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SPF-2022
Book of Abstracts

November 7-11, 2022, Lisbon, Portugal

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- S2** Life Cycle Closure: Advances in Process Understanding
- S3** Understanding Population- and Ecosystem-level Shifts: From Seasonal Timing to Tipping Points
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Oral Presentations

Plenary Session November 8

(General Plenary 15516)

Small pelagic fish in Portuguese waters: It all comes down to sardine (and some anchovy, recently)

Susana **Garrido**

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Sardine is a central part of the culture and economy of Portugal and is at the very heart of Portugal's seafood tradition. Each June, Portuguese celebrate the Popular Saints' Festivals where sardine, grilled on the streets, is the Queen. Sardines are mainly caught by purse-seine fisheries and represent approximately 50% of total volume of fish landed. In years of sardine crisis, horse mackerel, chub mackerel and more recently anchovy become main targets. Sardines off Atlantic Iberian waters suffer strong interannual fluctuations of abundance, thought to be related to the variability of environmental conditions. In the last decade, there was a long sardine crisis due to the lack of strong recruitments during more than a decade, with severe economic consequences. Contrary, the anchovy, that had a residual population in western Iberia since the beginning of data collection, more than 5 decades ago, has been increasing abundance each year to historical maximum levels, suggesting some modifications to the habitat. Portuguese waters are at the northern border of the Canary upwelling system, have a seasonal summer upwelling regime and are strongly influenced by freshwater outflow, which increases northwards. As in other parts of the world, ocean warming has been observed off the Iberia, which may have contributed to the observed changes in species dynamics. In this talk, studies carried out in Portuguese waters to try to facilitate understanding of the interactions between small pelagic fish and their habitat, and to identify key environmental drivers of small pelagic fish dynamics in this ecosystem will be presented, from analysis of historical series of data from surveys and fisheries, to laboratory controlled experiments and modelling.

(General Plenary 15222)

A way forward to elucidate small pelagic fish response to climate change

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Various studies have been conducted to elucidate the climate variability impacts on living marine resources including small pelagic species. Larval and juvenile stages are critical periods for the recruitment of living marine resources even for small pelagic species. However, limitations of observation methods for directly investigating the environments that larvae and juveniles experienced have been obstacles to our understanding. For small pelagic fish, it is also difficult to trace individual migration of adult and their experienced environments because they are fragile and small to equip electrical tags. New technologies to investigate environments that fish experienced using natural tags are recently developed. From chemical component analyses of otolith, it is possible to estimate migration route of the fish. Similar analyses are possible for eye lens, scales, and bones. Based on the new technologies, a new integrated method to elucidate environmental histories of larvae and juveniles and their hence migration routes, using otolith oxygen stable isotope analyses, eye lens nitrogen stable isotope analyses and fish growth-migration models, is proposed. To validate the estimated fish migration routes, environmental DNA in the open ocean (OceanDNA) is an effective tool. Together with the growth estimated from otolith daily increments, it is possible to elucidate environmental impacts on larval and juvenile growth through environmental histories of larvae and juveniles using their realistic migration routes. Coupling with the model application, small pelagic fish responses to historical and future climate change are expected to be elucidated.

(General Plenary 15273)**Sustainable collaborative approaches between the fishing industry and fisheries science**Martin A. **Pastors**

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Collaboration between fishing industry and fisheries science has a long history. Towards the end of the last century, the relationship between the fishing industry and science came to be more and more like a one-way streets: information flowing from fishing industry to fisheries science with limited feedback. Since the 2000s this tendency seems to be reversing with more emphasis on the possibilities and benefits of close cooperation.

We are experiencing rapid changes in environmental conditions at sea leading to spatio-temporal shifts in the occurrences of species, to changes in spawning periods and seasons, possibly also to changes in energy budgets or fish diseases. Management approaches are becoming more holistic than before, taking into account different aspects of ecosystems in the decision making systems. All these development, require a broadening of the knowledge base that underpin the management decisions. In that situation, close collaboration between fishing industry and science will allow for real time information streams on changes within the ecosystems. Harnessing the capabilities and curiosity of the fishing industry as integral part of the knowledge system offers great potential to address these ambitions.

During the keynote, I would like to address some of the recent examples on science-industry collaborations on small pelagic fish. I will address both the content of the collaboration and how it addresses new challenges. But also, focus on the institutional arrangements and the true interactions that are required to make these collaborations sustainable in the long term.

(S2 Plenary 15266)**Density-dependent egg production in small pelagic fish: A key to life cycle closure**Akinori **Takasuka**¹, Michio Yoneda², Yoshioki Oozeki³, Haruka Nishikawa⁴, Sho Furuichi⁵ and Ryuji Yukami⁵¹ Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan. E-mail: atakasuka@mail.ecc.u-tokyo.ac.jp² Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Imabari, Japan³ Headquarters, Japan Fisheries Research and Education Agency, Yokohama, Japan⁴ Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan⁵ Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Yokohama, Japan

A paradigm of fisheries science holds that spawning stock biomass (SSB) is directly proportional to total egg production (TEP) of fish stocks. This paradigm has been a basic premise underlying spawner–recruitment models for fisheries management and recruitment studies. Nonetheless, the paradigm has rarely been tested directly at multidecadal scales. Here, we review our recent studies on density-dependent egg production in small pelagic fish as a key to life-cycle closure. First, we directly tested the paradigm for Japanese sardine *Sardinops melanostictus* and Japanese anchovy *Engraulis japonicus* in the Kuroshio Current system, based on a combination of fishery-dependent stock assessment data and fishery-independent egg survey data. This test showed that the SSB–TEP proportionality was partially distorted by intraspecific (sardine) and interspecific (anchovy) density-dependent egg production at a multidecadal scale. Subsequently, we disentangled density-dependent effects on egg production and survival from egg to recruitment to demonstrate how the existence of these phenomena can change the current understanding of density-dependent processes. These lines of evidence led to a need to reconsider the validity of recruitment per spawning stock biomass (RPS), which is a SSB-based survival index from hatching to recruitment. Thus, we revisited sardine recruitment hypotheses based on recruitment per egg production (RPE), which is a TEP-based survival index. By adopting RPE, we detected statistically significant relationships of the survival to large-scale ocean climate anomaly, ambient temperature in the nursery grounds, and growth rate during the early life stages. We propose to develop egg-production-based frameworks for future fisheries management and recruitment studies.

(S3 Plenary 15383)**Detecting and forecasting the potential for community-level shifts in marine ecosystems**

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Ocean ecosystems are vulnerable to climate-driven perturbations, which are increasing in frequency and can have profound effects on marine social-ecological systems. Thus, there is an urgency to develop tools that can detect the response of ecosystem components to these perturbations as early as possible. Here we present a novel set of statistical tools that we developed to (1) generate indicators of community state, (2) identify potential shifts to a novel state, and (3) create short-term forecasts of community responses and individual species parameters to climate variables. We demonstrate the utility of these tools using case studies from northeast Pacific ecosystems, with an emphasis on small pelagic fishes, and we discuss their value with respect to informing ecosystem-based and climate-ready fisheries management. We also present some of the challenges associated with detecting and forecasting ecosystem shifts. While our work focuses on the northeast Pacific, our modeling framework is widely applicable to other ecosystems where scientists and managers are faced with the challenge of managing and protecting marine resources in a rapidly changing climate.

(S7 Plenary 15255)**Adaptation pathways for small-scale fishers facing climate change impacts**

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Fishing communities face increasing impacts on resource availability and fishing operations due to climate change impacting the oceans. These impacts are expected to grow in the future, as climate change hazards intensify. While these communities are highly dependent on fisheries for both subsistence and a livelihood, they differ in the adaptive capacities they hold, due to specific characteristics of the socio-ecological systems. Adaptive capacities cover the range of assets, organizational settings and processes, individual agency, flexibility and learning domains. In this work we explore how fishers respond to increasing levels of climate change induced impacts in their livelihoods. In particular, we are interested in understanding to what extent different communities follow similar adaptation pathways and what are the adaptive capacities driving adaptation and transformation in these systems. While adaptation involves adjusting and shifting fishing practices or the household economy, transformation entails a more drastic change in the livelihoods of fishing communities, often diversifying into new activities many times outside the sector. By reviewing evidence across case studies, we observe that the majority of fishers follow a remain-adapt-transform pathway, where adaptive capacities together with the impact intensity explain the degree of change in the social- ecological system. From this new evidence, we derive lessons learnt and policy implications in order to foster adaptation and transformation in small-scale fisheries.

Plenary Session November 9

(General Plenary 15210)

Winners, losers and shifts of the pelagic ecosystem in the Mediterranean Sea

Marta Coll

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Single-stock assessment approaches are the most used ones for the management of marine resources. However, the consequences of fishing on the dynamics of exploited stocks are not necessarily the only ones. Environmental and ecosystem dynamics, and economic and social aspects are also highly relevant, and can interact with fishing impacts. These factors are often overlooked when making management decisions. Small pelagic fish species (SPF), such as European sardine and European anchovy, are some of the most commercial species in the Mediterranean Sea. They have shown important changes in the last decade, such as shifts in abundance, biomass, body condition, growth, reproduction and spatial distribution. We generated new knowledge and integrated the available one into a multi-modelling platform to quantify the impacts and project future trajectories of change of the pelagic ecosystem in the Mediterranean Sea. The final aim was to (1) quantify the potential contribution of various drivers and the consequences of changes in SPF populations on iconic predator species, their fisheries and ecosystem dynamics, and (2) identify robust future management options to achieve resilient populations and their sustainable exploitation under climate change. I will showcase the analyses and tools that we used to generate and integrate results, going from stock assessments to species distribution models and process-oriented ecosystem spatial-temporal models. I will illustrate the importance to consider environmental, ecological and socio-economic factors when managing exploited resources from an ecosystem-based management perspective, considering the effects of climate change, and I will identify remaining knowledge gaps.

(General Plenary 15189)

The metamorphosis of small pelagic fish

Arnaud Bertrand

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The last twenty years have seen a metamorphosis in our view of small pelagic fish. Due to advances in many disciplines, notably trophodynamics, genetics, paleoecology, climate studies and more generally the use of ecosystem approaches, many paradigms have been called into question. Through a series of examples, this presentation proposes to revisit a number of hypotheses or paradigms that have, until proven otherwise, been refuted in recent years. This synthesis allows us to propose a new picture of the ecology of small pelagic fish while recognising the aspects that are still controversial or for which we lack information and which will be studied and debated during this Symposium.

(General Plenary 15226)**A key driver of change in small pelagic fishery (*dagaa*) in Lake Victoria, Tanzania**Modesta **Medard**¹, Han van Dijk² and Paul Hebinck²¹ World Wide Fund for Nature, Tanzania. E-mail: mmedard@wwftz.org² Wageningen University, The Netherlands

The central argument of this article is that, the global market for exotic species, notably the Nile Perch is a significant driver of change in Lake Victoria's fisheries. The incorporation of the Lake's resources into the global market dramatically transformed Lake Victoria's fishery landscape. It contributed to the reorientation of local market economy to one that is increasingly shaped by global market demands for Nile Perch. The combination of global and local forces has produced a specific site of struggle between actors, in their attempts to reap the benefits. In addition, while 'local' fish species escaped these transformations, *Dagaa* (*Rastreniobla argenticus*) fishing and trading strategies have been transformed in similar ways. Nile Perch and *Dagaa* do, thus, not simply co-exist biologically but their fishing practices and market organisations are similarly organised and created new actors who interact and compete with those that historically used the lake for their livelihood.

The paper focuses on aggressive form of entrepreneurship in *Dagaa* fishery that has gradually remodelled the organisation of fishing, through the introduction of fishing camps into large fishing empires. This entrepreneurship established a system of control exercised in strategic ways. Money, leadership structure, byelaws, divisions of labour and monitoring are the ways in which control is exercised and manifested through dependency on market access and credit provision.

(S6 Plenary 15428)**Including quantitative ecosystem objectives in Management Strategy Evaluation of South Africa's small pelagics**Carryn **de Moor**

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South Africa has a long history of using Management Procedures (MPs) to recommend quantitative catch limits for key commercial fisheries. The purse seine fishery for small pelagics is South Africa's second most valuable fishery in monetary terms, with the highest volume landed. For the past three decades, MPs have been used to calculate directed and bycatch limit recommendations for anchovy and sardine, the two species forming the backbone of this fishery. The MPs are regularly reviewed and updated, taking new information into account such as improved understanding of the sardine stock structure with associated spatial management implications. In addition to the fishery, many top predators in the Southern Benguela, including some which are endangered, are highly dependent on these fish. The first of these MPs to explicitly consider ecosystem objectives in addition to objectives for the target resources and socio-economic objectives was OMP-14, used to set total allowable catches and bycatches from 2015 to 2018. Quantitative performance statistics were calculated to correspond to each objective. A tiered approach was used to assist with narrowing the selection of a candidate MP from the large set of performance statistics. Most performance statistics used to measure ecosystem objectives for the previous two MPs have been based on the endangered African penguin, given the data and quantitative functional relationships available at those times. The next MP for this fishery aims to include new performance statistics for a wider range of top predators, thus broadening the ability to measure candidate MP's performance against ecosystem objectives.

Plenary Session November 10

(S1 Plenary 15366)

Trophodynamic processes and small pelagic fishes

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Small pelagic fishes (SPFs) play a key role in marine trophodynamic processes because of their mid-trophic level and often high abundance levels. These characteristics mean that SPFs can have substantial effects on both their planktonic prey and their predators, which are many and varied and include large fisheries. There has been much research on the trophodynamics of SPFs, and studies on their role as both predators and prey will be described and synthesized. Morphological and stomach content analyses, supplemented by laboratory experiments, biochemical analyses, and most recently genetic analyses, have been employed to examine the diet and feeding behavior of SPFs. In general, SPFs derive the bulk of their nutrition from filter- or particulate-feeding on zooplankton, and resource partitioning between co-existing species that is based primarily on prey size can occur. SPF aggregations can result in localized depletion of specific prey, and changes in zooplankton size composition have been linked to changes in SPF species dominance. SPF predators include a wide variety of other fishes, seabirds and marine mammals. Several of these are strongly dependent on their SPF prey and their population dynamics are tightly inter-linked. Collapses in SPF populations result in predators switching to alternate but often poor-quality prey and frequently showing substantial population declines themselves, and ecosystem models have highlighted the central trophic role of SPFs. Their responsiveness to environmental forcing/climate change, ecological role and economic importance, all emphasize the need for enhanced monitoring of these key trophic species and appropriate management of SPF fisheries.

(S4 Plenary 15298)

A paleoceanographic perspective on the future of fish productivity in the Humboldt Current system

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Climate change will drive marine ecosystems beyond the range of natural variability observed during the last century, impacting the distribution, abundance and diversity of fish populations. While modelling experiments can be used to explore future scenarios and forecast the response of fish populations to a warmer world, empirical data is needed to complement the modelling simulations. Geological records can provide insight on the responses of fish populations to past environmental and climatic change, especially during time periods warmer than present. Here, we focus on the Humboldt Current system (HCS) and show multiple fish debris records together with a suite of proxies for environmental conditions spanning the last 140,000 years. 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, a result that can hardly be obtained from modelling experiments. We discuss how insight offered by paleoceanographic records can be applied to better project small pelagic fish population responses to future anthropogenic climate change. Our rapidly warming world poses a threat to the fish productivity in tropical regions and emphasize the need for transdisciplinary research combining paleoceanographic and historical observations with model predictions.

(S5 Plenary 15492)

CalCOFI's past, present, and future role in the ecosystem approach to fishery research

Noelle M. **Bowlin**, Andrew R. Thompson, William Watson, Edward D. Weber, David A. Demer and Brad E. Erisman

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The California Cooperative Oceanic Fisheries Investigations (CalCOFI) Program has been an integrating and innovating force in ecosystem and fisheries research throughout its 73-year history. The program was started to determine the cause of the Pacific Sardine fishery collapse in the 1940s. However, the developers of the program recognized that it would likely be necessary to understand predators, prey, competitors, and underlying environmental conditions to determine the drivers of sardine survival and recruitment. Thus, the program collected both plankton and environmental data at sea, and identified as many taxa of larval fishes and zooplankton captured as possible. This process became known as the oceanographic approach to fishery research and is what we now call the ecosystem approach. The prescient design of the CalCOFI program has led directly to seminal research in the demography, development, and habitat requirements of fishes, and the development of many new instruments and research techniques. For example, CalCOFI researchers developed the Daily Egg Production Method (DEPM) for biomass estimation, a technique that is now used worldwide. The CalCOFI program has also contributed significantly to the development of the acoustic trawl method for SPF biomass estimation. CalCOFI has always been an inclusive community working together to advance our understanding of SPF stocks and their ecosystems. This work continues to evolve and incorporate new technologies such as eDNA monitoring and use of uncrewed systems to further improve our understanding of SPF dynamics and the California Current ecosystem.

Plenary Session November 11

(General Plenary 15475)

Historical perspectives of international collaboration on SFP research

Juergen Alheit (by Salvador E. Lluch-Cota)

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Wide distribution and high biomass of SPF, resulting in strong economic importance, require international research cooperation. This was early recognised by the leaders in European fisheries science in view of the fluctuations of the Great Herring Fisheries as a main reason for the creation of ICES in 1902. It was the starting point of highly successful international fisheries research on herring which has delivered a wealth of basic principles in fisheries science since. In the 1950s and 1960s, FAO played a leading role in supporting fisheries research on anchovies and sardines in the southern hemisphere by founding research institutions such as the Peruvian IMARPE and organizing international meetings in view of the dramatic collapses of SFP stocks. Since the 1980s, cooperation focused on processes determining recruitment variability (e.g. Stable Ocean Hypothesis, Optimal Environmental Window) under the umbrella of the SARP/OSLR programme jointly sponsored by IOC and FAO. Important technologies developed by SARP were the DEPM and the analysis of daily growth rings on larval fish otoliths. Since the mid-1990s, based to a large extent on the outcome of the SFP meeting in Costa Rica (1983) and the CEOS/IRD project, international cooperation changed the focus to the impact of climate variability on ecosystems supporting huge SFP populations. GLOBEC/SPACC furthered particularly retrospective studies wherein ecosystem histories were reconstructed by analysis of long-term time series on meteorological, oceanographic, zooplankton, fishery, paleoecological and other data. This presentation will offer a historical review of international collaboration on SPF research and highlight its big achievements.

(General Plenary 15200)

Future outlook for the science and management of small pelagic fish

Desiree Tommasi

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Small pelagic fish (SPF) play a central role in marine ecosystem, being a key trophic link between the planktonic food web and a host of predators, including many protected species. They also support some of the largest commercial fisheries in the world and are a key contributor to global food security. However, their highly variable, environmentally driven vital rates, short generation time, stock size dependent distribution and migratory behavior make them challenging to manage with traditional methods. New approaches are required to achieve emerging policy needs of SPF management such as routine assessment of the broader ecosystem impacts and tradeoffs of SPF management actions, indicators for forecasting under an increasingly variable environment, and climate risk assessment. Here innovative management approaches resulting from new advances in SPF monitoring, modeling, and prediction are presented. Such anticipatory and adaptive management approaches can help ensure future resilience of the global food supply and those ecosystems and coastal communities supported by SPF.

S1. Trophodynamic Processes

(S1 Invited 15343)

Trophic ecology of small pelagic fish in the Mediterranean Sea: Overall knowledge, recent advances and future challenges

Marta Albo-Puigserver

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Small pelagic fish (SPF) are key components of the ecosystem in the Mediterranean Sea and have a high socio-economic and cultural importance. Although fluctuations in SPF population are common, the rapid changes in growth, body condition and biomass observed in the last two decades are unprecedented. Climatic and anthropogenic impacts have been suggested as potential drivers of these changes, including the effects of bottom-up, top-down and competition processes. However, there is limited information available to corroborate these hypotheses. Fortunately, in the last decade there has been an increase in the number of studies on the trophic ecology of SPF and they have provided new insights. Here I will present an overview of recent advances in our understanding of the trophodynamics of SPF in the Mediterranean Sea, highlighting integration of data on several species and the relative value of different techniques for the study of trophic ecology (e.g. visual and DNA metabarcoding of stomach content, bulk and compound stable isotopes and fatty acid analysis) when combined with life-history traits and environmental variables. Despite significant advances, our ability to fully determine the causes behind the rapid changes in SPF are hampered by the lack of long-term monitoring and the complexity of integrating trophic data with other ecological processes at different levels of biological organization and spatial-temporal scales. Gaps in knowledge, current challenges, and future directions in combining information from different disciplines will be discussed.

(S1 Oral 15240)

SPF from different origin sharing an area limit of their latitudinal distribution: Dynamic factors facilitating habitat partitioning

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How small pelagic fish species from different zones cope to share a same habitat in seasons of reduced food availability, has scarcely been studied along the southeastern Pacific. Here we assess means by which anchoveta (*Engraulis ringens*, distributed from northern Perú and all along the Humboldt Current), southern sprat (*Sprattus fuegensis*, from South Argentina and all along the Chilean Patagonia), and common sardine (*Strangomera bentincki*, from central Chile), cope to share the northern Chilean Patagonia inshore area. Adult individuals of the three species were obtained for gut content, gill raker spines, and isotope analyses ($\delta^{15}\text{N}$, $\delta^{13}\text{C}$), along with zooplankton samples and hydrographic data, during autumn acoustics stock biomass assessments cruises (2019 to 2022) to the inner Sea of Chiloé (ISC, northern Chilean Patagonia). Results showed inter-annual differences in relative abundance of the different species among locations within the ISC. Southern sprat was the most abundant and only species present over the entire area. Differences in depth range during the daytime were also observed among species. Scarce gut content differences occurred between species co-occurring in a same location, except in areas of low zooplankton abundance. Small differences in isotopic signals and trophic positions were observed among species inter-annually and also among locations. These differences, along with gill raker measurements, were more notorious between southern sprat and common sardine. Overall, a complex and dynamic set of factors (location, depth, food, hydrographic characteristics) seem to play a role facilitating partitioning of the northern Patagonia inshore habitat in seasons of reduced food production.

(S1 Oral 15476)**Effects of climate change on the abundance of herring and sprat larvae in Kiel Fjord (Baltic Sea)**Catriona **Clemmesen**, Nicolas Ory and Felix Mittermayer

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The larval stages of clupeid fishes are vulnerable to environmental variability and changes in water temperature and food availability can effect their growth and survival and will influence their recruitment to the fisheries. Thus, we investigated the effect of changing temperatures on the abundance of larval herring (*Clupea harengus*) and larval sprat (*Sprattus sprattus*) as well as their main copepod food sources in the Kiel Fjord (Baltic Sea) from weekly to biweekly ichthyo- and zooplankton samples covering 2005 to 2021 to test the hypothesis that warmer winter temperatures lead to an earlier hatching of herring larvae with possible effects on match/mismatch situations. Sprat larvae abundances, which occur later in the season after the peak in herring larvae abundance, are analyzed to test whether changes in herring peak abundance will influence sprat abundance and food availability for sprat larvae from potential carry-over effects due to increased water temperature. Additionally larval growth rates, estimated by the determination of RNA/DNA ratios, from exemplary years will be compared to food availability and occurrence of dominant zooplankton groups for potential differences in food quality. Generalized linear models (GLM's) will be used to estimate the importance of temperature, food availability and adult spawning stock size on herring larvae abundance, to better understand effects of climate change on herring recruitment.

(S1 Oral 15474)**Spatio-temporal patterns of feeding intensity and relationship with productivity cycles in Portuguese waters**Susana Garrido and Hugo **Mendes**

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Data on feeding intensity is generally collected in specific and detailed studies focusing on a species or restricted period, associated to prey identification by visual inspection. However, to meet data collection requirements, thousands of fish are sampled each year, collected from fishing ports or during scientific surveys. A rapid method of attributing stomach fullness levels to every fish sampled provides valuable information of daily, seasonal, inter-annual and spatial variability of feeding intensity for many species. We analysed several decades of stomach data for sardine, anchovy, horse mackerel and chub mackerel off western and southern Iberian coasts. Variation in feeding behaviours can act through different metabolic and environmental variables and over time and geographic space a species can occupy wide ranges of environmental conditions, and in certain cases, spatio-temporal variation in feeding biology can have an impact on fish catchability and abundance patterns. This data is shown to provide valuable information to improve stock assessment and foodweb status and identify productivity cycles related to key environmental processes and human activities.

(S1 Oral 15315)**The pelagic species trait database, an open data resource to promote trait-based fisheries research**

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Trait-based frameworks are increasingly becoming useful techniques for describing dynamic species interactions to predict how ecological communities respond to ongoing global change. Prey ‘guilds’, based on a suite of shared traits, can simplify complex species interactions to describe similar roles in food web dynamics. To promote advances in trait-based fisheries research, we present the Pelagic Species Trait Database, a comprehensive resource synthesizing functional traits of many pelagic fish and invertebrate species in a single, open-source repository. We used literature sources, online resources and species images to collate traits for 521 pelagic species describing 1) habitat use and behavior, 2) morphology and morphometrics, 3) nutritional quality, and 4) population status information. Species in the database are primarily from the California Current Large Marine Ecosystem (CCLME) and broader NE Pacific Ocean, but also includes globally important pelagic species known to be consumed by top ocean predators from other ocean basins to promote the use of trait-based approaches in marine ecosystems and predator populations worldwide.

(S1 Oral 15514)**A global stable isotope-based trophic level comparison of small pelagic fish and other nekton across ecosystems with varying levels of productivity**

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Global and regional-scale variation in primary production and differences in community composition suggest concomitant differences in their respective energy pathways, and potential differences in responses to climate change. Here we performed a global comparison of stable isotope-based trophic levels of sardines, anchovies, mackerels and blue shark across ecosystems with varying levels of primary production and other attributes, the results of which may provide insight into drivers of ecosystem connectivity and resiliency. We used published and unpublished values of nitrogen stable isotope-based ($\delta^{15}\text{N}$) absolute trophic level (using a site-specific baseline) and relative trophic position (between nekton) to compare trophic level variability from high-production eastern boundary upwelling zones of the Benguela, Perú, Canary and California Currents, and regions of lower production including the Kuroshio Current, the Sea of Japan, and the Mediterranean and Yellow Seas. The results from this study provide a framework for incorporating stable isotopes in ecosystem comparison studies to assess trophic-level variability and anticipated responses to environmental change.

(S1 Oral 15185)**Small pelagic fish fitness relates to local environmental conditions and trophic variables**

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In recent decades, small pelagic fish (SPF) have undergone significant changes in biomass, growth and body condition in the Mediterranean Sea. However, the combination of seasonal and spatial information about changes in biological and ecological traits of SPF and their relationship with environmental variables is still missing. Here, we have investigated the seasonal patterns of fish fitness (in terms of body condition, fat content and reproduction activity) of two Mediterranean SPF, European anchovy (*Engraulis encrasicolus*) and European sardine (*Sardina pilchardus*) along a latitudinal gradient in the Northwestern Mediterranean Sea. We used non-parametric multivariate analyses and Generalized Additive Models (GAMs) to investigate which environmental and trophic variables could explain observed variations during a year. Mean fat content values, relative condition index (K_n) and gonadosomatic index (GSI) were calculated monthly. We also measured individual's stable isotope composition in muscle as a proxy of the assimilated diet. The results revealed spatial and temporal variations for both species in terms of condition, fat content and reproduction indices, as well as of stable isotopic values. GAMs showed that the variability in fitness for both species was mostly explained by environmental variables, in addition to the spatial and seasonal factors. Trophic variables also contributed to explain the variability of the indices, especially for anchovy. This study provides insights into the spatial and seasonal interplay of the fitness of two important commercial species along a latitudinal gradient, and contributes to understand the fluctuations of SPF population and recent declining trends.

(S1 Oral 15509)**Allometry of predator-prey relationships in SPF**

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Most fish species experience ontogenetic patterns in prey consumption such that as predators grow they include larger and more prey types in their diet. In piscivorous fishes the predator size-prey size pattern is generally triangular in shape, with minimum prey sizes unchanged while maximum prey sizes increase with predator sizes. Increases in mean prey size are generally driven by changes in the maximum prey size, and in turn changes in the maximum can be driven by changes in predator mouth width. Additionally, relative prey size tends to decline with predator size, suggesting a reduced trophic niche width with increasing predator size. Much less is known about the allometry of predator-prey interactions in SPF, but it is expected that they should show similar triangular patterns to piscivorous fishes although most SPF tend to be zooplanktivorous. In contrast, the few studies that have examined relative prey size allometry of larval and juvenile fishes have shown increasing trophic niche widths. Here we examine several predator-prey length datasets for selected SPF to assess predator-prey size relationships and driving factors such as mouth size and swimming speed, as well as ontogenetic patterns in trophic niche breadth. We will compare our results to those for piscivorous fishes and make inferences about the implications of these relationships for ecosystem dynamics.

(S1 Oral 15344)

Food ecology of the sympatric species of the snipefish *Macroramphosus* spp. in the Upwelling region between latitudes 26°N (Cap Bojador) and 20°50'N (Cap Blanc)Hounaida Farah Idrissi, Souad Kiffani, Kamal Mamza, Tarek Baibai and Najib Charouki.

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A series of episodes of rapid proliferation and sudden disappearance of the snipefish (*Macroramphosus* sp) on the continental shelf of the northern sub-region of the Canary Current upwelling ecosystem, has been observed for years since the fifties. The phenomenon was particularly accentuated during the seventies, the nineties and more recently during the last five years.

These species, which inhabit large parts of the pelagic ecosystem, constitute competitive organisms for the other indigenous small pelagic resources in terms of distribution areas and food and affect their dynamics. Two sympatric species are identified in the region; *Macroramphosus gracilis* and *Macroramphosus scolopax*. The dynamics and the occurrence frequency of the snipefish seems to be partly governed by its food ethology that represents a crucial factor in the stock development.

This work aims to deepen the understanding of the trophic behavior of the snipefish through an analysis of its diet in relation to the pelagic ecosystem's parameters. Stomach contents of *M. gracilis* and *M. scolopax* collected during scientific sea surveys carried out during the period 2018 – 2021 in the region Cap Blanc - Cap Boujdor are analyzed to estimate their trophic indices, in this case the preys' frequency index (Fr), the trophic level (TL) and the omnivory index (IO). The results obtained reveal a significant correlation between the range of engulfed prey through the snout of the snipefish and the size of zooplankton available and accessible on the continental shelf. The trophic strategy of the snipefish seems attesting to a case of a species responding to a marine ecosystem subject to hydrological disturbances generated by the level of the upwelling's intensity.

(S1 Oral 15234)

Seasonal and spatial variation of the trophic position of European sardine in the NW Mediterranean Sea using compound-specific stable isotope analysesJoan Giménez¹, Marta Albo-Puigserver^{1,2}, Raúl Laiz-Carrión³, Elena Lloret-Lloret¹, José María Bellido⁴, and Marta Coll¹

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The study of the trophic position (TP) of organisms is crucial to understand the trophodynamics of ecosystems within the ecosystem-based management approach. Its determination in highly exploited stocks is essential to detect whether changes in composition or abundance of planktonic communities can affect their diet and lead to stock declines. This is the case of European sardine (*Sardina pilchardus*) from the Western Mediterranean Sea, which has been highly exploited during the last decades and has shown an important population decline. To determine the TP of adult European sardine, we quantified seasonal $\delta^{15}\text{N}$ values of individual amino acids (CSIA-AA), as well as bulk $\delta^{15}\text{N}$ values in sardine muscle tissue from three different areas of the north-western Mediterranean Sea. Our results highlight that despite observing latitudinal changes in bulk nitrogen stable isotopes in our study area, the TP of sardine remains similar between different sites. These results suggest that changes in bulk nitrogen stable isotopes are mainly driven by the ecosystem nitrogen baseline variability. Furthermore, the seasonal variation in bulk stable isotope analysis is linked to differences in the baseline of the pelagic food web observed in the sources amino acids. The use of CSIA-AA allowed us to decouple the variation in the baseline from the trophic variation producing more accurate TP estimations. Without using CSIA-AA the interpretation of bulk stable isotope analysis was hampered by the lack of a proper regional baseline of the primary producers.

(S1 Oral 15468)**The big unknowns on the feeding dynamics during the early life stages of small pelagic fishes**Susana Garrido¹ and Marta **Moyano**²¹ Instituto Português Do Mar E da Atmosfera, IPMA, Lisbon, Portugal² Centre for Coastal Research, University of Agder, Kristiansand, Norway. E-mail: marta.moyano@uia.no

Early life stages of fish constitute a bottleneck for most fish populations. Finding the right food (in terms of type, size and quality) during these early stages is critical for larval survival and later recruitment success. In this work we synthesize the available literature on the diets and feeding dynamics of early life stages of small pelagic fish, including sardine species (*Sardina pilchardus*, *Sardinops sagax*, *S. melanostictus*) and anchovy species (*Engraulis encrasicolus*, *E. mordax*, *E. japonicus*, *E. ringens* and *E. anchoita*), and Atlantic herring (*Clupea harengus*). Results include studies on gut content analysis from field cruises as well as field and laboratory experiments. We also discuss the most recent knowledge gained through novel molecular tools (e.g. metabarcoding), multitrophic approaches, and in situ imaging techniques.

(S1 Oral 15225)**Understanding the vulnerability of Peruvian anchovy larvae to environmental variables**Claudia **Ofelio**¹, Anna Schukat², Dominik Auch¹, Stefanie Kurbjuweit¹, Marta Moyano³, Fanny Rioual⁴, Michael Sswat⁵, Arturo Aguirre Velarde⁶ and Myron A. Peck⁷¹ Institute of Marine Ecosystem and Fishery Science, University of Hamburg, Große Elbstraße 133, 22767 Hamburg, Germany. E-mail: claudia.ofelio@uni-hamburg.de² BreMarE – Bremen Marine Ecology, Marine Zoology, Universität Bremen (FB 02), Bremen, Germany³ Centre for Coastal Research, University of Agder, Postbox 422, 4604 Kristiansand, Norway⁴ Institut de Recherche pour le Développement (IRD), Calle Contralmirante Pedro Garezón Thomas 172, Miraflores, Lima, Peru⁵ GEOMAR Helmholtz Centre for Ocean Research Kiel, Düsternbrooker Weg 20, 24105 Kiel, Germany⁶ Laboratorio de Ecofisiología Acuática, Instituto del mar del Perú (IMARPE), Esquina Gamarra y General Valle S/N Chucuito Callao, Peru⁷ Department of Coastal Systems, Royal Netherlands Institute for Sea Research, P.O. Box 59, 1790 AB Den Burg, Texel, the Netherlands

Peruvian anchovy represents the largest single-species fishery worldwide and plays a key role connecting lower and upper trophic levels. We examined how prey characteristics and temperature influenced larval growth and development in the laboratory and field to better understand and predict how bottom-up processes regulate the stock productivity of Peruvian anchovy. In the laboratory, anchovy larvae were reared at two prey levels (ad libitum (HF) and restricted (LF)) and temperatures (14.5 and 18.5°C). Larval growth rate (GR) and otolith increment formation was examined through 30 days post-hatch. For larvae at HF and 18.5°C, mean GR was 0.65 mm d⁻¹ and ages and growth rates were well depicted in otolith microstructure. In LF at 18.5°C, mean larval GR was 0.18 mm d⁻¹ and ~43% of the daily increments were not detected (regular light microscopy). For larvae at HF and 14.5°C, mean GR was 0.23 mm d⁻¹ and ~51% of the daily increments were not detected.

During a cruise in austral summer 2018-19, zooplankton and anchovy larvae were collected at 48 stations along six transects perpendicular to shore between 8.5 and 16.0°S. In the north (8.5°S transect), *Calanidae* copepodites were most abundant (peak 173 Ind. m⁻³) and relatively small anchovy were found compared to in the south (12°S transect) where *Centropagidae* copepodites were most abundant (peak 646 Ind. m⁻³) and anchovy larvae were older and faster growing. We thoroughly discuss our laboratory and field observations on the links between prey and larval anchovy growth and development.

(S1 Oral 15445)**Fisheries metagenomics case study: Sardine and their prey**Bruno **Louro**, João Brazão, Marta Valente, Ana Marçalo and Adelino Canário

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Trophodynamics studies have identified food availability as one of the main explanatory factors for large population fluctuations in species with a R strategy, a characteristic of many small pelagic fish such as the European sardine. We propose a novel fisheries metagenomics approach to understand the food web relationships using the sardine school as the biological unit and their planktonic prey as a case study. Residual water samples from onboard sardine catch containers were sampled on arrival to the harbour (ongoing sampling from fisheries in gulf of Cadiz and Iberian west coast) for metagenomics Oxford Nanopore sequencing. The taxonomic profiling of the sequenced data was determined and compared to 16S and 18S genes database from SILVA, and the marine TARA database. The taxonomic composition of the analysed samples included phytoplankton, such as diatoms and dinoflagellates, and small crustaceans, namely copepods, decapods, and branchiopods organisms. Besides the expected sardine sequences, the analyses also indicated the presence of different fish lineages most probably of ichthyoplankton origin. With this genomic information, we aim to infer the sardine population variance and variance in their prey species, to assess trophic relationships to the sardine. This strategy presents great advantages for continuous detailed temporal and spatial monitoring of sardine (and other organisms) population dynamics, allowing us to understand in great detail their capacity to respond to the food web and environmental variability.

(S1 Oral 15358)**Egg predation by sardine and chub mackerel off the Iberia: No fish is safe**Ana **Veríssimo**^{1,2}, Pedro Fonseca³ and Susana Garrido³

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Cannibalism and intraguild predation occur in a vast number of small pelagic fish (SPF) species. Estimates of egg mortality due to cannibalism or intraguild predation vary greatly among SPF species and areas, but accurate assessment of egg and larvae consumption is highly important, because it might be a significant source of mortality. Previous studies have shown that the European sardine (*Sardina pilchardus*), followed by the Atlantic chub mackerel (*Scomber colias*), are the main predators of fish eggs among coastal pelagic fish species. Moreover, laboratory-controlled experiments have shown that adult sardines preferentially select fish eggs over other prey types. While sardine and anchovy eggs are visually identified in the stomachs due to their conspicuous characteristics, other fish eggs that are frequent and abundant in the stomachs are not identified visually. Here we present results on the molecular identification of fish eggs from stomach contents of sardine and chub mackerel from Western and Southern Iberian waters, combining Sanger sequencing of individual eggs with metabarcoding of multiple eggs on a per stomach basis, using COI and 12S markers. Results on visual and molecular fish egg identification show a very high diversity of prey for sardines and chub mackerel (total no. species: 20 and 34, respectively). The most frequent prey differed between predator species: sardines preyed predominantly on anchovy and sardine eggs depending on season, while chub mackerel showed a wider trophic diversity with the most frequent preyed eggs being sardines, anchovies, *Boops boops* and *Trachurus trachurus*.

(S1 Oral 15257)**Factors controlling reproduction of copepods in the Kuroshio region**Hiroaki **Saito**, Nao Nakagiri, Siyu Jiang and Yuichiro NishibeThe University of Tokyo, Kashiwa, Japan. E-mail: hsaito@aori.u-tokyo.ac.jp

Copepods are important prey for small pelagic fishes, especially at their early life stages. The composition and concentration of copepods influence crucially the recruitment of small pelagic fishes and the stock fluctuation. The Kuroshio region is a nursery ground of sardine and anchovy and important fishery ground in the western North Pacific. Different from other nursery grounds at upwelling regions, the Kuroshio region is characterized by oligotrophic condition with low phytoplankton biomass. Saito (2019) named the enigma of the high fisheries production in the oligotrophic Kuroshio region as *Kuroshio Paradox*. Recent studies revealed there were several nutrient supply mechanisms along the Kuroshio and suggested the new production supported the copepod production and the recruitment success of small pelagic fishes. However, it is not yet revealed the production of copepods and its control factors. It is suggested that copepods belonging to *grazing food chain* (from diatoms to *Paracalanus*, *Calanus*) and *tunicate food chain* (from pico- and nanophytoplankton to *Oncaea* through tunicates, Okazaki et al. 2019) respond in different ways to the change in nutrient regimes. Since we have limited information of the reproduction of *Oncaea*, we examined the factors controlling reproduction of *Oncaea* by counting the number of eggs in female-carrying egg sac and estimated the egg production rates. With considering the characteristics of the egg production of *Paracalanus* and *Calanus*, we will discuss the factors controlling the prey availability of small pelagic fishes in the Kuroshio region.

(S1 Oral 15454)**Hiding in plain sight: Predator avoidance behaviour of mesopelagic fish during foraging**Kjetil Gjeitsund **Thorvaldsen**, Stefan Neuenfeldt, Patrizio Mariani and J. Rasmus NielsenDTU Aqua, KGS Lyngby, Denmark. E-mail: kjgth@aqu.dtu.dk

Mesopelagic fishes are ubiquitous, ecologically important as well as a potential protein resource. However, how mesopelagic fish maneuver in their 3D environment, facilitating encounters is unknown. Individual behavior studies have been historically challenging due to previous limitations to technology. During a short period, we observed high-resolution 3d-trajectories of mesopelagic fishes within a Norwegian fjord. We acoustically tracked the swimming trajectories of juvenile *M.muelleri* and adult *M. muelleri* and *B. glaciale* separated within two distinct layers, measured swimming speed, and used a self-overlap model (ψ) to analyse the geometry of the trajectories. Our aim was to investigate, if and how the fishes were optimizing their swimming behaviour. We found that mesopelagic were moving actively within a large range between ballistic movements to convoluted movements. Some of the fishes were moving in a manner that minimized self-overlap in relation for prey search ($\psi < 0.1$), while increasing self-overlap with regards to a piscivorous predator ($\psi > 0.6$) with a hypothetical visual range of 1 m, while the large variation can possibly be explained by several factors driving the different behaviours.

(S1 Oral 15413)**A review of the thiamine status of Alaskan Chinook stocks and a note from the California Current Ecosystem**

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Thiamine plays a critical role in bodily metabolic functions and there is evidence that thiamine deficiency can affect aquatic species survival and recruitment. Thiamine deficiency causes abnormal neuromuscular signs and mortality in fish consuming diets lacking thiamine, or diets containing thiaminase, an enzyme that metabolizes thiamine. Large shifts in the dietary habits of juvenile and returning Chinook have been observed in Alaska and along the U.S. west coast following unusual ocean conditions. Thiamine may be an important link between the success of these predatory fish and their small pelagic prey base. The role of this essential nutrient is therefore an avenue of research that may have provided insight into the poor returns of Alaskan and other Chinook salmon stocks. Chinook salmon returns to western Alaska have markedly declined since the late 1990s. Most notably, Chinook salmon returns to the Yukon River have declined by approximately half of their 1982-1997 historical size. In a broader geographic scope, productivity has synchronously declined in numerous stocks across Alaska, beginning with those cohorts spawned in 2001. Poor returns have occurred despite adequate numbers of salmon escaping fisheries to spawn in previous generations. These poor returns have resulted in management actions dramatically restricting subsistence harvests, and closing or severely restricting commercial and sport fisheries. Such restrictions significantly impact Alaskan fishermen and communities that depend on Chinook salmon for subsistence needs and economic opportunities.

(S1 Oral 15470)**The role of small pelagic fish in diverse ecosystems: Information gleaned from food-web models**

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Small Pelagic Fish (SPF) are a critical mid-trophic energy transfer node between plankton and upper trophic levels within diverse marine ecosystems around the world. From the publicly available Ecopath food-web models archived within EcoBase (ecobase.ecopath.org), we have compiled the physiological rate parameters, biomasses, trophic levels, diets, and fishery catch rates that define SPF within food webs representing diverse ecosystems. From each model, several derived metrics representing SPF demand on ecosystem production (“footprint”) and contribution to total ecosystem production, pelagic and demersal fish production, seabird and mammal production, and fishery production (“reach”) were calculated using ECOTRAN techniques. ECOTRAN is a model platform that re-expresses the food web originally described as a matrix of consumer demand on each prey group (as produced by Ecopath) as a donor-driven matrix mapping the fate of production by each group among all consumers. Using this platform and classic Ecopath with Ecosim techniques, we also quantified the sensitivity of each food-web model to changes in SPF abundance. As nations recognize the importance of management and conservation of SPF for fisheries and ecosystem health, a better understanding of the role of SPF and how that role differs among ecosystems becomes crucial. Ecopath models in EcoBase and the large body of other food-web models in the literature are an invaluable resource for analyzing the role of SPF. However, two problems encountered during this analysis are the wide diversity of groups classified as SPF and the uneven representation of different regions and ecosystem types by available ecosystem models.

(S1 Oral 15192)

The role of small pelagic fishes on negative Pacific hake and salmon interactions along the Northern California Current

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The motivation of this work is to explore and quantify the spatiotemporal variability in Chinook salmon and Pacific hake diets across their CCLME distributions and the potential drivers of negative interactions between them (e.g., predation, competition, bycatch). Characterizing diets across the California Current provides insight into the proximate processes determining migration and distribution, contextualizes the consequences of a variable seascape on diet, and potentially provides a framework for developing regional boundaries within which seascape variability is reasonably coherent (biogeographic regions). Each of these species' diets generally represents the regional seascape with which they interact. For both species the top-ten taxa in the diet, estimated by weight, includes fishes and krill. Importantly, there is a common diet composition between the two species inshore at Oregon and Washington dominated by krill, Northern anchovy, smelt, Pacific herring, and Pacific sardine. In years when Pacific hake consume these fishes, they are typically inshore overlapping the distribution of salmon. Spatio-temporal analyses (e.g., VAST, NMDS) provide context for the processes linked to variability in forage assemblages along the Northern California Current, allowing us to explore the environmental drivers of diet variability and, hence, the proximate determinate of ecological interactions between salmon and hake.

(S1 Oral 15348)

Modelling diet shifts in a pelagic predator – albacore tuna – in relation to forage community composition and prey trait information across a 2005–2019 time series

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Efforts to link resource productivity and use by pelagic predators remain exploratory and limited by data. The California Current Large-Marine Ecosystem (CCLME) contains important foraging grounds for juvenile north Pacific albacore (*Thunnus alalunga*) which support productive fisheries from Baja California to British Columbia. In this system, long-term scientific surveys of pelagic forage communities and predator diets provide a key opportunity for comparative work on predator resource use and prey productivity. This paper uses multivariate community analyses to examine shifts in the composition and relative abundances of forage in albacore diets in relation to a regularly surveyed forage community across a time series from 2005–2019 in the CCLME, covering a range of oceanographic conditions and several marine heatwaves. Further, we investigate the role of species' traits influential in the predation process in explaining overlap or dissimilarity between consumed and surveyed assemblages – including habitat preference, predator avoidance behaviour, morphology and nutritional composition. Forage communities in albacore diets differed from those sampled by scientific surveys, and differences were significantly explained by species' traits through time and environmental gradients. Mesopelagic forage communities are not well sampled by surveying efforts and remain a significant knowledge gap in modelling pelagic predator resource use. Many key species including small coastal pelagic fishes and squid overlapped between the consumed and surveyed communities, and represent trait guilds useful in further modelling efforts for dietary shifts in albacore. Ultimately, we seek to explore synthetic ecological indicators of predator resource use to improve modelling of predator distributions and productivity.

(S1 Oral 15274) CANCELLED**Energy flow through marine ecosystems: Confronting transfer efficiency**

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Transfer efficiency is the proportion of energy passed between nodes in food webs. It is an emergent, unitless property that is difficult to measure, and responds dynamically to environmental and ecosystem changes. Because the consequences of changes in transfer efficiency compound through ecosystems, slight variations can have large effects on food availability for top predators. Here, we review the processes controlling transfer efficiency, approaches to estimate it, and known variations across ocean biomes. Both process-level analysis and observed macro-scale variations suggest that ecosystem-scale transfer efficiency is highly variable, impacted by fishing, and will decline with climate change. It is important that we more fully resolve the processes controlling transfer efficiency in models to effectively anticipate changes in marine ecosystems and fisheries resources.

(S1 Oral 15381)**Anthropogenic pollutants in Small Pelagic Fishes**

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Rapid economic development has led to a continuous release of anthropogenic pollutants, legacy and emerging, through diverse sources such as domestic wastewater and industry and agriculture runoff. These increasing pollutant levels and their impact on the ecology and toxicology of marine organisms has been of concern in recent decades and the presence of this complex mixture of pollutants in the environment presents a major challenge. However, adequate information on their abundance and effects is still lacking. The bioaccumulation of pollutants depends on species and geographical area. Small pelagic fishes are susceptible to accumulating chemical pollutants and microplastics because these species live in coastal areas, where pollutants are particularly high, and are planktivorous during their entire life cycle, which means their prey is of similar size, shape, and color to pollutants such as microplastics. Moreover, small pelagic fishes sustain coastal pelagic food webs and are the main prey of a large number of organisms at higher trophic levels, such as larger fish, marine birds and marine mammals, as well as being an important input for human consumption in a wide number of countries around the world. This review focuses on the accumulation of legacy and emerging pollutants, including metals, persistent organic pollutants (POPs), pharmaceuticals, rare earth elements (REEs), and microplastics in five small pelagic fish species (*Clupea harengus*, *Engraulis encrasicolus*, *Engraulis japonicas*, *Engraulis mordax* and *Sardinops sagax*) that are abundant in coastal waters.

(S1 Oral 15370)

Trophic ecology and its influence on metal transfer in the mesopelagic food-web from Norwegian Fjords and the North Sea: A multi-tracer approach using stable isotope and fatty acid analyses

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The biomass of mesopelagic fish has been estimated to be of large extent. In addition, many of the organisms are known to perform diel vertical migration. Thereby they might play a crucial role in the cycling and trophic transfer of both, essential and undesirable metals, as already shown for carbon. If they play a similarly important role for metals, this may have implications for nutrient cycling and food safety. A multi-tracer approach combining fatty acid and stable isotope analyses is applied to investigate the trophic ecology of different mesopelagic organisms, including fish. Trophic ecology is combined with metal analyses to trace the pathway, extent of transfer and bioaccumulation within and between the different trophic levels. We sampled a wide array of biota covering a broad trophic range from two different ecosystems, Norwegian fjords and North Sea, to establish the trophic relationship within and around mesopelagic fish. The samples include phytoplankton, zooplankton, macrozooplankton, cephalopods, jellyfish, mesopelagic crustaceans, mesopelagic fish, benthic fish, pelagic fish and sediment. Further, for larger specimens, samples of homogenized whole animals were analyzed to get a more accurate picture of the trophic metal transfer. This study delivers valuable information on how metals are transferred in the mesopelagic food-web and where they originate from.

(S1 Oral 15387)

Trophodynamics of mesopelagic communities elucidates their roles in food security and sustainable nutrition provision

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Mesopelagic communities are capable of providing low trophic marine resources which are known excellent sources for nutrients including long-chain n-3 fatty acids (e.g. eicosapentaenoic acid [EPA], docosahexaenoic acid [DHA]). To explore the potential in sustainable exploitation of these nutrients for food security, better understandings in the nutrient patterns and how these relate to trophodynamics among species are essential.

We collected mesopelagic organisms and basal production sources (e.g. phytoplankton) of the food web in the North Atlantic. We analysed the fatty acid profile, the concentrations of iron, iodine, and selenium in mesopelagic organisms, and related these to species, length, and region. In addition, we measured their bulk carbon ($\delta^{13}\text{C}$) and nitrogen stable isotope values ($\delta^{15}\text{N}$), and examined the iso-space and size-based trophic structure for all species to identify the origins of the nutrients and predator to prey relationships within the food web.

This study confirms that many of the mesopelagic fishes from the North Atlantic are good sources of nutrients including DHA and EPA. Our results provide important indications on the origins of these nutrients, and implications on the variation in nutrient levels among the mesopelagic species. Future studies should investigate how current and future disturbances may affect the producers (e.g. zooplankton exploitation, sea surface temperature increase), thus the mesopelagic communities, and consequently potential predators feeding on the mesopelagic species (i.e. trophic connectivity).

(S1 Oral 15209)**Acoustic detection of macrozooplankton, and its relationship with the concentration of omegas 3, obtained by the vessels of Pesquera Diamante**

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In the northern system of the Humboldt Current, the main pelagic fishery resources of industrial economic interest in Peru are anchovy (*Engraulis ringens*), horse mackerel (*Trachurus murphyi*) and mackerel (*Scomber japonicus*). The anchoveta is one of the most important species in ecological and economic terms. The high productivity of this species is mainly based on the availability of macrozooplankton.

Macrozooplankton has an important role and is one of the main components of the marine ecosystem, it is the link between low trophic levels and fish. Its importance is due to the concentration of fatty acids (omega 3), being the main food, in the anchovy diet and other resources. The dominant group of macrozooplankton in Peru are the euphasids and copepods.

The estimation of the abundance of macrozooplankton is possible through acoustic properties. This information is collected by fishing vessels during fishing operations. It allows to provide valuable information about the biological patterns and the processes that originate inside the marine ecosystem. (Greene et al., 1994; Roe et al., 1996; Wiebe et al., 1996). To analyze the acoustic data, the algorithm developed by Ballón et al. (2011), which allows extracting high-resolution information on the biomass and distribution patterns of macrozooplankton.

The general objective of this study is to analyze the abundance of macrozooplankton during fishing operations, and determine its relationship with the concentration of fatty acids (omega 3 – EPA, DHA).

For the development of this research, the Second Fishing Season 2021 has been chosen. The study area covers the entire coastline. Acoustic data was collected with commercial echo sounders ES60 and ES70 (120kHz) by our fleet. The omega 3 data has been collected by our fishing plants. With the development of the study, it is intended to use the methodology to determine the relationship between the omega 3 values and the NASC values of macrozooplankton, obtained during fishing operations.

(S1 Oral 15297)**Changes in the diet of Bay of Biscay sardines according to sampling location and age, through fatty acid composition**

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Natural populations' characteristics such as growth are strongly influenced by the quantity and quality of food, which is a considerable source of energy. Over the last decade, the size- and weight-at-age of European sardines (*Sardina pilchardus*) have decreased substantially in the Bay of Biscay (BoB), especially in fish aged 1 or 2 years, most likely due to changes in feeding conditions linked to bottom-up control. Here, we analysed the fatty acid (FA) composition in the neutral (NL) and polar (PL) lipids in sardine muscles collected across the BoB in May 2018 to establish changes in their diet with age. We found that the total FA contents in NL and PL varied with sardines' sampling locations and age. Indeed, sardines aged 1 and 2 years, living in Southern BoB, had particularly high contents in FA specific to non-diatom phytoplankton, while older sardines, living in Northern BoB, had higher total FA content and more FA specific to copepods. Therefore, prey availability across the BoB and to a lesser extent a change in sardine feeding behaviour with age were linked to feeding variations. In general, FA in NL clearly reflected finest dietary changes than FA of PL that are conserved at longer time scales. Based on the predominantly phytoplanktonic diet of the youngest sardines in spring, their decline in size-at-age could be the result of variations in primary production.

(S1 Oral 15218)**Trachurus lathami: A pelagic fish species of ecological and technological relevance currently sub exploited in the South West Atlantic (34°- 45°S)**

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In the South West Atlantic (34° - 45°S), the rough scad *Trachurus lathami* is captured as by-catch mainly in Argentine anchovy *Engraulis anchoita* and Atlantic chub mackerel *Scomber colias* fisheries, but commonly discarded as not a target of commercial fleets. The interaction with these economically important pelagic fishes and increasing abundances since the mid '90s have encouraged the integral study of the species. This work addresses recent knowledge on *T. lathami* biological (distribution, abundance, trophic ecology) and technological (nutritional parameters, quality control indices) aspects from Buenos Aires shelf (34°-39°S), El Rincon (39°-42°S), and north Patagonian waters (42°-45°S). Since 1947, *T. lathami* is recorded in Argentinean landings, being mostly destined to bait or canning industry. Rising abundances from 1998 (2000 kg h⁻¹) to 2005 (6550 kg h⁻¹) are evident from research cruises, with higher yields between 38°-41°S, being bottom temperature the main factor influencing distribution. Trophic studies revealed a zooplanktonic diet (copepods, and decapods and teleosts larvae) in every sector. Between 34°-42°S, a significant overlap (on copepods) with the diet of *S. colias* occurs. Proximate composition of trunk (edible portion) shows *T. lathami* as a semi-fat species (4-8%), with a n-3 polyunsaturated fraction (27% of total fatty acids) dominated by docosahexaenoic (DHA, 17%) and eicosapentaenoic (EPA, 6%) acids. Proteins (13%) and minerals (especially Ca and K) are also relevant. Chemical quality parameters indicate it is suitable to develop products for human consumption. Overall, results encourage commercial valorization of this sub exploited species by-catch through sustainable use, diminishing current discards.

(S1 Poster 15272) S1-P2 Poster & Talk**From West to East: Heterogeneity in the life history traits of the European sardine throughout the Mediterranean**

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In recent years, a drop in the condition and health status of the European sardine has been observed. Potential causes have been attributed to this issue, including overfishing and climate change. However, little is known about the impact of parasitisation in this small pelagic. In this study, sardine samples were obtained seasonally from five different areas along the Mediterranean, as well as from one location in the Atlantic Ocean (Southern Portugal). Ascaridoid parasites were recognized by combining naked eye and UV-press methods along the muscles and viscera. Afterwards, genetic markers were used to identify the ascaridoid larvae at species level from the fish host along the localities. The main species found along different areas was *Hysterothylacium aduncum*, but also few individuals of *Anisakis simplex* (s.s) and *A. pegreffii* were observed in the Atlantic and the Adriatic stocks sampled. The highest prevalence of *H. aduncum* larvae were observed in fish from the Atlantic, followed by the Adriatic, and the Catalan Coast. As we could obtain fresh samples from the latter, a monthly visual examination was carried out in this location.

S2. Life Cycle Closure: Advances in Process Understanding

(S2 Invited 15582)

What do we learn with Dynamic Energy Budget (DEB) models for small pelagic fish?

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Individual traits are the results of mass and energy transfers controlled by intrinsic (e.g. the species or the individual) and extrinsic factors (e.g. the environmental conditions it encountered). These traits are often key to understand how new, potentially stressful, environmental conditions may impact the dynamics of small pelagic fish (SPF) populations. However, SPF individual traits are challenging to study in the field, challenging to study experimentally, and not surprisingly, challenging to model as well. From a bioenergetic perspective, being multiple-batch spawners with indeterminate fecundity reduces for instance our ability to evaluate SPF energy budget due to the large uncertainty in their annual reproductive investment. To overcome these knowledge gaps, Dynamic Energy Budget (DEB) theory provides a conceptual and quantitative framework to model the life cycle of an organism, from the embryo to the juvenile and adult stage, according to the environmental conditions it encounters. Over the past 15 years, several studies have been focusing on developing DEB models for small pelagic fish or have been including a DEB module in their approach. This talk will address the contributions, limitations and future perspectives that this approach can provide. Two important messages will be discussed: (i) developing DEB models for small pelagic fish could foster a stronger coupling between field, experimental and modeling studies and (ii) comparing life-history traits of closely related SPF species using DEB models is a clearly difficult task worth undertaking as a community of SPF scientists.

(S2 Oral 15215)

A generalized Dynamic Energy Budget model including 3D shape changes for modeling small pelagic fish growth

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Small pelagic fish (SPF) are key components of marine ecosystems, transporting energy from the lower to the upper trophic levels and thereby influencing the dynamics of the entire ecosystem. Understanding their complex growth patterns from early life stages to adulthood is fundamental to accurately predict larval survival and predator-prey dynamics, which are influenced by individual size. However, growth models are generally unable to accurately reproduce the growth acceleration and deceleration phases observed, particularly during early life stages. Here we propose a growth model based on a Dynamic Energy Budget model (modified as in Maury, 2019 to properly account for size-dependence of maintenance) that captures deviations from pure isomorphy. It represents the fish's body as an ellipsoid and differentially allocates volumetric growth to length, height and width as a function of the distance between the current shape and characteristic stage-dependent shape attractors (expressed as width/length and height/width ratios). The resulting surface-to-volume ratios mechanistically explain the "metabolic acceleration" often invoked to explain early life growth patterns. We estimated model parameters for three important SPF species in the Benguela upwelling system, using data covering growth at all life-stages, transitions between life-stages, and reproduction. The calibrated models reproduced the observed deviations from isomorphy, with exponential length-dominated growth until metamorphosis, then a shift to height- and width-dominated growth (with a corresponding deceleration of length growth) until the adult shape is reached, and finally isomorphic (characteristic von Bertalanffy) length growth. These deviations from the usual von Bertalanffy growth model could profoundly affect our understanding of larval survival, predator-prey and ecosystem-dynamics.

(S2 Oral 15351)

Decreasing trend in size for small pelagic fish across European waters: Bioenergetic modeling to explore the underlying individual to population scale processes

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Small pelagic fish have shown a general decrease in size and body condition over the past two decades in several European regional seas. Although the underlying processes are still not well understood, recent studies point to a bottom-up control. In order to better understand how the environment impacts the main individual life history traits through phenotypic plasticity, we developed a comparative approach between two species, European anchovy and sardine, and across three regions of the Northeast Atlantic and Mediterranean Sea, namely the English Channel, the Bay of Biscay and the Gulf of Lion. We developed a bioenergetic modeling framework based on Dynamic Energy Budget theory (DEB). The first part of this work focuses on testing the bottom-up hypothesis at the individual scale. While this mechanistic framework successfully reproduced the spatial differences in size across the three studied regions, the temporal trends in the environment (temperature and zooplankton) were not strong enough to explain the drastic decrease in size through time. Through a scenario approach, we estimated the decrease in zooplankton quantity or quality required to reproduce the decrease in small pelagic size. Secondly, we assessed the effect of this bottom-up control on fish biomass and size distribution by scaling up to the population level using an existing DEB-IBM (Individual Based Model) in the Bay of Biscay. We also assessed the effects of population drivers, e.g. density-dependence, fishing and selective mortality, on population dynamics.

(S2 Oral 15203)

A new insight into feeding conditions of North Sea herring larvae: Combining field observations and physiological modelling

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Recruitment success of marine fishes is generally considered to be highly dependent on survival through the larval stage and this survival is often tightly linked to feeding success. The North Sea Autumn-spawning stock of herring (*Clupea harengus*) has had relatively poor recruitment success in the past decades. We combined novel observations of the in-situ zooplankton size-structure and larval physiological modelling to explore if prey fields between 2013 and 2019 were adequate to support larval survival and growth at two spawning grounds (Buchan/Banks in September, Downs in December). Although the mean temperature was 1.3°C lower and daylength was 4h shorter in the Downs area, the predicted minimal prey biomass required for larval growth was similar for all spawning grounds and decreased rapidly with increasing larval body size. The *in situ* prey field in the Buchan/Banks areas was not adequate to support the growth of larvae < 10 mm in length, whereas bigger larvae were able to reach their maximal temperature-dependent growth capacity. In contrast, herring larvae in the Downs in winter experienced food-deprivation at all sizes tested (from 6 to 26 mm). Our sensitivity analyses demonstrated that i) not only copepod nauplii but also other microzooplankters were important prey of young / small North Sea herring larvae, and ii) the overall starvation mortality of a cohort of herring larvae was highly dependent on the length distribution of first-feeding larvae, a trait which appears to be poorly known for the North Sea herring stock.

(S2 Oral 15263)

Fat dynamics of Atlantic herring (*Clupea harengus*) at the onset of sexual maturation: The dual-fuel powering used by maatjes herring

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Fat reserves are critically important for all stages of teleost ontogenesis. The acquisition, allocation and utilisation of fat reserves depend on the energetic demands imposed at each life-history stage. In Atlantic herring, juveniles largely rely on mesenteric fat for growth while adults primarily use muscle fat to fuel reproduction. However, fat dynamics at the onset of sexual maturation (i.e. within maturing virgin individuals) are not fully understood because maturation is a difficult life-history stage to routinely sample. Scottish and Dutch pelagic industries systematically measure proportion muscle fat content of maturing virgin herring (known commercially as 'maatjes' herring) for quality control purposes, thereby presenting a novel opportunity to study fat dynamics in sexually maturing herring. We aim to determine how the magnitude of muscle and mesenteric fat reserves changes interannually across three life-history stages of herring. We analyse two sources of data: 1) validated industry data on muscle fat content in maturing virgin and adult herring and 2) scientific data on mesenteric fat index in juvenile, maturing virgin, and adult herring. Results indicate that maturing virgin herring have higher, and more variable, muscle fat reserves than adults and larger mesenteric fat reserves than either juveniles or adults. These results illustrate the importance of both muscle and mesenteric fat reserves for sexual maturation. This dual fuelling strategy adopted by maturing virgin herring may support a successful first spawning event while also allowing remaining growth to occur. Additionally, this allocation strategy contributes to the flavour and commercial value of the maatjes herring delicacy.

(S2 Oral 15286)

Anchovy and sardine somatic condition and energy content in the North Aegean Sea (eastern Mediterranean)

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We examined the year-round changes in somatic condition and energy content of European anchovy (*Engraulis encrasicolus*) and European sardine (*Sardina pilchardus*), cooccurring species with contrasting energy allocation strategies. Sardine is a winter spawner that relies on energy reserves accumulated during the spring-summer growing season for egg production (mostly capital breeder) whereas anchovy is a summer spawner that relies primary on direct food intake (income breeder). Fish samples were collected monthly on board the commercial purse seine fleet of the North Aegean Sea. We calculated fish somatic and gonadal condition and energy density was measured with bomb calorimetry. We also tested the use of a fish fatmeter as a quick alternative to assess energy reserves by measuring % lipid content. Sardine somatic and gonadal condition showed opposite trends: from April to October, gonadal condition was low while somatic condition was high. This trend was reversed from November to March. On the contrary, anchovy somatic and gonadal condition had similar seasonal patterns, with higher values during spring-summer and lower values during the winter months. Compared to anchovy, sardine energy density and lipid content were much higher and exhibited pronounced year-round variability. The seasonal changes in energetic content of anchovy were relatively low.

(S2 Oral 15242)

Interannual variations in egg diameter of two mackerel species in the western North PacificMikio **Watai**¹, Tohya Yasuda¹, Jyunji Kinoshita¹, Mitsuo Nyuuji², Satoshi Nagai³, Akinori Takasuka⁴, Michio Yoneda⁵¹ Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Yokohama, Japan. E-mail: watai_mikio40@fra.go.jp² Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Nagasaki, Japan³ Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Yokohama, Japan⁴ Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan⁵ Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Imabari, Japan

Eggs of *Scomber japonicus* and *S. australasicus* have similar morphological features and emerge in the similar area in the western North Pacific. Although previous studies have suggested that these species could be identified by criterion value of egg diameter (1.1 mm), interannual variations in the egg diameter are still unclear. In this study, we measured the diameter of total 37,262 formalin-fixed eggs collected over 16 years (2006–2021) to describe distributions of egg diameters. To divide the annual egg diameter distribution into two groups, we applied the Gaussian Mixture Model (GMM). In addition, DNA analysis was performed on a portion of specimens to identify species. The annual egg diameter distributions were successfully divided into the two groups by fitting the GMM to the data. The DNA analysis showed that *S. australasicus* were larger than *S. japonicus* in egg diameter, suggesting that the small and large groups in the egg diameter distribution data indicated *S. japonicus* and *S. australasicus*, respectively. The annual mean egg diameters ranged from 1.009 to 1.045 mm for the small group and from 1.175 to 1.251 mm for the large group. The criterion values between the two groups (1.091–1.148 mm) were considered valid for the practical identification of mackerel eggs.

(S2 Oral 15267)

Egg size variability in Japanese sardine in the Kuroshio Current system at a multidecadal scaleRikuto **Utsugi**¹, Tomohiro Hirasawa¹, Mikio Watai², Junji Kinoshita², Mitsuo Nyuji³, Michio Yoneda⁴, Tohya Yasuda² and Akinori Takasuka¹¹ Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan. E-mail: 10191117re@gmail.com² Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Yokohama, Japan.³ Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Nagasaki, Japan.⁴ Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Imabari, Japan.

A paradigm of proportionality between spawning stock biomass and total egg production has long been a fundamental assumption in fisheries science. However, recent studies showed that this proportionality was partially distorted by intraspecific and interspecific density-dependent effects on egg production at a multidecadal scale. For Japanese sardine *Sardinops melanostictus*, a small pelagic species exhibiting a high level of population fluctuation, strong density dependence was found in total egg production per spawner individual. On the contrary, density-dependent and density-independent effects on egg quality (size) at large spatial and temporal scales have been unknown for sardine. In the present study, we examined variability of egg size in Japanese sardine based on historical sample collections of egg surveys in the Kuroshio Currents system during winter to spring seasons (sardine main spawning seasons) from 1986 to 2021. Based on the pooled data, we found that the egg size (egg diameter) was negatively related to sea surface temperature (SST). Thus, residual of egg size from the negative linear relationship of egg size to SST was used as an egg size index for comparison among different years and periods. Egg size fluctuated substantially over the high- and low-biomass periods of sardine under climate variability. Despite the complex interannual variations, we found a trend that egg size was smaller during the high-biomass periods of sardine (the late 1980s). We discuss density-dependent and density-independent effects on egg size of sardine in the Kuroshio Current system at a multidecadal scale.

(S2 Oral 15318)**Egg size variability in Japanese anchovy under the species alternations between anchovy and sardine in the Kuroshio Current system**

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A paradigm holding that spawning stock biomass and total egg production are proportional to each other has long been a fundamental assumption in fisheries science. However, recent studies showed intraspecific and interspecific density-dependent effects on egg production at a multidecadal scale. For Japanese anchovy *Engraulis japonicus*, a species exhibiting out-of-phase population oscillations with Japanese sardine *Sardinops melanostictus*, total egg production per spawner individual was sardine-density-dependent. Nonetheless, density-dependent effects on egg quality (size) have rarely been tested. Here we examined spatial and temporal variability of egg size in Japanese anchovy based on historical sample collections of egg surveys in the Kuroshio Currents system. Egg size was determined as ellipsoidal volume. First, seasonal and regional variability was examined in relation to environmental factors (sea surface temperature (SST), sea surface salinity, chlorophyll-*a* concentration, and zooplankton density) for the egg samples in representative years. Overall, egg size was smaller at lower latitudes and in summer under substantial variability (0.14–0.45 mm³). A strong negative relationship was detected between sea surface temperature (SST) and egg size. Thus, egg size was standardized by SST for interannual comparisons. Then, we examined long-term variability of egg size for the samples in winter to spring since the late 1980s. Overall, anchovy egg size tended to be smaller during the high-biomass period of sardine, although the trends were quite complex in the long term. We discuss possible factors causing egg size variability in anchovy under the species alternations between anchovy and sardine in the Kuroshio Current system.

(S2 Oral 15464)**Condition factor and Length-weight relationship for small pelagic fishes in the Atlantic Iberian coast**

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Length, Weight and their relationship of marine fish have been gained interest in the context of the ecosystem approach to fisheries and global change. Body conditions are influenced by environmental variability at seasonal and annual scale and are often used to evaluate individual growth patterns and reproductive potential at individual and population levels. Several studies on body condition have been published mainly in Bay of Biscay, English Channel and Mediterranean Sea. These studies showed a decreasing trend in body condition for Small Pelagic Species (SPF) which could impact the fishing and seafood industry sector.

In the Atlantic Iberian Area, the sources of variability in fish condition has never been accurately understood or studied. Here, we investigated the variability in body condition and its responses to environmental changes for the main SPF targeted by purse-seine fleet in the Portuguese Coast; Sardine (*Sardina pilchardus*), Anchovy (*Engraulis encrasicolus*), Chub mackerel (*Scomber colias*) and Horse Mackerel (*Trachurus trachurus*), based on 30 years of morphometric data from both Acoustics scientific surveys and market samples. To evaluate allometric growth, length-weight relationships will be established. Body condition annual and seasonal trends will be modelled taking into account the variability explained by age classes and sex. Also the relative effects of environmental factors and catch levels on the inter annual variability of body condition will be quantified. Finally multivariate relationships among all small pelagic species body condition and exogenous factors will be described to characterize the state of the population and its global environment over the 30 years.

(S2 Oral 15323)

Growth autocorrelation in small pelagic fish larvae in the Kuroshio Current system: Do early growth rates influence later growth rates?

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Johan Hjort's "critical period" hypothesis, which postulates that year class strength is determined right after the first feeding, has rarely been supported by empirical data. Instead, the current understanding holds that recruitment is determined by cumulative mortality throughout early life. Recent studies proposed a growth autocorrelation analysis using otolith daily increment width data to test the link between growth rate achieved early in life and during later stages. Based on this approach, we revisit the role of growth during early life stages in two small pelagic fish species, Japanese sardine *Sardinops melanostictus* and Japanese anchovy *Engraulis japonicus* throughout the larval stage, using a combination of published datasets of otolith increment widths. Strong growth autocorrelation was detected for both species throughout the larval stage, suggesting that early growth determines growth rate achieved during further life stage. The extent of autocorrelation became less in sardine than in anchovy in the older ages. This interspecific difference could be attributed to differences in sensitivity to environmental variability. Subsequently, we tested these trends of growth autocorrelation and interspecific differences with the samples of sardine and anchovy collected simultaneously from the coastal fishing ground in the Kii Channel. We confirmed that the results were essentially the same under the same environmental conditions. The present findings suggest that early growth rates influence later growth rates throughout the larval stage, which could reconcile the classic concept of "critical period" and the current "growth-survival" paradigm.

(S2 Oral 15251)

Growth trade-offs for spring- and autumn-hatched larvae; Results from a long-term experiment

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Atlantic herring populations differ in their spawning time, and spring and autumn spawning populations are genetically distinct. Offspring of these populations encounter seasonal variations in productivity. We conducted a crossing experiment and reared herring offspring for three years with seasonal varying light cycle starting either in spring or autumn, using two fixed temperature levels and food provided in excess. We hypothesized that longer daylengths early in life would provide an overall growth advantage compared to those experiencing this later in life due to higher size-dependent growth rates at smaller sizes. Larvae with initial spring conditions initially grew faster. However, contrary to our expectations, offspring with initial autumn conditions had caught up to similar size after one year. Our results also show that herring in higher temperatures were growing faster, even when correcting for the amount of day-degrees. After the first year, the growth trajectories were contradictory for the two temperature, while at warmer water temperatures individuals hatched in spring had a higher growth, at colder temperatures herring hatched in autumn were consistently growing better. On the other hand, the condition of herring followed the daylength with best conditions during summer and poorest during winter. This long-term experiment shows the plasticity of Atlantic herring, their ability to adapt to different environments, and their capability to scope with different trade-off situations.

(S2 Oral 15402)**Hatch earlier or late? Survival of sardine (*Sardina pilchardus*) juveniles in response to environmental and parental effects.**

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The aim of this study was to investigate maternal and environmental effects on the early survival of sardine (*Sardina pilchardus*). The hatch date distribution of young sardines (0 and 1 year old) from two year-classes recruited off the northwest Portuguese waters was determined using otolith microstructure analysis. The hatch date monthly distribution of the population was related to prevailing environmental conditions, sea surface temperature, Chlorophyll - a, and to female reproductive activity and condition using cross-correlations. Growth during larval and early juvenile stages was back-calculated from the width of otolith increments and compared between hatch-date seasons using Generalized Additive Mixed Models. Preliminary results indicated a spread hatch distribution consistent with a long spawning season reported for the species. Two main sub-cohorts per year, one hatched in the main spawning season and other one hatched outside the main spawning season were suggested. Survivors of the juveniles hatched outside the main spawning season appeared to descend from bigger and fatter females than those originating from the main spawning season. Moreover, they showed faster larval growth associated with higher temperature and enhanced productivity. Survivorship was related to larval and early juvenile growth and the hypothesis of growth-mortality was discussed.

(S2 Oral 15375)**Population structure, age and growth of sardine (*Sardina pilchardus*, Walbaum, 1792) in an upwelling environment**

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Information on the biological parameters of exploited fish stocks facilitates the objective assessment and management of these living resources. For instance, the sardine (*Sardina pilchardus*) is an overexploited small pelagic fish in northwest Africa. It is a key species of the Canaries current large marine ecosystem (CCLME) of the Atlantic Ocean due to its socioeconomic importance, as well as being a good indicator of fish stressors. Here, we analyzed the age and growth parameters of sardines (n = 3 951) in the Exclusive Economic Zone of northern Senegal. Maximum body size was 26 cm total length (TL). A growth performance index of 1.89 was determined, with this being the first record for this region. Sardines had higher asymptotic length (27.9 cm TL) and age in northern Senegal (Atlantic Ocean, seasonal upwelling) compared to Morocco (Atlantic Ocean, permanent upwelling) and the Mediterranean Sea. The asymptotic length found in Senegal was also higher than in other part of CCLME (e.g. Morocco) and Mediterranean Sea (e.g. Greece, Italy and Spain) 50 years ago. This difference might be attributed to differences in the pelagic habitat, environmental factors, and fishing pressure. In conclusion, this study provides new insights towards establishing management measures, especially in data poor countries.

Keywords: Clupeid, Size spectra, Small pelagic, Fish stock management, West Africa.

(S2 Oral 15281)**Using environmental and biological satellite data to understand recruitment in two small pelagic fish species in Atlanto-Iberian waters (European sardine and European anchovy)**Afonso **Ferreira**¹, Susana Garrido^{1,2}, José L. Costa¹, Ana Teles-Machado^{2,3}, Vanda Brotas^{1,4} and Ana C. Brito^{1,4}¹ MARE – Marine and Environmental Sciences Centre, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal. E-mail: ambferreira@fc.ul.pt² IPMA - Portuguese Institute for the Sea and Atmosphere – IPMA, Lisboa, Portugal³ IDL – Instituto Dom Luiz, Portuguese Institute for the Sea and Atmosphere, Lisboa, Portugal⁴ Departamento de Biologia Vegetal, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal

Whether it is due to anthropogenic, environmental, or biological factors, small pelagic fish populations' recruitment is often characterized by high variability. The European sardine (*Sardina pilchardus*) and the European anchovy (*Engraulis encrasicolus*) are the most socioeconomically important small pelagic fish species in Atlanto-Iberian waters. Overall, these species exhibit contrasting trends in the past 20 years: sardine abundance and recruitment have decreased, while anchovy abundance and recruitment has increased. Nevertheless, there is still much to be understood on the factors that drive this variability and trends. Therefore, the main objective of this work is to contribute to a better understanding of how sardine and anchovy recruitment in two major recruitment hotspots in Iberian Atlantic waters (NW Portugal and Gulf of Cádiz) is influenced by changes in regional environmental conditions. A complete satellite dataset including atmospheric, oceanographic and biological variables (1998-2020) was used along with *in situ* recruitment estimates from yearly sampling surveys within ICES Division 9.a. Preliminary results will be presented and discussed. This work is expected to provide valuable knowledge for the understanding and sustainable management of both anchovy and sardine stocks in Atlanto-Iberian waters, especially under the threat of climate change.

(S2 Oral 15457)**Environmental effects on sardine (*Sardina pilchardus*, Walbaum 1792) larvae somatic and otolith growth off Iberian Peninsula**Sónia **Antunes**¹, Ana Moreno¹, Isabel Meneses¹, João Pastor¹ and Susana Garrido¹

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Understand recruitment variability of small pelagic fishes is essential in the study of dynamics of the populations. Recruitment success drivers are sought to the environmental conditions such as temperature and food availability influencing survival of the early stages of development. In the present study, we analyse condition somatic and otolith growth of *Sardina pilchardus* larvae off the Portuguese coast at the beginning and in the end of the spawning season, in distinct environmental conditions. At the beginning of spawning season (late autumn) larvae were less abundant and found mainly in the vicinity of land flushed freshwater restricted to the more productive and colder water masses. In spring, when high chlorophyll-a concentrations extend to a wider area, sardine larval stages were more homogeneous all over the surveyed area. The number of increments on the otolith and the width of the last three increments were determined together with DNA content on the same individual larva to study growth. Generalized additive models were used to examine the influence of environmental variables on larvae distribution and individual growth rates. Further investigation shall proceed to evaluate the use of environmental drivers to predict recruitment strength of this small pelagic fish of great economic importance.

(S2 Oral 15244)

Caught in the middle: Bottom-up and top-down processes impacting recruitment in Western-Baltic herring

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Understanding the drivers of fluctuations in the recruitment of fish populations remains challenging because of the potentially complex interplay and non-stationarity of bottom-up and top-down processes impacting year-class strength within and among populations. Gaining a mechanistic understanding of these recruitment drivers requires a holistic approach, combining field surveys, laboratory experiments and biophysical modelling. We use Western Baltic Spring-Spawning herring (*Clupea harengus*) to highlight the complexity of recruitment drivers (and their interactions) and to exemplify the power of this holistic approach. Since the early 2000s, concerns about low recruitment have promoted a substantial amount of research on this stock. Our literature synthesis suggests that the major drivers are habitat compression of the spawning beds (mainly due to eutrophication and coastal modification) and warming, which indirectly leads to changes in spawning phenology, prey abundance and predator pressure. Other factors include increased intensity of extreme climate events (e.g. heatwaves, storms) and new predators in the system. Four main knowledge gaps are identified related to i) life-cycle migration and habitat use, ii) population structure and demographics, iii) life-stage specific impact of multiple stressors, and iv) predator-prey interactions. Specific research topics within these areas are proposed, according to its priority to support sustainable management of the stock. Given the history of severe impacts due to warming, eutrophication and altered precipitation in the region, changes in this western Baltic herring stock could be a harbinger of the consequences of changing environmental drivers to the recruitment of small pelagic fishes in other coastal areas in the world.

(S2 Oral 15392)

Worldwide appraisal of knowledge gaps in the space usage of SPF highlights across stock uncertainties and research priorities

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Knowledge of the spatial extent of life cycle components of SPF stocks is key to understanding population changes and managing fish stocks. The spatial extent of different life stages and ecologically relevant processes (e.g., reproduction) is temporally dynamic and responds to environmental, genetic, and demographic constraints. As a joint effort of the ICES/PICES Working Group on Small Pelagic Fish, we reviewed the knowledge gaps in within-stock spatial variability of key life cycle processes of SPF worldwide. In a semi-systematic review, we screened approx. 1700 SCI papers and databases on official SPF surveys and stock assessment reports, collecting information from 79 managed or commercially relevant datasets (39 officially managed stocks) from 14 species from 10 Large marine ecosystems and 36 coastal ecoregions. Only 27% of the datasets covered the known or suspected stock distribution in at least one life-cycle variable (Adults: feeding area, spawning migration, feeding migration, overwintering migration, spawning area, presence/biomass. Juveniles: presence/biomass, nursery area. Larvae: larval routes). Beyond the expected higher spatial information available for some Eastern Boundary Upwelling Systems and long-managed stocks, we identified many stock- and

stage-process-specific information gaps. Some gaps were related to information quality, whereas others were related to the deficient definition of the stock identity or spatial biases in data. Key information on SPF spatial variability could be extracted from existing surveys, particularly acoustics, but this is not straightforward for the scientific community. In this talk, we review the main consequences of identified gaps and discuss a series of priority research/monitoring actions for improvement.

(S2 Oral 15447)

Uncertainties derived from the hydrodynamic forcing of a Lagrangian IBM for the Iberian Atlantic sardine

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The Iberian sardine is a traditional fishery in western Iberia that has experienced a strong variability in recruitment in the last decades, remaining low after peaking in 2000, 2004 and 2019. Environmental variability during the early life stages (ELS) of fish has been recognized to be key for recruitment, and models that consider the interplay of the physical and biological factors involved have become established tools. In this contribution we present a Lagrangian modelling system for the ELS (eggs and larvae) of the Iberian Atlantic sardine, focusing on the influence of the underlying hydrodynamic model on the transport of particles released at different locations and periods associated with the spawning area and time. Lagrangian Individual-Based Models forced with 3D hydrodynamic models are frequently used to study the advection and dispersion of the planktonic stages of small pelagic fish, considering also their biological behaviour (growth, vertical migration patterns, etc). Different layers of complexity can be added to these models to build an end to end model, like using the results of a biogeochemical model to feed the larvae stages in the calculation of growth and mortality, adding fish movement, etc. However, the uncertainties related with the hydrodynamic models have an enormous influence on the model results. We will highlight here the importance of model aspects such as resolution and the parametrization of different physical processes in the results obtained from the Lagrangian model, discussing these effects in the context of sardine recruitment and connectivity of the Iberian Atlantic stock.

(S2 Oral 15302)**Fourteen months of continuous acoustic measurements: The behaviour and biomass of small pelagic fish in one of the passageways to the Wadden Sea revealed**Margot A.M. **Maathuis**^{1,2}, Bram Couperus¹, Jan Jaap Poos^{1,2}, Ingrid Tulp¹ and Serdar Sakinan¹¹ Wageningen Marine Research, IJmuiden, The Netherlands. E-mail: margot.maathuis@wur.nl² Wageningen University and Research, Wageningen, The Netherlands

Shallow marine estuaries are important coastal habitats for early life stages of many fish species. Because acoustic measurements with research vessels is often difficult in shallow areas, small pelagic fish (SPF) received little research attention in contrast to demersal fish. The Wadden Sea in Europe is such a large shallow marine estuary where the habitat use and connectivity of SPF between the North- and the Wadden Sea is poorly understood. To study the SPF dynamics of the area, we deployed an autonomous Simrad WBAT echo-sounder with a 38 kHz split beam and a 200 kHz single beam transducer, pinging vertically upwards, combined with a water current profiler. This setup provided measurements every 90 minutes of the entire water column for over 14 months. The high temporal resolution of the acoustic data enabled resolving dynamics of SPF in relation to tidal flow, water temperature and the temporal rhythms therein, from hourly to seasonal scales. Acoustically measured fish school dynamics such as size, compactness and vertical distributions as well as the swimming directions and speed of the single targets were used to infer behavioural aspects. Furthermore, studying biomass over time provided insight in large scale patterns in this area, such as migration. In this talk, the insight obtained on SPF behaviour and the connectivity between the two waterbodies will be presented, enhancing our understanding of the function of the Wadden Sea ecosystem in the life cycle of various small pelagic fish species.

(S2 Oral 15239)**Machine learning and otolith isoscapes to evaluate decadal trends in contingent mixing of Atlantic mackerel**Kohma **Arai**¹, Martin Castonguay², Vyacheslav Lyubchich¹, David H. Secor¹¹ Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, MD, USA; E-mail: karai@umces.edu² Fisheries and Oceans Canada, Institut Maurice-Lamontagne, Mont-Joli, QC, Canada

Small pelagic fishes exhibit spatial structure that confer population stability through asynchronous responses of population sub-components to ecosystem conditions. Complex spatial structure has been reported for the Atlantic mackerel (*Scomber scombrus*), a dominant pelagic schooling species in the Northwest Atlantic comprised of northern and southern components that have distinct spawning sites off Canada (northern contingent) and US (southern contingent), and seasonally overlap in US fished regions. Assessment and management of this population can therefore be sensitive to levels of mixing between contingents, which remain unknown. Here, we used otolith stable isotopes ($\delta^{13}\text{C}/\delta^{18}\text{O}$) and applied a novel machine learning classifier to assess contingent mixing within US waters over the past five decades (1975–2019). We also generated isotope landscapes (“isoscapes”) across the Northwest Atlantic based on SST and salinity datasets to assess biogeochemical mechanisms that give rise to spatial variations in otolith stable isotopes. Classification of adult fish showed that northern contingent mixing was prevalent within US waters during the past two decades (2000–2019), providing an important subsidy to the US fishery. Further, the 1973 year-class was composed largely of the northern contingent, which could suggest that the northern contingent historically supported the intensive foreign fleet fishery within US waters. The distinct otolith stable isotope values between the two contingents broadly matched the strong latitudinal variation in predicted Northwest Atlantic otolith oxygen isoscape. Information on contingent composition could further help develop spatially explicit stock assessment models for the Northwest Atlantic mackerel population to provide advice designed to conserve both contingents.

(S2 Oral 15214)

First evidence of precise homing behavior to natal spawning habitats in Atlantic herring (*Clupea harengus*) within the concept of a metapopulation

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Fish mass spawning events are a fascinating phenomenon worldwide. This behavior is considered to promote reproduction in established and appropriate spawning areas. However, spawning site fidelity despite drastic coastal modification poses an often underestimated risk for population resilience. The Atlantic herring (*Clupea harengus*) is a key component of marine food webs and a vital species for the commercial fishery. Current theory suggests that Atlantic herring is composed of meta-populations with high gene flow maintained by straying individuals adopted by passing schools. Striving for testing this theory, we used natural chemical tags in herring otoliths to reveal to what extent herring returns to natal spawning grounds and conversely quantifying the relative amount of straying individuals. Additionally, we investigated the genetic population structure of an independent sample set. Both approaches, revealed similar ratios where about 56-73 % of spawning individuals returned to their natal spawning sites. To our knowledge, these are the first empirical results testing the current “adopted migrant” hypothesis, indicating a high level of plasticity in homing behavior but also provide evidence that a major proportion of the population returned to the particular sites of their origin. With respect to increasing anthropogenic pressures, these findings demonstrate the essential function of coastal habitats as spawning grounds and highlight the need for sensitive coastal zone management strategies.

(S2 Oral 15453)

Spatial dynamics of *Sardinella lemuru* in central Philippine waters inferred from georeferenced sardine catches

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Sardines make up the bulk of the small pelagic fish in the Philippines. Among all the sardines found in the country, *Sardinella lemuru* is the most abundant, widespread, and commercially important. This study tracked fishing vessels targeting sardines in various areas within the Visayan Sea and Ticao Pass/San Bernardino Strait/Samar Sea. Insights into the movement patterns of *S. lemuru* and the relative roles of size- and age-related biological processes (e.g., feeding, ontogenetic changes, and reproduction), as well as the physical cues for movement, were drawn from the spatio-temporal distribution of biological characteristics (size-distribution, maturity stage, GSI) of georeferenced catches and remotely-sensed environmental data, respectively. The peak spawning of *S. lemuru* occurs during the northeast monsoon (October-December) in Ticao Pass timed with the increase in primary productivity in the area. The Bali sardine appear to disperse from and to this main spawning area after and before peak spawning: mature fish starts to appear in October/November while juveniles appear to disperse southwards into the Samar Sea as early as March/April. Dispersal of juveniles to the adjacent Visayan Sea is also possible, wherein *S. lemuru* catches are all immature and start only to appear in the catches during the southwest monsoon months (June-September). Mature fish in this area were only observed in deep adjacent waters e.g., mouth of Tañon Strait. Results of the study show a certain degree of connectivity between the stocks in the Visayan Sea and San Bernardino strait area wherein, some of the newly-hatched individuals during the spawning season from Ticao Pass are drifted to the Visayan Sea. These juveniles grow and develop in the Visayan Sea and then start to migrate to the deeper portions to spawn.

(S2 Poster 15481) Poster to Oral**Variable Anchovy dispersion patterns in the Iberian Current System**Ana **Teles-Machado**^{1,2} and Susana Garrido^{1,3}¹ Instituto Português do Mar e da Atmosfera (IPMA), Portugal. E-mail: ana.machado@ipma.pt² Instituto Dom Luiz (IDL), Lisboa, Portugal³ MARE, Lisboa, Portugal

Sardine has been the dominant small pelagic fish species off western Iberia for as long as data is recorded. In the last decade, anchovy whose abundance was residual before, has increased sharply and has an increasing trend. Anchovy recruitment has strong interannual variability, that is thought to be controlled, in large part, by the environmental conditions experienced by their early life stages (eggs and larvae). A set of different models are used to simulate the dispersion and survival of anchovy early life stages in the Iberian Current System. A high-resolution simulation (IBv2.0) with the hydrodynamic model ROMS provides the oceanographic fields that are used as background for the lagrangian simulations performed with the model Parcels coupled to an Individual Based Model (IBM) of anchovy eggs and larvae. The IBM is developed based on the relation between vital rates and key oceanographic factors, available in the literature and obtained through laboratory-controlled experimentation, it simulates the different early life stages of anchovy considering the effects of temperature and food availability on growth, survival, and development throughout ontogeny. The lagrangian/IBM models are used to study the dispersal of anchovy eggs and larvae during the anchovy spawning season off Iberian waters and the dispersal patterns are obtained for different years with contrasting recruitment strength, allowing to evaluate a possible connectivity between ICES subdivisions 9a South and West components, and the Cantabrian Sea during the egg and larval stage.

S3. Understanding Population- and Ecosystem-level Shifts: From Seasonal Timing to Tipping Points

(S3 Invited 15197)

Match-mismatch, trophic interactions and climate change

Joël M. **Durant**

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Climate change is affecting the trophic interactions on which we base our understanding of marine systems. The consequence is that we *must get used to a world where our hard acquired knowledge on ecosystem and trophic interactions is no longer accurate, or at least not reliably so*. In other words, the models we have developed based on long-term time series may not be reliable. We know that the physiology and the mechanisms it is driving are changing at the slower pace than climate. Building mechanistic models could thus be useful to explore the future consequences of climate change.

In fish, the major driver of population dynamics is the recruitment of individuals through the reproduction process (i.e., production and survival through the early life stages). Several mechanistic hypotheses have been set forth to explain changes in fish production in relation to phenology, which is well documented to be strongly affected by climate change. One of the most well-known is the “match-mismatch” hypothesis (MMH) elaborated by David Cushing. A question is if the MMH is a useful tool to understand animal recruitment in the context of global climate change. I will present some of the latest development from my group on match-mismatch models (role of abundance and spatial distribution...) and the role of MMH for population dynamics. Finally, I will address the value of the MMH to make projection and I will highlight some of the limitation of our current understanding of MMH.

(S3 Oral 15196)

Impacts of the match-mismatch hypothesis across three trophic levels – A case study in the North Sea

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Sustainable fishery practices require accurate predictions of fish recruitment – the abundance of the earliest age of fish entering a fishery. A key driver of recruitment is linked to understanding the impact of predator-prey dynamics fish early life stages has on their survival at later stages, as in the Match-Mismatch Hypothesis (MMH). MMH states that predator survival depends on the match (or mismatch) between the timings of predator feeding and prey availability.

The main objective of this study is to understand how the predator-prey spatio-temporal overlap at different levels of the food chain explain the variation in pelagic fish populations. We calculate the predator-prey overlap between each pair of three trophic levels in the North Sea: we use data from the International Bottom Trawl Survey from ICES.org for the herring (*Clupea harengus*) larvae; and the Continuous Plankton Recorder from Marine Biological Association for zooplankton (*Temora longicornis*, *Oithona* sp., *Pseudocalanus* spp, and *Acartia* spp) and the phytoplankton colour index from 1982 to 2017. We assessed whether the predator-prey overlap explains herring recruitment, there is a spatial pattern in the predator-prey overlap, and there is a spatial pattern in the relationship between the overlap and recruitment.

We demonstrate the applicability of the predator-prey overlap metric across the trophic chain and region tested, and, more importantly, its predictive power of 18 % with the possibility of predicting recruitment 3 years ahead of spawning, thereby substantially increasing the forecast horizon for identifying major recruitment variations.

(S3 Oral 15407)

Phenological variation in forage fishes and trophic consequences for top predators in the Gulf of MaineMichelle D. **Staudinger**^{1,2}, Dan Pendleton³, Keenan Yakola⁴ and Adrian Jordaan²¹ USGS, Northeast Climate Adaptation Science Center, UMass Amherst, Amherst, MA, USA. E-mail: mstaudinger@usgs.gov² Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, MA, USA³ Anderson Cabot Center for Ocean Life, New England Aquarium, Boston, MA, USA⁴ Department of Fisheries, Wildlife, & Conservation Sciences, Oregon State University, Corvallis, OR, USA

In the Northwest Atlantic Ocean, the Gulf of Maine (GOM) ecosystem exhibits strong seasonal production cycles that support a range of small pelagic fish and highly migratory top predators. Seabirds, large whales and predatory fishes have historically coincided critical life history events such as reproduction and foraging to align with seasonal environmental conditions and peaks in prey abundance. However, the region has experienced rapid climate change over recent decades with observed and projected alterations of the intensity and timing of warming and cooling cycles. This study synthesizes and compares model outputs quantifying phenological variation and the underlying climatic drivers across multiple small pelagic fish in the GOM ecosystem. Temporal changes in migration patterns and occurrence in predator diets are compared for alewife (*Alosa pseudoharengus*), hake (*Urophycis* sp.), sand lance (*Ammodytes* sp.), Atlantic herring (*Clupea harengus*), and butterfish (*Peprilus triacanthus*) relative to top predators including Common terns (*Sterna hirundo*) and humpback whales (*Megaptera novaeangliae*). Overall, phenological responses and associated climate drivers varied widely among species in terms of the strength, directionality, and spatial coherence observed, with some shifts in the opposite direction expected and at a lag with seasonal environmental conditions. Non-uniformity in responses across the community will be discussed in the context of trophic mismatches and reproductive success of top predators. Results also demonstrate how non-traditional data sources and monitoring programs such as citizen science networks and using predators as sentinels can provide new insights into ecosystem change due to climate and other anthropogenic influences.

(S3 Oral 15321) **CANCELLED**~~**Winter effects on the feeding phenology of early herring (*Clupea harengus*) larvae in a major Western Baltic Sea nursery area**~~Annegret **Finke**^{1,2}, Lina Livdane^{1,2}, Paul Kotterba¹, Patrick Polte¹ and Christian Möllmann²¹ Thünen Institute of Baltic Sea Fisheries, Rostock, Germany. E-Mail: annegret.finke@thuenen.de² University of Hamburg, Hamburg, Germany

~~Spring spawning herring (*Clupea harengus*) is a central component of the food web in the Western Baltic Sea and supports a large over-regional fishery. However, in recent years herring recruitment decreased drastically, causing the decline of the overall stock biomass. Herring early life stages growing up in shallow coastal waters, are particularly exposed to multiple anthropogenic stressors including eutrophication and fast changing temperature regimes. Earlier research found the reproductive timing of herring highly temperature dependent, with spawning and hatching occurring much earlier after mild winters. Because larval prey phenology might not be shifting synchronously during the season, an early onset of herring reproduction potentially results in a prey-mismatch for herring larvae. Based on weekly ichthyoplankton and mesozooplankton sampling in a major nursery area, we conducted larval gape size measurements to identify suitable prey items available for early and late hatching larvae during years with high and low winter temperatures. Our results show generally lower zooplankton abundance after a mild winter with densities of copepod nauplii, the major prey source for small larvae, ranging below common thresholds for larval survival. Food limitation became particularly evident at larval peak abundance early in the season. Consequently, the amount of 20 mm sized larvae, a proxy for larval production, was significantly lower after a mild winter. Our study hence reveals a shift in the feeding phenology of Western Baltic herring larvae, indicating that further climate change effects will increase a temporal predator-prey mismatch and consequently increase early life stage mortality through food limitation.~~

(S3 Oral 15335) CANCELLED**Seasonal variability in Northern anchovy (*Engraulis mordax*) in Monterey Bay, California**M. Elisabeth **Henderson**, Jacoby Baker, and Francisco Chavez

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Within the California Current System (CCS) pelagic forage fish function as critical links between upwelling driven productivity and upper trophic levels (seabirds, mammals, piscivorous fish). Historically, Northern anchovy (*Engraulis mordax*) and Pacific sardine (*Sardinops sagax*) have alternately dominated the region with anchovy being the current regime. Generally, these shifts have been linked to multidecadal climate change oscillations with cool anchovy regimes and warm sardine regimes. Recent warm years with anchovy dominance indicate that this dynamic is more nuanced. The exact mechanisms behind the alternating regimes are likely driven by species-specific physiological needs (i.e., temperature, prey) which are also non-stationary with respect to life history. While Northern anchovy have been known to spawn throughout the year, most spawning occurs in the spring season. Northern anchovy are considered adaptive feeders as they can switch between filtering and selective feeding depending on prey size, type, and density. We started a weekly survey in Monterey Bay, California collecting adult anchovy and metabarcoding their stomach contents with the intent to identify diet shifts throughout the year. Stomach contents were individually metabarcoded using three genetic markers targeting an array of taxa: CO1 (invertebrates), 12S (bony fishes), and 18S (zooplankton). Preliminary results support that anchovy diet in the bay is seasonally influenced and that environmental dynamics (i.e., upwelling intensity) may be driving this signal. This work aims to help identify the mechanistic drivers of Northern anchovy population dynamics in the CCS.

(S3 Oral 15473)**How accurately and precisely can fisheries-independent surveys assess phenological change?**Rebecca G. **Asch**¹, Lorenzo Ciannelli², Lauren Rogers³ and Andrew Thompson⁴¹ Department of Biology, East Carolina University, Greenville, NC, USA. E-mail: aschr16@ecu.edu.² College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA³ Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, Seattle, WA, USA⁴ Southwest Fisheries Science Center, National Oceanic and Atmospheric Administration, San Diego, CA, USA

Fisheries-independent surveys are key for diagnosing changes in spatiotemporal fish distribution although most surveys were designed to estimate biomass for stock assessments. While surveys can evaluate changing migration and spawning phenology, estimated changes could be biased by survey timing or frequency. We address this using Monte Carlo simulations to model changes in seasonal occurrence of early life history stages (ELHS) of Pacific sardine, northern anchovy, and Pacific herring with data from surveys spanning Baja California to Gulf of Alaska. Phenological shifts of 1-15 days decade⁻¹ were simulated and resulting distributions were sampled mimicking existing survey designs. Changes in the start, midpoint, centroid, end, and duration of ELHS occurrence were estimated using data from simulated sampling and model-based approaches, and compared with the operating model of fish seasonality. Initial results assess larval sardine and anchovy observations from California Cooperative Ocean Fisheries Investigations (CalCOFI). Sardine has a narrower window of seasonal occurrence and increased monthly variance compared to anchovy. Changes in sardine could be accurately assessed across all phenology measures, but with half the precision as anchovy. Estimated changes were most precise for the seasonal centroid and least precise for season duration. Biases in detecting phenological changes occurred among anchovy when assessing rapid change over extended periods. Following a switch from monthly to seasonal sampling after 1984, seasonal changes in the ELHS centroid could be assessed with reasonable, albeit reduced, accuracy; however, other phenology measures could not be computed. Overall, detectability of phenological change may be more species specific than previously recognized.

(S3 Oral 15446)**Using models of thermal time to observe the unobserved and identify meaningful change**Anna B. **Neuheimer** and A. Sofia A. Ferreira

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Exploring temporal variation in life history phenology is challenged by both a lack of consistent observations of relevant stages, and the complexity in identifying when variations in time indicate meaningful change (e.g. evidence of regime shifts or adaptive change). Here, we offer thermal time models as tools to address these challenges, and discuss the particular utility of such models for exploring phenological changes in small pelagic fish (e.g., herring).

Thermal time models use information about temperature-dependent development rates to define thermal constants that can be used to estimate the timing of unobserved stages (e.g., larval fish and their prey). These thermal constants can also be used as a novel strategy to tease apart expected environmental responses from potential tipping points (e.g., adaptive change, regime shifts), and to make forecasts of life-history phenology in a changing climate.

We demonstrate the utility of thermal time models to explain life history phenology by examining changes in Pacific herring (*Clupea pallasii*) spawning time over 65 years. Finally, we discuss the assumptions and limitations of thermal time models including how to identifying appropriate stages, species and systems, and model options in the face of limited information on physiological processes (data-poor species).

(S3 Oral 15229)**Evaluating factors affecting the distribution and timing of Pacific Herring spawn in British Columbia**Christopher N. **Rooper**¹, Jennifer L. Boldt¹, Jaclyn Cleary¹, Angelica Peña², Matthew Thompson¹ and Matthew Grinnell¹

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Pacific herring (*Clupea pallasii*) are an important forage fish in marine ecosystems, as well as being a target of commercial, recreational and subsistence fisheries. Herring spawn in nearshore areas in the late winter to early spring. Factors influencing the timing and distribution of spawning are not well known. This study modeled the spatial and temporal distribution of spawning for five Pacific herring stocks in British Columbia. Random forest modeling showed that the timing of spawning in each year was mostly influenced by the number of daylight hours and the cumulative degree days of temperature above 5 °C. Oceanographic variables, such as the salinity at the time of spawning and the change in temperature and salinity in the weeks prior to spawning also played a role in moderating spawn timing. The spatial distribution of spawning tended to occur at consistent areas over time. The realized spawning distribution was determined largely by the biomass of herring and the location of transects relative to the center of spawning. Environmental factors at the locations of spawning played a much smaller role (< 2% of the variability). There was no evidence for spatial expansion of spawning distribution in years of high biomass. Since Pacific herring recruitment has been linked to their ability to match spawn timing to the timing of the spring bloom and prey for larval stages, warming temperatures (and increased rates of egg development) in the future may push spawning earlier in the calendar year increasing the probability of mismatch with prey availability.

(S3 Oral 15326)**Comparison of the space-time dynamics of clupeiformes fish size-structured habitats in Atlantic (Bay of Biscay) and Mediterranean (Gulf of Lion) French shelf seas**Mathieu **Doray**¹, Pierre Petitgas², Martin Huret³, and Tarek Hattab⁴¹ DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, Institut Agro, Nantes, France. E-mail: mathieu.doray@ifremer.fr² Ifremer, Nantes, France³ DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, Institut Agro, Brest, France⁴ MARBEC, Univ Montpellier, Ifremer, IRD, CNRS, Sète, France

A consistent decrease in the size of clupeiformes (anchovy, sardine and sprat) has been reported since the early 2000s in two contrasted French shelf seas: the Gulf of Lion (GoL) in the Mediterranean and the Bay of Biscay (BoB) in the Atlantic. We characterized the spatial distributions and temporal dynamics of the size-structured communities of clupeiformes in both regions, to determine: i) if the decrease in size is associated with a spatial reshuffling of communities, ii) if it occurred in response to a local or rather a large scale environmental change, and iii) which environmental factors shaped the fish spatial distributions. Acoustic survey data were gridded to derive long-term time-series of spatially-explicit data. Multivariate space-time ordination methodologies were then applied to characterize space-time patterns in biomass-at-length and hydrology. Fish habitats were spatially consistent in time in both regions but structured differently, depending on local environmental gradients, related to chlorophyll-a and water column stratification in the GoL and sea bottom temperature in the BoB. The decrease in fish body size was caused by local changes in species: size compositions. Large anchovy and sardine were replaced by small sprat in coastal and mid shelf habitats in the GoL. In the BoB, large sardine near sea surface in North Western areas progressively disappeared, while small clupeiforms increased near the seabed in Southern and adjacent coastal areas. Though conditions structuring spatial distributions were different between regions, the two systems showed a replacement of large fishes by small fishes, not necessarily belonging to the same species.

(S3 Oral 15184)**Arctic sand lance range expansion in the Arctic – Analyses of spatial distribution related to oceanographic and physical habitat**Matthew R. **Baker**¹, Alex De Robertis², Robert Levine³, Daniel Cooper² and Edward Farley⁴¹ North Pacific Research Board, Anchorage, AK, USA. E-mail: Matthew.Baker@nprb.org² NOAA, Alaska Fisheries Science Center, Seattle, WA, USA³ University of Washington, School of Oceanography Seattle, WA, USA⁴ NOAA, Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau AK, USA

Sand lance or sand eels (*Ammodytes spp.*) are small planktivorous forage fishes that play an integral role in pelagic ecosystems in the Northern Hemisphere. Arctic sand lance (*Ammodytes hexapterus*) is prevalent in the Sea of Okhotsk, northern Bering Sea, Chukchi Sea, and Beaufort Sea. Few studies have focused on this species despite its critical role in energy transfer and trophic food webs. Recent surveys note an increase in the prevalence of this species in concert with reduced ice extent. We use comprehensive surveys conducted throughout the Chukchi Sea shelf over multiple years to evaluate spatial distribution and abundance relative to oceanographic variables in the water column and sediment composition on the seafloor. We applied logistic regression and generalized additive models to investigate presence and relative abundance of Arctic sand lance and to evaluate spatial distribution, as a function of oceanographic and benthic environmental variables. Arctic sand lance presence was influenced by surface water mass and positively associated with Alaskan Coastal Water. Relative abundance was positively associated with high surface temperature, low surface salinity, and coarser substrates. Evidence is mounting that the distributions of many boreal species are expanding on the margins of the Arctic. Our research report Arctic sand lance at the highest latitude on record, at the shelf break of the Arctic Basin. Results provide insight on how oceanographic and benthic habitat may influence the expansion of boreal species into Arctic marine habitats.

(S3 Oral 15320)**The influence of El Niño–Southern Oscillation (ENSO) events on the catches trends and habitat shifting of three swimming crabs in the Taiwan Strait**Muhamad **Naimullah**¹ and Kuo-Wei Lan^{1,2}¹ Department of Environmental Biology Fisheries Science, National Taiwan Ocean University, 2 Pei-Ning Rd., Keelung 20224, Taiwan, Republic of China. E-mail: kwlan@mail.ntou.edu.tw² Center of Excellence for Oceans, National Taiwan Ocean University, 2 Pei-Ning Rd., Keelung 20224, Taiwan

Adult swimming crabs are known to travel long distances using the last two segments of last pair make paddle-like movements, which results in having higher mobility than most other crustaceans. However, climate change is having a considerable impact across marine ecosystems, latitudes, and trophic levels, including swimming crabs. The purpose of this study was to understand the influence of El Niño–Southern Oscillation (ENSO) events on catch rates (CRs) trends and habitat shifts of three swimming crab species using a weighted habitat suitability index (HSI) model based on logbooks and voyage data from Taiwanese crab vessels (2013–2019) with the addition of environmental variables in the Taiwan Strait (TS). The CRs for *Charybdis feriatus* and *Portunus pelagicus* were higher (>7.0 and >8.0 kg/h) during La Niña events, whereas for *Portunus sanguinolentus*, the CRs were higher during La Niña and El Niño events (>8.0 kg/h) than in normal events during autumn; the major fishing season. However, the habitat suitability area for *C. feriatus* and *P. pelagicus* were shifting to the southern TS during normal and La Niña events, whereas *P. sanguinolentus* habitat areas were not affected by the ENSO events. Moreover, the low CRs for *C. feriatus* and *P. pelagicus* during normal and El Niño events and the low CR for *P. sanguinolentus* in normal events during autumn were highly consistent with substantial shrinkage of HSI. Our findings suggest that ENSO events strongly affected the catch and habitat suitability of *C. feriatus*, *P. pelagicus*, and *P. sanguinolentus* in the TS.

(S3 Oral 15253)**Spatial dynamics of the Pacific sardine (*Sardinops sagax*) in the California Current system: Connecting seasonal, interannual and long-term movements**Ruben **Rodriguez-Sanchez**, Hector Villalobos and Sofia Ortega-Garcia

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To understand how Pacific sardine (PS) movements on minor spatial-temporal (S-T) scales interrelate with large-scale, long-term changes in PS abundance, we reconstructed their seasonal migrations during the different stages of the interannual ENSO variability over the course of the last warming period (1980-1997), when the bulk of PS biomass and the center of distribution of the population moved northward of the California Current (CC). Based on analyses of relative abundance indices, a continuous change in the seasonal patterns was identified. The location, importance, and number of seasonal geographic groupings shifted northwards of the CC, with less important groups remaining in the south, suggesting a dynamic evolution of suitable habitats (SH) for recruitment. In the long term, when environmental conditions are favorable for PS to achieve the greatest latitudinal expansion and population size, even though PS could take advantage of SH in the large domain of a heterogeneous ecosystem, two distant but transient geographic groups are favored. Potential climatic drivers of S-T sardine shifts are not discussed. The absence/inconsistency of long-term data is problematic to identifying climate drivers in the extension of CC. Thus, a fundamental assumption underlying the S-T changes is the implicit association with seasonal-scale, and interannual changes in temperature associated with the different stages of ENSO events, and the regime shift toward warm ocean conditions that began in the mid-1970s. The spatial dynamics described here may help us think about the latitudinal reduction of SH in a cooling climate scenario, which would force the PS to shift southward.

(S3 Oral 15435)**Northward range expansion of Bay of Biscay anchovy due to increased temperature envelope and population increase**

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European anchovy is a widely distributed, warm-water species which has been postulated to be a climate change “winner”. The northern-most stock resides in the Bay of Biscay, where, in the south, it typically spawns during spring. An apparent regime shift in the mid-1990s saw the sudden appearance and subsequent increase of anchovy numbers in the North Sea and English Channel. This northward range expansion was found to be driven by improved survival of fish from remnant, genetically distinct, local summer spawning populations in the southern North Sea, rather than a northward migration of Bay of Biscay anchovy. No evidence of anchovy spawning was found in the English Channel and increases in anchovy observed here were due to seasonal migrations of North Sea adults and juveniles to overwinter. During the autumn of 2019 and 2020, for the first time, post-larval anchovy were found in the English Channel during an annual acoustic-trawl survey, several hundreds of kilometres from nearest known spawning grounds. Identifying the origin of these anchovy is important for management purposes and to understand the mechanisms driving populations at the limit of their distribution. This study examines the processes behind these observations, by combining acoustic and egg data from spring and autumn surveys in the Bay of Biscay and western English Channel with hydrodynamic modelling and genetics. We hypothesise that due to population growth and an improved temperature window, spawning activity in the Bay of Biscay expanded in space and time, improving larval survival during transport into the Channel area.

(S3 Oral 15332)**Density-dependence in the spatial distribution of Bay of Biscay anchovy**

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Research survey series provide knowledge on the spatial distribution of fish stocks across a large range of spatial scales as well as on their variability over the years. Among other drivers, density dependence is a major source of variation in spatial distributions. Here we explored how different ranges of local densities varied in their spatial occupation with global population biomass using a non-linear geostatistical approach. The spatial distribution in each year was discretized with a set of thresholds defining classes of values, which applied to all years. We explored area-abundance relationships for different thresholds and analysed which classes of values were affected when population biomass varied. This extends the usual approach, which considers positive area only. The different classes of densities were related to 3-dimensionnal school features derived from Simrad ME70 multibeam echosounder. A schematics is proposed to characterize how local schooling behaviour changes with global population biomass and how this translates across scales into area-abundance relationships for classes of density values. The work is performed on anchovy in the Bay of Biscay using the acoustic survey series Pelgas, where dramatic fluctuations in population biomass occurred from 2000 to 2021. When population biomass increases, low density values occupy a larger spatial range and high values progressively appear in particular areas and at random within these areas. Examples of school aggregation structures at different densities illustrate the effects of global density on schooling features. A spatial model accounting for density-dependent effects is proposed.

(S3 Oral 15416)**The school trap hypothesis predicts the distribution patterns and environmental preferences of Pacific Sardine in the California Current following the 2010s collapse**Juan P. **Zwolinski**^{1,2} and David A. Demer²¹ University of California Santa Cruz, Santa Cruz, CA, USA. E-mail: juan.zwolinski@noaa.gov² NOAA Southwest Fisheries Science Center, La Jolla, CA, USA

The oceanographic environment has been proposed as the main driver of boom and bust events in small pelagic species. However, for the Pacific sardine off the West Coast of the US, neither the mechanisms driving their dynamics nor the environmental proxies for their productivity are fully understood. For example, sardine's resurgence in the 1990s lagged the environmental regime-shift by approximately ten years, suggesting other mechanisms may be modulating the stock's productivity. One hypothesis proposes that the schooling nature of small pelagic fishes forces individuals of a depleted stock to join schools of other more abundant fishes. This "school trap" effect results in the depleted species compromising its own habits in exchange for the protection that the mixed-species schools offer. In this presentation, we show that the school trap hypothesis predicts virtually every distributional pattern observed from the currently depleted stock of Pacific Sardine, including interrupted migrations and shifts in their environmental preferences. The changes in behavior promoted by sardine schooling predominantly with the far more abundant Jack Mackerel may explain why the stock failed to respond positively to favorable oceanographic conditions that have occurred off the West Coast in the last five years.

(S3 Oral 15312)**Incorporating ecosystem information into science advice – A case study for Haida Gwaii Pacific Herring**Jennifer L. **Boldt**, Christopher N. Rooper and Jaclyn ClearyFisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada. E-mail: Jennifer.Boldt@dfo-mpo.gc.ca

Globally, national policies for managing fisheries increasingly require that environmental and biological conditions are taken into account when assessing stock status. Since 2000, the Haida Gwaii Pacific Herring (HG herring) stock has been in a low biomass state, with many years of low productivity, and, since 1980, natural mortality has increased. The root cause of increasing natural mortality rates has not been identified or linked to environmental variables, but it is thought to reflect underlying changes in the ecosystem. Environmental variables have not been included in previous assessments for this stock; however, time varying natural mortality is estimated within the assessment model. These mortality rates are used in the development of operating models for management strategy evaluation (MSE). The goal of this study was to create a place for and develop pertinent ecosystem information that could be incorporated into science advice to fisheries management as part of the HG herring assessment. The objectives of this study were to: 1) identify environmental and biological pressures hypothesized to mechanistically affect HG herring at different life history stages; 2) identify indicators of those pressures; 3) summarize the status and trends of pressures and potential herring response indicators; 4) examine pressure-response relationships; and 5) develop a standardized format for this information, including best approaches for communicating risk to managers. The primary lesson from this study is that an understanding of mechanistically-linked pressure-response relationships results in key indicators can be useful in short-term, single-species decision making, and also inform closed loop simulations and future/multi-year decision-making.

(S3 Oral 15480)**A recent decline in zooplankton density in the inshore Western Baltic Sea**Lina **Livdane**^{1,2}, Annegret Finke^{1,2}, Gesche Winkler³, and Patrick Polte¹¹ Thünen Institute of Baltic Sea Fisheries, Rostock, Germany. E-Mail: lina.livdane@thuenen.de² University of Hamburg, Hamburg, Germany³ Institut des Sciences de la Mer, Université du Québec à Rimouski, Québec, Canada

Current data demonstrate strong effects of climate change on plankton communities that can result in a decline of energy availability for higher trophic levels, as warming conditions lead zooplankton communities to shift towards lower densities, small sized zooplankton species, and individuals decrease in body size. We hypothesize that the observed substantial change in the plankton community in the Greifswald Bay has been induced by increasing temperatures. We describe the mesozooplankton community and test the relationship between zooplankton state and sea surface temperature, in addition to other pressure variables, using zooplankton data series sampled weekly in early spring through summer 2008-2020. Greifswald Bay is the major spawning area for western Baltic spring spawning herring (*Clupea harengus*), therefore, we additionally discuss potential consequences of the decline of zooplankton density on herring recruitment that has been at its historic low since 2015.

(S3 Oral 15296)**Kuroshio induced sardine stock fluctuation: From the Kuroshio dynamics to the food availability**Haruka **Nishikawa**¹, Hiroyuki Tsujino², Shiro Nishikawa¹, Hideyuki Nakano², Toru Sugiyama¹ and Yoichi Ishikawa¹¹ Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan. E-mail: harukan@jamstec.go.jp² Meteorological Research Institute, Tsukuba, Japan

Japanese sardine (*Sardinops melanostictus*) is known to undergo drastic and multi-decadal stock fluctuations. The largest landing of sardine in Japan was 4.49 million tons in 1988; in contrast, the catch in recent years has been < 1% of this amount. This drastic stock fluctuation was attributed to the survival rate variation during the early life stage. One of the main nursery grounds of larvae is near Kuroshio axis. In that region, long term environmental data suggested that the winter mixed layer was shallow during the low stock period. The analysis of ocean dynamics model revealed that the Kuroshio velocity controls the winter mixed layer depth. Since the zooplankton density generally depends on the winter mixed layer depth and sardine larvae feed on the zooplankton, it is possible that the Kuroshio velocity affects the sardine stock fluctuation. However, food availability has been a missing link. Due to the strong advection, it is difficult to develop a multi-decadal scale physical-biological coupled model in the Kuroshio system. Recently, Meteorological Research Institute succeeded to develop a physical-biological coupled model that reproduced the zooplankton density in the Kuroshio region from 1970s. By using this epoch-making dataset, we can confirm that the zooplankton density decreased when the stock collapse occurred. Collecting the previous studies and recent findings, this talk will illustrate the mechanism how the Kuroshio dynamics affected the sardine stock through a bottom-up control.

(S3 Oral 15307)

Do global ocean events modulate early survival through the larval retention-advection of anchoveta (*Engraulis ringens*) in the southern Humboldt system?Sebastián I. **Vásquez**^{1,2}, Andrés Ospina-Álvarez³, Cristian Salas^{1,4}, Marcos Arteaga^{1,5} and Aquiles Sepúlveda¹¹ Instituto de Investigación Pesquera, Talcahuano, Chile. E-mail: svasquez@inpesca.cl² Programa de Doctorado en Oceanografía, Universidad de Concepción, Concepción, Chile³ Mediterranean Institute for Advanced Studies (IMEDEA-CSIC/UIB), Balearic Islands, Spain⁴ Departamento de Geofísica, Universidad de Concepción, Concepción, Chile⁵ Programa de Doctorado en Ciencias, mención en Manejo de Recursos Acuáticos Renovables, Universidad de Concepción, Concepción, Chile

Small pelagic fishes in the southern Humboldt system constitute about half of the total pelagic landings, of which almost one-third is *E. ringens*. Anchoveta abundance depends mainly on the early life stage survival, which are highly susceptible to environmental variability. Here, we developed a biophysical model of the early life history of anchoveta by coupling an individual-based offline model with an interannual regional oceanic modeling system (ROMS). We used this model to investigate the main factors driving variability in egg and larval dispersal and survival in central-southern Chile with emphasis on variability forced by El Niño-Southern Oscillation (ENSO) cycle during the period 1994-2016. Precisely, for each spawning season, individuals were released from different spawning areas along the coast and tracked for a period until they reached 20 mm in length (planktonic phase). Individuals that remained in coastal areas were considered recruited. Simulation results show the importance of the southern spawning zone (38°-40°S) where lower wind stress, the larger continental shelf, and freshwater discharge from rivers prevent offshore advection. We show that larval spatial trajectories differ drastically from year-to-year following ENSO related wind-driven transport changes. During El Niño the probability of larval success increased by more than 30% (31% - 72%), while during La Niña it decreased by less than 10% (3% - 7%). We discuss ENSO modulation of offshore transport in central-southern Chile and the implications for anchoveta recruitment. Finally, we demonstrate that the biophysical simulations are coherent with existing recruitment proxies and therefore open new possibilities for fisheries management.

(S3 Oral 15374)

Bonga shad (*Ethmalosa fimbriata*) stock-recruitment relationship in an upwelling environmentBocar Sabaly **Baldé**¹, Saliou Faye¹, Patrice Brehmer^{1,2,3}¹ Institut Sénégalais de Recherche Agricole, ISRA, Centre de Recherche Océanographique de Dakar-Thiaroye, CRODT, BP 2241, Centre PRH, Dakar, Sénégal. E-mail: bocarbalde2005@hotmail.com² IRD, Univ Brest, CNRS, Ifremer, UMR Lemar, BP 1386, Dakar, Sénégal³ Commission Sous Régionale des Pêches, CSRP, Secrétariat Permanent de la CSRP, BP 25485, Dakar-Fann, Sénégal

In order to improve small pelagic management and conservation decisions, it is necessary to discern the underlying relationship between the stock and small pelagic recruitment, a relationship that is influenced by environmental conditions and fishing mortality. Environmental data from 1996 to 2013 (sea surface temperature (SST), coastal upwelling index (CUI), North Atlantic Oscillation (NAO), ENSO multivariate index (MEI) and Atlantic Multidecadal Oscillation (AMO)), spawning stock biomass (SSB) and recruitment of *E. fimbriata* in Southern Senegal were used. Annually, recruitment was higher between 1996 and 2001 than in other years (maximum in 1999). Spawning Stock Biomass was highest in 2001 and lowest in 2013. The relationship between recruitment and SSB of *E. fimbriata* (for the period 1996–2013) was best described by linear function. The correlation between recruitment and SSB shows that a decrease in recruitment leads to low SSB while successful recruitment allows to obtain a significant SSB. Our approach predicts respective influences of the SSB environment in the recruitment process of *E. fimbriata*, especially with regard to stock collapse and recovery.

Keywords: Culicidae; modelling; stock–recruitment; West Africa; Climate change

(S3 Oral 15306)**Environmental factors affecting anchovy *Engraulis anchoita* reproductive potential in the northern Argentinean Continental Shelf**Georgina D Cepeda ^{1,2}, Ezequiel Leonarduzzi ¹, Brenda **Temperoni** ^{1,2}, Marcelo Pájaro ¹, and Paula Orlando ¹¹ Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata, Buenos Aires, Argentina. E-mail: gcepeda@inidep.edu.ar² Instituto de Investigaciones Marinas y Costeras (IIMyC, UNMdP-CONICET) Mar del Plata, Buenos Aires, Argentina.

Reproductive parameters and condition of multiple spawners fish can vary temporarily, driven by fluctuations in the environmental features. The relationship between the reproductive potential of Argentine anchovy *Engraulis anchoita*, based on annual egg production (P_o), relative batch fecundity (F_r), and spawning frequency (S), and some environmental drivers: prey density and sea surface temperature in the northern Argentinean Continental Shelf (NACS, 34°-41°S) during the spawning season between 1995 to 2008 were examined. The mean abundance of the key copepod species, gathered in three size categories (small: <1 mm, medium: 1-2 mm and large: >2 mm), was selected as a quantitative indicator of prey density. Since *E. anchoita* adults select prey larger than 1 mm, a close relationship between the reproductive parameters and the larger prey-sized fractions was expected. P_o and F_r were higher from 1995 to 2003, sharply diminishing afterwards, following the 1-2 mm and >2 mm copepods decreasing trend. Both P_o and F_r showed positive and almost significant relationship with medium (P_o $\rho=0.58$; F_r $\rho=0.57$; $p=0.1$ in both cases) and large-sized (P_o $\rho=0.62$ $p=0.08$; F_r $\rho=0.58$; $p=0.1$) copepods. Strikingly, from 2003 to the latest years of the time-series the smallest copepods significantly increased ($\rho=0.7$; $p=0.04$). None variable was significant related with sea surface temperature. Results give insight about the bottom-up effect of the feeding environment upon anchovy reproductive potential in the NACS. Despite the shortness of our series, this approach is promising for further exploring the biotic mechanisms setting year class strength in advance of recruitment to the fishery.

(S3 also Poster 15379)**Habitat suitability modelling and impact of environmental factors on the distribution of *Sprattus sprattus* in the Adriatic Sea**Antonio **Palermينو**^{1,2}, Andrea De Felice¹, Giovanni Canduci¹, Ilaria Biagiotti¹, Ilaria Costantini¹, Michele Centurelli¹, Samuele Menicucci¹ and Iole Leonori¹¹ CNR-National Research Council, IRBIM-Institute for Marine Biological Resources and Biotechnologies, Largo Fiera della Pesca, 1 - 60125 Ancona, Italy² ALMA MATER STUDIORUM, Università di Bologna, Via Zamboni, 33 - 40126 Bologna, Italy. E-mail: antonio.palermينو@irbim.cnr.it

Sprattus sprattus is a plankton feeder which plays an important ecological role in contributing to the transfer of energy from lower to higher trophic levels. It is also considered as a cold favouring species, therefore increasing sea temperature caused by climate change could affect its spatial distribution and potentially drive to an alteration of the pelagic ecosystem. For this reason, a better investigation of sprat habitat distribution could be an important tool to monitor the status of Adriatic ecosystem. In the current study, habitat suitability model was applied to fishery-independent data collected from 2013 to 2021 during the MEDiterranean International Acoustic Survey (MEDIAS) in the western side of the Adriatic Sea, along with satellite environmental variables and bathymetry data, using Generalized Additive Models (GAMs). A set of nine environmental predictors was selected and the resulting best model was employed to produce maps of the probability of occurrence of *S. sprattus* for the entire basin considering two periods: early summer and late summer. Sea surface temperature and chlorophyll concentration resulted as the main explanatory variables in predicting the potential habitat, followed by bottom depth and dissolved oxygen. The species is mostly located in the northern Adriatic Sea, with occasional presence along the Italian coast up to the Gulf of Manfredonia due to the chlorophyll concentration. The maps reveal a slight west-east shift in the persistency area (probability of occurrence >0.5) between the two period, from the Italian shore to offshore and northern Croatian waters.

S4. Responses to Climate Variability and Change at Decadal to Centennial Time Scales

(S4 Invited 15208)

Long-term dynamics in marine ecosystems in the northwest Pacific—A lesson from sedimentary records

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In the recent decade, sedimentary records from Beppu Bay, Oita Prefecture, Japan, have shown the potential to be used as a powerful archive of millennial records of fish population dynamics in the Northwest Pacific. Paleoceanographic knowledge on the long-term dynamics of small pelagic fishes that cannot be invisible in the observational data has begun to be obtained. What kind of periodicity prevails over the past several millennia? Did the ecological regime shift from Japanese sardine to Japanese anchovy and back continue over the period? What drove these long-term dynamics? What factors determine the maximum population of Japanese sardines, which was recorded as the world's largest fish catch in the 1980s? For these questions, there have been great expectations for paleoceanographic research based on sedimentary archives. Paleoceanographic research has also begun to take on new challenges in line with advances in environmental DNA technology. The detection of species-specific DNA in sediments has opened up the possibility of reconstructing long-term dynamics in various fish species, zooplankton, and other organisms that were previously invisible only by fish scales. This paper will show the long-term population dynamics of Japanese sardines and Japanese anchovies based on fossil fish scales in the Beppu Bay core samples and the potential linkages between their dynamics and paleoclimate changes. Furthermore, the possibility of capturing the long-term population dynamics of diverse fish and zooplankton species as well as other marine organisms based on the DNA in sediments of Beppu Bay and Lake Biwa, central Japan, will be discussed.

(S4 Oral 15190)

Using ancient DNA to uncover the history of Atlantic herring exploitation and its impact on herring evolution and demography

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Atlantic herring has long been an important commercial species in Europe, facilitating the development of modern commercial trade networks and the rise of some European states. Today, the herring industry is still crucial for the economic welfare of many communities, with the Norwegian spring-spawning herring industry ranking as the 4th largest fishery in the world. Despite their large numbers, herring stocks have collapsed multiple times in the 20th century due to overexploitation, prompting extensive research into modern herring ecology. Yet, the long-term impact the industry has had on this species is still poorly understood. We have sequenced whole-genome ancient DNA from Atlantic herring bones found in archaeological sites around Europe, providing the first comprehensive ancient genomic database for Atlantic herring. Using these data, we analyze the advent of the herring industry in Europe. We use novel software programs to explore trade route development over time and model past demography to assess the potential anthropogenic and climate impacts on this species. We incorporate archaeological, ecological, and historical evidence to contextualize the genomic analysis. Finally, we place these results in the context of 20th century stock collapses and current management policies for various herring stocks in the Atlantic Ocean and Baltic Sea.

(S4 Oral 15361)

Interdecadal variabilities in growth and temperature histories of young jack mackerel off western Kyushu: 1960-70s vs. 2000-10sMotomitsu **Takahashi**¹, Tomihiko Higuchi², Shin-ichi Ito², Kotaro Shirai² and Mari Yoda¹¹ Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Nagasaki, Japan. E-mail: takahamt@fra.affrc.go.jp² Atmosphere and Ocean Research Institute, the University of Tokyo, Chiba, Japan

Using the archived otoliths, we examined interdecadal variabilities in growth and temperature histories of young Japanese jack mackerel *Trachurus japonicus* caught during summer to fall off the western Kyushu based on the otolith growth increment and microchemical analyses between 1960-70s and 2000-10s. Hatch dates of the young *T. japonicus* in 2000-10s ranged from February to April while those in 1960-70s from March to May, being consistent with previous studies showing that maturation index was highest in April in 1950-60s and in March in 2000-10s. Sequences in oxygen stable isotope ratio from the nucleus to the margin of otoliths showed that temperature experienced during the larval and early juvenile stages in 2000-10s was lower than that in 1960-70s while no significant difference was found during the later juvenile stage, suggesting that earlier hatching period results in the lower temperature experienced in 2000-10s than in 1960-70s. Otolith growth increment width during the late larval and early juvenile stages negatively correlated with the oxygen stable isotope ratio, indicating that temperature positively affects growth rate during the stages. Otolith radius from the nucleus to given ages, representing somatic growth trajectory, was smaller during the early juvenile stage in 2000-10s than in 1960-70s, while no significant difference was found during the later juvenile stage. Thus, our results demonstrated young *T. japonicus* with earlier hatching period in 2000-10s resulted in the lower experienced temperature during the larval and early juvenile stages and consequently the slower growth rate than did in 1960-70s off the western Kyushu.

(S4 Oral 15260)

Historical variability of fish body weight around JapanLin **Zhen** and Shin-ichi Ito

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Ocean has been warming over the last 100 years and is projected to continue to warm in the future. Rising water temperatures are expected to reduce the somatic size of aquatic organisms, an outcome known as the “temperature-size rule” (TSR). However, whether and to what extent TSR works in the nature remains unclear. The western North Pacific has a wide range of seawater temperatures, many fish species habitat and Japan is one of the most data-rich countries regarding fisheries data. We mined age-specific weight data for 26 populations of 16 fish species around Japan and picked up 6 fish populations from 1978 to 2018 and 17 fish populations from 1995/1997 to 2018. We investigated the weight variability of the two datasets. Dynamic factor analysis (DFA) is a multivariate time series analysis to estimate the general trends underlying short non-stationary time series. We defined fish life stages as juvenile, maturing, and mature stages by their maturity rate and their normalized wet weight anomaly for the 3 stages was used for DFA. As a result, the common trends derived by DFA revealed the strong influence of large biomass fluctuation of Japanese sardine until 1990 instead of sea surface temperature in the first time series (1978-2018). The influence of Pacific decadal oscillation (PDO) in the second time series (1995/1997-2018) was recognized in all life stages, instead of the influence of global warming. These results indicate TSR has not simply appeared in the western North Pacific.

(S4 Oral 15317) CANCELLED**Non-stationary effects of multiple drivers on the dynamics of Japanese sardine (*Sardinops melanostictus*)**

Shuyang **Ma**^{1,2}, Caihong Fu³, Jianchao Li^{1,2}, Peng Sun^{1,2}, Yang Liu^{1,2}, Zhenjiang Ye^{1,2}, Yoshiro Watanabe^{1,4} and Yongjun Tian^{1,2}

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Non-stationary driver-response relationships are increasingly being recognized by scientists, underlining that a paradigm shift out of conventional stationary relationships is crucial. Japanese sardine (*Sardinops melanostictus*) is a typical small pelagic fish in the northwestern Pacific with considerable fluctuations in productivity, bring about great economic and ecological concerns. Numerous studies support that the population dynamics of Japanese sardine is an integrated process affected by multiple density-dependent, fishing, and climatic drivers. However, little has hitherto been done to incorporate the non-stationary effects of multiple drivers, impeding progresses in understanding the population dynamics and in developing management strategies. In this study, we adopted variable coefficients generalized additive models to reveal the non-stationary effects of density dependence, fishing pressure, and climatic conditions on the population dynamics of Japanese sardine. Results suggest that the dynamics of Japanese sardine from 1976 to 2018 could be divided into four periods: the 1980s when suitable climatic conditions from strong Siberian High pressure system sustained high abundance; the 1990s when negative density-dependent effects and degrading climatic conditions due to temperature increase led to population collapse; the 2000s when negative triple effects, particularly high fishing pressure, restricted the population increase; and the 2010s when favorable climatic conditions with re-strengthening Siberian High pressure system companied by low fishing pressure contributed to the population recovery. The study highlights that precise identifications of population status and climatic conditions are helpful to achieve good trade-offs between resource exploitation and protection, and to facilitate ecosystem-based management for Japanese sardine fisheries.

(S4 Oral 15292)**Contrasting life-history responses to climate variability in eastern and western North Pacific sardine populations**

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Massive populations of sardines inhabit both the western and eastern boundaries of the world's subtropical ocean basins, supporting both commercial fisheries and populations of marine predators. Sardine populations in the western and eastern boundary current systems have responded oppositely to decadal scale anomalies in ocean temperature, but the mechanism for differing variability has remained unclear. Here, based on otolith microstructure and high-resolution stable isotope analyses, we found that habitat temperature, early life growth rates, energy expenditure, metabolically optimal temperature and, most importantly, the relationship between growth rate and temperature were remarkably different between the two populations in the western and eastern North Pacific. Varying metabolic response to environmental changes partly explained the contrasting growth responses. Consistent differences in the life-history traits were observed between subpopulations in the western and eastern boundary current systems around South Africa. These growth and survival characteristics can facilitate the contrasting responses of sardine populations to climate change.

(S4 Oral 15191)**Changes in the reproductive tactics of the anchoveta (*Engraulis ringens*) as compensation or adaptation to environmental variability?**Carola **Hernández-Santoro**^{1,2}, Úrsula Cifuentes¹, Mauricio F. Landaeta³ and José María Bellido⁴¹ Instituto de Fomento Pesquero (IFOP), Blanco 839, Valparaíso, Chile. E-mail: carola.hernandez@ifop.cl² Programa de Doctorado en ciencias del mar, Universidad de Alicante, Spain³ Laboratorio de Ictioplancton (LABITI), Facultad de Ciencias del Mar y de Recursos Naturales, Universidad de Valparaíso, Viña del Mar, Chile⁴ Centro Oceanográfico de Murcia, Instituto Español de Oceanografía (IEO-CSIC), San Pedro del Pinatar, Spain

Significant declines in biomass, landings and changes in the size structure of anchoveta (*Engraulis ringens*) have been observed in recent decades, particularly in northern Chile. In the present work, the reproductive activity of anchoveta between 1997-2019 was analyzed, evaluating the influence of spawning biomass and environmental variability in the proportion of mature. For this, the condition of the body and the weight of the females during the main and secondary spawning and the previous environmental condition were studied, using satellite SST, abundance of chlorophyll and the upwelling index. The results show that the higher proportion of mature individuals between 12.0 and 13.5 cm, is associated with the decrease of larger specimens with more than 50% of deviation explained for both spawning periods. In addition, a positive relationship of the SST of the Niño34 region stands out, explaining around 5%, while the spawning biomass (SSB) presented a negative relationship in maturation, mainly in Arica and Iquique, in Antofagasta these variables do not contribute to the explanation. Individuals between 12.0 and 13.5 cm showed in the main spawning, a poor condition ($K_n < 1$) before 2007, later the condition improves except in Antofagasta between 2009 and 2013. In the secondary period, this group presented a poor somatic condition, highlighting a positive trend until 2009 in Arica and Iquique, while in Antofagasta until 2003. The specimens with sizes > 16.5 cm, presented a poor condition ($K_n < 1$) throughout the analyzed period, in both spawning periods.

(S4 Oral 15394)**Marine heatwaves and availability of sardinella to coastal fisheries: The case of Angola, 1994-2015**Filomena **Vaz Velho**¹, Marek Ostrowski², Paulo Coelho¹, Virgilio Estevão¹, Founi Mesmin Avo³ and Mathieu Rouault³¹ Instituto Nacional de Investigação Pesqueira e Marinha, Luanda, Angola. E-mail: menavelho@gmail.com² Oceanography and Climate, Institute of Marine Research, Bergen, Norway³ Nansen-Tutu Centre for Marine Environmental Research, Department of Oceanography, University of Cape Town, Cape Town, South Africa

Sardinella fish off Angola constitutes about 80% of the total fish landed and 75% of animal protein in the diet of the coastal population. The all-year habitat of Angolan sardinella is in the region of remotely forced, windless upwelling, located north of 13 S. During austral summers, in synchrony with the seasonal poleward warm water intrusions, sardinella migrates south towards the Angola-Benguela Frontal region (ABF). However, the recent signals from fisheries indicate that the spawning and recruitment habitat may have expanded into the ABF. The ABF is a climatic hotspot in the southeastern Atlantic, warming at a steady rate and exposed to extreme climatic events interannually. This paper aims to understand the impacts of those extremes on changes in the southern stock range and structure as observed from 1994 to 2015. We compared the existing time series of data on sardinella distribution and age structure from annual acoustic surveys with climatic trends and marine heatwave indicators obtained from satellite imagery. The fish survey time series exhibited two prominent peaks, during 2006-2009 and 2012-2013; both were associated with the rise in the estimated biomass and the poleward shift of the southern stock range into the ABF. However, whereas the first peak reflected the movement of the adult sardinella stock from Gabon and Congo towards Angola, the second peak manifested successful recruitment in Angolan waters. We attribute the difference to contrasting climatic scenarios; deterioration in the sardinella habitat towards the stock's northern range due to persistent warming in the first case, in contrast to its sudden improvement in Angolan waters during a climatic hiatus that followed the 2010/2011 Benguela Niño in the second case.

(S4 Oral 15500)**El Niño as a predictor of round sardinella distribution along the northwest African coast**

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The El Niño Southern Oscillation (ENSO) produces global marine environment conditions that can cause changes in abundance and distribution of distant fish populations worldwide. Understanding mechanisms acting locally on fish population dynamics is crucial to develop forecast skill useful for fisheries management. The present work addresses the role played by ENSO on the round sardinella population biomass and distribution in the central-southern portion of the Canary Current Upwelling System (CCUS). A combined physical-biogeochemical framework is used to understand the climate influence on the hydrodynamical conditions in the study area. Then, an evolutionary individual-based model is used to simulate the round sardinella spatio-temporal biomass variability. According to model experiments, anomalous oceanographic conditions forced by El Niño along the African coast cause anomalies in the latitudinal migration pattern of the species. A robust anomalous increase and decrease of the simulated round sardinella biomass is identified in winter off the Cape Blanc and the Saharan coast region, respectively, in response to El Niño variations. The resultant anomalous pattern is an alteration of the normal migration between the Saharan and the Mauritanian waters. It is primarily explained by the modulating role that El Niño exerts on the currents off Cape Blanc, modifying therefore the normal migration of round sardinella in the search of acceptable temperature conditions. This climate signature can be potentially predicted up to six months in advance based on El Niño conditions in the Pacific.

(S4 Oral 15373)**“Move, adapt or go extinct”: Responses of small pelagic fish to global changes in the northeastern Atlantic**

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Small pelagic fishes (SPF) play a central role in marine ecosystems and are particularly sensitive to environmental changes. They are ectothermic, have high-metabolic requirements and high dependence on aerobic metabolism. In the context of climate change, shifts in these populations may have dramatic consequences in the ecosystem, and consequently, on fisheries. Therefore, it is pivotal to understand whether small pelagic fish will adapt to new environmental conditions or move and follow the environmental optima.

Here, we used both genomic and modelling approaches, of two SPF inhabiting temperate regions of the northeastern Atlantic and western Mediterranean, the European anchovy *Engraulis encrasicolus* and the European sardine *Sardina pilchardus*, to understand how SPF respond to environmental changes. Multilocus genomic analyses suggested newer perspectives on fish adaptation along the northeastern Atlantic and western Mediterranean, while habitat modelling suggested new suitable areas towards the north and habitat contractions over important spawning areas.

Science-based knowledge integrating different tools allow to predict more accurately complex and biological responses of SPF. Comprehending the response of SPF populations to global changes is vital to understand how these organisms will vary facing ongoing changing environments and consequently to sustainably manage these fishing resources.

(S4 Oral 15507) CANCELLED**Ecology and long-term dynamics of small pelagic fishes on the Northeast US continental shelf**Joel K. Llopiz¹ and Justin J. Suca²¹ Woods Hole Oceanographic Institution, Woods Hole, MA, USA. E-mail: jlllopiz@whoi.edu² Institute of Marine Science, University of California Santa Cruz, Santa Cruz, CA, USA

The continental shelf ecosystem off the northeast United States has long experienced human impacts from fishing, but it also undergoing rapid change associated with climate impacts—faster than most other regions of the world. However, our understanding of how such stressors cascade throughout the ecosystem is limited. Small pelagic fishes represent a critical trophic connection between planktonic production and large predators. While we know that small pelagics broadly consume zooplankton, the taxonomic resolution of their diet and the carbon pathways they represent has been limited, especially in the western North Atlantic. Similarly, we have a poor understanding of how bottom-up changes, including those related to physical properties (e.g. temperature) or zooplankton abundance and composition, alter forage fish feeding, condition, distribution, and abundance. We currently have several projects, either recently completed or still ongoing, focused on the important forage fish species in the NE US shelf ecosystem. We will highlight results and future activities from three of them. Among these is a Long-Term Ecological Research (LTER) project focused on the NE US shelf and elucidating the important linkages from physics through plankton to small pelagic fish, including how and why the trophic role of small pelagic species can change. Other work has been centered specifically on northern sand lance and how bottom-up processes and larval dispersal variability can lead to the enormous spatial and temporal fluctuations in their abundance.

(S4 Oral 15180)**Small pelagic fishes and fisheries in coastal waters of Catanduanes island, Philippines within climate variability**Jimmy T. Masagca^{1,2} and Mark Lorenz S. Trinidad³¹ College of Agriculture and Fisheries, Catanduanes State University, Virac 4800, Catanduanes, Philippines. E-mail: jtmasagca27@gmail.com² National Panel of Technical Experts (NPTE), Philippine Climate Change Commission, 6th Floor, First Residences, Inc. 1557 J.P. Laurel Street, Malacañang, San Miguel, Manila. Philippines³ CHED NAFES ACE-HEMS Program, Catanduanes State University, Virac 4800, Catanduanes, Philippines

This is a report on small pelagic fishes (SPF) and fisheries around the typhoon-prone island of Catanduanes marine coastal waters. Small pelagic fishes in the coastal waters have an important role to play in island's marine resources as the supply of fish dwindles when marine fishing is not possible due the identified hazards of the Philippine Climate Change Commission. Small pelagic fishes have been generally widely utilized as the focus is the marine fish catches of Catanduanes particularly in the Lagonoy Gulf area, Maqueda Channel, and bay areas of Cabugao and Kalapadan Bays) in the Pacific side of the island. Most abundant SPFs are the round scads, sardines, tunas, anchovies and other carangids. Fishing gears (e.g. ring net, gill net) exploit more of the SPF in terms of catch volume and sizes of the species caught. Excessive fishing effort lead to an overexploitation of the SPF and climate change hazards could have adversely affected subsequent recruitment of pelagic species. Inquiries on the effects to climate variability at decadal scale on fish reproduction and early life history stages of the major SPF need to be prioritized. Climate actions and more Covid-19 pandemic economic stimuli have to be focused for SPF small-scale fisherfolks to ensure sustainable management of SPF in coastal marine areas in the Philippine archipelago. Coastal policies are to be reviewed so that fishing problems on the unsustainable fishing practices due to unregulated use of fishing gears are to be abated to halt the continuous depletion of the SPF resources.

(S4 Poster and Oral 15339)**Impacts of climate change-induced environmental fluctuations on the structure of marine ecosystem around the Taiwan Bank**Po-Yuan **Hsiao** and Kuo-Wei Lan

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Taiwan Bank (TB) is located in the southern Taiwan Strait, where the uplifted continental slope and bottom currents bring upwelling areas and create an important fishing ground. Previous studies have confirmed that climate-induced fluctuations in fish populations have been demonstrated in Taiwan Strait. However, the predation and competition affect the interspecies relationships in ecosystem remains to be clarified. In this study, high grid resolution data on fishery activity (2013-2019) were collected to construct the ecosystem models by using Ecopath with Ecosim. Three mass-balanced models using Ecopath for the ecosystem influence by the ENSO events were constructed. The functional groups including representative pelagic, benthic, and reef species were collected for analyzes the relationship between migratory and sedentary species in ecosystem structure variation under climate change. The results showed that the system total throughput (TST) was about 3391-8619 (t km⁻²yr⁻¹), with average transfer efficiency is 18.69%. The keystone index reveals *Thunnus albacares* and *Katsuwonus pelamis* are the main key species with the top-down control has a relatively high impact on the ecosystem through Mixed Trophic Impact analysis. Total biomass, TST, consumption, and respiration increased during the El Nino and La Nina events. However, the diversity, omnivory, and connectance index were relatively low during La Nina events, caused by top predator biomass increased and low TL species decreased. Our results suggested during La Nina event, weak upwelling causes plankton populations decreased, with predator's high biomass and top-down control also enhance the decreasing pattern of low TL species population in TB ecosystem.

(S4 Oral 15280)**Evidence of density-dependent, time-varying processes in Pacific sardine stock assessments**Peter **Kuriyama**¹, Kevin Piner¹, Hui-Hua Lee¹, Kevin Hill¹, Paul Crone¹, Steve LH Teo¹, and Juan Zwolinski^{1,2}¹ NOAA Southwest Fisheries Science Center, La Jolla, CA, USA. E-mail: peter.kuriyama@noaa.gov² Institute of Marine Sciences University of California Santa Cruz, Earth and Marine Sciences Building, Santa Cruz, CA 95064, USA

The factors that drive Pacific sardine (*Sardinops sagax*) dynamics are not well understood. Sardine, have large population fluctuations and likely have a number of time-varying biological processes, such as movement and growth. These factors pose challenges to both stock assessments and studies that infer environmental relationships from stock assessment output. Here we develop a stock assessment approach, that synthesizes all data previously used in assessments, to first estimate growth and its temporal variation and second relate the output to environmental time series. The first goal is to evaluate the degree of biological complexity supported by the data. The most complex assessment configuration estimates time-varying age-based selectivity (as a proxy for sardine movement) and a form of time-varying growth (either cohort-specific or annually-varying). The simplest assessment configuration has constant selectivity and time-invariant growth. The second goal is to relate the output from the best fitting model to environmental time series (such as sea surface temperature and Pacific Decadal Oscillation) that have been hypothesized to drive sardine dynamics. The model with time-varying age-based selectivity and cohort-specific growth best fit the data. Cohort growth deviations seemed to be density-dependent as they were significantly negatively correlated with age 1+ biomass. Recruitment success, from the best fit model, was significantly positively correlated with combined summer and spring PDO ($r=0.76$) and annual sea surface temperature ($r=0.45$), among other covariates. While this is a statistical rather than mechanistic relationship, the results can inform the configurations and inclusion of environmental effects in future stock assessments.

(S4 Oral 15644)

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

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The contributions of different environmental and ecological drivers and fisheries to the boom-bust population dynamics of small pelagic fish 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 in the California Current, with early life stage survival and offshore transport, food availability for larvae and adults, migration and egg production driven by high-resolution ocean-biogeochemical model output. An ensemble model configuration set fit to observations is used to identify response mechanisms and quantify ecological uncertainty, and 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 resurgence of anchovy. Ensemble projections show a likely sardine recovery to early 2000's abundance and catch by mid-century and concurrent decreases in anchovy, driven by changes in recruitment success under warming temperatures and changing food availability. Ecological process uncertainty is 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 assesses the combined impacts of multiple environmental drivers on SPF population dynamics, and quantifies sources of uncertainty to future abundance and distribution under novel environmental conditions, identifying risks for stock declines and improving quantitative understanding of population responses to climate variability and change.

(S4 Oral 15396)

Population traits in small pelagic fish model: Emergence from interactions between a turbulent environment and individual behaviors in Upwelling Systems

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Small pelagic fish (SPF) populations in the Canary current system are shared among six Northwest African countries, along which they perform seasonal migrations. Round sardinella in particular is a critical species for the local economies and food security. We analyze the processes leading to the emergence of the Round sardinella spatio-temporal population dynamics, in a full life cycle biophysical model forced by realistic hydrodynamic and biogeochemical simulations around two decades (1990-2009). The fish traits considered were (1) their capacity of exploration, and (2) the natal homing behavior. In the model, super-individuals represented micro-cohorts with temperature and food dependent growth provided by a dynamic energy budgeted model (DEB) and size-dependent mortality. Robust population dynamics patterns emerged in the model. A "focal area" emerges off Mauritania (17-21°N) where the species was abundant all year round, bordered by seasonal abundance areas. The decisive

role of fish exploration ability linked to swimming capacity underline the importance of the accuracy of the hydrodynamics simulations used to force the fish model. Here, the spatial distribution of the population was largely driven by variability in the intensity of the nearshore current provided by the Regional Oceanographic Model Simulation. Environmental variability in the Sahara Bank, was the source of the low-frequency fluctuations of the sardinella abundance. The model produces diagnostics for population connectivity with heavy consequences for international stock managements. However the individual life history emerging from the model must be validated prior the use of this results for management purposes e.g. using otolith.

(S4 Oral 15224)

Development of a bioenergetics and population dynamics coupled model: An example of Pacific chub mackerel

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Pacific chub mackerel (*Scomber japonicus*) is a small pelagic fish that widely distribute in temperate zones in the waters around Japan, which has shown a phenomenon called as fish species alternation with other small pelagic fish like anchovy, sardine, and Pacific saury. For clarifying the mechanism of the fish species alternation, we are developing a coupling model of bioenergetics model and population dynamics model of chub mackerel, in which influence of temperature and prey plankton on growth and hence population can be represented. Fish growth and body size are calculated by the bioenergetics model and mortality in the population dynamics model depends on fish body size (or both body size and growth). However, the body size dependency parameter of mortality is not known for chub mackerel. Therefore, the model was forced by surface temperature and prey plankton density from 1998 to 2018, and the body size dependency parameter was tuned to minimize the residual between simulated RPS (recruitment per spawners) and a cohort model derived RPS. The prey plankton density was estimated from ocean color satellite data. The modeled population and biomass of chub mackerel showed similar tendency with the observed data. We are analyzing the mechanism how environmental factors are controlling the growth and population fluctuations in the model and the details will be reported at the meeting.

(S4 Oral 15206) Talk-19

Stronger together: Fisheries enhance pressure on Mediterranean regions and pelagic species already impacted by climate change

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Marine species are widely threatened by anthropogenic activities, including fishing and climate change. However, geographically broad and spatially-explicit assessments of the simultaneous impacts of these major threats at regional scales are mostly lacking due to the challenges of surveying vast geographical areas and obtaining adequately resolved data. Yet, these assessments are key for identifying highly and cumulatively impacted areas and species that should be prioritized for conservation through knowledge-based management strategies. Here, we analysed a 26-year (1993-2018) time series of highly-resolved remotely sensed environmental data to evaluate changes in optimal habitat availability (i.e., extent of marine areas encompassing optimal environmental conditions) for 15 species of small, medium and large pelagic fish inhabiting the Mediterranean Sea. We then combined spatial and temporal data on fishing pressure and changes in optimal habitats to identify areas of high risk of cumulative impacts. Overall, results showed how most of the Mediterranean pelagic species went through a reduction of optimal habitat availability over the past decades. The few species that showed positive trends in optimal habitat availability did not expand largely and hence were unlikely to compensate for the loss of key functional roles at the group level. Habitat loss concentrated in the western and central basins. Similarly, fishing pressure was found to be the highest in both basins, thus overlapping with the areas experiencing a higher reduction of optimal habitat. Small and large pelagic fish were the most impacted groups, having a larger proportion of their distribution in highly, cumulative impacted areas.

(S4 Oral 15334)**Effect of climate state on variation in nutritional value for small pelagic species**

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Nutritional composition is the result of an organism's efforts to acquire energy and nutrients and can vary significantly within and among marine species. A few studies have associated nutritional composition of small pelagic species (SPS) with environmental factors (e.g.: upwelling, sea surface temperature, seasonality, and geophysical location). However, detailed information on the response of SPS' body composition to climate variation is limited. We compared lipid, protein, and energy density values for individuals from 17 SPS known to be preyed by albacore tuna in the North Pacific Ocean to quantify the effect of climate state on intra and inter-species variation in nutritional composition. Species were selected from a literature-based dataset to represent regional (N–S) and temporal gradients (1965–2021), a range of traits, commercial and non-commercial importance, and low or high preference in albacore diet. Region and time serve as proxies for climate impact because sea temperature varies with latitude and Pacific decadal oscillation shows distinct cooling and warming trends associated with shifts in sea surface temperature, chlorophyll, and upwelling. Using Bayesian hierarchical models to explain variation in nutritional composition in relation to climate proxies, we found that nutritional value is highly conserved within some pelagic taxa, but varies greatly with climate state for others. Results underscore the importance of using nuanced individual values rather than a single species-defined value for energetic analysis, and of identifying traits that make some forage species more resilient to changing climate conditions and critical for stabilizing marine food webs and managing fisheries.

(S4 Poster and Oral 15504)**On the robustness of an eastern boundary upwelling ecosystem exposed to multiple stressors**

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The resistance of an east border upwelling system was investigated using relative index of marine pelagic biomass estimates under a changing environment spanning 20-years in the strongly exploited southern Canary Current Large marine Ecosystem (sCCLME). We divided the sCCLME in two parts (north and south of Cap Blanc), based on oceanographic regimes. We delineated two size-based groups (“plankton” and “pelagic fish”) corresponding to lower and higher trophic levels, respectively.

Over the 20-year period, all spatial remote sensing environmental variables increased significantly, except in the area south of Cap Blanc where sea surface Chlorophyll-a concentrations declined and the upwelling favorable wind was stable. Relative index of marine pelagic abundance was higher in the south area compared to the north area of Cap Blanc. No significant latitudinal shift to the mass center was detected, regardless of trophic level. Relative pelagic abundance did not change, suggesting sCCLME pelagic organisms were able to adapt to changing environmental conditions. Despite strong annual variability and the presence of major stressors (overfishing, climate change), the marine pelagic resources, mainly fish and plankton remained relatively stable over the two decades, advancing our understanding on the resistance of this east border upwelling system.

S5. Progress in Pelagic Surveys: From Biomass Estimates to Monitoring Ecosystems

(S5 Invited 15201)

Insights from Down Under: DEPMs on four species over 25 years and 350,000 km²

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Australia has two large-scale fisheries for small pelagic species, the South Australian Sardine Fishery (SASF) and Commonwealth Small Pelagic Fishery (SPF), which collectively take about 30% (~60,000 t per annum) of the total Australian catch. Estimates of spawning biomass (SpB) obtained using the Daily Egg Production Method (DEPM) are the primary biological performance indicators in both fisheries. Collectively, surveys for the four target species cover more than 350,000 km². Challenges vary among species and provide different insights into the method. Application of the DEPM to sardine since 1995 has resulted in refinements that have reduced coefficients of variation from 23–59% to 8–12%. The revised methods warrant evaluation for this species in other ecosystems. Changes in sardine SpB are driven primarily by variations in spawning area. Interannual variations in mean daily egg production (P_0) and adult parameters are low in comparison to statistical uncertainty. Estimating P_0 reliably is challenging for all species due to under-sampling of early-stage eggs and over-dispersal of egg data, and especially difficult for the species that spawns in the coolest water and has the longest hatch times. For all species, the precision of estimates of SpB can be increased by combining female weight and batch fecundity into a single parameter, relative fecundity (F'). Preliminary results from an ongoing study show that the presence/absence of fish species in plankton samples can be determined reliably using DNA-metabarcoding. Future DEPM surveys may provide a platform to monitor Australia's pelagic ecosystems as well as its key pelagic fish stocks.

(S5 Oral 15300)

Evaluation of the uncertainty of the Herring Acoustic-Trawl Survey – A Geostatistical approach

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Any spatially and temporally explicit sampling programme and derived estimates contain a given sampling and stochastic uncertainty. Understanding uncertainties is an important step when it comes to improving the sampling strategy, interpreting the survey outcomes or evaluating the performance of a survey over time. The uncertainty surrounding biomass estimates derived from acoustic-trawl surveys is composed of multiple components. These include the sampling error in the acoustic and biological data, stochastic errors as well as uncertainties surrounding the acoustic target strength (a metric allowing the translation of acoustic density information into biologically meaningful measures, such as abundance or biomass). Here we attempt to evaluate the uncertainty of a well-established acoustic trawl survey, the North Sea Herring Acoustic Trawl Survey (ICES coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf). Through a combination of geostatistical conditional simulations of the acoustic and biological data, we aim to estimate the sampling uncertainty surrounding the resulting biomass estimates. This will allow us to discuss the current sampling strategy, annual variabilities and the influence of the biological as well as acoustic sampling on the total sampling uncertainty. The stochastic uncertainty will be estimated through MCMC simulations. The combined error budget will be presented for the herring in North Sea and stratified by age or length.

(S5 Oral 15303)

Spatially explicit synthetic simulations towards an improved acoustic assessment of the North Sea herring stock

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The design of fisheries surveys and the interpretation of the results require assumptions and choices based on historical knowledge of distribution characteristics and the biology of the populations studied. These characteristics can change over time due to factors such as environment, fishing pressure or natural variability. Such changes may not be detected in due time by simply looking at the survey results year on year, depending on the survey design and estimation methods. Spatially explicit synthetic population simulations allow for testing different hypotheses or survey strategies and their influence on biomass estimates. Informed by historical survey data, we developed a model to simulate multiple replicates of a herring stock in the North Sea. A major benefit of such modelling approach is that for example we can track cohorts through their life history in space and time. We derive their contribution to the acoustic backscatter as well as the overall biomass estimates. Further we use these simulations to test alternative sampling strategies and survey designs. A thorough understanding of the influence of survey design and the parameters used to translate acoustic information into biomass estimate is of particular importance for the commercially highly important North Sea herring stock, where the acoustic biomass estimates play a major role in the assessment and therefore the management. We will present how the perception of how growth and mortality of a strong year class can change in a non-linear fashion based on inclusion/exclusion of the depth-dependent compression of the swim bladder in the acoustic calculations.

(S5 Oral 15491)

An end-to-end use of advanced acoustic surveys in spatial management of the lesser sandeel (*Ammodytes marinus*)

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The international management of the lesser sandeel (*Ammodytes marinus*) in the North Sea failed with the stock collapse in the 2000's. Severe local depletion of lesser sandeel in Norwegian waters resulted in a national spatial management model in 2011, which was the result of a close co-operation between researchers, managers and the fishing industry. The collaboration has continued and in the current refined management model the sandeel fishing grounds are divided into 5 areas, each consisting of two or three subareas, based on the differences in population structures. An area is closed for fishery unless the abundance is above a critical stock biomass directly estimated by acoustic trawl surveys. In these surveys the species identification is entirely based on the acoustic frequency response, and all abundance and biomass estimates given with confidence intervals are regarded to be absolute values. In accordance with the management model, a pre-season precautionary TAC advice and a recommendation of which subareas that should be open are given. This assessment is based on the acoustic surveys, catch statistics and a dredge survey recruitment index. After the annual acoustic survey in April-May an updated in-season advice presented and used as the basis for the final TAC and area closure decisions. In line with the continuous management plan work and survey methodology development, we have tested Unmanned Surface Vehicles (USV) and machine learning of the acoustic data. Future acoustic sandeel surveys will most likely be carried out with USVs and more use biotic information from the commercial fishery.

(S5 Poster and Oral 15412)**Purse-seine fishery in Portugal: No sardine, no future?**Diana **Feijó**^{1,2}, Alberto Rocha¹, Ana Marçalo³, Isabel Riveiro⁴ and Alexandra Silva^{5,6}¹ IPMA, Instituto Português do Mar e da Atmosfera, Matosinhos, Portugal. E-mail: dfeijo@ipma.pt² Universidade de Vigo, Campus de Vigo, Spain³ CCMAR, Centro de Ciências do Mar, Universidade do Algarve, Faro, Portugal⁴ Centro Oceanográfico de Vigo (COV-IEO), CSIC, Spain⁵ IPMA, Instituto Português do Mar e da Atmosfera, Algés, Portugal⁶ MARE, Marine and Environmental Sciences Centre, U-Lisboa, Portugal

In Portugal, small and medium pelagic species such as sardine (*Sardina pilchardus*), chub-mackerel (*Scomber colias*), anchovy (*Engraulis encrasicolus*) and horse mackerel (*Trachurus trachurus*) are the most landed species in the purse seine fishery, accounting for near 50% of total landings in weight. Historically, sardine has been the target species of the fishery and traditionally perceived as the most important species in the fleet. With the decline of the sardine stock and the reduction of annual quotas, this fleet has supplemented its incomes by targeting chub-mackerel in the Center and South and anchovy in the North. The present work aims to analyse changes in fleet behavior concerning the reduction of annual quotas and the establishment of daily quotas for sardines in the period 2005-2020, to assess their impact on annual landing dynamics and improve the assessment of pelagic species. Behavior changes have been observed in the fleet along the country, such as searching for new fishing grounds and species with more market value such as anchovy. Especially, fisheries data may be an important supplement to information obtained from traditional surveys, that cover a part of the history. Having the full picture is important to get a better assessment of pelagic species and further discussion and/or sharing with stakeholders (e. g. fishers and fisher associations, fisheries researchers, the industry, NGO's and general public).

(S5 Oral 15285)**Improved monitoring of forage species in the Gulf of Alaska in the absence of directed surveys**David **McGowan**, Alex De Robertis, Darin Jones, Samuel Urmy and Kresimir WilliamsAlaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA.
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Forage species (including small pelagic fishes and juvenile stages of groundfish) serve an intermediate trophic role in northeast Pacific marine food webs. In U.S. waters off Alaska, there is limited information on forage species due to a lack of directed fisheries, and existing surveys are not designed to sample them. Improved information on abundances and distributions of forage species is needed by fisheries managers to better understand how fluctuations in their availability impact predators under an ecosystem-based approach to fisheries management. However, new surveys for forage species are cost-prohibitive. To demonstrate how improvements in monitoring of forage species can be achieved in the absence of directed surveys, we present a case study for Pacific capelin (*Mallotus catervarius*) in the Gulf of Alaska. Existing data sources were summarized to characterize capelin spatial patterns and identify core areas to prioritize monitoring. Capelin abundance estimates derived from acoustic-trawl surveys targeting walleye pollock (*Gadus chalcogrammus*) were improved by characterizing the size- and species-selectivity of the survey trawl and allocating backscatter to multiple species using the selectivity-corrected trawl data. We also present ongoing work to develop a model-based estimator to improve survey estimates for capelin and an index standardization model that incorporates multiple survey- and predator diet-based indices. A summary of key findings and recommendations from the 2022 NOAA Alaska Fisheries Science Center Forage Species Congress will also be discussed, as well as potential improvements in forage species monitoring by using autonomous surface vehicles and eDNA sampling.

(S5 Oral 15170)**Investigation of bias in echosounder acoustic surveys using omnidirectional sonar from South to Northwest Africa***(presented by Hector Pena)*Hector **Peña**¹, Fannie W. Shabangu^{2,3}, Kamal Mamza⁴, Abdoulaye **Sarre**⁵, Mohamed Ahmed⁶, Uatjavi Uanivi⁷, Filomena Vaz Vehlo⁸ and Erling Stenevik¹¹ Institute of Marine Research, Norway. E-mail: hector.pena@hi.no² Department of Forestry, Fisheries and the Environment, Cape Town, South Africa³ University of Pretoria, Pretoria, South Africa⁴ Institut National de Recherche Halieutique, Morocco⁵ Centre de Recherches Océanographiques de Dakar-Thiaroye, Senegal⁶ Institut Mauritanien de Recherches Océanographiques et des Pêches, Mauritania⁷ National Marine Information and Research Centre, Namibia⁸ National Institute for Fisheries and Marine Research, Angola

Conventional downward looking echosounders are capable of collecting acoustic data from few meters below the sea surface to the seabed; however, an underestimation of pelagic fish biomass occurs when fish occupy the surface blind zone, which can extend down to 15 m below sea surface. Avoidance of the approaching surveying vessel by fish schools is another source of bias. Omnidirectional horizontal and vertical beams from fisheries sonars were used to collect the acoustic data to estimate the amount of pelagic fish underestimated by the conventional echosounder system during the Ecosystem Approach to Fisheries-Nansen Cruises from South to Northwest Africa (2017-2019). Different pelagic fish species were found including sardine, sardinella, anchovy, and different species of mackerel. Mean abundance of main pelagic fish species by depth was computed from sonar data and compared with echo sounder estimates. Acoustic estimates were aggregated by transects and by geographical regions comparing the fish school volume, densities of the predominant fish pelagic species. Here we show that side-looking sonars are efficient for deriving parameters of a pelagic fish schools and for estimating fish biomass to estimate the bias in abundance and distribution of fish from the vertical echosounder system.

(S5 Oral 15410)**NOAA Fisheries' approach to monitoring the Gulf and Atlantic Menhaden fisheries, 60 years of progress**Raymond M. **Mroch** III

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Gulf and Atlantic menhaden are small, filter-feeding, pelagic clupeids that support a large-scale purse-seine reduction fishery. Together, these stocks comprise the second-largest fishery by weight in the United States. In 1955, a perceived decline in abundance, concurrent with increased participation and technological sophistication in the fishery, brought about NOAA Fisheries' Menhaden Program. The program initially focused on basic biology and ecology, but gradually shifted to fishery monitoring and stock assessments. Primary tasks still include recording landings, effort, and life history data collection and analysis. Sampling parameters were initially set down in the early 1980s, in accordance with the technological level and statistical practices at the time. The fast pace of stock assessments, combined with the lack of resources necessary for continuous updates, has created a need for an overhaul in methods. We began by upgrading our age estimation methodology, followed by a reexamination of the port sampling techniques. We continued with automating tasks such as landings data collection and recording of length and weight data. The next step is satellite-enabled tablets to collect logbook information. These improvements increase accuracy and timeliness of data collection and greatly improve our ability to use the data for research. Today, the Menhaden Program supports cutting-edge single-species and multi-species stock assessment analysis with limited resources. Hopefully, with the recent upgrades and continued devotion to maintenance, we can provide the same services with available resources, as well as opening the door to more capabilities.

(S5 Oral 15363)**Large scale tagging and recapture of small pelagics**

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For short-lived small pelagic fish species like lesser sandeel (*Amodytes marinus*), high-resolution spatial and temporal information about life history parameters is a prerequisite for improving fisheries management considering climate change and ecosystem impacts. To move a step beyond standard scientific abundance surveys, we developed a largescale tagging and recapture experiment in which sandeels were tagged with Passive Integrated Transponders (PIT) tags. Catch and handling processes were developed to maximize survival during the tagging and release process. During a three-year period, covering both winter hibernation and spring fishing season, 15,647 sandeels were tagged on board survey ships and chartered fishing vessels and released at their sand bank habitats in different areas of the North Sea. Recaptures were identified by scanner systems mounted on the tubes of the ten major pumping stations receiving landings for the Danish fishmeal factories from the industrial fishery. Efficiency was estimated to >98% recovery of tagged sandeels passing a scanner, and more than 80% of all sandeel landings were scanned. The time stamp and pumping station of each recaptured tag was used to identify the vessel of recapture. By merging with logbook information from the respective fishing-trip and fleet effort distribution over time the most probable catch location could be estimated. Recaptures from two fishing seasons (total 61 and 108) showed correspondence with the development of the respective fishery over the season. From the data, detailed information on migration, local abundance, and potential fishing and natural mortality can be estimated.

(S5 Oral 15371)**DEPM BIOMAN survey series in the Bay of Biscay: Lessons learned after 35 years of tracking the anchovy population in its ecosystem.**

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The BIOMAN survey was originally designed for estimating the spawning stock biomass (SSB) of anchovy (*Engraulis encrasicolus*) in the Bay of Biscay by means of the Daily Egg Production Method (DEPM). It is carried out annually in May since 1987 (except in 1993), being one of the longest DEPM series worldwide. The anchovy SSB estimates range from a collapsed level in 2005 (5kt) to a historical maximum in 2020 (334kt). These estimates are determined by the Total Egg Production (P_{tot}) (CV=94% and $r^2=0.958$) divided by the Daily Fecundity (CV=23% and $r^2=0.292$). The estimation of P_{tot} has improved through more accurate delineation of the spawning area, using CUFES, and with better statistical inference of the egg production per surface unit. These two key parameters show comparable variability (CVs ~50%), and moderate positive correlation. Daily Fecundity is mainly driven by the spawning fraction (S) and the relative fecundity, which show comparable CVs (~33%). S estimation procedures have been reviewed after revisiting the degeneration rate of post-ovulatory follicles. Good adult sampling has allowed producing series of population-at-age estimates, allowing tracking cohorts in time. In this period, the survey has broadened its objectives to include concurrent estimates of sardine biomass and to achieve a holistic ecosystem monitoring by regular reporting of environmental variables (including debris and microplastic) and of ecosystem components like zooplankton, environmental DNA, megafauna (mammals, seabirds), etc. Thus, the survey contributes both to the integrated assessment of the target species and to monitor the environmental status of Bay of Biscay region.

(S5 Oral 15422)

The W and N Iberian pelagic ecosystem in spring assessed with Pelacus surveys: Environmental variability and spatio-temporal changes in food web structure and ecosystem functioning

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Since 1986, IEO carries out the Pelacus surveys every spring covering the shelf from Porto (Portugal) to the southeastern Bay of Biscay. The objective is to monitor the pelagic ecosystem from hydrography to fish, especially sardine. In this contribution, we show how the integrated monitoring of the pelagic ecosystem performed in Pelacus cruises provides insight on the variability of the pelagic ecosystem. The interpretation of environmental and plankton observations is complex because sampling is not synoptic (different areas are sampled in different dates) and there is a strong variability induced by short term events. We will show how a coupled physical-biogeochemical model is a tool to assess the variability of environment and plankton at shorter scales (days) and help to draw the picture of the variability in the area around the spring transition in different years. Productivity on this narrow shelf affected by seasonal upwelling results from the interplay of wind events, river plumes and light intensity, all of them varying at interannual, seasonal and event scales. Observations (stable isotopes, biomass, environmental data) combined with modelling can be used to evaluate changes in the composition and structure of the pelagic food web. To this respect, we will report on the development of several metrics of spatio-temporal changes in food web structure and functioning of the pelagic ecosystem obtained from observations and modelling and how they can be used for assessing the changes in the trophic interactions caused by environmental variability and by changes in the trophic position of selected consumers.

(S5 Oral 15463)

Spatio-temporal variability of the distribution and abundance of small pelagic fish off the Portuguese continental coast and relationship with environmental drivers

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Scientific tools capable of identifying species distribution patterns are important as they contribute to improve management. This study aims to estimate the spatio-temporal distribution of sardine (*Sardina pilchardus*, Walbaum 1792) in western and southern Iberian waters, relating the spatio-temporal variability of the biomass indicator with environmental conditions.

Acoustic data was obtained during Portuguese spring acoustic surveys (PELAGO) conducted by the Portuguese Institute for Sea and Atmosphere (IPMA) from 2000 to 2020 (gap in 2012). Daily environmental data was obtained for the region and time of study, particularly satellite derived sea surface temperature, chlorophyll-a concentration, bathymetry, and intensity and direction of surface ocean currents.

Species Distribution Models were used to relate sardine presence/absence and biomass with environmental conditions, aiming at predicting its distribution in unobserved locations and for the unobserved year of 2012. A hurdle Bayesian model was used such that species biomass is given by the product of two processes, occurrence and biomass under occurrence. In addition to considering the spatio-temporal structure, the impact of the environmental conditions with a time lag on biomass indicator is evaluated using a kernel gaussian function. Data from the west and south coasts are studied separately due to the large differences of the coast shape and the prevailing oceanographic conditions.

For the south coast, all covariates are shown to be important. Shallow and calmer locations favor both occurrence and biomass, while biomass is also higher for colder waters and where the chlorophyll-a varies between 10 and 25mg/m³.

(S5 Oral 15270)**Anchovy and sardine springtime habitats in the European Atlantic area**

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Springtime habitats of anchovy and sardine habitats were jointly characterised for the first time at the scale of the European Atlantic shelf seas (from the Gulf of Cadiz to northern Brittany), based on data collected over the 2003-2019 period by the ICES WGACEGG international joint effort spring acoustic surveys. Multivariate ordination methods were applied to extract the main spatial patterns from series of multivariate maps. Spatial patterns were expressed as hierarchised principal components (PCs), whose time-varying amplitudes were analysed to assess temporal dynamics. Space-time ordinations were performed on: i) fish acoustic densities collected during the joint survey, ii) sea surface temperature and salinity collected from survey and remotely sensed Chlorophyll-a conditions. Maps of fish mean PCs were modeled as a function of maps of mean environment PCs, to characterise the anchovy and sardine habitats in the European Atlantic area. Anchovy and sardine co-occurred in core springtime habitats located in onshore areas of the Bay of Biscay, Galicia and Western Portugal, and in the gulf of Cadiz. Core habitats were characterised by lower than average surface temperature and salinity and higher primary productivity. In those habitats, anchovy distribution expanded over time, while the sardine range shrank. Effects of the environment and fishing on anchovy and sardine distributions are discussed, as well as future changes under climate forcing.

(S5 Oral 15314)**Integrating forage surveys, diet studies, and trait information to explore prey preferences of a pelagic predator - albacore tuna**

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Anthropogenic stressors such as climate change are redistributing species, rewiring pelagic ecological food webs and impacting the socioeconomic benefits they provide. Yet scientific efforts to understand feeding relationships between top predators and forage species in pelagic ecosystems are limited by data availability. This paper addresses the methodological challenges and suitability of integrating diverse datasets with variable spatio-temporal resolutions and sampling designs to examine top-predator diet selection, using prey selection of albacore tuna (*Thunnus alalunga*) in the California Current Large Marine Ecosystem (CCLME) as a case study. In the CCLME, annual summer pelagic midwater trawl surveys and long-term stomach contents sampling from 2005-2019 enable us to examine prey consumption by albacore in relation to a diverse forage community. We found that trawl surveys suitably sampled most albacore prey, based on relative prevalence compared with diet data, and thus were appropriate for comparative analyses. However, several key prey species (anchovy, jack and chub mackerel) were surveyed at larger, adult size ranges compared to the smaller juveniles consumed, potentially representing a sampling gap in fully understanding albacore resource use. Prey selectivity analyses revealed several species were consumed by albacore in greater relative abundances than surveyed in the environment (including anchovy,

sardine, clubhook squid, octopuses), with regional nuances in these patterns of selection. Overall, this work assesses the utility of these data in modeling albacore tuna diet shifts, while highlighting recommendations for dataset integration in resource assessments.

(S5 Oral 15436)

Assessing small pelagic fish trends in space and time using piscivore diet data

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Changing distribution and abundance of small pelagics may drive changes in predator distributions, affecting predator availability to fisheries and surveys. However, small pelagic fish are difficult to survey directly, so we developed a novel method of assessing small pelagic fish aggregate abundance via predator diet data. We used piscivore diet data collected from multiple bottom trawl surveys within a Vector Autoregressive Spatio-Temporal (VAST) model to assess trends of small pelagics on the Northeast US shelf. The goal was to develop a spatial “forage index” to inform survey and/or fishery availability in the bluefish (*Pomatomus saltatrix*) stock assessment. Using spring and fall surveys from 1973-2020, 20 small pelagic groups were identified as major bluefish prey using the diet data. Then, predators were grouped by diet similarity to identify 19 piscivore species with the most similar diet to bluefish in the region. Diets from all 20 piscivores were combined for the 20 prey groups at each surveyed location, and the total weight of small pelagic prey per predator stomach at each location was input into a Poisson-link delta model to estimate expected prey mass per predator stomach. Best fit models included spatial and spatio-temporal random effects, with predator mean length, number of predator species, and sea surface temperature as catchability covariates. Spring and fall prey indices were split into inshore and offshore areas to reflect changing prey availability over time in areas available to the recreational fishery and the bottom trawl survey, and also to contribute to regional ecosystem reporting.

(S5 Oral 15347)

Detection of fish species by MiFish analysis from the eDNA samples collected from intake-water (3m), surface-water (0m) & Niskin bottles (5m or 10m) and comparison among them to understand their suitability

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Environmental DNA (eDNA) is gaining immense popularity in understanding fish species distribution pattern and biodiversity monitoring in the ocean due to its non-invasive nature and convenience to use. MiFish metabarcoding technique is a modern technique in analyzing fish community distribution in larger waterbodies which facilitates detection of huge number of species at a short time. However, several studies showed influence of water sampling methods on eDNA analyses. Therefore, we compared eDNA detection from different sampling methods. Intake (3m), bucket (0m) and Niskin bottle samples (5m or 10m) were collected from 69 different stations from different seasons and were then filtered and stored appropriately to extract the DNA and finally segregated in respective Operational Taxonomic Units (OTUs) by MiFish analysis. A total of 246 species has been recorded from 100 families which indicates a highly diversified environment of the study site. Among these species 128 species were common in all three sampling types while some species were recorded exclusively in only one sampling type. The detection percentage of most of the species did not vary significantly among different sampling types while some species vary significantly among each sampling type. For frequently detected species, most of them did not show any significant difference in the detection percentage. The results support an idea that the Niskin, intake and surface water samples can be used as a mixture or simultaneously for MiFish analysis. We will further investigate the influence of environments and species dependency for the detection difference between the three types of sampling.

(S5 Oral 15424)**Inter- and intra-annual variations in the fish community structure related to abiotic drivers in the Sylt-Rømø Bight, southeastern North Sea, Germany**Victor **Odongo**^{1,2}, Sabine Horn¹, Harald Asmus¹, Maarten Boersma^{1,2}, Harald Ahnelt³ and Benoit Lebreton⁴¹ Alfred Wegener Institut Helmholtz Zentrum für Polar- und Meeresforschung, Wadden Sea Station, Sylt, Germany. Email: victor.odongo@awi.de² FB2, Universität Bremen, Bremen, Germany³ University of Vienna, Vienna, Austria⁴ Université de La Rochelle, La Rochelle, France

The Wadden Sea is a transition area between estuaries and the North Sea and is of ecological importance for a wide range of fish species that use this area in the course of their life cycle for various purposes. It is highly dynamic and undergoes strong seasonal patterns and annual variability in abiotic conditions. Monthly juvenile fish monitoring in the Sylt-Rømø Bight (SRB) from 2007 to 2019 was analyzed to determine; the abundance trends; inter- and intra-annual changes in community structure and migration behavior related to changes in sea surface temperature, salinity and North Atlantic Oscillation (NAO). Results showed that herring (*Clupea harengus*) accounted for 67.6 % of the total catch, small sandeel (*Ammodytes tobianus*) at 14.6 %, sprat (*Sprattus sprattus*) at 5.8 %, whiting (*Merlangus merlangus*) at 4%, and sand goby (*Pomatoschistus minutus*) at 3 %. Peak abundances for calanoid copepod feeders occurred after ice-cold winters and vice-versa. Three common trends by Dynamic Factor Analysis (DFA) were important for different species with periodic rises and falls. Environmental variables explained 28.2% of the variations observed in the fish community. High overall community variations between summer and winter seasons, SIMPER (67.55 %), ANOSIM ($R = 0.64$, $p < 0.001$), and Jaccard's coefficient (0.58) caused by the spring immigration of Lusitanian species and autumn emigration of boreal species was observed. *C. harengus*, *A. tobianus*, *M. merlangus* and *S. sprattus* contributed 62.9% of these variations and higher variations observed after warm and ice-cold winters. The SRB is significantly important to small pelagic fishes.

(S5 Oral 15498)**Biomass and geographical distribution of seven small pelagic fish species in relation to temperature conditions in Mauritanian waters**Sidi Ahmed **Hemed**

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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.”

(S5 Oral 15231)**Relationship of oceanic vorticity to catches of jack mackerel (*Trachurus murphyi*) in the Peruvian Sea between 2011 and 2021**Susan Montero^{1,2}, Daniel Grados³, Gary Vargas⁴, Emilio Mendez¹ and Mariano **Gutierrez**^{5,2}¹ Pesquera Diamante² Universidad Nacional Federico Villarreal³ Instituto del Mar del Perú⁴ Universidad Federal de Recife⁵ Instituto Humboldt de Investigación Marina y Acuícola. E-mail: mgutierrez@ihma.org.pe

Surveying for fishing grounds makes it possible to direct fleets to the best available areas. However, the cost of these explorations is usually high, so it is necessary to generate predictive analyses that allow to increase the efficiency of fishing operations. Besides, there are limited resources for in situ monitoring of vorticity in the ocean influencing the processes of convergence and divergence of the aggregation of nutrients, plankton and fish. To address these limitations, the acoustic information collected aboard fishing vessels is valuable data that can be used to model the distribution of important species such as jack mackerel. To study the relationship between ocean vorticity - which is characterized by meso and sub-mesoscale cyclonic and anticyclonic structures - and the availability of jack mackerel (*Trachurus murphyi*), it was used satellite information on sea level anomaly (SLA) and georeferenced catch data from industrial purse seine vessels operating in the Peruvian national waters between 2011 and 2021. To study the relationship between sub-mesoscale structures and the local abundance of zooplankton and fish, it was used acoustic data collected during scientific surveys performed by the Peruvian Marine Research Institute (IMARPE) along the Peruvian coast. From echograms it was detected the upper limit of the minimum oxygen zone (ULMOZ) to identify structures such as internal waves by using wavelet analysis. The obtained results indicated that catches were found invariably and positively correlated with the local abundance of macrozooplankton and with the location of the fronts between the cyclonic (divergent) and anticyclonic (convergent) eddies, so that ranges have been defined on the SLA values to support habitat modeling of adult jack mackerel in Peru. Furthermore, it was found that the presence of jack mackerel and other species is related to the detected different types of sub-mesoscale structures.

Keywords: vorticity, jack mackerel, sea level anomaly, acoustics, zooplankton, upper limit of the minimum oxygen zone

(S5 Oral 15338)**A novel satellite-based approach to mapping spatio-temporal spawning patterns of sardines in northern Mindanao, Philippines**Asuncion B. **de Guzman**¹, Jerry P. Garcia² and Denmark B. Recamara³¹ MSU Naawan Foundation for Science and Technology Development, Inc. (MSUNFSTDI), Naawan, Misamis Oriental, Philippines. E-mail: sonydeguzman@gmail.com² Mindanao State University-Naawan, Naawan, Misamis Oriental, Philippines³ University of San Carlos, Cebu City, Philippines

Conventional methods of assessing fisheries production in the Philippines such as dockside surveys are constrained by the absence of spatially explicit catch and effort data which can accurately identify the specific fishing grounds for a target fishery. Under a government-funded sardine research project we launched the Research in Sardine Volunteer Program (RSVP), a novel satellite-based tracking strategy to produce time-series spatial maps of fishing effort and catch data and identify potential spawning grounds through a network of volunteer commercial and artisanal fishers along the northern Zamboanga and Bohol Sea corridor in southern Philippines. Logbook data and gonadal maturity analysis of the dominant Bali sardine *Sardinella lemuru* caught by RSVP volunteers during the peak spawning period for three years were used to plot the possible spawning grounds. Results show that most of the mature sardines are caught within a few kilometers from the shore indicating that spawning occurs nearshore across the NZP-Bohol sea system. However, results from RSVP are limited by the preference of volunteers to fish in nearshore waters where sardine and other SPF are abundant. Known to be migratory schooling fish, sardines possibly spawn in deeper waters outside the bays. Nonetheless, GPS tracking provides spatially explicit data on potential spawning grounds and demonstrates the benefits of combining geo-referenced information on fisheries data and biological surveys into time-series resource maps. RSVP also demonstrates the invaluable participation of fishers in producing spatially explicit information for improved fisheries management that will benefit the sardine fisheries industry.

(S5 Oral 15271)**Classifying pelagic fishing vessel activity based on data from electronic catch logs and positioning systems using machine learning methods**Cian **Kelly** and Morten Omholt Alver

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There are rising demands to utilize data available to fishing vessels for marine spatial planning, improved monitoring of fishing activity and dynamic management of stocks. Data from fishing vessels is part of best available information which is possible to utilize for the above purposes. In the Norwegian herring fishery, fishing vessels actively seek out schools of fish with fish finding equipment and there is a desire to utilize available data to harvest stocks more efficiently and sustainably. One constraint for sustainable harvesting is knowledge of the spatial distribution of fish when navigating between fishing grounds. Vessels spend more time and fuel than necessary pursuing target stocks. Given the scale of migrations of small pelagic fish such as herring, there are high uncertainties in spatial distribution at any point in time. Spatiotemporal abundance can be inferred from the activity of fishing vessels. Specifically, position, speed, turning angles and spatial extent of fishing vessels can be used to classify the activity of individual vessels. We present a time-series classification algorithm for classifying vessels based on whether they are searching, actively fishing, or steaming between locations. The classification is based on 2020 data from Automatic Identification Systems, which is updated approximately every 10 seconds. Following activity classification, we use a model that predicts the scale of the catch based on duration and spatial extent of the fishing event, and information about the vessel, such as length, width, and engine power. There were 186 purse seining vessels included in the dataset, which provided a comprehensive training set. The classifications for fishing and the weight of the predicted catch were compared to electronic catch logs, to confirm the correspondence to true reported values for individual vessels. Further work may integrate the activity of all vessels to derive information about the large-scale abundance of small pelagic fish.

(S5 Oral 15305)**Processing and interpretation of opportunistic acoustic data collected by Dutch fishing vessels**Benoit J.P. **Berges**¹, Serdar Sakinan¹ and Martin Pastoors²¹ Wageningen Marine Research (WMR), IJmuiden, The Netherlands. E-mail: benoit.berges@wur.nl² Pelagic Fish Association (PFA), Zoetermeer, The Netherlands

Since 2012 the Dutch pelagic fishing industry has been engaged in the routine collection of data alongside fishing operations at a large scale in the North Sea and Northeast Atlantic. This data collection program is generating an ever-increasing wealth of echosounder and biological data that enables monitoring of fish stocks at a fine spatial and temporal scale. However, there is two main bottlenecks in the use of these data. First, the processing of this wealth of acoustic data is challenging and warrants the development of automatic processing routines. This is because of the large data volume and inherent variability associated with these opportunistically collected data. Second, any use of processed acoustic outputs is hampered by obvious targeting behaviour from fishing as opposed to indices from scientific surveys that benefit from standardized sampling.

In the hereby presentation, the work undertaken to untap the potential of available industry data will be presented. First, the progress in the use of machine learning algorithms for scalable and flexible echosounder data processing will be shared. Second, an approach using synthetic transects (mimicking survey design) for the interpretation of processed acoustic outputs will be presented. Results of the application of this approach on Blue Whiting data from Dutch pelagic vessels from 2017-2021 will be shown and compared with the dedicated scientific survey (IBWSS).

(S5 Oral 15353)**Using Vessel Monitoring System, electronic log-book and landing data to link fishing effort and vessel trajectory to spawning stock biomass and catches**Paco **Rodriguez-Tress**¹, Claus Reedtz Sparrevojn¹ and Stefan Neuenfeldt²¹ Danish Pelagic Producers Organisation, Copenhagen, Denmark. E-mail: pacrigu@aqua.dtu.dk² National Institute of Aquatic Resources, Technical University of Denmark, Lyngby, Denmark

Scientific fisheries surveys use standardized catch per unit of effort (CPUE) data to monitor changes in fish stock abundance over time. For the application of commercial catch data, it is crucial to first identify clearly what metrics for effort can effectively be applied for CPUE calculation. With a focus on the Danish herring fisheries in the North Atlantic (ICES Area 4), we used vessel monitoring system (VMS), logbook information and landing declarations from 2013-2020 to determine how effort metrics, search time and estimated spawning stock biomass (SSB) relate to recorded catches. A recurrent-type neural network (LSTM) was used to identify fishing sets from the raw VMS data where records were missing in the logbooks and to classify trajectories into fishing, searching and steaming activity. The three datasets were merged to develop several variables characterizing fishing activities and metrics for vessel trajectories at the year, sea trip and haul scales. The metrics included trip and fishing duration, number of hauls per cruise, time to first haul and overall search for fish time. Finally, a GLMM type statistical approach with different error and correlation structures was used to test the effect of SSB on herring catches and identify the most reliable measure of effort. At both the trip and fishing haul temporal scales the SSB significantly explained the catch for the selected models, but this was not observed at the year level. With SSB fixed, different measures of effort were found to explain statistically the catch.

(S5 Oral 15328)**Cooperative research: The integration of fishing industry-collected data to improve temporal coverage of hydroacoustic data collection**Stefanie **Haase**, Daniel Stepputtis and Christopher Zimmermann

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Scientific hydroacoustic surveys are commonly used to estimate the abundance of small pelagics and give a snapshot of the current spatial distribution. Small pelagics are, however, highly migratory species with pronounced seasonal distribution patterns. Conducting a survey once or twice a year keeps questions often unanswered regarding spatial-temporal movements and behaviour as well as the overlap with predator and prey species outside the survey period. Rapid changes in environmental conditions and a movement towards ecosystem-based management increase the need for a more complete temporal coverage compared to the traditional surveys. This cannot be accomplished by research vessels alone. The collection of high-quality acoustic data recorded on commercial vessels during the regular fishing operation could increase the temporal coverage and provide knowledge of fish distribution during the fishing season. We use the Baltic Sea as a case study where a pelagic trawler collects hydroacoustic measurements with frequencies of 38 and 120kHz during its normal fishing operations targeting sprat. This information is coupled with catch information including effort and catch compositions. Further, an autonomous measurement system can monitor the hydrographic conditions during fishing. This gives a holistic overview of the fishing season targeting Baltic sprat. Conducted over several years it may enable us to spot changes in population structure outside the survey period. We present first results and lessons learned from the data collection during the first season. Collecting these data help us to supplement the scientific hydroacoustic pelagic surveys and to better understand the marine ecosystem and eventually improve fisheries management.

(S5 Oral 15330)**Ready for industry-led pelagic acoustic surveys?**Steven **Mackinson**

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State-of-the-art large pelagic vessels have state-of-the-art acoustic instruments including sonars with 5+ mile search radius, multi-beam bottom profiling systems and scientific-grade echosounders covering multiple frequencies. The reason is simple – these are the tools of the trade, so having them and knowing how to use them well is important. However, while many fishermen know how to optimise their tools to each specific fishery, few have a deeper understanding or interest in technical aspects that influence the performance of their operation. When pelagic vessels are chartered for scientific surveys, some of the skills and experience of acoustic scientists get picked up by skippers, thus equipping them with additional knowledge that might improve their effective use of these tools. Some of the skippers knowledge gets picked up by the scientists too, particularly regarding the context of their observations and how to interpret them. And while on board, scientists are frequently challenged about the design of acoustic surveys and why so little of the available acoustic capability is actually used in science. The opportunities to do better are there, but little explored – mainly because scientists doing acoustic surveys have to follow certain agreed procedures, and improving these is an evolutionary process. I put the case forward for enhancing research collaboration on acoustic surveys in partnership with the fishing industry for the following reasons (i) knowledge transfer is a rapid way to learn that empowers those involved, (ii) pelagic skippers are skilled professionals with a keen interest to learn if it affects their fishing performance, (iii) pelagic vessels are an ideal research platform being quiet, well equipped and stable, (iv) the data that is continually amassed by the fishing fleet is a goldmine of information on distribution, behaviour and abundance of fish, if only it can be harnessed. So what is needed to capitalise on these opportunities and could we envisage a time when fishing vessels do acoustic scientific surveys without the need for a scientist on board?

(S5 Oral 15496)**Assessing external environmental drivers for the Moroccan chub mackerel (*Scomber colias*) population dynamics**Ghoufrane **Derhy**¹, Diego Macías², Karima Khalil¹, Khalid Elkalay¹ and Margarita María Rincón³

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Small pelagic population are characterized by a considerable fluctuation dynamic forced by fishing pressure and natural factors. In the case of chub mackerel harvested in Moroccan Atlantic coast, the knowledge about this environmental forcing is very limited. This study region is characterized by high environmental variability due to the upwelling phenomenon, resulting in a significant abundance of small pelagic stocks. Therefore, considering the high important place that chub mackerel occupies in the total Moroccan small pelagic fishery, the understanding of its environmentally driven dynamics is of paramount importance. The objective of this study is to evaluate the correlation between environmental factors and population trend estimated by a DLM approach for stock assessment. To identified these drivers, an approach has been adopted to estimate first population fluctuations through a Surplus Production model in Continuous Time, and then proceed to the Pearson correlation analysis between the model outputs and environmental data. The results show a significant correlation with salinity, net primary production, oxygen, nitrate and chlorophyll concentrations that are consistent with spatio-temporal variations of chub mackerel. The years with high biomass are linked to the very high physical variability of the Upwelling, accompanied by specific variations of other environmental parameters that are also tested. Based on these results, the SPiCT model in which environmental covariates are modeled as random variability can be developed by integrating those relationships. The development of this model can help managers to improve stock assessment results to achieve a sustainable management of the stock considering all external factors.

S6. Reconciling Ecological Roles and Harvest Goals: Development and Testing Management Strategies to Enhance Marine Ecosystem Services

(S6 Invited 15238)

A novel multispecies framework for setting ecological reference points for Atlantic menhaden management

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Atlantic menhaden (*Brevoortia tyrannus*) is the target of the largest fishery on the East Coast of the United States and is a pelagic forage fish. Concern for the resource and acknowledgment of competing interests led to the development of ecological reference points (ERPs) for Atlantic menhaden. ERPs were developed using single species assessments, as well as several multi-species models. In particular, two Ecopath with Ecosim (EwE) models were developed to evaluate the trade-offs between Atlantic menhaden harvest and predation: a full EwE model and a MICE (Model of Intermediate Complexity) EwE. The MICE EwE had similar dynamics as the full EwE model but included a reduced set of predator and prey species. The MICE EwE model adequately addressed managers' objectives, required a comparatively reduced workload to update, and allowed for comparison of tradeoffs. Thus, the MICE EwE, coupled with the single species assessment, was used for development of ERPs. Striped bass (*Morone saxatilis*) was found to be the most sensitive predator species to fishing pressure on Atlantic menhaden. Therefore, the MICE EwE was used to assess tradeoffs in striped bass biomass and Atlantic menhaden fishing mortality, while other species were fished at their current rate. The ERPs recommended were those that permitted Atlantic menhaden harvest while leaving enough prey for striped bass when their population was at their target and threshold levels. In August 2020, ERPs were formally adopted to set harvest limits for Atlantic menhaden, advancing management of this forage fish from a single species to a multispecies framework.

(S6 Oral 15194)

Baltic sprat management strategy evaluation using a Surplus Production Model as biological model

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Management Strategy Evaluation (MSE) is a process designed to identify and operationalize fisheries management strategies that are robust to several types of uncertainty and capable of balancing multiple economic, social, and biological management objectives. MSE is a central part of the scientific advice to fisheries management. There are, however, known unknowns in the age-based frameworks with respect to considering ecosystem functioning via density-dependent mechanisms. Density-dependent growth, maturity, and natural mortality are generally unknown and neglected. The present study addresses these known unknowns by using well-known Surplus Production Models (SPMs), as the operating models in MSEs. SPMs allow considering ecosystem functioning via all four density-dependent mechanisms combined. Based on a comprehensive analysis of regime shifts in the Baltic relevant for the productivity of the Baltic sprat stock the best Surplus Production Model (SPM) to reflect the Baltic sprat productivity for 2020-2030 was obtained. This was based on 1) catch and total stock size from annual assessment by ICES, 2) a published meta-analysis on the average SPM curve shape for 147 data rich global stocks

by taxonomic group, 3) a published meta-analysis on MSY/B_{MSY} (F_{MSY}) for 53 data rich in the Northeast Atlantic fish stocks using an ensemble approach including a relationship to the population dynamic parameters ($Linf \cdot K$ from the von Bertalanffy growth curve, and age-at-50% maturity), and 4) good modelling practice including e.g. considerations of the AICc criteria and trends in residuals.

(S6 Oral 15219)

Evaluating robustness of harvest control rules to variability in Pacific sardine recruitment

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Pelagic forage fishes exhibit large, cyclic fluctuations in biomass driven by periods of highly successful recruitment followed by stock collapse. Fluctuations in ocean temperatures, currents, and productivity resulting from climate change may disrupt or alter these recruitment cycles, and fisheries management must adapt to this added uncertainty if sustainable harvest of forage species is to continue. Using Pacific sardine as a case study, we conducted a management strategy evaluation to assess the robustness of current and alternative environmental harvest control rules under a variety of recruitment variability scenarios. The current control rule for Pacific sardine determines catch limits for the northern subpopulation as a function of biomass estimates from the stock assessment and an environmental correction using average sea surface temperature measured during field cruises of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program. Alternative harvest control rules tested here included a constant harvest rate and rules developed to account for reliance of predators on forage fish prey. We tested each of these rules against scenarios in which randomly generated recruitment deviations were produced from distributions reflecting historical estimates, with and without autocorrelation, or in which the mean recruitment followed a trend as may be expected as climate changes. Successful harvest control rules had higher mean stock biomass and catch, with low catch variability, few fishery closures, shorter stock rebuilding periods, and higher mean lengths and ages on average. Our study explores the possibilities and potential impediments to sustainably harvesting highly variable forage fish stocks in an increasingly dynamic ocean.

(S6 Oral 15355)

Evaluation of harvest control rules for joint management of Atlantic menhaden and striped bass

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Atlantic menhaden (*Brevoortia tyrannus*) is a migratory forage fish that plays a vital role in Chesapeake Bay and Mid-Atlantic marine ecosystems by linking production at lower trophic levels with piscivorous predators. Given the critical ecosystem services menhaden provide as forage, the Atlantic States Marine Fisheries Commission has implemented an Ecosystem Approach to Fisheries Management (EAFM) for this species. Managers and stakeholders are particularly interested in potential impacts of menhaden management on its primary predator, striped bass (*Morone saxatilis*). We conducted a performance evaluation of a suite of alternative harvest control rules (HCRs) for menhaden using a linked, age-structured, predator-prey simulation model of Atlantic menhaden and striped bass. The model also included condition-based natural mortality for striped bass in which their natural mortality rate increased if their condition was below a threshold. HCRs tested in our model included constant and biomass-based fishing mortality rate HCRs. We examined the direct effects of alternative menhaden HCRs on the menhaden stock and fishery performance as well as the indirect effects of menhaden HCRs on the striped bass stock and fishery. Robustness trials included modifying assumptions about prey size preference for the predator and alternative recruitment scenarios. As expected, HCRs with higher fishing mortality rates on Atlantic menhaden resulted in lower Atlantic menhaden biomass and lower striped bass biomass. However, the effects on striped bass were dampened relative to those on Atlantic menhaden. Our model will be helpful in identifying ecosystem-based HCRs that address management objectives to account for menhaden's role as a forage fish.

(S6 Oral 15372)**Use of Management Strategy Evaluation to derive a sustainable and precautionary harvest rate for a data-limited stock of sprat in the English Channel**

Nicola D. Walker¹, Rosana Ouréns¹, Johnathan E. Ball¹, Jeroen van der Kooij¹, Andrés Uriarte², Jonathan White³, Piera Carpi⁴, Pia Schuchert⁵ and Richard D.M. **Nash**¹

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Empirical harvest control rules set catch advice based on directly observable indicators and are increasingly being used to manage fish stocks that lack a formal assessment of stock and exploitation status. Within the International Council for the Exploration of the Sea (ICES), trend-based rules that adjust advice according to recent survey observations have been adopted; however, there is increasing evidence that such rules do not work well for short-lived pelagic species that exhibit large fluctuations in stock size. Constant harvest rates that remove a fixed proportion of observed biomass have been proposed as a more suitable alternative, although the unknown catchability of data-limited stocks remains a barrier to implementation in practise. Here we employ a Management Strategy Evaluation (MSE) framework to derive a sustainable constant harvest rate for the English Channel sprat stock based on existing and borrowed life-history parameters and precautionary considerations. We show that the constant harvest rate outperforms trend-based catch rules in terms of maximising yields whilst reducing risks and propose an 8.57% constant harvest rate is sufficiently precautionary for catch advice for this stock.

(S6 Oral 15415)**Evaluation of harvest control rules under different productivity regimes - The Iberian sardine case study**

Laura **Wise**¹, Manuela Azevedo¹, Susana Garrido¹, Hugo Mendes¹, Alexandra A. Silva^{1,2}, Leire Citores³, Leire Ibaibarriaga³, Isabel Riveiro⁴, Andrés Uriarte³ and Sónia Sánchez-Maróño³

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Following a decrease in the abundance of the Iberian sardine, reaching values below B_{lim} , and the perceived impossibility of rebuilding above this level in the short-term (2 years), a full-feedback Management Strategy Evaluation framework was implemented in FLBEIA to test the performance of different Harvest Control Rules (HCRs) against a set of performance statistics. The achievement of management objectives and compliance with ICES precautionary criterion were quantified. The conditioning of the operating model was based on the stock assessment (Stock Synthesis) and included recruitment stochasticity. Since no high recruitment had been observed in the last years, the uncertainty if this was the result of a general decline or a shift of productivity regime was a matter of concern. Therefore, several scenarios with different Operating Models (four different Hockey-stick stock-recruitment models according to alternative scenarios of productivity) and different Management Procedures (i.e. advice assumptions on the Biological Reference Points) were simulated for 1000 populations in a period of thirty years. The management cycle, included observation error and the current assessment model in each simulation loop. Abundance indices were generated from the true population with lognormal distributed errors. Observation error was also introduced in the numbers-at-age in the catch as a multiplicative lognormal error. Performance statistics (such as catch, spawning stock biomass and fishing mortality) were estimated for three time periods: initial, short and long-term. Given the uncertain recruitment productivity of the stock, the selected HCRs are risk averse to the scenario of poorest productivity.

(S6 Oral 15418)**Managing data-limited stocks with harvest rate-based rules based on an abundance index**Sonia **Sánchez-Marroño**, Andrés Uriarte and Leire CitoresMarine Research, AZTI, Basque Research and Technology Alliance (BRTA), Pasaia, Spain. E-mail: ssanchez@azti.es

Managing small pelagic fish (SPF) stocks is challenging due to their fluctuating nature, and if they are data-limited (DL) stocks management becomes harder. For these DL stocks, when supported by historical catches and a biomass index, ICES concludes that advice could be based either on surplus production models (like SPiCT) or on a constant harvest rate (HR) of the biomass reported by the index estimated through management strategy evaluation (MSE). If this was not possible, advice could also be provisionally given based on the most recent catches times a relative trend from the ratio between the last available biomass index and the average of the two preceding ones (restricted by an 80% interannual catch variation limit). However, this harvest control rule was considered as interim because implies long-term yield losses to the fishery. Literature suggests that HRs might better serve to manage these data limited SPF stocks. Here we use the MSE approach (with the FLBEIA software) to test several alternative HR-based rules, proposed originally in literature as trend-based rules modifiers of previous advice. In addition, a new “perturbation reaction” rule is proposed, intended to correct initial HRs towards Maximum Sustainable Yield (MSY) levels based on the reaction of the abundance index to a 25% initial reduction of the mean HR prior to management. Some of these rules resulted in a reasonable compromise between the expected yields relative to MSY and the risks for the stock of falling below B_{lim} , for SPF stocks subject to different interannual variability.

Keywords: data-limited, management strategy evaluation, FLBEIA, short-lived stocks, harvest-rate control rules.

(S6 Oral 15421)**Development of management procedures for the Pacific saury, *Cololabis saira***Toshihide **Kitakado** and Nanako SekiguchiTokyo University of Marine Science and Technology, Tokyo, Japan. E-mail: kitakado@kaiyodai.ac.jp

Pacific saury is widely distributed in the subarctic and subtropical North Pacific and migrates widely between feeding grounds in the north and spawning grounds in the south. The stock is of commercial interest to several countries and is currently managed by the North Pacific Fisheries Commission (NPFC) as an international species. Recent stock assessment results in the NPFC based on a provisional model suggested that the stock has steadily declined from near environmental carrying capacity in the mid-2000s to the current record low level. However, the relative importance of fisheries and environmental factors in saury population dynamics remains unclear. Furthermore, the accuracy of future predictions is problematic due to the biological nature of their short life span and large migratory patterns. It is desirable to develop a systematic management procedure to recover and sustainably utilize this depleted stock. In this study, a hybrid management procedure with a traditional HCR based on a simple stock assessment model and a result of fishery-independent survey in the most recent fishery is formulated and evaluated under the framework of management strategy evaluation with relatively simplified operating models with and without environmental effects. The results suggest that there is large potential to improve performance in terms of both population conservation and catch performance compared to traditional HCRs. Results for further evaluation in terms of robustness testing are to be discussed.

(S6 Oral 15465)**The impact of natural mortality on reference points and management strategies of forage fish populations**Nis S. **Jacobsen**¹, Margaret C Siple², and Tobias K Mildenerger¹¹ Technical University of Denmark, National Institute of Aquatic Resources, Kemitorvet 1, Lyngby 2800, Denmark. E-mail: nsja@aqua.dtu.dk² Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, Seattle, WA, 98115, USA.

Natural mortality (M) is an essential parameter in stock assessments and ecological models. For small pelagic species, increases in M can function similarly to increases in fishing mortality, augmenting the extent and duration of collapse periods. Despite this, stock assessments rarely detect or include changes in M. Long term trends in M can cause different effects on management performance, depending on how detectable they are and how responsive management are to changes. We use management strategy evaluation to test the ways in which basic harvest control rules (HCR) perform under different M scenarios across a range of species and life history parameters. Using an age-structured operating model we simulate four natural mortality scenarios: a) decreasing, b) increasing, and c) autocorrelated random walk and d) constant mortality. We compare three simple HCR, a constant fishing rate, a “hockey-stick” rule with a lower trigger limit, and a biomass escapement rule. In each year of the simulation, a state-space surplus production model (estimation model, EM) is used to estimate reference points and the total allowable catch. The EM provides reasonable temporal biomass estimates based on total catch and an annual survey in all scenarios, but fail to accurately estimate reference points. Accuracy of estimation depends on life history, in particular maximum length and magnitude of mortality. We recommend employing management strategy evaluation to investigate the structural uncertainty of assessment models in fisheries where the stock has variable biological rates to find the best performing harvest control rules.

(S6 Oral 15434)**Spatial population dynamics of sardine in the Northeast Atlantic and the western Mediterranean Sea: Defining areas, estimating movement rates and exploring spatial stock assessment models**Alexandra A. **Silva**^{1,2}, Susana Garrido^{1,2}, Jilali Bensbai³, Pablo Carrera⁴, Leire Citores⁵, Erwan Duhamel⁶, Leire Ibaibarriaga⁵, Magdalena Iglesias⁷, Ana Teles-Machado^{1,8}, Ana Moreno¹, Richard Nash⁹, Lionel Pawlowski⁶, Isabel Riveiro⁴, Fernando Ramos¹⁰, Rosana Ourens⁹, Andres Uriarte¹¹, Jeroen Van der Kooij⁸, Pedro Torres¹², Ana Ventero⁵ and Laura Wise¹¹ IPMA - Instituto Português do Mar e da Atmosfera, Lisboa, Portugal. E-mail: asilva@ipma.pt² MARE – Marine and Environmental Sciences Centre, Lisboa, Portugal³ INRH - National Institute of Fisheries Research, Morocco⁴ Centro Oceanográfico de Vigo, Instituto Español de Oceanografía, Vigo, Spain⁵ AZTI, Bizkaia, Spain⁶ IFREMER, Lorient, France⁷ Centro Oceanográfico de Baleares, Instituto Español de Oceanografía, Palma, Spain⁸ IDL - Instituto Dom Luiz, Lisboa, Portugal⁹ CEFAS - Centre for Environment Fisheries and Aquaculture Science, Lowestoft, United Kingdom¹⁰ Centro Oceanográfico de Cádiz, Instituto Español de Oceanografía, Cádiz, Spain¹¹ AZTI, Pasaia-Bizkaia, Spain¹² Centro Oceanográfico de Málaga, Instituto Español de Oceanografía, Fuengirola, Spain

Previous research suggested that sardine populations of the Bay of Biscay and Iberian coast form a meta-population with source-sink movement from nursery to adult areas driven by the density of recruits and water temperature. This study aimed to: (i) investigate if the reported population structure, connectivity patterns and drivers have persisted over time and are similar in other areas of the species range; (ii) propose scenarios of spatial population structure and movement rates between areas; (iii) apply spatial stock assessment models and compare the results with those of non-spatial stock assessments conducted in the region. Area- and, in some cases, age- disaggregated data collected in scientific surveys and fisheries spanning the Celtic Seas and the English Channel, the Bay of Biscay and Atlantic Iberian waters, the western Mediterranean Sea and the Moroccan waters were used to model the spatial progression of cohorts and derive movement rates between areas. Several scenarios of stocks/areas and mixing matrices were explored with spatial assessment models using Stock Synthesis, the model currently used in the assessment of sardine stocks in the Bay of Biscay and the Cantabrian Sea and Iberian coast. The performance and biological realism of the spatial assessments compared to non-spatial assessments in corresponding areas was discussed.

(S6 Oral 15246)**Informing the ecosystem-based fisheries management of the Iberian sardine stock in the Portuguese continental shelf through a spatial-temporal food-web model**Dorota **Szalaj**^{1,2}, Alexandra Silva^{2,3}, Henrique Cabral⁴, Pedro Ré^{2,5}, Jeroen Steenbeek⁶ and Marta Coll^{1,6}¹ Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain. E-mail: dszalaj@fc.ul.pt² Marine and Environmental Sciences Centre (MARE), Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal³ Instituto Português do Mar e da Atmosfera (IPMA), Alges, Portugal⁴ INRAE, UR EABX, Cestas, France⁵ Faculdade de Ciências de Universidade de Lisboa (FCUL), Lisboa, Portugal⁶ Ecopath International Initiative, Barcelona, Spain

Marine ecosystem models are effective tools to support the management of depleted stocks. They are timely, as global policies around the world along with the scientific community, agreed that fisheries management should encompass ecosystem considerations. Iberian sardine (*Sardina pilchardus*) stock has undergone a considerable decline since 2009. Now the stock biomass has stabilised and is considered at the recovery stage, however, due to the high economic value, the need to better understand and manage this resource maintains a priority. We developed static Ecopath, time-dynamic Ecosim and spatial-temporal Ecospace models to better understand the drivers of sardine decline, its trophic interactions and to assess the management strategies that could maintain the future stock status at sustainable levels. Results illustrated that the main driver of sardine dynamics and at the same time its main future threat is an increase in SST. Also, results support the hypothesis that egg predation has contributed to the decline of sardine. Moreover, the model showed that sardine FMSY can maintain the sardine stock at a healthy state in future, having the ability to dampen the negative effects associated with changes in the biomass of sardine predators and competitors.

This study illustrates that ecosystem models can effectively support fisheries management, by improving the knowledge about the dynamic of the species and by allowing testing management strategies.

(S6 Oral 15311)**Investigating the influence of ‘minor’ krill-predators (the leopard seal, Adélie penguin, marbled rockcod, and mackerel icefish) on the krill-predator dynamics of the Antarctic ecosystem in the region where their abundance relative to the major krill-predators is relatively large**Naseera **Moosa** and Doug. S. Butterworth

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Krill (*Euphausia superba*) is a small pelagic crustacean and constitutes the largest forage fish resource in the Antarctic ecosystem. Over recent decades, a krill fishery has slowly expanded in this region. As a result, there is an increasing interest in how to harvest krill optimally without unduly impacting its natural predators. Many whale, seal, penguin and fish populations feed primarily on krill and share similar feeding grounds south of 60°S around Antarctica. In 2006, the Mori-Butterworth ecosystem model attempted to explain the population dynamics of the major krill-eating species in the Antarctic through predator-prey interactions only. Roughly ten years later, this krill-predator model was refined in Moosa (2017). Moosa found the important krill-predators south of 60°S to be the Antarctic blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), Antarctic minke whale (*Balaenoptera acutorostrata*), Antarctic fur seal (*Arctocephalus gazella*), crabeater seal (*Lobodon carcinophagus*), leopard seal (*Hydrurga leptonyx*), Adélie penguin (*Pygoscelis adeliae*), marbled rockcod (*Notothenia rossii*) and mackerel icefish (*Champscephalus gunnari*). However, as with the Mori-Butterworth (2006) model, Moosa also considered only the main krill-predators in her analysis. These main predators were determined to be the blue, fin, humpback and minke whale species, and the crabeater and Antarctic fur seal species, based on each of their annual circumpolar krill consumption by weight being estimated to exceed one million tonnes. The aim of this paper is to expand the ecosystem model developed by Moosa so as to include the ‘minor’ krill-predators, i.e. the leopard seal, Adélie penguin and the two fish species; the marbled rockcod and mackerel icefish. The region of focus, in contrast to the Antarctic-wide level considered in Moosa (2017), is a smaller area, the IWC (International Whaling Commission) Management Area II (60°W - 0°), which includes the Antarctic Peninsula and the area around South Georgia. This is also the only region for which abundance information is available for all the krill-predators considered. Furthermore, whereas these ‘minor’ krill-predators

have a negligible influence on the ecosystem dynamics at an Antarctic-wide level, for this single management area this may not be the case as abundances of many of these ‘minor’ predators is rather greater relative to the major predators. Outputs from the analysis in this paper are compared to those from Moosa (2017). The overall aim is to identify any appreciable differences in results when these ‘minor’ krill-predators are incorporated.

(S6 Oral 15380)

Fishing fleets vs Predator: Can we reconcile the ecological roles of small pelagic fish and their exploitation in a climate change context?

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Since small pelagic fish (SPF) are essential to many predators, management strategies for SPF should account for indirect effects of harvest rules on these species. Moreover, by changing SPF-predator trophic interactions, climate change may reduce robustness of management strategies. In the California Current (CC), a portfolio of SPF (e.g., Pacific sardine, Northern anchovy, market squid) supports a variety of protected and valuable commercial species. Over the last decades, these SPF have experienced distribution changes that are expected to heighten in the future. To study the sensitivity of the CC predators to SPF distribution shifts and alternative SPF fisheries strategies, we used an end-to-end ecosystem model. The CC Atlantis model notably integrates data from an extensive diet database, species distribution models (SDMs) of SPF and predators (e.g., tunas, pinnipeds, pelicans), and utilizes fishery logbook data and métier statistical clustering of relevant fleets. Forced by the SDMs, our model predicted spatiotemporal changes in the diet, consumption, and population dynamics of predators among past contrasting years. Once synthesized as metrics of sensitivity to SPF distribution changes, results highlighted heterogeneous responses among predators, reflecting their ability to maintain spatial overlap with their prey under changing conditions, diet plasticity, and life-history strategies. The integration of effort and spatial footprints of SPF fleets enabled characterizing fleets’ adaptation to such changes, and quantifying their interactions with predators. In the next steps, the CC Atlantis model will project climate change impact on SPF, predators and fisheries and perform management strategy evaluations via coupling to single-species models.

(S6 Oral 15400)

Sustainable exploitation of Celtic Sea sprat avoiding ecosystem impacts

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Sprat is a target species in the Celtic Sea; however, current harvest advice is based on landings, and there is insufficient information to estimate stock status, trends, or target and limit reference points. As well as being a valuable commercial species, sprat are a major predator on zooplankton, an abundant prey for piscivorous fish and a competitor for herring. Ensuring the sustainable exploitation of sprat is therefore important for both the health of the Celtic Sea’s marine ecosystem and for the wider fisheries sector in Ireland. To develop robust advice, we conduct Management Strategy Evaluation using a multi-stock single species sprat operating model conditioned on life-history theory and linked to an Ecosystem Model of Intermediate Complexity. We show how ecosystem understanding can be incorporated within the existing precautionary and maximum sustainable yield frameworks. This novel approach allows environmental drivers, such as sea surface temperature, to more complex emergent food web indicators, to be simulated and the benefits of alternative harvest control rules to be evaluated. As a result, we identify key improvements that could be made to current data collection, surveys, biological knowledge, and assessments and management to provide advice for sprat harvest in the Celtic Seas that is robust to uncertainty.

(S6 Oral 15319)

A bioeconomic model for the Portuguese purse seine fleet: Towards an ecosystem-based management

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Defining management plans for sustainable exploitation of fish stocks requires an effective multidisciplinary approach to combine detailed biological knowledge with economic modelling. Evidence of species ecological interdependence and the sensitivity of fish stocks to climate change emphasizes the need for an ecosystem-based approach to define harvest plans. Fisheries management, however, is still mostly grounded on single-species models and disregards broader biological, environmental, and economic interactions between different fish stocks.

We build an ecosystem-based bioeconomic model to optimize harvest rates of the Ibero-Atlantic purse-seine fishery targeting three major pelagic species: sardine, horse mackerel and chub mackerel. An age-structured multispecies model is thus parametrized to account for the trophic relationship between species and for the sensitivity of sardine recruitment to environmental variables.

Results of the model are then compared to single-species optimization and used to assess the current harvest control rules, highlighting the importance of ecosystem-based fishery management to ensure climate-resilient and economically sustainable fish populations.

(S6 Oral 15389)

Industry-science collaboration to enhance traditional fisheries data collection

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In recent years the Scottish pelagic industry has become increasingly involved with science and research activities. Scottish pelagic vessels provide valuable research platforms, with state-of-the-art technology, and highly experienced and knowledgeable crew, who are keen to engage with science. Participation in science activity in recent years has included both fisheries independent data collection (through industry surveys) and fisheries dependent data collection (through an industry-science collaborative programme). The Scottish Pelagic Industry Data Collection Programme was initiated as a pilot in 2018, developing to a fully established long-term data collection programme in 2021, and providing data to stock assessment in 2022. Early work during the pilot stage was focused on developing robust methods that could provide quality data for utilisation within science, research and stock assessment. Now an established programme with 5 years of data available, we take a critical look at the data being collected and assess their application to current, and future, stock assessment and research questions. We consider what additional insight the data can offer to traditional data collection methods? And with an established long-term data collection programme in place, what are the next steps in gathering further information to better inform management of Scottish pelagic fisheries? The significance of the programme is also considered in the wider context of international coordination of fishery data monitoring, with the potential to contribute to and improve regional catch sampling of widely distributed pelagic stocks in the north-east Atlantic.

(S6 Oral 15269)**The North Kenya Banks pelagic fishery in the context of climate change**

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Kenya's tropical coastal zone is characterized by a narrow continental shelf that widens at the northern part near the Somalian border where it extends to about 60 km offshore. As a regionally important extension to the otherwise narrow East African continental shelf, the North Kenya Banks remain under studied with implications for efforts to develop a sustainable fisheries management strategy. The local marine ecosystem is known to be strongly influenced by wind driven upwelling processes with seasonal variability driven by the changing monsoon seasons being of particular importance. Elevated phytoplankton biomass has been reported in coastal waters during the north east monsoon (NEM), a period of upwelling, which subsequently promotes an increase in zooplankton abundance. Climate change is projected to impact marine biogeochemical and oceanographic processes ultimately altering ecosystem dynamics. However, whilst climate change is expected to directly impact Kenyan fisheries, associated ecosystem biodiversity and ultimately impact livelihoods, considerable uncertainty remains around the future timing and severity of these impacts. Alongside efforts to increase fishing intensity are efforts to develop a sustainable fisheries management strategy for the North Kenya Banks. However, knowledge of the various system components, for which there is currently a lack of information, hinder this ambition.

(S6 Oral 15493)**Exploring responses in Norwegian spawning herring to multiple stressors using an end-to-end ecosystem model (NoBa Atlantis)**

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Climate change in the high North is expected to be more rapid and severe than in many other marine areas. It is anticipated that the Norwegian spring spawning herring (NSS herring) will experience a positive response to climate change, if managed well. Norwegian SSH is a divided stock, where the juveniles grow up in the Barents Sea, before moving out into the Norwegian sea when maturing. In this study, we used a complex end-to-end ecosystem model (NoBa Atlantis) to explore combined effects on the NSS herring stock, following a set of different physics, recruitment, temperature-response and management regimes. The physics (salinity, temperature, ocean currents) were either kept constant at 2017 conditions (a normal year) or followed a climate change projection (RCP4.5), until 2070. Fisheries management was changed between no harvest, harvesting at specific fractions of maximum sustainable yield of all commercial stocks, or adding selectivity (either constant or time-varying) for commercially exploited demersal stocks in the Barents Sea, while recruitment and temperature dependency each followed two paths. For all simulations but those harvesting at specific fractions of MSY, the management of herring was left untouched (following a historical pattern, and thereafter kept constant at MSY for the future projection). In the presentation, we will identify how climate, recruitment, temperature dependency and management each contribute to the responses in NSS herring stock. We will discuss how important the indirect ecosystem effect (e.g. predation while juvenile) is to the stock development, and how managers can possibly deal with the combination of multiple stressors to a variable stock.

(S6 Oral 15511)**Projections of climate change impacts on California Current pelagic species, and on the performance of harvest rules and stock assessments**Isaac C. **Kaplan**

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Small pelagic species in the California Current respond to this region's dynamic oceanography, exhibiting regimes evident over historical periods, and recent peaks and troughs of species such as sardine (*Sardinops sagax*) and anchovy (*Engraulis mordax*). Climate change impacts on these species are therefore expected, and will be a challenge to sustainable use and fishery management. Using Atlantis ecosystem model simulations, we have tested different mechanisms of climate impacts on the ecosystem. These include increasing ocean temperature and effects on metabolic rates; shifts in species distribution and changes in predator-prey overlap; and changes in recruitment. The Atlantis simulations include food web dynamics on a three-dimensional grid, forced by downscaled oceanography representative of what is expected for the 2060s. For sardine in particular, results suggest that temperature and metabolic shifts may lead to moderate changes in growth, while shifts in predation mortality and recruitment may have stronger impacts on the stock. Using the R package *AtlantisOM*, we link Atlantis simulation output to a Stock Synthesis assessment, evaluating the performance of different options for handling growth and natural mortality parameters, and how these account for climate-driven short-term variability and long-term trends. We evaluated stock assessment performance, and the management performance of harvest rules when fishing rates were set based on reference points estimated in the assessment. This work parallels similar simulation testing with the Nordic and Barents Seas Atlantis model, and benefits from a suite of models developed by the Future Seas project in the California Current.

(S6 Oral 15513)**Observation, prediction and early warning system for the resilience of small pelagic fisheries in the Humboldt Current Large Marine Ecosystem**Jaime Letelier¹, Dimitri **Gutierrez**², Jorge Tam² Telmo De la Cuadra³, Sergio Palma Silva⁴, Samuel Amorós⁴, Hector Soldi⁴, Erica Cunningham⁴ and Kristin Kleisner⁴.¹ Instituto de Fomento Pesquero, Valparaíso, Chile, E-Mail: jaime.letelier@ifop.cl² Instituto del Mar de Perú, Lima, Perú³ Instituto Público de Investigación de Acuicultura y Pesca, Guayaquil, Ecuador⁴ Environmental Defense Fund, Washington DC, United States

The Humboldt Current Large Marine Ecosystem (HCLME), an eastern boundary upwelling system, is one of the most productive and variable marine ecosystems in the world. Adaptation to climate change must be incorporated into fisheries management in this region for sustainability, resilience and ocean health. The increase in the frequencies of abnormal swells, assertion of the oxygen minimum zone, and increased intensity of coastal upwellings are effects of climate change that are impacting fisheries. The transboundary anchoveta fishery of Chile and Peru is an example of a small- pelagic fishery that is highly impacted by this seasonal and historic variability, and more recently the increased intensity and frequency of La Niña and El Niño events, which serves as examples of environmental disturbances affecting local ecosystems and the life cycles of the organisms and the fisheries that take part. The recent creation of a multinational *Observation, Prediction and Early Warning System* (known as S.A.P.O.) in the HCLME, serves as a tool for climate-adaptive fisheries management. S.A.P.O. generates early warning alerts for climate impacts on fisheries in the short, medium and long term, validated by the marine science institutes of Chile, Peru and Ecuador, and sent directly to each countries' management agencies. In addition, S.A.P.O. includes visualization of annual environmental and biological indicators linked to pelagic and small pelagic species. This talk will present how S.A.P.O. can benefit the management of small-pelagic fisheries, and the importance of international scientific collaboration for improved decision-making in the face of climate change.

(S6 Oral 15458)

Key lessons for fishing industry self-sampling programs

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Self-sampling techniques have been introduced in several fisheries during the past 20 years. These programs differ in scope and role definitions for the fisheries industry and research institutions. Here we will focus on some of the voluntary programs that have been developed in pelagic fisheries. The effective uptake of self-sampling techniques in pelagic fisheries has been facilitated by an explicit strategy to involve the crews in the setup and results of the sampling activities. Providing immediate feedback to vessel crews after sending in information is an important requisite as is regular visits of researchers on the vessel. Quality control mechanisms of self-sampling activities need to be strong and transparent and well communicated. Under such conditions, self-sampling provides a powerful mechanism of generating near real-time information from the fishing grounds with high spatio-temporal resolution and the potential to address new biological and ecological questions (e.g. on growth, condition, reproduction and temporal/spatial resolution).

S7. Advancing Social-ecological Analyses and Sustainable Policies for Human Communities Dependent on SPF

(S7 Oral 15451)

Small low-cost pelagic fish in relation to food security and nutrition

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Fish are the largest source of harvestable animal-sourced food available, and most species are small. 80% of all freshwater species are less than 15 cm (\approx 50 grams), and 70% of all marine species are less than 30 cm (\approx 300 grams). Small fish are processed and prepared in diverse ways and are valued in cuisines around the world. Due to their small size, many are consumed whole or beheaded, which makes them more nutrient-dense than fillets. They are often sun-dried, which makes them accessible and affordable for consumers in the Global South suffering from micronutrient deficiencies. Processing and trade support livelihoods for millions of people. Small pelagic fish (SPS) are low trophic level with a P/B ratio of 2-5 times per year. Besides their abundance and nutritive, cultural, and economic values, SPS constitutes the most energy and cost-efficient human food production system available. They have the fewest environmental impacts of all human food production systems. Just a few marine pelagic families (anchovies, herrings, mackerels, and scads) contribute one fourth of global catches. They are harvested by industrial fisheries for reduction and small-scale fisheries for food. Significant amounts of SPS are used for fishmeal and fish oil (FMFO). The FMFO industry is now expanding from offshore fisheries into coastal and inland fisheries which undermines the potential contribution of small fish for affordable healthy food. This talk summarizes results from four sister projects that focus on the undervalued importance of SPS for human food security and nutrition in the Global South.

(S7 Oral 15221)

The Visayan Sea Seasonal Fishery Closure: Effectiveness from the standpoints of fishery-dependent communities and fishery management

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A seasonal fishery closure (SFC) implemented for the conservation of important pelagic species in the Visayan Sea, Philippines has been ruled a success after its stricter implementation in 2012 despite the lack of a comprehensive, detailed, and robust analysis. Using a difference-in-differences (DID) framework, we estimated the effect of SFC on the interannual and seasonal catch for sardine and mackerel. We also conducted semi-structured interviews (N = 235), focus group discussions (N = 9) and key informant interviews (N = 37) involving municipal fisheries stakeholders in the surrounding municipalities around the Visayan Sea, and representatives from the government and non-government agencies, to complement our analyses. Seasonal analyses of catch data show a significant increase in sardine catch at the end of the SFC among SFC-participating provinces. However, overall, the SFC had no significant effect on sardine interannual catch among the provinces participating in the SFC. We also found no significant effect of the SFC on interannual and seasonal catch for mackerel. Interview results corroborate our DID findings for mackerel, but not for sardine. The varying perceptions on the outcomes of the SFC policy can be attributed to several challenges such as lack of implementing guidelines, lack of alternative livelihoods for the

affected stakeholders, persistence of illegal fishing, and uneven implementation of the SFC. We recommend a more consistent enforcement, improved cooperation and communication between fisheries managers and stakeholders, fish size or gear restrictions, and identification and conservation of key habitats needed to restore overexploited species.

(S7 Oral 15204)

Lake Malombe fishing communities' livelihood, vulnerability, and adaptation strategies

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This paper presents a case study from Lake Malombe, Malawi. It demonstrates Lake Malombe fish stock fluctuation and its implications on fishing community livelihoods. The main challenges that fishing communities are confronted with and their adaptation strategies developed over the years. This study's findings suggest that Lake Malombe riparian communities are not regarded as vulnerable so long as they have access to fishing. Fishing supports their livelihood, but declining catches and other factors (siltation of the lake, climate change (heavy rain, drought, and heavy wind), increased mud in the Lake (IML), and lake level fluctuation) beyond their control also expose them to risks and vulnerability. The strategies on how they have survived over the years from the shocks and stress triggered by the decline in fish stocks from the lake are not sustainable in the face of increased human pressures and other environmental drivers. Therefore, an effort towards the governance of the complex socio-ecological systems in which fishery is embedded is required to understand the conditions that define fishers' adaptation strategies. The study further recommends that a combination of coping strategies should be developed to define the fishing communities' level of adaptive capacity and create flexible socio-economic conditions within fishing communities to generate a robust system that can deal with stress.

Keywords: Adaptation strategies, Fish stock fluctuation, Livelihoods, Lake Malombe, Vulnerability, Malawi

(S7 Oral 15377)

Assessment of risks and resilient of the coastal fisheries industry under climate change - A case study of set-net fishery in Taiwan and Japan

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Fishery is a crucial resource for island countries. And facing the direct impact of climate change, making fishery industries more vulnerable. With the adoption of important international agreements (UN SDGs, Rio+20, Rome Declaration, Paris Agreement, etc.), the interaction between climate change and marine fishery resources has become a worldwide topic. To mitigate and avoid disasters and losses caused by climate change, scientific evidence and basis are necessary to formulate appropriate adaptation strategies.

Hence, this research explores the impact of climate change on the coastal marine environment, fishery resources, and industries of small and medium-sized migratory fish in Taiwan and Japan, which has a common geographical environment and fishery resources. By exploring the climate impacts, risks, and mutual influences on the fishery resources of the two countries, this study aims to reveal the similarities and differences of local fishery adaptation strategies in response to climate change. Set-net fishery was selected as the target, which plays an important role

in the coastal fishery in both countries. And, more feasible to connect the impact of environmental changes on fishery resources because the change of catches is mainly dependent on natural factor. This study focuses on the transboundary migratory fish species in the set-net fisheries of Taiwan and Japan and discusses the long-term trend of the migratory index fish species in case sites. Using environmental data to assess the relationship between changes in the marine environment and fishery resources, as well as differences in catch changes in different geographic locations.

(S7 Invited 15510)

Seventy years of management of the Peruvian anchoveta fishery under high environmental variability: Lessons and challenges for future climate change scenarios

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The Peruvian anchoveta (PA), *Engraulis ringens*, supports the largest monospecific fisheries in the globe, attaining about 4 million tons (MT) of catch per year during the past decade off Peru. The very high PA production is due to the moderate upwelling-favorable winds enabling relatively low-turbulent conditions for its early life-stages, its high fecundity and short life span that confer resilience under the high interannual, ENSO-driven variability, and the relative tolerance to the low-oxygen conditions of upwelled waters, among others. The history of the PA industrial fishery started in 1950 and its fishery management, as defined by the activities of monitoring, stock assessment and decision-making, were progressively implemented during the development phase (1950-1963). Stock assessments were implemented in the 1960s, but lack of control on the fishing effort and the occurrence of a strong El Niño event lead to the collapse of the stock by 1972 that lasted for nearly 20 years, favored by adverse 3-D habitat configuration given warmer interdecadal conditions. Since the recovery of the resource, evidenced in 1993, until present, reproductive closed seasons were applied and landings followed closely the TACs. By 2009, individual quotas were implemented to modulate the overcapacity of the fleet and the overall impact of fishing on the PA biomass. Currently the development of at least two acoustic surveys per year, protocols to apply assessment-based decision rules and near real-time monitoring of fishing and environment are the main advisory tools to ensure the sustainable resource use. However, recent oceanographic trends (which indicate a shoaling of the oxycline and warming off the Northern Peruvian coast reducing the potential PA habitat volume) and regional climate change projections (which also predict significant surface warming and decreased coastal upwelling by the mid of the century under pessimistic scenarios of global greenhouse gas emissions), demand to further adaptation of the PA management. This adaptation should aim to maximize its added value, promote the direct human consumption, and make a responsible use of the potential new fishery resources.

(S7 Oral 15237)

Resilience for whom and according to what criteria? An examination of adaptations to changes in the Bay of Biscay anchovy fishery

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We investigate the empirical application of resilience analysis, considering how fishing communities and fishery management institutions have responded and adapted to large-scale changes in the Bay of Biscay anchovy fishery. The system has undergone important transformations in the last two decades, with a closure of the fishery from 2005 to 2010. This has had negative repercussions due to displacement of fishing effort increasing pressure on other species and loss of market for the French operators. Spanish fishing industries on the other hand seem to have been more robust to changes. While the anchovy stock has recovered, the fishery socio-ecological system has not returned to its pre-collapse status. Through a multidisciplinary and systemic approach combining quantitative methods (time series analyses of fisheries data) and qualitative methods (interviews with key stakeholders), we

1) analyze adaptive responses of fishing communities and industries as well as fisheries management, 2) examine potential opportunities or barriers to adaptation in France and in Spain, and 3) identify governance mechanisms that support adaptation towards more resilient and sustainable fishery systems. We highlight the difficulties in answering the question “was the anchovy fishery socio-ecological system resilient to the collapse of the resource?”; We find the response depends on whom is asked, as well as on the management objectives and their application scales. This retrospective analysis can serve as a basis for a more comprehensive assessment and understanding of the long-term responses at the sectoral, coastal community and institutional levels in this and other fisheries systems, in the face of possible future shocks.

(S7 Oral 15357)

Fish quantity, and quality, impact french small pelagic fisheries through bottom-up and industry controls

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Small pelagic fisheries have undergone numerous crisis through history, with socio-economic impacts on fishermen and coastal communities. Anchovy fishery was closed in the Bay of Biscay from 2005 to 2010 due to stock collapse, sardine fishery has been closed since 2010 in the Bay of Seine (English Channel) due to pollutants, and size of sardine has decreased so that French can-industry stopped provisioning from the Gulf of Lion (Mediterranean Sea). We gathered information from all components of the socio-ecological system of the French small pelagic sector (environment, resource, fishery and industry) to analyse what have been its main drivers over the last two decades. Our dataset covered times-series of temperature and zooplankton, size- and abundance-at-age from surveys, spatially-explicit catches, fat-content from can-industry, price and international trade from European databases. Their analysis highlighted both the interannual and seasonal time scales for the structuration of this sector, with a strong dependence on fish quality. For anchovy, adverse environmental conditions in the early 2000’s together with high fishing pressure have led to bad recruitment and the closure of the fishery with dramatic reduction in fleet size. The stock recovery was insufficient for the fishery recovery due to market loss in a context of decreasing fish size. For sardine, a bottom-up control has occurred through a likely decrease in zooplankton quality impacting fish condition. This combined with a can-industry control which provisioned based on criteria of minimum size and fat-content. This study is a first step towards proposing sustainable scenarios to this fishing sector.

(S7 Oral 15508)

The sardine fisheries under economic scrutiny

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While substantial progress continues to be made on understanding the dynamics of small pelagic fish in different ecosystems, the associated coupled socio-ecological system has been less covered. However, the human dimension (e.g. socioeconomics) is also shaping the future of small pelagic fish and deserves accurate comprehension and comparative research. The Brazilian sardine (*Sardinella brasiliensis*) purse-seine fishery is an important fishing activity in the Southwestern Atlantic Ocean that often targets other small pelagic fishes. The fleet and its performance heterogeneity have been investigated since the 2010s in terms of socioeconomic indicators and financial structure, however, a clear understanding of fleet behavior requires further economic comparison. Here, we explore the economic efficiency and profitability of the different regional fleet’ units as the main drivers of the fisheries behavior and viability, and in contrast to other sardine fisheries elsewhere, particularly in European waters.

In Southeastern Brazil, the average profit margin has been varying significantly among vessels, although the cost structure remains quite the same. Labor cost has been a key component shaping the different performance of the fleet's units, while fuel cost shows gradual increase. The purse-seiners of Rio de Janeiro has more recently showed high profit margin but the poorest economic efficiency overall, indicating a warning signal to that particular unit. The comparative approach will illustrate the factors that should be taken into consideration for a better management of the fisheries.

W1. Application of Genetics to Small Pelagic Fish

(W1 Oral 15477)

From allozymes to eDNA: An overview of molecular methods

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A range of molecular methods has been used to better understand and conserve marine fisheries resources. Genetic markers have progressed from allozymes to polymerase chain reaction (PCR) based methods of assaying variation including mitochondrial DNA, nuclear microsatellites, and single nucleotide polymorphisms (SNPs). Traditionally marker discovery was burdensome and constrained the number of markers available for a particular species, limiting the power to discriminate among populations. The advent of next generation sequencing (NGS) enabled a variety of genotyping-by-sequencing (GBS) methods that have streamlined the marker discovery process and vastly increased the number of loci available for quantifying differences among populations. NGS has also facilitated advances in analysis of gene expression including RNASeq and environmental DNA approaches (eDNA and eRNA). This talk will provide a brief non-technical overview of each of these marker types and methods including costs, necessary sample sizes, sample quality, bioinformatic burden, and limitations.

(W1 Oral 15385)

From allozymes to neutral molecular markers: Population genetics of sardines and anchovies

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Efficient fisheries management depends on scientific information, and genetic approaches are one tool that can help inform the conservation and management objectives unique to marine systems. This tool generates knowledge on genetic structure which is key to understand species connectivity patterns and to define the biological units and spatiotemporal scales over which conservation management plans should be designed and implemented. Small pelagic fish resources, namely European sardine (*Sardine pilchardus*) and European anchovy (*Engraulis encrasicolus*) are some of the marine species concerned by addressing these aspects. Indeed, throughout their range, these species are subjected to an intense fishing activity. They are important for the fisheries sector and fish canning industries in many countries. In addition to their strong socio-economic interests, small pelagic fish play a major ecological role in their ecosystem. For this purpose, sardines and anchovies populations structure has been addressed using several genetic markers to know the existing number of stocks which is an important information to integrate in the stock assessment process. This presentation will provide a general overview on how the field of population genetics in sardines and anchovies has advanced through time, and what was gained over the years in terms of information in the Northwest Africa coasts and adjacent seas.

(W1 Oral 15254)

The potential of Next-Generation-Sequencing: From genes to genomes, and from single to multiple markers

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Next-generation sequencing (NGS) is a major technological improvement in sequencing methods that allows an easy and cost-efficient access to whole genome and transcriptome data from virtually all living species. This breakthrough has shifted the focus of previous studies from single/few genes to whole genomes. Currently, hundreds of individuals can be genotyped at 1000s-10 000s of genetic markers simultaneously, and in species

for which no genetic resources are available. It is also possible to identify the genes being expressed in any given tissues, and quantify their expression levels, at any stage of development, sex, age or size. Of particular relevance to fisheries, access to whole genomes of target fish allows greater power to detect genetic differences among populations of large sizes and high gene flow, as many marine species. The development of large panels of genome-wide markers for stock delineation can also be used to monitor the genetic diversity of populations in time and space, to aid the traceability of individuals to their populations of origin, or to improve mix-stock analysis even among closely related populations. In this talk, we will introduce the basics of NGS and provide several case-studies highlighting its potential applications to relevant questions in fisheries science and management, as well as in fish biology, ecology and evolution.

W1 Oral 15243)

Small pelagic fish genomics: How far have we gone?

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Small pelagic fish play central ecological roles in marine ecosystems. The species' short generation times and dependence on lower trophic levels lead to massive decadal to centennial patterns of boom-and-bust dynamics. These patterns are closely linked to climate variability, severely impacting some of the most economically valuable fisheries resources of the world. The consequences of these pendular dynamics, combined with large dispersal potential during several planktonic life-stages and the apparent absence of physical barriers to movement between ocean basins or adjacent continental margins, conduct to shallow population histories. For those reasons, the management units of small pelagic fish are therefore difficult. Traditional techniques such as genetic analyses based on a small number of markers, body shape, otolith morphometrics or microchemistry and parasites have shown equivocal power to distinguish unique reproductive units in small pelagic fish. The recent developments of genomic-based methods, which rely on thousands to millions of markers, can contribute to clarifying questions of stock delineation and population structure, which are pivotal for sound fisheries stock management advice. This presentation will introduce emblematic case studies illustrating how genetics have positively contributed to addressing fisheries' existing management and policy needs.

(W1 Oral 15250)

From genome assembly to fisheries assessment: A case study of Atlantic herring

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The population structure of Atlantic herring (*Clupea harengus*) is very complex and has been highly debated in recent times, as this knowledge is a requirement for sustainable fisheries assessment. Development of new sequencing technologies have enlightened the population structure immensely. Within a recent project, we produced a chromosome-level genome assembly of Atlantic herring based on long-read and sequencing HiC analysis. This reference genome, along with whole genome sequence data of 53 populations from across the Atlantic Ocean and the Baltic Sea enabled the identification of genetic markers that discriminate populations, and are associated with ecological adaptation, for example, in spawning time, temperature or salinity at spawning. Different panels of markers have been established to successfully discriminate herring populations for assessment purposes. In different areas several discrete herring populations may mix during different times of the year and are subjected to mixed-stock fisheries. Therefore, it is essential to allocate catches to the correct populations. These newly developed SNP panels have been applied for the first time in this year's herring assessment. The newly developed capacity has now identified populations that were not assumed to occur in given areas and mixed-stock fisheries. Thus, the development of new genetic methods has helped us to understand the population structure and mixing of herring, further studies are needed but these methods have the potential to substantially improve future fisheries assessment.

(W1 Oral 15277)

Range-wide genetic stock delineation of the European sardine (*Sardina pilchardus*) using whole genome sequencing (Pool-Seq)

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The European sardine, *Sardina pilchardus*, is a small pelagic fish species that inhabits the Mediterranean and Black Seas, and the eastern North Atlantic Ocean from the North Sea to Senegal. This species represents one of the most commercially relevant fisheries resources throughout its geographic range and has a world-renowned, and centuries-old, cultural and gastronomic heritage. Over the last few decades, sardine stocks have experienced large fluctuations in terms of biomass and catch, with marked reductions in catches since 2006. This has led to large quota limitations and fisheries closures in several countries. Efficient fisheries management requires a clear understanding of stock structure and connectivity; however, results from studies on European sardine stock structure using different methodological approaches vary concerning the number and spatial extent of distinct stocks. In this study, we generated whole-genome sequencing of pools of juveniles and adults individual sampled across the Atlantic (11 regions) and Mediterranean (5 regions) with a focus on the Iberian and Moroccan coasts. This resulted in population allele frequency estimates for millions of SNP markers. We are using this data to infer the genetic structure and spatial connectivity of European sardine populations. The results will be compared with those from previous studies to try to reach a consensual structure of sardine stocks and to improve stock assessment and fisheries management advice.

(W1 Oral 15324)

Combining ecologic and genomic modeling to inform sustainable management of fisheries stocks in a tropical sardine

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The delineation of stocks provides the foundation to plan and implement sustainable fisheries management. Yet this is a challenging task, as environmental dynamics affects the connectivity and stability of such stocks over time and stretches of unsuitable habitat in the marine environment can constrain the dispersal ability of considered highly mobile species. Combining methodologies, such as ecological and genetic approaches, is fundamental to uncover structure in pelagic species often wrongly regarded as widespread. Here we focus on the scaled-sardines *Harengula* sp., an economically important lineage of a yet undescribed species of sardine putatively endemic to Brazil. We combined ecological niche models with genomic methods to estimate habitat connectivity for this species, population structure, and their change over time. Our results indicate that *Harengula* sp. is divided into two highly differentiated populations. A larger coastal population shows signs of expansion with a latitudinal gradient of diversity reflecting isolation by distance at the Brazilian coast. A smaller island population, exclusive to the oceanic archipelago of Fernando de Noronha, shows less diversity and potential signs of bottleneck. Genetic patterns are consistent with habitat discontinuity driven by depth isolating the archipelago. The low connectivity between these populations shows that recent deregulation of sardines' fisheries in the archipelago should be reversed, because observed higher inbreeding may compromise population resilience to exploitation. Coordination to set size and catch quotas of *Harengula* sp. among littoral states is required to attain sustainable management of the larger coastal stock.

(W1 Oral 15349)

A genetic toolkit to better understand small pelagics and their interactions with the ecosystem

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Achieving a sustainable small pelagic production relies on appropriate understanding of the status of resources and their interaction with the ecosystem. This understanding, in turn, depends on the availability of accurate and complete scientific information, which is often compromised by economical or technological limitations. Thus, there is a need to explore alternative or complementary approaches that can improve small pelagic fisheries assessment while allowing for an ecosystem-based management. Genetics-based approaches offer the most promising alternatives as they allow to gather information at individual, species and ecosystem levels that cannot be measured otherwise. Yet, despite this potential, the uptake of genetic methods by routine monitoring and thus by the fisheries assessment process is not a reality. Here, we will show examples from our group on how advanced genetic technologies have improved knowledge about small pelagics. Analyzing environmental DNA, we have determined the abundance and distribution of small pelagics in the Bay of Biscay, and revealed patterns of diel vertical migrations of small (meso)pelagics; using metabarcoding of stomach contents, we have studied trophic interactions between several species, including anchovy, sardine, mackerel and horse mackerel; using simulations, we have evaluated the potential of close kin mark recapture (CKMR) for abundance estimation in small pelagics; and, using population genomics, we have determined the connectivity of Atlantic mackerel throughout the Atlantic. Finally, we will discuss the potential impact of these new findings on species conservation and review the lessons learnt from the course of communicating and integrating genomic data into fisheries assessment.

W2. The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models

(W2 Oral 15382)

Integration of species distribution models into Atlantis end-to-end models: Should fish stay or should fish go? ...and other distribution parameters

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Shifting spatial distributions of fish species is a major consequence of climate change. Modifications of fish assemblages induced by distribution shifts may affect food-web dynamics through the alteration of existing prey-predator interactions or the creation of new ones. Over the last decade, the increasing availability of global and regional biogeochemical models has facilitated the development of modeling frameworks to project species distribution up to the end of the 21st century. Though these species distribution model (SDM) projections cannot be used as a standalone for predicting climate change impacts on marine ecosystems, they are a precious resource to inform multispecies/ecosystem models. In Atlantis end-to-end models, the distribution of functional groups can be informed by SDMs of various temporal resolutions and following different parameterizations. In particular, Atlantis can alternatively consider that functional groups are sedentary, fixed (seasonal/temporal variation but strictly distributed as informed by the SDM) or mobile among spatial units at each time-step, hence partly overriding SDM outputs. These movements can be driven by the prey availability in each spatial unit or can be altered by specific environmental conditions. We will briefly review the different parameterization options in Atlantis while compiling a brief review of the literature to highlight what type of SDMs have been integrated in this framework so far and how. Last, we will explore the integration of a set of different SDM options applied within the California Current and Barents Sea Atlantis models, illustrating the implications of each of these modeling options.

(W2 Oral 15441)

Habitat impact on the interannual variability of fish in the northern Humboldt Current System

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The northern Humboldt Current System (NHCS) has the largest fish production of the four major eastern boundary upwelling systems. The Peruvian anchovy is the largest single-species fishery of the planet. Due to its proximity to the Equator, the NHCS is subjected to strong interannual variability which has a strong impact on the fisheries, especially regarding small pelagic fish such as anchovies. However, the mechanisms in which these fluctuations impact the fish are still poorly understood.

In this study, we simulated the marine ecosystem of the NHCS using an end-to-end model. The modelling system consists of the physical-biogeochemical model CROCO-BioEBUS coupled to the individual-based multispecies model OSMOSE. The habitats of the fish groups are simulated by distribution maps that were developed by Oliveros-Ramos (2014) using habitat niche models.

We assessed the sensitivity of the model to: 1) Interannual variability in the fish food (plankton), 2) variability in the larval mortality of anchovy, 3) variability in the plankton accessibility and 4) variability in the habitat of the fish (distribution maps).

We concluded that the model is more sensitive to the changes in larval mortality of anchovy than to changes in the food. We also observed an impact of variability in the habitat comparable and in some species larger than the variability in food. Our study points out the importance of including different sources of variability in end-to-end models and to understand their impact separately.

(W2 Oral 15494)**Realized vs. Fundamental Niche SDMs for the coupling with complex multispecies and ecosystem models: The OSMOSE model as case example**Ricardo **Oliveros-Ramos**^{1,2}, Criscely Luján-Paredes² and Yunne-Jai Shin^{1,3}¹ Marine Biodiversity, Exploitation and Conservation (MARBEC), Univ. Montpellier, IRD, IFREMER, CNRS, Montpellier, France.

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The realized spatial distribution of fish represent the conditions actually used by the species after the interactions with other species are taken into account (the Realized Niche, RN). Species distribution models (SDM) may aim to improve this realized distribution by adding geographical covariates or controlling for sampling bias (e.g. fishing effort). On the other hand, some SDM may aim to model the environmental conditions under which the species can survive and reproduce itself (the Fundamental Niche, FN), using a simpler variable selection or including a more mechanistic description of the tolerance to the environment. Depending on the nature of the coupling of SDM with complex multispecies and ecosystem models, modeling the RN or the FN could be necessary. In the former case, SDM are forcing directly the spatial distribution of fish, while in the latter are forcing habitat suitability, movement or both. We illustrate this ideas using as case example the ROMS-PISCES-OSMOSE model for the Peru Current Upwelling Ecosystem, which includes 15 species of marine organisms explicitly modeled, including 4 small pelagic fishes. We present two versions of the model: i) with the SDM forcing the relative spatial distribution of biomass and, ii) with the SDM used to build gradients of habitat suitability directing the movement of fish. We also discuss why SDM for the FN are better suited to be extrapolated (spatially and temporally) to match the need of complex multispecies and ecosystem models.

(W2 Oral 15505)**Understanding the impact of the spatial distribution of fish in the ROMS-PISCES-OSMOSE model for the Peru Current Upwelling Ecosystem: Insights from a sensitivity analysis of model forcings**Criscely **Luján**¹, Ricardo Oliveros-Ramos^{1,2} and Yunne-Jai Shin^{2,3}¹ Instituto del Mar del Perú (IMARPE), Callao, Perú. E-mail: criscelylujan@gmail.com² Marine Biodiversity, Exploitation and Conservation (MARBEC), Univ. Montpellier, IRD, IFREMER, CNRS, Montpellier, France³ Marine Research (MA-RE) Institute and Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa

Marine ecosystem end-to-end models aim to represent the system from primary producers to top predators and fisheries, linked through trophic interactions and affected by the abiotic environment. The ROMS-PISCES-OSMOSE model includes two main forcing variables: the spatial distribution of fish and the biomass of plankton, both as spatial time series. The OSMOSE model for the Peru Current Upwelling Ecosystem includes 15 species of marine organisms explicitly modeled, including 4 small pelagic fishes, and was calibrated using a likelihood approach to fit monthly time series data of landings, abundance indices, and catch at length distributions from 1993 to 2019. For 11 species, species distribution models (SDM) were used to produce the spatial distribution of fish forcing the model. To better understand the impact of the spatial distribution forcing in the OSMOSE model, we analyzed the impact of the interannual vs. climatological forcing for the spatial distribution of the 11 species using SDM. The sensitivity of these components to the likelihood for each data type as well as the biomass by species, size, and the trophic level was measured using sensitivity indexes. In this work, we highlight the issues to carry on a sensitivity analysis of the forcing component of a complex model like OSMOSE, given the spatio-temporal nature of the distribution maps of fish. Finally, we highlight the importance of implementing this type of analysis with complex models as a key step to improve their reliability for tactical applications.

Keywords: sensitivity analysis, species distribution models, model forcing, Peru Current ecosystem, OSMOSE model.

W3. Small Pelagics for Whom? Challenges and Opportunities for the Equitable Distribution of Nutritional Benefits

(W3 Oral 15829)

A contextualized understanding of small fish consumption

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Small, low-cost fish consumption is highly diverse, shaped by a wide range of factors including its availability and access, but also social norms. This diversity in small fish consumption precludes one-size fits all food system interventions. Moving away from top-down, production-minded interventions in fish value chains, governance efforts also need to have a consumer-centered perspective. Our paper explored a contextualized understanding of small fish consumption that aligns food security and nutrition goals with local realities and consumption practices. The notion of agency – people’s capacity to decide what fish to eat within the limits of local food systems – facilitates such contextualized understanding of small fish consumption practices. It goes beyond numerical representations of consumption, showing how marginalized people acquire small fish through fragile and vulnerable channels. We acknowledged that future research is needed to further highlight consumers’ choices beyond generalized and poorly substantiated consumption estimates. It requires precise data sets concerning small fish as dietary component, connected to fine-grained case studies.

(W3 Oral 15502) **RECORDED TALK**

Heavy Metals Ingestion via Consumption of *Engraulis encrasicolus*, *Sardinella aurita* and *Sardinella maderensis* from the Coast of North-Western and Southern Africa: Implication for Human Risk

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Fish is a good source of protein and micronutrients, however, consumption of fish may be a source of heavy metals, as a result of anthropogenic activities. This study assesses the levels of contaminants; Arsenic, Cadmium, lead, Mercury and implication for human health via consumption of Anchovy and Sardinella captured along the coast of North Western and Southern Africa.

Engraulis encrasicolus (n=1,485), *Sardinella aurita* (n=635), *Sardinella maderensis* (n=565) were sampled by the R/V Dr. Fridtjof Nansen in April, 2017. The fishes were treated as whole fish (WF), whole fish without head, tail and visceral (WF-HTV) and fillet with skin (FS). Concentrations were measured using plasma-mass spectrometry. Using Pallisade @Risk Software, Hazard Quotient (HQ), margin of exposure (MoE) and carcinogenic Risk (CR) were estimated for adults and children.

Exposures, HQ and CR to consumers varied significantly among regional countries. Consumption of WF, WF-HTV and FS showed significant difference to the heavy metals. Concentration of As, Cd, Hg and Pb varied on the type of fish tissue and decreased in the order of WF > WF-HTV > FS. HQ values were < 1 for all fish types, indicating the consumers would not pose significant health hazard through fish consumption, except As (HQ >1) for all tissues. Risk profile of adult and children population, Pb showed a modal risk <10⁶ or out of 1 million (an acceptable risk), and a MoE for children <100 for WF and FS. Arsenic (As) recorded a modal cancer risk of 10⁻³ and 10⁻⁴ for all consumers (CR >10⁶).

(W3 Oral 15455)**Potential contribution of micronutrients and fatty acids of small pelagic fish species to food and nutrition security among vulnerable groups**

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Small pelagic fish species have the potential to reduce malnutrition because it is a good source not only of protein but fatty acids and micronutrients. This paper seeks to determine the potential contribution of three commercially important fish species sampled along the coast of Africa to the recommended nutrient intake (RNI) of women of child bearing age (WCA), pregnant and lactating women (PLW), and infants (6-23 months). *Engraulis encrasicolus* (Anchovies), *Sardinella maderensis* (Flat sardinella) and *Sardinella aurita* (Round sardinella) were sampled from 73 geographical locations and processed after standard protocol on board the research vessel *Dr. Fridtjof Nansen*. Accredited methods were used to analyze nutrient concentrations. Nutrient values were compared across countries/regions. Potential contribution to daily recommended nutrient intake (RNI) were calculated using standard portion sizes. Based on the Ackman standard, almost all analyzed samples contained low to moderate fat (2-8%). All 3 species contributed >100% to the RNI of the fatty acids EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) for WCA, PLW, and infant. All the fatty acids analyzed passed the nutritional quality test for cardiovascular health. Whole fish contributed more to RNI of Ca, Zn and I for WCA, PLW and infants.

Conclusion: This study demonstrates the varying levels of nutrients in commercially important fish sampled along the coast of Africa and their potential in reducing malnutrition and improving cardiovascular health among WCA, PLW and infants.

(W3 Oral 15497)**Towards urban food security and nutrition in Ghana: the role of small pelagic fish value chains**

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Although scholars have noted that small pelagic fish value chains contribute significantly to the food security and nutrition of poor urban consumers in developing countries, limited attention has been given to their precise role in different country contexts. This paper examines the role of small pelagic fish value chains involving domestic and imported marine catches in contributing to the food security and nutrition of poor urban consumers in coastal (Accra) and inland (Tamale) cities, Ghana. The data derives from a two-year study, through trader surveys and interviews with fish smokers and traders as well as consumer surveys conducted among low-income households in both cities. Findings indicate that small pelagic fish value chains are important for food security and nutrition in urban areas. Fish traders engaged in pelagic fish chains are influential in guaranteeing fish availability, accessibility, and stability in cities, but with better outcomes in coastal cities compared to inland cities. However, fish quality and safety could be compromised due to poor handling and chemical adulteration of fish. This potentially has serious health nutrition implications for poor urban consumers.

(W3 Oral 15356)**Regional trade integration and its relation to income and inequalities among Tanzanian marine dagaa fishers, processors and traders**Lilian J. **Ibengwe**^{1,2}, Paul O. Onyango¹, Aloyce S. Hepelwa³ and Martin J. Chegere⁴¹ School of Aquatic Sciences and Fisheries Technology, University of Dar Es Salaam, P. O. Box 60091, Dar Es Salaam, Tanzania² Fisheries Development Division, Ministry of Livestock and Fisheries, Government City of Mtumba, P. O. Box 2847, 40487 Dodoma, Tanzania. E-mail: lilyibengwe@gmail.com³ Department of Agricultural Economics and Business, University of Dar Es Salaam, P.O. Box 35096, Dar Es Salaam, Tanzania⁴ School of Economics, University of Dar Es Salaam, P. O. Box 35045 Dar Es Salaam, Tanzania

Examining fisheries derived income and inequality from regional trade integration is a fundamental step in improving fishing community's economic benefit. However, detailed analysis remains poorly understood. This study was carried out in three fishing communities and one border post in mainland Tanzania to address this gap. Key actors and their roles within the value chain were identified. Differences in seasonal income were tested and examined how cross border fish trade (CBFT) contributes to income inequalities among actors in marine small pelagic fishery locally known as *dagaa*. Findings showed that 12 marine dagaa actors are involved in value-addition activities that link production to consumption. Fishers earned the lowest average seasonal income, and a significant difference in income was found in the four seasons among actors. Further, it was found that processors and traders earned above the Tanzanian minimum wage per month for fishing and marine activities, suggesting that regional trade integration benefits actors through *CBFT*. However, the study observed that traders had higher income inequality than processors and fishers, indicating the oligopolistic market characteristics attributed to the financial power, market bargaining power, access to the market information and social network relationship. Such findings provide important insights for designing effective policies that balance the fair distribution of income derived from CBFT to generate positive livelihood implications.

Keywords: Marine dagaa, season, cross border fish trade, income, income inequality, regional trade integration.

(W3 Oral 15236)**Small pelagic fish are the cheapest nutritious food caught in wild fisheries globally**James PW **Robinson**¹, David J Mills², Godfred Ameyaw Asiedu³, Kendra Byrd², Maria del Mar Mancha Cisneros^{4,5}, Philippa J Cohen², Kathryn J Fiorella⁶, Nicholas AJ Graham¹, M Aaron MacNeil⁷, Eva Maire¹, Emmanuel K Mbaru⁸, Gianluigi Nico⁹, Johnstone O Omukoto^{1,8}, Fiona Simmance², Christina C Hicks¹¹ Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, UK. E-mail: james.robinson@lancaster.ac.uk² WorldFish, Jalan Batu Maung, Batu Maung, Bayan Lepas, Penang 11960, Malaysia³ Ghana Fisheries Recovery Activity, Tetra Tech ARD, Accra, Ghana⁴ Nicholas School of the Environment, Duke University, Durham, NC, US⁵ Scripps Institution of Oceanography, University of California San Diego, US⁶ Department of Public & Ecosystem Health, Cornell University College of Veterinary Medicine, NY, US⁷ Ocean Frontier Institute, Department of Biology, Dalhousie University, Halifax NS, B3H 3J5, Canada⁸ Kenya Marine and Fisheries Research Institute, Mombasa, Kenya⁹ Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Rome, Italy

Wild-caught fish contribute to healthy diets across the world, providing an irreplaceable source of essential nutrients in food-insecure places. Fisheries are supported by thousands of species, yet this wide diversity of aquatic foods is often categorised homogeneously as 'fish', obscuring understanding of which fisheries supply food that is affordable, nutritious, and abundant. Here, we use catch, economic and nutrient data on 2,348 species to identify fisheries that supply affordable and nutritious fish in 39 low and middle-income countries. Small pelagic fishes (herrings, sardines, anchovies) were the cheapest nutritious fish in 72% of countries, often caught in large volumes in marine and freshwater ecosystems. In sub-Saharan Africa, <20% of small pelagic catch could provide all children under five living near to water bodies with recommended annual seafood intakes. Policies that promote local consumption, food safety, and sustainable exploitation of small pelagic species can enhance the contribution of fish to healthy diets.

(W3 Oral 15742)

Community-based fisheries management in Bangladesh supports nutrition security

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To increase equitable access to fisheries, Bangladesh has employed community-based fisheries management (CBFM). In contrast to historically inequitable fisheries licencing practices that prioritized profit, CBFM allowed some of the poorest people in Bangladesh to access nutrient-rich fish, important for addressing the high prevalence of micronutrient deficiencies. In this study, we analyse data compiled from three separate CBFM intervention projects in Bangladesh and examine fishers' nutrient intake from changes in fish consumption across the scope of the projects. CBFM was correlated with increased fish consumption for subsistence fishers. Additionally, through the market exchange of high-value wild fish for large quantities of cultured fish, fishers have increased micronutrient intake of calcium, iodine, iron, and zinc. Purchased aquaculture species increasingly contributed to National Recommended Nutrient Intakes of the four nutrients, whereas contributions from wild fish species decreased (particularly those from small fish). Although there is a common belief in the literature that wild fish are more nutritious than cultured fish, understanding nutrient intake from a systems-perspective could allow us to make policy choices that support more nutritious food systems.

W4. Evaluating Inter-Sectoral Tradeoffs and Community-Level Response to Spatio-Temporal Changes in Forage Distribution and Abundance

(W4 Oral 15220)

Portfolio substitution between coastal pelagic species under shifting target species distributions and policy constraints

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Fishers often target a diverse set of 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. However, what factors influence diversification and how climate-driven changes in target species distribution may interact with other constraints to affect changes in substitution behavior remains unclear for many fisheries. In this study, we analyze how historical changes in forage species distribution and the closure of the Pacific sardine fishery affected landing substitution between 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. Using a discrete choice modeling approach, we also study how spatial distribution and closure affected the coastal pelagic species fisheries' participation decisions over the 2000-2019 period. Our preliminary results showed strong substitution between market squid and Pacific sardine when both were available, while the Pacific sardine closure in 2015 was associated with lower fishers' participation in the market squid fishery.

(W4 Oral 15393)

Investigating Portugal's mainland purse seine fishery spatiotemporal activities footprint based on georeferenced data

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Increasing fisheries and ocean zoning intelligence is fundamental to improve knowledge of spatial displacement and pressure on marine species. Knowledge of fisheries spatial activity is, however, still underdeveloped. This study aims to address that issue by combining satellite data and machine learning (ML) algorithms to evaluate Portugal's mainland purse seine fisheries spatial footprint, allowing the fleet's fishing grounds identification and economic value attribution.

Trips were defined by using Automatic Identification System (AIS) data and high-resolution spatial polygons to extract vessel positions at specific locations. Using observer data, supervised machine learning algorithms were trained to classify vessel's trips operations. The estimated ML models generalized well, outputting the fishing locations for the given fleet from 2015 to 2020. Vessel trips corresponding to the official at auction reported landings were isolated as official fishing trips, with volume and revenue estimated by species and commercial size. Preliminary results indicate similar spatial patterns for vessel groups with similar technical characteristics and targeted species. While some fishing grounds face consistent focused pressure over time, other areas show a broader range of activity, suggesting different strategies between the vessel groups. Fishing grounds with higher generated revenue operate closer to shore and might overlap critical spatial areas (e.g., recruitment or primary production).

To promote a healthy ecosystem, it is fundamental to reconcile objectives under fisheries management policies, namely the fisheries economic value and the necessity to protect certain areas. This study is part of a broader framework to assess fishermen's spatial footprint of any fishing gear or métier.

(W4 Oral 15322)

Spatial-dynamic model of commercial fishermen trip decision-making

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High-resolution mobility data improves the understanding of human behavior. With global positioning data in fisheries, we can empirically model fishers' decision-making. In the short run, after choosing the fishing gear, fishers decide where to fish, how much to fish and when to return to the port on a given trip. Most of the research exploring these decisions has focused on one aspect (e.g., fishing location), treating other aspects exogenous. These decisions, however, are interconnected and conditional on the underlying vessel capital stock (e.g., hold and fuel capacity). This research constructs a novel spatial dynamic model of an individual fisher's trip level decision-making on location choice, fishing effort, and travel route. It is motivated by the fishing trip observations from the Gulf of Mexico's bottom longline fishery. Simulation results show that technology constraints endogenously determine the trip length. They also impose a shadow price affecting the fisher's choice of location and effort from the outset of a trip.

We compare these optimal patterns with those from a myopic fisher (one choice ahead decisions) and a partially myopic fisher (2, 3, or 6 decisions ahead). The myopic fisher does not optimize route planning or consider the technological constraints until returning to port. Both factors result in large trip profit reductions, although catches can be the same across the myopic and dynamic fisher. For the partially myopic fisher, the degree of route planning and technological constraints consideration depends on the level forward-looking: the more forward-looking, the closer it approaches the dynamic optimal.

(W4 Oral)

Historical perspective and modeling of Spanish inshore fishery dynamics in relation to changes in abundance of small pelagic species

Dorleta **Garcia**

W5. Recent Advances in the Daily Egg Production Method (DEPM): Challenges and Opportunities

(W5 Oral 15287)

Alternative methods for estimating total daily egg production

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In South Australian snapper, new methods have been developed to estimate P_0 that do not separate sampled eggs into daily cohorts, but retain use of the egg stages. This ‘stage-based’ approach assumes a prior range of estimates for egg mortality rate, z . At each station, with measured temperature and thus time since spawning for each stage, the method is to (1) reverse exponential egg mortality given the time since spawning to compute the spawning density from that stage, (2) sum over all stages in the sample, and (3) divide by the hatching time. This gives a single measured value for daily egg spawning density ($P_{0,i}$) at each station in the egg survey. For snapper, P_0 was estimated as the mean of $P_{0,i}$ over all stations, i . Standard geostatistical methods can be applied to DEPM when a single value for egg density ($P_{0,i}$) is obtained at each sampling location. Snapper spawning area (A) was estimated using geostatistical interpolation as the area where egg density is greater than a pre-chosen cutoff. For South Australian sardine, this geostatistical approach was unified and extended to compute an estimate of total daily egg production ($P_0 * A$) across the study region as the integral (volume) under the geostatistical egg density surface. This avoids separate estimations of P_0 and A which are not, in practice, independent. It averages across sometimes troublesome high density samples by spatial interpolation, statistically advantageous if these are correlated in space. We evaluate and compare the precision of this geostatistical method.

(W5 Oral 15232)

A Bayesian estimation of daily egg production: application to sardine in the Bay of Biscay

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In the Daily Egg Production Method (DEPM), the daily egg production (P_0) and the daily egg mortality rates (Z) are obtained from the exponential decay mortality model fitted as a Generalized Linear Model (GLM) to the egg daily cohorts. Frequentist approaches for this GLM can result in mortality estimates out of the proper domain. In this work a Bayesian approach for estimation of P_0 and Z is proposed, where estimates of Z are restricted to the proper domain through a prior distribution based on literature. This proposed Bayesian approach was applied to the Bay of Biscay sardine case study using the plankton samples collected during the BIOMAN survey from 2005 to 2021. Annual point estimates and the corresponding credible intervals for the Bay of Biscay sardine egg production obtained with this Bayesian procedure were compared to the frequentist estimates. Overall, the results of both methods were very similar, except for the years in which the frequentist method resulted in inappropriate mortality estimates. In these years the proposed method overcame the problem of inappropriate sign for mortality estimates, resulting in tighter credible intervals of both P_0 and Z . Furthermore, a sensitivity analysis to the prior distribution of Z showed that the influence on posterior distributions was minimal.

(W5 Oral 15301)**Towards spatial-explicit daily egg production estimates**Leire **Ibaibarriaga**, Leire Citores, Maria Santos and Andres Uriarte

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The original Daily Egg Production Method (DEPM) provides an overall estimate of daily egg production per day and surface unit (P_0) as a mean over all the spawning area. However, the egg surveys are designed to have a high spatial resolution and provide detailed information about the spatial dynamics at spawning time. In this work we extend the usual exponential decay egg mortality model to provide spatial-explicit daily egg production estimates. The daily cohort egg abundances and their corresponding mean ages are fitted as a Bayesian Generalized Linear Model (GLM) allowing random effects by stations. On the one hand, the Bayesian framework ensures that the daily egg mortality rate estimates have the proper sign and allows the potential use of expert knowledge through the prior distribution. On the other hand, estimation of random intercepts for each station provides different daily egg production rates per station. Then, the total daily egg production is estimated as the sum across all the stations of the product between the daily egg production rates and the area represented by each station. This new approach was applied to the sardine data collected in the BIOMAN surveys from 2005 to 2021. The results were compared with respect to the Bayesian GLM with non-spatial-explicit daily egg production. In most of the years the results were similar. However, in some years (e.g. 2012, 2014 and 2018) the estimates differed. Although the proposed approach looks promising, the reasons behind these differences need to be further studied.

(W5 Oral 15405)**Spatial effects of daily egg cohort on the daily egg production rate of anchovy and common sardine off central-southern Chile**Luis A. **Cubillos**^{1,2}, Juan Ant3n Heredia², Leonardo R. Castro^{1,2}, Gabriel Claramunt³

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The daily egg production rate (P_0) is one of the main parameters utilized to estimate spawning biomass through the daily egg production method (DEPM). The conventional estimation of P_0 and egg mortality does not consider the spatial field structure of daily egg cohort distribution. This study aims to analyze the spatial effects of daily cohorts on egg production for anchovy and common sardine in central-southern Chile (33°S-41°30'S). We utilized DEPM data from surveys representing high and lower egg abundance. Egg counts were aging with Lo's model, and ages were grouped into daily cohorts. A Bayesian hierarchical model considering that egg count followed a negative binomial distribution as a function of age, bottom depth, and daily cohorts distributed into a gaussian spatial field. We utilized the stochastic partial differential equations (SPDE) approach and the integrated nested Laplace approximation (INLA) method to estimate unknown parameters. We contrasted a non-spatial model (Model 0), with a constant spatial field (Model 1), and a changing spatial field among daily cohorts (Model 2). We found significant spatial effects of bottom depth and distribution of daily cohorts on egg density of anchovy and common sardine. The daily egg production was estimated through a weighted area estimation, improving the precision. Changes in the spatial distribution among daily cohorts could be associated with effects of dispersion and mortality, which are difficult to separate. The spatial dependence of bottom depth suggests coastal egg retention, probably due to heterogeneous spatial habitat where fronts and retention processes are related to bathymetry.

(W5 Oral 15403)**The precision of daily egg production and mortality rates: The importance of weighting by egg aggregation indices of the daily cohort**Luis A. **Cubillos**¹, Leonardo R. Castro¹, Gabriel Claramunt²¹ Center for Oceanographic Research COPAS Sur-Austral and COPAS COASTAL, Departamento de Oceanografía, Universidad de Concepción, Concepción, Chile. E-mail: lucubillos@udec.cl² Facultad de Recursos Naturales Renovables, Universidad Arturo Prat, Iquique, Chile.

Daily egg production is a key parameter for estimating spawning biomass with the Daily Egg Production Method (DEPM) in small pelagic fishes with indeterminate fecundity. Spatial irregularity accounts for the natural daily mortality of pelagic fish eggs and early-stage larvae. The aggregation of fish eggs in patches may be more vulnerable to predators since they have not developed the motility and behavior necessary to evade predators. Our objective was to use daily egg cohort aggregation indices to weight the influence of spatial irregularity on the egg abundance of pelagic fishes with indeterminate fecundity; and hence, on the precision of estimates of daily egg production (P_0) and total mortality rate (Z). We utilized the DEPM database for anchoveta and common sardine, available for northern and central-southern Chile. As a result, the precision of the P_0 and Z estimates increases significantly, maintaining the expected value. Thus, high (low) egg abundance could be a consequence of concentration processes (dispersion) and not necessarily mortality. In this way, the aggregation indices computed for each daily cohort allow weighting the concentration/dispersion influence in the egg production required for the DEPM.

(W5 Oral 15283)**Precision of P_0 ; Insights from simulation modelling and field experiments**Alex R. **Ivey**¹, Charles James¹, Gretchen L. Grammer¹, Rick McGarvey¹ and Tim M. Ward²¹ South Australian Research and Development Institute, Adelaide, South Australia, Australia. E-mail: alex.ivey@sa.gov.au² Institute of Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia. E-mail: timothy.ward@utas.edu.au

A simulation model was constructed to assess factors affecting the precision of estimates of P_0 . The model consisted of: 1) the 'egg-space'—a constrained, random, three dimensional distribution of egg concentrations and 2) a simulated field survey and sampling strategy based on vertical and oblique tows. Simulated surveys were conducted over 300 sites sampled over ~20 days. Results suggested that oblique tows were more likely to produce precise estimates of P_0 than vertical tows. Field experiments were undertaken to test this hypothesis. A Continuous Underway Fish Egg Sampler was used to locate areas with moderate to high densities of Sardine egg. A marker buoy and drogue were used to ensure that repeated sampling was conducted in the same egg patch. Each hour, samples were taken using three different samplers: Nackthai, CalVET and Bongo. Estimates of egg density and P_0 derived from the Nackthai were lower and less precise than those obtained from the CalVET or Bongo. The Nackthai was also more difficult to deploy than the other samplers. Samples obtained from the Nackthai also contained more eggs and took longer to process than those from the other nets. There was no evidence to suggest that replacing the traditional samplers with the Nackthai would enhance estimation of P_0 . However, using a Bongo, which filters more water and captures more eggs than the CalVET may be warranted for species with low egg densities, such as Jack Mackerel. We concluded that other opportunities for improving the precision of P_0 needed to be explored.

(W5 Oral 15346)

Egg production estimation for Atlantic Iberian sardine using CUFES sampling. Implementation of a biophysical model to assess the egg vertical density distribution

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In the Atlantic Iberian waters the fisheries independent data used for sardine stock assessment are gathered during acoustics and DEPM surveys undertaken by IPMA and IEO coordinated efforts. While acoustic surveys are conducted annually the DEPM campaigns occur in a triennial basis. During DEPM surveys plankton samples are collected with two systems, PairoVET (primary sampler) and CUFES (auxiliary sampler) whereas in acoustics surveys CUFES is the principal ichthyoplankton sampler. As CUFES samples are collected underway, along the acoustic transects, egg data is obtained with high spatial resolution, nonetheless these information reports to the surface layer, where the majority of the sardine eggs occur, but cannot account for the whole vertical egg abundance distribution. In order to obtain egg production (EP) estimations using data from both sampler (survey) types, CUFES egg concentrations can be converted to vertically integrated egg abundances, using a biophysical model of egg vertical distribution, followed by a procedure similar to the one applied for DEPM - Daily EP. Here we implement the approach developed by IFREMER for the PELGAS survey, using results from IPMA (PT-DEPM-PIL) and IEO (SAREVA) sardine DEPM series, together with *in situ* and modelled hydrographic and wind information. The implementation of an index of EP, derived from CUFES sampling, allows obtaining an annual estimate filling in the gap for the years without dedicated DEPM surveys. Moreover, the combination of CUFES and acoustics surveying can assist in the cross-validation of the two sampling methods and improve our understanding on their respective bias.

(W5 Oral 15282)

How precise are estimates of spawning area and spawning biomass of sardine off southern Australia?

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Previous studies have shown that Sardine (*Sardinops sagax*) abundance is strongly correlated with spawning area (A). Application of the daily egg production method (DEPM) to Sardine off southern Australia between 1995 and 2019 confirmed that A is a good proxy of adult abundance for this stock. Ward et al. (2021) showed that spawning biomass could be calculated most precisely using estimates of all parameters, except A , that were calculated from historical (cf. annual) data. Using this approach, inter-annual fluctuations in estimates of spawning biomass are driven entirely by changes in A . Like most other DEPM studies, Ward et al. (2021) did not estimate the precision of A . The precision of A is critical to understanding the precision of estimates of spawning biomass. This information is needed because spawning biomass is the key biological performance indicator for the South Australian Sardine Fishery. During recent DEPM surveys off South Australia, a second plankton sample was taken in each sampling grid at a randomised distance from original sampling site. Two gear types were tested: a CalVET net, which was the standard sampling gear for the surveys, and a bongo net, which filters more water per tow than a CalVET net and provides different estimates of A (higher) and mean daily egg production (P_0 , lower). Estimates of A , P_0 and total daily egg production obtained using each sampling method for each survey are compared to evaluate the precision of the estimates of these parameters.

(W5 Oral 15256)**Combining two parameters increases precision: Benefits of replacing batch fecundity and female weight with relative fecundity**Tim M. **Ward**¹, Gretchen L. Grammer², Alex R. Ivey², Jonathan Smart², Rick McGarvey²¹ Institute of Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia. E-mail: timothy.ward@utas.edu.au² South Australian Research and Development Institute, Adelaide, South Australia, Australia

In the original formulation of the DEPM for northern anchovy, *Engraulis mordax* (Parker 1980), mean daily fecundity was estimated using three parameters: sex ratio (R), spawning fraction (S) and relative fecundity (F'). However, following Lasker (1985), most recent applications have estimated batch fecundity (F) and total female weight (W) separately. The change from three to four adult parameters was made because preliminary data suggested that the relationship between F and $W_{\text{ovary free}}$ for northern anchovy was non-linear (Picquelle and Stauffer, 1985), whereas more recent studies have shown that this relationship is linear for many species, including northern anchovy (e.g. Dorval et al, 2018). The benefits of estimating F' as a single parameter from data obtained over multiple years were evaluated for Sardine (*Sardinops sagax*), Jack Mackerel (*Trachurus declivis*), Blue Mackerel (*Scomber australasicus*) and Redbait (*Emmelichthys nitidus*) off south-eastern Australia. The relationship between $W_{\text{ovary free}}$ and F for females with hydrated oocytes was used (accounting for variance) to estimate \hat{F} for mature females without hydrated oocytes. For all four species, F' had lower coefficients of variation (CVs) than both \hat{F} and W , and was stable across years and a wide range of W . For example, for Sardine, the CVs of mean F' calculated across all years (305 eggs.g⁻¹) was 0.2%, whereas the CVs of the overall means of W (58.4 g) and \hat{F} (17,835 oocytes.batch⁻¹) were 31% and 40%, respectively. The benefits of estimating F' as a single parameter should be evaluated for other species in other ecosystems.

(W5 Oral 15342)**Estimating spawning interval as the ratio of oocyte growth period to the number of oocytes cohorts**Kostas Ganias and Katerina **Charitonidou**

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Spawning frequency, S , is a key parameter for the daily egg production method which can be estimated either as an individual parameter (spawning interval) or as a population parameter (spawning fraction). The postovulatory follicle (POF) method is the most widely used method for estimating S , however, its application requires many samples and much laboratory effort. In this study, the spawning interval of the Mediterranean sardine, *Sardina pilchardus*, was estimated using the ratio of the oocyte growth period, i.e., the time lag between the onset of secondary growth to spawning, to the oocyte cohorts' number in spawning capable females. Tiny oil droplets, cortical alveoli, and the disassembled Balbiani-body were used as markers of the reproductive period commencement. Germinal vesicle migration, oocyte hydration and POFs were used as markers of the spawning period onset. The mean calendar dates for the reproductive and spawning period onset were estimated by analysing the prevalence of the respective markers as a factor of the calendar date, using logistic regression. Clustering analysis algorithms were applied to the fine structures of secondary growth oocytes to determine the oocyte cohorts' number. The ratio of the estimated oocyte growth period (n=34d) to the oocyte cohorts' number (n=5), resulted in a spawning interval of ca. 7 d, which is comparable to previous estimates for this sardine population. This method overcomes the problem of estimating S as a population parameter since it only needs a short-term survey, covering the initial phase of the population reproductive season, from the beginning of ovarian development to the onset of spawning.

(W5 Oral 15293)

Calculations of spawning-stock biomass of sprat in the Gotland Basin of the Baltic Sea with the DEPM in the years 2019-2021

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Spawning-stock biomass of sprat (*Sprattus sprattus balticus* Schneider) has been calculated with the daily egg production method for the years 2019 – 2021 using the data bases of Institute "BIOR" on ichthyoplankton and hydrography. Quasisynoptic ichthyoplankton surveys were conducted during 3 days from 15 to 21 June, which is close to the peak of spawning season. Investigations with BIOMOC multiple opening/closing net in the second half of the 1990s provided us with the knowledge of the vertical distribution of sprat eggs and the regularities of its changes during the spawning season. It allowed to determine the temperature of ambient water and thus the duration of the developmental stages. Mortality rates were calculated from the total amounts of sprat eggs on stages 1 and 2 in the investigated area. These numbers were computed from the maps of distribution of eggs. This method allowed taking into account the drift of eggs during their incubation, and also avoiding the influence of the irregularities in the distribution of sampling positions. Daily egg production was very similar in the years 2019 and 2020, but differed in 2021: $1970 \cdot 10^9$, $2024 \cdot 10^9$, and $2446 \cdot 10^9$ respectively. Egg production and then SSB were calculated in 2 versions: precautionous and taking into account possible elimination of eggs in the lower part of the water column, where they were exposed to low concentrations of oxygen: below 1 ml/l. Determining of fecundity is the weakest part of the work. It was calculated from the number of portions and mean weight of females.

W6. Small Pelagic Fish Reproductive Resilience

(W6 Oral 15327)

The reproductive resilience paradigm: Integrating behavior and feedback loops into understanding productivity and resilience in marine fish

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We introduce the reproductive resilience paradigm to stimulate workshop discussions on current understanding of SPF reproductive success, knowledge gaps, and future research directions. Reproductive resilience is the capacity of a population to maintain the reproductive success needed to result in long-term population stability despite disturbances. A stock's reproductive resilience is driven by the underlying traits in its spawner-recruit system, selected for over evolutionary timescales, and the ecological context within which it is operating. Current measures of reproductive potential for SPF are based on the same assumptions as those used in harvested terrestrial animals, even though adult and offspring abundance relationships differ greatly. In terrestrial animals they are linear. In marine fish, they often are not observable. This is due to the complexity of marine fish spawner-recruit systems and difficulties in estimating abundance. Spawner-recruit systems are multi-dimensional, affected by space, time, and density in ways most harvested terrestrial animals are not. Pelagic spawners often use disparate habitat depending on life stage, with spawning site selection and diversity affecting later spatial components of the life cycle and the productivity and vulnerability of the stock to spatial disturbances, climate change, and fishing. Reproductive success occurs when reproductive and offspring performance result in offspring surviving to reproductive age. In this fashion natural selection has shaped species-specific traits that allow fish to persist in high and highly variable mortality environments. Traits associated with the reproductive resilience paradigm will be briefly compared to the more commonly used r vs K paradigm of resilience.

(W6 Oral 15235)

Monitoring programme of the Canary small pelagic fish (Spain, NW Africa) in the Spanish Data Collection Framework

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The small pelagic fish (SPF, i.e. *Scomber colias*, *Trachurus* spp, *Sardina pilchardus* and *Sardinella* spp) in the Canary Islands (Spain) are mainly targeted by artisanal purse-seiners, whose monitoring is included in the EU Data Collection Framework. Since 2013, commercial landings are sampled monthly to describe and to detect changes in their demographic structures and reproductive annual cycles. Several life history traits have been obtained and/or updated and are used as input for the assessment models; however, reliable results have not been obtained yet, due to both the short time series of landings and fishing effort, as the uncertainty of several species' traits. In addition, histologic analyses of gonads and fecundity studies have not been addressed so far. In the current Climate Change scenario, SPF are proving their high plasticity by mean of rapid changes of their populational life history traits, distribution and abundance. Therefore, to foresee and anticipate future collapses and keep the fishery activity sustainable, collaborative initiatives are mandatory to understand their reproductive differences among adjacent areas, and to elucidate their population structures and migration processes comprising their whole geographical distribution, unknown in most of the cases.

(W6 Oral 15341)**Combination of Continuous Underwater Fish Egg Sampler and acoustic data for estimating and mapping fish daily fecundity**Mathieu **Doray**¹, Jean Baptiste Romagnan¹, Pierre Petitgas² and Martin Huret³¹ DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, Institut Agro, Nantes, France. E-mail: mathieu.doray@ifremer.fr² Ifremer, Nantes, France³ DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, Institut Agro, Brest, France

Life-history traits are thought to regulate the dynamics of fish populations. Fecundity is an important trait to consider, as it informs on the growth-reproduction trade off, and ultimately population stability. Fish Daily Fecundity (DF) is also a key parameter in the Daily Egg Production Method used to assess small pelagic fish spawning stock biomass. Fish fecundity is classically assessed through time consuming biological sampling, which precludes its estimation at large scale and high resolution. Anchovy and sardine acoustic biomass and Continuous Underwater Fish Egg Sampler (CUFES)-derived egg production have been mapped at high spatial resolution during the PELGAS survey since 2000 in the Bay of Biscay (BoB). We here propose to divide the total daily egg production estimated from CUFES samples by the adult acoustic biomass, to derive a novel Daily Fecundity proxy. This DF index was calculated annually for anchovy and sardine at the scale of the BoB, and within 140 km square grid cells. Empirical Orthogonal Function analysis applied to the time series of DF proxy maps revealed DF hotspots in Southern and/or offshore areas for anchovy and sardine. Anchovy DF proxy displayed a dome-shaped time series with a maximum in 2010, whereas no time trend was observed for sardine. Space-time dynamics of the DF proxy were compared to those of fish mean weight, in an attempt to detect changes in the fish growth-reproduction trade-off, that might contribute to explain the sharp decrease of anchovy and sardine condition observed in BoB since 2000.

(W6 Oral 15279)**Reproductive behavior of north-center Peruvian anchovy *Engraulis ringens* stock from Peru during El Niño and La Niña events categorized by reproductive index anomalies 1992-2020**Antonio **Cuba**, Javier Sánchez, Julio Mori, Grecia Chavez, Javier Castillo, Cecilia Roque, Betsy Buitrón

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The gonadosomatic index (GSI) and spawning fraction (SF) anomalies allow to determine the effect on the resource in front of environmental change. The objective in this work was categorized the reproductive index anomalies and to determine the effect of ENSO events on the reproduction of the anchovy during and after the event. The monthly anomalies were calculated as of the difference of the monthly values and the monthly values from the pattern, while their level was determined using the methodology from Cuba and collaborators. The ENSO events were gotten from El Niño coastal index (ENCI) that it was founded in the ENFEN web. During weak and moderate El Niño events the SF had a negative anomaly with moderate and strong effect, whereas after the event the index showed a strong positive or negative anomaly. Throughout strong and extraordinary El Niño events, the SF and GSI showed strong negative anomalies over the first months, follow by strong positive anomalies produced by the mismatch in the reproductive period causing by the event. This behavior demonstrated that anchovy tried to have a compensatory effect in their spawning. On the other hand, during weak and moderate La Niña events it was observed moderate and strong positive anomalies, while after the event it was possible to detect moderate positive and negative anomalies depending on the reproductive cycle where the event was developed. Finally, during a strong La Niña event, both index showed positive anomalies, strong effect for SF and moderate and strong effect for GSI.

(W6 Oral 15469)

Changes in the reproductive behavior and critical values of peruvian anchovy *Engraulis ringens* of north-center stock of Peru, determined as of their reproductive index patterns. 1992-2020

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The peruvian anchovy *Engraulis ringens* sustains the flour fish industry in the world, having a great importance for the economy of Peru. It has two principal reproductive seasons. One of them in winter-spring and the other in summer. In this work, through the analysis of the time series from 1992 to 2020 from spawning fraction (SF) and gonadosomatic index (GSI), it was determined three different periods of reproductive behavior in both index and it was calculated their patterns. Although, it was estimated the critical values of SF and GSI in the principal and secondary reproductive seasons. It was observed that all the SF patterns had two reproductive seasons, one in winter-spring and other in summer. In the case of GSI, the first period (1992-1998) had two important reproductive moments in September and February; while the second (1999-2012) and the third (2013-2020) periods showed an important moment from August to February. On the other hand, the critical values of SF and GSI in the principal reproductive season did not register significantly differences, being to the SF 28,52% (1992-1998), 26,97% (1999-2010) and 26,26% (2011-2020) and to GSI 4,98% (1992-1998), 5,37% (1999-2010) y 5,33% (2011-2020). It was discussed the results with possible change in the environment.

(W6 Oral 15248)

Associations between egg quality, female traits and abiotic factors: Insights from 40-year-long Baltic herring monitoring program

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We examined the egg properties of the Baltic herring (*Clupea harengus membras*), a key pelagic fish species in the Baltic Sea, over a period characterized by major changes in the ecosystem. The samples were collected from the northern Baltic Sea, where a spawning herring population has been monitored by annual samplings since 1984. In addition to traditional fish traits, lipid and thyroid hormones (THs) levels in the female's ovaries were studied from preserved samples. Associations between these and abiotic factors were studied using Generalized Additive Mixed Models. In addition, relations between maternal phenotype, egg quality and larval characteristics were experimentally investigated in 2020-22 under current (7 °C) and in warming (14 °C) temperature conditions.

During the monitoring period, the spawning population have underwent several changes, of which the most notable has been a decrease in body size. The amount of lipids and THs in the herring eggs suggest an overall decrease of egg quality in the population, which is associated to abiotic factors and to a decrease in the total lipid reserves of the female. The monitoring data also indicates of a possible change in reproductive strategy as small body size may aid in reducing the environmental impact on egg quality. The role of abiotic factors and factors intrinsic of the female also differed between periods characterized by declining and stable salinity conditions. The experimental studies indicated that the female's ovarian lipid and THs levels affects the egg quality and larval characteristics, but that the effect varies with incubation temperature.

POSTERS

General Poster Session

(GP Poster 15262) GP-1

Temporal variations in otolith shape population structure on a small pelagic fish, the European sardine *Sardina pilchardus* (Walbaum, 1792), in a decadal period

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Otolith shape analysis can be considered a natural marker and indirectly infer connectivity among fish populations making otoliths efficient tools for distinguishing fish populations spatially and temporally. Here, we explored the possible temporal differences in terms of population structure in the European sardine *Sardina pilchardus* (Walbaum, 1792), a fast-growing and short-lived coastal pelagic fish species, with a great dispersal capacity, as well as variable population dynamics. Population structure results from a recent year (2019) were compared with those from previous studies using samples collected over the last ~20 years (2003 and 2013), which includes years of higher (2003) and lower fish biomass (2013 and 2019) following an extensive period of poor recruitment, providing temporal variation insights in the population structure of the species. Following the methodology used in the previous studies, a combination of Elliptic Fourier descriptor and shape indices was explored using multivariate statistical methods. The overall results comparison among studies on that decadal time scale revealed differences in the population structure and connectivity patterns when compared to the earlier period. The major temporal differences pertain to the Mediterranean waters and Atlantic waters, separately. Still, all studies agree that the Strait of Gibraltar is not an effective obstacle to the separation of European sardine stocks, suggesting instead that individuals might migrate among adjacent areas. These differences may be attributed to changes in environmental variables leading to changes in population dynamics but can also be the result of the sharp decrease in sardine biomass that occurred in the last decade.

(GP Poster 15264) GP-2

Influence of environmental variability on population traits of small pelagic fish in the Canary Islands (NW Africa, Spain)

Alba **Jurado-Ruzafa**¹, Gema Canal¹, Marta Quinzán², Begoña Sotillo¹, Zoraida Santana-Arocha¹, Clara Estil-las¹, Gustavo González-Lorenzo¹, Catalina Perales-Raya¹

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Small pelagic fish (SPF) have relatively short life-cycles, with fast growth, high mobility and plankton-base feeding. Therefore, they are highly sensitive to fluctuations in environmental conditions, including those related to Climate Change and fishing. Foreseeing potential variations in the life history traits of SPF is critical for effective management measures in the current Global Warming scenario. Since 2013, the main SPF caught by the purse-seine artisanal fleet in the Canary Islands (i.e. *Scomber colias*, *Trachurus picturatus*, *Sardinella aurita* and *Sardina pilchardus*) are monitored monthly as part of the EU Data Collection Framework. Statistically significant interrelationships were found between key history traits of these species with oceanographic parameters (such as Sea Surface Temperature and the concentration of chlorophyll *a* as a productivity proxy) using generalized linear models (GLMs), generalized linear mixed model (GLMM) and generalized additive model (GAM), what represents the first attempt to determine potential exogenous drivers of the dynamics and life history characteristics of SPF in the Canary waters.

(GP Poster 15268) GP-3**Using otolith phenotypic variability to infer potential population differences of *Scomber colias* in the Northeast Atlantic and Mediterranean Sea**

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In the last decade there has been a growing interest in the Atlantic chub mackerel, *Scomber colias*, due to a noticeable expansion of this species from areas of greater abundance off northwest Africa to Atlantic Iberian waters, and in the Mediterranean Sea. To implement sustainable management measures in the current global warming situation it is crucial not only to identify biologically-meaningful management unit, but also to understand the geographic variation of phenotypes and their connectivity among distribution areas. We explore the otolith phenotypic variability of *S. colias* in the NE Atlantic waters (the Cantabrian Sea, Madeira and The Canary Islands) and in the Mediterranean Sea (the Ligurian Sea, NW Italy) from otolith contour considering wavelet transform and a non-parametric algorithm of classification. All the individuals were analysed as a single pool to detect how many phenotypes are present in each region. A high number of phenotypes (between 4 and 7) in different proportions was detected by region, with certain degree of overlapping. These shared phenotypes among fishing grounds may open new management approaches in migratory species. These findings show that the phenotypic diversity is a key issue not assumed by the current management plans.

Keywords: phenotype, otolith shape, wavelets, commercial species, management

(GP Poster 15433) GP-4**Prevalence of nematodes in *Sardinella aurita*, *Scomber colias* and *Trachurus picturatus* caught in the Canary Islands (Spain, NW Africa)**

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Anisakidae is a nematode family known as a danger for human health causing different stomach diseases and allergic reactions by the ingestion of different larvae stages in undercooked marine fish. We investigated the prevalence of aquatic nematodes in the abdominal cavity and viscera of small pelagic fishes (SPF) caught by the artisanal fleet of the Canary Islands. A total of 980 fresh individuals including *Sardinella aurita* (n = 201), *Scomber colias* (n = 478) and *Trachurus picturatus* (n = 301) were analyzed during the routinely samplings performed in the EU Data Collection Framework. Worm parasites were extracted and stored in labelled vials. They were deposited in 'Petri dishes' observed under reflected light microscope after cleared using lactophenol. Different species of Acantocephala (n = 24) and *Anisakis* spp (n = 77) were identified. Based on these observations, *S. colias* presented the highest prevalence of these parasites, with the 13% of individuals infected by one or more parasites vs. *S. aurita* which presented the lowest prevalence (0.5%).

(GP Poster 15337) GP-5

Evaluation and prediction of small pelagic fish dynamics by an interspecific relation model under regime shiftsNaoya **Iwamoto**, Akinori Takasuka and Takashi Yamakawa

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Regime shifts are known to cause large changes in abundance of small pelagic fish. Predicting these changes is critical for sustainable exploitation of fisheries resources; however, there are many difficulties in climate-based predictions. In the present study, an interspecific relation model that expresses the dynamics of multiple fish species is proposed and its effectiveness is verified. The state in abundance of species i in year t ($X_{i,t}$) is represented by the product of powered states of n species in the previous year:

$$X_{i,t} = r_i X_{i,t-1} \exp(-F_{i,t-1}) \prod_{j=1}^n X_{j,t-1}^{b_{i,j}} \quad (\text{Eq.1})$$

where r_i is intrinsic rate of natural increase of species i , $F_{i,t-1}$ is fishing coefficient for species i in year $t-1$, and $b_{i,j}$ is a power exponent to represent the sign (positive/negative) and strength of interrelationship from species j to species i . By taking logarithms of Eq.1, it becomes a linear equation and can be incorporated into a state-space model with a matrix form:

$$\ln(\mathbf{X}_t) \sim \text{multi_normal}(\ln(\mathbf{r}) + \ln(\mathbf{X}_{t-1}) - \mathbf{F}_{t-1} + \mathbf{b}\ln(\mathbf{X}_{t-1}), \mathbf{S}_{\text{process}}^2) \quad (\text{state equation})$$

$$\ln(\mathbf{X}_t^{\text{obs}}) \sim \text{multi_normal}(\ln(\mathbf{X}_t), \mathbf{S}_{\text{obs}}^2) \quad (\text{observation equation})$$

where $\mathbf{S}_{\text{process}}$ and \mathbf{S}_{obs} are covariance matrices of process and observation errors, respectively. Estimation was conducted using catch and abundance data for six species of small pelagic fish (*Sardinops melanostictus*, *Engraulis japonicus*, *Scomber japonicus*, *Scomber australasicus*, *Trachurus japonicus*, and *Todarodes pacificus*) in waters around Japan from 1951 to 2018. In consequence, we adequately reproduced the dynamics of these species with long-term large changes in abundance. Parameter selection using Bayesian LASSO with k -fold cross-validation was effective for conducting parsimonious modeling to prevent overlearning.

(GP Poster 15365) GP-6

Climate risks and opportunities of the marine fishery industry: A case study in TaiwanTse-Yu **Teng**¹, Ching-Hsien Ho*¹, Chih-Heng Cai² and Zhen Lu³

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As climate change and extreme weather intensify, forecasting natural environmental changes involves high uncertainty and variation. Planned policy changes and the ability of fisheries to withstand these changes and impacts are major challenges in regard to addressing future climate hazards in Taiwan. Taiwan's geographic location is favorable for the marine fishery industry, which is an important primary industry and a source of animal protein for residents of Taiwan. Recently, both long-term climate change and extreme climate hazards have led to shocks in the marine fishery industry. The resulting instability of the industry directly affects the market supply of and demand for seafood. We conduct a case study of a marine fishery industry in Taiwan that incorporates social concern assessments of risk perception and judgements of risk acceptance through risk management processes. Furthermore, we incorporate stakeholder participatory processes to reduce the gap in awareness of adaptation and to increase the opportunity to reach consensus and develop an integrated risk management model that enables decision-makers to better meet the needs of society. These measures will enhance all parties' willingness to adapt and help achieve the goal of public-private collaboration in facing climate change challenges.

(GP Poster 15367) GP-7**How do Atlantic herring early life stages cope with ocean warming and bacterial infection?**

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Fish eggs and larvae are the most vulnerable life stages and therefore heavily impacted by changing environmental factors. Climate change is driving shifts in abiotic factors influencing biotic factors, for example marine diseases. Hence, investigating how early life stages cope with changing interacting abiotic and biotic factors is crucial for predicting future ecosystem dynamics. However, this has been largely neglected so far. Considering that fish larvae are highly susceptible towards pathogenic infections (due to their limited immunocompetence), it is of particular importance to assess how they cope with changes in abundance and virulence of infectious disease agents. Thus, we investigated the effect of rising temperatures combined with opportunistic bacterial infections (*Vibrio* spp.) on the larval development of Atlantic herring (*Clupea harengus*), one of the economically and ecologically most important fish species in the northern hemisphere. To better understand the acclimation potential and disease resistance of Western Baltic spring-spawning herring larvae, we are currently analyzing the full transcriptome gene expression, epigenetic response, microbiota and life-history traits. The ultimate aim is to unravel the underlying mechanisms driving the changes in larval survival, growth and disease resistance due to climate change. The obtained results can provide essential information for environmental agencies and policy makers involved in ecosystem and fisheries management since the potential negative effects of environmental change on herring early life stages might impede the species' recruitment success.

(GP Poster 15417) GP-8**Uncertainty analysis reveals key species and indicators in the Peru Current Ecosystem**

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Substantial progress has been made in increasing the sustainability of small pelagic fishes worldwide over the past decades. This is important not for the sustainable exploitation of target species, but also because of the role of marine biodiversity in providing multiple ecosystem services. In this context, ecosystem modelling has emerged as a useful tool for these broader sustainability objectives. However, one main criticism of complex marine ecosystem models is that their potential large complexity can make ecosystem model projections highly uncertain and therefore limit their use in decision making. In this work, by using the OSMOSE model applied to the Peru Current Ecosystem we implement an uncertainty analysis that quantifies the effect of parameter uncertainty in a set of ecological indicators that evaluate the state of important small pelagic fishes. The results of this work helped to identify key sources of uncertainty that could be of use to focus future research and point to the most reliable indicators in the face of uncertainty. As part of our main results, the uncertainty in the parameters of some species, in particular, a key zooplankton species and Humboldt squid, have far-reaching impacts on the modeled biomass of other key species. Second, the uncertainty in the parameters of anchovy is almost exclusively related to uncertainty in its own life cycle parameters. We also highlight the difficulties of studying the uncertainty in an ecosystem model, where the uncertainty could propagate differently over time and across different output variables. Finally, we suggest that more guidelines and methods could be useful for addressing the difficulties linked to working with ecosystem models.

Keywords: uncertainty analysis, parameter uncertainty, ecosystem model, Peru Current ecosystem, OSMOSE model.

(GP Poster 15488) GP-9**Growth performance of larval anchoveta *Engraulis ringens* in a natural plankton community: First insights from a mesocosm study off Peru on the effect of different light regimes and upwelling intensities**

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In the Humboldt Upwelling System (HUS), nutrient-rich deep water fuels a short, efficient food web from phytoplankton to small pelagic fish giving rise to the world's most productive fishery. Yet, uncertainty about how environmental conditions shape biological productivity is hampering our understanding of the future of this ecosystem service.

We studied the growth performance of larval anchovy *Engraulis ringens* in nine 30-m³ off-shore mesocosms as part of a natural food web exposed to different light regimes and upwelling intensities. The plankton community developed under the treatment conditions for 19 days, before anchovy larvae were introduced to each mesocosm. After 17 days within the mesocosms, all remaining fish larvae were caught and morphological and biochemical measurements were made (dry mass and fatty acid composition) to explore the link between fish production and changes at lower trophic levels. Both, light regime and upwelling intensity, affected anchovy survival and growth. Survival increased with upwelling intensity in the high light treatment but was generally lower than under low light, where upwelling intensity had a negative effect on larval survival. Growth, however, was positively affected in both light regimes, although a stronger effect was found under high light. The differences in growth and survival between treatments, may be explained by a combination of bottom-up changes in the phytoplankton community, and competition between fish larvae. Our results highlight, how different light regimes and upwelling intensities affect the food web up to anchovy larvae and thus may have major ecological and economic implications for the HUS.

(GP Poster 15820) GP-10**Stock status of small pelagic fishery in Sultanate of Oman**

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The study provides an overview of trends in abundance and fishing effort on small pelagic fish stocks assessment in Oman between January 2022- December 2024. The aim of this study is to assess the stock status of three small pelagic species (*S. longiceps*, *R. kanagurta* and *D. russelli*) in Omani waters. This is ongoing project; the results below include analysis of six months' data. Total of 4447 samples were collected from four landing sites along Sea of Oman, and Arabian Sea. R platform was used to analysis morphometric characteristics for target species. Analysis of variance (ANOVA) between the monthly mean total length in the studied seas were significantly different (ANOVA; $p < 0.01$). The minimum total length recorded was 11 cm and the maximum was 33 cm of *S. longiceps*, while the minimum total length was 10.5 cm, 15.8 cm and the maximum was 38.8 cm, 44.4 cm for *R. kanagurta* and *D. russelli*, respectively. The monthly gonado-somatic index (GSI) for three species indicated that patterns for both sexes were similar. Result expected after two years sampling will identify the stock status of the target species and comparing it with previous studies and a long- term management will be propose to sustain this fishery.

(GP Poster 15827) GP-11

Occurrence of parasite-induced ‘soft flesh’ in some commercially important pelagic fish species from off Morocco: Product quality implications

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Small pelagic fishes represent the major target in the fisheries in the Northwest coast of Africa. *Engraulis encrasicolus* (anchovy), *Sardina pilchardus* (sardine), *Trachurus trachurus* (horse mackerel) and *Scomber colias* (chub mackerel) are the most abundant and commercially valuable pelagic species. Despite their economic significance, little is known about the infections with flesh invading myxosporean parasites of genus *Kudoa* (Cnidaria, Myxozoa). Heavy infections in the flesh may be associated with *post-mortem* myoliquefaction, commonly known as ‘soft flesh’. This condition may reduce the quality and marketability of the fish fillet, resulting in both economic losses to the commercial fisheries and loss of consumer confidence. In this study, we investigated *Kudoa*-induced ‘soft flesh’ occurrence in anchovy, sardine, horse mackerel and chub mackerel caught in 2019 off Moroccan Atlantic coast. 500 specimens of each fish species were examined for ‘soft flesh’ by texture testing and microscopy 48 hours after thawing. Prior to examination, the fish host weight and length, sex and maturity stage were recorded. ‘Soft flesh’ was detected in 0.2% of the anchovies, 0.6% of the horse mackerel, 1.4% of the sardines, and in 4.4% of the chub mackerel. Microscopic examination and SSU rDNA analyses revealed that ‘soft flesh’ fishes were infected with *K. thyrssites*. The sequences were 100% identical with sequences of the eastern Atlantic *K. thyrssites* genotype. Even if there are no known human health consequences associated with such parasite, the unsightly appearance of some infected fillet is a food quality issue, that can lead to reduced marketability and income.

(GP Poster 15874) GP-12 **CANCELLED****How do different seabird species reflect fluctuations of the Atlantic Herring population in the Bay of Fundy?**

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In the Gulf of Maine and the Bay of Fundy, Atlantic Herring *Clupea harengus* is among the most targeted fish species by both Canadian and U.S.A. fishing industries. Overfishing and climate change have significantly impacted this population, leading to its decline and, consequently, to demographic declines of some of its predators. This is the case of seabirds which depend on herring during the Northern hemisphere Spring and Summer months. Seabirds can be good indicators of their environment and of the abundance of their prey, but different species can reflect shifts in different ways. Thus, in this study, we aim to describe how three sympatric seabird species, the Atlantic Puffin *Fratercula arctica*, the Razorbill *Alca torda*, and the Common Murre *Uria aalge*, may reflect the availability of Atlantic Herring in the Bay of Fundy. Here, we hypothesize that the differences found in their diet are directly linked with their foraging areas and behaviour, and the fishing pressure exerted in each area. Using previous knowledge about the foraging areas of each species in the Bay of Fundy, we analyzed a long-term diet data set (1995-2022) together with landing and acoustic data of herring for the same period. Atlantic Puffins are currently consuming the least herring (<20% of total mass) of the three seabirds (>25%), and this is probably related to the incremental fishing pressure observed in the deep waters of the Nova Scotia shelf where puffins forage, and to their diving behaviour. Puffins rarely dove deeper than 20 meters, and it is thought that herrings are escaping to cooler waters, which could mean moving to deeper waters. Razorbills and Common Murres forage in shallower areas than the puffins, close to the Maine and New Brunswick coasts, where landings have been slowly decreasing. This could explain why they have been more successful feeding their chicks higher proportions of herring than puffins. This study is a step forward towards the use of seabirds as tools to help inform fisheries about herring’s population in the Bay of Fundy.

S1. Trophodynamic Processes

(S1 Poster 15207) S1-P1

Trophic importance of small pelagic fish to marine predators of the Mediterranean Sea

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In the Mediterranean Sea, small pelagic fish (SPF) species such as European sardine (*Sardina pilchardus*), European anchovy (*Engraulis encrasicolus*), round sardinella (*Sardinella aurita*) and European sprat (*Sprattus sprattus*) play important ecological roles in marine ecosystems. Recent changes of SPF abundance and biomass have been observed in the Mediterranean Sea. Therefore, uncovering the trophic importance of SPF for their predators is key to unravelling potential ecological causes and consequences of SPF population changes related to predator dynamics. Here, we reviewed 101 studies reporting the presence of SPF species named above in the diet of predators inhabiting the Mediterranean Sea. We found that the number of predatory species preying on SPF was higher highest for teleost fish species, followed by elasmobranchs, seabirds, marine mammals, cephalopods and sea turtles. These predators were both commercial and non-commercial taxa and, ranged from medium to highly vulnerable, and were mostly Least Concern species from a conservation point of view, with exceptions such as the Balearic shearwater (*Puffinus mauretanicus*), a Critically Endangered species. Geographic information showed that European sardine was more important in the diet of predators from the western Mediterranean basin, while European anchovy consumption was higher in the eastern side. Round sardinella was particularly consumed in the Tyrrhenian Sea, and European sprat was anecdotally consumed. The importance of SPF in the diet of Mediterranean predators may indicate a bottom-up control of the marine ecosystem, despite the limited temporal information that precluded evaluation of temporal changes, highlighting the need to develop new studies in this direction.

(S1 Poster 15272) S1-P2 Poster & Talk

Variability in the ascaridoid parasites load in the European sardine along the host distribution and its reproductive cycle

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In recent years, a drop in the condition and health status of the European sardine has been observed. Potential causes have been attributed to this issue, including overfishing and climate change. However, little is known about the impact of parasitisation in this small pelagic. In this study, sardine samples were obtained seasonally from five different areas along the Mediterranean, as well as from one location in the Atlantic Ocean (Southern Portugal). Ascaridoid parasites were recognized by combining naked eye and UV-press methods along the muscles and viscera. Afterwards, genetic markers were used to identify the ascaridoid larvae at species level from the fish host along the localities. The main species found along different areas was *Hysterothylacium aduncum*, but also few individuals of *Anisakis simplex* (s.s) and *A. pegreffii* were observed in the Atlantic and the Adriatic stocks sampled. The highest prevalence of *H. aduncum* larvae were observed in fish from the Atlantic, followed by the Adriatic, and the Catalan Coast. As we could obtain fresh samples from the latter, a monthly visual examination was carried out in this location.

Furthermore, results suggested a higher parasitic load during the coldest months of the year, coinciding with the reproductive period of sardine. We consider of interest to carry out future studies that analyse the potential impact of nematodes on sardine stocks covering its entire distribution along the year, both at an ecological level and from the perspective of the consumer.

(S1 Poster 15310) S1-P3

Effects of prey concentration on ingestion rates of European anchovy *Engraulis encrasicolus* larvae in the laboratory

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To understand small pelagic fish recruitment success, it is essential to know how key factors such as prey availability and feeding behaviour can affect larval fish growth and survival. The effect of prey concentration on ingestion rates of the European anchovy *Engraulis encrasicolus* was estimated for larvae from hatching to 15 days post-hatch (dph) under controlled laboratory conditions at 17.5°C and 35 of salinity. Three prey concentration of the calanoid copepod *Acartia grani* nauplii were provided (0.5, 2 and 6 nauplii ml⁻¹). An increase of swimming capacity and hunting success was observed throughout ontogeny. Anchovy larvae preferred mean prey size classes had within the range of 130-160 µm prosome length. Ingestion rates increased with prey concentration. For intermediate and high food concentrations, ingestion rates were 82.36 prey larva⁻¹ h⁻¹ and 145.13 prey larva⁻¹ h⁻¹, respectively. Ingestion rates for low food concentration were not significant. Feeding rates are higher and preferred prey are larger when compared with European sardine *Sardina pilchardus* larvae at the same age in similar feeding experiments, hence decreasing direct competition by feeding at a higher trophic level. As sardine, anchovy inability to feed at low prey concentrations suggests that these species depend on dense prey patches to survive. Therefore, bottom-up processes which causes food limitation can have a strong impact on anchovy's survival and growth.

(S1 Poster 15336) S1-P4

Diet shifts in small pelagic fishes during a marine heatwave: Insights from isotope mixing models

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The U.S. west coast marine ecosystem has recently experienced unprecedented ocean warming due to a major marine heatwave lasting several years. The heatwave led to profound changes in species composition, spatial distribution, and food web structure throughout the California Current ecosystem (CCE). A key unknown that warrants attention is how ocean warming may impact marine food web interactions, and particularly the trophic interactions of small pelagic fishes. In the CCE, the major small pelagic forage species include Northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific herring (*Clupea pallasii*), whitebait smelt (*Allosmerus elongatus*), and surf smelt (*Hypomesus pretiosus*). Previous diet studies indicated that crustaceans were the dominant prey item of forage fishes in cool or normal years but gelatinous species, such as salps, were the dominant prey during the marine heatwave. Our goal is to use stable isotope signatures in forage fish muscle tissue combined with a Bayesian mixing model to determine if we detect similar changes in their feeding habits during warm ocean conditions. Most species fed on a narrower diet and had a lower trophic position during warm ocean conditions, and the proportion of gelatinous material in the diet increased during the heatwave compared to normal ocean conditions. Overall, our results corroborate the findings from the stomach content analyses, providing further support of a shift in forage fish feeding habits from a crustacean to a gelatinous dominated diet during warm conditions.

(S1 Poster 15340) S1-P5**Gastric evacuation rate of European sardine and Atlantic chub mackerel: The effects of different diets and the application of the results to predation estimates**Pedro **Fonseca**¹, Marisa Barata², Sara Castanho², Pedro Pousão-Ferreira² and Susana Garrido^{1,3}¹ Portuguese Institute for the Ocean and Atmosphere (IPMA), Rua Alfredo Magalhães Ramalho, 6, 1495-006 Lisbon, Portugal. E-mail: pedromfonseca@gmail.com² IPMA, EPO—Aquaculture Research Station, Av. Parque Natural da Ria Formosa s/n, 8700-194 Olhão, Portugal³ MARE – Marine and Environmental Sciences Centre Faculdade de Ciências, Universidade de Lisboa Campo Grande, 1749-016 Lisbon, Portugal

Cannibalism and Intraguild predation of fish eggs are frequently observed for small pelagic fish and can be an important cause of mortality. Previous works have identified the European sardine (*Sardina pilchardus*) and the Atlantic chub mackerel (*Scomber colias*) as the major egg predators off Atlantic Iberian waters. A recent work estimated that 71% of the anchovy eggs spawned in the spring of 2018 on the Northern Portuguese shelf may have been consumed by sardines inhabiting the same area. However, estimations of egg mortality due to predation rely on a number of parameters that are usually assumed as equal to other predators or areas, such as gastric evacuation rate. These assumptions can severely affect egg mortality estimates. We have conducted laboratory experiments to estimate gastric evacuation rates of sardine and chub mackerel, with diets based on different concentration of fish eggs, Artemia, rotifers and microalgae, and different temperatures were tested, 16°C and 19°C for chub mackerel and 15, 17, and 21°C for sardine. Chub mackerel digested prey at a faster rate than sardine and diet composition had a larger effect on digestion rates than temperatures tested. For sardines, the gastric evacuation rates for fish eggs varied between 0.10459 h⁻¹ and 0.27345 h⁻¹, and for chub mackerel varied between 0.11780 h⁻¹ and 0.18356 h⁻¹. In light of this new data, recalculating egg mortality considering species-specific gastric evacuation rate of sardine on fish eggs (0.27345 h⁻¹), the estimated values of predation on anchovy eggs by sardine is 28%. This study provides important information on gastric evacuation rates that allow improving estimates of egg mortality by predation, to improve understanding of SPF population dynamics, and specifically to inform models for an ecosystem approach to fisheries management.

(S1 Poster 15345) S1-P6**A wolf in sheep's clothing – Planktivorous Baltic herring preying on estuarine demersal fishes**Paul **Kotterba**¹, Helmut Winkler², Annegret Finke^{1,3}, Patrick Polte¹ and Dorothee Moll¹¹ Thünen-Institute of Baltic Sea Fisheries, Rostock, Germany. E-mail: paul.kotterba@thuenen.de² University of Rostock, Institute of Biosciences, General and Systematic Zoology, Rostock, Germany³ University of Hamburg, Hamburg, Germany

Herring (*Clupea* spp.) is considered a key element in many marine food webs, linking trophic cascades from zooplankton to higher trophic levels. Besides its prominent ecological importance as so-called “forage fish”, herring has also been an essential marine resource for humans since the Middle Ages. Consequently, intensive research has been focused on herring biology making Atlantic herring (*C. harengus*) one of the world's best studied marine fish species. The textbook paradigm that this species feeds exclusively on zooplankton, ichthyoplankton and small crustaceans is, however, based on a plethora of studies that focused solely on herring behavior in their offshore habitats. We studied Western Baltic herring which immigrates regularly into inshore systems, hypothesizing that the species is capable to adapt its preying behavior to the specific prey availability in these ecotones. We further investigated the potential impacts of filial cannibalism since a strong spatio-temporal overlap of adult spawners and already hatched larvae of earlier cohorts can be observed in the nursery areas. Adult herring stomachs were sampled during spring spawning and in fall of three consecutive years (2010-2012). Despite high larvae and mesozooplankton abundances in the system, most spring herring stomachs were empty. Thus, we excluded cannibalism as a driver of larval mortality. Surprisingly, fall stomach sampling revealed an intense and recurrent preying on demersal fish, mainly gobies of the genus *Pomatoschistus*. We will discuss the implications of our findings for herring ecology and management as well as the importance of holistic ecological research as indispensable basis for the latter.

(S1 Poster 15350) S1-P7**Understanding protein requirements in *Sardina pilchardus***

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European sardine (*Sardina pilchardus*) is a social and economic important small pelagic species widely distributed throughout the eastern Atlantic Ocean and its associated seas. Its production in aquaculture derived from the announced risk of reduced reproductive capacity situation reported in the beginning of 2015. The Aquaculture research station in Olhão from the Portuguese Institute for the Ocean and Atmosphere (EPPO-IPMA) is a pioneer in sardine production and has now second-generation sardines, foreseeing an opportunity in the canning industry, a Portuguese tradition with more than one century of existence. Its production under captivity implies the fulfillment of several critical element, among which a detailed knowledge of the nutritional requirements to insure an optimal growth and health status. In fish diets, protein usually represents the most expensive dietary component, therefore it is important to understand and determine fish protein requirements not only from an economical perspective but also from zootechnical and environmental ones. With this study, we intended to investigate the protein requirements of *S. pilchardus* juveniles based on growth performance, digestibility, proximate composition and protein degradation analysis.

Acknowledgments

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(S1 Poster 15359) S1-P8**Preliminary contribution on the aspect ratio (A) of small and large pelagic species in the South Atlantic area of Morocco**

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The southern Atlantic region of Morocco is between Cap Boujdour (26°N) and Cap Blanc (20°50'N), this region is very rich in fish due to the permanent upwelling that ensures the nutrients and salts. The Small pelagic fish (*Sardina pilchardus*, *Scomber colias*, *Engraulis encrasicolus*...) are a key component of pelagic ecosystem owing to their high overall biomass at a mid-trophic level, which provides an important energy linkage between upper and lower trophic levels. However, studies have shown that the ecosystem is not yet a mature system and is resistant to disturbance. The morphometry of pelagic fish is an important aspect in studies of taxonomy and fish biology. The aspect ratio (A) of fish is related to metabolism and food consumption. In this work, the aspect ratio (A) of small pelagic fishes (*Sardina pilchardus*, *Scomber colias*, *Engraulis encrasicolus*...) and large pelagic fish of the piscivorous type (*Prionace glauca*, *Sarda sarda*, *Auxis thazard thazard*) from the South Atlantic area of Morocco was calculated using a digital imaging method (ImageJ). This ratio will help us to feed the trophic model EwE (Ecopath with Echoism) that will be applied in our South Atlantic region.

(S1 Poster 15364) S1-P9**The spatiotemporal abundance, distribution, and energy content of sandeel (*Ammodytidae spp.*) in the southern North Sea. Potential top-down impacts of seal populations on this forage fish resource**

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Sandeel (*Ammodytidae spp.*) is a forage fish which plays a crucial role in the North Sea food web as a prey item for many predatory fish, bird, and marine mammal species. As sandeel is poorly represented in standard demersal fish surveys, there is a lack of knowledge on the spatial distribution, abundance, behaviour, and energy content on this forage resource. In this study a deep digging dredge was used, a particularly suitable gear for quantitatively catching (small) bottom fish, including the burrowed sandeel species *A. marinus* and *A. tobianus*. R-INLA (Integrated Nested Laplace Approximations) models were fitted to make habitat distribution predictions, and, by including distribution of predators (harbour and grey seals) from tracking data, we attempted to understand predator-prey overlap and the potential magnitude of top-down forces from seal population in Dutch coastal areas. Furthermore, by combining distribution patterns with information on season- and size-specific energy densities, a spatiotemporal map was created. Such prey-specific energy maps are vital for understanding behaviour and population dynamics of marine mammal and seabird species that heavily depend on forage fish, such as sandeel, and for including ecological tradeoffs within marine spatial planning

(S1 Poster 15404) S1-P10**Diet of SPF larvae off Atlantic Iberian waters: New insights using molecular techniques**

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The diet of small pelagic fish (SPF) larvae is largely unknown for most species, due to the low number of studies compared to adult stages and to the high vacuity rate when conducting gut content analysis. However, a good understanding of the trophic ecology of these important fisheries resources, and especially at the early life stages, is essential information to allow predictions of recruitment strength based on the conditions experienced at the larval stage. To this purpose, food availability must be assessed considering knowledge of diet composition and main prey items throughout larval development. Here we make a first attempt to study the diet of sardine and anchovy larvae collected from the Western and Southern Iberian coasts using metabarcoding of stomach contents and compare it with results of visual inspection of prey items. Different genetic markers (barcodes) will be used to target different taxonomic groups, including prokaryotic and eukaryotic phytoplankton (23S rRNA), and eukaryotic zooplankton (18S rRNA and COI). Application of metabarcoding in stomach content analysis of early life stages holds great potential to unravel the hidden prey diversity in the challenging small size scales of SPF larvae.

(S1 Poster 15440) S1-P11**Dietary and spatial overlap among jellyfish and small pelagic fish in the eastern Bering Sea**Emily Fergusson¹, Mary Beth **Decker**², Ellen Yasumiishi¹, Kristin Ciciel¹, Richard Brodeur³ and Todd Miller¹¹ NOAA Alaska Fisheries Science Center, Auke Bay, AK, USA² Yale University, New Haven, CT, USA. E-mail: marybeth.decker@yale.edu³ Hatfield Marine Science Center, Oregon State University, Newport, OR, USA

Populations of scyphozoan jellyfish in the eastern Bering Sea (EBS) can grow rapidly within a single season and have fluctuated widely over recent decades. Understanding the role of jellyfish in the EBS ecosystem is required for fishery and ecosystem management, however we lack direct measurements of the impact that changes in jellyfish abundance have had upon this ecosystem and its fish populations. We examined the role of jellyfish as competitors and predators by (1) observing the diets of the dominant scyphozoan jellyfish in the region, *Chrysaora melanaster*, and (2) estimating the dietary and spatial overlaps among jellyfish and major planktivorous pelagic fish taxa. Ocean sampling for diet analyses occurred in 2014, 2015 and 2016. Jellyfish diets contained primarily copepods and pteropods, but showed little overlap with small pelagic fishes. Fishery research data were used to examine the spatial overlap of small pelagic fish and jellyfish within the EBS during the summers of 2014-2016. Generally, jellyfish and small pelagic fishes showed low spatial overlap, but there were some high spatial overlaps among the small pelagic fish. Spatial overlap and trophic relations are not uniform throughout the EBS nor across years, however, regions of high overlap do occur, which could result in resource competition in low productivity years or areas.

(S1 Poster 15443) S1-P12**Prevalence and molecular identification of *Corynosoma* in Baltic herring (*Clupea harengus membras*) and great cormorant (*Phalacrocorax carbo*)**Johannes **Sahlsten** and Jari Hänninen

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Baltic herring (*Clupea harengus membras*) is one of the most abundant and commercially important fish species in the Baltic Sea. In the Archipelago Research Institute, a long-term monitoring program was established in 1984 with an intention to monitor herring's reproductive health and changes in the population. In 2014, some of the herrings were infected with *acanthocephalas* or thorny-headed worms of genus *Corynosoma*. Thorny-headed worms are intestinal parasites that occur in vertebrates. Their life cycles include an amphipod as the intermediate host and a fish as a paratenic host. *Acanthocephalas* of the genus *Corynosoma* mature in the intestines of mammals such as seals and piscivorous birds. Between the years 2014 and 2019 total of 7002 herring and 65 Great cormorants (*Phalacrocorax carbo*) were examined and *acanthocephalas* were collected. Their species were identified using DNA-analysis.

The prevalence of the *Corynosoma* infections increased from 2014 to 2018 but decreased in 2019. There was a significant difference in infection prevalence between two areas, The Bothnian Sea and the Archipelago Sea (14% and 20% respectively). DNA-analysis showed that three different *Corynosoma* species were responsible of the infections: *C. semerme*, *C. strumosum* and *C. magdaleni*. 26% of the cormorants were infected and DNA-analysis showed that all the parasites in cormorants were *C. semerme*. This implies that growing numbers of cormorants might be one factor behind the increasing number of infections in fish.

(S1 Poster 15489) S1-P13**Isotopic niche plasticity of sardine larvae in the northern Alboran Sea (W Mediterranean)**

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The Alboran Sea sardine (*Sardina pilchardus*) is the most abundant small pelagic fish in the Mediterranean Sea. Along the northern coast of the Alboran Sea, Málaga and Almería Bay are two important nursery grounds with contrasting oceanographic characteristics. Seasonal and spatial variability in sardine post-larvae isotopic niche was investigated to estimate the trophic plasticity in order to better understand the trophic ecology of their critical early life stages. Physical and biological data (including different phytoplankton and zooplankton size fractions as components of the planktonic food web) were collected for analyzing the early life trophodynamics of the two post-larval populations. Spatial isotopic differences were observed analyzing both nursery areas, with a general pattern of higher nitrogen isotopic signatures in Málaga Bay for all seasons. Isotopic niche width estimations from stable isotope Bayesian ellipse in R suggested seasonal and spatial differences in the diversity of the sardine larval diet. Bayesian standard ellipse area values from sardine indicated that the diet of larvae from Málaga Bay is more euryphagous than in the Almería Bay. The results are discussed considering early life trophodynamics influence on larval growth potential and survival, on the basis of a comparative approach analysing ontogenetic variations of the isotopic signatures with age. This work was supported by TROFOALBORAN (CTM2009-07776) and MOLDIALB (P11-RMN-7354) projects.

(S1 Poster 15515) S1-P14**Atlantic sardine *Sardina pilchardus* is able to elongate and desaturate LC-PUFA?**

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The risk of reduced reproductive capacity situation reported for Atlantic sardines (*Sardina pilchardus*) in the beginning of 2015 led to the development of aquaculture production as a complementary way to supply this pelagic fish species. It is well known the high nutritional value based in the richness of long chain omega 3 fatty acids (n-3 LC-PUFA) as 20:5n-3 and 22:6n-3.

The Aquaculture research station in Olhão from the Portuguese Institute for the Ocean and Atmosphere (EPPO-IPMA) is a pioneer in sardine production and has third-generation sardines. Sardines produced in aquaculture, feeding on artificial diet showed higher percentage of non-polar lipids (NPL) in their muscle, with high levels of 18:1n-9, 18:2n-6 and lower of 20:5n-3 and 22:6n-3 compared with wild fish. Polar lipids (PL), as expected, were less influenced by captivity since the fatty acids profile was more stable. The excess of energy in the diet of captive sardines was reflected in lipid accumulation in subcutaneous layer and visceral fat but not in the liver.

Moreover, obtained data suggest the power of endogenous capacity of this pelagic species to biosynthesize LC-PUFA. This reinforces the potential of the enzymatic system of Atlantic sardine to elongate and desaturate LC-PUFA when a not adequate level is present in the feed. With the present study, was intended to investigate the lipid requirements of *S. pilchardus* based on growth performance, feed digestibility, lipid classes composition and fatty acid profile with a special emphasis on the endogenous capacity to biosynthesize LC-PUFA, using metabolomics and transcriptomics approaches.

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(S1 Poster 15518) S1-P15 CANCELLED**Endoparasites occurrence on farmed European sardine (*Sardina pilchardus*)**

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European sardine (*Sardina pilchardus*) is one of the main targets of Iberian fisheries, and one of the most commercially important species in the canning industry. The decrease of European sardine stock due to prolonged low recruitment and high catch levels lead to the developing of aquaculture production in the latest years.

Intensive aquaculture promote conditions for parasite occurrence and transmission, and so it is very important to evaluate the sanitary status of fish to prevent the development of diseases. Few information exists on parasites affecting wild European sardine. As a new aquaculture specie, the screening of parasites is therefore necessary to guarantee the welfare of this species in captivity. Endoparasites, specially Myxozoa, are a potential harmful for marine fishes, being present in several tissues, responsible for severe fish mortalities rates or chronic diseases that can reduce fish growth, welfare, and consequently the commercial value of fish.

The present study aims to report the occurrence of endoparasites in *S. pilchardus* reared at the Aquaculture Research Station of Olhão (EPPA-IPMA). For three years, different endoparasites from the Myxozoa class were identified in sardines and characterized through fresh microscopy, histology, and molecular biology techniques. Also, a five-levels infestation scale was defined to prevent fish outbreaks and to improve fish welfare.

Acknowledgments

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(S1 Poster 15522) S1-P16**Parasites of small pelagic fishes reflect their place in marine ecosystems**

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The important role that small pelagic fishes play in the marine ecosystem is indisputable, occupying a critical intermediate trophic level and serving as prey for an immense variety of predators. Evidence of their role in the marine food web can be provided not only by visual analyses of the diets of small pelagic fishes and their predators, but also by studies of the trophically-transmitted parasites found in these fishes. Many parasites use trophic interactions to complete complex life cycles and with their relatively long life-spans within a host relative to stomach contents can provide a unique diet history within vertebrate hosts. The presence of trophically-transmitted parasites can not only be a direct indication of prey consumed, but also infer important predators. In addition, they can infer past feeding history even in fish with otherwise empty stomachs or with unrecognizable prey. Here we provide a global perspective of parasitological studies of small pelagic fishes and how they have contributed to our understanding of the roles of small pelagic fishes in marine ecosystems. We synthesize results of studies that utilized parasites of small pelagic fishes to infer their hosts' diets and their role in the food web, in addition to those comprehensive parasitological studies from which such information can be derived. Furthermore, we compare studies that have used coordinated efforts combining analyses of parasites and stomach contents, parasites and stable isotopes, in addition to all three methods within a single study.

(S1 Poster 15830) S1-P17

Helminth parasites of *European pilchardus*, *Sardina pilchardus* (Walbaum, 1792) from the Portuguese coast

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The European pilchard, *Sardina pilchardus*, is one of the most abundant small pelagic fish with an important commercial value and highly appreciated by the Portuguese consumers. However, little data on parasitic fauna is available. Within the scope of MAR2020-01-04-02-FEAMP-0009 - SARDINHA 2020 project, the present study aimed to identify the parasitic fauna in sardines along the Portuguese coast. A total of 357 sardines from ten sampling points along the Portuguese coast and two on the south coast of Spain were obtained. Thirteen specimens per sampling point were individually frozen and used for parasitological analyses. Parasites were analysed individually and parasites were searched in different organs and tissues, preserved, and studied. The digeneans were the most abundant group in terms of number of individuals and species. A total of 2 116 digeneans were recovered and identified: *Pseudobacciger harengulae*, *Pronoprymna ventricosa*, *Aphanurus virgula*, *Aphanurus stossicii*, *Parahemiurus merus*, *Lecithaster confusus* and *Lecithaster gibbosus*. The Monogenea, *Mazocraes alosae*; the Cestoda, *Scolex pleuronectis*; the Acanthocephala, *Rhadinorhynchus* sp. and the Nematoda, *Anisakis* sp. and *Hysterothylacium* sp. larvae were also identified. Although all the identified parasites had already been cited, data show that sardines from the Portuguese coast had an important helminth diversity and the occurrence of three digeneans (*A. virgula*; *P. merus* and *L. gibbosus*) was registered for the first time in the northeast Atlantic. The residual presence of the zoonotic *Anisakis* larvae could probably be related with the sardine diet composition, predominantly small plankton where euphausiids, the intermediate hosts of *Anisakis* were absent.

S2. Life Cycle Closure: Advances in Process Understanding

(S2 Poster 15261) S2-P1

Comparing otolith shape descriptors for population structure inferences in a small pelagic fish, the European sardine *Sardina pilchardus* (Walbaum, 1792)

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Otolith shape analysis has been one of the most used methods to study population structure in the last decades. Currently, two different sets of shape descriptors are used to perform otolith shape analysis: Elliptic Fourier descriptor, which focuses on the overall otolith shape differences, and Discrete Wavelet descriptor, which is sensitive to local differences along the otolith contour. Here, we conducted a comparative analysis of the performance of both descriptors in reconstructing the population structure and connectivity patterns in a small pelagic fish species with a wide geographic distribution and fast growth rate, the European sardine *Sardina pilchardus* (Walbaum, 1792), to understand the possible population structure differences related to the descriptor, using Discrete Wavelet transform technique for the first time in this species. A combination of each otolith shape descriptor and shape indices was explored using multivariate statistical methods. The two otolith shape descriptors showed similar although limited overall classification success associated with the population dynamic characteristics of the species. Both descriptors point to migration among adjacent areas, such as northern Atlantic locations, eastern Mediterranean, and even beyond well-defined geographical barriers such as the Gibraltar Strait, among Atlantic and western Mediterranean locations. Both descriptors supported the division of the populations of Mediterranean waters into two main groups but differed in the grouping of Atlantic waters.

(S2 Poster 15290) S2-P2

Predator abundance shifts spawning ground use in the Barents Sea capelin (*Mallotus villosus*)

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Interannual variation in spawning ground use is common in migratory pelagic fish. Factors governing habitat choice can occur both during spawning migration and at arrival at the larger potential spawning area. The Barents Sea capelin (*Mallotus villosus*) spawn across a large coastal region in Northern Norway and Russia, and is assumed to have yearly variation in local patterns of spawning area use. Quantification of this variation is scarce, with little or no support for ecological hypotheses explaining the proposed patterns. We investigated whether or not there is variation in spawning ground use of the Barents Sea capelin, and its potential link to sea temperature preferences, winter distributions and predator effects. Combining long-term data on larva distribution from Soviet-Russian ichthyoplankton surveys from 1959 to 1993, with ocean drift modelling, we discovered several longitudinal (west or east) shifts in spawning ground centres of capelin along the coast. Further, through a generalized additive model (GAM), we found that the high abundance of the major capelin predator, juvenile NEA cod (*Gadus morhua*), shifted capelin spawning grounds to the east. Traditional hypotheses differentiating between warm and cold periods did not explain much of the variation in spawning ground use. Due to species distribution patterns of juvenile cod and mature capelin in these areas, this shift is unlikely to reflect local depletion of capelin by cod. Alternative explanations are behavioural responses to predators or density-dependent habitat choice by capelin.

(S2 Poster 15295) S2-P3**Understanding the underlying mechanisms affecting growth of small pelagic fish: An experimental meta-analytical approach**

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Understanding the underlying mechanisms affecting growth is essential to better assess and manage the status and dynamics of small pelagic fish stocks worldwide. Experiments provide an effective approach to isolate and quantify direct effects of single factors acting on growth of individual species at a given life stage. However, exploring the combined effect of multiple factors, or comparing effects across several species, or even among regions is challenging and more complex. In this study, we collected and compared experimental growth rates of several species of small pelagic fish (e.g. sardines, Atlantic- and Pacific herring) among regions experiencing a variety of both biotic and abiotic environmental conditions. Raw data were gathered from conducted laboratory and field experiments, complemented with reported information on growth parameters from available literature. This joint dataset provides a unique overview of conducted experiments including all life stage, from larvae to adults, of small pelagic fish. Experimental growth rates will be standardized against the varying environmental factors so that they are directly comparable between experiments. A following meta-analysis will provide new insight how growth rates of small pelagic fish are affected by varying mechanisms across regions and species.

(S2 Poster 15309) S2-P4**Assessing sardine larvae condition: Results from the lab to the sea**

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Fish larvae nutritional condition, their health status and potential survival strongly associated with food supply and feeding success, are of double interest to aquaculture and fisheries sciences. The aim of this work is to compare the nutritional condition of *Sardina pilchardus* larvae reared in the laboratory under different diets (starvation, low and high prey concentrations), using nucleic acid ratios and histological indices. Sardine larvae survival was highly variable, being higher for larvae reared with high food concentration diets (75dph) and lower for larvae under starvation (12 dph). Growth varied significantly between diet treatments. During the first 2 weeks after hatch, growth rate was lower for larvae under starvation followed by low food conditions (around 0.32 mm day⁻¹) and higher for larvae reared with high concentration diet (0.45 mm day⁻¹). Sardine larvae showed better condition in well fed tanks compared to the starving larvae. DNA/DW index was the only one able to differentiate the nutritional condition of larvae under different diets, both for the younger larvae (first 2 weeks after hatching) and for larger larvae (during the first month of life). This nucleic acid derived index was independent of larval age and size. Histological indices from intestine (vacuolization, type of nucleus and number of microvilli), significantly separated larvae reared under different diets only for the first weeks post hatching. Comparing the different methods, DNA/DW index allows a straightforward analysis and appears to be the best to evaluate nutritional condition which can be very useful to better understand and predict fisheries sardine recruitment strength under environmental variability.

(S2 Poster 15331) S2-P5**Growth related selective mortality in adult anchovy and sardine**Christophe Lebigre¹, Andy Boëns² and Pierre **Petitgas**³¹ UMR DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, Institut Agro, Plouzané, France. E-mail: pierre.petitgas@ifremer.fr² UMR DECOD (Ecosystem Dynamics and Sustainability), IFREMER, INRAE, Institut Agro, Nantes, France³ Department of Biological and Environmental Sciences, IFREMER, Nantes, France

In many exploited marine fish there is a decline in size-at-age, a process that can either be attributed to a plastic response to environmental changes and/or the selective mortality of rapidly growing fish due to fishing or environmental constraints. Using otoliths collected in anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) since 2000 in the Bay of Biscay, we measured individuals' growth at age-0 and followed its changes within cohorts to quantify the magnitude of selective mortality, identify its causes, and determine its genetic consequences. We found in both species a systematic selective disappearance of individuals with large growth at age-0. In anchovy, high selective mortality was related to high harvest rates (environmental variables having more limited effects), while in sardine the selective disappearance of large individuals was greater in years with low food quantity. Among generations changes in growth at age-0 in anchovy were due to both density and selective mortality, indicating that an adaptive response occurred in this species and that density dependence prevented the stock to recover its initial growth. In sardines, the response to selection was not related to the magnitude of selective mortality, indicating that the decline in growth in this species is primarily driven by a plastic response to a change in their environment. These analyses clearly show that the selective disappearance of large individuals is a natural process that can be amplified by fishing and which can have long lasting consequences especially if followed by a steep increase in density.

(S2 Poster 15354) S2-P6**Spatio-temporal distribution and abundance indices for common sardine (*Strangomera bentincki*) and anchovy (*Engraulis ringens*) in the southeastern Pacific coast between 1999 and 2021**Jairo **Gutiérrez**¹, Jorge Castillo¹ and Carolina Lang^{1,2}¹ Instituto de Fomento Pesquero-IFOP, Blanco 839, Valparaíso-Chile. E-mail: jorge.castillo@ifop.cl² The University of British Columbia, Institute for the Oceans and Fisheries, Vancouver-Canada

In Chile, anchovy and common sardine cohabit between latitudes 33° and 40°S. These species support a fishery composed of more than 300 small purse seiners (<50 GRT), representing an important economic and social value to the country.

Since 1999, hydroacoustic surveys carried out in summer to assess anchovy and common sardine recruitment have contributed to the knowledge of the Spatio-temporal dynamics of both pelagic resources. This study aimed to determine variations in the Spatio-temporal patterns of species distribution and abundance between 1999 and 2021 by analyzing acoustic data and using spatial indices such as the gravity center, inertia, Gini, spatial overlapping, biomass, acoustic density and schools' number and area.

The findings highlighted three periods of acoustic abundance. First, from 1999 to 2006, both species had similar biomasses of roughly 50% of the total. Second, the common sardine dominated the upwelling system between 2007 and 2013, accounting for more than 65% of the total biomass. Finally, anchovy recovered from 2014 by increasing its occupied area and biomass.

Fluctuations in abundance were associated with an expansion (contraction) when the abundance of the species increased (decreased). Moreover, species' school density levels of both species, as well as their centers of gravity and inertia remained similar until 2008, when spatial changes in common sardine revealed a southerly distribution along the coastal region, while the anchovy's range has expanded since 2014.

(S2 Poster 15368) S2-P7**A cross-system comparison of internal and external forcing regulating growth of small pelagic fish throughout ontogeny**

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The underlying factors affecting growth of small pelagic fish (SPF) throughout ontogeny are poorly known and often unaccounted for in formal stock assessment and fisheries management at large. Since growth of SPF is highly variable and has direct effects on the stock status and yield derived from a stock, it is of paramount ecological and commercial interest to better understand and be able to predict changes in growth; especially under the pending global changes. In this study, we performed a cross-system comparison and assessment of internal and external forcing factors regulating the highly variable growth of sardine and anchovy stocks throughout their ontogeny, by compiling and analyzing long-term time series of weight-, length- and numbers-at-age from available stock assessments worldwide. Using a multi-model approach, including both non-linear regression models and machine learning, our results demonstrate a negative relationship between total abundance and weight, as well as a significant, yet stock-dependent effect of environmental conditions acting on weight throughout ontogeny. The derived responses and predictive accuracy of weights based on observations not used during model fitting (i.e., cross-validation routine) demonstrated consistent and robust patterns and results across methods. To that end, our findings, demonstrating clear signs of density-dependent regulation and environmental forcing acting on growth across species and stocks, provide a stronger scientific basis for management advice to ensure the sustainability and profitability of fisheries, particularly on commercially valuable small pelagic fish species with fast and highly variable growth.

Key words: population dynamics, growth, stock assessment, short-term forecasts, fisheries management

(S2 Poster 15408) S2-P8**Demographic study of early life history stages of *Sardina pilchardus* (Walbaum, 1792) larvae off the northwestern Portuguese coast**

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The distribution, growth and hatching dates of sardine larvae off northwestern Iberian waters was investigated. Larvae were collected in November and December 2016, using a Bongo net with 780 µm mesh size in oblique tows. Sardine larvae were mainly distributed beyond ~50m bathymetric, being present in those areas in higher numbers than in stations closer to the coast. Those areas seem to guarantee conditions for the ontogenic development of the sardine early life stages, that were present in bi-modal cohorts of smaller/younger and bigger/older larvae. Larvae were mainly concentrated in areas related to geographic and hydrographic features, e.g., rivers and canyons. Distribution of larvae was significantly related to environmental drivers, such as salinity, followed by temperature.

More than 55% of the variance observed was explained by salinity in the upper 10m of the water column, and about 20% by sea temperature. Mean growth rate was estimated as 0.34mm day⁻¹ and there was a north-south gradient of sardine larvae growth rate. Particularly, growth rates were higher for larvae distributed further north, between Cabo Mondego and Aveiro Ria (0.34mm day⁻¹), when compared to other southernmost regions off Nazaré Canyon (0.28mm day⁻¹) and Cabo da Roca (0.27mm day⁻¹), which can be explained by environmental conditions. Back calculated birth dates were mainly between 11 September and 5 December 2016, which ranges from early spawning season to the spawning peak.

(S2 Poster 15409) S2-P9

Otolith daily growth of sardine (*Sardina pilchardus*, Walbaum 1792) larvae off western Iberia: Effect of environmental variables

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Growth of Atlantic sardine (*Sardina pilchardus*) larvae collected between November and December of 2016 in the major spawning ground of the southern Iberian stock (38.5 to 41.5°N) was investigated. Otolith microstructure was analysed with the objective to follow otoliths growth trajectory, geographical variability, and its relation to environmental variables. Otoliths sagittae and lapilli had different growth trends: sagittae radius was related to somatic growth and explained by an exponential model ($r^2=0.92$), and lapilli by a linear model ($r^2=0.75$). However, from hatch to ~7mm SL (standard length), both types of otoliths grew in a similar trajectory. Sagittae radii were related to somatic size (logarithmic model, $r^2=0.94$) and mean somatic growth rate was estimated as 0.24mm μm^{-1} . Sagittae daily growth was 0.83 $\mu\text{m day}^{-1}$. Hatch (HC) and first feeding (FF) checks had average radius of, respectively, 5.36 μm (± 0.42 SD) and 6.65 μm (± 0.48 SD). In general, HC radii differences between regions were not significant. But FF radii had a spatial trend, being wider in the northwestern Iberia compared to larvae collected further south. We found increment width chronology related to ontogeny of the larvae. We could identify the onset of active swimming after notochord flexion and caudal fin completion (between 12 days old and 21 days old larvae, when otolith growth stabilized). There was geographical patterns of sagittae recent deposited increments widths: south of Cabo Carvoeiro (~39.21°N), until Cabo Mondego (~40.18°N) and further north, until Ria de Aveiro (~40.5°N) where recent increments were wider comparing with the others. Temperature was the main environmental parameter explaining recent increment variability.

(S2 Poster 15425) S2-P10

Insight into the stock structure of *Scomber colias* along the Northwest coast of Africa

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Otolith shape as a phenotypic character is a response to the environmental factors and the genetic background. The genetic variability can affect the otolith locally, mainly in the rostrum and the anti-rostrum. Otolith shape analysis was used to investigate *Scomber colias* stock structure long the northwest Atlantic coast, from Senegal to the north of Morocco. Wavelet descriptors on 377 otoliths were included in the multivariate analysis carried out in R. The results show a high level of variability and imply the existence of a barrier at the level of 28°N (Tarfaya), suggesting limited connectivity between two populations. Therefore, the reconstruction of the main shape of the two otoliths reveals high phenotypic plasticity of two morphotypes. The main variation between the two otoliths highlights the environmental heterogeneity of the Northwest coast of Africa. Moreover, the regional difference in the two morphotypes, mainly in the rostrum and the anti-rostrum, may reflect the genetic variation among the two populations.

A genetic study using microsatellites on Atlantic chub mackerel is in progress to test this hypothesis formulated by the present results.

(S2 Poster 15430) S2-P11**The influence of ontogeny and size on the distribution of juvenile forage fishes**

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During early life stages, marine organisms undergo rapid changes in their body size and habitat use. Size-specific species distribution models can more accurately predict species distribution than unstructured models, but are also more demanding of data and parameter estimation. Fish species exhibit diverse life histories which may impact the way we can best model their distribution. Some species restrict their spawning to specific locations and times, while others use a wider range of locations throughout the year. Dispersal distance and growth during the pelagic larval and post-larval phases may also influence performance of size-specific models. Here we compare the performance of size-structured and size-aggregated species distribution models. We hypothesize that species with punctuated spawning phenology and geography, fast growth, and long pelagic duration would have early life distributions that are better predicted by size-structured models. In comparison, for fishes that have extended spawning phenology, reproduce in coastal areas, and have slower growth, size-aggregate models could be sufficient. To explore the benefits of utilizing size-explicit models, we fit species distribution models to abundance data for Pacific hake, Pacific sanddab, anchovy, shortbelly rockfish, and widow rockfish in the California Current System. Multiple methods (e.g., GAMs, predictive-process GLMMs) were implemented to analyze data from pelagic scientific surveys. We found that for hake and sanddab, change in size indicates a change in distribution, resulting in larger hake moving inshore and larger sanddab moving northward. By exploring the variability in life stage distribution, we may better understand how species will respond to climate change.

(S2 Poster 15431) oral to poster S2-P12**Otolith microchemistry methods to identify migration life history variation in Pacific Herring (*Clupea pallasii*) in the Strait of Georgia, British Columbia, Canada**

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Pacific Herring (*Clupea pallasii*) are key forage fish that occur throughout the Salish Sea; an inland sea that has experienced broad ecosystem-level changes over the last four decades. The majority of herring in the Salish Sea occur in the Strait of Georgia (SoG) and seasonally migrate between summer feeding grounds along the continental shelf and spring spawning grounds within the SoG. However, some herring are non-migratory and spend at least part of their adult lives within the Salish Sea. In recent years, large schools of non-migratory herring have been consistently observed in the northern SoG and appear to be important prey for piscivorous fish, seabirds, and marine mammals during the summer. Characterizing variation in migratory behaviours and underlying causes is precluded by limited methods available to differentiate alternative migration types in fish populations. We investigated the potential of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ stable isotopes to act as a natural tag to differentiate resident from migratory SoG herring. Additionally, first year growth of known resident and migratory herring was indexed as a measure of otolith increment distance to test for an association between early growth rate and migration life history type. Identifying factors that influence herring migration life history type will provide insights into interannual trends in adult herring abundance and distribution in the SoG; an area that contains important spawning and foraging habitat for both adult and juvenile herring.

(S2 Poster 15450) S2-P13**Response of Atlantic herring larvae to ocean alkalinity enhancement**

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Ocean alkalinity enhancement (OAE) has emerged as a promising negative emission technology. It accelerates a natural process – weathering of minerals – that increases the capacity of seawater to store CO₂ from the atmosphere and, by elevating pH, counters ocean acidification. Yet, the impacts of OAE on marine organisms and ecosystem services such as fisheries are largely unknown. Here, we tested the direct effects of OAE on early life stages of Atlantic herring (*Clupea harengus*), in parallel to a mesocosm study addressing the indirect food web effects. We exposed 18-day old herring larvae to non-air equilibrated OAE (ΔTA 600 $\mu\text{Eq l}^{-1}$) for three weeks, with a concurrent pH increase from 8.0 to 8.7. We assessed growth, development, routine metabolic rate and ontogenetic changes in swimming behavior. Preliminary results showed no effect of elevated alkalinity and/or pH on growth suggesting that herring larvae may be resilient to short-term OAE.

(S2 Poster 15472) S2-P14

Verification, corroboration and validation of the anchovy, *Engraulis engrasicolus* (Linnaeus, 1758) age analysis in the Central-Southern Tyrrhenian Sea (West Mediterranean)

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The validation of European Anchovy, *Engraulis engrasicolus* (Linnaeus, 1758) age and growth presents several gaps, despite the age and growth has been widely studied using different methods. The uncertainty in estimating the age of anchovy by otolith reading is linked to i) identification of the first growth ring; ii) the presence of certain number of false increments; iii) disagreement in the applied ageing scheme (e.g. theoretical birthdate: 1st January vs 1st July); and iv) the overlapping of the annulus in the older specimens. The analyses of the otolith margin type elucidate the deposition patterns of the annuli. The modal components of the length–frequency distribution analysis (LFDA) were identified through winter surveys (Bhattacharya methods), and they did not show significant differences from the length back-calculation of the winter annuli. Moreover, no significant differences was found between the growth curves calculated by otolith reading (back-calculation and direct otolith reading) and the LFDA. The agreement between the length-frequency results and the otolith age estimation either corroborated or indirectly validated the growth pattern estimated from the otoliths of European anchovy, thus representing an important results for species, like the Anchovy, for which direct validation methods (e.g. mark-recapture, captivity, radiochemical) were difficult to implement.

(S2 Poster 15479) S2-P15**Performance of herring larvae under ocean alkalinity enhancement, an ocean-based carbon dioxide removal technique, in a mesocosm approach**

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The oceans are the largest carbon sink on planet earth, buffering climate change and accompanying effects. The weathering of alkaline rock plays a large role in the oceans capacity of sequestering CO₂. In nature, this process happens on the timescale of millennia, but the artificial acceleration of ocean alkalization has the potential of reducing atmospheric CO₂ concentrations in timescales needed for mitigating climate change. This ocean alkalinity enhancement (OAE) comes along other changes in ocean carbonate chemistry, increasing pH while decreasing CO₂ concentrations and dissolved inorganic carbon. This manipulation might have direct physiological effects on fish larvae as well as indirect effects through changes on other trophic levels. To include both pathways in which OAE could impact fish larvae we performed a large scale mesocosm study on a fully functional pelagic community under different intensities OAE.

In total, ten mesocosms were deployed in the Raunefjord, Norway for 56 days. Five mesocosms were assigned along a gradient of OAE to each of two alkalization methods, calcium-based and silicate-based OAE. On the day of the OAE treatment each mesocosms received 100 individuals of 25 days old larval herring, *Clupea harenaus*. Preliminary results of this study will be presented, focussing on the combined direct and indirect effects of OAE on growth and survival of herring larvae. Understanding how OAE may affect pelagic communities and especially the link between small pelagic fish and lower trophic levels, will aid in balancing pros and cons of different ocean-based carbon dioxide removal methods.

(S2 Poster 15517) S2-P16**Thermal tolerance sharply increases during larval development for European sardine (*Sardina pilchardus*)**

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European sardine (*Sardina pilchardus*) larval survival is strongly dependent of temperature. Previous laboratory experiments have shown that tolerance limits for sardine eggs and early larvae are very narrow, and high mortalities are observed for larvae reared at temperatures above and below 17 and 13°C, respectively. However, it is unknown how these limits vary with ontogeny. We conducted one experiment where sardine larvae were reared at optimal (16°C) and higher temperatures (19 and 22°C) to test for effects on survival, growth, behaviour, swimming and oxidative stress parameters, throughout ontogeny. While no larvae survived at 22°C until 15 days post-hatching (dph), and survival was severely impaired at 19°C, tolerance to temperature increased sharply with age. When reared at optimal temperature during the 2 first weeks and changing temperatures at that time, survival rates were similar between 16 and 19°C, while growth rate increased with temperature for larvae reared until approximately 30 dph. Survival rate from 15 to 33 dph at 22°C was lower and growth was similar for larvae reared at colder temperatures, but the tolerance to higher temperatures clearly increased with larval age. These results show that larval dispersal models should parametrize the tolerance limits for temperature considering larval developmental stage, and that the two first weeks after hatching are the most critical in terms of vulnerability to temperature.

(S2 Poster 15554) S2-P177

Age validation of Atlantic chub mackerel (*Scomber colias*) in the Northeast Atlantic area

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Atlantic chub mackerel (*Scomber colias*) is a middle-size pelagic species that mostly inhabit warm waters, distributed along the Eastern Atlantic coasts, from South Africa to the Bay of Biscay.

The dynamics of this species within the pelagic ecosystem in Atlantic Iberian waters are poorly known and the interpretation of the growth pattern of chub mackerel is relatively limited in the western Iberian population, due to the difficulty of the identification of the two first annuli, linked with the high presence of false or double rings and also the difficulty in the edge type identification associated with the overlapping of translucent rings on the otoliths' margin. The present work attempts to validate the periodicity of formation of the growth increments on chub mackerel otoliths collected monthly on the Northwest Iberian coast from 2014 to 2016, using semi-direct validation methods such as marginal increment analysis and edge type. Also, accuracy and precision of age readings were verified applying the precision indexes to the age reading of 2 readers. Preliminary results pointed out that only one growth increment is laid down annually, with the marginal increment showing an increasing trend from April to August. Highest marginal increment ratios occurred between June and July, suggesting that new increments are formed during this period. Concurrently, opaque edges were more frequent in May-August, while translucent edges prevailed in September-February. A good consistency of age interpretation between readers was also observed. Growth annual patterns will be analysed among age groups and compared with other areas.

S3. Understanding Population- and Ecosystem-level Shifts: From Seasonal Timing to Tipping Points

(S3 Poster 15217) S3-P1

A review on the dynamics of small pelagic fish species in the Western Iberia Upwelling ecosystem

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In light of climate change and biodiversity loss, there is a current urgency in evaluating the state of the ocean. The conservation of marine resources is a central concern, which will only be possible with more integrated knowledge on fish stocks, in particular of small pelagic fish (SPF) species. SPF species are especially important in Eastern Boundary Upwelling Systems, where social and ecological communities rely on them. The causes of the multi-decadal and year-to-year dynamics presented by populations of SPF species and their response to ecosystem variability through time remains an ongoing study. The aim of this work was to synthesize what is known about the dynamics of important SPF species in the Western Iberia Upwelling Ecosystem WIUE, such as the European sardine (*Sardina pilchardus*), European anchovy (*Engraulis encrasicolus*) and Chub mackerel (*Scomber colias*), and identify where information may be lacking. Other than the gap in ecosystem knowledge and approach to management, as already pointed by many fisheries studies, the effects of possible biological changes in the population dynamics of SPF is poorly studied. Changes in SPF species life history characteristics can have consequences for its population structure. Metrics like length, weight and age relationships are valuable tools to assess fisheries ecology, population responses to stresses, evaluate important vital functions such as the ability to store reserves, growth patterns and reproductive potential. The study of multi-decadal changes in such indicators may explain the biomass oscillations observed in these stocks and contribute to SPF fisheries science.

Keywords: Upwelling Ecosystem, Stock structure, Oceanography, Fisheries biology and ecology

(S3 Poster 15233) S3-P2

The influence of environmental factors on different life stages of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in the Mediterranean Sea

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European anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) are two of the most important small pelagic fish species in terms of biomass and commercial interest in the Mediterranean Sea. Their populations are clearly influenced by environmental variations, making them good bio-indicators of climate-driven changes. Here, we reviewed the different environmental factors documented to affect anchovy and sardine biology by using a systematic review approach. Our results show that available studies were heterogeneously distributed, being more abundant for anchovy adults in the Western Mediterranean. Among all the environmental factors found significant, temperature, depth, salinity and chlorophyll-a concentration were the most studied for both species. Further emphasis was placed on the effect of these four variables. The relationship between depth and anchovy and sardine parameters was mostly negative. We found contrasting effects of temperature, chlorophyll and salinity on the different life stages of species and the different areas. This review provides a general insight of what is known about how the environment influences growth, spawning, abundance and distribution of anchovy and sardine in the Mediterranean Sea, and identifies gaps of knowledge for future research, addressing several topics of the symposium (e.g. S3 and S4). Our study sets a knowledge baseline for future studies about climate variability and change in the Mediterranean basin.

(S3 Poster 15313) S3-P3**Canada's forage fish: An important but poorly understood component of marine ecosystems**

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Forage fish form a critical trophic link in marine ecosystems, and yet, for many species, there is limited information available. As nations move from single species stock assessments to ecosystem approaches to fisheries management (EAMFs), more information on forage fish will be required. In this study, 50 years of scientific literature were systematically mapped for 11 forage fish species in Canada's Arctic, Atlantic, and Pacific oceans. The objectives were to identify 1) knowledge clusters and gaps and 2) the pressures studied in relation to forage fish outcomes. Of the 2910 articles mapped, the majority studied adults, and the distribution, growth and life history, and productivity of commercially fished species. Knowledge gaps were identified for forage fish: 1) that were non-commercially exploited; 2) egg and larval life history stages, juveniles of non-commercial species; 3) diets of most species; 4) migration and performance for all species, and survival of non-commercial species; and 5) the effects of some pressures (e.g., large-scale climate pressures). Addressing these knowledge gaps would improve the application of EAFMs.

(S3 Poster 15462) S3-P4**Revisiting the stability of the environmental constraints shaping the spatial distribution of Peruvian and European anchovy**

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Forage fish present a boom-and-burst strategy, responding rapidly to changes in environmental conditions. Gaining a deep understanding of how small pelagic fish respond to environmental conditions and their changes is thus essential for developing sustainable fisheries and ecosystem-based management. However, there is still limited knowledge on how non-stationary environmental factors impact fish populations across multiple scales (time, space, and ontogeny). Here we revisit the relationship between environmental factors and the spatial distribution for two anchovy species inhabiting different ecosystems: Peruvian anchovy (*Engraulis ringens*) in the Northern Humboldt Current Upwelling System, and European anchovy (*Engraulis encrasicolus*) in the Northeast Atlantic (from the northern end of the Canary Current System to the English Channel). We used spatially-gridded acoustic data from fisheries surveys (Pelagic surveys for Peruvian anchovy; PELGAS, PELACUS, PELAGO, PELTIC and ECOCADIZ for European anchovy). Environmental variables were obtained from both in-situ, satellite (MUR) and climate reanalysis models (Copernicus), and included temperature, salinity, upwelling intensity, chlorophyll-a, mixed layer depth among others. These environmental variables are then classified as "direct" or "indirect" based on their impact on spatial distribution of each species, and their stability over time is tested. We discuss the results in the light of current trends in distribution and biomass of both species and the ramifications to modelling approaches relying on these relationships (e.g. Dynamic Energy Budget models). This first comparison will be a steppingstone for a global comparison of the stability in the environmental constraints shaping the distribution of anchovies, sardines and herrings.

(S3 Poster 15483) S3-P5**Interannual wind variability as a key driver of anchoveta (*Engraulis ringens*) recruitment in southern Humboldt system**Marcos A. **Arteaga**^{1,2} and Sebastián I. Vásquez^{1,3}¹ Instituto de Investigación Pesquera, Talcahuano, Chile. E-mail: marteaga@inpesca.cl² Programa de Doctorado en Ciencias con mención en Manejo de Recursos Acuáticos Renovables, Universidad de Concepción, Concepción, Chile³ Programa de Doctorado en Oceanografía, Universidad de Concepción, Concepción, Chile

The study of the recruitment dynamics in exploited fish has been of wide scientific interest, highlighting that the environment can have a strong effect on recruitment. Anchoveta is one of the most important pelagic fisheries in the southern Humboldt system. Annual landings of anchoveta are directly related to the strength of recruitment, which is susceptible to environmental variability that controls the early survival of this species. Using remotely-sensed observations together with the outputs of an age-structured stock assessment model we address the impact of interannual wind variability on anchoveta recruitment. Using generalized additive models, we show that there is a dome-shaped relationship between alongshore wind magnitude and anchoveta recruitment suggesting that levels above the 7 m/s and extreme events more than 15 days with 15 m/s threshold negatively affect early survival, which we attribute to an increase in offshore advective losses. In addition, we show that the inclusion of wind significantly improves the modeling of recruitment instead of using only spawning biomass as a predictor. Finally, we discuss the implications for the predictability of fisheries yield, its response to environmental variability, and tactical fisheries management decisions.

(S3 Poster 15512) S3-P6**Linking events affecting timeseries of landings of small-pelagic fisheries in the Mediterranean Sea: Does it affect current stock assessment?**

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The stock assessment and consequently advice provided for small-pelagic priority stocks in the Mediterranean have been mainly based on timeseries of landings since 2000 and on a geographical subarea (GSA) basis. Aimed at distinguishing the adopted management regulations and events from different origins (hereinafter “Events”) in relation to available historical timeseries of reported landings, the General Fisheries Commission for the Mediterranean (GFCM) is leading the construction of so-called timelines. In order to reach the final timeline by fishery (stocks sharing gear and area), Events were initially linked to 1) all target stocks by country and 2) single stock by GSA. The timeline in the Alboran Sea (Algeria, EU-Spain, Morocco) indicates that the current production levels of small pelagics are one fifth of landings in 1950’s. The contribution of mackerels and the movement of fleets from different-home ports are important drivers of the landings trend. The timeline of round sardinella in the eastern (Cyprus, Egypt, EU-Greece, Lebanon, Palestine and Turkey) has been importantly affected by

patchy data across countries. However, landings reflect contributions of inland fertilizers, sea-water warming and technical measures aimed at reducing fishing effort. The timeline in the Adriatic Sea (Albania, EU-Croatia, EU-Italy, Montenegro and EU-Slovenia) differs among stocks (sardine and anchovy), because different-sourced Events and divergent catch trends among countries occur. Findings emerging from the timelines may promote rethinking of both the length of timeseries and the landings trends used to provide advice on stock status and can also facilitate an appraisal of adopted and potential management measures.

S4. Responses to Climate Variability and Change at Decadal to Centennial Time Scales

(S4 Poster 15223) S4-P1

Deepening our pelagic vision of the small pelagic fish in the Canary Islands (NW Africa, Spain)

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The small pelagic fish (SPF, i.e. *Scomber colias*, *Trachurus* spp, *Sardina pilchardus* and *Sardinella* spp) in the Canary Islands archipelago (Spain) are mainly targeted by artisanal purse-seiners, whose monitoring is included in the EU Data Collection Framework. The waters in the archipelago (located in the coastal transition zone of the Canary Current Eastern Boundary Upwelling System) are monitored since the late nineties by a hydrographic section (RAPROCAN) designed to study the temporal variability of the eastern subtropical gyre. Official fish landings, reported by the Government since 2007, are annually analyzed to assess the stock status of the SPF in the Fishery Committee for the Eastern Central Atlantic (CECAF) context. In this study we analyze the relationship between the SPF abundance assumed from official landings and the oceanographic parameters. Using the sea temperature in the 200-800 m layer, we obtained a statistically significant correlation with the SPF landings (ρ -Pearson=0.454, $p<0.03$) when we considered one-year time-lag. This layer is less affected by atmosphere variations and probably influence on the success of the SPF spawning and recruitment processes. In fact, recruitment to the fishery (i.e. individuals attain legal catchable sizes) approximately occurs for one-year-old individuals, and explaining the one-year time-lag. Keeping the monitoring systems is crucial to understand, foresee and anticipate potential variations in the fishery resources and to aim the sustainable exploitation of the SPF populations, even more challenging in the current Climate Change scenario.

(S4 Poster 15325) S4-P2

Climate modelling indicates poleward shift and range contraction of the scaled sardines *Harengula* sp. in the Atlantic Southwest

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Global warming affects marine biodiversity, and the ecosystem services it provides to human communities, including fisheries. Yet, how fish species abundance and distribution will be impacted by ongoing climate change still requires investigation. Here we used a machine-learning algorithm to calibrate an ecological niche model of the Brazilian scaled sardine *Harengula* sp. and project it to three climatic scenarios estimated to year 2100 based on trends of greenhouse gas emissions. Models reveal a decrease in environmental suitability for the occurrence of *Harengula* sp. in the Brazilian coast between present and future climates, and a southward shift in distribution that is stronger as the scenario modelled is aggravated, mainly driven by changes in sea surface temperature and salinity. We infer that global warming may lead to a decrease in the abundance of *Harengula* sp. particularly in the northernmost part of its current distribution, where this species has high economic and cultural value. The models also show an increase in environmental suitability for the occurrence of this species on the coasts of Uruguay and Argentina, where they do not yet occur. Besides ecosystems disturbance of newly occupied areas, a decrease in abundance coupled with a distribution shift in which fish schools' cross-country borders can lead nations to dispute this fishery.

(S4 Poster 15398) S4-P3**The Atlantic chub mackerel (*Scomber colias*) in the Iberian Atlantic waters: Growth patterns and cohorts strength**

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One of the Northeast Atlantic commercial fish that is expanding northward is *Scomber colias*. This species is abundant fundamentally in NW African waters and constitutes a relevant fishing resource in southern Europe, in Atlantic Iberian waters, in the most recent period. Estimating the age and growth of *S. colias* is necessary to understand its population life traits and to assess stock status using age-based models in ICES. In this study, the growth pattern, parameters and performance index of *S. colias* are estimated based on the otoliths of a decadal time series in different areas of the Iberian Atlantic. Differences are observed in the demographic structure and growth parameters among areas. Geographical similarities in the strength of the abundant cohorts are found, showing a common Iberian Atlantic pattern in the cohort dynamics of *S. colias*.

S4 Poster 15439) S4-P4**Scales of variability: Shifts in spatial distribution with population size can complicate interpretation of the sedimentary scale record for small pelagic fish of the California Current**

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Modern observations of population sizes of anchovy and sardine populations have cultivated the hypothesis that changes in oceanographic conditions have opposing impacts on each taxon, stimulating out-of-phase alternations in their biomasses in the California Current and other coastal pelagic ecosystems. Analyses of fish scales preserved in anoxic sediments challenge this idea. Deposition rates of anchovy and sardine scales have been interpreted to indicate population variability that is inconsistent with relationships in observational records, as the scale record indicates positive correlation at decadal time periods. However, the assumption that scale-deposition rate is indicative of population sizes is questionable, and controversy remains as to whether the sediment record offers sufficient evidence to discount paradigms from the modern era. We use a spatially resolved ichthyoplankton record to explore relationships between estimated population biomass and the presence of sardine and anchovy eggs in a coastal location coincident with the area of a paleo-oceanographic fish scale record in the California Current. We find that the spatially limited sampling leads to an inadequate (and perhaps opposite) impression of population variability. Fish spatial distribution varies with population size, and change in the abundance of fish at one nearshore location is not indicative of similar changes in population biomass. While the sediment record of fish scales can overcome some of the limitations of short observational records of population sizes, overinterpretation of the scale record could produce a misleading perspective concerning population variability.

(S4 Poster and Oral 15339) S4-P5**Impacts of climate change-induced environmental fluctuations on the structure of marine ecosystem around the Taiwan Bank**Po-Yuan **Hsiao** and Kuo-Wei Lan

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Taiwan Bank (TB) is located in the southern Taiwan Strait, where the uplifted continental slope and bottom currents bring upwelling areas and create an important fishing ground. Previous studies have confirmed that climate-induced fluctuations in fish populations have been demonstrated in Taiwan Strait. However, the predation and competition affect the interspecies relationships in ecosystem remains to be clarified. In this study, high grid resolution data on fishery activity (2013-2019) were collected to construct the ecosystem models by using Ecopath with Ecosim. Three mass-balanced models using Ecopath for the ecosystem influence by the ENSO events were constructed. The functional groups including representative pelagic, benthic, and reef species were collected for analyzes the relationship between migratory and sedentary species in ecosystem structure variation under climate change. The results showed that the system total throughput (TST) was about 3391-8619 (t km⁻²yr⁻¹), with average transfer efficiency is 18.69%. The keystone index reveals *Thunnus albacares* and *Katsuwonus pelamis* are the main key species with the top-down control has a relatively high impact on the ecosystem through Mixed Trophic Impact analysis. Total biomass, TST, consumption, and respiration increased during the El Nino and La Nina events. However, the diversity, omnivory, and connectance index were relatively low during La Nina events, caused by top predator biomass increased and low TL species decreased. Our results suggested during La Nina event, weak upwelling causes plankton populations decreased, with predator's high biomass and top-down control also enhance the decreasing pattern of low TL species population in TB ecosystem.

(S4 Poster and Oral 15504) S4-P6**On the robustness of an eastern boundary upwelling ecosystem exposed to multiple stressors**Ndague **Diogoul**^{2,6}, Patrice Brehmer^{2,3,6}, Yannick Perrot³, Maik Tiedemann⁴, Abou Thiam¹, Salaheddine El Ayoubi⁵, Anne Mouget³, Chloé Migayrou³, Oumar Sadio² and Abdoulaye Sarré⁶¹ University Cheikh Anta Diop UCAD, Institute of Environmental Science (ISE), BP 5005, Dakar, Senegal² IRD, Univ. Brest, CNRS, Ifremer, LEMAR, Campus UCAD-IRD de Hann, Dakar, Senegal³ IRD, Univ. Brest, CNRS, Ifremer, LEMAR, DR Ouest, Plouzané, France⁴ Institute of Marine Research IMR, Pelagic Fish, P.O. Box 1870 Nordnes, 5817 Bergen, Norway⁵ Institut National de Recherche Halieutique INRH, Agadir, Morocco⁶ Institut Sénégalais de Recherches agricoles ISRA, Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), BP 2221 Dakar, Senegal. E-mail : diogoulndague@yahoo.fr

The resistance of an east border upwelling system was investigated using relative index of marine pelagic biomass estimates under a changing environment spanning 20-years in the strongly exploited southern Canary Current Large marine Ecosystem (sCCLME). We divided the sCCLME in two parts (north and south of Cap Blanc), based on oceanographic regimes. We delineated two size-based groups ("plankton" and "pelagic fish") corresponding to lower and higher trophic levels, respectively.

Over the 20-year period, all spatial remote sensing environmental variables increased significantly, except in the area south of Cap Blanc where sea surface Chlorophyll-a concentrations declined and the upwelling favorable wind was stable. Relative index of marine pelagic abundance was higher in the south area compared to the north area of Cap Blanc. No significant latitudinal shift to the mass center was detected, regardless of trophic level. Relative pelagic abundance did not change, suggesting sCCLME pelagic organisms were able to adapt to changing environmental conditions. Despite strong annual variability and the presence of major stressors (overfishing, climate change), the marine pelagic resources, mainly fish and plankton remained relatively stable over the two decades, advancing our understanding on the resistance of this east border upwelling system.

S5. Progress in Pelagic Surveys: From Biomass Estimates to Monitoring Ecosystems

(S5 Poster 15171) S5-P1 (No Show)

Summary of the study on tuna fishing in the Mediterranean Sea in Egypt

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The first study began in 2006 on catching blue tuna fish from the Egyptian territorial waters by vessels long liner, licensing the Damietta fisheries. The aim of the study is to allocate an international quota to Egypt from fishing for blue tuna. This study resulted, after officials from the fisheries and the Institute of Marine Sciences communicated with international organizations, to allocate an international quota for Egypt to catch tuna fish from the Ikat organization in 2010.

The second study began in 2015 on fishing for Albacore tuna from the Egyptian territorial waters by vessels long liner, licensed by the Damietta Fisheries Office. The number of 40 long liner vessels that catch these fish from the month of 6 to the month of 9 annually, using the long liner thread, number one from 100 to 140, and the use of the hook, number 7 and number 8, and the fishing output ranged from one boat to another and from one trip to another from the weight of 1 ton to 3 tons. For one trip, it was estimated that the quantity of tuna fish caught in the type of albacore for this year was about 600 tons (this is what we were able to count).

The aim of the study / is to inventory the quantities of Albacore tuna fish caught in preparation for the experiment of manufacturing tuna fish locally in the form of canned.

To document this study, the Albacore tuna fishing process was filmed as a 30-minute documentary film about the fishing process (link is attached).

(S5 Poster 15230) S5-P2

Surveying and monitoring nearshore forage fish in the Salish Sea using acoustic-optic technologies

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Forage fish comprise an important link between zooplankton and predatory fishes, birds and mammals. In the Salish Sea, adult Pacific herring (*Clupea pallasii*) spawn in the spring, larvae hatch approximately 2 weeks later, and juveniles occupy nearshore habitats in the summer and fall. Since 1992, Fisheries and Oceans Canada has conducted a standard survey using a small seine vessel to document the relative abundance of juvenile herring in the Salish Sea. In 2021 a project was initiated to use advanced sampling technologies (acoustics, optics and spatial modeling) to assess and compare multiple methods of estimating herring abundance and to improve our understanding of juvenile herring residency nearshore. The time of residency of juvenile herring was assessed by deploying upward looking autonomous echosounders and stereo cameras. Echosounders were deployed at 2 sites where juvenile herring were observed during the seine survey and these sites will continue to be monitored for up to one year to document juvenile herring occupancy of nearshore habitats. In addition, stationary stereo camera systems have been deployed monthly over 24 hour periods to visually identify and measure species observed by the echosounders. Future work includes combining the data into spatial models that will be developed on a monthly basis for juvenile herring and applied to the Strait of Georgia to predict areas and times when herring are likely to be present and moving within the ecosystem. These data and analyses should generate both new methods using advanced survey technologies to sample forage fish, as well as new data that can inform our knowledge of forage fish (in particular juvenile herring) use of nearshore habitats throughout the year.

(S5 Poster 15265) S5-P3**A staging system for *Clupea harengus* based on its skeletal development**Vivian **Fischbach**^{1,2,3}, Annegret Finke^{2,4}, Timo Moritz^{1,3}, Patrick Polte⁴ and Philipp Thieme⁵¹ Institute of Biological Sciences, University of Rostock, Universitätsplatz 1, 18055 Rostock, Germany. E-mail: vivian.fischbach@googlemail.com² Thünen-Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany³ Deutsches Meeresmuseum, Katharinenberg 14-20, 18439 Stralsund, Germany⁴ University of Hamburg, Olbersweg 24, 22767 Hamburg, Germany⁵ MARBEC, Université de Montpellier, IRD, CNRS, cc093, Place E. Bataillon, 34095 Montpellier Cedex 05, France

The Atlantic herring (*Clupea harengus*) is of high economic importance and plays a major role in temperate marine food webs. Herring stocks are often subject of monitoring programs and as recruitment dynamics directly translate into future stock development, its early life stage ecology has been thoroughly addressed in fisheries research. The assessment of herring stocks often includes larval surveys which usually incorporate larval length measurements to estimate the recruitment dynamics. However, larval length data lack critical information on the larval stage and the coherent functional morphology. Also, larval lengths are strongly influenced by environmental factors such as temperature and food availability and the size range can vary significantly between populations, habitats, and ecotypes. An existing staging system from the 70ies provides the most frequently used guide to date for herring larval development, however it does not fully resolve important developmental stages. Therefore, we propose an improved staging system based on the skeletal development of the herring. By the clearing and double staining method bone and cartilage were made visible and development of postcranial elements could be traced. In combination with external features a staging system comprising 15 stages in five major developmental phases (Yolk sac, dorsal fin development, caudal fin development, ventral fin development and juvenile phase) is proposed. The proposed stages are supposed to reflect developmental changes which can be linked to changes in the behavioral ecology and can therefore, provide evidence to potentially critical environmental conditions when applied to long term data series.

(S5 Poster 15278) S5-P4**Comparison of ages determined by using an Eberbach projector and a stereo microscope to read scales from Atlantic menhaden (*Brevoortia tyrannus*) and Gulf menhaden (*B. patronus*)**Amy M. Schueller, Amanda R. **Rezek**, Raymond M. Mroch III, Eric Fitzpatrick and Alicia Cheripka

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Estimating fish ages is critical for stock assessments. As fish ageing staff and technology change, consistency in ageing is paramount, especially in production ageing. The Menhaden Sampling Program began in 1955 and encompasses one of the longest and most complete time series in the United States. This study compared age estimates from the previously used Eberbach projector (circa 1930) to an updated stereo microscope for 1,317 Atlantic (*Brevoortia tyrannus*) and 1,569 Gulf menhaden (*B. patronus*). Age sets contained ages from three years and their respective reference collections and were evaluated for precision or repeatability and bias by comparing percent agreement (PA), average percent error (APE), Chang's average coefficient of variation (ACV), bias tests (Bowker's, Evans and Hoenig's and McNemar's) and simultaneous multinomial confidence intervals. Overall, Atlantic and Gulf menhaden age comparisons yielded the following results, respectively: PA, 88.9% vs. 89.7%; APE, 2.7% vs. 3.5%; and ACV, 3.8% vs. 5%. Variations were generally found to be within standard, accepted levels. Some bias was detected in age comparisons between the two devices but was attributed to compromised scales and poor image quality on the projector. Overall simultaneous multinomial confidence intervals were slightly different for ages 1 and 2 in both species. Based on this study's comparisons, the updated methodology using a stereo microscope to provide age estimates for assessments and maintain the continuity of the long-term monitoring of Atlantic and Gulf menhaden was deemed acceptable. The microscope technique demonstrates additional advantages including viewing options, imaging software capabilities and accessibility to digital data for research and training purposes.

(S5 Poster 15288) S5-P5**Stock status of European anchovy and sardine in Ligurian and northern Tyrrhenian Sea: Recent insights from fifty years of data**

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Small pelagic fisheries in the Ligurian and Northern Tyrrhenian Sea (NW Mediterranean, FAO GFCM GSA9) are based on the exploitation of European anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*). The two species are fished mainly by purse seiners, especially along Ligurian and Tuscany coasts; they are also by catch, mainly discarded, of bottom trawling, though landings of the two species by bottom trawling are usually less than 10% and 5% respectively. In order to assess the state of these resources, the temporal variation in the population abundance of European anchovy and sardine in GSA9 was investigated using landings time-series, available for the period 1972-2020. In this time period, the annual amount of landings ranged from a minimum of around 1000 to a maximum of almost 9000 tons for anchovy, with an average of 5000 tons, and a minimum of around 1000 to a maximum of 13000 tons for sardine, with an average of 4600 tons. A Surplus production model in continuous time (SPiCT) was also applied for each stock, using landing data tuned with data from two experimental surveys: the absolute biomass estimated by the outcomes of the acoustic survey MEDIAS and the relative biomass indices (Kg/Km²) resulting from the bottom trawl survey MEDITS. Based on the SPiCT assessments, an increasing trend in biomass was estimated both for anchovy and sardine stock. The model results also suggested that the two stocks are sustainably exploited in this area.

(S5 Poster 15360) S5-P6**Deep learning and surplus production models for multivariate autoregressive modelling and simulation of the jack mackerel fishery associated with environmental conditions**

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This work studies jack mackerel fishery in Southeastern Pacific (SEP) from 1973-2020, under single-stock unit assumption, the following variables: i) total SEP catch (C); ii) catch per standard unit of effort (CPUE) as abundance index of industrial purse-seine fleet off central-southern Chile; iii) standard fishing effort ($E=C/CPUE$); and iv) NOAA satellite sea surface temperature (SST) between 32°-42°S-71°-80°W.

The approach proposes modelling and simulation procedures for both surplus production models and deep-learning-based models with environmental variability integration. The implementation of surplus models was performed using CLIMPROD software, proposing several ad-hoc models; the deep learning approximation, considers sets of convolutional neural network architectures. Selected models were used for simulation of environmental and fisheries management scenarios resulting in different maximum sustainable yields (MSY).

Results show a proposed surplus model that considers E and SST as explaining variables: $CPUE = (-a + bTSM) \exp(-cE)$, assuming landings containing 5-year age classes, recruitment at 2 years age, and environment affecting abundance, with good performance ($R^2=0.86$). Two environmental scenarios are then proposed, using SST average from 1999-2014, and a period not-warmer-than 13°C, obtaining a MSY of 563476 and 945446 ton, for both scenarios, respectively. Regarding the deep learning approach, using monthly data, an autoregressive multivariate convolutional neural network is implemented that considers 36-months lagged SST and fishing effort, obtaining good performance ($R^2=0.84$), and capture simulations that range from 481656-1167933 ton, on different scenarios. The latter models consider longer autoregressive periods and long memory properties of time series, this approach could be used for short to long-term forecasts, helping with national to international fisheries sustainability-based policies.

(S5 Poster 15369) S5-P7**Ecosystem Based-Management for small pelagic fisheries – From local to regional scales**

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The Campania coast is an important spawning and nursery area for small pelagic fishes in GSA10.

European anchovy (*Encraulis encrasicolus*) represents an important resource for coastal communities, even if in the last 5 years fishermen complain a decreasing trend in catches. Therefore, at the end of 2021, the Italian Ministry of Fishery and the Regional Administration paid great attention to this sector by funding a specific research project involving both scientists and fishermen.

The aim of the project is the development of a local scale management, based on strong scientific evidences, arising from a solid agreement among fishermen and researchers, by means of a continuous data sharing leading to an adaptive approach, to promote increasing trust and transparency among participants with economic and social effects.

A sampling program lasting for 18 months was developed to collect ecological (oceanographic and biological) data on target population and its habitat. The field activity will be carried out on monthly basis, in three distinct fishing grounds, in order to investigate on the following indicators: LFD, age at length, maturity (macroscopic and microscopic), condition factor, fish body condition and feeding habits (isotopic investigation).

Acoustic surveys will be also carried out in autumn in order to evaluate the strength of recruitment.

The proposed approach, although developed at local scale (Campania Region), could be applied at wider scales (e.g. GSA) to improve higher performances of stock assessment models, leading to more effective management policies.

(S5 Poster 15378) S5-P8**Challenges in DEPM implementation for NE Atlantic mackerel**

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Egg production surveys provide a fishery independent method of estimating SSB to be used in the stock assessment process. There are two primary methods, the annual egg production method (AEPM) designed for species with a determinate fecundity and the daily egg production method (DEPM) that can be applied to indeterminate and determinate spawners. Since 1977 the AEPM has been used for estimation of SSB of Northeast Atlantic mackerel stock under the assumption that mackerel has a determinate fecundity. During the ICES Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA, 2012), spawning strategy of mackerel was discussed and it was concluded that it has probably indeterminate fecundity and it was recommended to attempt a contrast between AEPM and DEPM results. As consequence, WGMEGS has been investigating using the DEPM for estimate NEA mackerel SSB since 2012 The comparison between both methods has been carried out during the last three triennial egg surveys. A peak spawning period and area were defined in the existing survey design and additional adult sampling were taken for DEPM adult parameters estimation, but maintaining the AEPM time-series. We describe the questions that had arisen during the DEPM implementation in relation to adult parameters calculation and that are principally due to the fact that mackerel ovary organization is different from anchovy, the species for which DEPM was developed.

(S5 Poster 15386) S5-P9**The implementation of the DEPM in Western horse mackerel during the Triennial mackerel and horse mackerel surveys (MEGS): Pros and cons**

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The triennial mackerel and horse mackerel survey has been designed to apply the annual egg production method (AEPM) to estimate spawning stock biomass (SSB) of mackerel and horse mackerel since 1977. However, the evidence of indeterminate fecundity of horse mackerel led to the need to implement the daily egg production method (DEPM) for this species and to adapt the survey protocols. However, after three years of implementing this method along with the AEPM (2013,2016, 2019), the results are not reliable, basically due to the quality of sampling. In this study we analyse the weaknesses we observed when estimating the reproductive parameters of horse mackerel using samples from a survey initially designed for the annual method for mackerel.

(S5 Poster 15395) S5-P10**Long time series (2009-2020) analysis of *Trachurus trachurus* and *Trachurus picturatus* spatial distribution and life history traits in the Western Mediterranean**

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Trachurus trachurus and *Trachurus picturatus* are accessory species of the fishing fleet in the Spanish Mediterranean, generally landed as *Trachurus* spp. Although these species play an important ecological role in the trophic webs, there is a lack of knowledge about them, especially in the study area. The knowledge of their distribution, abundance and main biological parameters is fundamental to achieve their sustainable exploitation and contribute to the ecosystem approach. The time series (2009-2020) data set analyzed in this study came from two geographical subareas (GSAs) defined by the General Fisheries Commission for the Mediterranean (GFCM), Northern Spain (GSA06) and Northern Alboran Sea (GSA01), sampled in July during the MEDiterranean International Acoustic Survey (MEDIAS). According to the results, both species showed a preferential distribution in GSA01 compared to GSA06 and seemed to share niches. For the analyzed time series, the highest levels of abundance, biomass and density were found, for both species, in GSA01, probably favored by a greater availability of food and more optimal environmental conditions. However, the largest individuals were found in GSA06. In addition, the results suggest a size-segregated distribution, with the smallest individuals found closer to the coast and the largest at greater depths. Potential changes in the life history traits of both species were evidenced in both GSAs with a decreasing trend in the size at first maturity and condition factor over the years which could be related to an uncontrolled exploitation of the immature stock or changes in the environmental conditions.

(S5 Poster 15399) S5-P11**Biological parameters and overlapping distribution of *Sardinella aurita* spawners and eggs in the Spanish Mediterranean Sea continental shelf**Gloria Blaya-Valencia, Ana Ventero and Magdalena **Iglesias**

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In this work, a holistic insight into population dynamics of round sardinella (*Sardinella aurita*) in the Spanish Mediterranean Sea is presented. An interannual (2018-2020) analysis of the main biological parameters of the species (length frequency distributions, length-weight relationship, sex-proportion and maturity) has been estimated and their spatial dependence has been assessed. Moreover, the interannual distribution and overlapping of round sardinella spawners and eggs is presented. The analyzed data comes from the MEDiterranean International Acoustic Survey (pelagic hauls and Continuous Underway Fish Eggs Sampler samples) carried out during the day in July and its subsequent processing (biomass per nautical mile). According to the results, the biological parameters showed spatial differences related to the origin area (Northern Spain or Northern Alboran Sea). It is noteworthy that although the survey period coincided with the round sardinella spawning season, the most common maturity stages were pre- or post- spawning. This fact would indicate that the species, like other pelagic species such as anchovies, spawn at night. On the other hand, its distribution was neritic and patchy throughout the study area. The spatial distribution of spawners and eggs showed a high degree of overlap in the 3 study years, with eggs showing a greater area of distribution than adults, perhaps due to their greater dispersal capacity associated to currents dynamic.

(S5 Poster 15414) S5-P12**Adding value to regular fisheries surveys for pelagic ecosystem monitoring. Water quality assessment for MSFD requirements**Maria M. **Angélico**¹, Ana Moreno¹, Cristina Nunes¹, Pedro Amorim¹, Marta Nogueira¹, Pedro Nunes¹, Vanda Brotas², Andreia Tracana² and Paulo B. Oliveira¹¹ IPMA - Portuguese Institute for the Ocean and Atmosphere, Lisbon, Portugal. E-mail: mmangelico@ipma.pt² MARE/FCUL - Centro de Ciências do Mar e do Ambiente, Faculdade de Ciências, Universidade de Lisboa, Portugal

Egg and acoustics surveys for pelagic fisheries assessment are carried out regularly by IPMA, in Atlantic Iberian waters, for more than three decades. Over this period, many technological and methodological improvements have been introduced which have revamped the monitoring processes and outcomes of surveying, allowing for more comprehensive observations of the ecosystem. In addition, in recent years, complementary sampling has been in demand for compliance with MSFD requirements and consequently the contribution of information coming from these large-scale surveys, with high spatial resolution, has been expanded. Here we report the additional results, obtained during IPMA pelagic surveys during the period 2018-2022 (IPMA-PNAB-DCF), which assist in water quality assessment for eutrophication (MSFD Descriptor 5) and pelagic habitats (MSFD Descriptor 1), namely nutrients concentrations and phytoplankton biomass and size spectrum spatial distributions. Phytoplankton biomass *in situ* observations, are also complemented with remote sensing and modelling results to investigate winter-spring spatial patterns. These studies are conducted within the framework of the research project iFADO (EU-Interreg).

(S5 Poster 15423) S5-P13**A review of the contribution of deep learning and machine learning to fishery acoustic**Anas **Yassir**, Said Jai Andaloussi, Ouail Ouchetto, Kamal Mamza, and Mansour Serghini

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In fishery acoustic, surveys using sensors systems such as Sonars and Echo-sounders have been widely considered as accurate tools for acquiring fish species data, fish species biomass, and abundance estimations. During the acoustic surveys, the research vessels are equipped with Echo-sounders which produce sound waves and then record all echoes coming from objects and targets in the water column. The pre-processing and scrutinizing of acoustic fish species data have always been manually conducted, and have been considered time consuming. Meanwhile, deep learning and machine learning-based approaches were also adopted, to automate or partially automate the acoustic echoes scrutinizing process, build an objective process with which the species echoes classification uncertainty is expected to be lower than of the uncertainty of scrutinizing experts. A review of the state-of-the-art of the different deep learning and machine learning applications in acoustic fish species echoes classification is highly requested. Therefore, the present paper aims to provide an overview of the studies and papers conducted on the acoustic fish echoes identification, which can be extended also to other marine objects, that have been based on deep learning and machine learning approaches. To search for related papers, we have based on a systematic approach over the most known electronic databases. Hence, we were able to identify 19 related works, which have been processed and scanned to give an overview of multiple approaches and methodologies of deep and machine learning used in acoustic fish species identification, and then compare among their architectures, performances, and their encountered challenges of applications.

(S5 Poster 15427) S5-P14**Validation of growth increment formation and first annual increment formation in European anchovy (*Engraulis encrasicolus*) in the Northwest Atlantic Area**Dina **Silva**¹, Andreia V. Silva¹, Raquel Milhazes² and Susana Garrido¹¹ IPMA – Instituto Português do mar e da atmosfera, Lisboa, Portugal. E-mail: dsilva@ipma.pt² IPMA – Instituto Português do mar e da atmosfera, Matosinhos, Portugal

For accurate and efficient determination of age of exploited fish populations, the interpretation of the periodic growth increments (*annuli*) on calcified structures e.g., otoliths, needs validation. Several studies on anchovy age and growth validation have been published, mainly in Bay of Biscay, Gulf of Cadiz and Northern Western Mediterranean but no data exists for the western Iberian population. This population that had residual abundance in an upwelling area clearly dominated by sardine, has had a huge increase in abundance in recent years and consequent increase for local fisheries, specially the purse seine fishery. The present work attempts to validate the periodicity of formation of the growth increments on anchovy otoliths collected in the Northwest Iberian coast during 2017-2021, by the means of the widespread Marginal Increment Analysis (MIA) and Edge Type Analysis. In order to validate the first annual increment deposition, age of early juveniles captured in 2019, were estimated based on otolith microstructure analysis. Exploratory analysis pointed out that the otolith hyaline and opaque zones were laid down once during the study period, the increment of the translucent ring increased slowly from February to April while the deposition of the opaque ring occurred from May to July. Annual patterns will be analysed among age groups and compared with other areas.

(S5 Poster 15429) S5-P15**Plankton-sized microplastics in Portuguese coastal waters. Taking advantage of regular monitoring surveys.**Clara Lopes^{1,2}, Maria Manuel **Angélico**¹, Miguel Caetano^{1,2}, Susana Garrido^{1,3}, Ana Moreno¹ and Joana Raimundo^{1,2}¹ IPMA - Portuguese Institute for the Ocean and Atmosphere, Lisbon, Portugal. E-mail: E-mail: mmangelico@ipma.pt² CIIMAR – Interdisciplinary Centre of Marine and Environmental Research, Avenida General Norton de Matos S/N, 4450-208 Matosinhos, Portugal³ MARE – Marine and Environmental Sciences Centre Faculdade de Ciências, Universidade de Lisboa Campo Grande, 1749-016 Lisbon, Portugal

Plastic has gained prominence in modern society, with different applications in a variety of sectors. Plastic debris, whether accidentally lost or deliberately rejected, tend to accumulate along coastlines and gradually break down into fragments smaller than 5 mm known as microplastics. These small fragments, which are similar in size and appearance to natural food items, pose potential risks to many marine organisms, including zooplankton and zooplanktivorous. Here we report on the spatial distribution of microplastics along the Portuguese coast. This study, made possible due to the regular, high resolution, pelagic surveys undertaken by IPMA, is relevant in the context of water quality monitoring (MSFD Descriptor 10) and impact assessment of microplastics in the ecosystem. The samples analysed were collected with bongo nets (200 µm mesh size) performing oblique tows in the top 60m of the water column, in May 2018 during IPMA Pelagic Ecosystem Survey – PELAGO (PNAB-DCF). In the laboratory, samples were filtered with a 100 µm polycarbonate membrane and microplastics were characterized by stereomicroscope and FTIR spectroscopy. The results indicate that fibers are the dominant shape category, representing 77% of the total. Blue and black were the most frequent colour of microplastics while rayon, polyester and acrylic were the most frequent polymer found. The median concentration of microplastics was 1.1 particles.m⁻³, having varied between 0.14 and 3.54 particles.m⁻³. Results also suggest an increment of microplastics from North to South of the Portuguese coast.

(S5 Poster 15448) S5-P16**Monitoring catch and effort and linking fleet movement of sardine fishery in Fisheries Management Area (FMA) 7, Philippines**Kim P. **Nuñez**^{1,2}, Wilfredo L. Campos^{1,2} Alexanra Bagarinao-Regalado^{1,2}, Antonio Mendoza³, Plutomeo Nieves³ and Jesus T. Racuyal⁴¹ OceanBio Lab, CAS, UP Visayas, Miag-ao, Iloilo² Division of Biological Sciences, College of Arts and Sciences, UP Visayas, Miag-ao, Iloilo³ Bicol University Tabaco Campus, Tabaco City, Albay⁴ Samar State University, Catbalogan City, Samar

Sardines comprise a major fishery resource in the Philippines, making up 1 of every 6 kg of marine catches. The inner interisland waters of east central Philippines (FMA 7) is the second most productive sardine fishing ground where *Sardinella lemuru* dominates the catches. Reports of decreasing catches in the past decade make management of the fisheries urgent, but estimates of annual catch are still lacking. This study was conducted from February 2020 to April 2021 to provide such an estimate and to characterize the distribution of the stock.

Seven monitoring sites in FMA7 were selected based on initial fisheries profiling. At each site, daily records of catch (kg/trip), effort (% fleet fishing per day) and fishing location (via gridded map) were recorded. In addition, GPS data loggers were deployed in 7 vessels to track fleet movement. The estimated overall annual catch of sardines from FMA7 was 56,338.6 MT, with 99% of this caught by drift gill nets. Seasonal catch and effort data, information from tracked vessels, and parallel data on reproductive stages indicate that the stock aggregates in Ticao Pass to spawn in November/December, timed with upwelling-driven high primary productivity during these months, then disperses southwards into other basins in June/July of the following year, before aggregating again northwards in November. About 80% of the total catch is landed by the fleet of a single municipality in Ticao Pass. Because these vessels are relatively larger, they can follow the stock as it disperses southwards beyond reach of smaller vessels.

The implications of these results on managing the fisheries are discussed.

(S5 Poster 15482) S5-P17**DEPM surveys and spawning behaviour of horse mackerel (*Trachurus trachurus*) from the Atlantic Iberian-southern stock (ICES 9a).**

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Since the application of Daily Egg Production Method (DEPM) started being implemented by the Portuguese Institute (IPIMAR, IPMA) for the southern stock horse-mackerel (*Trachurus trachurus*) in 2007, various questions have been addressed, related to methodological aspects (survey sampling, laboratory processing and statistical analyses) as well as to the species reproductive biology (fecundity), which resulted in several developments being already introduced, with the goal of more adequately applying the DEPM to this resource. Pursuing these efforts of improving the precision and accuracy of SSB estimates for horse mackerel, work has continued been undertaken, specifically in relation to the daily behaviour of the spawning individuals, the spatial distribution (geographic, bathymetric) of *T. trachurus* spawning (eggs and mature reproductively active fish), and evaluation of the less unbiased estimator of the species spawning frequency based on the Post-Ovulatory Follicle (POF) method. For these purposes, all the available data collected over the years during the egg production surveys was further analysed, and the findings obtained were briefly discussed in relation to the general reproductive biology of the horse-mackerel in our coast and the potential implications for the application of the DEPM.

(S5 Poster 15499) S5-P18**Biomass and distribution of cnidarians and ctenophores in Icelandic waters during the summer in relation to environmental variables and lumpfish distributions**

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In the past two decades, jellyfish research interest has increased globally as they are essential in pelagic systems and have been hypothesized to benefit from climate-change induced warming waters. The sub-Arctic oceanic region is highly vulnerable to these warming waters which impacts jellyfish diversity and abundance. As jellyfish play a vital role in the trophic food web and the carbon cycle, it is crucial to understand their biomass in Icelandic waters, which is currently unknown and thus so is their influence on other pelagic species such as lumpfish. By using jellyfish displacement volume data obtained from the Icelandic Marine and Freshwater Research Institute from the years 2012 to 2022 jellyfish and lumpfish biomass will be assessed along with environmental data. Hence thereafter, the jellyfish biomass fluctuations around Iceland can be interpreted in coordination with known lumpfish biomass. Jellyfish and lumpfish biomass are hypothesized to be dependent on one another, having a negative correlation. As lumpfish are an economically viable species and dominant jellyfish predators in Icelandic waters, it is essential to understand the jellyfish-lumpfish relationship around Iceland. This study also delves into the feeding ecology of lumpfish on jellyfish, which has never been studied. Conclusions from this project allows researchers to understand better the dynamics of jellyfish populations in Iceland and their interactions with other organisms, like lumpfish. Jellyfish are often neglected in plankton research monitoring thus this project aims develop these capacities, to better understand and possibly enhance the current monitoring program of jellyfish in Icelandic waters.

(S5 Poster 15525) S5-P19

Pelagic Ecosystem Surveying in NE Atlantic Waters: WGACEGG Internationally Coordinated Surveys

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Small pelagic fish are short-lived, highly productive species that play a key role in the world's shelf seas as they channel energy from lower trophic levels to top predators. Sustainable management is therefore critical and requires accurate monitoring. This is complicated as SPF distribution and abundance may exhibit huge fluctuations due to natural variation in the ecosystem and anthropogenic pressures. Consequently, it is important that not just the numbers of fish but also their biological parameters and the wider pelagic system are monitored in coordinated efforts across national borders. Surveying the Atlantic shelf waters of southwestern Europe, began in the 80s and has progressed from overseeing single-species surveys, to the current structure where, under the auspices of the Working Group on Acoustic and Egg Surveys for Small Pelagic Fish in NE Atlantic (WGACEGG), integrated ecosystem surveys are coordinated and standardised. In addition to the indices provided to the individual fish stock assessments, a plethora of information is collected, from the hydrography, plankton and top predators. These ecosystem variables themselves are used to monitor the health of the ecosystems and enable the group to study the ecological processes that drive the observations in SPF. The group developed a standardised gridded database to compile data from all the surveys and facilitate studies on the ecology of the pelagic ecosystems of the shelf seas from Cadiz to Ireland. This poster shows some of the joint indices, highlighting spatial and seasonal patterns as well as inter-annual variability that can help improve ecosystem dynamics affecting SPF.

(S5 Poster 15495) moved to poster S5-P20

Ichthyoplankton evidences of European sardine connectivity between north and south of Alboran Sea, and adjacent waters

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A multidisciplinary oceanographic survey was carried out during late winter 2020, with the main objective of identify potential connectivity processes between *Sardina pilchardus* from north and south of the Alboran Sea, and adjacent waters, and validated the hydrodynamical models. A total of 81 stations, arranged in 14 transects perpendicular to the coastline, were sampled. The area of study was divided into four regions: Gulf of Cadiz, Atlantic south, Alboran north and Alboran south. The highest sardine egg abundance was recorded in the coastal region of the northwestern Alboran Sea, but also relatively high abundances were recorded in an oceanic region, in the easternmost Alboran north. However, differences in egg abundance between regions were not significant.

Sardine larvae were the second most abundant and the most ubiquitous larval fish species, with abundances significant higher in the Gulf of Cadiz. A high number of positive stations for larvae in the oceanic region was observed in the horizontal distribution. Results are discussed combining the information obtained from the multidisciplinary analyses performed in the TRANSBORAN project (hydrodynamic modelling; genetics, microchemistry and shape in otoliths among others) that reveal a general stock differentiation between north and south of the Alboran sea with high similarity in some contiguous management units. A synthesis of the most relevant results illustrating the contrasting connectivity patterns of the European sardine in the while Gulf of Cadiz-Alboran Sea transitional systems are presented, along with some implications in terms of fisheries assessment and management are discussed.

(S5 Poster and Oral 15412) S5-P21

Purse-seine fishery in Portugal: No sardine, no future?

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In Portugal, small and medium pelagic species such as sardine (*Sardina pilchardus*), chub-mackerel (*Scomber colias*), anchovy (*Engraulis encrasicolus*) and horse mackerel (*Trachurus trachurus*) are the most landed species in the purse seine fishery, accounting for near 50% of total landings in weight. Historically, sardine has been the target species of the fishery and traditionally perceived as the most important species in the fleet. With the decline of the sardine stock and the reduction of annual quotas, this fleet has supplemented its incomes by targeting chub-mackerel in the Center and South and anchovy in the North. The present work aims to analyse changes in fleet behavior concerning the reduction of annual quotas and the establishment of daily quotas for sardines in the period 2005-2020, to assess their impact on annual landing dynamics and improve the assessment of pelagic species. Behavior changes have been observed in the fleet along the country, such as searching for new fishing grounds and species with more market value such as anchovy. Especially, fisheries data may be an important supplement to information obtained from traditional surveys, that cover a part of the history. Having the full picture is important to get a better assessment of pelagic species and further discussion and/or sharing with stakeholders (e. g. fishers and fisher associations, fisheries researchers, the industry, NGO's and general public).

S6. Reconciling Ecological Roles and Harvest Goals: Development and Testing Management Strategies to Enhance Marine Ecosystem Services

(S6 Poster 15276) S6-P1

The spatiotemporal distribution of seabird prey fish in the North Sea

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During the breeding season seabirds are central place foragers and are critically dependent on the distribution of certain key prey fish species such as sandeels and sprat. In the North Sea populations of both seabirds and their fish prey have declined over the past 20 years, and it has been shown that seabirds have been declining due to breeding season prey shortages. However, the reasons for the declining fish populations have been harder to understand. Prior to population declines in the early 2000s, sandeels were the largest single species fishery in the North Sea, with annual catches peaking at over 1.2m tonnes. Overfishing and predator resource competition remain major concerns today, however, studies into these threats have been hindered by lack of fine scale data of the prey fish distributions. To investigate the mechanistic role of overfishing on small pelagic fish population dynamics and associated predator-prey relationships, detailed prey distribution models are needed. ICES DATRAS fishery-independent trawl surveys were combined into a single database covering the entire Greater North Sea. The newly available HERAS acoustic survey was also available for sprat. We applied relatively novel Bayesian spatial modelling techniques using R-INLA. This method accounts for spatial and temporal autocorrelation and allows the estimation the fine scale spatial-temporal distributions of small pelagic fish biomass across the entire North Sea.

(S6 Poster 15362) S6-P2

Fishing practice and the ecosystem approach - Case studies on Panama and Ecuador small pelagic fisheries and how Fishery Improvement Projects can effect management strategy and sustainability

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A basic principle of the ecosystem approach to fisheries management is that harvesting is conducted with minimal impact on juvenile fish, non-target species, and marine habitats. A range of management measures aimed at improving monitoring and reducing the impact of the fishery is available to help achieve these goals, but their effectiveness varies. Through two case studies, we describe how fishery improvement projects have influenced management and the adoption of ecosystem approaches and demonstrate how conservation goals can be discouraged or encouraged by the strategy.

Panama and Ecuador were facing several fisheries challenges, including the depletion of fishery resources, excessive fishing effort, conflicts among the fishers and illegal fishing. This paper presents case studies on a stakeholder driven exploration of management actions to meet overall fisheries goals such as sustainability and profitability in the small pelagic fisheries in the Gulf of Panama and the Ecuadorian coast based on a set of assessment criteria. The criteria are based on “best practice” fisheries management as specified in international norms and guidance.

This process, known as a Fishery Improvement Project, works closely with the government of Panama to reform fishery management. The case study reveals that FIPs use a systematic approach to guide a fishery to improvement and looks at which practices were most effective in creating impact. Another important layer of information reviewed is the inclusion of environmental and socioeconomic impact indicators, which help assess FIPs that prioritize problems with habitat degradation and bycatch or FIPs with interlinked socioeconomic and sustainability issues.

(S6 Poster 15401) S6-P3**Combining data on fish size and VMS to model the spatio-temporal distribution of sardine and chub mackerel juveniles**Inês C. **Dias**¹, Laura Wise¹, Gonçalo Araújo², Isidora Katara^{1,3}, Renato Rosa² and Alexandra A. Silva^{1,4}¹ Portuguese Institute for Sea and Atmosphere, Lisbon, Portugal. E-mail: inesc.dias@ipma.pt² Nova School of Business and Economics, Lisbon, Portugal³ International Whaling Commission, Impington, Cambridgeshire, UK⁴ Marine and Environmental Sciences Centre (MARE), Lisbon, Portugal

Vessel Monitoring System (VMS) records combined with fishery data can give insight into the spatial and temporal distribution of exploited populations. Using this approach, we pretend to analyse the spatio-temporal distribution of landings per unit of effort (LPUE) of sardine (*Sardina pilchardus*) and chub mackerel (*Scomber colias*) by combining data on fish size from daily sales and onshore sampling with VMS records of the Portuguese purse seine fishery for 2013 and 2014. Individuals of sardine and chub mackerel will be defined by the size at first maturity, L95, and by the commercial size category, T4, a criterion used by stakeholders and therefore more intuitive for implementation of management measures. Finally, we calculate two spatial indicators to provide information on the location and spatial occupation of the juvenile population on the fishing grounds. Our results contribute to a better characterization of areas and periods which might be considered to implement fishery management measures for the protection of juvenile fish.

(S6 Poster 15406) S6-P4**A keystone issue: Managing forage fishes in a changing climate**Beatriz Dias¹, Lian Guo², and Michelle **Staudinger**³¹ College of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, Fairbanks, AK, USA² California Sea Grant Program, University of California San Diego, Scripps Institution of Oceanography, La Jolla, CA, USA³ USGS, Northeast Climate Adaptation Science Center, UMass Amherst, Amherst, MA, USA, E-mail: mstaudinger@usgs.gov

In recent decades, there has been increased recognition of the critical services that small pelagic fish provide to aquatic ecosystems, particularly as forage. Indeed, the explicit consideration of forage fish is a goal of successful ecosystem-based management approaches. However, the rising impacts of climate change are altering the availability and condition of many forage populations and challenging traditional management goals. We assembled an international and multidisciplinary expert panel of fisheries scientists and practitioners to synthesize the current state of knowledge of forage fish in a changing climate. Our approach was framed using a holistic concept that assemblages of forage fish and certain invertebrates comprise an “ecological buffet” of options for top predators. These functional assemblages represent a key pool of biomass that support higher trophic levels but are expected to increasingly vary in composition through changes in biodiversity and abundance over spatiotemporal scales as species respond to climate impacts. Our goals are to: 1) synthesize the current understanding of historical and projected biological responses and vulnerabilities of forage fish to climate change; 2) evaluate the ecological consequences and management challenges for forage fish and fisheries to climate change; 3) highlight opportunities, tools, emerging technologies, and case studies that can support sustainable forage fish management and climate adaptation strategies across broad spatial scales. This review serves to increase understanding of how key forage species affect overall community resilience in the face of climate, identify high-priority climate adaptation challenges and risks, and outline future pathways to achieving climate-smart management approaches.

(S6 Poster 15501) S6-P5

Impact of climate and ecosystem change on the California Current forage complex and the fishing communities and predators it sustains

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In the California Current Large Marine Ecosystem (CCLME), small pelagic fish (SPF) are a key trophic link between the planktonic food web and a host of top and mid trophic-level predators. They also support commercially important fisheries. 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 SPF 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 aims to quantify, using multi-model inference, climate impacts on SPF in the CCLME and assess the vulnerability of protected species and fishery participants to projected variability in forage and fishing portfolios, respectively. The project is also developing a climate informed ecosystem 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.

S7. Advancing Social-ecological Analyses and Sustainable Policies for Human Communities Dependent on SPF

(S7 Poster 15181) S7-P1

An integrated risk-based assessment of Cabugao bay in Catanduanes, Philippines for small pelagic fishes to guide ecosystem-based management

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This inquiry provides an integrated view to ecosystem based management (EBM) by considering a number of societal goals, i.e. sustainable small pelagic fish (SPF) supply, clean water, a healthy bay ecosystem, and a selection of management measures to achieve them. The primary aim of this paper is to provide advice for an integrated EBM in Cabugao Bay area (CBA) based on an initial evaluation of the effectiveness of available management measures found in the research records of the Catanduanes State University (CatSU) and both published and grey literatures in contributing to the sustainable management of SPFs. A secondary purpose is to identify the requirements of the present knowledge base on CBA to guide the future EBM initiatives on water critically influenced by both natural and anthropogenic factors. Starting from the societal goals, we produced data sets from the scoping exercise to identify the local social-ecological system (SES) factors but still require additional data sets for adequacy of information to guide EBM for sustainable management of SPF in CBA. A partial quantitative and qualitative risk assessment dealing on human activities, their pressures and the impacted bay system was then applied to identify the main threats to the CBA fish biodiversity and other biological resources. The findings are the initial inputs to the development of EBM for an integrated perspective needed for decision-making in the fisheries resource management, wherein the university is currently initiating expert advice and support from the recently formulated academic and research collaboration with other institutions in the Philippines.

(S7 Poster 15432) S7-2

COVID-19 pandemic disrupts the supply chain of small-scale tropical pelagic fisheries: Lessons from Bangladesh

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While the impacts of the Covid-19 pandemic and its mitigation measures have created unprecedented crises worldwide, small-scale fishing communities are likely to be among the worst affected professional groups. These poor communities live close to the coast, usually far from the market and economic centers. With little savings, they mainly depend on daily fishing for subsistent living and income. Based on a case study of a tropical pelagic fishery of Bangladesh, this study will describe the impacts of the pandemic on the market structure and value chain of the hilsa shad fishery and how actors in the value chain respond to the changes, identify constraints to adaptive responses. The findings suggest that the COVID-19 pandemic affects all aspects of fish supply chains, which puts the fishing communities' income and food security at risk. In the different phases of the pandemic restrictions of the government, the supply chain of the hilsa shad fisheries faces a different level of disruptions. In the early phases of lockdowns, fishing activities were seriously halted due to government restrictions on mobility and increasing health concerns. Other supply chain actors also face constraints in reaching the local consumers due to restrictions of movement, lack of labor and transportation facilities, and reduction of consumer demand due to economic hardships. While the government declared incentives plan for different sectors affected by the pandemic, actors in the fish supply chain failed to draw attention from the government. Nevertheless, some well-off fishers adopted a new strategy to directly sell to endpoint consumers through door to door selling. At the same time, many of them had to take a loan from a middleman or money lender for subsistent living that increased outstanding debts. This situation highlights the vulnerability of the supply chain of small-scale fisheries to any macroeconomic crisis. This study calls for enhancing the financial capacity and well-being of all supply chain actors and strengthening the local network and flexible institutions within the supply chain that would help build resilience to any sudden disruption.

W1. Application of Genetics to Small Pelagic Fish

(W1 Poster 15205) W1-P1 (No show)

A morphological and phylogenetic investigation of tilapiine fishes of the genus *Oreochromis* in Southern Tanzania

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Tilapiine cichlids are an economically important source of cheap dietary protein. Previous survey have indicated that *Oreochromis placidus* was present in the Ruvuma River and its tributaries, while *Oreochromis urolepis* was found in the Rufiji River and its tributaries. This study was aimed at elucidating the distribution of *Oreochromis species* in South-eastern Tanzania. Our field collections broadly supported what other researchers found in terms of distribution. However, the species found in Lake Rutamba (*O.sp. "Rutamba"*) is a distinct dwarf species. The distinctive is in the form of morphological features, pharyngeal bone proportions and mitochondria DNA sequences. mtDNA analysis suggested that there is an affinity with *O.amphimelas* found far away in the central-north-western parts of Tanzania. Our study also revealed the presence of the invasive alien species of *O.niloticus* in all river systems in the area. This is for the reason that *O.niloticus* phenotype was found to contain mtDNA sequences of both native species. There was however an absence of native phenotype at Lake Kitale despite the presence of their mtDNA in the *O,niloticus* population from lake Kitale. This suggests either that the natives' population of *O.placidus* and *O.sp. "Rutamba"* were exterminated by *O.niloticus*, or that the newly colonising population had previously been in contact with both natives species. We, therefore, consider that the biodiversity of *Oreochromis* in Tanzania is richer than previously thoughts and greatly at risk from the introduction of a highly invasive species.

Keywords: mitochondria DNA (mtDNA), native species, species invasion.

(W1 Poster 15249) W1-P2

GenClim – A project on the evolutionary and socio-economic consequences of shifting distribution ranges in commercially exploited marine fishes

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Ongoing climate change is rapidly transforming marine ecosystems and communities throughout the world's oceans. Increases in temperature are considered one of the main drivers of latitudinal distribution shifts in marine fishes, which are predicted to migrate towards cooler areas. These range shifts mean that commercially important species are likely to cross geopolitical boundaries, increasing the likelihood of mismatches between current fishing practices (and policies) and future distributions. Forecasting models that predict range shifts are thus essential to anticipate and mitigate potential fisheries conflicts and the subsequent socio-economic impacts of a moving resource.

GenClim aims to investigate the evolutionary consequences of distribution shifts in key fishery species (hakes and anchovy) throughout the Eastern Atlantic. The sample design will cover three major areas: the North Sea, the Iberian Coast and southern Africa. These regions are considered hotspots for climate change, as warming is occurring faster than the global average. Genomic data will be obtained from the core, leading and trailing edges of the populations in these regions, and insights from these analyses will be incorporated into climatic forecasting models in order to increase their predictive capacity for future distribution changes. Furthermore, GenClim will develop new state-of-the-art bio-economic modelling, to analyse key socioeconomic outcomes, with the aim of identifying new policies that perform well in a climatic variability setting. The outcome of this project will be used to provide advice to stakeholders on changes in distribution, abundance and evolutionary resilience of fishery species, as well as on potential conflicts arising from shifting resources.

(W1 Poster 15391) W1-P3**Lack of panmixia of Gulf of Bothnia vendace - Implications for fisheries management**

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Overexploitation of fish stocks is recognized as a major environmental and socioeconomic problem. To reliably monitor the status of exploited stocks, distinguishing demographically independent and genetically distinct populations is crucial. This is especially challenging in pelagic species, with high dispersal capacity, gene flow and large population sizes. In this study, we aim to assess the extent of genetic differentiation and structure of vendace (*Coregonus albula*), a small salmonid fish that inhabits deep and oligotrophic lakes in Western and Northern Europe and the northern-most part of the Baltic Sea. We collected 266 individuals from eight sampling locations along coastal and lowermost river stretches flowing into the Gulf of Bothnia. We used restriction site-associated DNA sequencing (RAD-seq) to identify 21,792 SNPs and characterized the genetic divergence and population structure between samples. Furthermore, we identified candidate loci under selection and carried out functional annotation of putative outlier loci. Overall genetic differentiation was low through the system. However, a clear pattern of population differentiation was observed for River Kalix sample. Secondly, we detected weak but significant structuring between vendace collected from Swedish and Finnish coasts. Our study provides first genome-wide perspective on genetic structuring of Baltic Sea vendace and clearly rejects the hypothesis of panmixia in Gulf of Bothnia. As such, our work demonstrates the power of RAD-sequencing to detect low but significant genetic structuring relevant for fisheries management.

W2. The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models

(W2 Poster 15506) W2-P1 (No show)

Understanding the distribution and transport processes for the early life stages of *Todarodes pacificus*, *Scomber japonicus*, *Trichiurus japonicus* using behavioral-hydrodynamic modeling approaches

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Todarodes pacificus, *Scomber Japonicus*, *Trichiurus japonicus* are very important species in Korea, Japan and China. To understand the distribution and transport process for the early life stages of three important species, we conducted a broad larval survey in Korean Waters during last 5 years, then used a coupled bio-physical model that combines an individual-based model (IBM) incorporating ontogenetic vertical migration for larval behavior and temperature-dependent survival process with a ROMS oceanographic model. From the backward experiment using distribution of larvae collected in not only adjacent waters of Korea but also East China Sea (ECS), the spawning ground for three species are estimated from central ECS to Southwestern East/Japan Sea. Also, the forward experiment from the potential spawning ground satisfactorily reproduced the larval distribution obtained by the field survey. Moreover, the survival individuals well described the inter-annual variability of recruitment process for each species. Nowadays, we adapt the these model to predict the fishing condition and catches level for *Todarodes pacificus*, *Scomber Japonicus*, *Trichiurus japonicus*.

W3. Small Pelagics for Whom? Challenges and Opportunities for the Equitable Distribution of Nutritional Benefits

(W3 Poster 15484) W3-P1

Health effects, nutrients and contaminants availability from consumption of mesopelagic species in C57BL/6J mice

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The global biomass of the mesopelagic fish found at 200 – 1000m depth is estimated to be approximately 8-10 gigatons and is barely exploited as a potential food source for humans. It is documented that mesopelagic species contain high levels of proteins, omega-3 polyunsaturated fatty acids, Vitamin A and B12, and they are also rich in calcium, selenium, iron, and iodine. However, some species may contain undesirables such as cadmium, arsenic, fluorine, erucic acid and wax esters. This study aimed to investigate the suitability of mesopelagic species for consumption in comparison with other common protein sources. Three abundant mesopelagic species from Norwegian fisheries areas including glacier lanternfish (*Bentosema glaciale*), Silvery lightfish (*Maurolicus muelleri*) and Northern krill (*Meganyctyphanes norvegica*) were included as part of the protein source in a western diet and were fed to mice for 13 weeks. Additionally, two control groups fed a commonly consumed seafood mixture and a land-based meat mixture were included for comparison. Weekly measured body weight development showed different weight gain among experimental groups. One week before the termination, a glucose tolerance test was performed to evaluate the development of type 2 diabetes. After termination, we investigated the accumulation of cadmium, arsenic and fluorine in target organs and the apparent digestibility of wax esters and erucic acid were measured by comparing feed and feces. The metabolism and accumulation of different fatty acids and fatty alcohol were investigated in liver tissue. This study provides novel information on suitability of mesopelagic species for direct human consumption.

(W3 Poster 15388) W3-P2

Investigating the spatial variation in nutrient and contaminant levels of *Maurolicus muelleri* among Norwegian fjords, the North Sea and Bay of Biscay

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Mesopelagic communities in the North Atlantic have been estimated to encompass high biomasses of mesopelagic organisms. Some of these were found to be nutrient-dense, and may contribute to food and nutrition security. Here we aim to understand the spatial variation in nutrient and contaminant levels.

We sampled *Maurolicus muelleri* from Norwegian fjords (Bjørnafjorden, Boknafjorden, Hardangerfjorden and Osterfjorden) and the North Sea (NS) during 2018 to 2020, and from the Bay of Biscay (BB) during 2019 to 2020. We measured the concentrations of micro- and macronutrients, hazardous elements, and persistent organic pollutants (POPs).

Individuals from the fjords had higher concentrations of fatty acids (EPA and DHA) and POP concentrations (e.g. PCDD + PCDF), and lower cadmium concentrations than the NS and BB individuals; individuals from the NS had higher iron concentrations and middling POP concentrations (e.g. dioxin and dioxin-like PCBs) than the fjords and BB individuals; and individuals from the BB had lower POP (e.g. PBDE7), arsenic and mercury concentrations, and higher nickel concentrations than the fjords and NS individuals. Individuals from the NS and BB may be a concern for their cadmium levels exceeding the safety limit in relevant EU regulations for food.

100 gram portion of *M. muelleri* from these three habitats is able to provide more than 15% of recommended intake of selenium and vitamin A1. These individuals also had similar or higher levels of total fatty acids, SFA, MUFA, PUFA, DHA, total ω 3 & 6 compared with those of sardine (*Sardina pilchardus*).

This study confirms that *M. muelleri* may play an important role in food and nutrient security, but spatial variation shall be taken into consideration when utilising such a marine resource. Further investigation on the composition and temporospatial variations in stock, nutrients, contaminants and trophic ecology is essential to ensure sustainable exploitation of this mesopelagic species.

(W3 Poster 15519) W3-P3

15 years of evolution of the Gulf of California small pelagics fishery MSC certification

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Sustainability ecolabels in fisheries, such as the one issued by the MSC (Marine Stewardship Council), aim to improve the management and surveillance of fisheries through a certification granted to producers that meet specific criteria, including good practices and enough knowledge. By design, the producers search and pay for the certification because it allows them to access markets and higher prices covered by conscious consumers. However, certification didn't result in a direct market incentive for the Gulf of California small pelagics fishery. Still, the producers have remained within the certification loop since 2006, obtaining certification in 2011 and recertification in 2018. In this contribution, we review the evolution of the certification process in the Gulf of California small pelagics fishery to document: a) the particularities of the assessment due to the large fluctuations of the fishery and the dynamic nature of their trophic role in the ecosystem, b) the improvements of the fishery during the two certification cycles and the annual audits of the last three years, and c) the incentives and perception behind the willingness of the producers to maintain the ecolabel.

W6. Small Pelagic Fish Reproductive Resilience

(W6 Poster 15329) W6-P1

Effects of maternal phenotype on egg quality in the Baltic herring at two temperatures

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Egg quality, i.e. the eggs potential to produce viable fry, is one of the major factors behind recruitment variability observed in many wild stocks. In this study, we examined the relationships between maternal phenotype, egg quality and larval characteristics in the Baltic herring (*Clupea harengus membras*) at two temperatures: ambient (7 °C), typical of the main spawning time at present, and a somewhat higher (14 °C), expected to prevail at the spawning time as a result of the increasing winter and spring temperature. The aim of the study was to improve our understanding of the mechanisms varying environmental conditions in the Baltic Sea are affecting the reproduction of small pelagic fishes like the Baltic herring. The experimental studies were conducted in 2020-2022 in the northern Baltic Sea. Female length, age, somatic condition and lipid resources in the muscle and ovary were considered as key maternal traits. The effects of ovarian thyroid hormone levels (T3 and T4) on embryonic development were also studied due to their central role in the regulation of the metabolic rate and ontogenesis. The herring females were observed to exhibit large variation in their reproduction success, and several relations between maternal phenotype and offspring properties were observed. It was also apparent that the incubation temperature was associated not only with the rate of embryonic development, but also with egg survival and hatching success.

(W6 Poster 15485) W6-P2

The effects of maternal thyroid hormones on the egg size, hatching success and larval properties of the Baltic herring (*Clupea harengus membras*) in the Baltic Sea

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The maternal condition of spawning fishes has long been recognized to have a direct effect on the viability of the offspring produced, however studies on maternal effects have been scarce on Baltic fish stocks. The impact of thyroid hormones (T3 and T4) as a maternal trait is also relatively unknown, despite them having a large role in regulating embryonic development. In this study we examined how the maternal thyroid hormones of Baltic herring (*Clupea harengus membras*) effected the quality of the offspring. The aim of the study was to examine the impact of maternal condition in the variable Baltic Sea conditions. The experimental studies were conducted in 2020-2022 in the Finnish waters of the northern Baltic Sea as well as the area of Rügen, Germany. Offspring quality was measured via measuring egg size, hatching success, and the length, yolk sac size and percentage of vertebral malformations of the hatchlings. Length, age and the lipid resources of the muscle and ovaries were among the measured maternal traits along with the T3 and T4 concentrations of the ovaries. The larvae hatched in the incubation experiments was found to exhibit measurable variation in quality, which can be partly explained with hormone level differences as well as other maternal effects.

(W6 Poster 15289) W6-P3

Drivers of the short-term changes of reproductive potential in *Scomber scombrus* and *Sardina pilchardus* in the North Iberian Peninsula waters

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The fish reproductive potential is linked to the condition of females, which is modulated by environmental and population factors. Females with higher reproductive potential produce higher quality eggs that are more likely to survive. Short-lived pelagic species are sensitive to environmental and abundance fluctuations. The Iberian sardine (*Sardine pilchardus*) stock suffered a historical decline in abundance and biomass until 2019, when high recruitment rates and an increase in stock abundance began to be recorded. In contrast, in the NE Atlantic area, mackerel (*Scomber scombrus*) is a very abundant species that in recent years has shown high reproductive capacity leading to good recruitment, which seems to contradict the hypothesis of dense-dependent effects on reproductive potential. Additionally, Iberian sardine predates on mackerel eggs; thus, sardine condition may be influenced by the reproductive success of mackerel. Given the life history strategies of both species, these factors can lead to changes in their reproductive potential in relatively short periods of time. The objective of this study is to model the influence of maternal characteristics and environmental variables on egg quality in both species before and after the change in the sardine abundance. For this purpose, egg and adults' samples collected during spring scientific surveys delivered by IEO in the Cantabrian Sea in 2016, 2019 and 2021 were analyzed. Disentangle the influence of extrinsic and intrinsic factors on reproductive potential and recruitment success, as well as the interaction between these drivers, is key to understanding and predicting population dynamics and estimating resilience to external disturbances.