more prone to flooding. It is therefore established that the area is highly exposed to flooding. Owing to low relief, the climatological factor has greater impacts on the area and has contributed immensely to the flood vulnerability of the Ayetoro Coastal Community.

POSTER BOARD ID: GP-P3

(GP-15824 Poster)

Evaluation of sea cucumber abundance in Abu Hashish area on the Sudanese Red Sea coast during the years 2000 and 2021: Are *Holothuria atra* resilient to climate change?

Mona Y **Ibrahim**, Shaheen shakir, Adam Kh Badreldein, Osman Kh Hala, Ali M Sayed.

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Shallow benthic communities, such as coral reef ecosystems, are among the most vulnerable to ocean warming and acidification. Sea cucumbers are essential member of these benthic communities. The presence of high density sea cucumber populations, as characteristic of unfished reefs may be particularly important for the integrity of reefs due to the potential of sea cucumbers to buffer changes in local carbonate chemistry caused by ocean acidification through the digestion of benthic sands and particles. The aim of the study is to provide information on abundance of sea cucumbers from a selected area of the Sudanese coast, and to assess the tolerance of *Holothuria atra* present in the area during two time periods (2000) and (2021) using line transects method. Two species of sea cucumber were found from two different families The most dominant species found along transects was *H. atra* which found on substrate of seagrass zone (0.5315 ind./m^2) and back reef corals (0.0356 ind./$m^{2)}$. Significant correlations was found between abundance and most of the physical factors. Almost same abundance was noticed regarding *H. atra* population ($p>0.05$), in contrast to *Actinopyga echinites* population which disappeared during 2021 study. The difference in abundance among the investigated zones, indicate the tolerance of *H. atra* within two decades of time which underscore the importance of *H. atra* as an adaptive and resilient organism nominating it among organisms that are adaptive and resilient to climate change and qualifies it for further studies in this aspect. Sea cucumber communities are in dire need of managing their current fisheries and areas to continue their ecological benefits.

POSTER BOARD ID: GP-P4
(GP-15824 Poster)

Forecasting and projecting swordfish quality for industrial climate adaptation

Jessica A. **Bolin**[1, 2], David S. Schoeman[1, 3], Karen J. Evans[2], Claire M. Spillman[4], Thomas Moore[2], Jason R. Hartog[2] and Kylie L. Scales[1]

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[4]Bureau of Meteorology, Melbourne, Australia

Meat quality is of paramount importance for high-value fisheries, but the quality of fish can be affected by environmental variability and change. Reports from fishers operating in Australia's Eastern Tuna and Billfish Fishery (ETBF) suggest that fishing for broadbill swordfish in anomalously warm waters is linked with myoliquefaction of muscle tissue ("jellymeat"), mediated by infection by *Kudoa* parasites. Jellymeat renders the meat unsuitable for export, reducing profits and increasing wastage. If there is a thermally-sensitive mechanism underpinning jellymeat, there may be a concomitant increase in future jellymeat events as a result of climate change. However, the links between physical seascape conditions and the mechanisms underpinning jellymeat are unknown. Using microscopy and multiomic techniques combined with dynamic spatial modelling, we are investigating the biophysical drivers of the occurrence and intensity of *Kudoa* infection in swordfish harvested in the ETBF and developing predictive models of spatiotemporal risk zones over the fishery domain. Initial results indicate higher rates of infection both in warmer waters and in the region dominated by the East Australian Current, the latter being a marine climate change hotspot. In partnership with industry, we are co-creating a prototype tool that provides seasonal outlooks and decadal-scale climate projections of the relative likelihood of harvesting swordfish likely to become jellied, to inform best handling practices when fishing in conditions conducive to jellymeat. We aim to reduce wastage along the supply chain and support proactive, climate-ready industry adaptation under rapidly changing conditions.

POSTER BOARD ID: GP-P5
(GP-15834 Poster)

Slipping away! A socio-ecological approach to provide insights into reviving the slipper lobster fishery in Amami, Japan

Shubha **Singh** [1,2] and Takashi Torii [1]

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Lobsters are being harvested for consumption at an alarming rate. Members of the Scyllaridae family (slipper lobsters) are more abundant and are understudied compared to their close relatives the Panuliridae (spiny lobsters). In recent years, due to the catch constraints on spiny lobsters and an increase in management regulations, Japanese fishermen are now turning towards slipper lobsters to meet the growing consumer demands. Due to this increasing pressure, the catch of slipper lobsters has fallen by almost 75% in the last 7 years. The decline continued despite the implementation of a few management measures in the Amami and Okinawa Islands. The lack of information on slipper lobsters and gaps in knowledge regarding the ecological aspect of this fishery has now raised quite a few problems and reviving this fishery is currently a challenge. Therefore, my research aims to investigate the *Scyllaride squammosus* (blunt slipper), and evaluate the external factors influencing this fishery, and look into the current management

strategies to figure out why it's failing. I believe incorporating a socio-ecological, qualitative modelling approach may help to account for limited data availability and uncertainty as is the case for this fishery. Finally, socio-ecological approaches might provide valuable insights into this fishery and help pinpoint areas of concern to successfully revive this it.

POSTER BOARD ID: GP-P6

(GP-15837 Poster)

Bonga shad (*Ethmalosa fimbriata*) key biological parameters variability under the effects of environmental changes

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Ethmalosa fimbriata is a small, often overexploited, pelagic fish species that occurs off tropical and subtropical coastlines. It constitutes the main catch of artisanal fisheries off the coast of West Africa. We examined growth rates and reproductive characteristics of *E. fimbriata* off The Gambia and other coastal areas to determine how they relate to variations in environmental characteristics of coastal waters. Based on fish length-frequency data and a coastal upwelling index, we found that *E. fimbriata* recruitment tends to occur during the periods of most intensive upwelling. The evolutionary trait of peak reproduction corresponds to periods of low sea surface temperature. We hypothesize that *E. fimbriata* takes advantage of the higher zooplankton productivity that occurs in coastal waters when upwelling brings nutrient-rich water to the surface (i.e., it increases its growth rate and accumulates energy reserves for spawning). Growth performance appears to be strongly dependent on environmental conditions. The timing of spawning seems to occur when food (zooplankton) is most available for supplying the energy requirements needed by adults for spawning and early development of larvae. Environmental changes seem to have a significant effect on *E. fimbriata* growth and reproduction, which endorses their high phenotypic plasticity.

POSTER BOARD ID: GP-P7

(GP-15838 Poster)

Subsurface climate variability derived from Argo floats and sea surface temperature in the Pacific Ocean

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The oceanic and atmospheric variability at global and regional scales and the oceanic and atmospheric dynamics have been explained with primary climate indices, including El-Nino and Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and North Atlantic Oscillation (NAO). The primary spatial modes and corresponding time series are derived from

statistical analysis, often using empirical orthogonal functions (EOFs), to capture the dominant variability in terms of variance. With the advent of satellite observations collected on a global scale, climate indices are actively derived from sea surface observations, such as sea surface temperature (SST) and sea surface height (SSH). In particular, as the traditional climate indices are highly related to the air-sea interactions associated with climate dynamics and weather conditions in the upper ocean or surface ocean, they may have limitations in explaining the long-term subsurface circulation and variability to understand large-scale oceanic motions. Because long-term subsurface observations and reanalysis data have become available recently, the spatial and temporal modes and structural functions describing the subsurface variability can be useful for investigating the subsurface oceanic variability and forecasting climate change. For instance, deep water circulation and overturning circulation at the basin and global scales, and their subsurface tracking allow us to better understand subsurface ocean circulation. In this talk, we present the subsurface climate indices in the Pacific Ocean and their relevance with the regional and basin circulations.

POSTER BOARD ID: GP-P8

(GP-15844 Poster)

Impact of Future Climate on Agriculture and Modeling the Crop Water Requirement using Machine Learning Approach: A Case Study in a Semi-Arid Climatic Zone of Karnataka, India

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The potential of remote sensing data in weather forecasts and agricultural practices has been widely acknowledged. However, in reality, operational applications of remote sensing and machine learning techniques in irrigation management are few. The applicability of remote sensing technologies to evaluate the potential requirement of crop water in a pilot region in India was investigated in this study. Understanding global crop yield production is key to meeting food security challenges and reducing the impacts of climate change, which indirectly helps India achieve zero hunger, one of the United Nations' Sustainable Development Goals 2030.

Accurate weather forecasting is not an easy task due to the non-stationarity nature of the weather. Traditional time series data often have relatively low dimensionality. While data volumes continue to grow, traditional statistics techniques can no longer deal with massive amounts of data. Many methods have been developed to model the evolution of meteorological simulations. Compared to parametric methods like ARIMA, nonparametric methods are more effective in prediction performance, even for stochastic weather data.

We describe a performance modeling method that uses a K-Nearest Neighbor (KNN), a non-parametric version of a machine learning approach. We calculated the Normalized Difference Vegetation Index at each station using kriging. We use the CROPWAT, a Crop Water Requirement application algorithm, to estimate the crop water requirement for annual water allocation planning. This model can predict crops with a high spatial resolution months before harvest, using only globally available covariates, and help make agricultural decisions. This approach shows that it surpasses both classical statistical methods and a parametric time series model in predicting the output of years held during model training. This research helps determine crop water requirements by using Quantitative analysis and Remote Sensing at the regional level.

POSTER BOARD ID: GP-P9

(GP-15860 Poster)

Fencing lands to Enhanced Climate change Resilience, promoting biodiversity regeneration and Improved Livelihoods of climate change in Makueni and Baringo Counties.

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Kenya is a food insecure country, weather patterns are drastically changing and people are losing livelihoods and\Earnings when their lands dry, water for domestic supply lacks and livestock die further frustrating livelihoods of the poor. This paper briefly discusses Fencing of lands as prerequisite to biodiversity protection and faster water Retention mechanism, through tree planting, enhancing CO2 sequestration as trees, shrubs and vegetation's find Suitable environment to grow. Baringo and Makueni County are characterized by unsustainable agriculture,environmental degradation resulting from soil erosion, high poverty levels and food insecurity due to Unpredictable dry spells and climate change.

The present paper illustrates that Fencing of lands improves Agricultural land management practices, biodiversity growth increased soil carbon sequestration. Key words, food security, soil carbon sequestration, climate change, soil erosion Introduction, the greenhouse effect. Trees also influence hydrology by absorbing, intercepting and storing precipitation, and releasing water to the atmosphere through transpiration, maintaining ground water levels and reducing runoff. Trees are a source of food, shelter, and habitat for many organisms and soil erosion has contributed to Desertification, growing water scarcity, and climate events such as flooding, storms and final loss of biodiversity. Fencing helps regeneration increasing soil biodiversity and organic matter, leading to more resilient soils that can better withstand climate change impacts like flooding and drought in Makueni and Baringo counties.

POSTER BOARD ID: GP-P10

(GP-15935 Poster)

Scoping an Integrated Ecosystem Assessment for the southern Benguela: fisheries still biggest risk

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The interactive impacts of anthropogenic and climate drivers manifest as changes in structure and functioning of the southern Benguela ecosystem. To curb loss of ecosystem services, cross-sectoral management has been proposed, however implementation has been slowed by the complex interactions of pressures caused by various sectors on ecological components. Integrated Ecosystem Assessment (IEA) identifies sectors and pressures needing most urgent management action, through using linkage chains and impact risk scores calculated based on the exposure and severity of impacts faced by ecological components. This study builds on a South African-wide marine IEA scoping exercise to more closely inspect dependent sectors in the southern Benguela. Current research and expert knowledge highlight fishing as the most important sector due to its high connectance and impact risk to ecological components. The fisheries sector is disaggregated, and the demersal trawl and small pelagic fisheries were found to have greatest impact on ecological components. Species extraction, bycatch and incidental loss emerged as key pressures. Findings emphasise the need to lower the impacts of the identified key pressures to maintain healthy ecosystems. However, IEAs are underpinned by knowledge on specific habitats, species and ecosystem services and need to be considered in the context of climate impacts. To improve confidence in future ecosystem service assessments, research is needed on key knowledge gaps, such as the impact of underwater noise and recreational fisheries in the southern Benguela. Ecosystem modelling that can account for interactive impacts of multiple anthropogenic pressures under climate change, is also encouraged.

POSTER BOARD ID: GP-P11

(GP-15954 Poster)

Seasonal variability, morphometric relationships, size structure, and conservation status of shark and ray species caught as by-catch during two major monsoon seasons in the prawn trawl fishery in Malindi-Ungwana Bay, Kenya

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We characterize elasmobranch bycatch of the prawn trawl fishery in the Malindi-Ungwana Bay. 5,373 individual elasmobranchs (38 species; 18 shark and 20 batoid species) were landed as bycatch in the prawn trawl fishery during the sampling period, September 2019-March 2021. Seasonal species variability shows more elasmobranches caught during the NEM season compared to the SEM. Length-weight relationships and lengths-at-first maturity, L_m are derived for 21 species; 10 shark (n = 3532) and 11 batoid (n = 1786) species. L_m and asymptotic lengths superimposed on length-frequency distributions are provided as frameworks for evaluating exploitation status of the bycatch species. The speckled catshark, *Halaelurus boesemani* and the thornback ray, *Raja clavata* were the most landed shark and batoid species respectively. Four species landed are listed as Critically Endangered (CR) in the IUCN redlist. Six species are categorized as Endangered with extinction (EN). The bycatch also included species that are universally rare and with restricted distributions. The length coefficient (b) values for most of the species sampled occurred within the expected range of 2.5-3.5. The L_m for males of most of the species of sharks and rays sampled was observed to be lower than their female counterparts. A number of species of rays and sharks are caught while immature suggesting potential effects of trawling on recruitment success. The generated information contributes to the poor database on elasmobranchs in the Western Indian Ocean (WIO) region and forms a pioneering benchmark for future studies in the region.

POSTER BOARD ID: GP-P12
(GP-15979 Poster)

Changes in body size, geographical distribution and abundance of fishes between two distinct marine regions: Norway and New Zealand

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As global oceans warm, marine ectothermic species are expected and have been observed to shift in geographical distribution, as well as reduce in maximum body size. Such changes have the potential to disrupt ecological processes, and in turn impact population abundance, as well as the fisheries that rely on them. We investigated the temperature-size rule within populations of fishes and invertebrates collected with research trawls in two distinct marine regions: the boreal and Arctic waters of Norway, plus the sub-tropical, warm-temperate and deep-sea waters of New Zealand. We found that large species, and species found in warmer waters are more likely to experience stronger negative temperature-size responses (i.e., smaller in warmer water) compared to smaller, or cold-water species. Further, we investigated changes in geographical distribution and abundance of species in line with ocean warming using the mean temperature of the catch index (MTC, i.e., the mean temperature assemblage of recorded species, weighted by abundance) in Norwegian and New Zealand waters. In Norway, both research and fisheries data reveal a strong increase in the abundance of warm-water fishes, although fisheries catches did not change in parallel with the MTC of the research data, indicating scope for fisheries to better adapt to changing climate conditions. Analyses of fisheries catch data in New Zealand reveal a separation in trends of the temperature assemblage between in-shore and offshore fisheries. These results can inform climate-smart fishing adaptations with regards to changes in marine ectotherm body size and geographical distribution in line with ocean warming.

POSTER BOARD ID: GP-P13
(GP-16004 Poster)

Trends in size of mature sockeye and pink salmon near the southern limit of their range in the eastern Pacific Ocean

REVISION: Authors: Steve Latham, Dejan Brkic, Angela Phung, Eric Taylor, Catherine Ball, and Julie Sellars

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Size of salmon is of great importance to their value, both in fisheries and on the spawning grounds (where egg size and fecundity are strongly related to body size, and nutrient transport to natal locations from the ocean relies directly on body size). Declines in size have been reported for Chinook, chum, pink and sockeye salmon in the eastern North Pacific Ocean. We present data showing declines in abundance and size-at-age of sockeye and pink salmon from

the Fraser River, near the southern limit of their range in North America. The size of older age-classes of sockeye seems to have declined more than the size of younger age-classes. Leading hypotheses for declining sizes include climate-mediated effects on physiology, food availability, and inter-specific competition with more abundant northern stocks. Spawning escapement targets and other fisheries management plans for Fraser River sockeye and pink salmon do not currently consider trends in body size (they are based on counts of fish). We are making relevant data available online through Shiny in RStudio to stimulate broader, improved research on this issue and on appropriate management responses.

POSTER BOARD ID: GP-P14

(GP-16016 Poster)

Simultaneous estimation of the sinking, dissolved and active export components from in-situ data in the region of South Georgia

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The vertical export of organic carbon from the surface ocean to the ocean's interior exerts a fundamental control on atmospheric CO_2 concentrations and it is contributed to by a variety of mechanisms, notably the export of particulate organic carbon (POC), dissolved organic carbon (DOC) and active fluxes by migrating organisms. Although quantifying the relative contribution of these flux components is essential to understand the vulnerability of export to climate change and its potential feedbacks, they are rarely measured at the same time. Here we present the first simultaneous estimation of the dissolved, sinking and active flux components for the region of South Georgia, Southern Ocean. We combine in situ data collected during the same cruise expedition with an inverse model. We find that, at this location, the POC flux is dominant, with a mean value of 409 mg C m^{-2} day^{-1}, the DOC total export contributes about 6.6% to the total flux (23.0–37.5 mg C m^{-2} day^{-1}), while the active flux has no discernible contribution. Diapycnal fluxes of DOC obtained from the cruise data constitute a minor fraction (0.05–1.28 mg C m^{-2} day^{-1}) of the total DOC export, which we estimate to be driven by isopycnal transport using an observationally constrained model and subduction estimates. This study aims to encourage future expeditions to simultaneously measure the particulate, dissolved and active export of organic carbon to resolve the spatiotemporal variability of their relative contribution and better understand the functioning and vulnerability of the ocean's biological pump to future changes.

POSTER BOARD ID: GP-P15
(GP-16036 Poster)

Physical controls and ecological implications of the timing of the spring phytoplankton bloom on the Newfoundland and Labrador shelf

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The Newfoundland and Labrador (NL) shelf, and more specifically the Grand Banks of Newfoundland, are located at the extreme east of the North American continental shelf. They have been known as iconic fishing areas for centuries. Match/mismatch hypotheses have linked the recruitment and biomass of forage and commercial fish species, to the timing of the phytoplankton spring bloom (PSB). The timing of the PSB in this region has been historically linked to the melting of sea ice, which stratifies the water columns and promotes conditions that are favorable to plankton growth and accumulation. But with sea ice gradually disappearing from the region, we revisited here the physical drivers responsible for the initiation of the spring bloom on the Grand Banks and on the NL shelf as a whole. In particular, we found that the initiation of the PSB on the Grand Banks can be predicted from the stratification of the water column measured at a nearby monitoring station. We also showed that large-scale climate indicators are good proxies for the timing of the PSB on the NL shelf, and for the surviving success of the zooplankton species *Calanus finmarchicus*, the keystone of many food webs. This work paves the way for a better integration of physical properties into ecosystem modeling and for the inclusion of climate variables into an ecosystem approach to fisheries management.

POSTER BOARD ID: GP-P16
(GP-16070 Poster)

Restoring Australia's endangered giant kelp (*Macrocystis pyrifera*) forests

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Kelp forests are the foundation of the Great Southern Reef, Australia's continent-wide temperate reef system that supports high levels of biodiversity, endemism, and economic value. Unfortunately, in Australia and elsewhere, kelp forests are declining due to climate change, overgrazing from herbivores, and coastal development and pollution. Globally, some of the most dramatic declines have occurred in Tasmania, Australia, where 95% of giant kelp (*Macrocystis pyrifera*) surface canopies have disappeared since the 1950's. Habitat restoration is one potential tool for kelp forest conservation, but critically, any restoration intervention must first address the ongoing challenge of climate change that continues to drive giant kelp loss.

Here we outline the key drivers of giant kelp forest loss in Australia – increasing water temperatures and reductions in coastal nutrients – and present a body of work relevant to novel restoration efforts at the forest-scale. We summarise research regarding our novel restoration

efforts, including the trialing and efficacy of kelp planting methods at scale, ecological interactions of juvenile kelp, and the 'future-proofing' of restoration efforts through the use of warmwater-tolerant giant kelp genotypes. We will also briefly introduce components of the broader project looking at the physiology, genetics, and breeding of *Macrocysti*s in Tasmania, and of kelp restoration ethics and decision-making. Ultimately, we aim to provide a foundation for future efforts to maintain and restore kelp forest resilience in a global ocean-warming hotspot, and to provide risk-management to habitat restoration in a rapidly changing climate.

POSTER BOARD ID: GP-P17

(GP-16079 Poster)

Coccolithophore calcification response to acidification under calcite/aragonite sea

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Coccolithophores, a key functional phytoplankton group, evolved since about 220Ma, with their calcitic plates (coccoliths) found in the sediment record (Bown et al., 2004). Over their geological history, coccolithophores have experienced various changes in Earth's climate and the geochemical composition of their intracellularly produced has been the focus of numerous studies coccoliths reconstructing past oceanographic, climate and environmental conditions (Young and Henriksen, 2003; Stoll and Ziveri, 2004; Erba, 2006; Ziveri et al., 2012).

During Oceanic Anoxic Events (OAEs) like early Toarcian OAE (T-OAE) and Cenomanian/Turonian OAE2 (C/T OAE), associated to the increase of atmospheric temperature and CO2 (Hesselbo et al., 2000; Jenkyns 2010; Heimdal et al., 2021), calcareous nannofossils have experienced a large variation on species richness and abundance (Lamolda et al., 1994; Paul et al., 1999; Jenkyns 1985, 2003). The crisis of heavily calcified plankton groups in the pelagic sea, i.e. biocalcification crises (Weissert, H., & Erba, E., 2004; Takashima R et al., 2006), occurred coinciding with OAEs and it is thought to be evidence of oceanic acidification (Erba, E., 2004; Mattioli, E et al., 2009). However, the causes of the different biocalcification crises are still under debate.

During the biocalcification crises, the coccolithophores were probably submitted simultaneously to the different chemical and physical stresses, like temperature, CO_2 (pH acidification), and different Mg/Ca ration. This is why this experiment proposed to analyses in a concomitant way the effect of temperature together with Mg/Ca and simultaneously effects of pH.

POSTER BOARD ID: GP-P18
(GP-16089 Poster)

Sub-regional variability to climate change in the Canary Current upwelling

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Upwelling intensity in eastern boundary coastal ecosystems, is expected to increase as result of global warming. However, in some areas, as the Canary Current upwelling ecosystem, which have a strong geographical diversity, this trend could vary latitudinally. The identification of consistent units alongside their long-term and seasonal changes will help anticipating the impact of climate change and contribute to a better fisheries management in the region.

Using spatially-explicit and monthly-resolved datasets from satellite and reanalysis, we described the spatio-temporal dynamics of oceanographic processes from northern Morocco to Guinea-Bissau over the last decades. For this purpose, we employed two complementary methods for time-series decomposition: trend and seasonal regression and wavelets.

Our results show contrasting trends depending on latitude, showing an upwelling increase in the north and a decrease in the southernmost areas, unlike temperature which increases in the south and decreases in the north. Chlorophyll presents a decrease in all the area. Also, seasonality changes are observed, with an upwelling increase and a chlorophyll decrease in the south versus an upwelling decrease and a chlorophyll increase in the north.

Based on the above we identified three main subregions: (1) a winter-spring seasonal upwelling zone off the coasts of Guinea-Bissau, Senegal and Mauritania (12-21ºN) characterised by increasing temperatures and decreasing upwelling intensity, (2) a permanent upwelling area off Western Sahara (22-28ºN) featuring a decrease in temperatures and increase in upwelling and (3) a weaker summer upwelling area north of Cape Bojador (29-35ºN) where upwelling has increased while temperatures have remained stable.

POSTER BOARD ID: GP-P19
(GP-16093 Poster)

Fish body size responses to climate variability around Japan using assessment data

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One of the fish responses to climate change is fish size reduction under higher temperature. Temperature-size rule indicates that fish living in a warmer temperature grow faster while ends up with a smaller body size. However, the fish size is potentially affected by many factors including inter-species and inner-species competition for limited food and bottom-up effects through altered prey production. How these factors drive the growth of fish communities in the western North Pacific, remains unclear. We searched fish size data from marine fisheries stock assessment reports. But length-at-age data were not available most of the species. Weight-at-age data were available over a 40-year period (1978-2018) only for six populations of four

species. For 1995-2018, weight-at-age for 17 populations of 13 species were available. Using the limited data, we found weight reduction of most of populations in 1980s which was co-occurred with the biomass peak of Japanese sardine, indicating the effect of inter-species and inner species competition. Another weight reduction was found in 2010s, which was associated with a stronger stratification in the surface layers, indicating the potential bottom-up effects through less nutrient supply to the surface from the subsurface. These findings highlight the complexity of fish growth fluctuations for fish communities in the western North Pacific. To monitor the size responses of fish communities, basic data including length and weight should be archived and opened to the public. Worldwide open data set for the basic size information will improve our understanding on fish responses to climate change.

POSTER BOARD ID: GP-P20

(GP-16123 Poster)

Understanding the spatial habitat distribution of moonfish (*Mene maculata*) in southwestern Taiwan waters in relation to oceanographic factors

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Habitat models are widely used to connect species occurrence to a plethora of environmental variables to map regional and global predictions, serving as a significant tool for sustainable ecosystem-based fishery management (EBFM). The current study developed a habitat prediction of moonfish abundance using generalized additive model (GAM) in relation to ten oceanographic predictors, namely: sea surface chlorophyll-a (SSC), mixed layer depth (MLD), dissolved oxygen (O), pH, sea surface height (SSH), sea surface salinity (SSS), sea surface temperature (SST), northward velocity (V), eastward velocity (U), and eddy kinetic energy (EKE). The major fishing seasons for moonfish in Southwestern Taiwan, i.e., October to April from 2014 to 2019 were selected for this study out of which higher catch was found mainly from January to April. Hence, these months were considered for the final analysis. GAM revealed that SSH has the highest contribution for this species followed by MLD. The optimum ranges for the parameters are SSC: 0.3-0.5 mg m^{-3}, MLD: 40-44 m, O: 210-215 mmol m^{-3}, pH: 8.08-8.1; SSH: 0.65-0.7 m, SSS: 34-35 PSU, SST: 22°-24°C, U; 0-0.2 m s^{-1}, V: -0.1-0.2 m s^{-1} and EKE: 0-0.1 m^2 s^{-2}. The final interpretation displayed predictive maps of moonfish distribution generated by modelling regions of high fish catch based on environmental features. High standardised catch per unit effort (S. CPUE) was mainly concentrated between 22°-24°N and 119°-121°E. Therefore, the approach used here can serve as a powerful tool to understand and describe species' habitat distribution and interactions, and bolster sustainability.

POSTER BOARD ID: GP-P21
(GP-16130 Poster)

Spatial distribution and habitat suitability of tigertooth croaker (*Otolithes rubber*) in relation to the oceanic environment in the Taiwan strait

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Marine ecosystem is defined as an essential ecosystem that provides habitat and food for marine organisms which influences their distribution as well. Marine ecosystem is sensitive to environmental changes. This study aims to discover how oceanic environment and fishing operation data can describe the distribution and the suitable habitat of tigertooth croakers by remote sensing. Fishery data were collected from the Taiwan fishery agency from 2014 to 2019 (March to August) by using gillnet fisheries in the Taiwan strait. Ten environmental variables were employed as follows: Mixed Layer Depth (MLD), Oxygen (O), Sea Surface Chlorophyll-a (SSC), Sea Surface Height (SSH), Sea Surface Salinity (SSS), Sea Surface Temperature (SST), Eastward velocity (U), Northward Velocity (V), Eddie Kinetic Energy (EKE), and Power of Hydrogen (pH) for finding the related environmental influence in the spatial distribution of tigertooth croaker. The determination of suitable habitat was performed by GAM. The results showed that the suitable range of tigertooth croaker habitat is as follows; MLD (5-28 m), O (118-218 mmol m^{-3}), SSC (0.2-0.62 mg m^{-3}), SSH (0.55-0.75 m), SST (23-28 ^{o}C), U (0-0.4 m/s), V (0-0.5 m/s), EKE (0-0.15 m^2/s^2), SSS (32-34.5 PSU) and pH (8.04-8.08). This result may be beneficial to have more understanding of tigertooth croaker habitat in order to develop fisheries management in marine waters under climate change and human activity issues.

POSTER BOARD ID: GP-P22
(GP-16143 Poster)

Long term zooplankton community redistribution in response to ocean warming across the North Atlantic and Mediterranean Sea

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Relatively simple habitat metrics have proven informative for understanding species redistributions under environmental change from mid- to long-term timescales. However, efforts addressing community level ecological responses to long term ocean warming across

different regions in the North Atlantic and Mediterranean Sea remain elusive. Here, we undertook a collaborative effort to analyze to what extent zooplankton community composition changes over the last three decades are tied to ocean warming using time-series data collected at L4, Urdaibai, Saronikos and the Kattegat. First, using community β-diversity metrics and the Community Temperature Index (CTI), which tracks the mean thermal affinity of a community, we analyzed if the temporal shift in the zooplankton composition corresponded to the community thermal preferences. Second, we investigated the underlying ecological processes underpinning CTI variations over time, including the tropicalization, deborealization, borealization and detropicalization. The β-diversity analysis revealed a high temporal community turnover (30−45%), with a significant similarity decrease over time associated to environmental drivers, including sea temperature (SST). SST increased significantly in Saronikos and the Kattegat, however, the CTI increase over time was only significant in the Kattegat. Overall, CTI changes were positive (0.015°C/year), but not significantly different to zero, meaning that the community changes over time are not attributable only to thermal niche tracking. Tropicalization (37-77%) prevailed in Saronikos, Urdaibai and Kattegat and deborealization in L4 (51%). Taken together, results reveal a strong resilient capacity of zooplankton to ocean warming, as species can remain in place without the need to relocate to find favorable conditions.

POSTER BOARD ID: GP-P23

(GP-16164 Poster)

Where marine protection is most needed to protect carbon pathways from threat

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Ocean nature conservation and climate mitigation has lagged behind that on land but is finally gaining spotlight from policy makers, scientific and societal attention. Coastal and ocean ecosystems can act as important nature-based solutions to climate and nature loss crises, as these can significantly contribute to carbon export from atmosphere to sediment burial. NGOs and high-profile reports have pressured governments to more actively protect marine ecosystems by creation of marine protected areas, but little productive blue carbon environments are under meaningful protection from threat. Cavan & Hill (2021) highlighted the overlap of high fishing effort on pelagic carbon export hotspots. We further map areas of high carbon benthic productivity onto their pelagic fishing-carbon export threat and compare these to the geography of established Marine Protected Areas. We argue that lack-of-overlap-areas between carbon-rich nature and fishing threat hotspots should be amongst the pivotal areas where marine protection is most needed to synergistically tackle both climate mitigation and nature loss. Intervention into fishing hotspot areas is difficult because ocean food is an important resource and livelihood for growing human populations. Not tackling the lack of protection for carbon hotspots would be omitting an important chance of mitigating climate and nature loss crises together as urged by IPCC/IPBES. Better establishment of judicious marine conservation areas that protect both high biological carbon environments while preserving equity and quality of life should be at the forefront of immediate climate change mitigation actions.

POSTER BOARD ID: GP-P24
(GP-16166 Poster)

Onset of the Mediterranean West-to-East biodiversity gradient

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Physical connectivity between marine basins facilitates population exchange and hence controls biodiversity. The Mediterranean Sea is a semi-restricted basin with only a small two-way connection to the global ocean, and it is a region heavily impacted by climate change and biological invasions today. The massive migration of non-indigenous species into the basin through the Suez Canal, driven and enabled by climate warming, is drastically changing Mediterranean biodiversity. Understanding therefore the origin and cause(s) of pre-existing biodiversity patterns is crucial for predicting future impacts of climate change. Mediterranean biodiversity exhibits a west-to-east decreasing gradient in terms of species richness, but the processes that resulted in this gradient have only been hypothesized. By examining the fossil record, we provide evidence that this gradient developed 5.33 million years ago at the end of the Messinian Salinity Crisis, and it was therefore caused by the re-population of the basin by marine species with a dominating western source at the Mediterranean–Atlantic gateway.

POSTER BOARD ID: GP-P25
(GP-16176 Poster)

Complementarity of morphological and molecular tools in zooplankton monitoring at the Berlengas Biosphere Reserve, Portugal

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Zooplankton plays a fundamental role in marine ecosystems, contributing substantially to the biogeochemical cycling and as food source for commercially important fish and marine mammals. Therefore, zooplankton monitoring is a prerequisite for an ecosystem approach to management. The application of molecular tools, such as environmental-DNA (eDNA) metabarcoding, has proved to be a helpful tool in monitoring marine ecosystems. The aim of this work was to compare the results of molecular and morphological methods in zooplankton

taxonomic classification and analyse its complementarity.

Four plankton samples collected vertically with a WP2 net (200 µm) at the Berlengas Biosphere Reserve were subjected to classic taxonomic identification and DNA extraction. Additionally, four 1L-water samples collected at the same moment were subjected to filtration (0.22 µm) and eDNA extraction. Subsequently, all samples were High-Throughput Sequenced, targeting the 18S rRNA and COI genes.

The sequencing results showed differences in species richness between samples, and a higher value than in the morphological approach. Comparing results from both molecular approaches, metabarcoding of zooplankton bulk samples presented a higher species richness than eDNA samples. However, some species were only detected through eDNA (e.g.: *Harpacticus sp.*). It was also possible to detect DNA sequences of NIS in the analysis of zooplankton samples, e.g., *Balanus trigonus*, which has not been reported yet at Berlengas.

This work highlights the importance of using several identification approaches to improve, in a more effective way, the monitoring of marine ecosystems and, also early detect new NIS in order to carry out an efficient ecosystem management.

POSTER BOARD ID: GP-P26
(GP-16178 Poster)

Impact of present and future temperature conditions in North Atlantic fisheries: an elasticity analysis approach

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Most marine fish species express life-history changes across temperature gradients; thus, ocean warming will likely impact fish stock composition and fishery productivity. This study investigates the role of life-history determinants in the response of fish stocks to ocean warming. Building on work by the Working Group on Fisheries-induced Evolution of ICES, data on the life-history parameters describing growth, maturation, recruitment, and mortality and on the stock-recruitment relations of 40+ commercially exploited marine fish stocks was compiled to study fisheries sensitivities to ocean warming. For each one of these stocks, a stock-specific bioenergetically driven age-, size-, and stage-specific demographic model with density-dependent recruitment has been calibrated. The detailed causal model of the life cycles enables predictions out of the sample of previously observed temperatures and with no assumption on the independence of the life-history processes. On this basis, elasticity analyses have been performed to assess how climate-induced perturbations in all individual life-history parameters affect a matrix of stock characteristics describing the abundance, biomass, average age, and average length of all fish, spawning fish, maturing fish, naturally dying fish, and caught fish. Furthermore, two diametrical temperature-impact scenarios have been constructed to assess how changing ocean temperatures are expected to affect life-history parameters. Through the systematic elasticity analysis, we advance a classification of the investigated stocks by their response to temperature change and identify stocks particularly vulnerable to ocean warming.

POSTER BOARD ID: GP-P27
(GP-16205 Poster)

Climate-induced species range shifts and their impacts on the protected seascape on Canada's east coast

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Marine Protected Areas (MPAs) within Canada's exclusive economic zone help ensure the conservation and sustainability of marine ecosystems and the continued provision of ecosystem services to society (e.g., food, carbon sequestration). With ongoing and accelerating climate change, however, MPAs may become undermined in terms of their effectiveness at fulfilling these outcomes. Many populations of species, especially those at their thermal range limits, may shift to cooler waters or become extirpated due to climate change, resulting in new species compositions and ecological interactions within static MPA boundaries. While Canadian MPA management follows international guidelines for marine conservation, no consistent approach exists for adapting MPA networks to climate change and the resulting altered ecosystem conditions. To fill this gap, we analyze projected climate driven shifts in species distributions on Canada's east coast, identifying when native species emigrate and novel species immigrate within the network, and how high mitigation and carbon emission scenarios influence these timelines. We also develop indicators of the ecological changes caused by these species shifts in the biological community. Overall, our research provides projections of climate change impacts and helps to guide adaptive management responses within the Canadian east coast MPA network.

POSTER BOARD ID: GP-P28
(GP-16223 Poster)

Exploring the interaction between larval predation and Winter flounder dynamics from an ecosystem perspective using a multi-stanza Chance and Necessity model.

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Winter flounder spawning stock biomass has declined 6-fold during the last 40 years. There is much debate about the underlying mechanisms resulting in the observed decline in the population and the debate is still ongoing. The two major hypotheses proposed to explain this pattern correspond to (1) an increase in larval/YOY mortality due to higher temperature in the area and (2) inappropriate management regulations leading to overexploitation of the winter flounder stock for over two decades. We suggest that that higher predation on larvae/YOY may lead the stock to collapse instead of increased temperature. Chance and Necessity (CaN), and associated models, simulate possible food-web dynamics accounting for stochastic biomass variations. Thus, CaN models explore stochastically (chance) the possible trajectories of the modelled food-web complying with physical and biological constraints (necessity). The RCaN model uses available data and knowledge to constrain reconstructions and allows to test for hypothesis about the past trophic dynamics of natural systems. Using the generic form of the

RCaN model, and accounting for multiple stanzas, we tested if increased predation on winter flounder larvae/YOY could have influenced the collapse of the winter flounder spawning stock in the Southern New England and Mid-Atlantic Bight areas. We constrained our model using stock assessment model outputs, landings data, and historical diet data for larvae, juvenile, and adult winter flounder and diet data from their predators. Finally, we tested for an effect of the variability of winter flounder larvae biomass on the dynamics of the winter flounder spawning stock biomass.

POSTER BOARD ID: GP-P29

(GP-16235 Poster)

What drives climate change? The perceptions and attitudes of the fisherfolks of India. A Traditional Ecological Knowledge approach

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Climate change driven ecological responses are creating several chaos in the traditional harvesting such as agriculture and fisheries. Though curbing the change is beyond the capacity of the fisherfolks, they are focused on the evidence based decision making with the assistance of traditional ecological knowledge. The present study investigates the fisher folks attitude and perceptions on climate change.

The study was conducted in three major coastal districts in Kerala, using semi-structured questionnaires, fisherfolk's opinions of how recent variation in climate affected their livelihoods and the environment was assessed. Demographic data were described and differences between study sites were evaluated by $\chi 2$ test of contingency tables in R. Likert response format scale answers were visualized using the R package "likert".

A total of 218 fishers were responded from the three sites with highest respondents are from Kozhikode (86) followed by Eranakulam (71) and Thiruvanathapuram (61). Fisherfolk perceived that climate had changed in the past decade and were negatively impacted by this. Interviewees reported average higher temperatures, a greater frequency of floods, unpredictable timing of seasons, and erratic rainfall. Destruction of fishing villages, loss and damage of fishing equipment, shifts in the fishing calendar, reduction of fish trade, and fish catch declines as well as psycho-social problems were given as the major consequences of climate change. Our study provides an example of how fisherfolks' Traditional ecological knowledge can be used as an early warning system of the negative impacts on livelihoods and fish populations and support adaptation to the changing climate.

POSTER BOARD ID: GP-P30
(GP-16241 Poster)

Using an end-to-end ecosystem model to assess the impacts of climate change on juvenile Chinook salmon in the California Current.

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Salmon are a group of iconic anadromous fishes that are ecologically, culturally, and economically important. Many populations of salmon are imperiled due to human impacts including overfishing, loss of habitat, blocked freshwater passage, and climate change. For some populations of Chinook salmon (*Oncorhynchus tshawytscha*), for example, marine survival is strongly correlated with sea surface temperature, suggesting climate change is a severe threat. However, we lack a mechanistic understanding of climate drivers in the ocean, partly due to complex interspecific dynamics that likely underlies this correlation. We have integrated new research into an end-to-end ecosystem model using data from long-term ocean surveys, phytoplankton satellite imagery, a recently assembled diet database, fishery landings information, species distribution models, and existing literature. This spatially explicit model includes 90 living and detrital functional groups ranging from phytoplankton, krill, and forage fish to salmon, seabirds, and marine mammals, and nine fisheries. We have used this model to assess the sensitivity of the marine stage of salmon to various simulation-based, climate-induced perturbations including shifts in the availability of temperature-sensitive prey, the abundance of predators, and northward-expanding competitors. We have assessed the efficacy of management actions to mitigate the complex impacts of climate change in the marine food web, such as redistributing fishing pressure (amongst salmon, their competitors, predators, and prey), predator population management, and improving the condition of salmon entering the ocean. Our ecosystem model allows us to make inferences about the effects of climate change on entire marine food webs in a holistic, highly interconnected way.

POSTER BOARD ID: GP-P31
(GP-16279 Poster)

Jumbo Squid (*Dosydicus gigas*) and Giant swimcrab (*Callinectes toxotes*) as alternatives target species for the artisanal fishery of the southern region of Chocó, Pacific Ocean of Colombia

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Monthly capture of Jumbo squid and Giant swimcrab were carried out in Pizarro, chocó, Pacific Ocean of Colombia during 10 months, in order to evaluate the stock available for artisanal catch efforts. Jumbo squid were captured at night in three stations at 10km, 30km and 50 km from the shore and during the day two types of crabs net were used to capture gigant swimcrab in the river Baudó delta. The most abundant catch of Jumbo squid was registered in February with 284 individuals and a landing of 93 kg, and March with 230 individuals and a landing of 82.6 kg. Giant swimcrab captures were represented by a total of 523 individuals, of which 60% were males with an average size of 10.1 ± 2.5 cm long (L) and 6.2 ± 1.4 cm wide (W), the

minimum size of maturity that was calculated is 9.6 (L) x 6.2 (A) cm for males and for females it has been 9.9 (L) x 5.9 (A) cm. This study contributes to recognizing the existence in the study area of stocks of species that can be exploited by artisanal fishermen as alternative food resources and economic sustenance in order to reduce pressure on fish comercial species that may be affected in their populations as consequences of overexploitation or decrease in their natural populations due to climate change.

Keywords: Dosidicus gigas, squids, reproduction, feeding, life history, Chile.

POSTER BOARD ID: GP-P32

(GP-16308 Poster)

Percent contribution of small pelagic fish species to recommended nutrient intake (RNI) of under 5 children living along the four coastal regions of Ghana

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About 80% of artisanal fish production is consumed daily, with 80% coming from small pelagic fish species. Small pelagic fish species (SPS) provide vitamins, minerals, and essential fatty acids, making them crucial for nutrition and food security. This study aims to determine the dietary intake of small pelagic fish species among children under five years living in the four coastal regions of Ghana. An enumerator-administered 24-hour recall of two non-conservative days (1 weekday and 1 weekend) using dietary aids in the form of household food models was used to record dietary intake. Fish consumption recalls were summarized under mealtime, fish name, and quantity (g). Nutrient intakes were also summarized into mean ± SD. Each specific nutrient was compared to the age-specific dietary reference intakes and multiplied by 100 to obtain the %RNI. Over 10 different SPS were consumed during the survey period. The average consumption of SPS among children under 5 was 60 ± 51 g (Central= 71 ± 58 g, Greater Accra= 39 ± 29 g, Volta =60 ± 57 g, Western= 63 ± 47 g). Protein and vitamin B_{12} intakes exceeded the RNI by 53% and 112% respectively (Central = 81%, 135%; Greater Accra = -19%, 41%; Volta = 43%, 135%; Western = 90%, 123%). However, vitamin A, vitamin D, folate, iron, and zinc contributed less than 40% to the RNI- 4%, 10%, 1%, 38% and 26%, respectively. Consuming SPS with other food sources will augment the nutrient intake of children under 5 and contribute to improved food and nutrition security.

POSTER BOARD ID: GP-P33
(GP-16317 Poster)

Harmful Algal Blooms (HAB's) in the Coast of Ghana, West Africa

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The presence of harmful algal toxins is a worrying threat to coastal and marine environments considering the vast number of resources obtained from such ecosystems around the world and Ghana not excluded. This study focused on the characterisation of the changes in the cell density and environmental conditions of harmful phytoplankton species at the coast from Accra to Narkwa lagoon located in the Central Region of Ghana. The study identified five potentially harmful species which are mostly toxin-producing thecate dinoflagellates some of which are *Lingulodinium polyedra, Gonyaulax spinifera, Dinophysis caudata, Dinophysis ovum* and species of *Alexandrium.* Both the diversity and density of HABs species showed seasonal variations. *Lingulodinium polyedra,* with cell maxima of 50- 3251 cells/L, was observed in December 2018 and August 2022 followed by *Gonyaulax spinifera* (115-890 cells/L) and *Prorocentrum gracile* signaling the risk of harmful algal bloom events in the study area. Though *Alexandrium* species (2-425 cells/L) had lower densities as compared with other harmful species, preliminary toxin profile using HPLC/FLD in the bloody cockle (*Anadara senilis*) widely consumed in the area was observed to contain traces of Paralytic Shellfish Poisoning (PSP) toxins: dcSTX, Neo and GTX 2,3 below LOQ. The importance of continuous monitoring of cell densities, climate pattern and harvested cockles for the Ghanaian shellfish market is highlighted by this investigation.

POSTER BOARD ID: GP-P34
(GP-16328 Poster)

Studies on the use of locally available (Coxs Bazar and Saint Martin) alternative renewable seaweeds wastes as compost organic fertilizer resources.

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Marine algae Marine red algae from the Bangladesh Bay of Bengal Hypnea Sp are often regarded as an underutilized bio-resource seaweed have been used as organic materials due to the presence of a number of plant growth stimulating compounds. The effect of various seaweed species on plant growth and development with an emphasis on the use of this renewable bio-resource in sustainable agricultural northern fertilizers raw materials system. A plant needs organic fertilizer for it to grow in a balanced way .The combined use of organic and inorganic fertilizers can improve crop production and maintain soil health. Many important soil properties depend on to some degree on the quality of organic matter. Organically made fertilizers play an important role in increasing the crop yield and the quality of crops promises improvements considering climate adaptation. Research on marine products has enormous unexploited potential and significant advantages. Although Bangladesh possesses a part of the

Bay of Bengal, the vast ground of our marine resources is yet to be explored and the application of biotechnology to marine biodiversity remains poorly developed. This part of the study is directed towards the analysis of the future trend and performances of Composting Seaweeds wastes. Demo plot- one Zoom production betel-leaf 2880 per day, Control plot-one zoom production betel-leaf 2780 per day. Difference 100 leaf meaning increased plucking 100 leaf production per day used by seaweeds wastes mixed compost organic fertilizer.

Keywords: Seaweed, Plant Growth, Organic Material, northern fertilizer, Sustainable.

POSTER BOARD ID: GP-P35

(GP-16356 Poster)

How would different kinds of seafood traceability information affect people's MWTP?

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Establishing seafood traceability is an important goal spanning many domains, including food safety, resource conservation, and human rights. However, the traceability system has not been enough developed in global seafood markets, including Japan.

We conduct a study to examine how much consumers value traceability in seafood and the kind of information that helps add value to traceability. The study examines marginal willingness to pay (MWTP) for traceability for four types of information packages: A) "safety guarantee," B) "safety guarantee + resource conservation", C) "safety guarantee + human rights" and D) "safety guarantee + mislabeling of origin". The total number of participants is 218 people and participants are randomly allocated by groups A to D. Participants watch a video explained by experts based on each group.

In the discrete choice experiment, MWTP on type C is significantly higher than on A, B, and D. Additionally, people with high altruism in all groups have higher MWTP than people with low altruism. Contrary, MWTP on less altruistic people with the information type of D is higher than that of people facing other information packages. People with low altruism tend to reduce the risk for themselves by knowing the seafood's origin through traceability when decision-making.

In conclusion, there is a possibility that seafood traceability has the effect of adding value to seafood products. To enhance people's MWTP for traceability, adding information on the "human rights" and "mislabeling of origin" risk reduction could contribute to improving the seafood traceability system effectively.

POSTER BOARD ID: GP-P36
(GP-16424 Poster)

Impact of dynamic dust deposition on Pacific Ocean biogeochemistry

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Deposition of mineral dust plays an important role in upper-ocean biogeochemical processes, particularly by delivering iron to iron-limited regions. Here we examine the impact of dynamically changing dust deposition on tropical Pacific ocean biogeochemistry in a fully coupled earth system model projection under a high-emissions scenario projection of future climate (SSP5-8.5) through comparisons with an otherwise identical projection that implements a static, climatological estimate of preindustrial dust deposition. Under SSP5-8.5, warmer air temperatures due to anthropogenically perturbed radiative forcing and changing land-use practices, increase soil aridity and exposure, respectively. These contribute to elevated concentrations of dust in the atmosphere, which, in combination with redistribution of equatorial Pacific precipitation, drives an increase in dust deposition in the central tropical Pacific ocean. This results in an end-of-century reduction in, and eastward contraction of, equatorial Pacific phytoplankton iron limitation and consequent shifts in projected changes for primary production and particulate organic carbon flux. The impact of enhanced export on Oxygen Minimum Zones, however, is not discernible above substantial low frequency, subsurface oxygen variability in the dynamic and static projections. These results highlight modeling advances in representing coupled land-air-sea interactions to project basin-scale patterns of ocean biogeochemical change.

POSTER BOARD ID: GP-P37
(GP-16246 Poster)

Bioindicators species of Indian Fish

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After the green revolution in India in the early 1960s, India is self-sufficient in terms of energy demand. However, a decline in the protein intake is observed, the reason for which may be promoting only cereals and neglecting other better protein-rich sources. According to National Sample Survey Office (2014), by 2012, the average protein intake by rural India was 57g/capita/day, which were about 3 gm/capita/day lower than in the 1990s. This has led India to host 37 % of stunted, 21 % of wasted and 34 % of underweight children. Hence, policymaker has shifted the goal of increasing the production of food grains towards nutrient- rich food. India is the second largest fish producer in the world. This review takes into account the observations from the open literature about the metal (loid) concentrations in of Indian freshwater and marine fish species. Metal (loid) concentrations in edible part (muscle) of Indian fish species were compared with the international standards and the higher metal accumulating species were considered for bioindicator studies. The freshwater species *Aorichthys Aor*, *Heteropneustis fossilis*, *Labeo rohita*, *Mastacembelus armatus* and *TriplophysaKashmirensis* were regarded as bioindicator species for freshwater ecosystems of India. However, *Arius parkii*, *Cynoglossus*

spp., *Gerres oyena*, *Lates calcarifer*, *Liza parsia*, *Mugil cephalus* and *Nemipterus japonicas* were considered as bioindicators of Indian marine ecosystems.

Keywords: India; Freshwater; Marine; Fish species; Bioindicator**.**

POSTER BOARD ID: GP-P38

(GP-16447 Poster)

PROBABLE ANCHOVY HABITAT VARIATION DUE TO OCEANOGRAPHIC CONDITIONS

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Climate change may imply variations in the distribution and abundance of the different fish species, as a result of the modifications that may occur in the temperature of the sea and the availability of food. The ecosystem off Peru is characterized by its greater sensitivity to interannual and multidecadal climate variability in relation to other ecosystems in the world (Chávez et al., 2008).

In the Humboldt Current System (HCS), primary and secondary production are directly affected by climate change through oceanographic conditions and exert a bottom-up control on the abundance of forage fish at a population scale. The SCH supports the largest monospecific fishery on the planet, composed almost exclusively of anchovy (Bertrand et al., 2004b).

The anchoveta (Engraulis ringens) plays an important role in the food chain of the Humboldt Current System. For decades, attempts have been made to explain the variability in anchoveta distribution through the environmental variables that structure its habitat.

Routine statistical analysis methods such as linear regressions are generally inadequate to detect and quantify environmental effects (Maravelias, 1997).
Machine learning algorithms such as maximum entropy modeling (MaxEnt) have been shown to outperform traditional regression-based approaches.

The main objective is to develop a probabilistic model to describe the potential habitat of anchovy (Engraulis ringens) using information from satellite oceanography and catches that includes positional variables. The analysis period for the developed model is between 2019 and 2022. The model will be run every two weeks. The final model is constructed as the average of six probability parameters that meet a specified range.

POSTER BOARD ID: GP-P39
(GP-16450 Poster)

Climate adaptive fisheries management plan of the Sultanate of Oman

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The impacts of climate change on marine ecosystems and dependent fisheries are becoming increasingly evident. However, incorporating climate science into management and policy processes continues to be challenging. Many of the fisheries management policies and approaches do not currently incorporate climate-adaptive measures. The aim of the study is to discuss the existing fisheries management plans implemented in Oman, and to propose a climate adaptive fisheries management plan. The study finds out the exiting management policies, compare with global and regional fisheries management policies. Then identify the impacts of climate change on fisheries of Oman, through finding out the relationship between the sea surface temperature (SST) and the fish assemblage and catch. There has been a major change in the Arabian Gulf, Oman Gulf and Arabian Sea due to climate changes. In the Arabian Gulf, there is a positive trend in monthly time series in the sea surface temperatures (SST), with 0.7 ◦C/decade increase. In the Arabian Sea, there is also a noticeable increase in the SST, and a strong intensification of the Oxygen minimum zone (OMZ) in the region which is already considered one of the largest OMZ worldwide. Climate assessments by international and national organizations have raised the issue of the need for evaluating current fishery management plans for climate change adaptation. A good climate- resilient fishery management are the one following an effective management system, developing participatory systems for fisheries management, suddenly-occurring risk- adaptive, and management should be adaptive.

Keywords: Climate change; sea surface temperature; fisheries management; climate adaptive, Sultanate of Oman.

POSTER BOARD ID: GP-P40

(GP-16477 Poster)

Sustainable Overfishing: establishing and maintaining a harvest industry for a low value range-extending species to protect lucrative endemic fisheries and key ecological habitats.

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The climate driven range extension of the Longspined Sea Urchin, *Centrostephanus rodgersii*, in south-eastern Australia has led to the establishment of a population off the island state of Tasmania to increase from zero to 20 million within four decades. Extensive overgrazing has resulted in 15% of the eastern coast becoming unproductive urchin barren, with predictions barrens could increase to more than 50%. Sustainable overfishing of the urchin has become the key management tool to prevent reef destruction and substantial negative impact on reef dependent fisheries. Harvest subsidies were first used to accelerate the fishery to ecologically meaningful levels after a decade of stop-start operations, overcoming start-up barriers relating to processing knowledge, systems, and financing. Now, harvest subsidies are being spatially applied to direct urchin fishing effort to areas of importance (e.g. key habitat for lucrative

endemic species), facilitating the fish-down of urchin to lower densities. Marine Spatial Planning (MSP) tools are being developed to direct enhanced fishing techniques (all-size class harvests) to protect critical habitats. Carefully management of the urchin fishery is required into the future, as fishery collapse from overfishing would result in processor shut-down and termination of the key control mechanism. Harvest strategies need to facilitate sustainable overfishing; fishing urchin populations beyond MSY but not to levels were fisheries collapse.

REVISION: New General Poster Session Poster GP-41

POSTER BOARD ID: GP-P41

(GP-16485 Poster)

FishSCORE: Fisheries Strategies for a Changing Ocean and Resilient Ecosystems — Building resources and networks for climate-ready fisheries

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Building resilient fisheries is essential for ensuring the continued flow and equitable distribution of benefits, such as nutritious foods, economic benefits, and cultural traditions, that are necessary for achieving many of the SDGs. The UN Decade of Ocean Science endorsed programme FishSCORE (Fisheries Strategies for a Changing Ocean and Resilient Ecosystems) will form a network of collaborators from across the globe to develop the scientific information base needed to sustain resilient marine fisheries in changing oceans. This programme will integrate transdisciplinary knowledge into new understandings of how climate change will affect marine fisheries at local to regional scales, and moreover, how healthy marine ecosystems and resilient fisheries can be achieved in the context of these changes. FishSCORE will rely on co-development of products through ongoing collaborations between scientists and fishery practitioners in local and regional fisheries. This process will improve the scientific products, ensure they are tailored for applied needs, and support their use in real-world fishery systems. This co-development and application approach will strengthen partnerships and build capacity for forward-looking resilience planning in marine fisheries across the globe, including in industrial and artisanal fisheries as well as in developed and developing countries. FishSCORE will advance these collaboration and application experiences among diverse types of marine fisheries, including those from developing states and least developed countries, thereby contributing to equity of knowledge and capacity among fishery systems. This network of interdisciplinary scientists, fishery stakeholders, resource managers, community practitioners, and policy makers will (1) co-produce information and tools for assessing climate resilience, (2) develop approaches and best practices for using the tools to identify climate resilience strategies in diverse types of fishery systems, and (3) support the implementation of processes and solutions to advance climate resilience.

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	Vineeta Ghosh	S19-16047-Oral-Ghosh	Vineeta Ghosh, Shanta Ghosh, and Anupam Ghosh	Role of ocean acidification in changing characteristics of coastal ocean system in Bay of Bengal and Arabian Sea – Evidence from pre- & post- Covid'19 lockdown conditions	328
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	Darcy Dugan	S19-15956-S19-P5-Dugan	Darcy Dugan, Jessica Cross, Amanda Kelley, Dorothy Childers, Jamie Goen, Tom Hurst, Jeff Hetrick, Kris Holderied and Scott Goodman	The Alaska Ocean Acidification Network: Connecting Alaskans through monitoring, information sharing and the quest for solutions	340
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