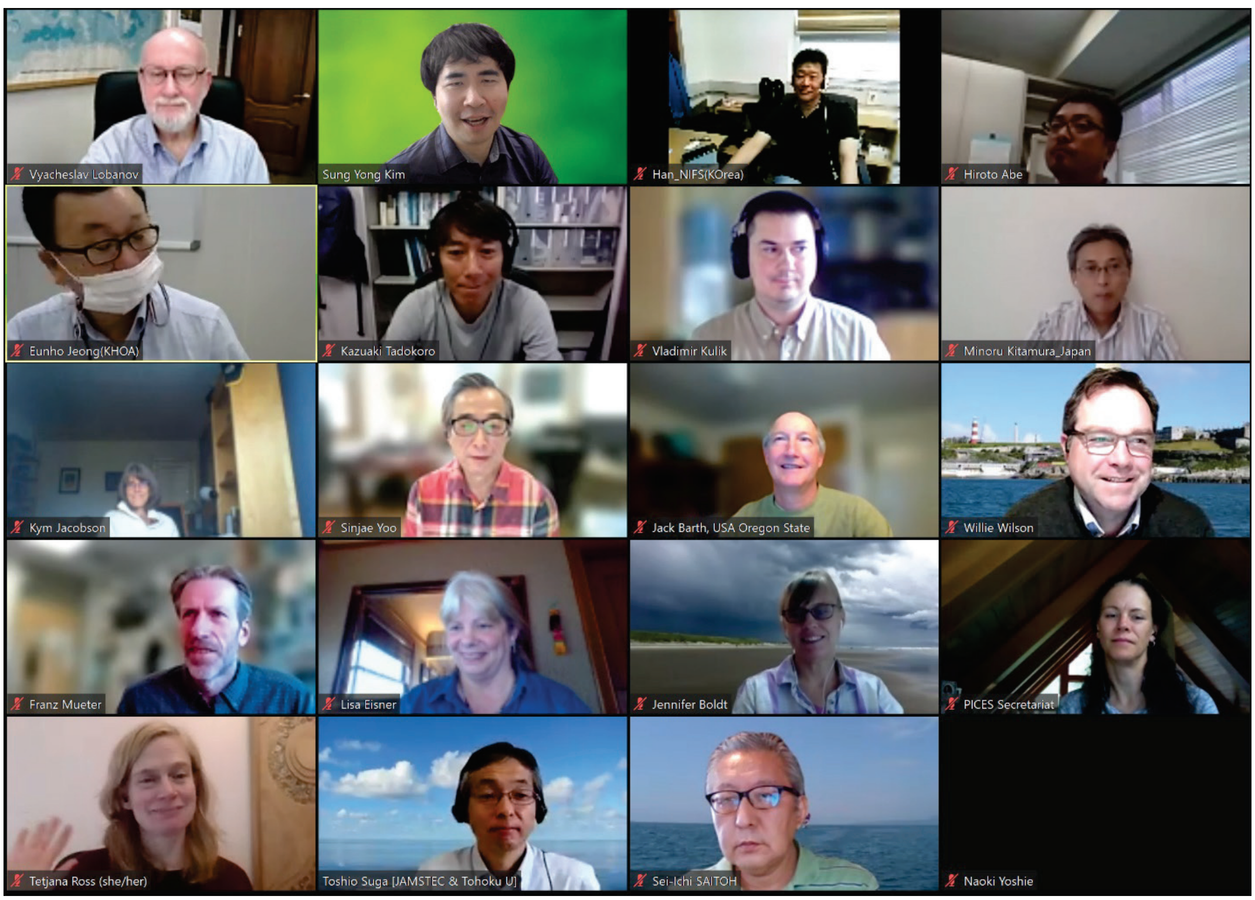
Report of the Technical Committee on Monitoring

DAY 1

October 4/5, 2020 hh:00-hh+2:30

AGENDA ITEM 1
Welcome and introductions

MONITOR Chair, Prof. Sung Yong Kim, called the meeting to order, and participants introduced themselves (*MONITOR Endnote 1*). The agenda was reviewed and adopted (*MONITOR Endnote 2*). The teleconference was hosted by PICES Executive Secretary, Dr. Sonia Batten.



Day 1 meeting participants at PICES-2021: Vyacheslav B. Lobanov (Russia), Sung Yong Kim (MONITOR Chair, Korea), In-Seong Han (Korea), Hiroto Abe (Japan), Eunho Jung (Korea), Kazuaki Tadokoro (Japan), Vladimir V. Kulik (Russia), Minoru Kitamura (Japan), Kym Jacobson (USA), Sinjae Yoo (WG 35 Co-Chair, Korea), Jack Barth (USA), Wille Wilson (CPR), Franz Mueter (ESSAS, USA), Lisa B. Eisner (MONITOR Vice-Chair, USA), Jennifer L. Boldt (Canada), Sonia Batten (PICES), Tetjana Ross (Canada), Toshio Suga (Argo, Japan), Sei-Ichi Saitoh (observer, Japan), Naoki Yoshie (AP-NPCOOS Co-Chair, Japan).

AGENDA ITEM 2

Updates from the Inter-sessional Science Board meeting

1. MONITOR
   a. The NPSER3 synthesis report was officially published.
   b. The revised EAST-II Scientific Report was approved by POC and MONITOR and is in a final stage of publication.
   c. TOR3: Contribute to the development of NPSER and TOR1: Identify principal monitoring needs of the PICES region, and develop approaches to meet these needs, including training and capacity building.
   d. Impact on ocean monitoring due to COVID19" in progress (pending). We are targeting to publish a report in the PICES Press by the end of this year.
   e. POMA 2021 recommendation.
   f. New member: Dr. In-Seong Han (Korea).

AGENDA ITEM 3

Updates from PICES expert groups

1. Activities of WG 35: Sinjae Yoo

NPESR3 synthesis report:
- Has been published as a hard copy,
- Individual regional reports/chapters will be put on the website soon.

NPESR4 synthesis report:
- A proposal for a study group will be submitted to Science Board at ISB-2022.
- WG 35 to be disbanded at PICES-2021.

2. Activities of FUTURE: Vyacheslav Lobanov

   - FUTURE is moving from phase II to phase III; FUTURE SSC is summarizing phase II progress towards objectives; many overall objectives and key questions remain relevant; phase III implementation plans have been finalized.
   - Convened Annual and intersessional FUTURE SSC meetings were convened.
   - A product matrix of PICES products relevant to FUTURE was completed. In their final report, each expert group is required to map their products to FUTURE science questions.
   - The product matrix will be on the FUTURE website and a peer-reviewed manuscript will be developed (highlighting questions addressed by FUTURE, gaps in FUTURE science, implications for large-scale science programs).
   - Open Science Meeting planning for 2023 is underway; may be in Hawaii (Kona); FUTURE SSC will serve as the Organizing Committee; PICES is primary sponsor, but may seek co-sponsorship; ~200 participants; draft plan/format/agenda has been formed (4 days).
   - SG-ECOP (Early Career Ocean Professionals) held a workshop on "*Building a PICES early career professional network*" at PICES-2020; are developing an engagement plan, conducting a survey of Committees and expert groups to identify gaps and opportunities for ECOPs, and developing a perspectives article and connecting with other ECOP efforts.
   - SG-UNDOS (United Nations Decade of Ocean Science): SmartNet was established to link PICES and ICES to UNDOS.

- A working group proposal on climate extremes is being considered at PICES-2021; FUTURE SSC hosted a virtual workshop in June 2021 to engage the PICES community to develop this proposal; proposed parent committees = FUTURE, POC, BIO, HD; the WG will contribute to PICES activities supporting the UNDOS, including SmartNet.
- **Comments:** MONITOR and AP-NPCOOS should be involved in the WG-Extremes.

3. Activities of AP-CREAMS: Vyacheslav Lobanov

- Business meetings were held inter-sessionally and at PICES-2021,
- No international cruises because of the COVID pandemic,
- National activity was quite high in 2021,
- Surveys were done by each country, but need to coordinate.
- Future plans:
    - Establish a permanent platform for information on cruise plans,
    - Include socio-economic aspects; organize a special session on HD in the AMS at the next AP-CREAMS meeting; propose workshop on SEES in AMS for next PICES Annual Meeting; improve communication with other PICES committees,
    - Have closer collaboration with international organizations,
    - Realign CREAMS activities with those of UNDOS goals,
    - Establish AP-CREAMS website and database,
    - EAST-II report (Oceanography of the Yellow Sea and East China Sea, PICES Scientific Report No. 62, 2021, J. Ishizaka, G. Kim, J.H. Lee, S.M. Liu, F. Yu and J. Zhang) was published, and NPESER3 Regional Chapters are pending.
- Training courses:
    - Ocean turbulence, Qingdao, China, 2022 postponed; has been postponed multiple times,
    - Satellite remote sensing (NOWPAP), November–December 2021 webinar; no request for funds because it is only a webinar now.
- 2021–22 activities include meetings, joint cruises, training courses, workshops, webpage, database.

4. Activities of AP-NPCOOS: Naoki Yoshie

- A Spring School in Kagoshima, Japan, was cancelled due to COVID:
    - The AP proposes to organize an ocean big data virtual Summer School in August 2022 that would focus on learning skills for analyzing time series of oceanographic data sets from the coastal zone,
    - It will have pre-recorded lectures for data context, methods and analytical tools, and real time tutorials.
    - ONC will host the datasets and virtual machine.
- AP-NPCOOS strongly request to participate in the proposed working group on climate extremes,
- AP-NPCOOS/MONTOR/TCODE/BIO/FUTURE Workshop (W4) on "*Monitoring Essential Biodiversity Variables in the coastal zone*" was held at PICES-2021.
- **REQUEST**: funds to support staff and facility costs (no travel costs) with proposed Summer School on ocean big data.

AGENDA ITEM 4
Updates from international organizations

1. Activities of the CPR Survey: Clare Ostle (recorded)

This year marks the 22nd consecutive year of data collection and the figure below (Figure 1) shows the sample coverage.

Funding remains consistent and there have been no major issues with ships or deployments so far this year. The APL Qingdao container ship that tows the east-west transect has been delayed getting into port in Vancouver, so the second east-west tow only started at the beginning of September. We will therefore analyze extra samples from the new transect that tows through the Bering Sea in July, in order to maintain the number of samples collected during the summer months.

We discovered, unfortunately, that the CTD purchased in 2005 had flooded on the spring 2021 east-west transect and the components had been corroded and are no longer functioning. This instrument had been deployed on almost all east-west transects for 15 years, working without issue all that time and so had provided very good service. We will explore options for sourcing one of the next generation sensors that are being added to CPRs in the North Atlantic survey to provide additional measurements on this transect in the future.

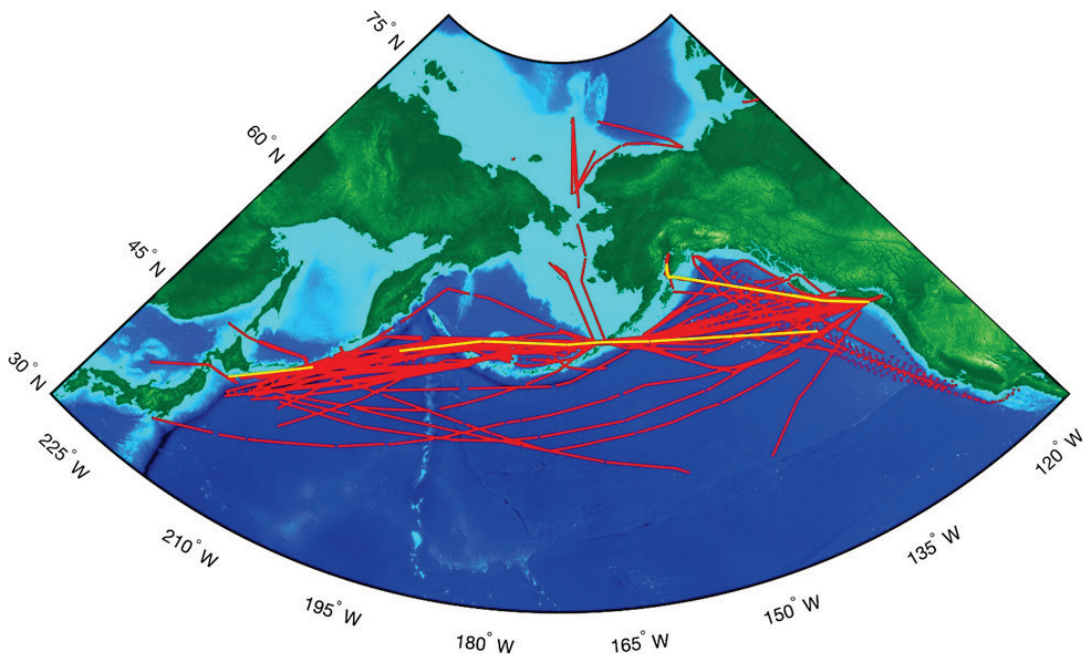


Figure 1 Historical CPR sample locations in red (2000-2020) and samples collected in 2021 so far in yellow. Please note there are additional transects to be added to the figure for 2021 once sample processing has been completed.

As well as the regular Pacific CPR sampling, the Canadian icebreaker Sir Wilfrid Laurier has now sampled the Bering shelf and in the western Chukchi and Beaufort Sea during the summer months of 2018, 2019 and 2020 (Figure 2). The SWL is currently towing a CPR in the same region for 2021. These Arctic routes have been funded via annual research bursary schemes that have now come to an end; we are therefore looking for long-term funding to continue sampling in these areas in the future, as they provide important information on this transition area, and we are planning on feeding into the Eastern-Bering-Sea (EBS) Ecosystem Status Report as a 'hot topic' to highlight the research. If there are any potential avenues for such funding, please contact either Clare Ostle (claost@mba.ac.uk) or Sonia Batten (Sonia.Batten@pices.int).

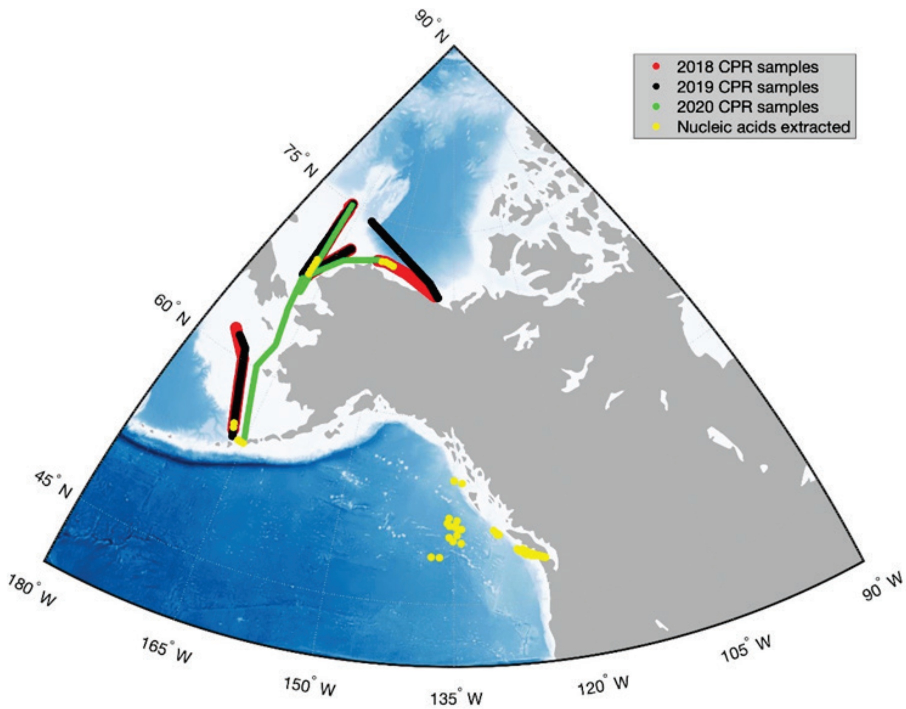


Figure 2 CPR samples collected from the CCGS Sir Wilfrid Laurier in 2018 (red), 2019 (black) and 2020 (green). Yellow dots are where nucleic acids have been extracted from CPR samples for genetic analyses.

<u>Recent publications, reports and articles</u>:

Arimitsu, M., J. Piatt, S. Hatch, R. Suryan, S. Batten, M. A. Bishop, R. Campbell, H. Coletti, D. Cushing, K. Gorman, R. Hopcroft, K. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, W. S. Pegau, A. Schaeffer, S. Schoen, J. Straley, and V. von Biela. (2021). Heatwave-induced synchrony within forage fish portfolio disrupts energy flow to top pelagic predators. Global Change Biology.

Ashlock L, García-Reyes M, Gentemann C, Batten S and Sydeman W (2021) Temperature and Patterns of Occurrence and Abundance of Key Copepod Taxa in the Northeast Pacific. Frontiers in Marince Science.

Batten, S., Helaouet, P., Ostle, C. and Walne, A. Responses of Gulf of Alaska plankton communities during and after a marine heatwave. Deep Sea Research II (submitted).

Hoover, B.A., García-Reyes, M., Batten, S.D., Gentemann, C., and Sydeman, W. (2021). Spatio-temporal persistence of zooplankton communities in the Gulf of Alaska. PLOS ONE. 16(1): e0244960. https://doi.org/10.1371/journal.pone.0244960

Ostle, C., and Batten, S. (in prep.) NOAA Ecosystem Status Report 2020: Continuous Plankton Recorder Data from the Aleutian Islands and Southern Bering Sea: Lower Trophic Levels in 2020.

Ostle, C., and Batten, S. (in prep.) NOAA Highlight Report 2020: Continuous Plankton Recorder Data from the Eastern Bering Sea: Lower Trophic Levels in 2020.

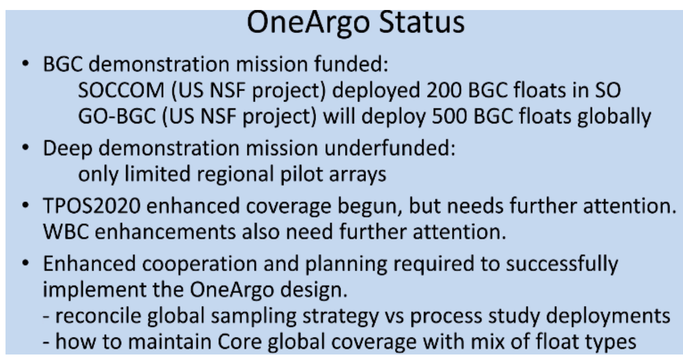
Ostle, C., and Batten, S. (in prep.) NOAA Ecosystem Status Report 2020: Continuous Plankton Recorder Data from the Gulf of Alaska: Lower Trophic Levels in 2020.

Pinchuk, A.I., Batten, S.D., and Strasburger, W.W. (2021). Doliolid (Tunicata, Thaliacea) blooms in the southeastern Gulf of Alaska as a result of the recent heat wave of 2014-2016. Frontiers in Marine Science – Marine Ecosystem Ecology.

Suryan, R. M., M. L. Arimitsu, H. A. Coletti, R. R. Hopcroft, M. R. Lindeberg, S. J. Barbeaux, S. D. Batten, W. J. Burt, M. A. Bishop, J. L. Bodkin, R. E. Brenner, R. W. Campbell, D. A. Cushing, S. L. Danielson, M. W. Dorn, B. Drummond, D. Esler, T. Gelatt, D. H. Hanselman, S. A. Hatch, S. Haught, K. Holderied, K. Iken, D. B. Iron, A. B. Kettle, D. G. Kimmel, B. Konar, K. J. Kuletz, B. J. Laurel, J. M. Maniscalco, C. Matkin, C. A. E. McKinstry, D. H. Monson, J. R. Moran, D. Olsen, W. A. Palsson, W. S. Pegau, J. F. Piatt, L. A. Rogers, N. A. Rojek, A. Schaefer, I. B. Spies, J. M. Straley, S. L. Strom, K. L. Sweeney, M. Szymkowiak, B. P. Weitzman, E. M. Yasumiishi, and S. G. Zador. (2021). Ecosystem response persists after a prolonged marine heatwave. Scientific Reports.

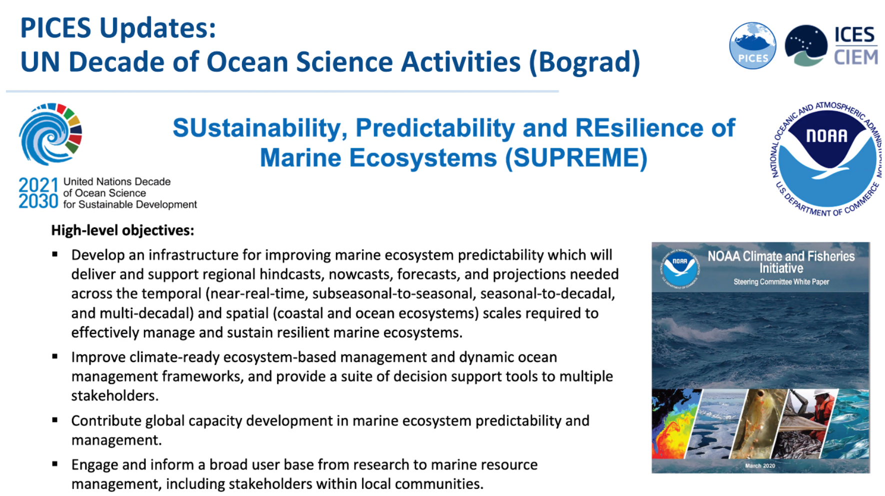
2. Activities of Argo: Toshio Suga

- Website has been updated to: https://argo.ucsd.edu
- Nearly 4,000 operational floats:
  - 24 active countries,
  - SE Pacific is a priority for 2021,
  - Need planning for the Indian Ocean and Southern Ocean and marginal seas.
- Three missions: core (T, S, P, to 2000m); Deep Argo (T, S, P to 6000 m); BGC-Argo (T, S, p, O_2, pH, Nitrate, chlorphyll, backscatter, irradiance to 2000 m)



3. Activities of the UN Decade: Steven Bograd

- Joint PICES/ICES SG-UNDOS to plan participation in the UNDOS:
  - Submitted a proposal: SmartNet (Sustainability of marine ecosystems through global knowledge networks); submitted in January 2021, and endorsed by the Ocean Decade in June 2021
  - Will likely request an extension to develop a working group,
- SUPREME (Sustainability, Predictability and Resilience of Marine Ecosystems) proposal submitted by NOAA in January 2021:
  - Builds upon NOAA's climate-fisheries initiative,
  - Has synergies with S-CCME,
  - Endorsed by Ocean Decade in September 2021,
  - Has begun to develop an engagement plan.
- Ocean Decade-endorsed programs do not come with funds, but may perhaps in the future,
- They will need resources for both SmartNet and SUPREME to accomplish objectives.



4. Activities of SCOR WG(P-Obs): Sonia Batten

- Objective is to identify best practices and feasibility to incorporate plankton measurements into global ocean observing platforms,
- For report, see oceanbestpractices.org,
- Products are pertinent to PICES Working Group on *Towards best practices using Imaging Systems for Monitoring Plankton* (WG 48).

SCOR Working Group-154 "*Integration of plankton-observing sensor systems to existing global sampling programs, P-Obs***"**

Objective: identify best practices (technologies and sampling protocols) and technical feasibility to incorporate plankton measurements into global ocean observing platforms (GO-SHIP and OceanSITES in particular):

Technologies considered: Imaging, HPLC, Molecular methods, Flow Cytometry, Bio-optics, Bio-acoustics

Product: Report can be found at oceanbestpractices.org Recommendations for plankton measurements on the GO-SHIP program with relevance to other sea-going expeditions. SCOR Working Group 154 GO-SHIP Report. (oceanbestpractices.org). Report includes; costs, protocols, personnel time, required infrastructure, parameters captured etc.

Final stage is to produce similar recommendations for OceanSITES moorings (no physical meeting since 2019)

Relevant to new PICES WG 48 (*Towards best practices using Imaging Systems for Monitoring Plankton*)- some shared interests.

5. Activities of the ESSAS: Franz Mueter

- Overview and status of monitoring programs in the Arctic and subarctic:
- US:
  - ASGARD (US Arctic Shelf Growth, Advection, Respiration and Deposition rate experiments), spring 2017–19,
  - US Arctic Marine Biodiversity Observation Networks (2015, 2017); eDNA, nets, benthic grabs, seabirds/mammals,
  - Ongoing: Distributed Biological Observatory (BS Shelf, Chukchi Sea)
- Japan recent and ongoing research: 2 programs,
- Korea ongoing research,
- **Discussion:** no information on Russian research/monitoring because there is no Russian ESSAS member; looking for an active Russian member to join ESSAS (Dr. Lobanov to email Dr. Mueter).

AGENDA ITEM 5
Other issues

1. Potential POMA candidates

Dr. Kim asked MONITOR members to encourage nominees for the POMA. can consider Nominees will be considered for two consecutive years without the need for re-submission. There were several good nominees this year, so these could be reconsidered again next year.

2. Other issues

PICES-2022 will be in Busan,Korea. A hybrid meeting can be expected as the MONITOR meeting usually has the most observers than any committee.
Action: Members to send any COVID issues regarding monitoring to Dr. Kim and Dr. Tetjana Ross.

The Day 1 meeting was adjourned.

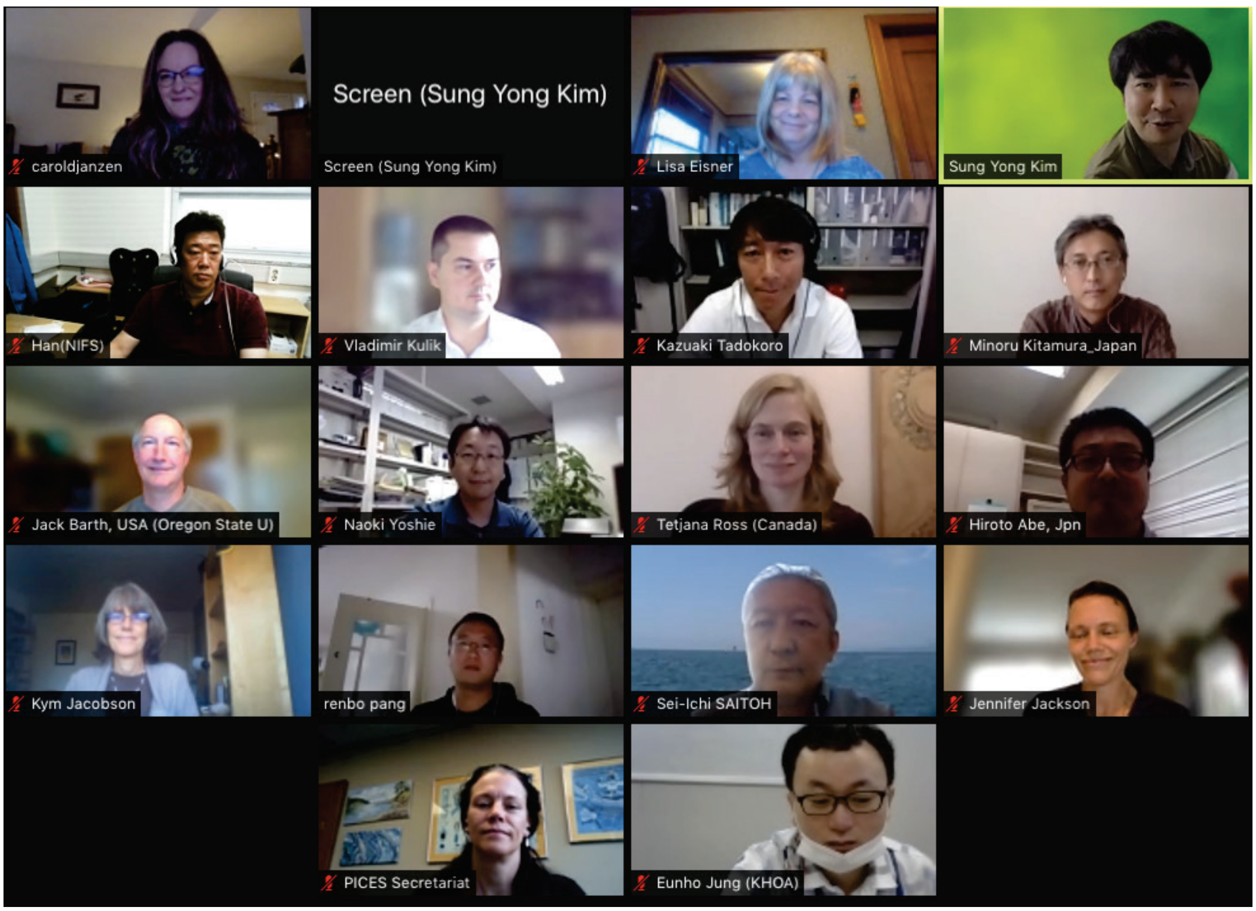
DAY 2

October 6/7, 2020 hh:00-hh+2:40

AGENDA ITEM 6

Welcome and introductions and review of first day

MONITOR Chair, Prof. Sung Yong Kim called the meeting to order, participants introduced themselves, the meeting agenda for Day 2 was reviewed and adopted.



Day 2 meeting participants at PICES-2021: Carol Janzen (AOOS, USA), Lisa B. Eisner (MONITOR Vice-Chair, USA), Sung Yong Kim (MONITOR Chair, Korea), In-Seong Han (Korea), Vladimir V. Kulik (Russia), Kazuaki Tadokoro (Japan), Minoru Kitamura (Japan), Jack Barth (USA), Naoki Yoshie (AP-NPCOOS Co-Chair, Japan). Tetjana Ross (Canada), Hiroto Abe (Japan), Kym Jacobson (USA), Renbo Pang (NEAR-GOOS), Sei-ich Saitoh (WGICA, Japan), Jennifer Jackson (CIOOS, Canada), Sonia Batten (PICES), Eunho Jung (Korea).

AGENDA ITEM 7
Review of proposals for PICES-2022

Not discussed.

AGENDA ITEM 8
Updates from international organizations (cont'd)

1. Activities of Alaska Ocean Observing System (AOOS): Carol Janzen

   - AOOS is 1 of 11 regional IOOS organizations.
   - Marine operations-coastal data information program buoys (2–3 locations), NEW: Bristol Bay CDIP Wave Buoy. Surface current mapping using HFR (Arctic locations too). Expanding weather observing.
   - Coastal Hazards: 12 water level stations New: AKDNR and community led Hydroball shallow water bathymetric mapping using a towed system.
   - Ecosystems and Climate: 4 Ecosystem moored observatories: GOA, Chukchi Sea (CEO), build out existing Bering mooring M2 and M8. Upgrades of U of Alaska glider fleet. New add acoustic transducers, develop ecometrics dashboard, Chukchi marine mammal glider support LTER Seward line GOA transect. Support ocean telemetry Network acoustic arrays in GOA to track fish and marine mammals.
   - Water quality: focus on ocean acidification (OA) but expanding HAB network. Support continuous carbon chemistry –Burk-o-later, PMEL OA on 2 moorings
   - Data Access and visualizations: Tools for public to access and data visualization. Mariculture map. Host networks for coordination and outreach (*e.g.*, OA, HABs).
   - Dr. Lisa Eisner expressed appreciation on the Alaska HAB monthly calls with researchers all over Alaska reporting on local conditions.

2. Activities of Canadian OOS: Jennifer Jackson

   - History: regional nodes - push for an Arctic node and great Lakes node.
   - Phase 2 (now) expanding. National platform and regional nodes (RA) are where users get data. Science Committee – Dr. Jackson is Co-Chair with Dr. Richard Dewey. National coordination on data priorities. Establish data quality and attach a flag. Essential ocean variables: CO_2, nutrients, O_2, …physical sea ice, waves, T, currents, S, speed of sound… Biological is coming soon. New Essential Ocean Variables. Asset Map https://cioospacific.ca. Benefits of CIOOS: one is knowledge exchange, increase transparency,… Multi-sector engagement. Ex of Line P data, putting together a marine heat wave app. Preparing for the future- become integrated with the larger Ocean Observing systems.
   - Arctic data not available yet, but we are working on it.

3. Activities of the NE Asian Regional (NEAR) GOOS: Renbo Pang (on behalf of Guimei Liu)

NEAR-GOOS main activities ocean observing data sharing and providing ocean forecasting. Ocean Observing Data Sharing Portal. Gateway Website will be operational in December 2021. It will provide interactive overview of metadata and observing tools; keep increasing data year by year. Ocean forecasting products include wind, currents, temperature. There is a working group on data management objective to maintain and develop the database network. Pilot Project climate monitoring. Pilot Project ferry-based monitoring. Slides: Meetings. Decade of Ocean science. Engage in GOOS 2030 strategy. Cooperate between NEAR-GOOS and PICES- seek cooperation on ocean observing- very important.

4. Activities of the NW Association of Networked Ocean Observing Systems (NANOOS): Jan Newton

NANOOS is increasing focus on the UN Decade. Its domain is in the NW (Washington, Oregon), and northern extent of the California Current. The intent is to understand users' needs: diverse groups (evenly balanced) that are supported by or offer support to NANOOS. Areas of emphasis: climate, climate and weather, ecosystem assessment, fisheries and biodiversity, maritime operations. Serve data for models. Visualization system example - NVS data explorer - *e.g.*, can visualize water T anomalies. Can run different models and visualize output (Cool!). Can select different depths. Feature called comparator to compare data. App for maritime operators that include only data relevant to their interests. Trying to serve society as well as science. Scientific contributions: OA, coastal climate change, Live Ocean model output examples. Local to global: NANOOS to US IOOS to GOOS. Examples of local and global visualizations. UN Decade: NANOOS can connect dots of regional issues within a global network. Need for sustainable development means need to engage local stakeholders and strive to connect broader user community across all of the UN Decade programs.

5. Activities of the PICES/ICES/PAME Working Group on an *Integrated Ecosystem Assessment for the Central Arctic Ocean* (WG 39/WGICA): Sei-Ichi Saitoh

Future September sea ice is predicted to disappear by ~ 2050 in the CAO. The Pacific gateway and Atlantic Gateway are important to the CAO. WG 39 has 3 co-chairs, one from each organization. The WG will meet in April 2022 and will produce a report an Integrated Ecosystem Assessment. Four reports are planned. First IEA Central Arctic Ocean report (2021) is in revision; 2nd report on the ecosystem is in preparation. Dr. Saitoh presented revised TORs for 2022–2024. A WG39/WG 44 joint workshop (both WG cover Arctic regions) is planned for PICES-2022 to consolidate WG 39's findings and advice. WG 39 will hold a virtual annual inter-sessional meeting October 12–14, 2021 as well as a spring meeting.

AGENDA ITEM 9
National reports

See *MONITOR Endnote 3*

AGENDA ITEM 10
Other issues

Action: members to get the COVID-19 impacts on monitoring to Dr. Kim and Dr. Ross by end of month, so they can compile and write up an article for January PICES Press.

The DAY 2 meeting was adjourned.

MONITOR Endnote 1

MONITOR participation list

Members

Sung Yong Kim (Korea, Chair)
Lisa B. Eisner (USA, Vice-Chair)
Jennifer Boldt (Canada)
Tetjana Ross (Canada)
Hiroto Abe (Japan)
Minoru Kitamura (Japan)
Kazuaki Tadokoro (Japan)
In-Seong Han (Korea)
Eunho Jung (Korea)
Vladimir Kulik (Russia)
Vyacheslav B. Lobanov (Russia)
Jack A. Barth (USA)
Kym Jacobson (USA)
Clare Ostle (*ex officio*, representing CPR)

Members unable to attend

China: Honghui Huang, Zhifeng Zhang, Xianyong Zhao

Observers

Carol Janzen (AOOS)
Franz Mueter (ESSAS)
Sei-Ichi Saitoh WG 39 PICES Co-Chair, Japan)
Toshio Suga (Argo)
Sinjae Yoo (WG 35 Co-Chair, Korea)
Naoki Yoshie (AP-NPCOOS Co-Chair, Japan)
Wille Wilson (CPR)

PICES

Sonia Batten (Executive Secretary)

MONITOR Endnote 2

MONITOR meeting agenda

Day 1: October 4/5, 2021 hh:00-hh+2:30 (Note: hh:00 indicates the local starting time; times may shift)

1. Welcome, Introduction, and Sign-in (ZOOM screen capture)
2 PICES-2021 issues: Updates from the ISB Meeting
3. Updates from PICES Expert Expert Groups
   a. Activities of WG 35: Yoo
   b. Activities of FUTURE: Lobanov
   c. Activities of AP-CREAMS: Lobanov
   d. Activities of AP-NPCOOS: Yoshie
4. Relations with international organizations
   a. Activities of the CPR Survey (recorded): Ostle
   b. Activities of Argo: Suga
   c. Activities of the UN Decade: Bograd
   d. Activities of SCOR WG(P-Obs: Batten
   e. Activities of ESSAS (Mueter)
5. Other business
   a. Discussion on potential POMA award candidates and other issues

Day 1: October 6/7, 2021 hh:00-hh+2:30 (Note: hh:00 indicates the local starting time; times may shift)

6. Welcome, Introduction, and Sign-in (ZOOM screen capture)
7. A short discussion
   Review of proposals for PICES-2022 support for topic sessions, workshops, and inter-sessional workshops
8. Relations with international organizations
   a. Activities of AOOS: Janzen
   b Activities of the Canadian OOS: Jackson
   c. Activities of NEAR-GOOS: Liu
   d. Activities of NANOOS: Newton
   e. Activities of WGICA: Saitoh
9. National Reports – Written and Oral
   - Canada Boldt, Ross
   - Japan Kitamura, Tadokoro, Abe
   - Korea Kim, Han, Jung
   - Russia Kulik, Lobanov
   - United States Barth, Eisner, Jacobson
   - China Huang, Zhao, Zhang

10. Other business

MONITOR Endnote 3

National Reports[1]

1. Canada

I. Overview and Summary of 2020

Fisheries and Oceans Canada (DFO), Pacific Region, conducts annual reviews of physical, chemical and biological conditions in the ocean (Fig. 1), to develop a picture of how the ocean is changing and to help provide advance identification of important changes which may potentially impact human uses, activities, and benefits from the ocean. The report from 2021 (for conditions in 2020) is available at: http://waves-vagues.dfo-mpo.gc.ca/Library/4098297x.pdf.

Figure 1. Map of areas reported on in the State of the Ocean report, including Line P, and Ocean Station Papa. Source: Boldt *et al*. (2021).

Below is the overview and summary from that report, with the same Figure and Section numbers as in the report (Boldt *et al*. 2021):

Climate change continues to be a dominant pressure acting on Northeast (NE) Pacific marine ecosystems. Globally, land and ocean temperatures in 2020 were the second warmest on record. B.C. air temperature and precipitation data show trends to warmer and wetter conditions (Anslow, Section 6). In 2020, B.C. river discharges were greater and peaked later than normal (Anslow, Section 6; Chandler, Section 35). The long-term record of sea surface temperatures (SSTs) collected at lighthouses along the B.C. coast showed that 2020 was generally cooler than 2019 but was still a continuation of the warm period that started in 2014 (Chandler, Section 10). Overlying the multi-year oscillations in the annual SST there remains a long-term

[1] No report was available for China at this time.

trend towards rising ocean temperatures: 0.88°C over the last 100 years (Figure 3-1; Chandler, Section 10). Increasing CO_2 in the atmosphere has increased the acidification of the ocean, which will continue to intensify with the rise of anthropogenic carbon levels in the atmosphere (Evans, Section 34). In 2020, the occurrence of severe high-pCO_2, and acidic conditions varied seasonally; however, the duration of severe conditions was shorter than in 2019 (Evans, Section 34).

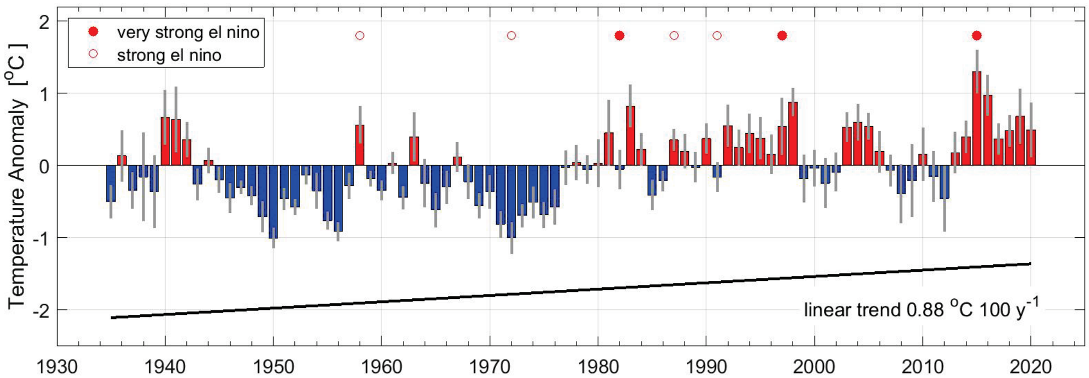


Figure 3-1. The trend in the annual temperature based on the observations of all lighthouses. The data shown are the anomalies from the long-term average temperature (1935–2020). The bars represent the anomalies averaged over all stations (a coast wide indicator), (red – above average, blue – below average), the vertical grey lines show the variability in the lighthouse data for each year. Source: Chandler, Section 10.

For most of 2020, the NE Pacific was in marine heatwave conditions for both surface and subsurface waters, which was a continuation of the marine heatwave that started in 2019 (Ross and Robert, Section 7). Marine heatwave (MHW) conditions persisted, despite the cooling effects of La Niña conditions throughout the latter half of 2020, suggesting that temperatures would have been warmer in the NE Pacific if not for the phase of the ENSO cycle (Figure 3-2). The MHW resulted in above average SST anomalies in both surface and subsurface waters (Figure 3-3; Ross and Robert, Section 7; Sastri, Section 14). The occurrence of MHWs in the NE Pacific is increasing, with MHWs observed in 2014–2016, 2018, and 2019–2020; this span of eight warm years (2014-2020) has been observed only once before in the last 80 years (during 1992–1998; Chandler, Section 35).

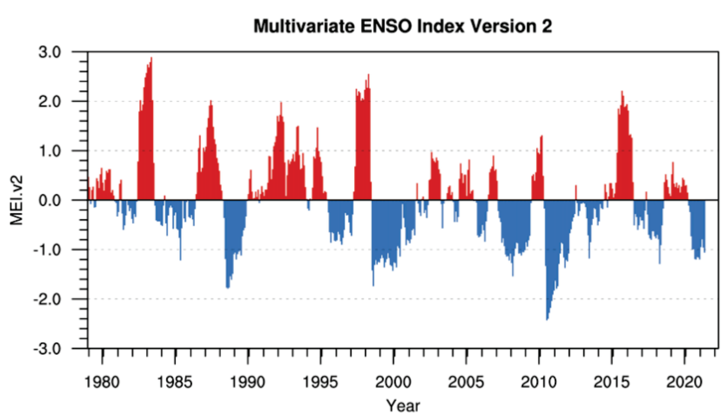


Figure 3-2. The multivariate ENSO Index. Data source: NOAA/ESRL/Physical Sciences Division – University of Colorado at Boulder/CIRES; https://psl.noaa.gov/enso/mei/.

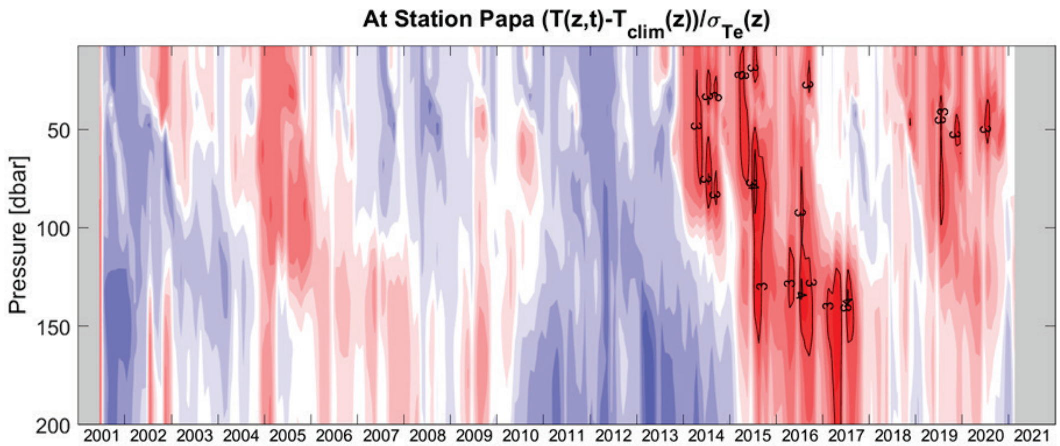


Figure 3-3. Plot of temperature anomalies relative to the 1956–2012 seasonally-corrected mean and standard deviation (from the Line P time series), as observed by Argo floats near Station Papa (P26: 50°N, 145°W). The cool colours indicate cooler than average temperatures and warm colours indicate warmer that average temperatures. Dark colours indicate anomalies that are large compared with the 1956–2012 standard deviations. The black lines highlight regions with anomalies that are 3 and 4 standard deviations above the mean. Source: Ross and Robert, Section 7.

Marine heatwaves are associated with reduced vertical mixing causing increased winter stratification. This results in decreased nutrient supply from deep to surface offshore waters. The winter stratification was strong in 2019/20, but not as strong as the previous winter which showed extremely low winter mixing, similar to the winters during the 'Blob' years (2013/14, 2014/15; Freeland 2015; Ross and Robert, Section 7). This suggests that nutrient supply from deep waters should have been weaker and therefore early spring nutrient levels lower in the spring of 2020, but not quite as low as in 2019 (Ross and Robert, Section 7).

Reduced ecosystem productivity during MHWs has been identified as the cause of reduced abundance of lipid-rich boreal copepods (Galbraith and Young, Section 18), seabird die-offs (Jones et al. 2018), reduced size-at-age and late entry into streams and rivers by adult salmon (Hyatt et al., Section 24) due to prolonged drought in northern B.C. (Anslow, Section 6).

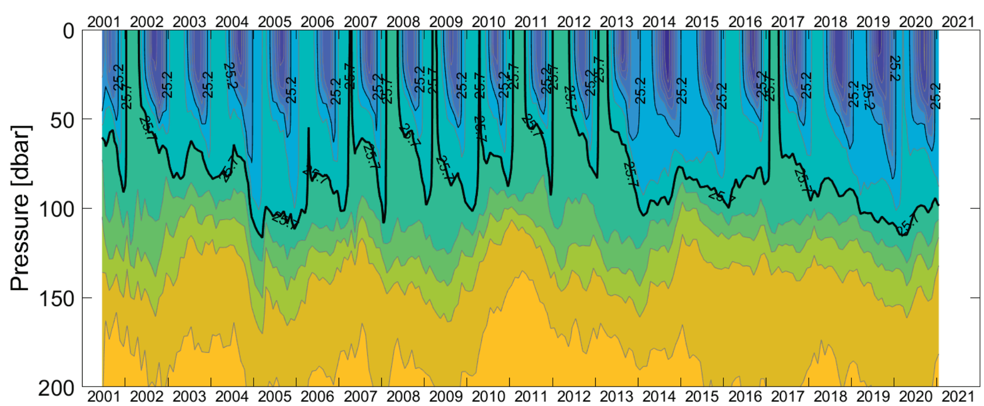


Figure 3-4. Coloured contour plot of density as observed by Argo floats near Station Papa (P26: 50°N, 145°W). The colours indicate potential density (yellow is denser and blue lighter). The black lines highlight the 25.2 kg/m^3 (thin) and 25.7 kg/ m^3 (thick) isopycnals. Source: Ross and Robert, Section 7.

The timing and magnitude of upwelling of deep, nutrient-rich water off the west coast of Vancouver Island (WCVI) is an indicator of marine coastal productivity across trophic levels from plankton to fish to birds. Variability in the upwelling index corresponds with variations in the strength and/or longitudinal position of the Aleutian low-pressure system in the Gulf of Alaska. In 2020, the winter downwelling season ended early but there was a slow start to the upwelling season. The magnitude of the upwelling-favourable winds in the summer of 2020 was near-normal with an expectation of average productivity (Hourston and Thomson, Section 8; Dewey *et al*., Section 36). The 2020 Spring Transition timing was very early relative to the 1991–2020 mean and this is associated with average to above-average upwelling-based coastal productivity (Hourston and Thomson, Section 8; Dewey *et al*., Section 36; Figure 3-5).

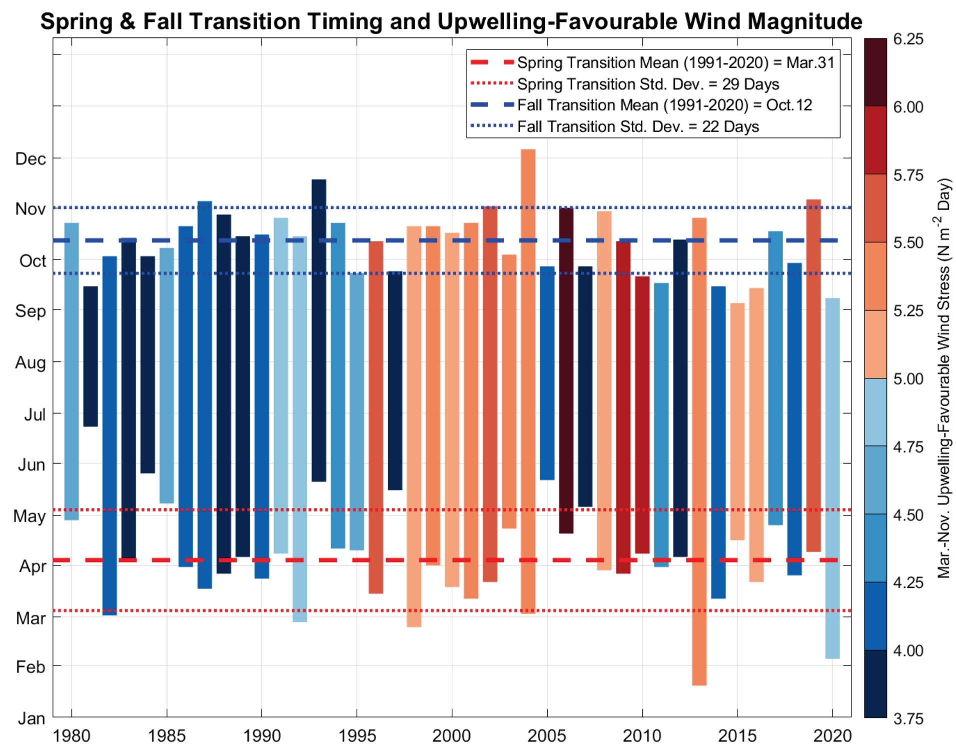


Figure 3-5. Annual Spring and Fall Transition Timing and March-November upwelling-favourable wind stress magnitude, 1980–2020. The length of the bar corresponds to the duration of the upwelling season, coloured by the intensity of the upwelling (red indicates intense upwelling, blue indicates weak upwelling). Bold dashed lines indicate the average spring (red) and fall (blue) transition dates. Light-dashed lines indicate standard deviations of the spring (red) and fall (blue) transition dates. Source: Roy Hourston, Section 8.

In 2020, winter surface nutrient concentrations along Line P were among the lowest on record due to increased stratification that restricted nutrient renewal from vertical transport, similar to that observed in previous years (Peña and Nemcek, Section 16). A Haida eddy with lower than normal surface nutrients was present at the offshore stations of Line P in winter of 2020. By summer, surface nutrients were similar to or higher than those observed in winter. Phytoplankton biomass was relatively low along Line P in 2020 but community composition was similar to that of previous years, except for a decrease in diatom abundance (Peña and Nemcek, Section 16; Batten and Ostle, Section 19).

In some areas off the WCVI , the zooplankton community continued to reflect warm water conditions, with above average abundances of southern species (*e.g*., southern copepods along Line P and southern chaetognath species in all areas) (Galbraith and Young, Section 18) and, on the shelf, a dominance of small-sized copepod species (Batten and Ostle, Section 19). Large subarctic and boreal copepods are more favourable for fish growth than small, southern copepod species. In 2020, biomass anomalies of boreal and subarctic copepods anomalies moved to near average in most areas (Galbraith and Young, Section 18; Figure 3-6). Southern copepod anomalies were positive along and off the south coast of Vancouver Island (Figure 3-6; (Galbraith and Young, Section 18); warm water copepods were still abundant in offshore waters (Ostle and Batten, Section 19).

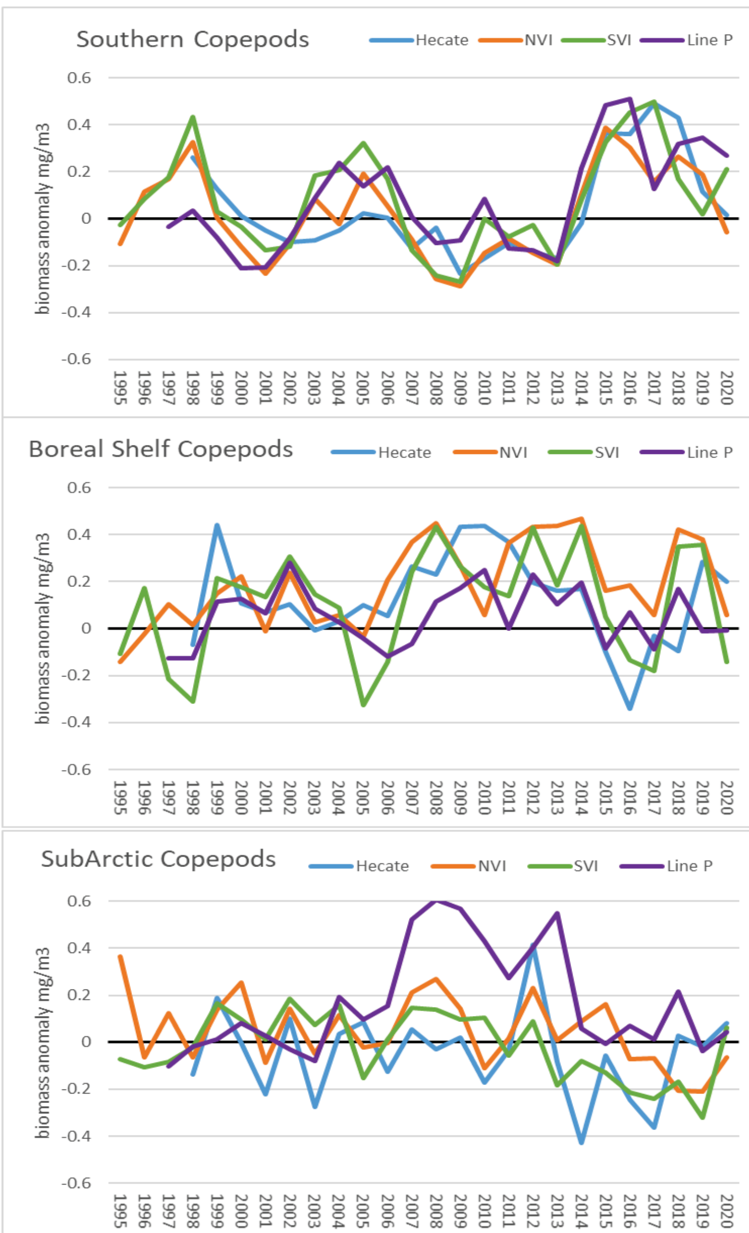


Figure 3-6. Zooplankton species-group anomaly time series for the regions shown in Figure 16-1. Line graphs are annual log scale anomalies. Southern Vancouver Island (SVI) green; Northern Vancouver Island (NVI) orange; Hecate Strait blue; Line P purple - for all graphs. Blank years mean no samples were collected. Source: Galbraith and Young, Section 16.

Changes to the physical environment, and phytoplankton and zooplankton communities can have impacts on higher trophic levels. The survey that usually monitors WCVI Smooth Pink Shrimp biomass, which is negatively correlated with SST (lagged 1 year), was cancelled in 2020 due to COVID-19. Groundfish surveys were also cancelled; however, new analyses of groundfish biological status from published stock assessments have been provided. The average groundfish stock status declined from 1950 to around 2000 and has remained relatively stable since then. The change around 2000 followed the implementation of individual transferable quotas for the trawl fleet and the commencement of the synoptic trawl surveys (Anderson et al., Section 27). Albacore tuna annual catch-per-unit-effort (CPUE) increased in 2018–2020 (Zhang, Section 28).

The growth rate of Cassin's Auklets is linked to the abundance of their primary prey, *Neocalanus cristatus* copepods, which are more abundant during relatively cold years (Hipfner et al. 2020). In 2020, growth rates of Cassin's auklet nestlings on Triangle Island could not be measured due to COVID. Marine mammal population trends are not updated annually; however, readers are referred to the 2020 SOPO report for recent information.

The Salish Sea spring biophysical survey was cancelled due to the COVID-19 pandemic. The summer survey showed near-normal temperature and salinity conditions through most of the Salish Sea with lower than normal oxygen concentrations in the upper 100 m. The fall survey captured an intrusion of cooler, saltier and poorly oxygenated water from the Pacific Ocean. Water exchange in Haro Strait mixed this low oxygen Pacific water with fresher and warmer water from the Strait of Georgia causing lower than normal oxygen conditions extending northwards through the Strait of Georgia at depths of 50-100 m. (Chandler, Section 35). The Fraser River discharge was significantly higher than normal in 2020 (about 30% more than the 100 year average) (Figure 3-7; Chandler, Section 35).

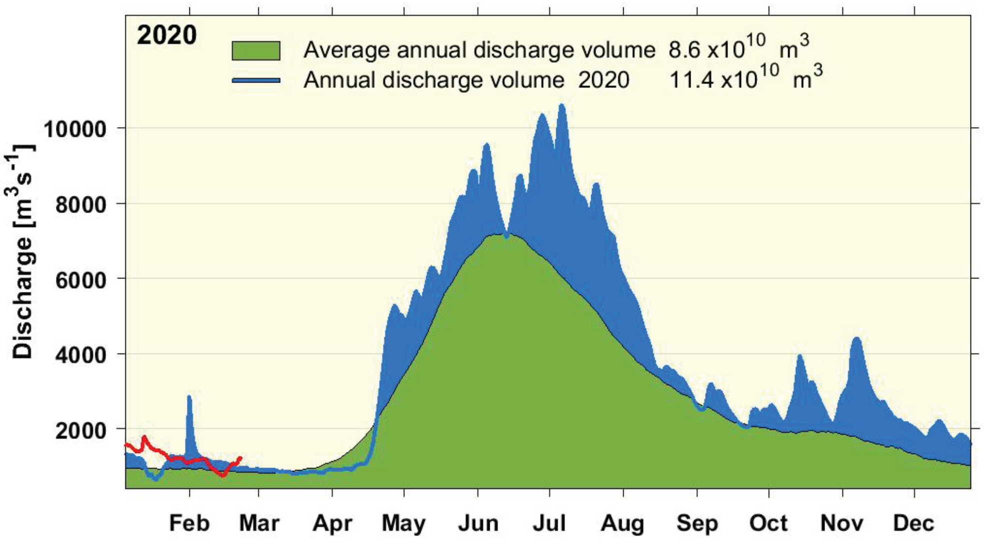


Figure 3-7. Fraser River discharge at Hope B.C.; 2020 (blue), 108 year average (green), the above normal discharge in early 2021 (red line). Extracted from the Environment and Climate Change Canada Real-time Hydrometric Data web site (https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html) on 23 Feb 2021.

There were local *Heterosigma akashiwo* blooms with concentrations reaching thousands cells per mL in Cowichan Bay, Sunshine Coast, and Irvine's Sechelt in July and August, 2020. The *Heterosigma* blooms of 2020 were more abundant than in 2015-2017 and 2019, but less than in 2018 (Esenkulova *et al*., Section 38). European Green Crab, an Aquatic Invasive Species that was first observed in B.C. following the 1997/98 El Niño, is widespread along the

WCVI and found in low numbers on the Central B.C. coast and in the Salish Sea (Howard and Therriault, Section 43). This high-impact invader that negatively affects eelgrass, an important fish habitat, was detected for the first time on Haida Gwaii in July 2020 (Howard and Therriault, Section 43). Vessel traffic introduces a variety of stressors to marine ecosystems (*e.g.*, oil, noise, shipstrikes, *etc*). Marine vessel traffic intensity increased in the Salish Sea from 2015–2017 for nearly all types of vessels and evidence of increasing intensity for recreational and other vessels (O'Hara *et al*., Section 44).

Annual variation in spring bloom timing and community composition may affect the food web, through a temporal match or mismatch between prey and their predators. In the SoG, the spring bloom timing was similar to the long-term average (Allen *et al*., Section 37; Dewey *et al*., Section 36) – which implies good feeding conditions for juvenile fish.

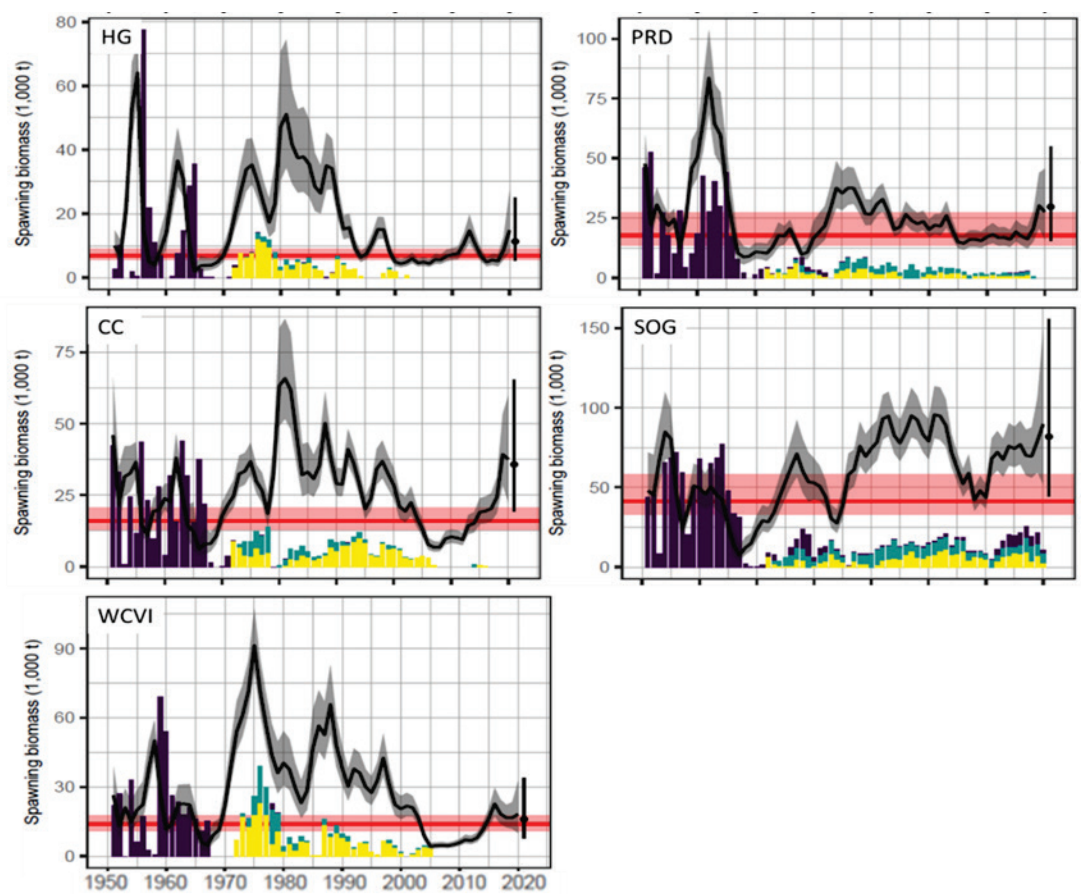


Figure 3-8. Summary of the dynamics of the five Pacific Herring stocks from 1951 to 2020, where solid lines with surrounding grey envelopes, represent medians and 5–95% credible intervals. Also shown is the reconstruction of spawning biomass for each year, with unfished values shown at far left (solid circle and vertical lines) and the projected spawning biomass given zero catch shown at the far right (solid circle and vertical lines). Time series of thin vertical lines denote commercial catch (excluding commercial spawn-on-kelp; colours indicate different gear types; see DFO 2021). Red line = limit reference point (0.3B0). B0 = unfished biomass. Figure adapted from DFO (2021). Figure adapted from DFO (2020).

In 2020, SoG zooplankton biomass was above the long-term average (Young *et al*., Section 39). The abundance and biomass trends were similar to those observed in 2019 for crustacean zooplankton taxa, that are important food for juvenile salmon (Young *et al*., Section 39). In 2020, Pacific Herring spawning biomass varied among assessed areas. For example, since 2000, Haida Gwaii biomass has been low with an increase in 2020. Also, in 2020, the Strait of Georgia stock biomass was relatively high compared to historic levels (Cleary *et al*., Section 21; Figure 3-8). In 2020, the Strait of Georgia juvenile Pacific Herring survey was cancelled due to COVID. In 2020, the index of Fraser River Eulachon spawning stock biomass was estimated to be relatively high (~624 tonnes), approximately equal to the 2001 index and higher than all years since 2001 (Flostrand, Section 20). In 2020, a freshwater benthic diatom known as Didymo was confirmed to be a major component of the material collected in the Fraser River Eulachon egg and larval survey water samples. The extensive growth of Didymo in upper watersheds in B.C. and high outflow of Didymo in the lower Fraser River have unknown and possibly negative implications to upper and lower watershed habitats and ecosystem (Flostrand, Section 20).

In the SoG, the spring juvenile Pacific salmon survey was cancelled but the fall survey was completed revealing the index of Coho Salmon abundance was the fourth highest observed in the time series (Neville, Section 40). Also, the index of Chinook Salmon abundance was the largest observed in the time series (Neville, Section 40). The summer Integrated Pelagic Ecosystem Survey was cancelled, so updates of Pacific Herring and juvenile Pacific Salmon abundance could not be updated. In October 2020, a juvenile salmon survey was conducted in Queen Charlotte Sound, Dixon Entrance, and Hecate Strait to measure relative abundance, condition, and genetic stock identification of different species (Anderson *et al*., Section 22). Abundance and condition anomalies varied among regions and species (*Anderson et al*., Section 22). Adult Sockeye, Chinook, and Chum, Salmon returns in 2019 were generally poor (Grant *et al*., Section 23). Coho and Pink Salmon returns in 2020 were mixed: Pink Salmon generally had better returns than most species in recent years in some areas of Johnstone Strait, while Coho returns were generally average to below average with a few exceptions (Grant *et al*., Section 23). In 2015-2020, most B.C. Sockeye Index stocks generally exhibited returns below to far below their 40 year average (Hyatt et al. Section 24) and returns and productivity of the Fraser River Sockeye Salmon aggregate were poor (Figure 3-9, Grant *at el*., Section 23). Fraser River Sockeye Salmon that matured in odd-numbered years were generally smaller than those that matured in even-numbered years, with size at age in 2019 and 2020 among the lowest observed in over 60 years (Latham *et al*., Section 26). For the entire North Pacific, recent salmon abundances were at (2018) or near all-time high levels until 2020 when far fewer salmon returned than expected; the North Pacific ecosystem may have been sufficiently disrupted by consecutive abundant Pink Salmon years to reduce salmon returns in 2020 (Irvine *et al*., Section 25).

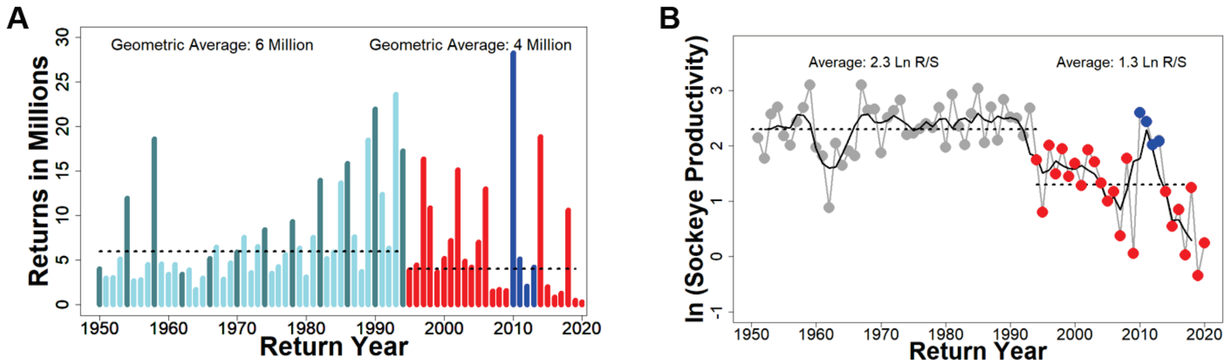


Figure 3-9. (A) Total Fraser Sockeye annual returns. For years from 1950 to 1994 dark green bars are the 1950 cycle line, and light blue bars are for the three other cycle lines. For years from 1995 to 2020, red vertical bars highlight a period of reduced Fraser Sockeye productivity, with the exception of a period from 2010 to 2013 (blue vertical bars) where productivity was closer to the previous period (1950–1994). (B) Total Fraser Sockeye productivity (loge (returns/effective female spawners)). The grey dots and lines represent annual productivity estimates. Productivity and returns have declined in recent decades, highlighted red, with the exception of four years from 2010-2013, which were closer to the previous period (1950–1994), highlighted blue. For both figures, the dashed line is the time series average. Source: Grant *et al*., Section 23.

References

DFO. 2020. Stock status update with application of management procedures for Pacific Herring (*Clupea pallasii*) in British Columbia: Status in 2019 and forecast for 2020. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/004.

Freeland, H. 2015. The "Blob" or Argo and other views of a large anomaly in the Gulf of Alaska in 2014/15. In Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2015. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3131: vi + 211 p. Available online: http://www.dfo-mpo.gc.ca/Library/358018.pdf

Hipfner, J.M., Galbraith, M., Bertram, D.F., and Green, D.J. 2020. Basin-scale oceanographic processes, zooplankton community structure, and diet and reproduction of a sentinel North Pacific seabird over a 22-year period. Progress in Oceanography 182: Article 102290.

Jones, T., Parrish, J.K., Peterson, W.T., Bjorkstedt, E.P., Bond, N.A., Balance, L.T., Bowes, V., Hipfner, J.M., Burgess, H.K., Dolliver, J.E., Lindquist, K., Lindsey, J., Nevins, H.M., Robertson, R.R., Roletto, J., Wilson, L., Joyce, T., and Harvey, J. 2018. Massive Mortality of a Planktivorous Seabird in Response to a Marine Heatwave. Geophysical Research Letters. https://doi.org/10.1002/2017GL076164

II. Observational programs

In 2020, many surveys were cancelled and others were reduced, due to COVID-19 concerns.

A. Monitoring by research vessel surveys (physical/chemical/biological/fisheries oceanography)

Ongoing:

Line P: continuing at 3 surveys/year (February, May/June, August/September; May/June was shortened and occurred in July in 2020), starting in the 1950s; in early years there were >3 surveys per year (Fig. 1). The main goal is to determine ocean conditions and water property changes in the open NE Pacific. Areas of emphasis: hydrography, biogeochemistry, plankton dynamics (http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/line-p/index-eng.html). It is run by DFO/IOS, but there is extensive participation by university and international scientists for specialised water chemistry sampling related to dissolved organic carbon, pH, trace gases, etc. Sampling is conducted during both day and night. Types of sampling include CTD profiles, Niskin bottles, and plankton tows using a Bongo and a mutinet. Physical measurements include temperature, salinity, phytoplankton fluorescence and many chemical analyses (*e.g*., oxygen, nutrients).

NE Pacific continental margin: continuing at ~4 surveys per year, covering outer coast of Vancouver Island and parts of Queen Charlotte Sound/Hecate Strait. Areas of emphasis: time series of zooplankton and hydrography (nutrients, O_2, T, S, pH), and their links to climate variability and trends. The La Perouse plankton survey is carried out twice per year in May–June (July in 2020) and September, 1979–present; in early years, surveys were conducted >2 times each year. Sampling occurs off the WCVI (shelf and offshore) during the day and night. Sampling includes hydrographic, acoustic, zooplankton (Bongo and multinet and acoustics), CTD, and water samples. Endeavour Ridge physical and biological sampling and current meter mooring, 1984–2006.

Strait of Georgia (Fig. 1): continuing at 4 surveys per year (3 in 2020), with intensified sampling in 2010 and 2011. Areas of emphasis: hydrography and circulation, nutrients, phytoplankton, vertical flux of organic matter and contaminants.

Strait of Georgia zooplankton survey (is part of the Canada/US Marine Survival of Salmon in the Salish Sea study: see https://www.psf.ca/what-we-do/salish-sea-marine-survival-initiative). The main survey goal of this survey is to determine the species composition, spatial and temporal trends in zooplankton in the Canadian waters of the Salish Sea, for understanding interannual variability in salmon survival. It began in 2015 and is expected to continue for 1–5 additional years. This survey occurs twice per month during February to October in the Strait of Georgia mostly during daytime, but with some nighttime operations. Sampling includes surface water samples, net tows (Bongo, ring net), CTD for temperature, salinity, and phytoplankton fluorescence.

British Columbia central coast near Calvert Island (Fig. 2). Since 2012, year-round daily to monthly CTD and sensor (fluorescence, turbidity, photosynthetically available radiation, oxygen) profiles are collected at 65 stations located in Rivers Inlet, Fitz Hugh Sound, Kwakshua Channel, Hakai Pass, and Queen Charlotte Sound. In 2020, stations in Toba Inlet and Burke Channel were added. At five of these stations, Niskin bottles collect water to measure nutrients, particulate organic matter (for isotopes and fatty acids), particulate organic phosphate, CO_2, DO13C, dissolved inorganic carbon, chlorophyll, HPLC, phytoplankton composition, viral and bacterial abundance, and zooplankton (biomass, composition, fatty acids and isotopes). Areas of emphasis include ocean climate, ocean acidification, marine food webs, watershed to oceans, and salmon.

Discovery Islands near Quadra Island (Fig. 2). Since 2014, year-round weekly to monthly CTD and sensor (fluorescence, turbidity, photosynthetically available radiation, oxygen) profiles are collected at 30 stations located in Sutil Channel, Okisolla Channel, Hoskyn Channel, Calm Channel and Bute Inlet. At three of these stations, Niskin bottles collect water to measure nutrients, particulate organic matter (for isotopes and fatty acids), particulate organic phosphate, CO_2, DO13C, dissolved inorganic carbon, chlorophyll, HPLC, phytoplankton composition, viral and bacterial abundance, and zooplankton (biomass, composition, fatty acids and isotopes). Areas of emphasis include ocean climate, ocean acidification, marine food webs, watershed to oceans, and salmon.

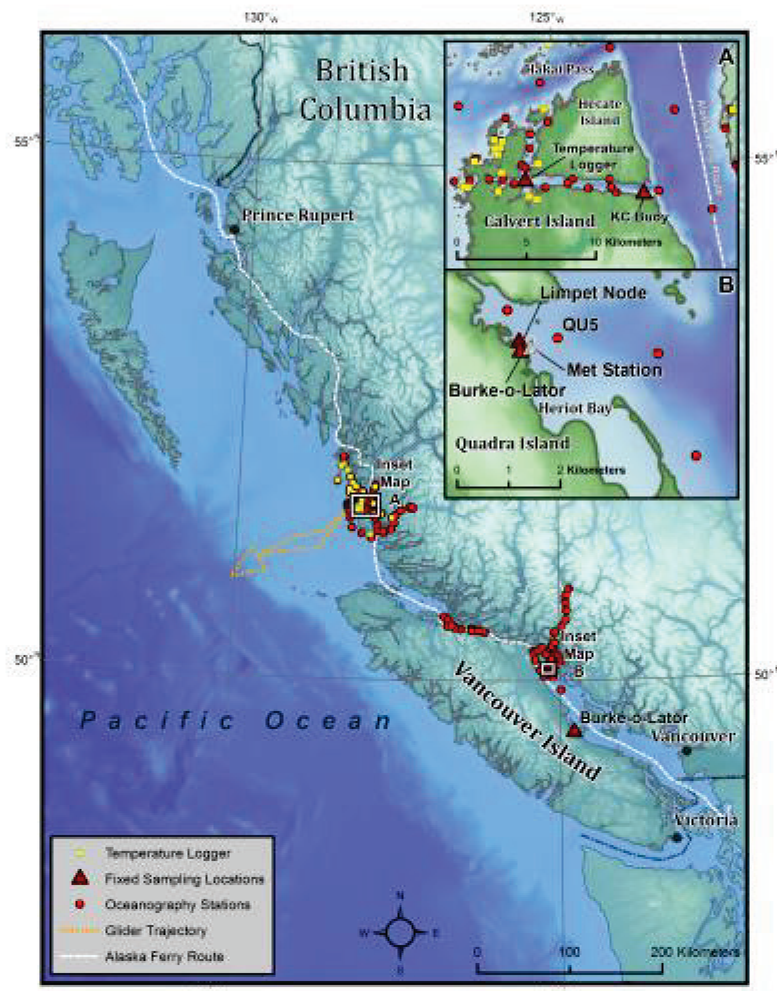


Figure 2. Locations where the Hakai Institute collects ocean data in British Columbia. Hydrographic stations (red circles) are where physical, biological and chemical measurements are made at bi-weekly to monthly frequencies. High frequency data from fixed sampling locations (red triangles) and temperature loggers (yellow circles) are output every 5 minutes. Instrumentation on board the Alaska Marine Highway System (AMHS) M/V Columbia measures surface parameters while underway every 2.5 minutes along weekly ~1000 nm transits between Bellingham, Washington (48.75°N) and Skagway, Alaska (59.64°N).

B. Ecosystem process surveys (including some surveys used for species stock assessments)

Small mesh multi-species survey: The main goal is to estimate abundance and trends of shrimp and other species (*e.g*., eulachon). Areas and years of the survey are WCVI 1973-present (except 2020), Queen Charlotte Sound (QCS; 1998–2014). The survey is conducted annually in May for WCVI, and the future of the QCS survey is unknown. This is a trawl survey conducted during daytime with a small mesh bottom trawl. All species captured are recorded and quantified, and a sub-set of species sampled for biological traits (*e.g*., length, weight, age). Also, temperature at depth is recorded. Results for the WCVI survey are reported annually in the DFO State of the Pacific Ocean reports (http://www.pac.dfo-mpo.gc.ca/science/oceans/reports-rapports/state-ocean-etat/index-eng.html).

Juvenile and adult Pacific salmon marine surveys: multiple surveys annually; Strait of Georgia (1997–present); west coast Vancouver Island (1998–present), Queen Charlotte Sound (1998–present); Central and Northern British Columbia (1998–2012); zooplankton and oceanographic data.

La Perouse pelagic ecosystem survey: annual (biennial after 2015); daytime acoustic-trawl survey; west coast Vancouver Island (2012–2015; presence data for 1982–2011); zooplankton, oceanographic data. Partially integrated into the Integrated pelagic ecosystem survey (see below).

Juvenile herring and nearshore pelagic survey: annual; Strait of Georgia (1992–present, except 1995 and 2020) and Central British Columbia (1992–2011); zooplankton and oceanographic data.

Night time pelagic species and Pacific sardine survey: annual night-time trawl survey (biennial after 2014); west coast of Vancouver Island (2006–2014); zooplankton, oceanographic data, daytime acoustic data, and marine mammal and seabird observations. Integrated into the Integrated pelagic ecosystem survey (see below).

Integrated pelagic ecosystem survey: annual (2017–present, except 2020 and 2021) day/night trawl survey; north and west coast of Vancouver Island; zooplankton, oceanographic data, daytime acoustic data collection.

C. Fishery-independent stock assessment and species-at-risk surveys

Fishery-independent surveys carried out either annually or at regular intervals for a number of harvested species (hake, multispecies groundfish, invertebrates) or species-at-risk. Increasing use of acoustics and underwater video, and increasing effort to collect and incorporate environmental information. Main surveys include:

Groundfish synoptic bottom trawl surveys: biennial; in even numbered years west coast of Vancouver Island (2004–present), and west coast Haida Gwaii (2006-present), in odd numbered years Hecate Strait (2005–present) and Queen Charlotte Sound (2003-present) (Anderson et al. 2019); includes temperature, salinity, and dissolved oxygen data (2009–present). Historically, multispecies assemblage surveys were conducted at irregular intervals in Hecate Strait (1984–2004).

Pacific hake acoustic survey: biennial (was triennial); west coast North America, Southern California to Dixon Entrance (1977–present).

Other fish surveys: sablefish (trap), lingcod (dive), rockfish (video), Pacific halibut (longline; conducted by the International Pacific Halibut Commission).

Groundfish hard bottom longline survey: Conducted in inside and outside waters (important primarily for rockfish and Pacific Halibut). Alternates north and south BC regions in even and odd years. 2003-present for inside waters; 2006–present for outside waters.

Salmon abundance (freshwater): estimates of adult salmon leaving and juvenile salmon arriving at the ocean are obtained annually in many rivers.

Dungeness crab trap survey: The goal is to index crab population. Survey times: 1988–present; May and October; semi-annual. Area: Strait of Georgia. Samples collected in daytime. This is a trap survey that uses crab traps. All species captured are recorded and quantified, and all crabs are sampled.

Green sea urchin dive survey: The goal is to estimate population abundance; Survey times are 2008–present for southeast Vancouver Island and 1995 to present for northeast Vancouver Island; during September; surveys are biennial and conducted during the daytime. This is a dive survey. All species observed on transect recorded, and green urchins are sampled.

Marine mammal surveys throughout British Columbia: 2018 – Pacific Region International Survey of Marine Megafauna (PRISMM) –goal of PRISMM was to estimate the abundance and distribution of cetaceans within the Canadian Pacific Exclusive Economic Zone's 200 nautical mile offshore limit. These estimates are necessary to assess the sustainability of current bycatch levels of marine mammals in Canadian fisheries, in order to abide by the NOAA rule for seafood exports under the U.S. Marine Mammal Protection Act. Visual and acoustic detections were made along 17,000 km of pre-determined systematic line transects (Fig. 3), http://dfo-mpo.gc.ca/science/atsea-enmer/missions/2018/prismm-eng.html

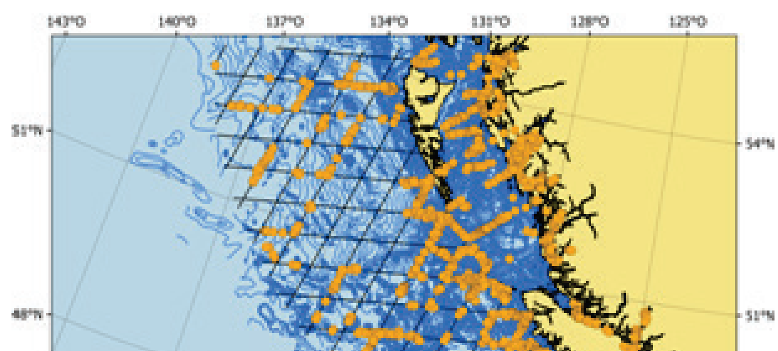


Figure 3. 2018 Pacific Region International Survey of Marine Megafauna (PRISMM). Visual and acoustic detections were made along 17,000 km of pre-determined systematic line transects. The survey resulted in over 2800 sightings of marine mammals, mostly concentrated in inshore passages and inlets, on the continental shelf and shelf break, as well as around some seamounts offshore. Source: Thomas Doniol-Valcroze (DFO).

Seal Island Intertidal clam survey: The goal is to estimate population abundance. Survey times are 1940–present, spring/summer, conducted on a triennial basis in the Strait of Georgia during the daytime at low tide. This is a beach survey, where transects are sampled using quadrates and clam rakes for butter clams.

Inshore shrimp assessment surveys: The goal is to estimate shrimp abundance and trends. Survey times are: 1998-present during spring/summer/fall, conducted annually until 2012, and are now biennial surveys in the Strait of Georgia, Knight Inlet, and Chatham Sound during daytime. This is a trawl survey that uses a small mesh bottom trawl (with excluder). All species captured are recorded and quantified, and shrimp sampled for length and weight.

Prawn survey: The goal of this survey is to index spawning population. Survey times are 1985-present, November and February, on a semi-annual basis in Howe Sound during the daytime. Prawn traps are used and all species captured are recorded and quantified; spot prawns are sampled for length and weight.

Species-at-risk monitoring surveys for Northern Abalone: The main goal is to monitor abalone populations relative to recovery targets. Surveys have various start dates, some as early as 1978–present; conducted during May on a five year rotation in the Central Coast and south coast during daytime. This is a dive survey and all species observed on transects are recorded, and abalone are measured in-situ.

Species-at-risk monitoring surveys for Olympia Oyster: The goal is to estimate and monitor abundance and trends. Survey times are 2009–present, during spring/summer on a five year rotation in the Strait of Georgia and WCVI during daytime at low tide. This is a beach survey using quadrats. All species are counted in quadrats.

Sea cucumber surveys: The goal is to provide biomass estimates. Survey times are 1997–present. Month of sampling is area dependent (February–September) on -year+ intervals, coast-wide. This is a dive survey in which the following species are sampled: Parastichopus californicus (sometimes *Cucumaria miniata* and *C. pallida*).

D. Aquatic Invasive Species Surveys

Aquatic Invasive Species intertidal monitoring surveys: annual surveys with shifting geographic focus to eventually provide baseline information coastwide (2006–present).

Aquatic Invasive Species European Green Crab trap surveys: annual surveys with shifting geographic focus, annual monitoring of Pipestem Inlet, Barkley Sound, tagging and depletion studies (2006–present).

E. Habitat and offshore area of interest surveys

1. Offshore areas of interest

2015 – SGaan Kinghlas - Bowie Seamount Marine Protected Area (SK-B MPA) - Survey to collect Visual and Oceanographic data around SGaan Kinghlas Seamount Marine Protected Area (SK-B MPA).

2016 – Survey of Endeavour Hydrothermal Vents Marine Protected Area (MPA); 2020 mapping survey by Ocean Networks Canada and Ocean Exploration Trust

2017, 2019 – Survey of the Offshore Area of Interest (AOI) (Fig. 4). This was the first survey into the Area of interest that was focused on collecting visual data on seamounts in this area. This survey was able to confirm the height and location of 7 seamounts in the AOI with 5 of them new to science because they were projected from models. This survey collected over 70 hours of videos from 4 seamounts and collected Oceanographic and eDNa samples around each of these seamounts http://dfo-mpo.gc.ca/science/atsea-enmer/missions/2017/offshoreaoi-sihauturiere-eng.html

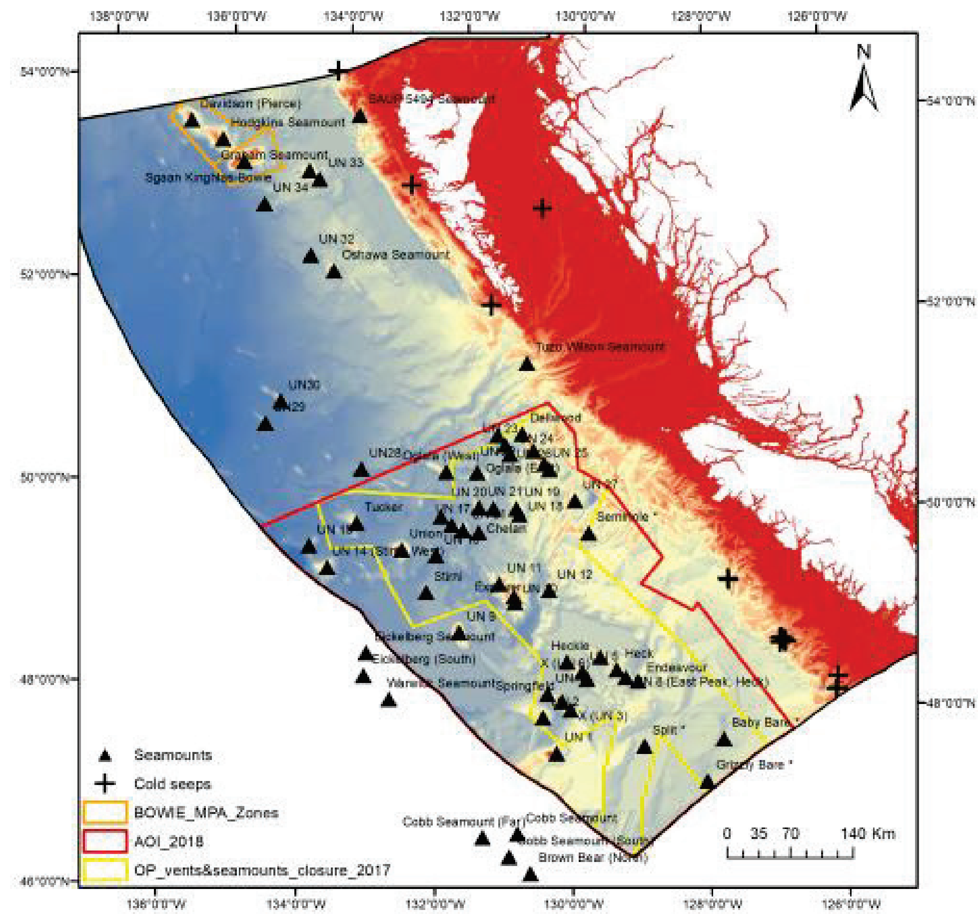


Figure 5. 2019 Survey of the Offshore Area of Interest (AOI). Source: Tammy Norgard (DFO).

2018 – Survey to SGaan Kinghlas - Bowie Seamount Marine Protected Area (SK-B MPA) and to the offshore AOI – This survey was a partnership between Haida Nation, Fisheries and Oceans Canada, Oceana Canada, and Ocean Networks Canada and was able to completed high resolution multibeam maps of 5 seamount and collect data on seamounts heights from 13 seamounts of which 6 were new to science. The survey focused on collection of visual survey data on 6 seamounts and collected voucher specimens along with eDNA samples at each of these 6 seamounts. http://dfo-mpo.gc.ca/science/atsea-enmer/missions/2018/seamounts-sousmarins-eng.html

2019 – Fisheries and Oceans Canada in partnership with the Nuu-chan-nulth Tribal Council and Ocean Networks Canada completed an offshore Drop Camera Survey. 4 seamounts were visually surveyed with the deep sea drop camera. This survey also heights of 13 other seamounts. During this survey we launched 2 ocean gliders and collected oceanographic samples at 25 sites.

2021 – Fisheries and Oceans Canada in partnership with an onshore team from the Nuu-chan-nulth Tribal Council and the Council of the Haida Nations, and Ocean Networks Canada completed an offshore Drop Camera Survey focusing in Deeper seamounts. This survey has been able to confirm the locations and depths of 30 (21 before 2021 and +9 during 2021) unnamed seamounts and collected accurate mapping of 15 (13 <2021 and +2 during 2021) well known seamounts (in total, 45 seamounts at least partially mapped). This work has increased the number of known seamounts in the Canada Pacific offshore from the 24 known in 2017 to 65 (62 <2021 and +3 during 2021). We have been able to visually survey 17 seamounts, (12 <2021 and +5 during 2021) [bonus: plus an bathyal plane, a knoll, and a cold seep field].

2. Epibenthic animals and oxygen

Saanich Inlet ROV transect: annual survey; 2006–present; one standard transect; Patricia Bay, Saanich Inlet; data collected includes dissolved oxygen, video. Goal is to compare hypoxia-induced shifts in the epibenthic animal distributions over time.

3. Glass sponge reef assessment and monitoring surveys:

2012, 2013, 2016, 2019 – Four Remotely Operated Vehicle (ROV) surveys to map, assess, and develop monitoring methods for glass sponge reefs in the Salish Sea (Strait of Georgia and Howe Sound; Dunham *et al*. 2018a, b; DFO 2018). This work supported two initiatives to establish 17 fishing closures to protect the reefs in the Strait of Georgia and Howe Sound under the Sensitive Benthic Area Policy; these closures apply to all bottom-contact fisheries and as such qualify as Other Effective Area Based Conservation Measures, contributing to the achievement of Canada's commitment to marine conservation targets under the United Nations Convention on Biological Diversity. Data analysis for 7 potential reef areas in Howe Sound is currently underway. Data collected include video (approx. 180 hours) and still imagery, as well as temperature and salinity 1 m above bottom along line transects.

2015, 2017 – Two Remotely Operated Vehicle (ROV) surveys to map and study glass sponge reefs within the Hecate Strait and Queen Charlotte Sound Hecate Strait MPA. Targeted research to (1) better understand, in situ, sensitivity of glass sponges to suspended sediment (Grant *et al*. 2019), (2) to collect macrofauna samples for isotope analysis to construct reef food webs, and (3) to ground truth sponge cover in areas with different acoustic signature. Data is used for monitoring indicator development. Both surveys were done in collaboration with researchers from the University of Alberta: http://www.dfo-mpo.gc.ca/science/atsea-enmer/missions/2017/hecate-eng.html

2017 – Remotely Operated Vehicle (ROV) survey to ground truth a recently discovered large glass sponge reef in Chatham Sound. Data collected include video and still imagery, as well as temperature and salinity 1 m above bottom along line transects. http://www.dfo-mpo.gc.ca/science/atsea-enmer/missions/2017/chathamsound-eng.html

In 2018, 2019, 2021 DFO completed ROV surveys in the deep water inlets and Channels in the Central Coast of BC. These surveys examined coral and sponge distribution in these unexplored habitats. New sponge and coral habitats were discovered on all surveys.

F. Autonomous monitoring with gliders and Argo profiling drifters

Canada has been very active in this successful international Argo program. Since the start of the program, Canada has deployed many floats (see http://www.argo.ucsd.edu/). In 2019, a glider monitoring program began in Canada's Pacific waters, with a DFO/academic collaboration completing two repeat glider transects of

Line P and several across Queen Charlotte Sound (north of Vancouver Island). Over the course of the year, Canadian gliders logged ~5500 km, ~6900 CTD profiles and flew ~225 days at sea in the NE Pacific. The data are available at http://cproof.uvic.ca/gliderdata/.

G. North Pacific Continuous Plankton Recorder

Canada has contributed financial support since 2008 for the North Pacific CPR program plus hosts a local sorting center (at IOS), and collaborates with project lead Clare Ostle on some of the analyses and publications (see http://pices.int/projects/tcprsotnp/).

H. Ocean observatory networks (Ocean Networks Canada)

The coastal component of Ocean Networks Canada's observing system consists of:

1) Cabled undersea oceanographic sensor and benthic camera installations in Saanich Inlet (since 2006), the Strait of Georgia (since 2008), outer Barkley Sound (since 2011), together with seven community-based cabled observatories on Vancouver Island, the British Columbia mainland, in the Canadian Arctic at (Cambridge Bay, Nunavut), and in Conception Bay, Newfoundland.
2) Data delivery from partner Smart Atlantic buoys around Newfoundland, New Brunswick and Nova Scotia
3) Sensor platforms on ferries on three routes between Vancouver and Vancouver Island was completed in 2015.
4) A growing network of HF radar installations and Automatic Information System receivers in the Strait of Georgia and on the northern coast of British Columbia that provide real-time information on surface ocean conditions and vessel traffic.
5) A growing Community Fisheries program where coastal community members conduct regular CTD profiles at fixed locations in coastal waters of British Columbia, Nunavut and Atlantic Canada.
6) Autonomous oceanographic moorings (since 2012) in the Salish Sea provide continuity between Salish Sea and offshore observing systems.

The 'offshore' cabled network (NEPTUNE) is a part of a broader US/Canada northeast Pacific observing system. The Canadian component (installed 2009) consists of a fully operational, 812 km elliptical undersea cabled observatory loop extending from southern Vancouver Island across the continental shelf and slope to the Endeavour Segment of the Juan de Fuca Ridge. The observing system at the Endeavour node underwent expansion in 2017–2018.

ONC began hosting the Pacific node of the Canadian Integrated Ocean Observing System in early 2019.

I. British Columbia Shore Station Oceanographic Program

The British Columbia Shore Station Oceanographic Program (often referred to as the BC lighthouse data) began in 1914. Sea surface temperatures and salinities have been monitored daily at lighthouses on the west coast of Canada. Observations are logged and forwarded monthly to the Institute of Ocean Sciences where they are quality controlled and archived (https://www.dfo-mpo.gc.ca/science/data-donnees/lightstations-phares/index-eng.html).

J. Hakai Institute autonomous instrumentation

Fixed autonomous stations and other monitoring instruments include:

- Burke-o-later (BoL) for determining T, S, pCO_2 and TCO_2 in Hyacinthe Bay, near Quadra Island since 2015,
- Multiple temperature sensors at fixed nearshore locations throughout the central coast near Calvert Island since 2015,
- A MApCO2 buoy near Calvert Island that measures S, T, surface seawater and atmospheric pCO2, and meteorological data since 2018,
- A cabled observatory called the Limpet has measured T, S, and oxygen at the seafloor in Hyacinthe Bay off Quadra Island since 2015,
- A string of moored temperature and salinity sensors has collected T data every 10 minutes in 10 meter intervals since 2017,
- The Alaska Marine Highway System M/V Columbia has collected T, S, O, and seawater and atmospheric pCO_2 since 2017,
- A 150 kHz ADCP that has measured currents in a few locations around Calvert and Quadra Islands since 2019,
- A mooring that measures temperature, salinity and oxygen at 2 depths in Rivers Inlet since 2020,
- Collaboration with CPROOF to deploy and recover gliders from Calvert Island since 2019.

References

Boldt, J.L., Javorski, A., and Chandler, P.C. (Eds.). 2021. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2020. Can. Tech. Rep. Fish. Aquat. Sci. 3434: vii + 231 p.

Dunham, A., Archer, S.K., Davies, S., Burke, L., Mossman, J., Pegg, J. 2018a. Assessing ecological role of deep-water biogenic habitats: Glass sponge reefs in the Salish Sea. Marine Environmental Research 141: 88-99.

Dunham, A., Mossman, J., Archer, S., Pegg, J., Davies, S., Archer, E. 2018b. Glass sponge reefs in the Strait of Georgia and Howe Sound: status assessment and ecological monitoring advice. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/010.

DFO. 2018. Glass sponge aggregations in Howe Sound: locations, reef status, and ecological significance assessment. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/032.

Grant, N., Matveev, E., Kahn, A.S., Archer, S.K., Dunham, A., Bannister, R., Eerkes-Medrano, D., Leys, S.P. 2019. Effect of suspended sediments on the pumping rates of three species of glass sponge in situ. Marine Ecology Progress Series 615: 79-100.

2. United States of America

Jack Barth (Oregon State University), Kym Jacobson (Northwest Fisheries Science Center, NMFS, NOAA) and Lisa Eisner (Alaska Fisheries Science Center, NMFS, NOAA)

There is a wide range of coastal ocean observing off the US Pacific coasts. These include:

- NOAA fishery surveys (groundfish, hake, coastal pelagics)
- Long-term hydrographic and zooplankton lines: CalCOFI (California), Newport Hydrographic (Oregon), Trinidad Head (California)
- US Integrated Ocean Observing System (NOAA)
- Moorings, hydrographic and biogeochemical sampling off Monterey Bay, California
- Gliders
- Wave buoys and wave models
- Rocky intertidal biodiversity and recruitment
- Carbon chemistry (pCO_2, pH) (NOAA, university)
- National Science Foundation's Ocean Observatories Initiative (OOI)
- Native American
- Bird and marine mammal observations
- Harmful Algal Bloom monitoring

US West Coast Ocean Observatory Efforts, 2020-2021

The west-coast regional associations of the U.S. Integrated Ocean Observing System (IOOS) funded by the U.S. National Oceanic and Atmospheric Administration continue to operate year-round during 2020-2021. This includes the regional association that includes the states of Oregon and Washington, namely the Northwest Association of Networked Ocean Observing Systems (NANOOS, www.nanoos.org). NANOOS continues to improve and add features to its data visualization and data products web page, the NANOOS Visualization System (www.nvs.nanoos.org). Both observational data, from buoys, gliders, land stations, high-frequency radars, and satellites, and output from circulation, wave, weather, and biogeochemical numerical models are hosted on NVS. Even with COVID-19 challenges for field operations, most NANOOS observational systems are up and running. As just one example, in August 2021, a NANOOS team deployed the Environmental Sample Processor (ESP) "Eddie" off the coast of La Push on the Washington shelf. This was the sixth deployment of an ESP at this location, and it is the first of seven deployments jointly funded by IOOS and the NOAA NCCOS Monitoring Event Response for Harmful Algal Blooms (MERHAB) over the next four years. The instrument provides near real-time observations of domoic acid (DA) six days per week as well as archived samples for subsequent eDNA analysis. The "Real-Time HABs" website (http://www.nanoos.org/products/habs/real-time/home.php) incorporates contextual data and other data products to enhance interpretation and understanding of the ESP data (*e.g*., maps of water paths).

During 2021, the summer upwelling season in the northern California current started early in mid-March, and persistent southward winds were prevalent all summer leading to the second highest amount of cumulative upwelling in the last 36 years (Figure 1). One consequence was widespread, low-oxygen water near the seafloor all along the Oregon and Washington continental shelf.

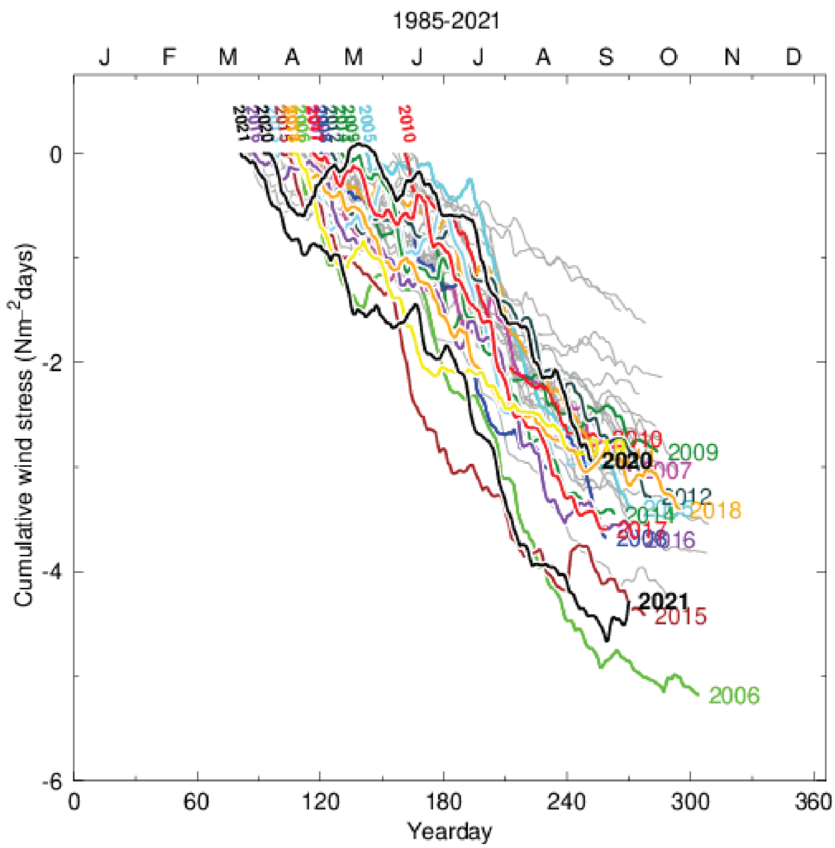


Figure 1. Cumulative north-south wind stress measured off Newport, Oregon, showing that the 2021 upwelling season started early (mid March) and produced the second most cumulative upwelling in the last 36 years (Courtesy of S. Pierce and J. Barth, Oregon State University, http://damp.coas.oregonstate.edu/windstress/allyears.html).

The U.S. Ocean Observatories Initiative (OOI; www.oceanobservatories.org) continues to operate a set of moored surface buoys, seafloor experimental packages, profiling moorings, and gliders off central Oregon (Newport) and Washington (Grays Harbor). The Regional Cabled Observatory suffered a break in the seafloor cable connecting some instrument platforms to shore. A partial repair was executed in summer 2021. The OOI Endurance Array was successfully serviced using large research vessels in April and September, 2021, resuming the twice per year servicing intervals that were interrupted by COVID in 2020. The OOI created a new web interface to its near real time and archived data sets, reachable from www.oceanobservatories.org .

Sea surface temperature (SST) was above normal offshore in the California Current during summer 2020, with colder than average upwelled water near the coast. During winter 2020–2021, SSTs in the California Current were about 1°C cooler than average consistent with the existence of La Niña. In summer 2021, warm water re-established itself offshore, reaching 2–3°C warmer than average (Figure 2). As during summer 2020, the vigorous upwelling-favorable winds of summer 2021 brought colder than average water to the surface near the coast and held the warm water off shore (Figure 2).

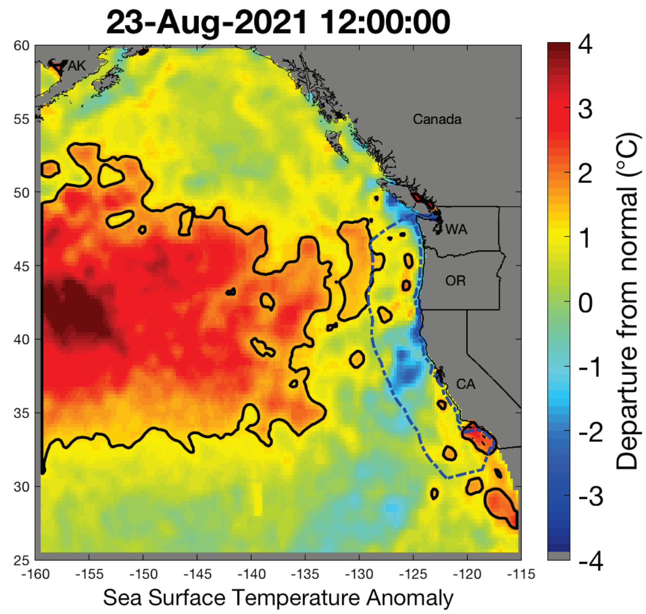


Figure 2. The California Current Marine Heatwave Tracker, an experimental tool for tracking marine heatwaves (Courtesy of A. Leising and S. Bograd, SWFSC, NOAA, https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-projects-blobtracker).

National Ocean and Atmospheric Administration (NOAA) Survey Monitoring Efforts on the US West Coast, 2020–2021

There are three NOAA surveys that collect physical data through lower trophics seasonally to bi-weekly (depending upon the program) off Washington, Oregon and California. These include research and monitoring programs on the Newport Hydrographic Line in Oregon, the Trinidad Head Line in Northern California, and the California Cooperative Fisheries Investigations (CalCOFI) in Southern California. An additional three ecosystem projects sample annually for oceanographic conditions, lower trophics and fish, of different target species. These transects and the location of the seabird colonies and stationary sea lion monitoring site at San Miguel Island, California are shown in Figure 3.

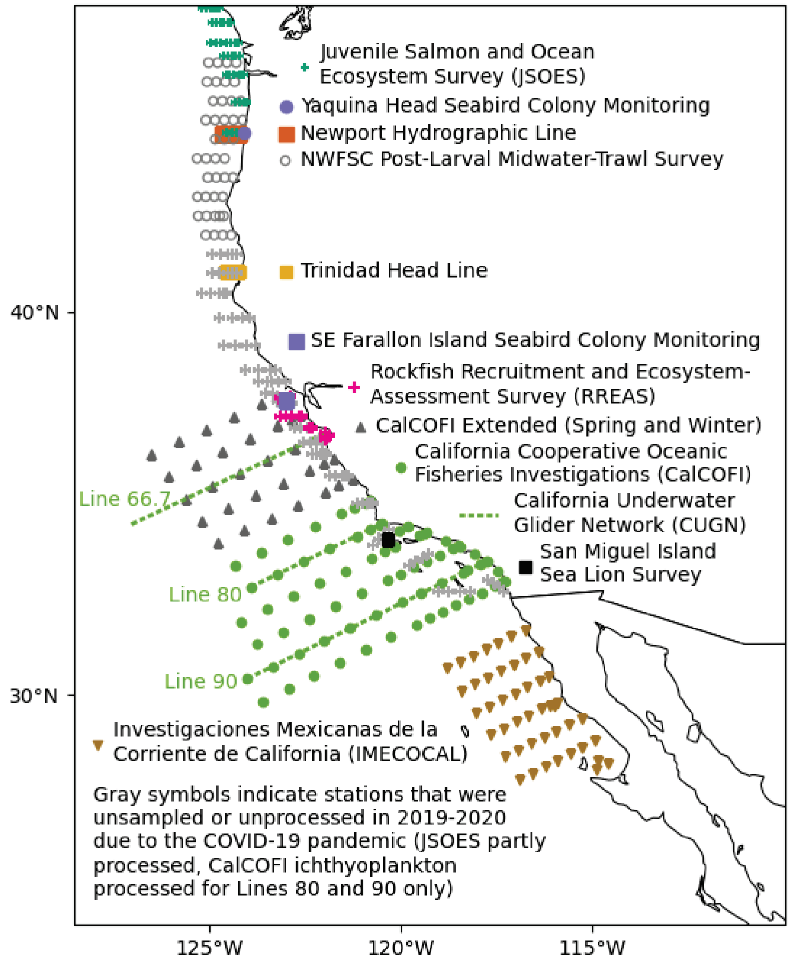


Figure 3. Hydrological and biological surveys used to assess the state of the California Current ecosystem. From the State of the California Current Report by E. Weber, NOAA Fisheries, SWFSC.

Each of these projects exceed ten years of sampling. Results are summarized in the annual State of the California Current (cited below) and/or the California Current Integrated Ecosystem Assessment Report to the Pacific Fisheries Management Council (PFMC) March 2021 (https://www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-1.pdf/).

In addition to these surveys there are several coastwide fisheries surveys designed to provide data for stock assessments: the NOAA Fisheries Northwest Fisheries Science Center (NWFSC) in collaboration with Canada's Department of Fisheries and Oceans conduct semi-annual Pacific hake surveys. Most recent surveys have been in 2019 (Figure 4) and 2021. The initial NWFSC hake survey was conducted in 2003. An acoustic survey took place in the summer of 2021. The 2021 design of the survey took into account COVID-19 protocols for ship operations, available ship time in both Canada and the United States, and the need to conduct an inter-vessel calibration. Transect spacing was expected to be 10 nmi from Point Conception (34.5°N) to the north end of Vancouver Island (50.5°N) and 20 nmi spacing north of Vancouver Island to Dixon Entrance (54.5°N). To cover the entire survey area with the above constraints, the survey returned to the 1500 m offshore limit protocol used in the pre-SaKe survey period (1995–2011), and also skipping every eighth transect from the starting point to the north end of Vancouver Island.

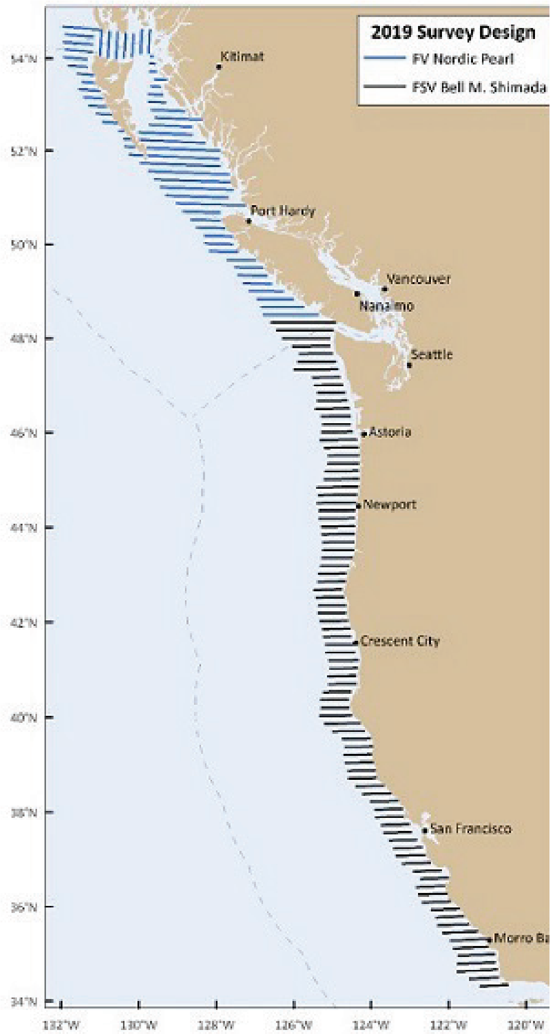


Figure 4. Acoustic-trawl survey transects for the NOAA Ship *Bell M. Shimada* (black, NWFSC) and the chartered vessel Nordic Pearl (blue, DFO).

Groundfish surveys have also been conducted over the shelf and slope (55–1,280 m) annually by the NWFSC since 2003 from the border with Mexico to Canada. However, the 2020 survey was canceled due to COVID-19 restrictions. The summer–fall 2021 (Figure 5) survey was underway during the writing of this report. In addition, the NOAA Fisheries Southwest Fisheries Science Center conducts an annual Acoustic-Trawl Method Coastal Pelagics Survey that samples annually from off northern Vancouver Island, British Columbia to San Diego, California. However sampling this year included sampling off of Mexico and nearshore sampling in collaboration with the industry (Figure 6).

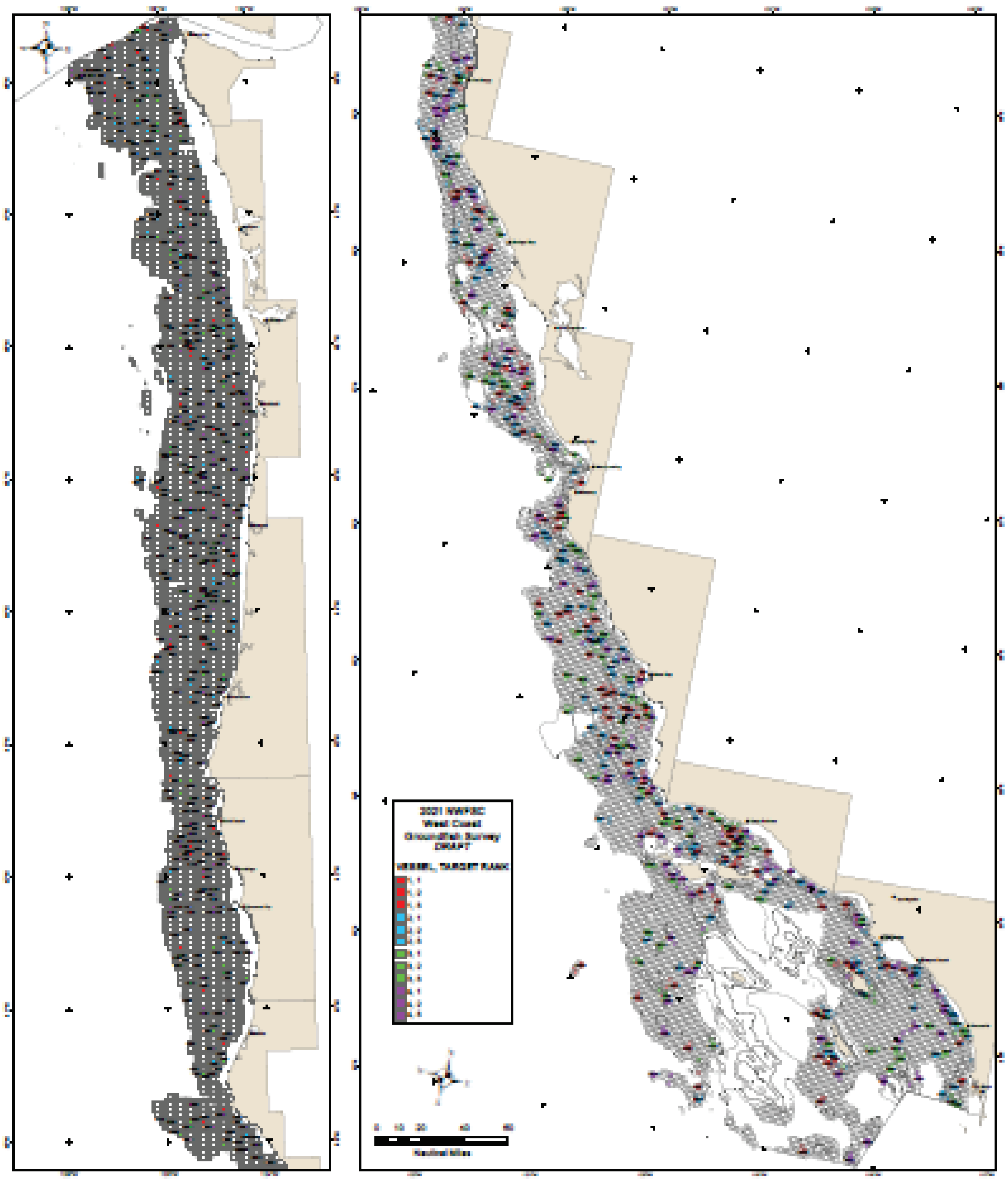


Figure 5. Target stations for 2021 NOAA groundfish survey off U.S. west coast.

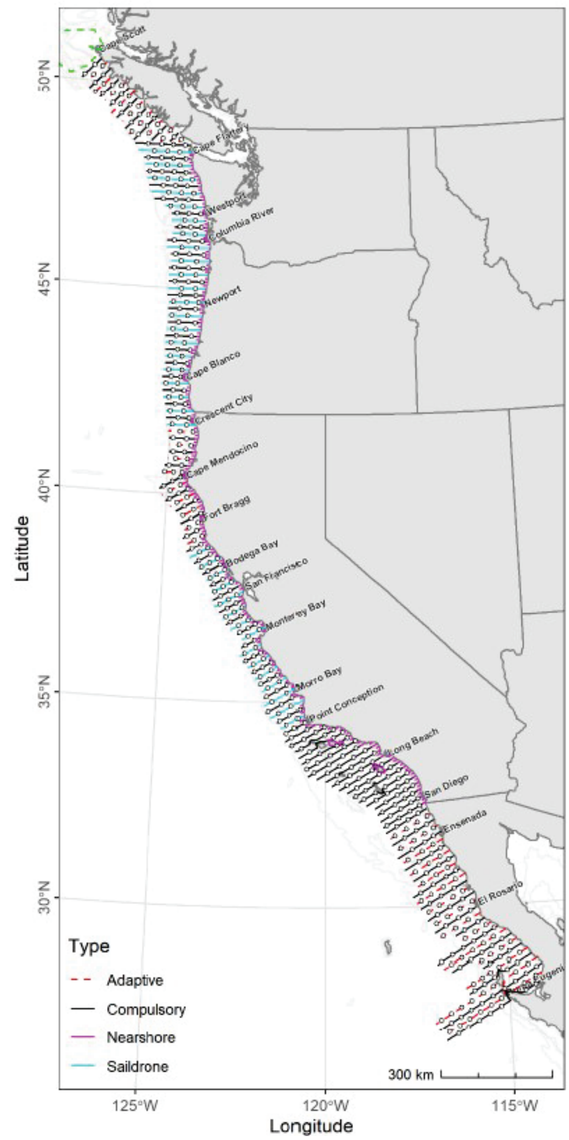


Figure 6. Planned transects for the NOAA SWFSC survey for coastal pelagic species.

NOAA Ocean Acidification Program West Coast Cruises

Hydrographic measurements were made offshore of the west coasts of the United States and Canada on the RV *Ronald H. Brown* on the West Coast Ocean Acidification cruise in June and July of 2021 (WCOA2021) (Figure 7). This program reoccupied many of the hydrographic stations that were measured previously by WCOA cruises that sailed in 2007, 2011, 2012, 2013, and 2016. The WCOA cruises collectively aim to measure the coastal and shelf waters from Baja California, Mexico to the Queen Charlotte Sound in British Columbia, Canada, and to create an enduring near-synoptic record of natural and anthropogenic ocean acidification, deoxygenation, and biogeochemical cycling in these essential waters. This coastline is a natural laboratory for the chemical and ecological impacts of ocean acidification and deoxygenation due to spring and summertime wind-driven upwelling of old, cold waters that are rich in remineralized carbon and nutrients and poor in oxygen. The upwelled nutrients drive intense cycling of organic matter that is created through photosynthesis in the surface ocean and degraded through biological respiration in subsurface and benthic habitats. These biogeochemical processes create natural gradients in seawater temperature, oxygen, nutrients, pH and carbon concentrations, thereby allowing observations of a range of conditions (*e.g.*, saturated *vs.* corrosive with respect to carbonate minerals, ventilated vs. hypoxic, and cold vs. warm) all from near-synoptic transects of the region. This region is an area of interest and concern for several ongoing climate changes including global warming and associated increases in the frequency of marine heatwaves, ocean acidification and deoxygenation, and shifts in wind patterns and natural oceanic circulation pathways that have a potential to impact biological, ecological and ecosystem parameters along the CCE. There is also concern that regional warming or deoxygenation will lead to enhanced production or mobilization of greenhouse gases such as methane and nitrous oxide that are trapped and/or created in shelf sediments. The WCOA2021 cruise provides a critical climate timeseries that speaks to all these topics of interest and concern.

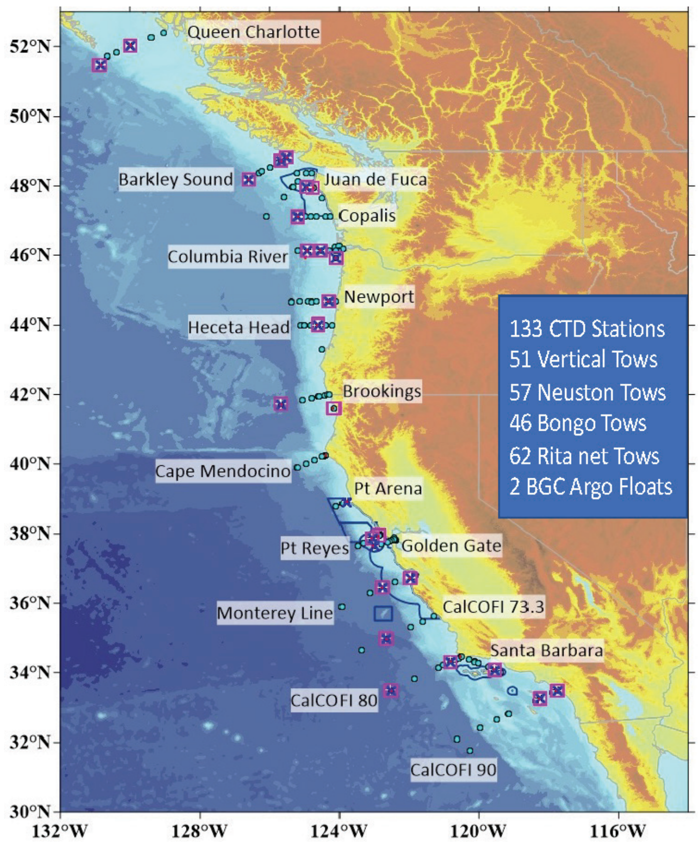


Figure 7. Station locations for the NOAA Ocean Acidification Program WCOA2021 West Coast Cruise (June–July 2021).

The following highlights (and select figures) of conditions observed from these surveys in 2020 include information from the CCIEA report to the PFMC (https://www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-1.pdf/).

- West Coast research efforts in 2020 were heavily impacted by the COVID-19 pandemic. The Westcoast groundfish bottom trawl survey and the coastwide survey for coastal pelagic species were both cancelled in 2020. A number of other surveys and monitoring efforts were shortened or delayed.
- 2020 saw a transition from El Niño conditions and positive PDO signals to La Niña conditions and a negative PDO for the first time in many years. These conditions are generally associated with higher productivity in the CCE.

- The second largest marine heatwave observed in the North Pacific occurred in 2020, but stayed mostly offshore.
- Strong winter upwelling preceded the start of an average to above-average upwelling season, providing a good nutrient supply to the base of the food web.
- Foraging conditions appeared to be above average, based on measures of the zooplankton community, continued high abundance of anchovies, and production of offspring at seabird and sea lion colonies.
- Signs of concern included widespread harmful algal blooms, continued presence of species associated with warmer waters, and mixed outlooks for returns of Chinook salmon in 2021.
- Near-bottom DO at station NH05 off Newport, Oregon fell below the hypoxia threshold in June-August 2020, and was similar in intensity to 2019 (Figure 3.3.1, top). Off San Diego at CalCOFI station 93.30, near-bottom DO was above the hypoxia threshold in winter and summer, but summer DO at CalCOFI stations further offshore was generally below average, and many stations had the lowest summer DO observed since monitoring began in 1984.
- In 2020, exceedances of domoic acid were detected in razor clams and crabs from northern California to the Canadian border (Figure 8), which caused protracted fishery closures and delays for much of the West Coast, many of which continued into early 2021. Domoic acid led to closure of northern California rock crab fisheries throughout 2020, and also delayed opening of the Dungeness crab fishery from Cape Falcon to the Oregon/Washington border for all of December 2020. Domoic acid also led to closures of commercial, recreational and Tribal Dungeness crab fisheries in Washington for parts of November and December 2020.

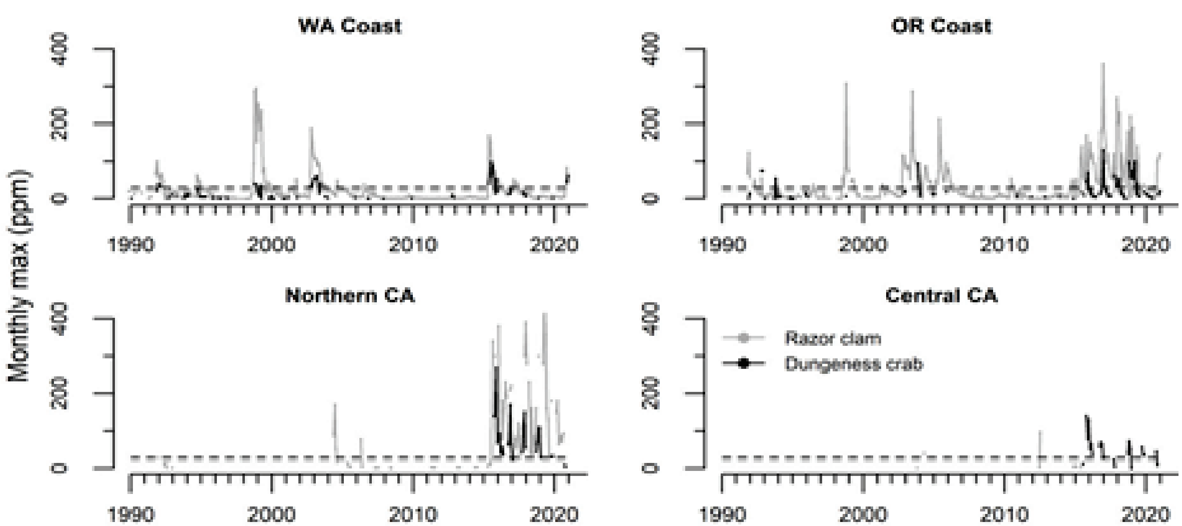


Figure 8. Monthly maximum domoic acid concentration (ppm) in razor clams (gray) and Dungeness crab viscera (black) through 2020 for WA, OR, northern CA, and central CA. Horizontal dashed lines are the management thresholds of 20 ppm (clams in gray) and 30 ppm (crabs in black). https://www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-1.pdf/

- In 2020, northern copepods continued an overall increasing trend since the extreme lows during the 2014–2016 heatwave. They were >1 s.d. above the mean in spring- summer 2020 before their regular seasonal transition in the fall (Figure 9). The spring-summer anomaly was among the highest of the time series. This trend continued again in the spring and early summer of 2021, along with an early transition to a northern copepod community in early March of 2021.

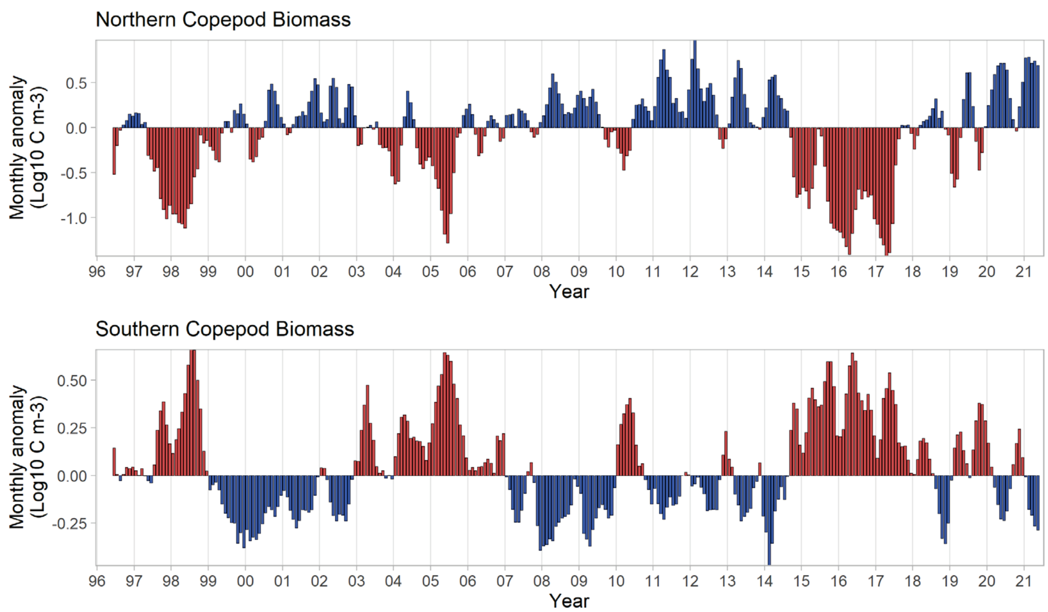


Figure 9. Three-month running mean of anomalies of biomass of northern and southern copepod taxa recorded off Newport, OR at NH05: Peterson Zooplankton Lab, NOAA, NMFS, Newport, OR.

- Off northern California, *Euphausia pacifica*, the key krill species, is sampled year-round off Trinidad Head. Mean length of adult *E. pacifica* in spring and summer of 2020 were above average (Figure 10). The overall trend for krill lengths has been increasing since poor growth at the onset of the 2014–2016 heatwave.

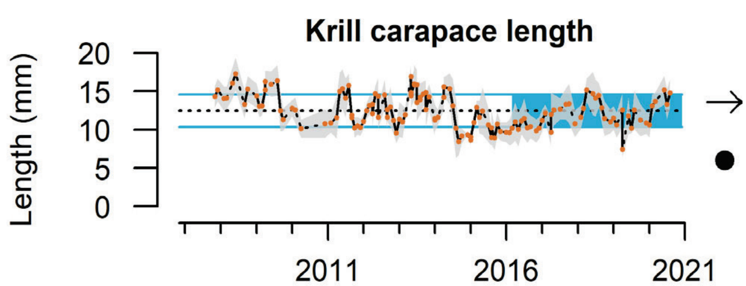


Figure 10. Monthly mean krill carapace length (mm) off Trinidad Head, CA from 2007–2020. Gray envelope indicates ±1.0 s.d.

- Our ability to understand dynamics of the CCE's diverse forage community was impacted by COVID- 19, which disrupted regional forage surveys and sample processing. The Northern CCE survey off Washington and Oregon targets juvenile salmon in surface waters, and also samples surface-oriented fishes, squid and jellies. In 2020 the most striking observation as unprecedented catches of YOY sablefish. Juvenile subyearling Chinook salmon catches were higher than the previous two years, but were within 1 s.d. of the long-term average. Juvenile yearling Chinook salmon catches declined in 2020, and were ~1 s.d. below average. Yearling coho salmon catches were similar to 2019, and were within 1 s.d. of the time series average. In the Central CCE, adult anchovy remained highly abundant in 2020, while YOY rockfish catches were well below average. Forage data for the Southern CCE come from CalCOFI larval fish surveys. The spring survey was cancelled in 2020 due to COVID-19. The southern forage community in January- February appeared to experience a shift from 2019 to 2020. Larval anchovy decreased from 2019 to 2020, but were still above the long-term average. Southern mesopelagic fishes also decreased from 2019 to 2020. Rockfishes were uncommon in 2020, as were larval flatfishes and sardines (data not shown).
- In 2020, NOAA scientists were able to conduct counts of sea lion pups via aerial surveys. The 2020 cohort was the fourth consecutive year of above-average pup counts and continued the positive trend since the relatively low counts in 2015-2016. The relatively high pup count in 2020 implies abundant and high-quality prey for adult female sea lions in their foraging area (data not shown).

References

Harvey, C., T. Garfield, G. Williams, and N. Tolimieri, eds., 2021. California Current Integrated Ecosystem Assessment (CCIEA) California Current Ecosystem Ecosystem Status Report, 2021. https://www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-1.pdf/

Weber, E. and 47 others. 2021. State of the California Current 2019-2020. Back to future with marine heatwaves? Front. Mar. Sci., 10 August 2021. https://doi.org/10.3389/fmars.2021.709454

Alaska fisheries oceanography surveys and observations for 2020–2021

Compiled by Lisa Eisner, NOAA Alaska Fisheries Science Center (AFSC), USA

Acknowledgements: Alisa Abookie, Nick Bond, Lyle Britt, Matthew Callahan, Seth Danielson Janet Duffy-Anderson, Ed Farley, Emily Fergusson, Andrew Gray, Russ Hopcroft, Ben Laurel, Mike Litzow, Jamal Moss, Jim Murphy, Wayne Palsson, John Richar, Lauren Rogers, Elizabeth Siddon, Rob Suryan, Rick Thoman, Jordan Watson, Ellen Yasumiishi, Leah Zacher

Climate

N Pacific Climate

Sea level pressure (SLP) and sea surface temperature (SST) anomalies from the NCEP/NCAR Reanalysis project were compiled by Nick Bond (NOAA PMEL). In autumn 2020, SLP were positive in the Aleutian Islands (AI) and Gulf of Alaska (GOA) with warm SSTs (Fig. 1). In the Eastern Bering Sea (EBS), winds were from the SW and there was suppressed storminess for the south EBS shelf and GOA. In the Gulf of Anadyr, temperature anomalies were > 2°C; La Niña conditions. In winter 2020/21, in the AI and GOA there were westerlies; in the SW Bering Sea there were negative Sea Level Pressure (SLP) anomalies with low pressure across Alaska. In the GOA and EBS there were minimal temperature anomalies (< 0.5°C); La Nina conditions.
In spring 2021, the positive SLP continued in the NE pacific, with westerlies in the GOA and EBS. In the south EBS there was a slight increase in temperature; in the GOA there were minor cold temperatures in lower Cook Inlet (Fig. 2). In summer, in Alaska there were lower SLP's, in the north and east GOA there were anti-cyclonic winds, and in the north Bering Sea Chukchi Sea and West AI there were negative SLP implying enhanced storm activity. The temperature in the western AI had positive anomalies of ~ 1°C. In the South EBS there were minor warm SST anomalies and in the north GOA temperatures were near average.

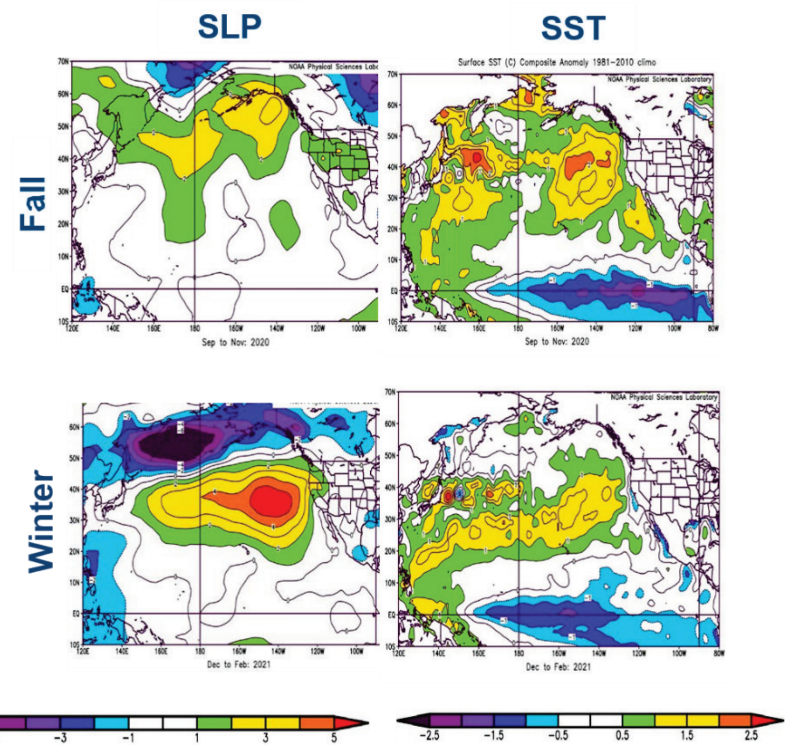


Figure 1. Fall (2020) and winter (2020/21) Sea Level Pressure (SLP) and sea surface temperature (SST) anomalies in the north Pacific. Figure courtesy of N. Bond.

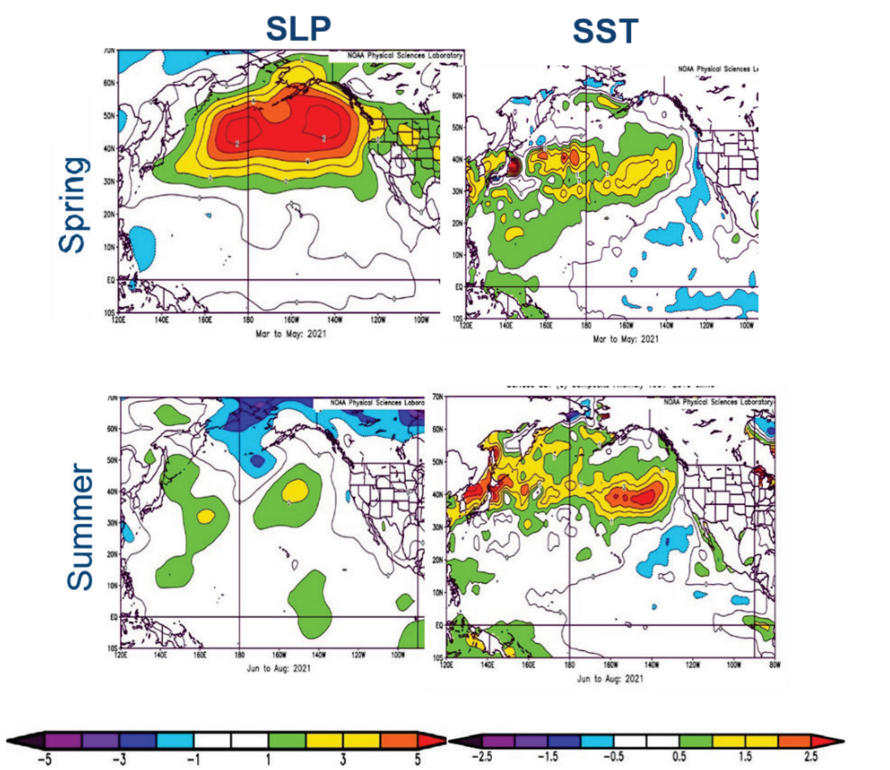


Figure 2. Spring (2021) and summer (2021) Sea Level Pressure (SLP) and sea surface temperature (SST) anomalies in the north Pacific. Figure courtesy of N. Bond.

Gulf of Alaska SST

Satellite-derived estimates of SST for the GOA were compiled by Jordan Watson and Matthew Callahan (NOAA AFSC). The western GOA SST data indicate temperatures were above average for winter/ early spring 2021, and then starting in ~ April were close to the long term mean (1985–2015) (Fig. 3). In the eastern GOA, there were moderate SST's with two brief marine heat wave periods in spring and summer.

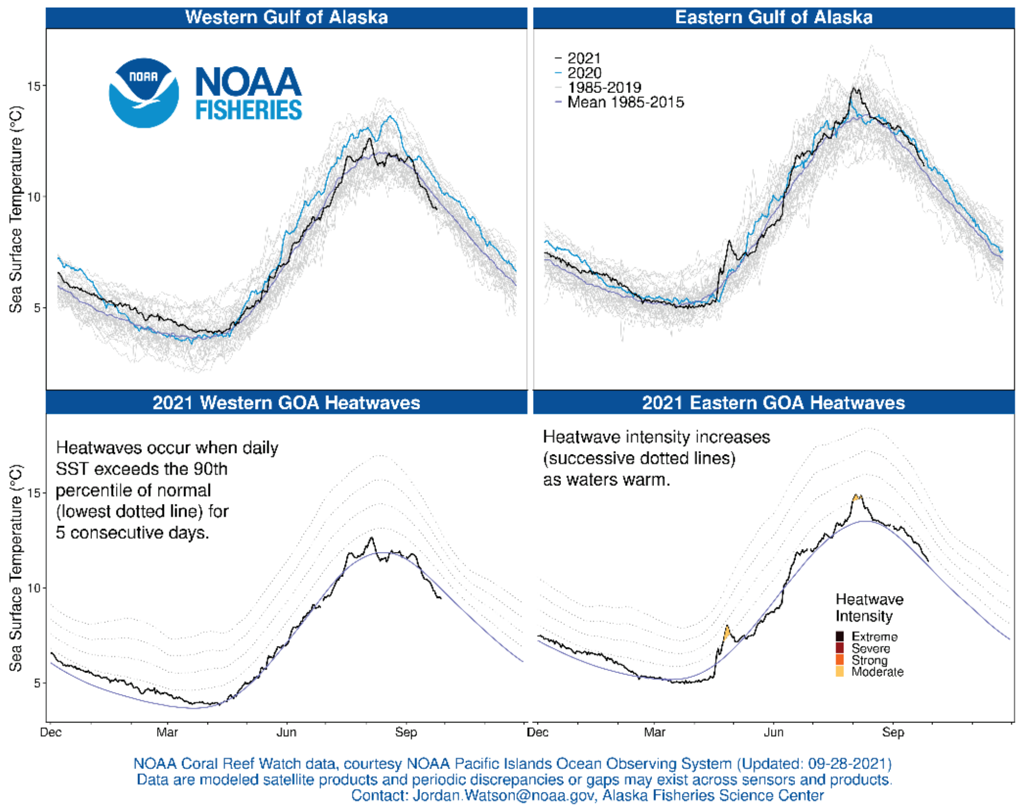


Figure 3. GOA SST for the western and eastern GOA for 2021 and 2020 compared to means for 1985–2015 from satellite analysis. Courtesy of Jordan Watson.

Bering Sea Ice Extent

Bering Sea ice extent in 2020/2021 was compiled by Rick Thoman (https://uaf-accap.org/). Sea-ice data indicate that residual warmth delayed freeze-up into winter; cooling in late winter resulted in a rapid build-up of sea ice; and ice advance stalled at end of January and remained unusually steady from February through early April (Fig. 4).

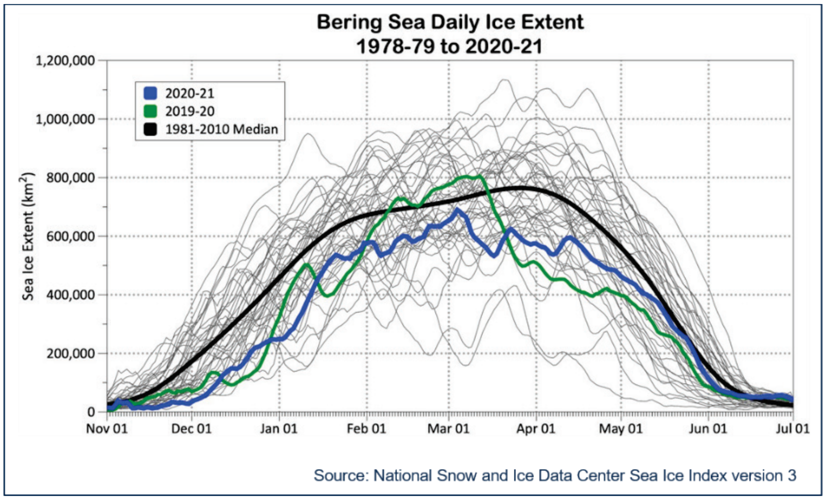


Figure 4. Bering Sea daily ice extent for 1978/79 to 2020/21 from ACCAP (courtesy of Rick Thoman).

Satellite-derived estimates of SST for the Bering Sea were compiled by Jordan Watson and Matthew Callahan (NOAA AFSC). Both the northern Bering Sea and southeastern Bering Sea continued to experience SSTs warmer than baseline (1985–2015, Fig. 5). In the northern Bering Sea 2021 fall and winter SST's were similar to the previous year (2020), while summer temperatures in 2021 were cooler and closer to long term mean than in 2020. In the southeastern Bering Sea in 2021 SST's were generally cooler than in 2020, although still above the long term mean. The time series graphs for the Bering Sea and the Gulf of Alaska can be updated daily at https://mattcallahan.shinyapps.io/NBS_SEBS_SST_MHW/.

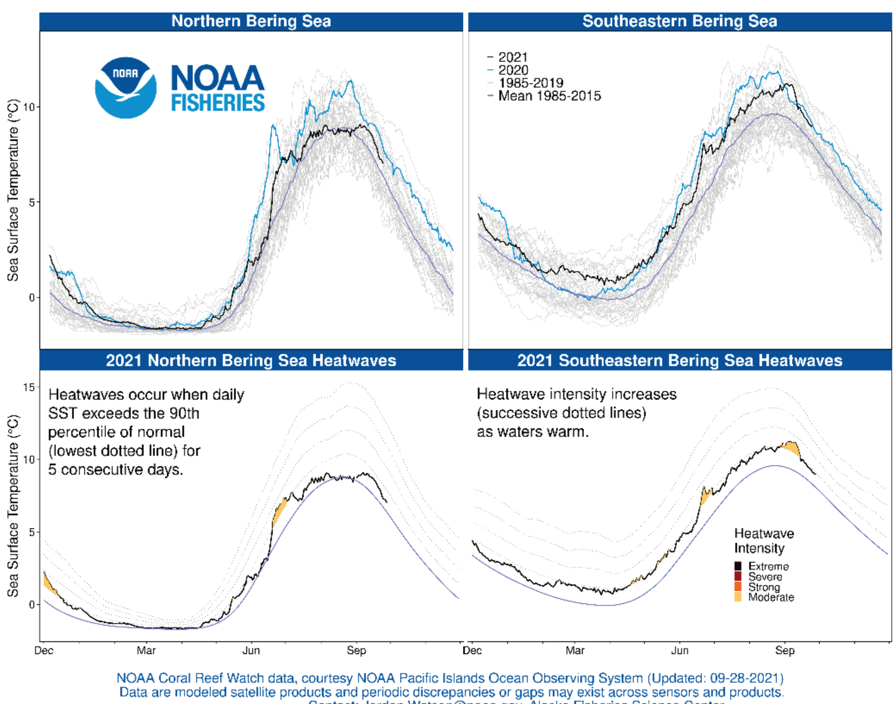


Figure 5. Daily mean SST for 2021 and 2020 compared to means for 1985-2015 for the northern Bering Sea (north of 60°N) and southeastern Bering Sea (south of 60ºN) from satellite analysis. Courtesy of Jordan Watson, NOAA AFSC.

2021 Ecosystem Surveys: Gulf of Alaska and Bering Sea

For this report we have focused primarily on ecosystem surveys in the Gulf of Alaska (Fig. 6) and Bering Sea compiled by NOAA AFSC scientitsts: Ellen Yasumiishi, Lauren Rogers, and Rob Suryan. Many other 2021 AFSC fisheries surveys are described in the link: https://www.fisheries.noaa.gov/alaska/science-data/2021-alaska-fisheries-science-center-field-season.

Cross division/agency collaboration focused on ecosystem research to support ecosystem based fisheries management includes the following AFSC programs:

- Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI: PMEL and Recruitment Processes Program), Seattle
- Ecosystem Monitoring and Assessment, Juneau/Seattle
- Recruitment, Energetics & Coastal Assessment, Juneau
- Fisheries Behavioral Ecology, Newport
- Shellfish Assessment Program, Kodiak

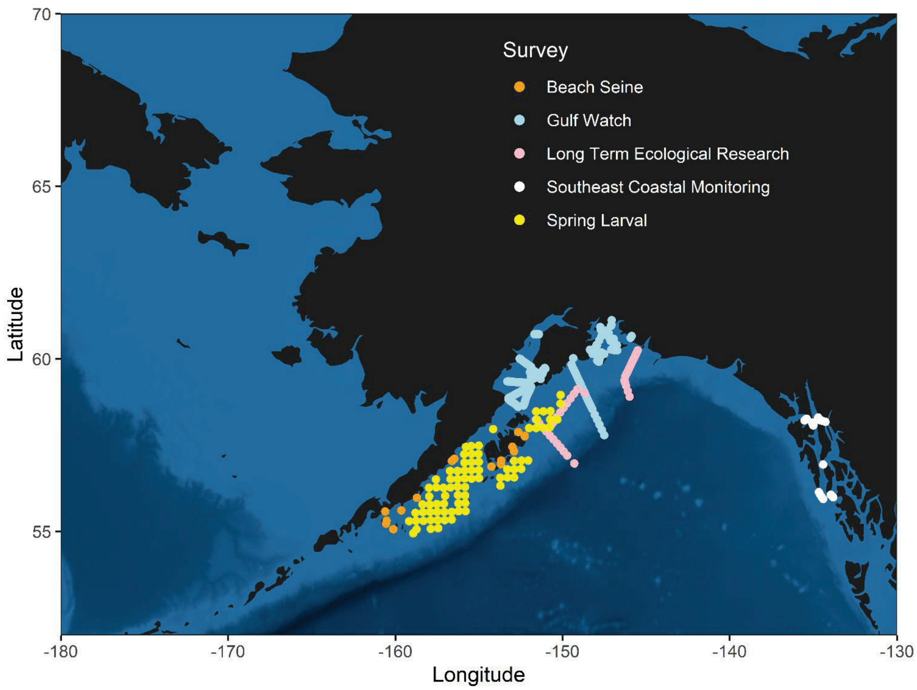
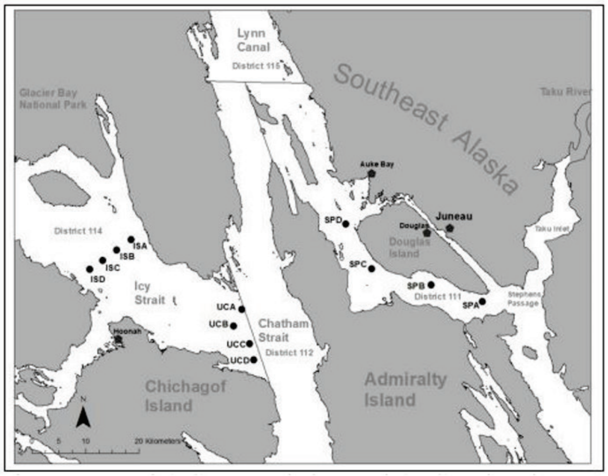
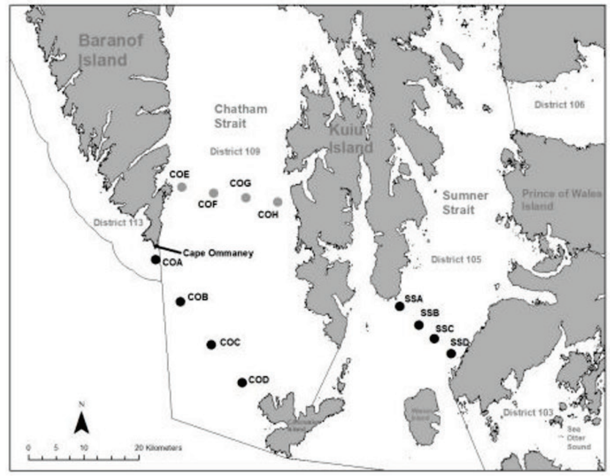


Figure 6. 2021 Gulf of Alaska ecosystem surveys.

Eastern GOA Southeast Coastal Monitoring (SECM) (map shown below), Contacts (AFSC): Andrew Gray, Jim Murphy, Emily Fergusson, Jamal Moss





Focus: Juvenile salmon, YOY gadids (Pacific cod, saffron cod, pollock), sablefish

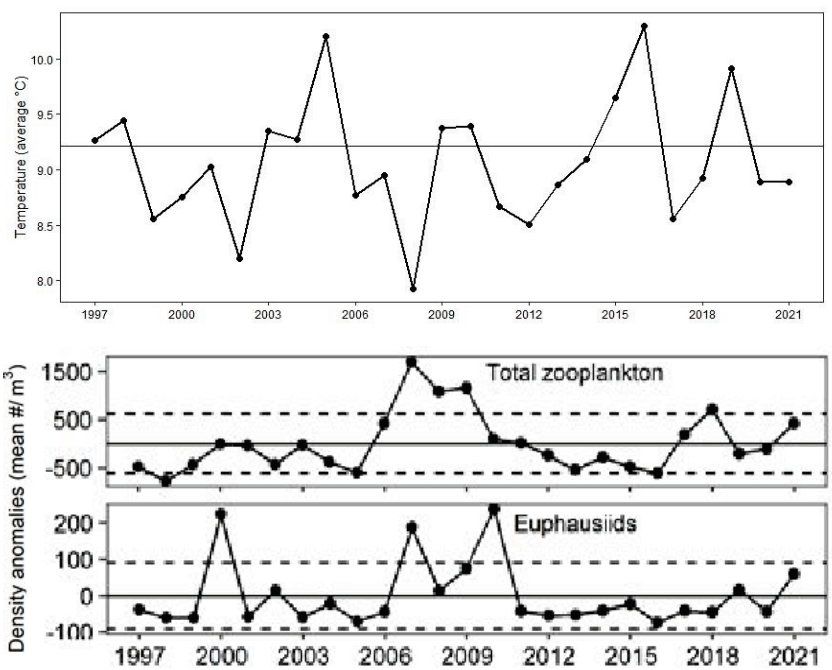
When: 1997-2021 June/July/August (August cancelled) 25 years

Where**:** Northern SEAK expanded to southern SEAK

Operations: Surface trawl, CTD, zooplankton/phytoplankton

Indicators: Onshore-offshore gradient of juvenile gadid growth and energetics. Feeding ecology of southern coastal age-0 groundfish, HABs

2021 Observations: Temperature was below average in Icy Strat, zooplantkon density was above average, and juvenile salmon had an average size (Fig. 7).



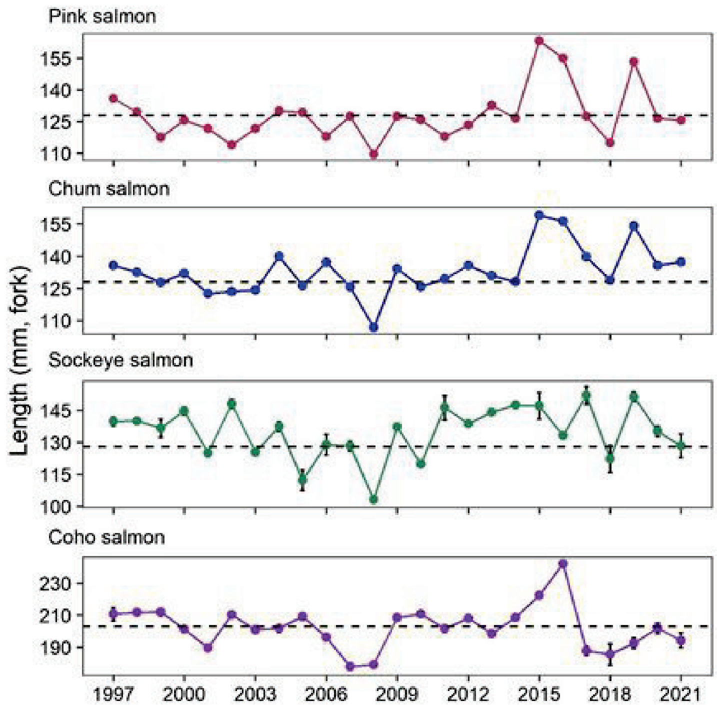


Figure 7. Average water temperature (top), zooplankton density anomalies (center) and juvenile salmon sizes (bottom) from SECM surveys, 1997–2021.

Gulf Watch Alaska, Contacts: Rob Suryan (AFSC), Seth Danielson and Russ Hopcroft (UAF)

Gulf Watch Alaska is the long-term ecosystem monitoring program of the Exxon Valdez Oil Spill Trustee Council for the marine ecosystem affected by the 1989 oil spill. Gulf Watch Alaska and Northern GOA Long Term Ecological Research (LTER) programs conduct surveys in the northern GOA (Fig. 8). Temperature in spring 2021 (May) were cooler and fresher in deep waters, there was a large spring bloom of diatoms, nearhsore at GAK1 was warm compared to the 50 year mean, seabird abundance was among the lowest recorded in the 20-yr time series,and there were moderate numbers of large copepods (Fig. 9).

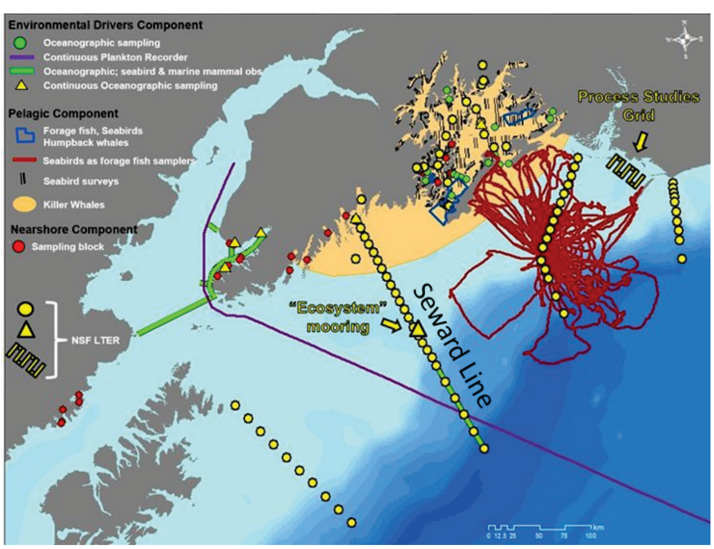


Figure 8. Gulf Watch Alaska and N. GOA Long Term Ecological Research (LTER) Surveys.

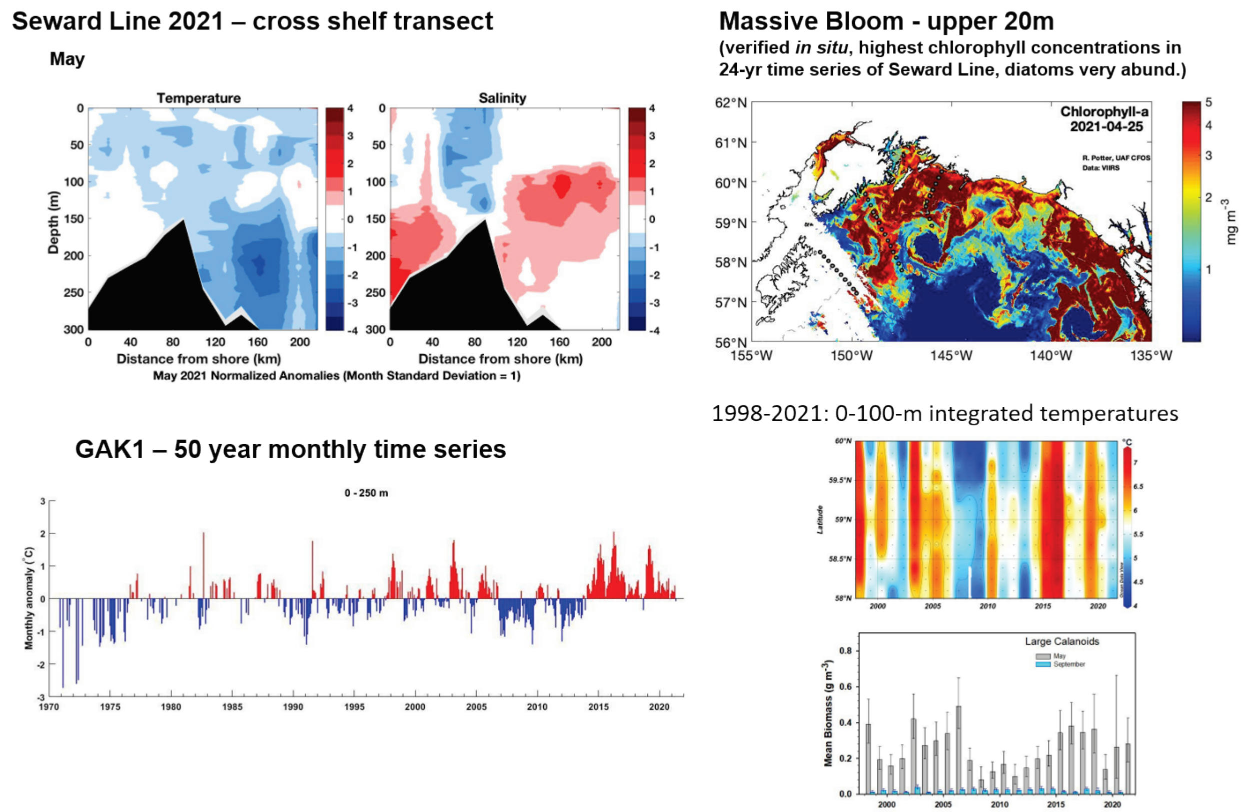


Figure 9. May 2021 data: temperature and salinity (top left), temperature times series (bottom left), chlorophyll (top right), and time series of integreated temperature and large calinoid copepod mean abundance (bottom right) in the northern GOA from Gulf Watch and the N. GOA LTER (contibuted by S. Danielson, R. Hopcroft).

Western GOA Spring Larval Survey, contact Janet Duffy Anderson (AFSC)

Focus: Larval fishes and lower trophic-level processes (fisheries oceanography)

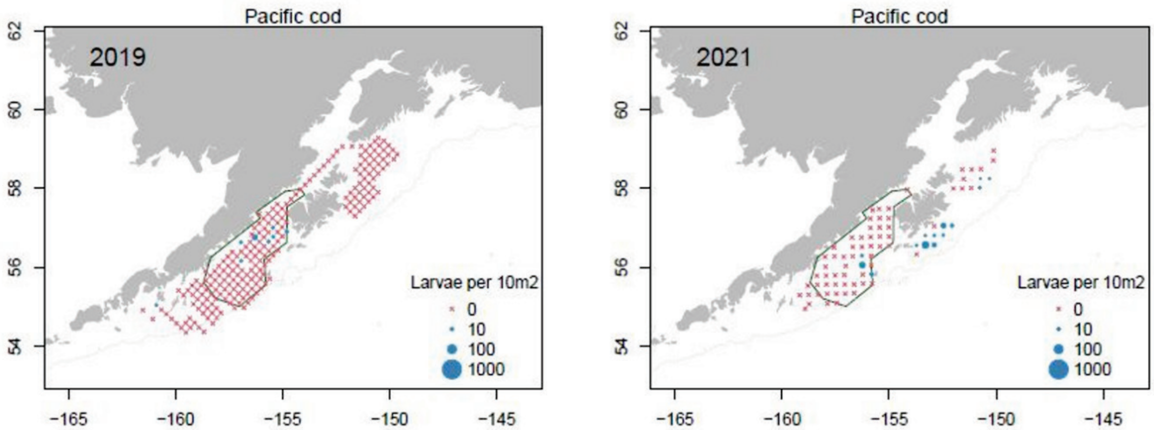
When: May

Where: Western GOA shelf from Kodiak to Shumagins

Operations: CTD, Bongo, CalVET, Neuston

Indicators: Larval abundance, growth, spawn timing, zooplankton, temperature

Observations: Larval Pacific cod nearly absent from core area in 2021, simialr to 2015 and 2019 (Fig. 10). The highest catches were offshore of Kodiak. Larval walleye pollock had record low abundaces in the core sampling area (Fig. 11). There was an unusual distribution with the highest catches offshore of Kodiak.



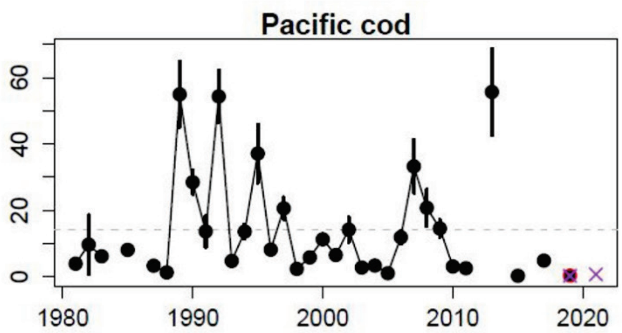
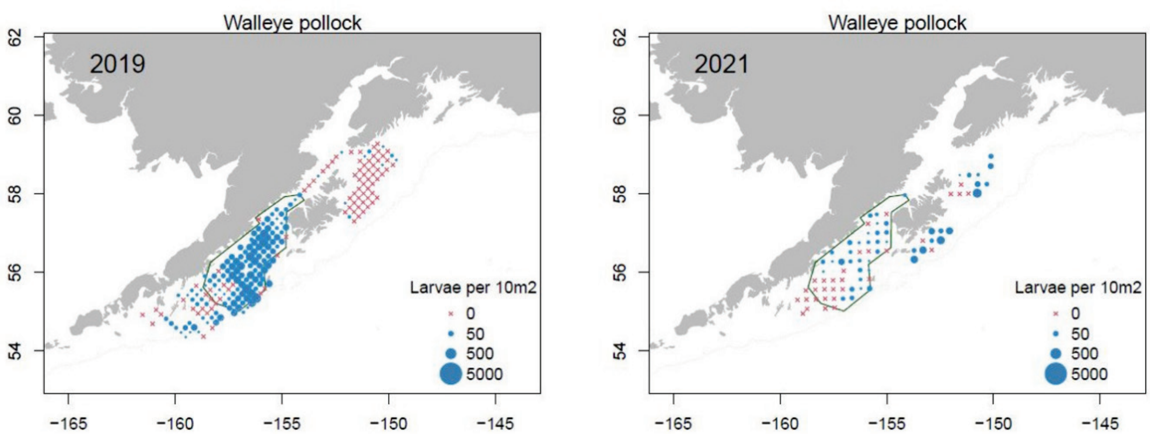


Figure 10. 2021 larval Pacific cod abundances from the spring rapid larval assessment on the Western GOA shelf.



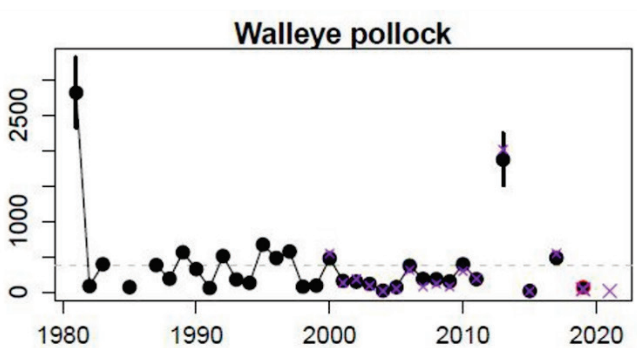
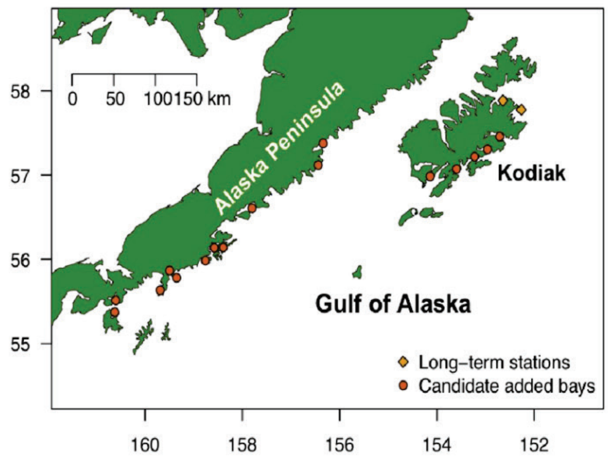


Figure 11. 2021 larval walleye pollock abundances from the spring rapid larval assessment on the Western GOA shelf.

Western GOA Summer Beach Seine Survey (map shown below), Contacts (AFSC): Ben Larual, Mike Litzow, Alisa Abookie



Focus: YOY gadids (Pacific cod, saffron cod, pollock)

When: Kodiak: July/Aug (4 surveys, 16 sites across 2 bays) 2006-2021

Expanded WGOA: July/Aug (75 sites across 14 bays) 2018-2021

Operations: Beach seine, CTD, baited cameras

Indicators: abundance and size, genetics, diets, temperature, salinity, oxygen

Please contact Ben Laural for 2021 observations.

Bering Sea coccolithophore bloom

An extensive coccolithophore phytoplankton bloom was observed in the southeastern Bering Sea during September 2021 (Fig. 12). These blooms can be detrimental to fish and seabirds. For example, a large bloom in 1997 was associated with a die-off of short-tailed shearwaters. These blooms are thought to reduce foraging success for visual predators.

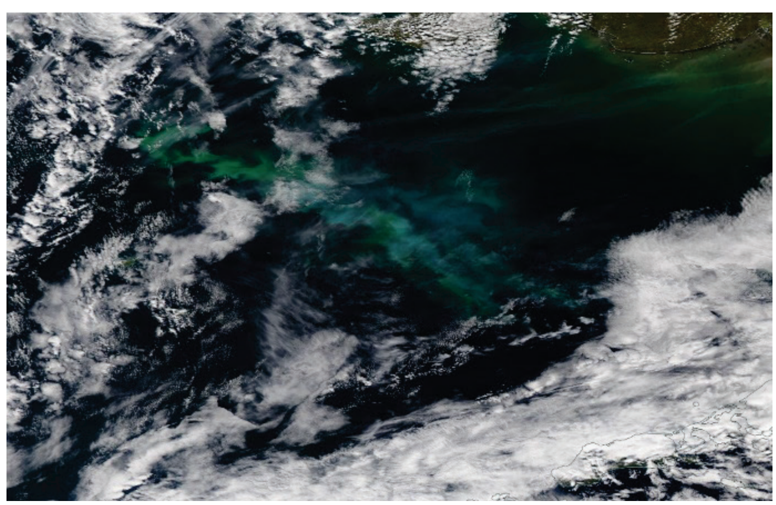
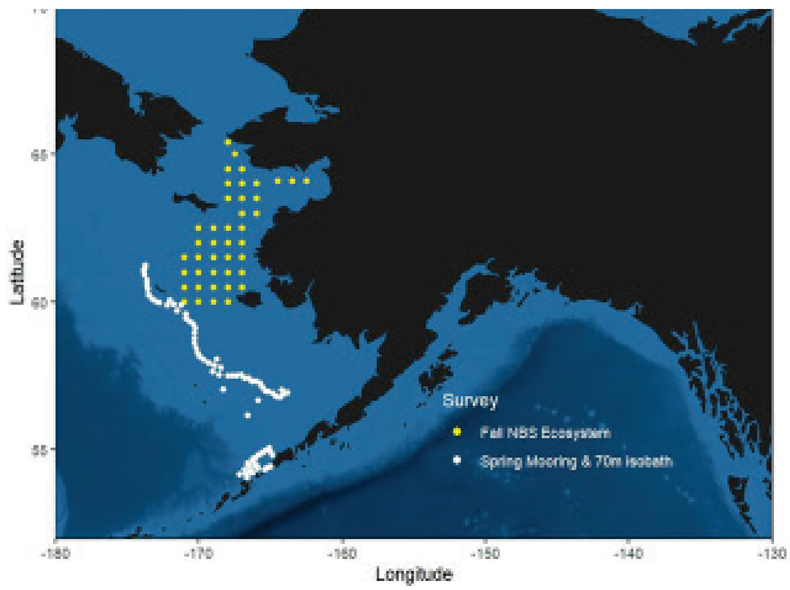


Figure 12. Coccolithophore bloom (aqua color water) in the southeastern Bering Sea observed on September 16, 2021. https://go.nasa.gov/3uHEcNr. We acknowledge the use of imagery from the NASA Worldview application (https://worldview.earthdata.nasa.gov), part of the NASA Earth Observing System Data and Information System (EOSDIS).

Two eastern Bering Sea ecosystem surveys were completed in 2021. These include the spring mooring and 70m isobaths survey and the northern Bering Sea surface trawl survey (map below).

Eastern Bering Sea moorings and 70m isobath (map below), Contact: Janet Duffy-Anderson (AFSC)



<u>Focus</u>: Deploy moorings and sample lower trophic levels.

<u>When</u>: Spring and Fall (FALL CANCELLED)

<u>Operations</u>: Surface, subsurface moorings and instrumentation (incl Prawler), CTDs, Bongos, Pop-up floats.

<u>Indicators</u>: Integrated chlorophyll; temperature, salinity, oxygen, zooplankton.

Please contact Janet-Duffy Anderson for observations

2021 North Bering Sea surface trawl survey, Contacts (AFSC): Ed Farley, Jim Murphy

<u>Focus</u>: YOY Pacific cod, Arctic cod, saffron cod, pollock, juvenile salmon, capelin, herring, ATF sablefish, sand lance, crab, zooplankton, phytoplankton

<u>When</u>: August 27- September 28, 2003–2021, excluding 2008 (19 years)

<u>Operations</u>: CTD, bongo tows, benthic grabs, surface trawl, beam trawl

<u>Indicators</u>: Growth and consumption model output. Fish abundance, conditions, diets, Salmon forecasting, Crab habitat, HABs, eDNA.

<u>Observations</u>: Cold pool south of St Lawrence with warm bottom temperatures nearshore (Fig. 13); surface temperatures ranged 7-11°C and bottom temperatures ranged 0-11°C; beam trawl catches consisted of smaller sized snow crab, few large snow crab, and shrimp on the benthos; surface trawl catches consisted of age-0 and age-1 pollock, age-0 Pacific cod, herring, and juvenile salmon.

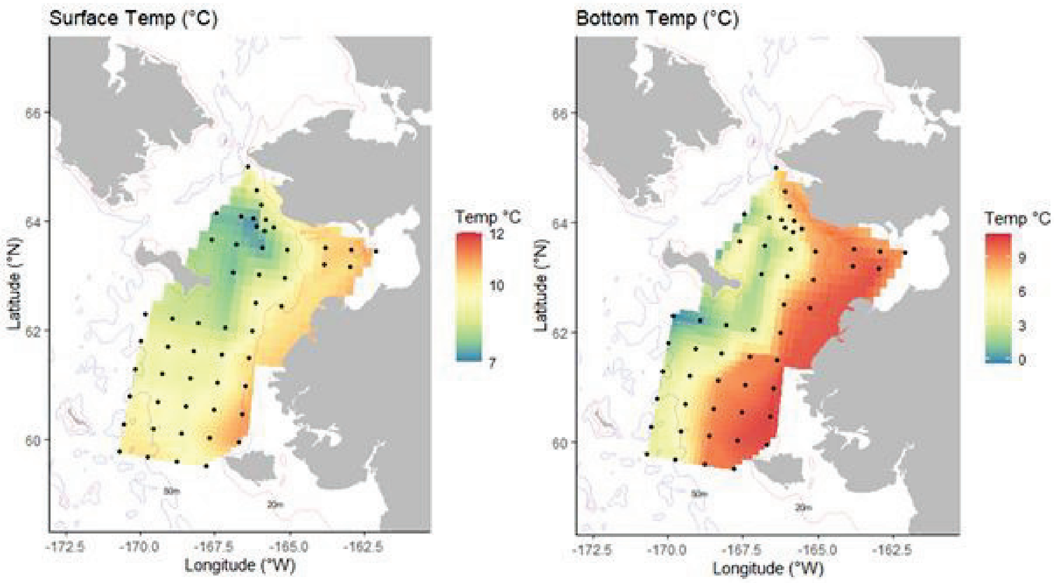
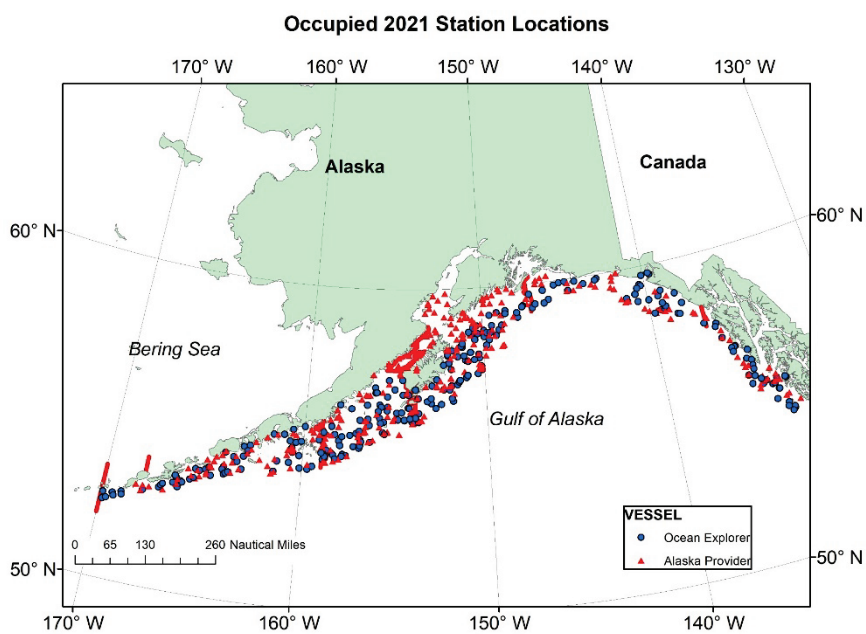


Figure 13. 2021 surface and bottom temperatures observed on the late summer /early fall North Bering Sea surface trawl survey.

Bottom Trawl fisheries surveys

Gulf of Alaska summer bottom trawl survey (see map below)*,* Contact Wayne Palsson (AFSC)



Eastern and Northern Bering Sea summer bottom trawl survey, Contact: Lyle Britt (AFSC)

Summer (June-August) bottom trawl surveys for fish and invertebrates were conducted in the standard core region in the southeastern Bering Sea and in the northern Bering Sea (N. Bering Sea expansion) in 2021 (Fig. 14). Temperature sensors attached to the trawl net recorded bottom temperature throughout the Bering Sea (Fig. 14).

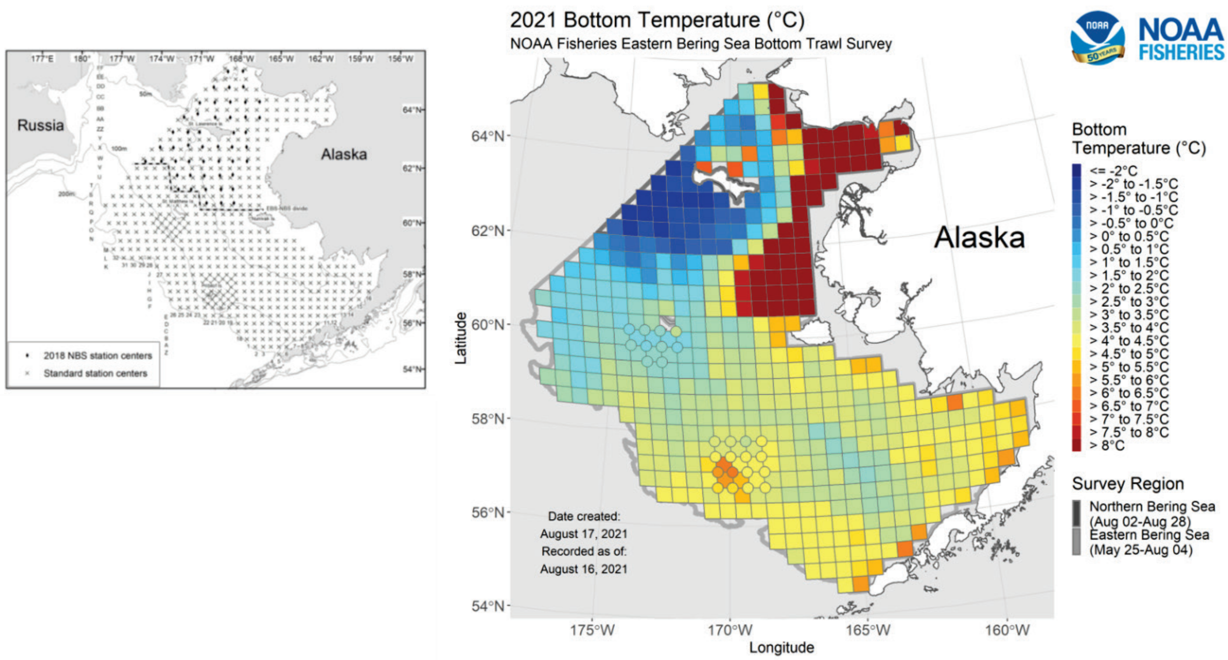


Figure 14. Bottom Trawl locations in the south eastern Bering Sea and northern Bering Sea (left) and bottom temperature (right). For details see https://www.fisheries.noaa.gov/alaska/science-data/near-real-time-temperatures-bering-sea-bottom-trawl-survey.

A major finding from the bottom trawl surveys is that crab biomasses were low, with the lowest total mature male crab biomass in the 1975–2021 times series observed in 2021 (Zacher *et al*. 2021 draft). Snow crab in particular showed sharp drops in populations (Fig. 15).

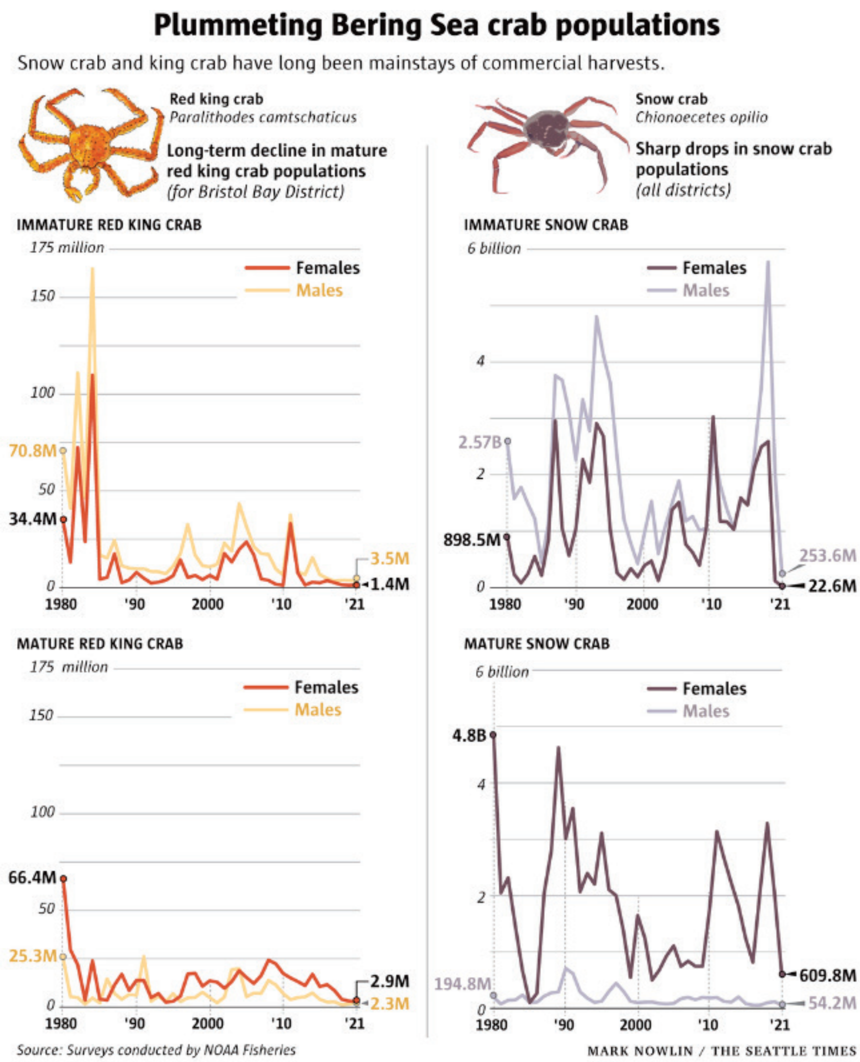


Figure 15. King Crab and Snow Crab population time series, from Seattle Times newspaper article, September 21, 2021, https://www.seattletimes.com/seattle-news/valuable-crab-populations-crash-in-a-warming-bering-sea/.

Reference

Zacher, L.S, Richar, J.I., Litzow, M.A. (September 3, 2021 draft). The 2021 Eastern Bering Sea Continental Shelf Trawl Survey: Results for Commercial Crab Species. NOAA Technical Memorandum NMFS-AFSC, https://apps-afsc.fisheries.noaa.gov/Documents/Temp-for-NOAA-IR/2021_EBS_Crab_SurveyTech_Memo_approved_draft.pdf

4. Republic of Korea

1. National Institute of Fisheries Science (NIFS)

Marine Heatwaves (MHWs) monitoring in the Korea Waters

In summer of 2021, record breaking marine heatwaves were strongly occurred in the Korea Waters. Especially, these strong marine heatwaves were started from mid-July and were continued to mid-August because of the early end of rainy season and maintaining for a long time of strong heatwaves around the Korea Peninsula. In this period, SSTA (Sea Surface Temperature Anomaly) around the Korea Peninsula was about 2~5℃. To serve real-time water temperature along the coast of Korea, NIFS operates 140 real-time water temperature monitoring system with 30-minute interval. In addition, NIFS issues abnormal water temperature warning to minimize the fisheries damage in aqua-farm when the abnormal water temperature appears in the coastal area.

Impacts to the marine ecosystem and oceanic conditions by the passing of typhoon using Wave-glider in the Korea Waters

To understand the change of oceanic conditions and impact to marine ecosystem by the passing of typhoon, NIFS operates 2 wave-gliders around the Korea Waters. The one was deployed around the Jeju Island and the other was deployed around the East Sea. Ocean and meteorological sensors like air temperature, air pressure and wind speed, water temperature, salinity and so on were attached in these 2 vehicles. NIFS deployed these 2 vehicles on 10 and 13 September to understand the impacts by the passing 202114 typhoon (14^{th} typhoon Chanthu), which passed across Northern East China Sea from 16 September to 18 September. NIFS will analyze these data to find out the change of oceanic conditions before and after the passing of this typhoon.

System construction for the real-time providing of serial oceanography data (NSO)

NIFS carry out NSO (National Serial Oceanography Observation) since 1961. In the past, these observed data were served 0.5~1 year later after observations. To serve the real-time or near real-time NSO data for scientific users, NIFS construct network system from R/V to NIFS computer server. NIFS is now pilot operation with one R/V. They have a plan to construct network system for all R/Vs of NSO within a few years to serve the rapid service of ocean observational data.

2. Korea Institute of Ocean Science and Technology (KIOST) & Seoul National University(SNU)

CSK-2 (the 2^{nd} Cooperative Study of the Kuroshio and Adjacent Regions)

KIOST and SNU joined the project "time series observations of Kuroshio variability in the East China Sea" in the CSK-2. The goal of this observation project is to obtain continuous time series of the Kuroshio variability at more than one latitude band in the East China Sea and to understand the connectivity of the Kuroshio Current from its upstream to downstream and meridional transport of heat, material and so on. To observe horizontal and vertical structures of the Kuroshio, KIOST and SNU with Kagoshima University deployed 4 75kHz ADCPs (Acoustic Doppler Current Profilers) in the East China Sea since June 2020. In June 2021, they recovered 4 ADCPs to obtain one-year-long time series and re-deployed using T/V Kagoshima-maru of the Kagoshima University. They have a plan the one-week research cruise for the maintenance of the mooring system and deploying additional instruments during June 2022.

3. Korea Meteorology Administration (KMA)

Ocean weather observation system around the Korea Peninsula

KMA operates 23 ocean data buoys to observe the wind, air pressure, humidity, water temperature, wave heights and wave direction in the Korea Waters. They will install 3 large scale ocean data buoys, which were 3m discus and 10m discus, in the coastal region of Yellow Sea, center of East China Sea and East Sea in this year.

4. Korea Hydrographic and Oceanographic Agency (KHOA)

Operation Korea Ocean Observing Network

KHOA operates Korea Ocean Observing Network (KOON) that consists of tidal stations, ocean research stations, ocean buoys and surface currents stations. KOON is providing the real-time ocean information with improved data quality for the needs of oceanic industry, military and general public. KHOA currently operates 52 tidal stations, 3 ocean stations, 3 ocean research stations, 35 moored ocean buoys and 44 HF radar systems.

5. Japan

National Report of Japan Fisheries Research and Education Agency (FRA)
by Kazuaki Tadokoro, Fisheries Resources Institute, Shiogama branch

Zooplankton sample collection of Japan Fisheries Research and Education Agency

FRA has collected zooplankton samples from the 1950s to present. The sampling gears are NORPAC net, Bongo net, Larval net, Neuston net, MTD net, VMPS, IKMT, MOHT, *etc*. Total number of samples is 211,574 at September 25, 2021. The samples are preserved by 5% buffered formaldehyde. Sampling area is mainly in the waters around Japan. However, the samples were also collected in the western North Pacific, central North Pacific, and Peruvian waters. Samples were collected by FRA, prefectural fisheries institutes, Japan Meteorological Agency, and university. Sample number of each decade is indicated in Figure 1. Although the sample number was 1708 in the 1950s, it has increased decade by decade, reaching 80,958 in the 2010s. A part of the samples was collected by Dr. Kazuko Odate and it is well known as the Odate collection. Those samples have been used for study of relationship marine ecosystem and climate change and biodiversity of marine ecosystem. Moreover the samples collected by Neuston and Larval nets are used for the study of geographical and temporal variation of micro plastics in the western North Pacific (*e.g*. Miyazono *et al*., 2021), https://ocean.fra.go.jp/plankton/hyohon_home.html (in Japanese).

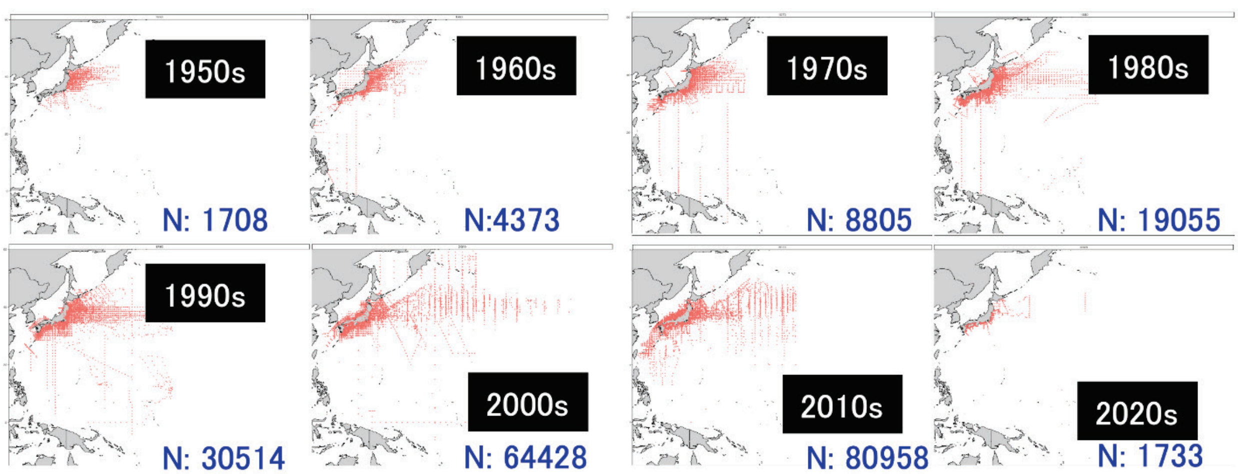


Fig. 1 Sampling location and number (in blue) of zooplankton collections for the each decade.

Observation of monitoring lines

FRA has carried out oceanographic observation monitoring at 6 lines around Japan (Fig. 2). Details of the observation are described as below.

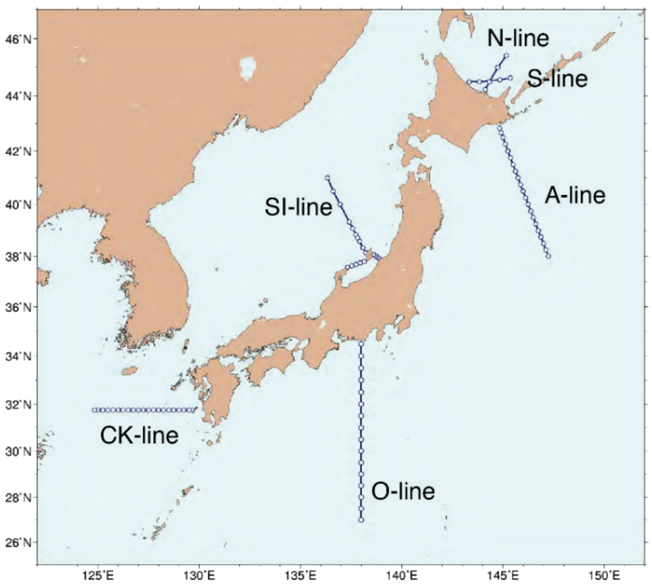


Fig. 2 Six monitoring lines around Japan has been conducted by Fisheries Resources Institute of FRA.

A-line

The Shiogama and Kushiro branches of the Fisheries Resources Institute, FRA, have carried out oceanographic monitoring from 1987 to present at a transect A-line in the Oyashio and Kuroshio-Oyashio transition waters (Fig. 3). In recent years, observations were carried out 5 times in January, March, May, July, and October throughout the year. Observation items are CTD, water sampling by Niskin bottles, NORPAC net, and Bongo net. The oceanographic data are open and available from the website. The period of published data is from 1990 to 2019 for CTD and from 1990 to 2015 for others.

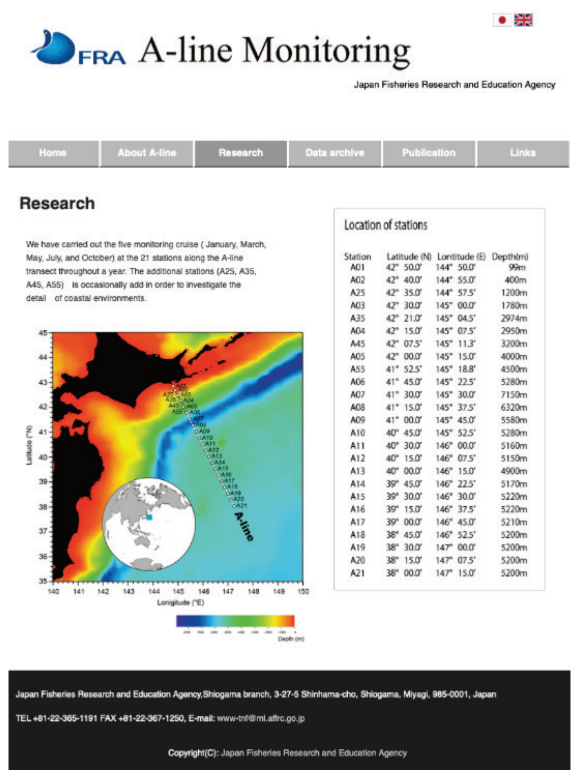


Fig. 3 Website of A-line monitoring, https://ocean.fra.go.jp/a-line/a-line_index2.html.

O-line

Yokohama headquarters of the Fisheries Resources Institute, FRA, have carried out monitoring from 1999 to present at a transect O-line (138°E, 27°N to 34.30°N) in the Kuroshio waters. The observations are carried out in January, March, May, August, and October throughout the year. Observation items are CTD, water sampling by Niskin bottles, and NORPAC net.

CK-line

Nagasaki headquarters of the Fisheries Technology Institute, FRA, have carried out monitoring from 2002 to present at a transect CK-line in the East China Sea. The observations are carried out in February, March, June, July, and October throughout the year. Observation items are CTD, water sampling by Niskin bottles, and NORPAC net.

SI-line

The Niigata branch of the Fisheries Resources Institute, FRA, has carried out monitoring since 2016 in the Sea of Japan. The observations were carried out in February, April, June, and September throughout the year. Observation items are CTD, water sampling by Niskin bottles, and NORPAC net.

N-line, S-line

The Kushiro branch of the Fisheries Resources Institute, FRA has carried out the monitoring since 2000 in the Sea of Okhotsk. The observations were carried out in May and September throughout a year. Observation items are CTD, water sampling by Niskin bottles, and NORPAC net.

Stock assessment monitoring project commissioned by FRA

The observations have been carried out at 760 stations in the waters around Japan except with Okinawa and Hokkaido from 1972 (Fig. 4). The frequency of the observations is monthly except with the station in the Sea of Japan. In the Sea of Japan, observations are carried out during spring and autumn. Annual sampling number is about 7000. The prefectural fisheries institute mainly carry out the monitoring. Observation items are CTD, and NORPAC net. Data on CTD and abundance of eggs, larvae, juveniles of pelagic fish are archived in the database of FRESCO (Fisheries Resource Conservation) system managed by JAFIC (Japan Fisheries Information Service Center).

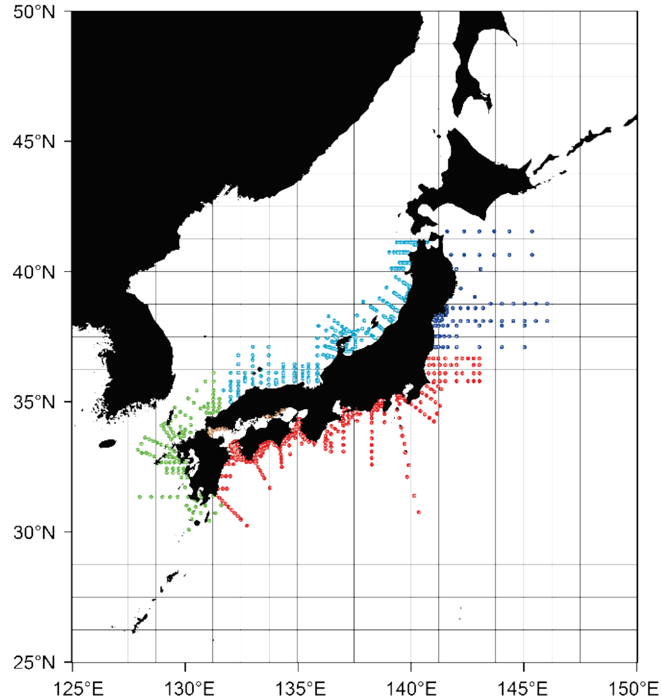


Fig. 4 Sampling location of the Monitoring of stock assessment project

Fish eggs, larvae, juvenile sample collection

Yokohama headquarters of the Fisheries Resources Institute, FRA, started collecting the samples in 2015. The samples are mainly collected during stock assessment monitoring project commissioned by the Fisheries Agency of Japan (Fig. 5). Although recent samples are being collected now, historical samples will be collected in immediate future.

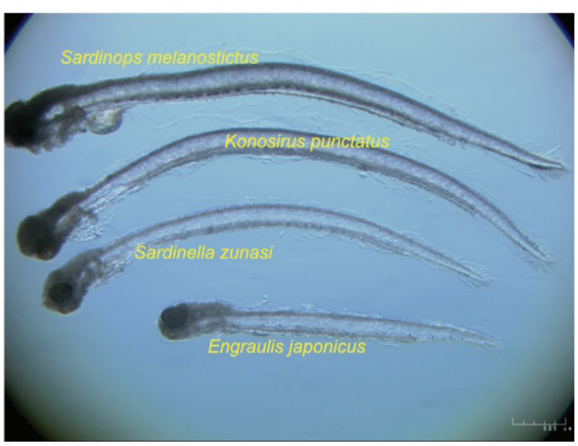


Fig. 5 Fish larvae specimen samples collected during stock assessment monitoring project.

Fish specimen sample collection

Nagasaki headquarters of the Fisheries Technology Institute, FRA, collect fish specimen samples (Fig. 6). The number of species is about 1200, and the total number of sample is about 32,000. The samples are mainly preserved by isopropyl alcohol. DNA samples are also collected from a part of the sample.

Fig. 6 Sample storage building (above) for the fish specimen collection, and the specimens (below).

Reference

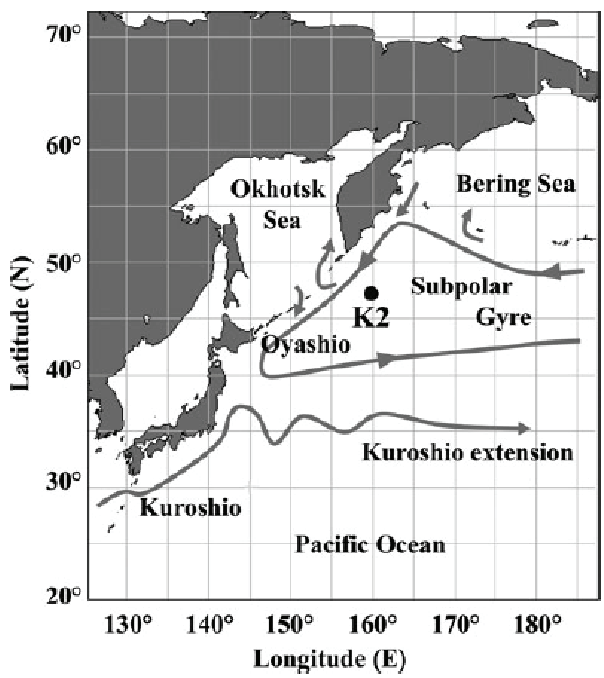
Miyazono K., R. Yamashita, H. Miyamoto, N. H. A. Ishak, K. Tadokoro, Y. Shimizu, and K. Takahashi (2021) Large-scale distribution and composition of floating plastic debris in the transition region of the North Pacific, Marine Pollution Bulletin, 10.1016/j.marpolbul.2021.112631

Report from Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
by Minoru Kitamura, RIGC JAMSTEC

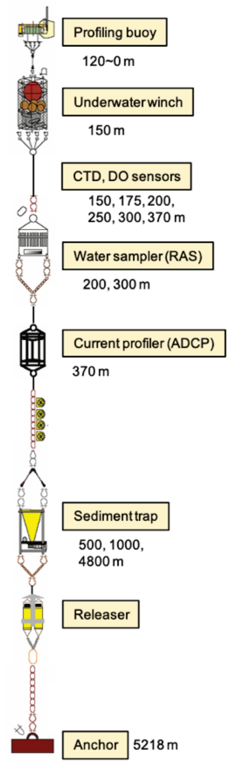
JAMSTEC is in charge of variety of ocean observation programs. In 2021, there were outbreaks of COVID19 at two vessels of JAMSTEC. These programs, however, are under operation.

1. Biogeochemical time-series at K2, the western subarctic Pacific

K2 (47°N, 160°E, 5200 m) is a time-series station to observe biogeochemical processes in the western subarctic gyre of the North Pacific. Sediment traps have been deployed in this station since 2001. In the current mooring system, an underwater winch is installed and the winch manipulates an observation buoy equipped with sensors to acquire vertical profiles of water temperature, salinity, pH, nitrate concentration, irradiance, and chlorophyll-*a*. Below the winch system are attached conductivity-temperature-depth recorders (CTDs), pH and dissolved oxygen (DO) sensors, two water samplers, an acoustic Doppler current profiler (ADCP), and two or three sediment traps.



Further hydrographic observations are made from shipboard during annual maintenance visits by a surface vessel. During the visits at K2, CTD casts up to 10 m above the sea floor, analysis of seawater (salinity, dissolved oxygen, phosphate, silicate, nitrate, nitrite, dissolved inorganic carbon, dissolved organic carbon, total alkalinity, and phytoplankton pigments) and incubation experiments for primary productivity are carried out.



Schematic diagram
of K2 mooring

The mooring system was recovered in November 2020 and was redeployed in February 2021. Hydrographic observations were also conducted during the two cruises.

2. Sediment trap experiment at KEO, the western subtropical Pacific

The Kuroshio Extension Observatory (KEO; 32°18′N, 144°36′E), a mooring station maintained under NOAA's Ocean Climate Stations Project, has meteorological instruments as well as sensors to measure upper ocean environments. JAMSTEC has deployed moored sediment traps near the KEO since 2014. In March 2021, the mooring system was recovered and redeployed. During a research cruise of the R/V *Mirai* from December 2021 to January 2022, the mooring will be recovered and redeployed again.

3. Argo JAMSTEC

The Pacific Argo Regional Center (PARC) has been established as a joint collaboration between the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the International Pacific Research Center (IPRC) at the University of Hawaii, and the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. The PARC takes on the responsibility to validate all float data in the Pacific through rigorous scrutiny and to derive regional products based on these floats.

4. Deep NINJA: Deep ocean observation by deep-sea float

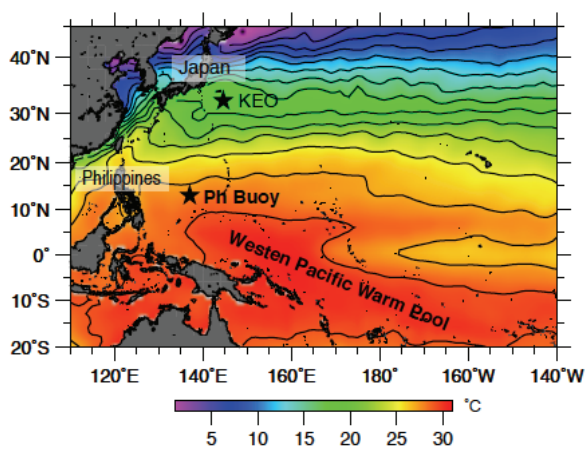
Deep NINJA is a deep sea profiling float, jointly developed by JAMSTEC and Tsurumi-Seiki Co. Ltd. Length and weight of this float are 210 cm and 50 kg (in air), respectively, and operation depth is up to 4000 m. JAMSTEC deployed 31 Deep NINJA floats primarily in the Southern Ocean from 2012 up to 2020. Among the 31 floats, three are active as of September, 2021. Deployment of Deep NINJA floats in 2022 is planned.

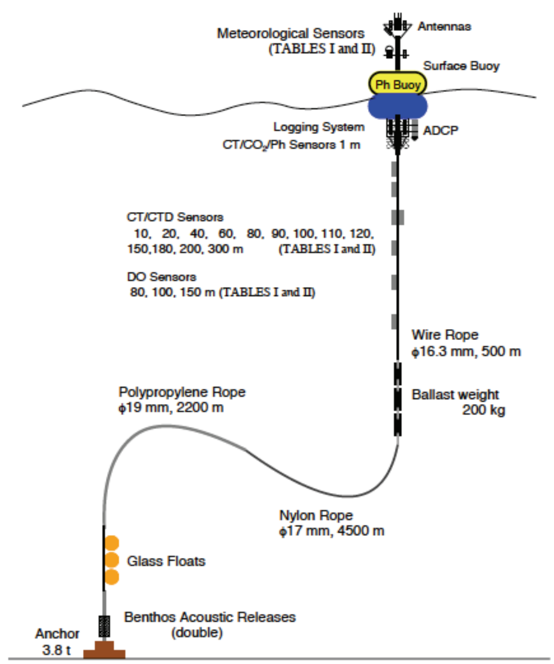
5. TRITON project

Since 1998, time-series observations using a surface buoy (TRITON buoy) have been conducted in the equatorial western Pacific. The purpose of this project was to obtain real-time air–sea data for improved detection, understanding and prediction of El Niño and La Niña. From May to June 2021, TRITON buoys were recovered from two sites of the western equatorial Pacific (0º, 156ºE; 8ºN, 137ºE), and the TRITON project was finished.

6. Ocean–atmosphere observations in the Philippine Sea by moored buoy

A time-series observation station was established in the Philippine Sea (13ºN, 137ºE) in 2016. To obtain real-time air–sea data, a surface buoy system (Ph buoy) has been deployed at the site. Payloads in this buoy for atmospheric observations are temperature, humidity, wind, atmospheric pressure, rainfall amount, long and short wave radiations sensors. In addition, to collect environmental parameters in the surface ocean, water temperature, salinity, and dissolved oxygen sensors and an ADCP are installed to the bottom of the buoy or the mooring wire rope above 300 m in depth. Recovery and redeployment of this surface buoy system was successfully conducted in June 2021.





7. Post-WOCE Hydrography

Repeat hydrography along the WOCE observation lines. Observations are conducted for chemical tracers, total alkalinity, pH, Ω, and nutrients to accurately quantify influences of global warming and ocean acidification on marine ecosystems, as well as to depict changes of the ocean heat content and the distribution of substances in seawater. From July to August, 2021, cruise of repeat hydrography along the P01 WOCE observation line (47ºN) was successfully conducted.

National Report from Hokkaido University

by Hiroto Abe and Sei-Ichi Saitoh, Faculty of Fisheries Sciences

Hydrographic observations by training ships *Oshoro-Maru* and *Ushio-Maru*

Hokkaido University has two training ships, the T/S *Oshoro-Maru* and the *Ushio-Maru*. The former has contributed to monitoring open ocean/marginal seas in the North Pacific, including the Bering Sea, over the decades, while the latter has monitored coastal areas around Hokkaido island. We reported in last year's national report that many of scheduled cruises for both educational and research purposes were cancelled under the COVID-19 crisis. The situation has not essentially changed since last year; most of the cruises have been cancelled, especially cruises of the *Oshoro-Maru*. Coastal monitoring in Tsugaru Strait by T/S *Ushio-Maru*, which has been quarterly conducted with researchers from Mutsu Institute for Oceanography (MIO) JAMSTEC since 2009 (Fig. 1), has also been influenced. Figure 2 shows a cross-section of temperature and salinity data in Tsugaru Strait that has been measured in one of the few cruises by the *Ushio-Maru* over the last year. The data will be made available online after all arrangements are finalized.

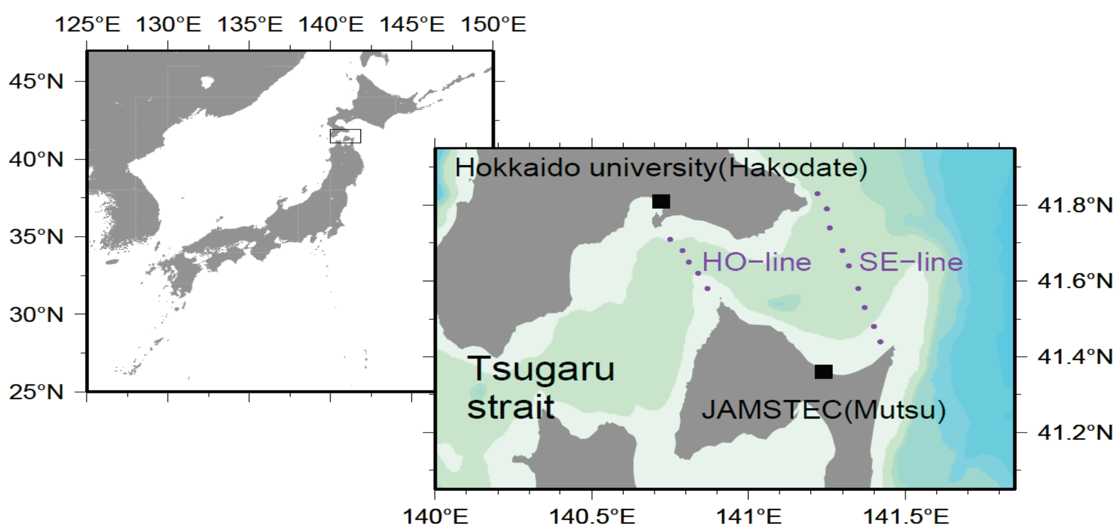


Fig. 1. Location of Tsugaru Strait showing the SE (Shiriya-Esan) line and HO (Hakodate-Ooma) line.

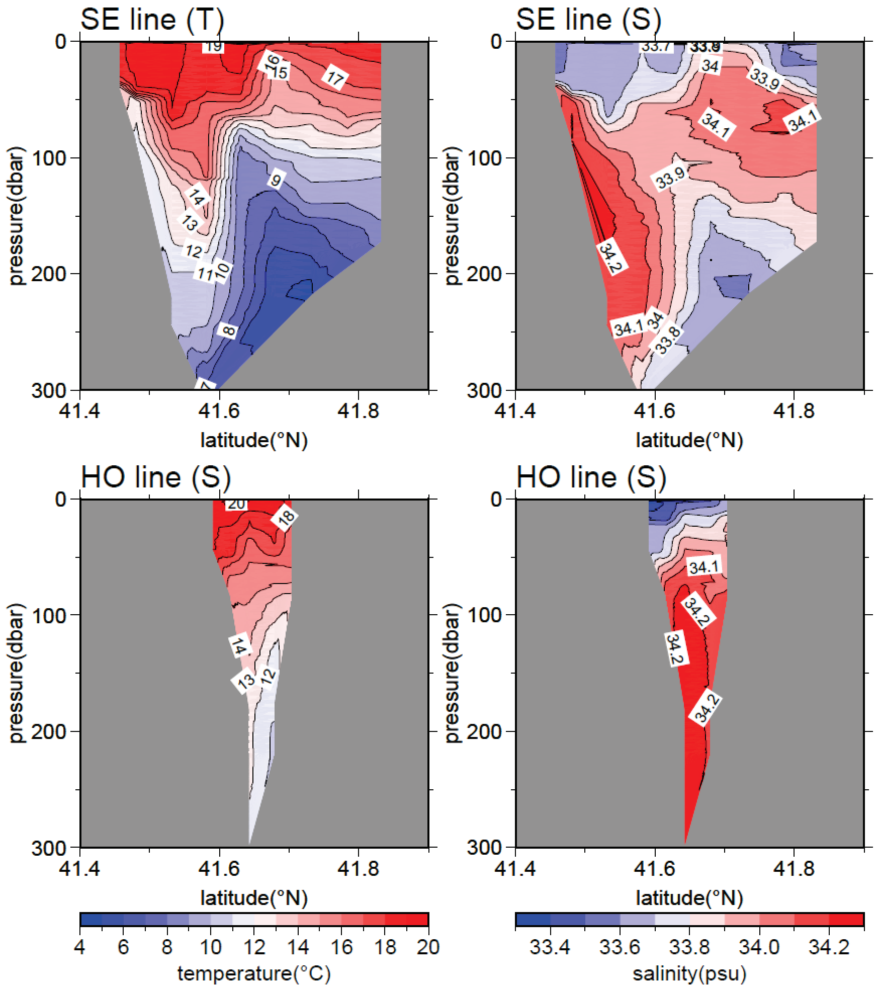


Fig. 2. Vertical section of temperature and salinity profiles measured at SE line and HO line in October 2020.

Surface current monitoring by High Frequency Radars in Tsugaru Strait

Mutsu Institute for Oceanography, JAMSTEC, deployed three high frequency (HF) radar systems on both coasts of Tsugaru Strait in April 2014. Seamless surface current monitoring has been done since the deployment. Figure 3 shows a map of long-term monthly mean surface currents measured by the HF radars. Detailed behavior of the Tsugaru Warm Current is revealed. The systems are in operation for the last year as well. Currently, the measured data are not available online, but will be available in the near future.

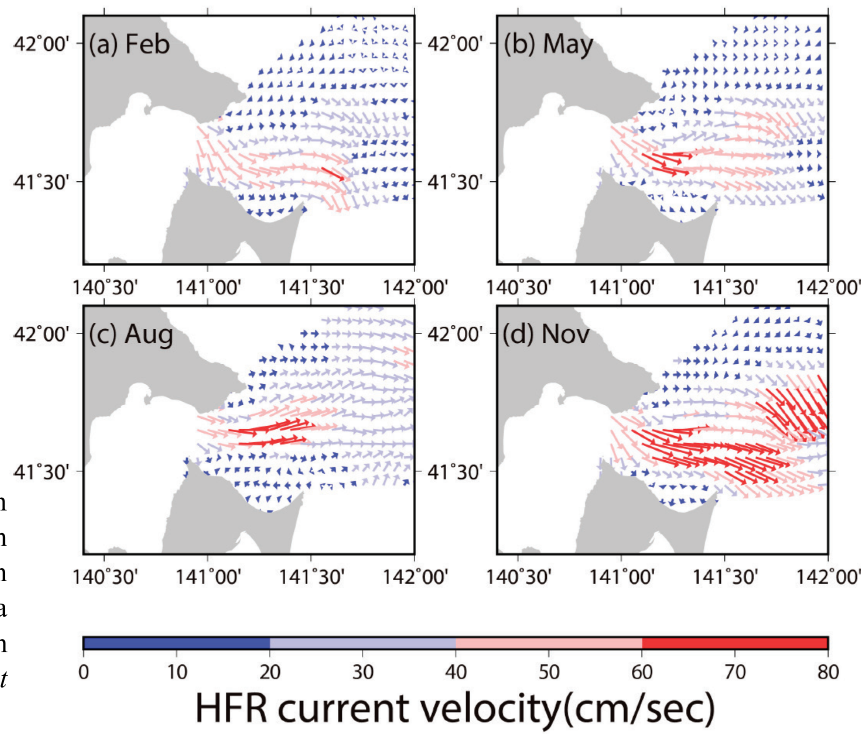


Fig. 3. Map of monthly mean surface currents observed by High Frequency radars in the eastern mouth of the Tsugaru Strait. Data from 2014 to 2018 have been used. (Reprint permission; Abe *et al*. (2020), Kaiyo Monthly)

Sea surface temperature observations by satellites

A map of monthly mean sea surface temperature (SST) is shown in Fig. 4, which is created using SST data measured by satellites (Aqua/AMSR-E and GCOM-W/AMSR2). This is SST anomaly with respect to monthly climatology during the period of 2002 to 2021. SST around Japan islands is under normal condition except for July when positive SST anomaly exceeding 3°C prevails over large area of Sea of Japan. Time series of SST was created using the satellite data with focus on the region west of Hokkaido island (Fig. 5, see Fig. 4 for location of the box region). The SST anomaly was approximately +3°C in July, which is much higher than moderate temperature of +/-1°C in other quarterly months.

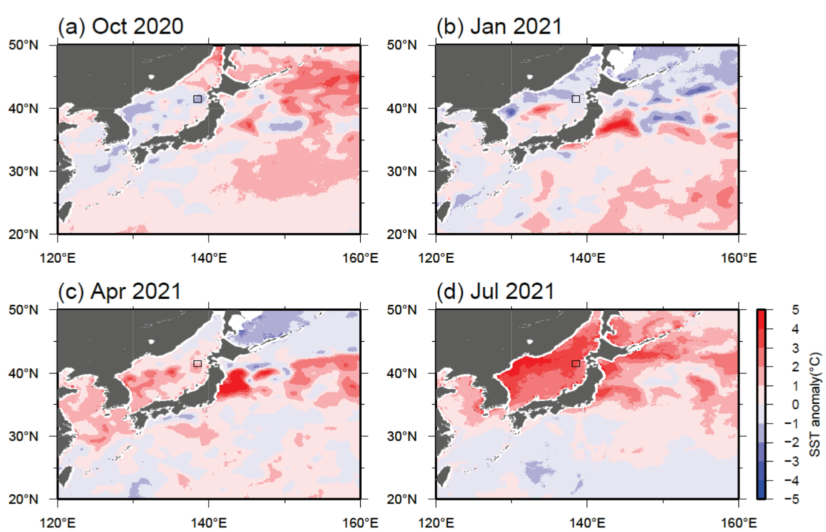


Fig. 4. Map of monthly mean sea surface temperature anomaly in (a) October, (b) January, (c) April, (d) July of the last one year with respect to monthly climatological SST over 2002–2021. SST data observed by satellites (Aqua/AMSR-E and GCOM-W/AMSR2) have been used. SST data were downloaded from G-Portal, data server of JAXA (Japan Aerospace Exploration Agency)

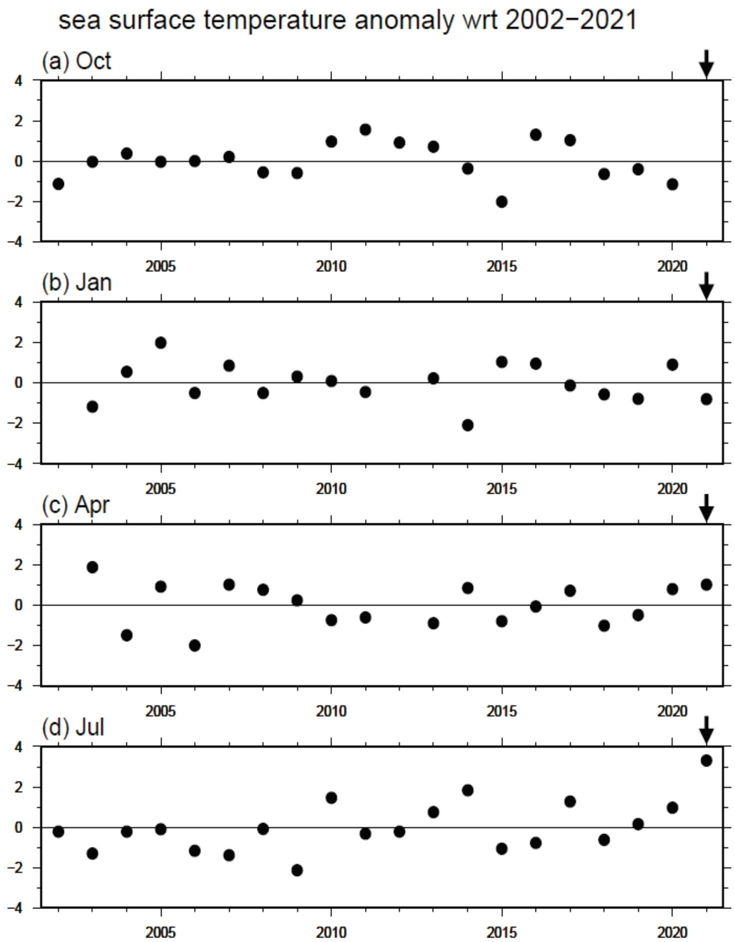


Fig. 5. Time series of monthly mean sea surface temperature anomaly in (a) October, (b) January, (c) April, (d) July of the last year with respect to monthly climatological SST over 2002–2021 averaged over the box region shown in Fig. 4. The year 2021 is marked by an arrow. SST data observed by satellites (Aqua/AMSR-E and GCOM-W/AMSR2) have been used. SST data were downloaded from G-Portal, data server of JAXA (Japan Aerospace Exploration Agency).

6. Russia

V.I.Il'ichev Pacific Oceanological Institute of the Far Eastern Branch of Russian Academy of Sciences has been continuing its monitoring programs in 2020–2021 under the following projects:

1. Primorye upwelling system and its impact on Peter the Great Bay.

One of the mooring sites is located near Vladivostok, to the south of Russkiy Island at 22 m depth. Observations of temperature and salinity in the bottom layer have been implemented every summer–fall since 2008. Since 2019 the observations cover a whole year cycle (24 month). In 2021 a CTD section across the bay was added (Fig. 5).

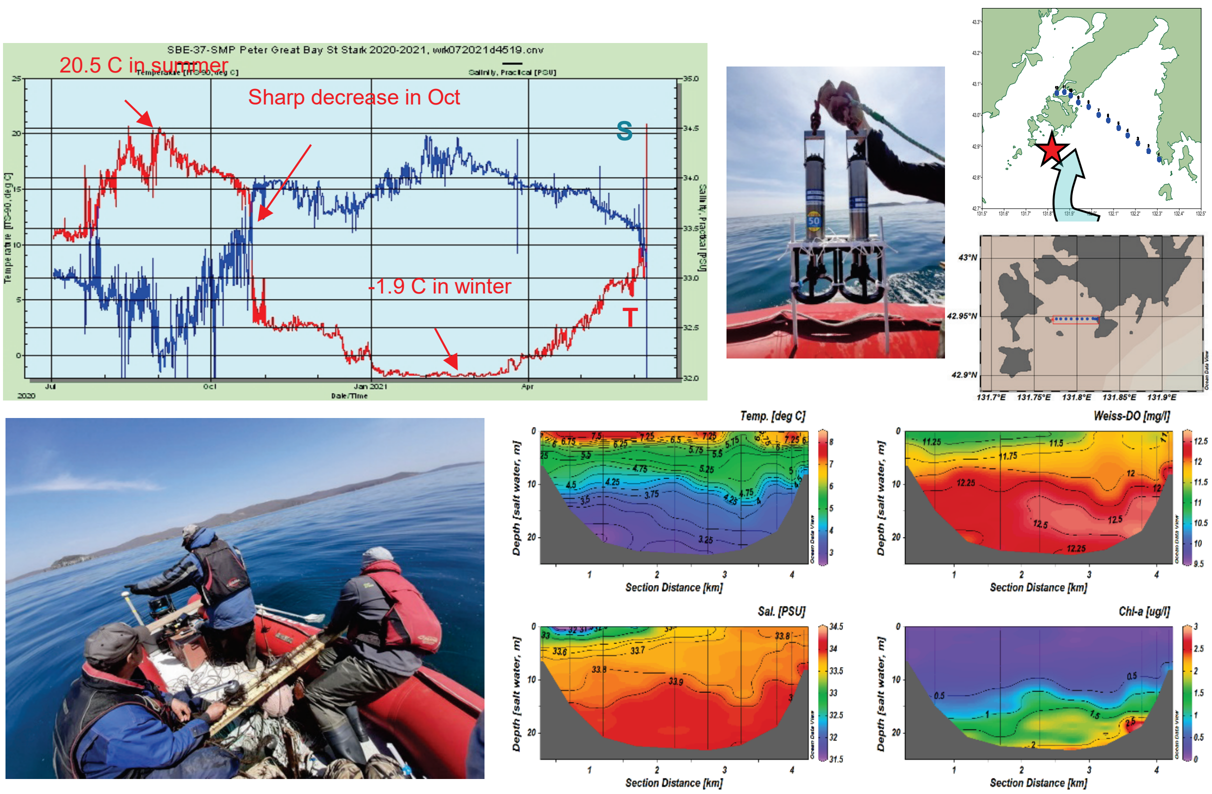


Fig. 1. Peter the Great Bay monitoring site of POI FEB RAS near Russkiy Island, Vladivostok

2. Climate monitoring sections in the EAST-I region

These includes two sections of ship based CTD and chemical observations: CREAM line (along 132°20 E) implemented jointly with Seoul National University (Korea) and NEAR-GOOS line (along 134°E) implemented jointly with the Japan Meteorological Agency. The CREAMS line was started in 2001 and is observed every 1 to 3 years. The NEAR-GOOS line has been observed every fall season since 2011. Recent analysis of the collected data show an increased rate of acidification and deoxygenation of the sea (Fig. 2). The rate of increasing pCO_2 in the upper 1500 m of the sea is much higher than in the atmosphere, which suggests that the sea is a sink for atmospheric CO_2 which may be caused by increased primary production caused by increased nutrients flux (Tishchenko *et al*., 2021).

3. Ferry box monitoring between Russian and Korea, started jointly with the East Sea Research Institute of NIFS, was interrupted in 2020 because of ferry cancellations associated with COVID-19. We hope to re-start it when the pandemic situation allows.

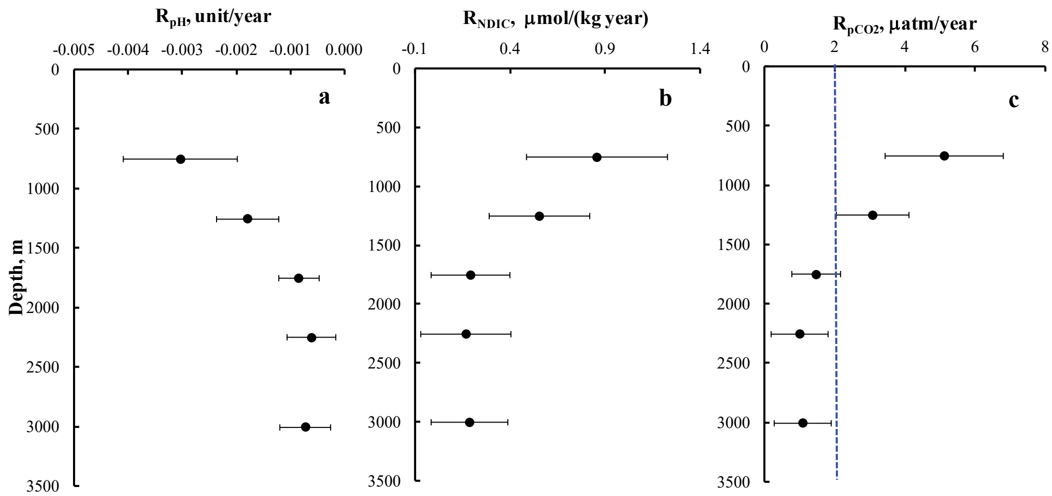


Fig. 2. Rates of temporal variability of the averaged carbonate system parameters in the JES as a function of depth. (a) $R_{[pH]}$, pH unit/year; (b) $R_{[NDIC]}$, µmol/(kg·year); (c) $R_{[pCO2]}$, µatm/year. Bars are 3·s.d. of rates estimated by LSM with the 95% confidence interval. The dashed line shows the rate of expected changes based on atmospheric CO_2 alone (Tishchenko et al., 2021).

Monitoring activities conducted by the Pacific branch (TINRO) of the Federal State Budget Scientific Institution “Russian Federal Research Institute of Fisheries and Oceanography” (VNIRO)

Each midwater trawl station is accompanied by hydrological and hydrobiological stations just before or after the trawling.

TINRO’s vessels conducted 641 midwater trawls during fishery-independent surveys in the northern part of the Pacific Ocean (Fig. 1). Fifty-two of those trawls were conducted in the high seas.

There were 662 midwater trawls conducted by R/V of TINRO in the Northwestern part of the Pacific Ocean in 2021, which have been processed already (Fig. 2). In the high seas there were 77 trawls conducted during summer.

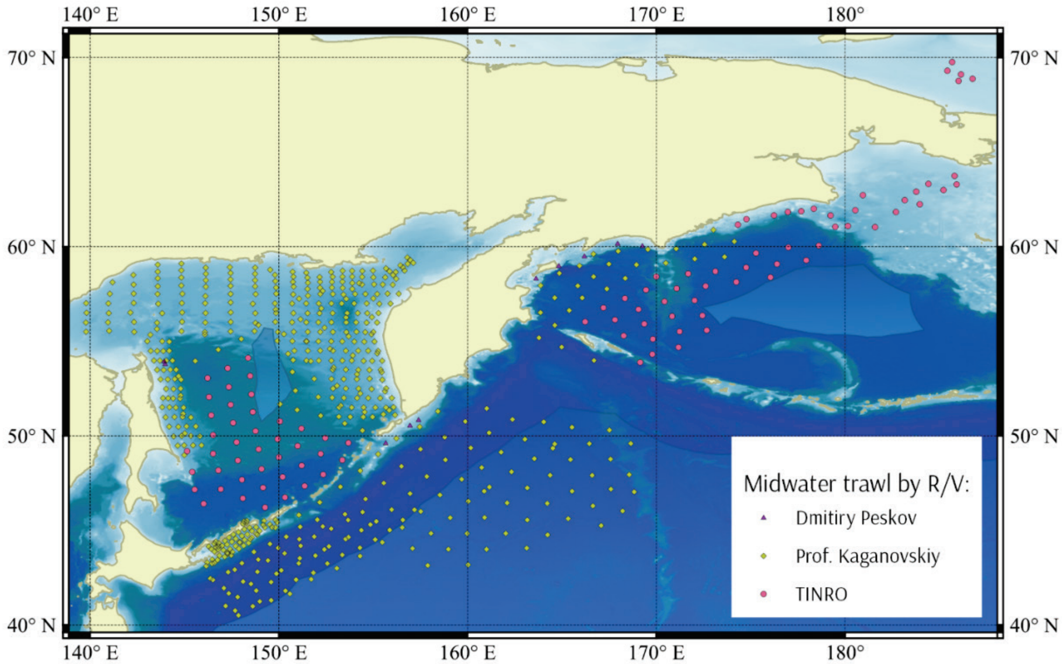


Fig. 1. Macroscale surveys conducted by TINRO's R/V in 2020.

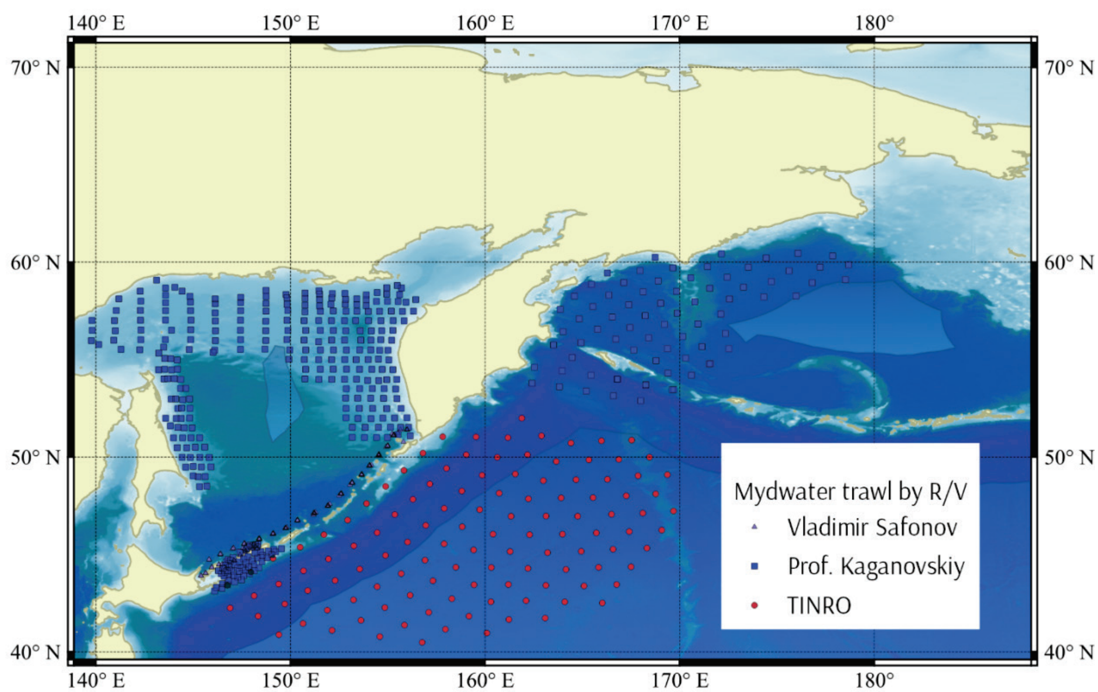


Fig. 2. Midwater trawls, conducted by TINRO's R/V in 2021 so far (the figure will be updated in 2022).

There were 435 bottom trawls conducted by TINRO's R/V in 2020 (Fig. 3).

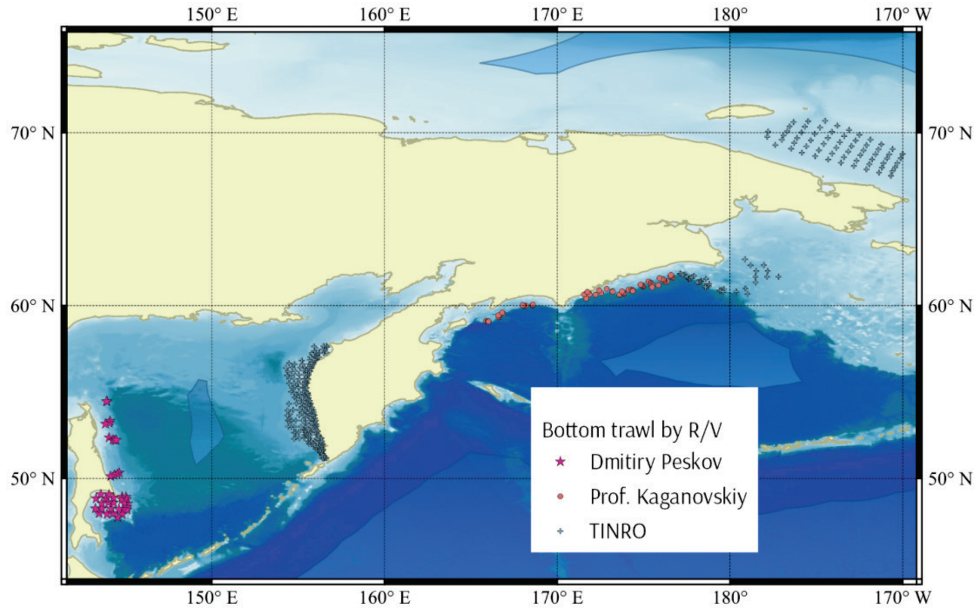


Fig. 3. Bottom trawls conducted by TINRO's R/V in 2020

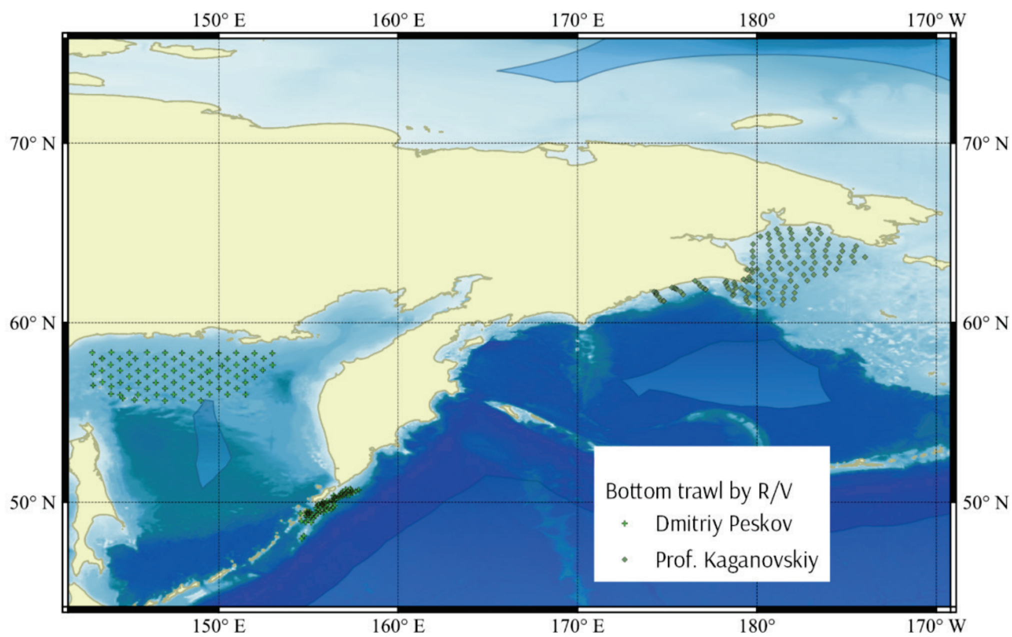


Fig. 4. Bottom trawls conducted by TINRO's R/V in 2021, which have been processed so far (the figure will be updated in 2022).

In 2021 the Division for fishing statistics and databases has processed fully only 2 surveys with 284 bottom trawls (Fig. 4). Other surveys are in progress or have not been processed yet.