2022 Report of MONITOR Committee

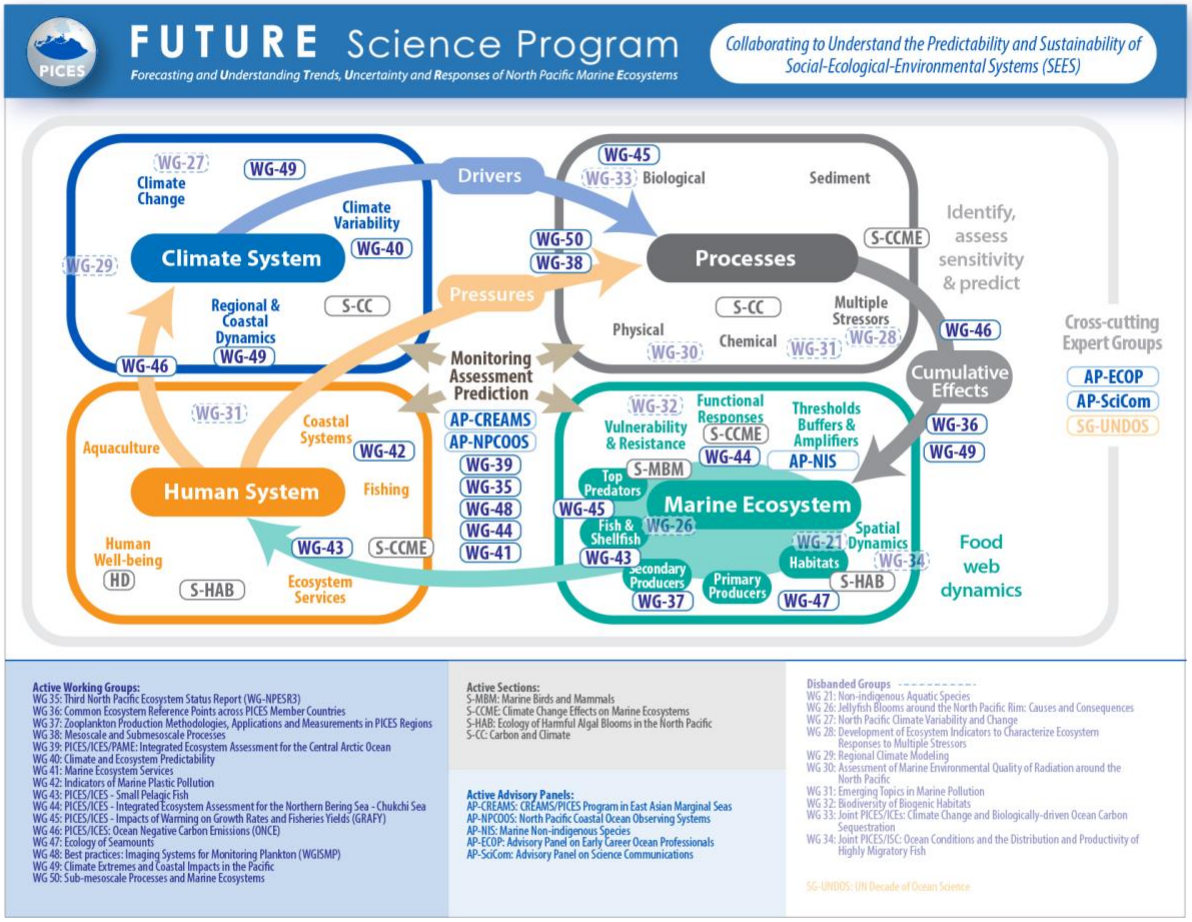
The Technical Committee MONITOR has two-day business meetings in September 25 and 28, 2022 in Busan, Republic of Korea and virtual. The MONITOR Chair, Prof. Sung Yong Kim called the meeting to order, participants will introduce themselves, and the agenda will be reviewed and adopted.

AGENDA ITEM 2: UPDATES FROM THE INTERSESSIONAL SCIENCE BOARD

1. MONITOR
    a. Discussion on future of FUTURE (+ SB/FUTURE SSC in Aug.)
        i. Refocus/engage/maintain FUTURE [*Phase III*/ECOPs/as it is]
    b. POMA/Zhu-Peterson Awards decision
    c. Requested to review "Action Plans" of individual committees (done in 2020)
    d. Expert Group proposals
        i. AP-UNDOS: Advisory Panel on United Nations Decade of Ocean Science
        ii. SG-GREEN: Study Group on Generating Recommendations to Encourage Environmentally- Responsible Networking
        iii. WG on Human Networks to Power Sustainability
    e. PICES Annual Meeting 2023
        i. Title: Connecting Science and Communities for Sustainable Seas
        ii. Venue and dates: Seattle (Oct. 23-27)
    f. New member(s): Dr. Hea-Kun Jung (Korea)

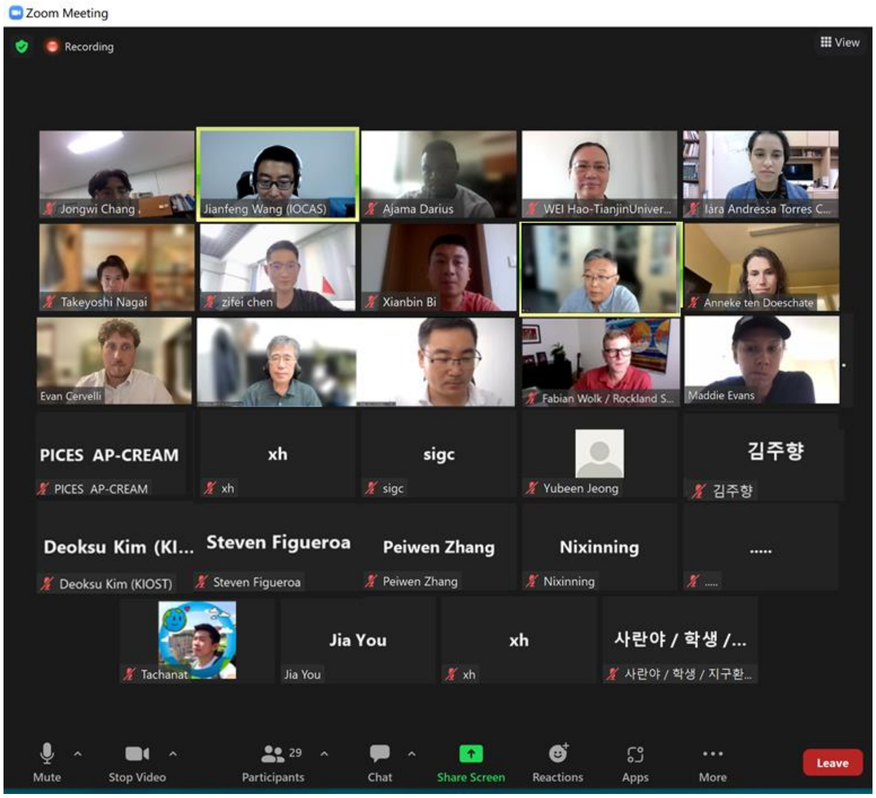
AGENDA ITEM 3: UPDATES FROM PICES EXPERT GROUPS

1. Activities of FUTURE: Slava Lobanov
    - FUTURE product matrix is underway and all current expert groups are requested to fill out the matrix based on the expert groups' activities; FUTURE is preparing a peer-reviewed journal based on questions addressed by FUTURE, gaps in FUTURE science, and implication for large-scale science programs
    - New version of FUTURE schematic



- FUTURE Open Science Meeting: Expected at Hawaii in Spring 2024 with themes of 'FUTURE of PICES science' reviewing FUTURE accomplishemtns/plans and strategizing about next phase of PICES flagship science program
- Discussion on future of FUTURE (+ SB/FUTURE SSC in Aug.): Refocus/engage/maintain FUTURE [*Phase III*/ECOPs/as it is]

2. Activities of AP-CREAMS: Slava Lobanov
   - Developement of AP-CREAMS Webpage
   - Collaboration with IMBER Coninentla Margin WG and WESTPAC
   - 2023 PICES Annual Meeting Workshop Proposal submitted; Changing social-ecological-environmental system of the North East Asian Marginal Seas: new challenges for integrative marine science
   - 2022 Virtual Summer School on Ocean Turbulence: From observing to research (August 22-26, 222) hosted by IOCAS
   - 25 reginstered students including six PICES member countries, and Mozambique, Thailand, India and Peru



3. Activities of AP-NPCOOS: Sung Yong Kim
   - 2022 Virtual Summer school on Ocean Big Data (August 8-19, 2022) hosted by ONC
   - Recorded lectures and instruction modules, group projects, and final presentation (2 weeks)
   - Data analysis on regional observational data sets: gliders, high-frequency radars (WERA, CODAR), hydrographic lines, and station P
   - 27 registered participants (Canada 7, Korea 5, China 4, USA 4, Japan 2, Russia 1, other countries 4)
   - 25 participants completed (92.5%)
   - 25 teaching staff, 7 group projects (there are two groups for a single lecturer), average 4 sutdents for a group (3 min, 5 max); 8.5 hours recoreded lectures;
   - Chanllenges on discussion due to time zone difference; scope and duration suggestion (reduce the scope or increae the duration), recored lectures are helpful.

AGENDA ITEM 5: OTHER BUSINESS

1. POMA recruitment and announcement

With given eligibility of POMA, applications with new technologies and existing applications with minor improvement for strategic purposes are recommended.

Recipients may include, for example, research vessels, research or administrative institutes or portions thereof, or technical groups involved in monitoring, data management, and dissemination, or the development of tools or technologies that enhance ocean monitoring, or a combination of these activities. Outstanding individual efforts may also be recognized (Excerpt from Eligibility of POMA).

2. Summer school for local and regional marine-related users

To provide and help fishermen, indigenous people, beach goers with observations and ocean data; proposed from MONITOR; need to find potential connections with WG44 outcomes; targeting 2025 between consecutive AP-NPCOOS summer schools.

AGENDA ITEM 7: CHAIR AND VICE-CHAIR OF MONITOR COMMITTEE VOTING

Sung Yong Kim was elected as the MONITOR Chair for his 2nd term (2022-2025) and Kym Jacobson was elected as the MONITOR vice-chair for her 1st term (2022-2025) under Sanae Chiba's guidance.

AGENDA ITEM 8: REVIEW

For 2023 PICES Annual Meeting, 16 session and 11 workshop proposals were submitted and have been reviewed by committee members based on the following criteria – (1) Relevance to PICES 2023 Scope, (2) Quality of proposal, and (3) Do your Committee Sponsors this proposal? Title: Connecting Science and Communities for Sustainable Seas

Scope: PICES-2023 occurs just a few years into the United Nations Decade of Ocean Science for Sustainable Development and is a chance to assess PICES progress to date and set a path for the rest of the Decade. The meeting will focus on developing and strengthening PICES diverse partnerships, building on existing joint activities and promoting cross-fertilization. Priorities for PICES within the Decade focus on climate change, fisheries and ecosystem-based management, social, ecological and environmental dynamics of marine systems, coastal communities, traditional ecological knowledge and human dimensions. Opportunities to engage new partners, especially around the cross-cutting themes of Early Career Ocean Professionals, diverse communities, and engaging with local and Indigenous communities are especially encouraged.

1. Sessions

4 sessions were recommended out of 16 session proposals, including comments on merging of similar and related sessions and on ocean observations/monitoring related topics

2. Workshops

4 sessions were recommended out of 11 session proposals, including comments on merging of similar and related sessions and on ocean observations/monitoring related topics

AGENDA ITEM 10: UPDATES FROM INTERNATIONAL ORGANIZATIONS

1. Activities of the CPR: Clare Ostle

North Pacific CPR Survey:

This year marks the 23rd consecutive year of data collection, the figure below (figure 1) shows the sample coverage:

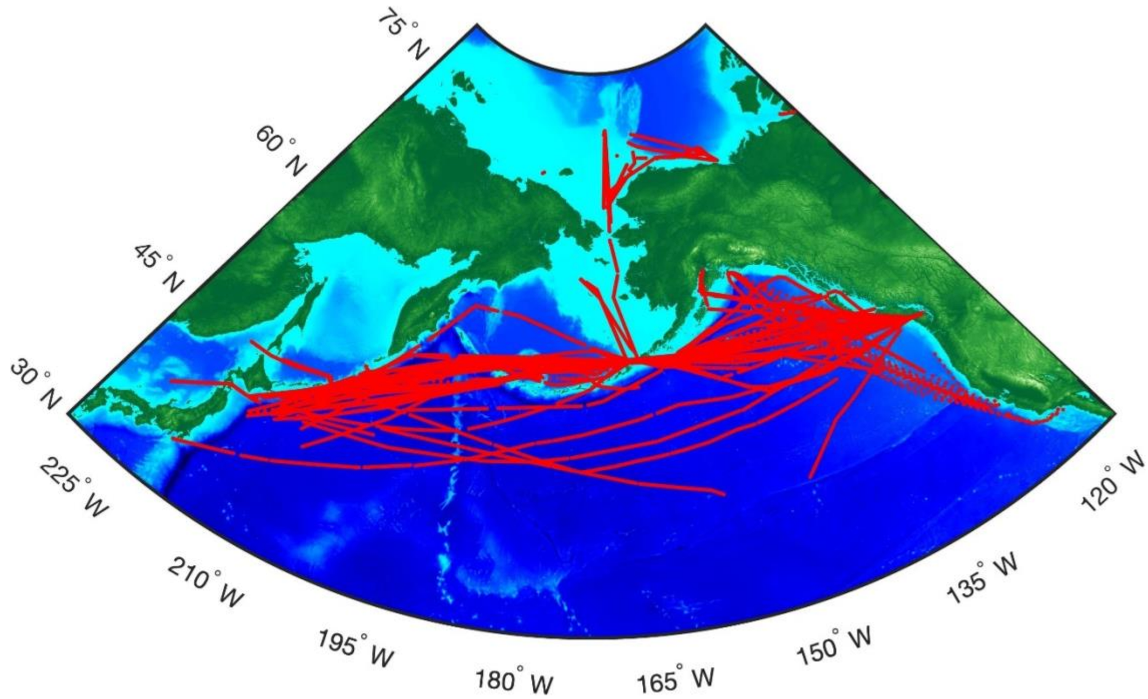


Figure 1. CPR sample locations in red (2000-2022). Please note samples often overlap, and there are additional transects to be added to the figure for 2022 once sample processing has been completed.

Funding remains consistent, although there has been a 5 month delay in the funding provided by the Exxon Valdez Oil Spill Trustee Council due to starting a new 10-year funding contract. Unfortunately, two of our ships of opportunity (the APL Qingdao - east to west transect, and the MV Kodiak - north to south transect) had to go into dry-dock for maintenance in July 2022. 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. The CPR survey managed to sample the east-west transect in March and April, and the north-south transect from March-June this year before the vessels were taken into dry-dock. Due to uncertainty surrounding the maintenance schedule of the APL Qingdao we have decided to fit a CPR tow hitch to a new vessel (the MV TITAN), in order to tow the east-west transect. We plan to tow another east-west transect towards the end of September 2022 once the MV TITAN crew have been trained and the ship has been fitted with a tow hitch to tow a CPR.

We have recently been collaborating with Robert Naviaux's lab (UCSD School of medicine) to investigate the use of North Pacific CPR samples to create a time-series of pollutants generated using exposomics (Li et al., (in prep)). We have also sent two next generation PlankTag sensors that measure temperature, salinity, and fluorescence to the CPR technicians based in Sidney British Columbia, which we plan to deploy on the east-west transect of the Pacific CPR Survey in 2023.

As well as the regular Pacific CPR sampling, the Canadian icebreaker Sir Wilfrid Laurier (SWL) has now sampled the Bering shelf and in the western Chukchi and Beaufort Sea during the summer months of 2018-2021 (Figure 2). The SWL is currently towing a CPR in the same region for 2022. These Arctic routes have been funded via annual research bursary schemes that have 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).

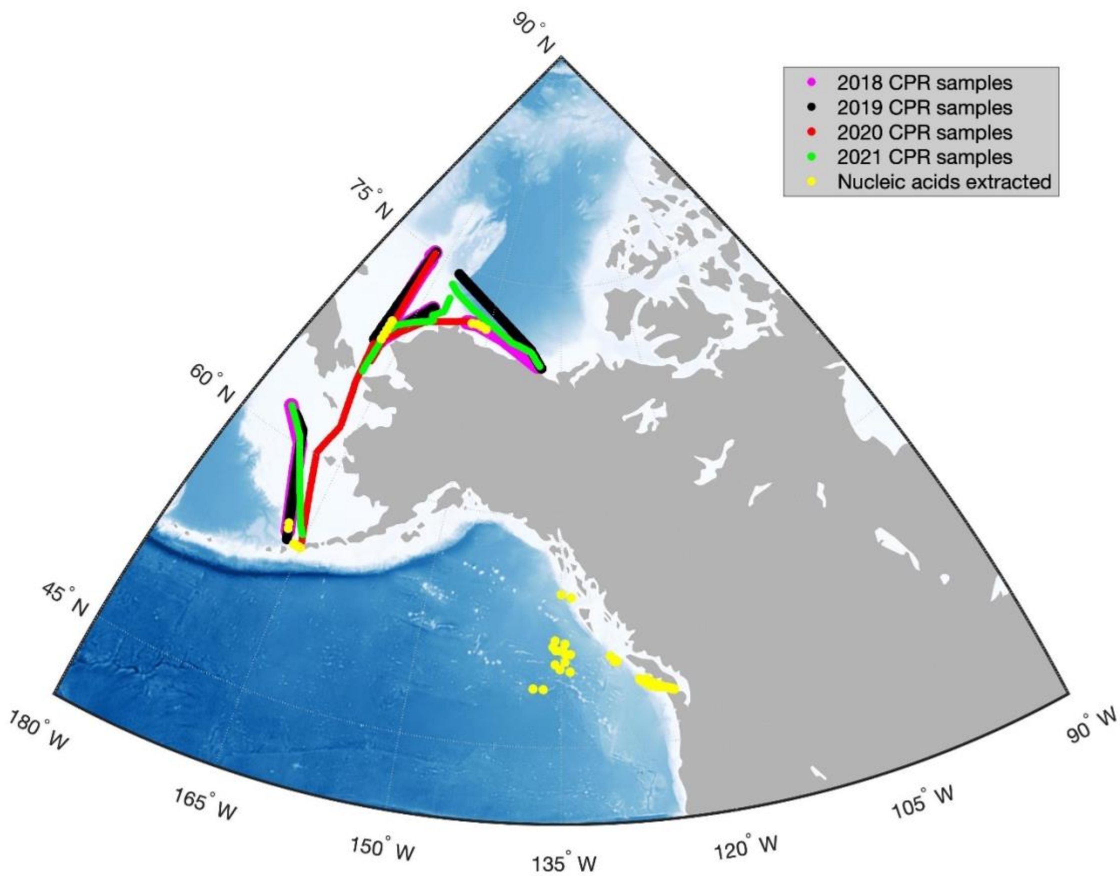


Figure 2. CPR samples collected from the CCGS Sir Wilfrid Laurier in 2018 (pink), 2019 (black), 2020 (red) and 2021 (green). Yellow dots are where nucleic acids have been extracted from CPR samples for genetic analyses.

Recent publications, reports and articles:

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. D., C. Ostle, P. Hélaouët, and A. W. Walne. 2022. Responses of Gulf of Alaska plankton communities to a marine heat wave. Deep Sea Research Part II: Topical Studies in Oceanography 195:105002.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

Li K., J. C. Naviaux, S. S. Lingampelly, L. Wang., J. M. Monk., S. Batten, C. Ostle, C. M. Taylor, D. Moore, R. K. Naviaux. (in prep) Historical biomonitoring of pollution trends in the North Pacific using archived samples from the Continuous Plankton Recorder project.

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.

Ostle, C., and Batten, S. (submitted.) NOAA Ecosystem Status Report 2022: Continuous Plankton Recorder Data from the Aleutian Islands and Southern Bering Sea: Lower Trophic Levels in 2021.

Ostle, C., and Batten, S. (submitted.) NOAA Highlight Report 2022: Continuous Plankton Recorder Data from the Eastern Bering Sea: Lower Trophic Levels in 2021.

Ostle, C., and Batten, S. (submitted.) NOAA Ecosystem Status Report 2022: Continuous Plankton Recorder Data from the Gulf of Alaska: Lower Trophic Levels in 2021.

Suryan, R. M., et al., (2021). Ecosystem response persists after a prolonged marine heatwave. Scientific Reports.

2. Activities of the U.S. IOOS and OOI: Jack Barth

U.S. Integrated Ocean Observing System, IOOS (NOAA), 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 2021-2022. We were pleased that some funds to buy equipment were received by IOOS from the U.S. infrastructure bill. The U.S. west coast IOOS includes the regional association for waters off 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. 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).

The U.S. west coast IOOS also includes the regional association for waters off northern and central California, namely the Central and Northern California Ocean Observing System (CeNCOOS, https://www.cencoos.org/). One notable achievement this last year is that CeNCOOS has coordinated with the regional association to the south, the Southern California Coastal Ocean Observing System (SCCOOS) to create a data portal for all of California waters: https://data.caloos.org/. CeNCOOS continues to support and expand a set of In-Situ Flow Cytobots (IFCBs), optical plankton cameras for the study of plankton communities and especially those that contribute to Harmful Algal Blooms, mounted on piers along the California coastline. CeNCOOS is also playing a leadership role in expanding the Marine Biodiversity Observation Network (https://www.tos.org/oceanography/issue/volume-34-issue-02).

U. S. National Science Foundation's Ocean Observatories Initiative (OOI)

The Ocean Observatories Initiative (OOI) is a science-driven ocean observing network that delivers real-time data from more than 800 instruments to address critical science questions regarding the world's ocean. The OOI instrument arrays off the coasts of Oregon and Washington started delivery data in 2014 and the system has been renewed for another five years from 2022-2027. OOI data are freely available online to anyone with an Internet connection (https://oceanobservatories.org). Data can be explored and downloaded from: https://dataexplorer.oceanobservatories.org/. There are five arrays of platforms collecting continuous data including three in the Northeast Pacific: Endurance coastal array off the coasts of Oregon and Washington; Regional cabled array including Axial Seamount and Hydrate Ridge; Ocean Station Papa.

There are 800 instruments deployed, 36 different types measuring more than 200 parameters. The instruments are deployed on 80+ platforms consisting of cabled and uncabled moorings, cabled instruments, and autonomous vehicles. To date, there were 287 million requests for data, 90 terabytes of data provided including 119 billion rows of data stored.

In the second half of 2021 into 2022, the OOI team conducted the following cruises to maintain the OOI observing arrays:

Endurance Array off Oregon and Washington

- 6 Sep - 23 Sep 2021 aboard the *R/V Thomas G. Thompson* (Newport, Oregon - Newport)
- 21 Mar - 2 Apr 2022 aboard the *R/V Sikuliaq* (Newport - Newport)
- 21 Sep - 6 Oct 2022 aboard the *R/V Thomas G. Thompson* (Newport - Newport)

Regional Cabled Observatory

- 30 Jul - 3 Sep 2021 aboard the *R/V Thomas G. Thompson* (Seattle, Washington - Newport)
- 8 Aug - 16 Sep 2022 aboard the *R/V Thomas G. Thompson* (Seattle - Newport)

Station Papa

- 18 Jul - 2 Aug 2021 aboard the *R/V Sikuliaq* (Seward, Alaska - Seward)
- 12 May - 1 Jun 2022 aboard the *R/V Sikuliaq* (Seward - Seattle)

3. Activities of the NPRB: Matthew Baker

- Title: NPRB's Investments in longterm monitoring – application of time series data and ecosystem indices to improve understanding of marine ecosystems and inform fishery management

- The North Pacific Research Board (NPRB) views monitoring as a key component to furthering comprehensive understanding of marine ecosystems and processes and to inform fishery management. NPRB Long-term Monitoring (LTM) Program has supported a series of projects designed to provide time series data that track ecosystem variability and the effect of this variability on marine resources. The overall goal is to support new or existing time-series research that enhances our ability to understand the current state of the marine ecosystem and predict future states, including ecosystem responses to changing ocean conditions. NPRB currently supports three LTM projects.

- The continuous plankton recorder (CPR) leverages ships of opportunity to survey production indices, and plankton community abundance and composition across main trade and transportation routes. Understanding variability in plankton helps to inform our understanding of system production, timing and spatial processes. With NPRB's funding contribution, the CPR survey will continue sampling along two paths through the North Pacific, as well as a potential new route through the Bering Strait. Annual updates (data and text) are provided to the NOAA Ecosystem Status Reports for the Bering Sea, Aleutian Islands and Gulf of Alaska regions, as well as the Fisheries and Oceans Canada report on the State of the Pacific Ocean. Time series from several regions have been contributed to the PICES Ecosystem Status Report III. The Chukchi Sea Oceanographic Mooring Array (CEO) provides data that improves understanding the underlying dynamics of the ecosystem with relevance to subsistence resources and potential commercial fisheries. The moorings use a broad suite of sensors to measure the physical environment and plankton community, which enable researchers to observe and understand seasonally and inter-annually varying environmental conditions. This data informs the NOAA Ecosystem Status Report for the Arctic and Arctic report card. The Seward Line Survey maintains a transect and series of oceanographic stations across the Gulf of Alaska to develop baseline data and examine seasonal and inter-annual variation in physical and chemical oceanographic processes and the distribution and abundance of plankton. These data are incorporated in NOAA's annual Gulf Ecosystem Status Report.

- NPRB also engages in collaborative partnerships with other entities engaged in monitoring programs including the North Pacific Anadromous Fish Commission to study the winter ecology of salmon in the North Pacific Ocean. This effort includes scientists from Canada, Japan, the Republic of Korea, the Russian Federation, and the United States continue their research on the winter ecology of Pacific salmon in the North Pacific. It includes pelagic trawling and detailed sampling of marine life in the upper ocean and will include research on physical, biological and chemical oceanography. NPRB serves on the steering committee for this project and has informed discussions in workshops on a conceptual model on salmon survival and life history, winter ecology of Pacific salmon and oceanic distribution and data mobilization. NPRB is also helping to inform the development of a Science Plan for the Basin Events to Coastal Impacts (BECI) project. This aims to develop an international ocean intelligence system of monitoring, research and analytical approaches that provide advice to decision makers regarding the impact of current and future ocean conditions from the high seas to coastal systems. Also, NPRB is supporting the Indigenous Sentinels Network in the Aleut community of St. Paul, Alaska. This work provides remote, indigenous communities with tools, training, networking and convening, coordination, and capacity for ecological, environmental, and climate monitoring.

This program provides local monitoring in the Pribilof Islands and Aleutian Islands as well as the Yukon River drainage and communities in the Arctic. This work aims to fill critical data gaps in local processes, provide baseline assessments, and enhance climate adaptation strategies. Data and products include archival, query tools, access through apps and consultation and maintenance of intellectual property rights within each participating community.

AGENDA ITEM 12: NATIONAL REPORTS

See Endnote 3

AGENDA ITEM 13: OTHER BUSINESS

1. Discussion

- The Chair recapitulated the DAY1 discussion on POMA and Summer school for indigenous community;
- The committee members agreed to understand the status of Chinese delegates' attendance in other committees as our Chinese MONITOR committee members have been absent for three consecutive years (2020, 2021, and 2022); The Chair has reported the given situation to SB and Executive Secretary, and they have been aware of situation; The Chair will contact a primary contact of Chinese national delegates (e.g., Fangli) to encourage them to attend the MONITOR business meetings;
- A suggestion on business meeting format: We can use in-person meetings on Sunday and Wednesday in an effective and wise way (e.g., workshops on ocean sciences and technologies related to ocean monitoring and observations) if we could allocate regular online meetings for updates and reports that we have done in in-person meeting;
- 2023 PICES Annual meeting is held at Seattle, USA
- Suggestion for the information in the MONITOR reports to made more easily accessible to the general scientific community, perhaps with assistance from the new AP-SciCOM chaired by Tammy Nograd (Canada) who was in attendance at the MONITOR meeting.

Endnote 1

MONITOR participation list

Members

[in person]
Sung Yong Kim (Korea, Chair) [for Committee reports]
Lisa Eisner (USA, Vice-Chair)
Vyacheslav B. Lobanov (Russia)
Hea Kun Jung (Korea)
Hiroto Abe (Japan)
Kazuaki Tadokoro (Japan)
Jack Barth (USA)

[virtual]
Jennifer L. Boldt (Canada)
Minoru Kitamura (Japan)
Eunho Jung (Korea),

Members unable to attend

Canada: Tetjana Ross
China: Honghui Huang, Zhifeng Zhang, Xianyong Zhao
Japan :
Korea :
Russia: Vladimir Kulik
USA: Kym Jacobson

Observers

Matthew Baker (USA) [for NPRB report]
Tammy Nograd (Canada)

PICES
Sanae Chiba [for Chair/Vice-Chair election]

Endnote 2

MONITOR meeting agenda

Day 1: September 25, 2022 18:00-19:20 (KST; *Note: times may shift*)

1. 18:00-18:10 Welcome, Introductions, and Sign-in [10 mins]
2. 18:10-18:20 PICES-2022 issues: Updates from ISB [10 mins]
3. 18:20-18:50 Updates from PICES Groups [30 mins]
    a. 18:20-18:30 Activities of FUTURE: Lobanov [10 mins]
    b. 18:30-18:40 Activities of AP-CREAMS: Lobanov [10 mins]
    c. 18:40-18:50 Activities of AP-NPCOOS: Kim [10 mins]
4. 18:50-19:00 Break [10 mins]
5. 19:00-19:20 Other business [20 mins]
    a. 19:00:19:20 Discussion on potential POMA award candidates and other issues [20 mins]

Day2: September 28, 2022 14:00-17:10 (KST; *Note: times may shift*) and 18:30-20:30

6. 14:00-14:05 Welcome, Introductions, and Sign-in [5 mins]
7. 14:05-14:25 Chair and vice-Chair voting [20 mins]
8. 14:25-14:50 Review [20 mins]
   Review of Proposals for PICES-2023 support for topic sessions, workshops, and inter-sessional workshops
9. 14:50-15:00 Break [10 mins]
10. 15:00-15:50 Relations with international organizations [50 mins]
    a. 15:00-15:10 Activities of the CPR: Ostle [10 mins]
    b. 15:10-15:20 Activities of the USOOI/NaNOOS: Barth [10 mins]
    c. 15:30-15:40 Activities of the NPRB: Baker [10 mins]
11. 15:50-16:00 Break [10 mins]
12. 16:00-17:00 National reports – Written and Oral [60 mins]
    Written: Please provide national reports prior to the PICES meeting. Include relevant monitoring activities for relevant years. Written reports will be posted to the PICES web page.
    Oral: Please include highlights and updates in national reports of relevant monitor/observation activities from the last year. PowerPoint presentations will be posted to the PICES web page.
    The presentation will be given in a random order this year:
    - Canada Boldt, Ross
    - Japan Kitamura, Tadokoro, Abe
    - Korea Kim, HK Jung, E Jung
    - Russia Kulik, Lobanov
    - United States Barth, Eisner, Jacobson
    - China Huang, Zhao, Zhang

13. 17:00-17:10 Other business [10 mins]
14. 18:30-20:30 Dinner [120 mins] (*Note the venue and ways to get the restaurant*)

Endnote 3

National Reports[1]

1. Canada

I. Overview and Summary of 2021

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 2022 (for conditions in 2021) is available at:

https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41067113.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. (2022).

Below is the overview and summary from that report, with the same Figure and Section numbers as in the report (Boldt et al. 2022):

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

Climate change continues to be a dominant pressure acting on Northeast (NE) Pacific marine ecosystems. B.C. air temperatures continued to increase (1950-2021) and set new all-time high records across southern B.C. in June 2021 (Anslow and Sobie, Section 6). This led to severe drought in southern B.C. in July-September before shifting to record wet conditions in the fall, with extreme flooding during November (Anslow and Sobie, Section 6). In 2021, river discharge in southern B.C. was greater than normal, but was close to average in northern B.C. (Anslow and Sobie, Section 6; Chandler, Section 10). In 2021, strong negative Pacific Decadal Oscillation (PDO) and La Niña conditions, that typically result in below average Sea Surface Temperatures (SSTs), were juxtaposed onto a background of long-term climate warming, resulting in near average SSTs in the NE Pacific (Ross and Robert, Section 7; Figures 3-1 and 3-2). The average annual SST, collected at shore stations along the B.C. coast, was cooler than 2020 but was still a continuation of the warm period that started in 2014 (Chandler, Section 10). Overlying multi-year oscillations in the annual SST, there is a long-term trend towards rising ocean temperatures of 0.87°C over the last 100 years (Figure 3-3; Chandler, Section 10). Surface waters in the NE Pacific were anomalously fresh in 2021; this continues a freshening trend observed for the last five years (Ross and Robert, Section 7). 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 31). In spring 2021, marine CO_2 conditions in the northern Salish Sea improved compared to 2018-2020, but returned to more corrosive and low pH conditions for the remainder of the year (Evans, Section 31).

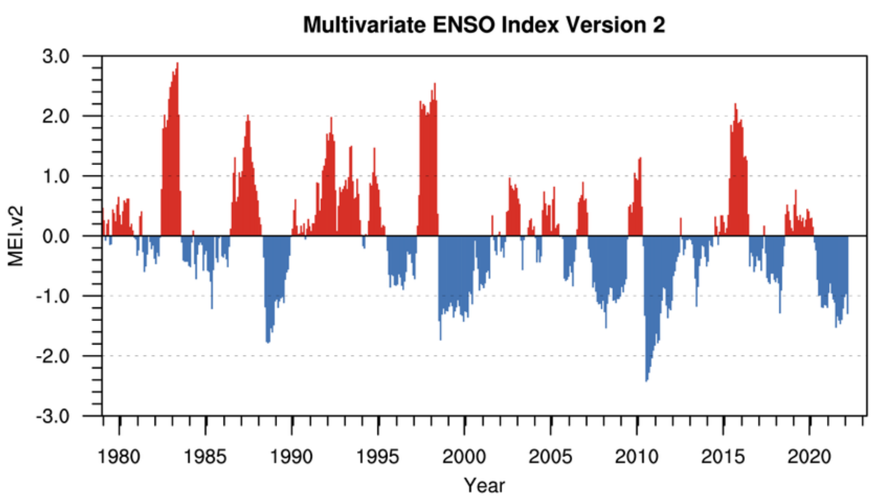


Figure 3-1. The multivariate ENSO Index. Data source: NOAA/ESRL/Physical Sciences Division – University of Colorado at Boulder/CIRES; https://psl.noaa.gov/enso/mei/

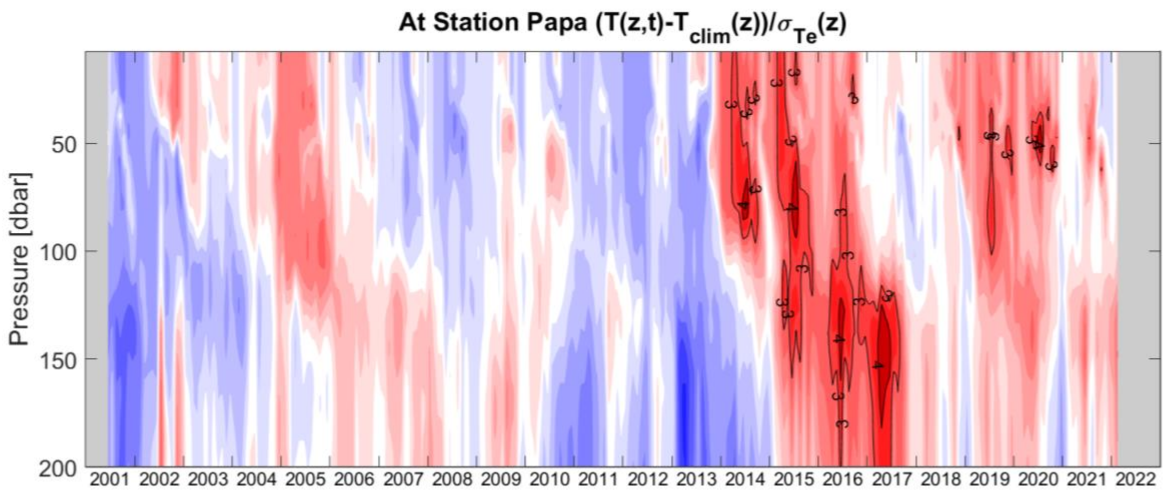


Figure 3-2. Plot of temperature anomalies relative to the 1956-2012 seasonally-corrected mean and standard deviation (from the Line P time series), as observed by Argo floats near Ocean Station Papa (P26: 5° N, 145° W). The cool colours indicate cooler than average temperatures and warm colours indicate warmer than 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.

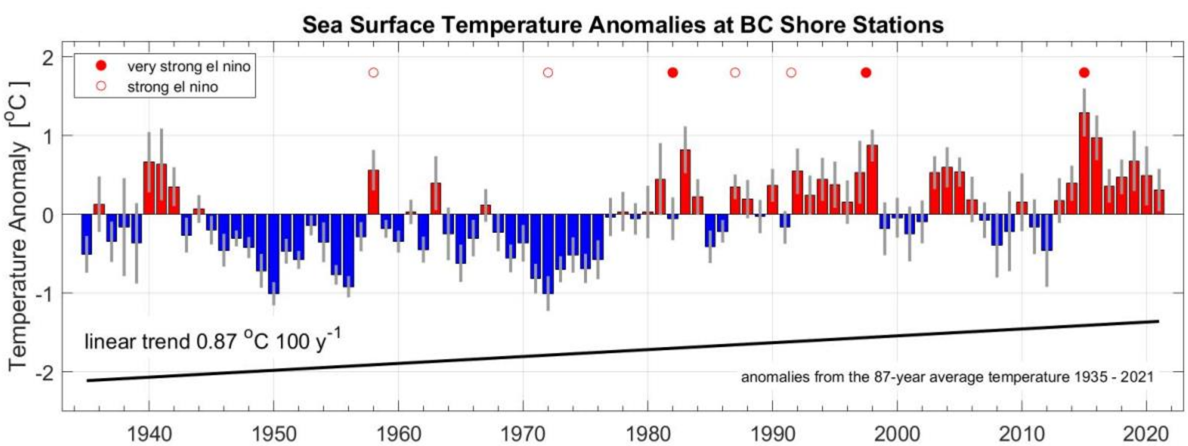


Figure 3-3. The trend in the annual temperature based on the observations of all lighthouses. Data shown are anomalies from the long-term average temperature (1935-2021). Bars represent the anomalies averaged over all stations (a coast wide indicator), (red – above average, blue – below average), vertical grey lines show the variability in the lighthouse data for each year. Source: Chandler, Section 10.

Multiple marine heatwaves (MHWs) were identified in the NE Pacific in 2021; the largest MHW areas remained offshore in the open ocean for much of the year. There was a short-lived MHW on the shelf during the atmospheric heatwave event (the "Heat Dome", June 25 to July 1; Hilborn and Hannah, Section 11).

The size, intensity, and frequency of MHWs in the NE Pacific is increasing (Hilborn and Hannah, Section 11).

Marine heatwaves are associated with reduced vertical mixing, which causes increased winter stratification. This results in decreased nutrient supply from deep to surface offshore waters. Mixing in the winter of 2020/21 was closer to normal than the previous two years, suggesting normal surface nutrient levels in the spring of 2021 (Figure 3-4; Ross and Robert, Section 7).

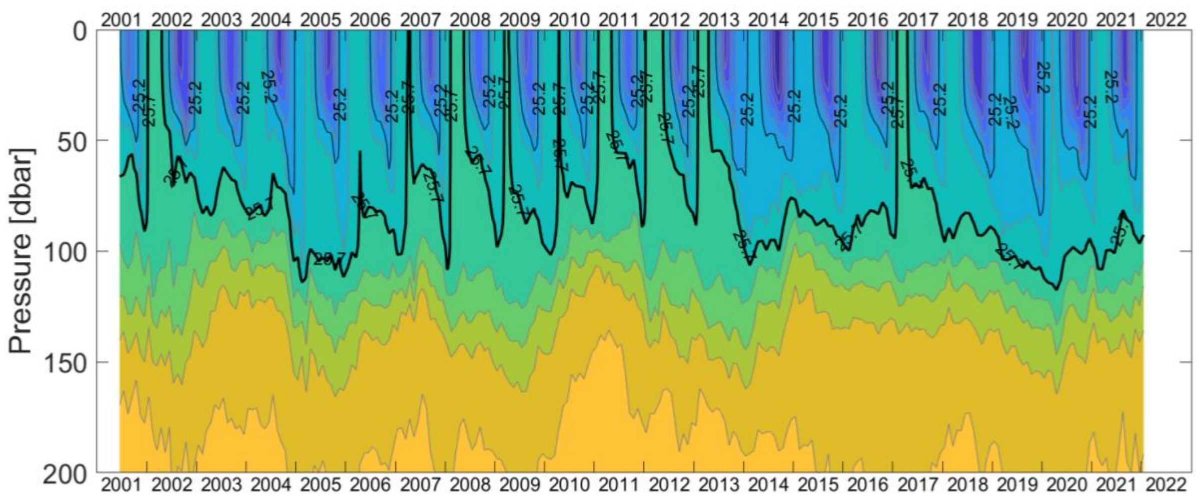


Figure 3-4. Coloured contour plot of density as observed by Argo floats near Ocean Station Papa (P26: 50^{o} N, 145 ^{o} W). The colours indicate potential density (yellow is denser and blue lighter). Black lines highlight the s_q 25.2 kg/m^3 (thin) and 25.7 kg/ m^3 (thick) isopycnals. Source: Ross and 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. The 2021 spring transition timing of upwelling was early and the magnitude of summer upwelling was near the long-term average, resulting in an expectation of average to above average productivity (Hourston and Thomson, Section 8; Dewey et al., Section 33; Figure 3-5).

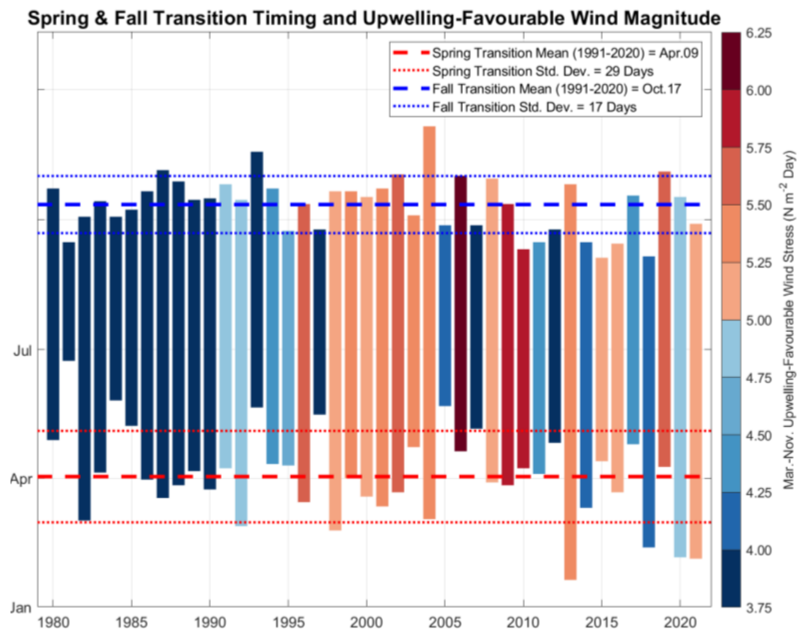


Figure 3-5. Annual spring and fall transition timing and March-November upwelling-favourable wind stress magnitude, 1980-2021. Bold dashed lines indicate the average spring (red) and fall (blue) transition dates. Light-dashed lines indicate standard deviations of the spring (red) and fall (blue) transition dates. Source: Roy Hourston, Section 8.

Persistent upwelling, particularly along the southern Vancouver Island continental slope, brought California undercurrent source waters onto the shelf, supplying nutrients and saline water to surface waters and extending deep, oxygen-poor waters over the shelf eastward (Sastri et al., Section 13; Dewey et al., Section 33). In the summer, there was a rare hypoxia event on the outer southwest shelf off the west coast of Vancouver Island; dissolved oxygen concentrations were the lowest recorded in the last 20 years. Phytoplankton communities appear to be returning to average values after the MHW (2014-2016) in the shelf region (Ostle and Batten, Section 18).

The zooplankton community also returned to average values (Galbraith and Young, Section 17; Ostle and Batten, Section 18). In 2021, there were positive biomass anomalies of boreal and subarctic copepods in most areas (Galbraith and Young, Section 17; Figure 3-6). Southern copepod anomalies were negative or close to average on the shelf and in offshore areas (Figure 3-6; Galbraith and Young, Section 17; Ostle and Batten, Section 18). Large subarctic and boreal copepods are more favourable for fish growth than small, southern copepod species.

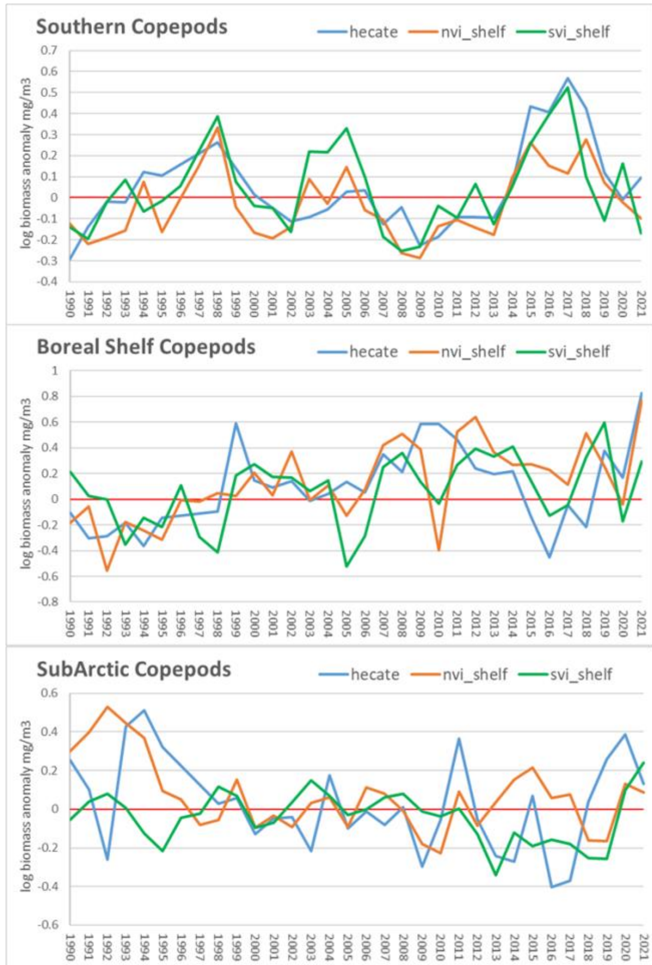


Figure 3-6. Zooplankton species-group anomaly time series. Line graphs are annual log scale anomalies. Southern Vancouver Island (SVI) green; Northern Vancouver Island (NVI) orange; Hecate Strait blue; Line P purple - for all graphs. Blank years mean no samples were collected. Source: Galbraith and Young, Section 17.

Changes to the physical environment, and phytoplankton and zooplankton communities can have impacts on higher trophic levels. Extreme heat events, such as the atmospheric heat dome of 2021, may have a long-term effect on Olympia Oyster survival and reproduction (Herder and Bureau, Section 19). The proportion and biomass of the Pacific Hake coastal migrating stock in B.C. waters was the lowest on record, despite an average year for the coast-wide total biomass (Gauthier et al., Section 25). There was an increase in the biomass of shelf rockfish, some slope rockfish, and many flatfish species in the recent 5-10 years. Arrowtooth Flounder and Pacific Spiny Dogfish biomass declined (Anderson and English, Section 24).

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 2021, the representation of *N. cristatus* in Cassin's auklet nestling diets on Triangle Island was well below what would be expected based on PDO conditions (Hipfner, Section 26). Several populations of marine mammals have shown strong recovery trends (notably humpback whales) after commercial whaling ended in 1967, and are once again important components of marine ecosystems, resulting in increased overlap with human activities and potential conflicts with fisheries (Doniol-Valcroze et al., Section 27).

In the Salish Sea, there are trends of increasing temperature and decreasing oxygen at all depths, and salinity is generally becoming fresher in surface waters and saltier at depth (Chandler, Section 32). During the spring of 2021, conditions seaward of Haro Strait were cooler, saltier, and less oxygenated than normal, while conditions in the Strait of Georgia (SOG) were near normal. In the summer, the SOG was cooler and less oxygenated than normal in the surface waters, with a warm, salty, oxygenated mid-depth layer in Juan de Fuca Strait. In the fall, there was less oxygenated water throughout the system, especially in Juan de Fuca Strait. The annual Fraser River discharge was slightly above normal in 2021, while the impact of the atmospheric river resulted in very high flows in mid-November (Figure 3-7; Chandler, Section 32) and significant freshwater discharge into the surface waters of the Salish Sea (Dewey et al., Section 33).

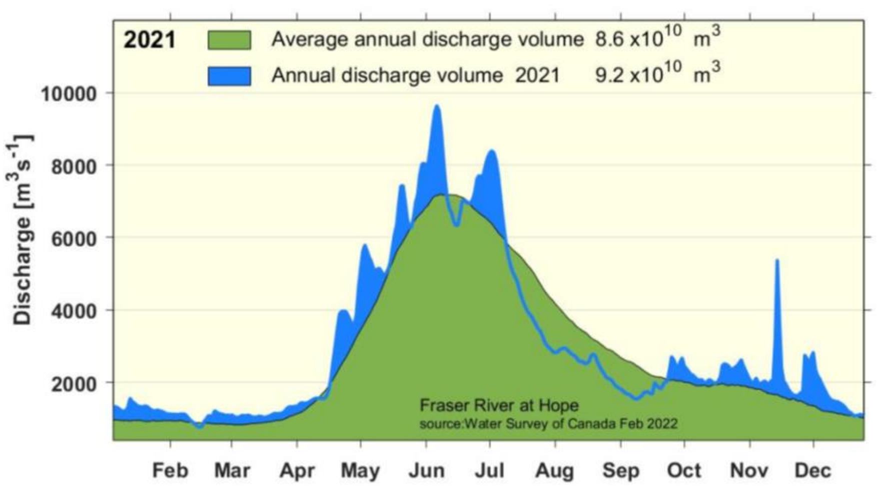


Figure 3-7. Fraser River discharge at Hope B.C.; 2021 (blue), 109-year average (green). Extracted from the Environment and Climate Change Canada Real-time Hydrometric Data web site (https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html) on 10 Feb 2022. Source: Chandler, Section 32.

In the SOG in 2021, harmful algal blooms were similar to conditions in 2016 and 2017: there were no *Heterosigma akashiwo* blooms but there were blooms of silicoflagellate *Dictyocha* in some areas in July and August, and there were summer diatom blooms of *Rhizosolenia setigera* and *Pseudo-nitzschia* spp. (Esenkulova et al., Section 35). Harmful algal blooms can cause finfish and shellfish mortalities, impacts to human health, and economic losses. Marine Aquatic Invasive Species are increasing in both range and abundance in B.C. For example, there has been an expansion of European Green Crab around Haida Gwaii and the Salish Sea (Gale et al., Section 41). This high-impact invader that negatively affects eelgrass, an important fish habitat, was detected for the first time on Haida Gwaii in July 2020 (Gale et al., Section 41). Vessel traffic introduces a variety of stressors to marine ecosystems (e.g., oil, noise, shipstrikes, etc).

Marine vessel traffic intensity, based on Automatic Identification System data from 2016-2020, varied among vessel types in the Salish Sea, however cargo vessels continue to increase in the Southern Gulf Islands and SOG (O'Hara et al., Section 42). Passenger vessel traffic intensity decreased with year, but only during the summer, and likely as a result of COVID-19 associated reduced ferry service (O'Hara et al., Section 42). Commercial vessel noise is chronic in Juan de Fuca Strait and on Swiftsure Bank; whereas, in Boundary Pass and Haro Strait, it is acute with more periodic transiting of vessels (Burnham and Vagle, Section 43).

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 moderately late compared to the long-term average (Allen and Latornell, Section 34; Dewey et al., Section 33), which implies poorer feeding conditions for juvenile fish.

In 2021, however, the SOG zooplankton biomass was above the long-term average (Young et al., Section 36). The composition of the medium and large-sized copepods, important food for juvenile salmon, was similar to 2020 (Young et al., Section 36).

Coastwide Pacific Herring biomass has been increasing since 2010, dominated by the SOG stock; however, in some assessed areas, such as Haida Gwaii, there have been prolonged periods of low biomass (Cleary et al., Section 21; Figure 3-8).

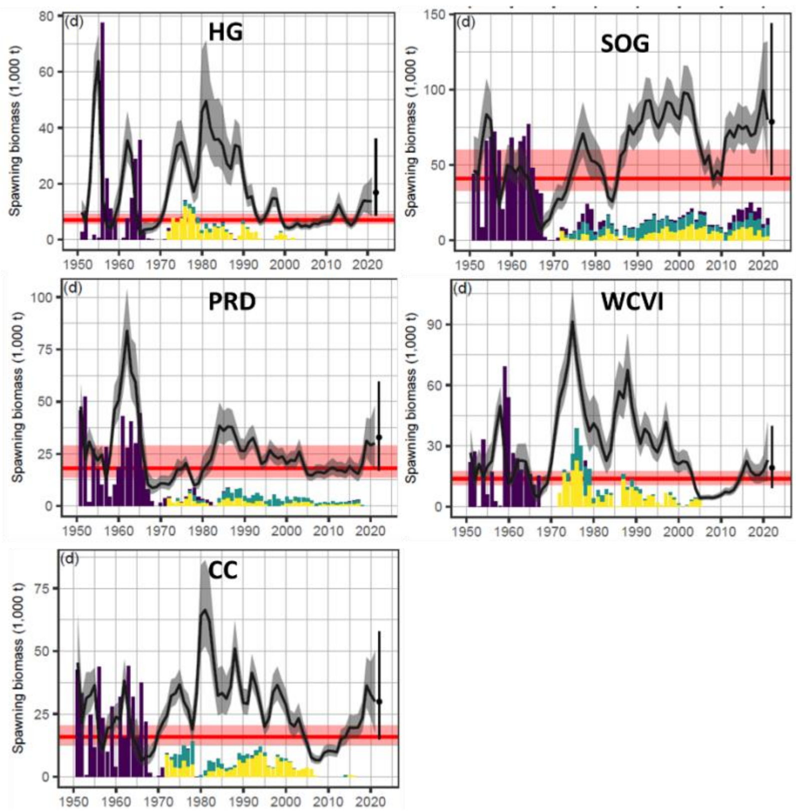


Figure 3-8. Pacific Herring spawning biomass, 1951- 2021. Black lines with surrounding grey envelopes represent medians and 5-95 % credible intervals. The projected spawning biomass given zero catch is shown at the far right (solid circle and vertical lines). Time series of thin vertical lines denote commercial catch (excluding commercial spawn-on-kelp; colours indicate different gear types; see DFO 2021). Red line = limit reference point (0.3B0). B0 = average unfished spawning biomass. Figure from DFO (2021).

In 2021, the relative biomass of age-0 Pacific Herring in the SOG was similar to that observed in 2019, but still below the time series mean and median; a very low biomass estimate of age-0 may indicate low recruitment to the adult population (Boldt et al., Section 37). In 2021, Northern Anchovy were present in 48% of the age-0 Pacific Herring survey sets; this is the second highest percentage in the time series (Boldt et al., Section 37). In 2021, the index of Fraser River Eulachon spawning stock biomass was estimated to be moderately low (~141 tonnes; Flostrand and Ens, Section 20). However, mean Eulachon catch per unit effort from a west coast of Vancouver Island multispecies bottom trawl survey was moderately high (Flostrand and Ens, Section 20). In 2021, a freshwater benthic diatom known as Didymo was confirmed to again be a major component of the material collected in the Fraser River Eulachon egg and larval survey water samples, similar to observations in 2018 and 2020 (Flostrand and Ens, Section 20). 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 for upper and lower watershed habitats and ecosystem (Flostrand and Ens, Section 20).

In the summer and fall of 2021, juvenile salmon survey indices of Coho and Chum Salmon abundance (catch per unit effort) were above average (Neville, Section 38). Also, juvenile Coho Salmon were bigger than average (Neville, Section 38). The return abundances of B.C. Sockeye Salmon indicator stocks were below the long-term average, whereas Bristol Bay Sockeye Salmon, making sea entry into the Bering Sea, Alaska, achieved record returns in 2021 (68M fish: 25% above forecast; Stiff et al., Section 22). The June atmospheric heat dome generated thermal barriers to many southern salmon stocks attempting to return to natal rivers to spawn, causing migration delays and enroute mortality (Stiff et al., Section 22). There has been a decline in the size at maturation of some Pacific salmon species. Average weights of mature Fraser River Pink Salmon have declined since the 1960s and, in 2021, were the third smallest on record (Latham et al., Section 23). Sockeye Salmon sizes have declined since the 2000s and ranked as the third and fifth lowest for 3- and 2-ocean salmon, respectively (Latham et al., Section 23).

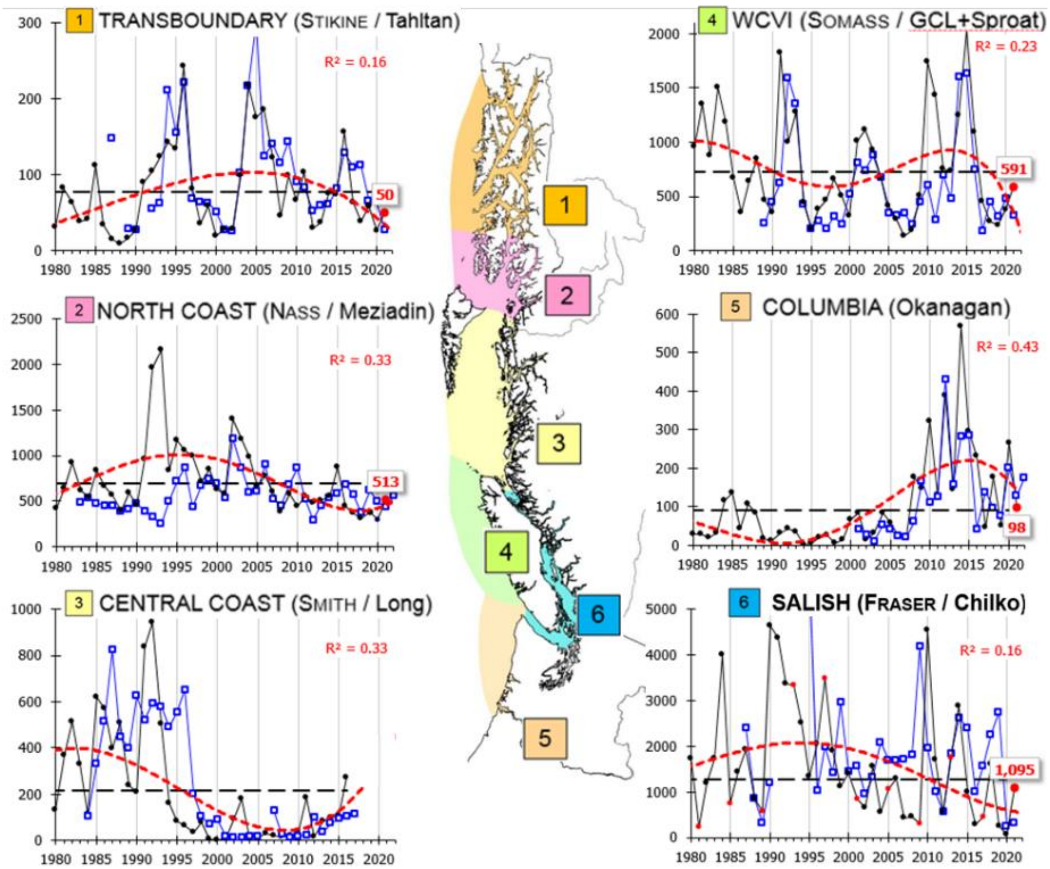


Figure 3-9. Trends in the total annual returns (black line) to 2021 (thousands of fish) and median management forecasts (blue line) to 2022 for B.C. Sockeye indicator stocks, by DOMAIN (Watershed/Management unit). Note: dashed line: 40-year average; red dashed line: quadratic fit to total returns. Source: Stiff et al., Section 22.

References

Boldt, J.L., Joyce, E., Tucker, S., and Gauthier, S. (Eds.). 2022. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2021. Can. Tech. Rep. Fish. Aquat. Sci. 3482: vii + 242 p.

DFO. 2021. Stock status update with application of management procedures for Pacific Herring (*Clupea pallasii*) in British Columbia: Status in 2021 and forecast for 2022. DFO Can. Sci. Advis. Sec. Sci. Resp. 2022/039.

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.

II. Observational programs

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

Ongoing:

1. Line P: continuing at 3 surveys/year (February, May/June, August/September), 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 multinet. Physical measurements include temperature, salinity, phytoplankton fluorescence and many chemical analyses (e.g., oxygen, nutrients).
2. 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, O2, 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 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.
3. Strait of Georgia (Fig. 1): continuing at 4 surveys per year (3 in 2021), with intensified sampling in 2010 and 2011. Areas of emphasis: hydrography and circulation, nutrients, phytoplankton, vertical flux of organic matter & contaminants.
4. 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.
5. 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.

6. 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.

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

1. 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)
2. 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.
3. 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).
4. 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.
5. 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).
6. 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:

1. 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).
2. Pacific hake acoustic survey: biennial (was triennial); west coast North America, Southern California to Dixon Entrance (1977-present).
3. Other fish surveys: sablefish (trap), lingcod (dive), rockfish (video), Pacific halibut (longline; conducted by the International Pacific Halibut Commission).
4. 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.
5. Salmon abundance (freshwater): estimates of adult salmon leaving and juvenile salmon arriving at the ocean are obtained annually in many rivers.
6. 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.
7. 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.
8. Marine mammal surveys: throughout British Columbia
    a. 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
9. 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.
10. 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.

11. 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.
12. 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.
13. 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.
14. Sea cucumber surveys: The goal is to provide biomass estimates. Survey times are 1997 – present. Month of sampling is area dependent (Feb-Sep) on 4year+ 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

1. Aquatic Invasive Species intertidal monitoring surveys: annual surveys with shifting geographic focus to eventually provide baseline information coastwide (2006-present).
2. 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:

   a.) 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).

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

   c.) 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

   d.) 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

e.) 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.

f.) 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:
   a) 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:
   a) 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.
   b) 2015 and 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

c) 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

d) 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 ~5100 kilometers, ~5300 CTD profiles and flew ~220 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 (Fig. 2):

i) Burke-o-later (BoL) for determining T, S, pCO_2 and TCO_2 in Hyacinthe Bay, near Quadra Island since 2015
ii) Multiple temperature sensors at fixed nearshore locations throughout the central coast near Calvert Island since 2015
iii) A $MApCO_2$ buoy near Calvert Island that measures S, T, surface seawater and atmospheric pCO_2, and meteorological data since 2018
iv) A cabled observatory called the Limpet has measured T, S, and oxygen at the seafloor in Hyacinthe Bay off Quadra Island since 2015
v) A string of moored temperature and salinity sensors has collected T data every 10 minutes in 10 meter intervals since 2017
vi) The Alaska Marine Highway System M/V Columbia has collected T, S, O, and seawater and atmospheric pCO_2 since 2017
vii) A 150 kHz ADCP that has measured currents in a few locations around Calvert and Quadra Islands since 2019
viii) A mooring that measures temperature, salinity and oxygen at 2 depths in Rivers Inlet since 2020
ix) Collaboration with CPROOF to deploy and recover gliders from Calvert Island since 2019.

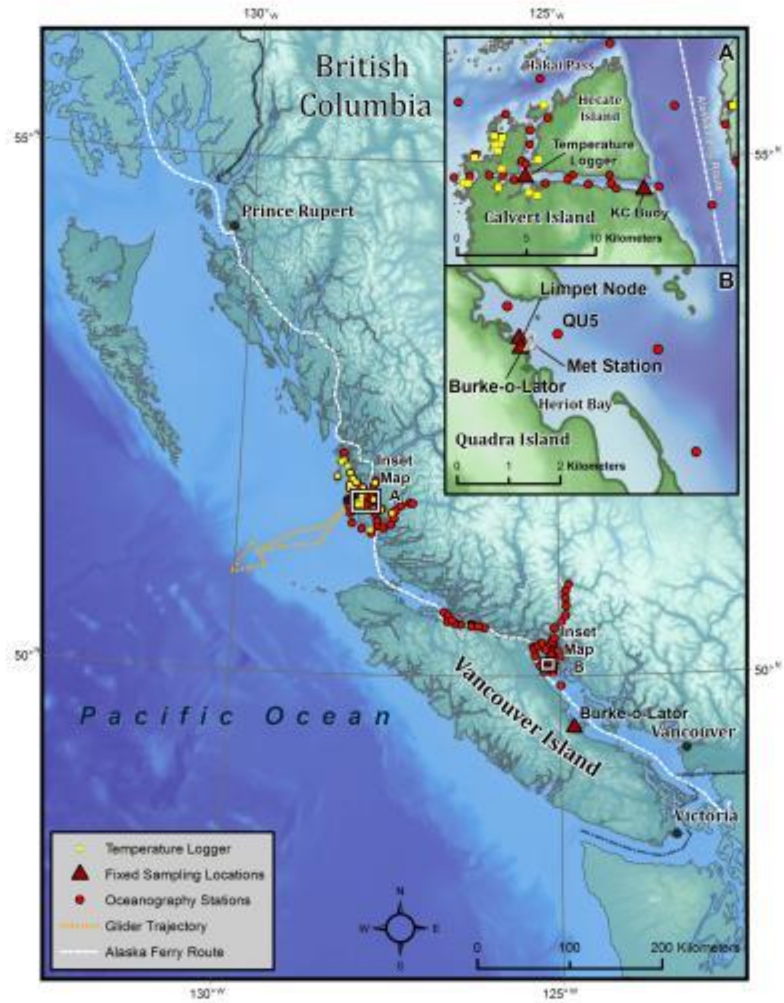


Figure 2. Locations where the Hakai Institute collects ocean data in British Columbia. Hydrographic stations (red circles) are where physical, biological and chemical measurements are made at bi-weekly to monthly frequencies. High frequency data from fixed sampling locations (red triangles) and temperature 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).

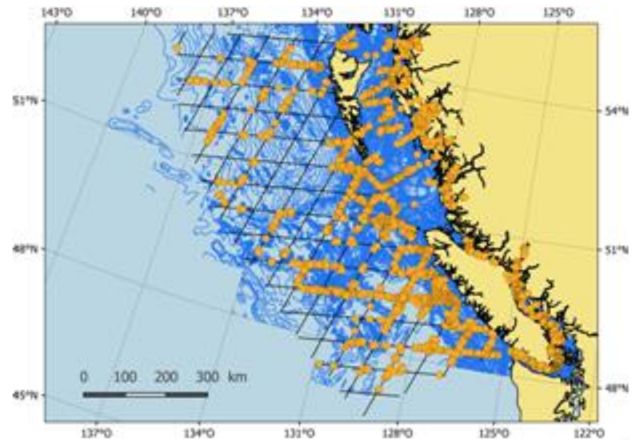


Figure 3. 2018 Pacific Region International Survey of Marine Megafauna (PRISMM). Visual and acoustic detections were made along 17,000 km of pre-determined systematic line transects. The survey resulted in over 2800 sightings of marine mammals, mostly concentrated in inshore passages and inlets, on the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

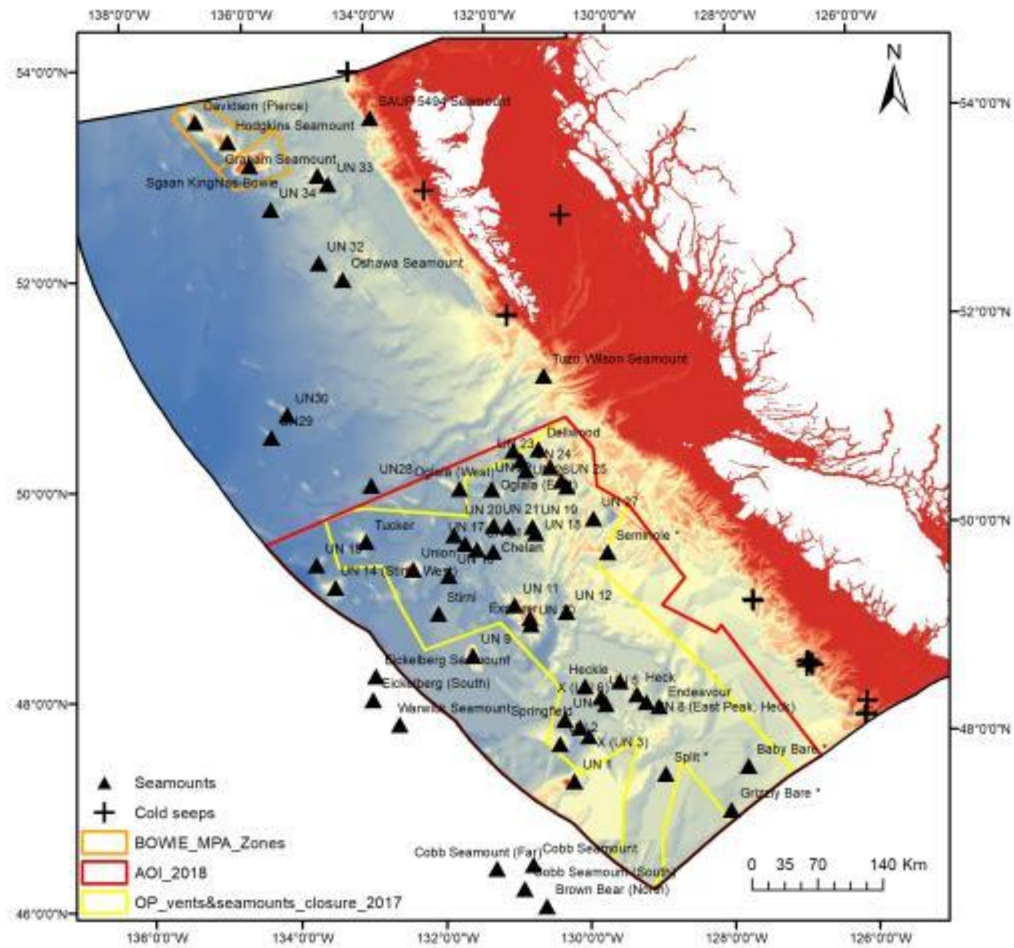


Figure 4. 2019 Survey of the Offshore Area of Interest (AOI). Source: Tammy Norgard (DFO).

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)

US Pacific west coast

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

- NOAA fishery surveys (groundfish, hake, coastal pelagics)
- Long-term hydrographic and zooplankton lines: CalCOFI (California), Newport Hydrographic (Oregon), Trinidad Head (California)
- U.S. Integrated Ocean Observing System, IOOS (NOAA)
- U.S. National Science Foundation's Ocean Observatories Initiative (OOI)
- Moorings, hydrographic and biogeochemical sampling off Monterey Bay, California
- Observations from National Marine Sanctuaries (NOAA)
- Underwater gliders
- Wave buoys and wave models
- Rocky intertidal biodiversity and recruitment
- Carbon chemistry (pCO2, pH) (NOAA, university)
- Native American ocean observing
- Bird and marine mammal observations
- Harmful Algal Bloom monitoring

Here we give highlights from a few of these programs.

U.S. Integrated Ocean Observing System, IOOS (NOAA), 2020-2021 (also described under Agenda Item 10: Updates from International Organizations)

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 2021-2022. 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. 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 2022, the summer upwelling season in the northern California current started at about the same time as the long-term average in mid-May, but an intraseasonal wind oscillation delayed the start of accumulating southward, upwelling-favorable wind stress until mid June (**Figure 1**, right). To date, the 2022 cumulative upwelling is on the low end of the long-term average. This contrasts with the 2021 upwelling season that started early and resulted in the second highest amount of cumulative upwelling in the last 36 years (**Figure 1**, left).

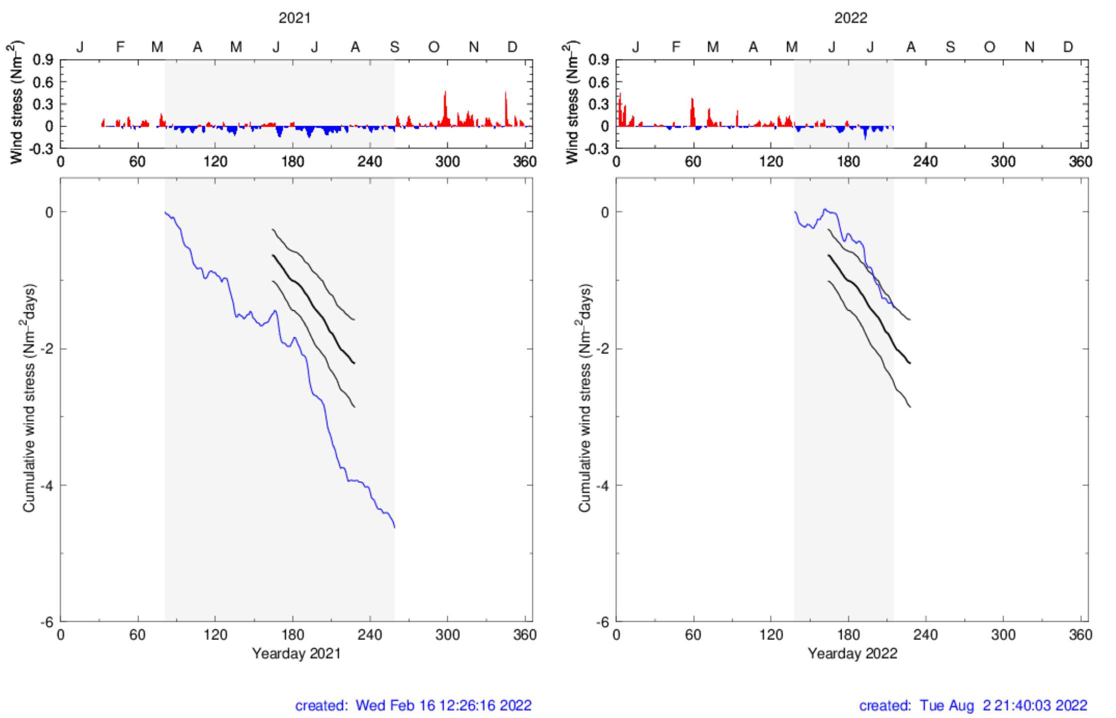


Figure 1. Cumulative north-south wind stress measured off Newport, Oregon, from (left) 2021 and (right) 2022. (Courtesy of S. Pierce and J. Barth, Oregon State University, http://shadow.ceoas.oregonstate.edu/windstress)

Sea surface temperature (SST) was above normal offshore of the California Current during the first half of 2022, with colder than average water near the coast consistent with the existence of an extended La Niña. In late summer 2022, warm water is found along the North Pacific Current and in the southern California Current (**Figure 2**). As during previous summers, upwelling-favorable winds of summer 2022 brought colder than average water to the surface near the coast and held the warm water offshore (**Figure 2**).

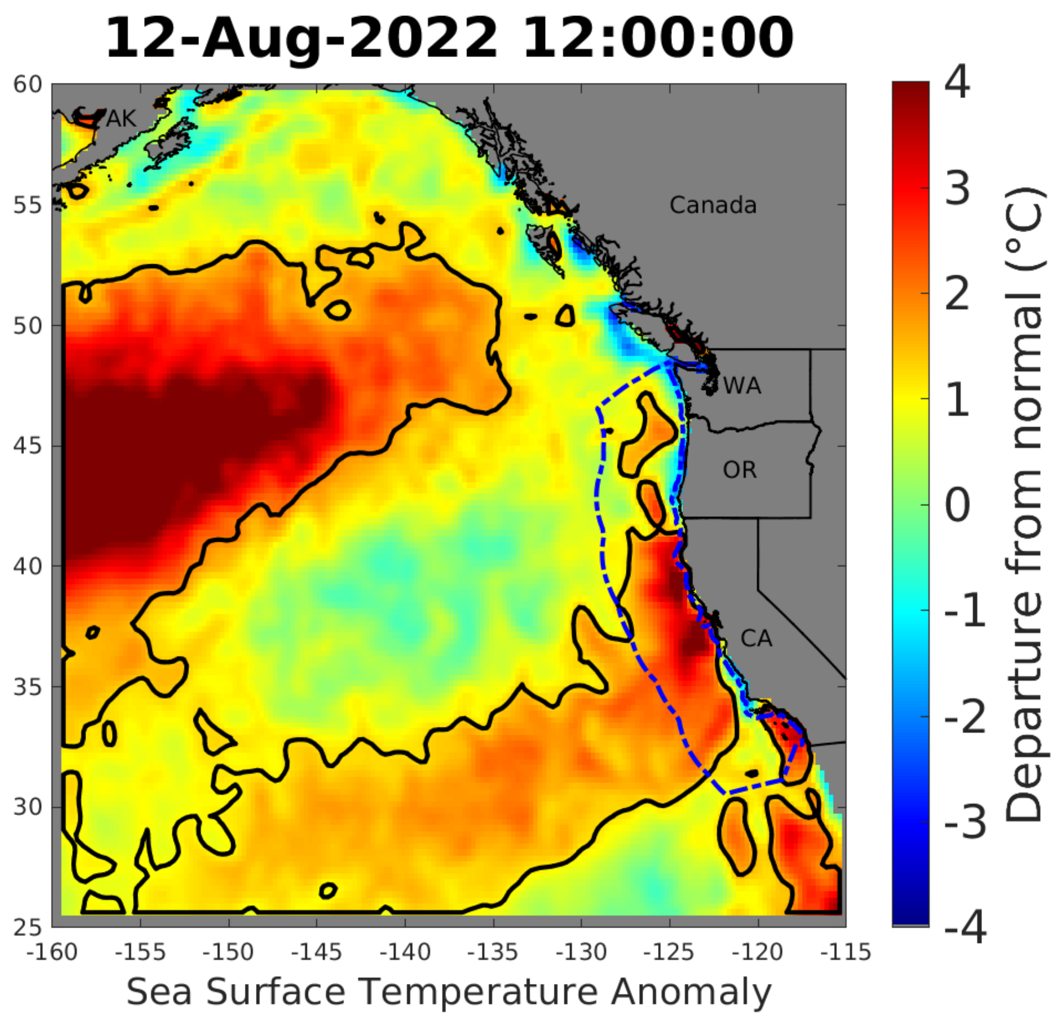
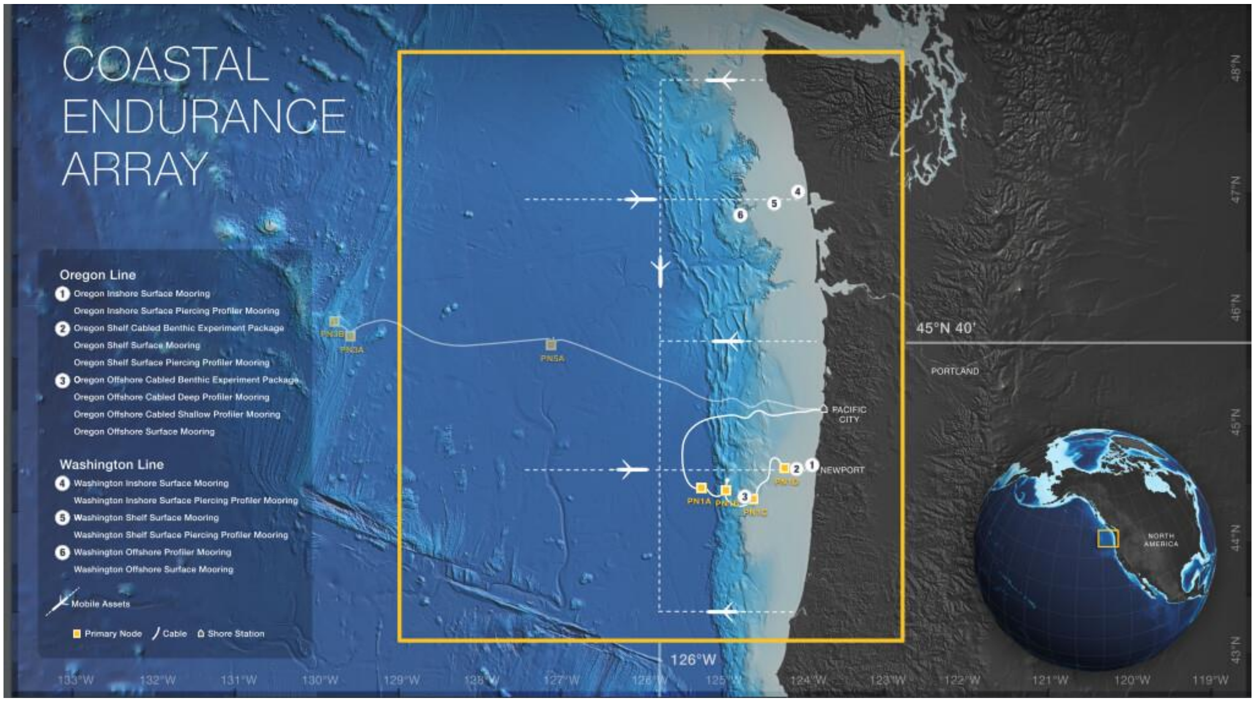
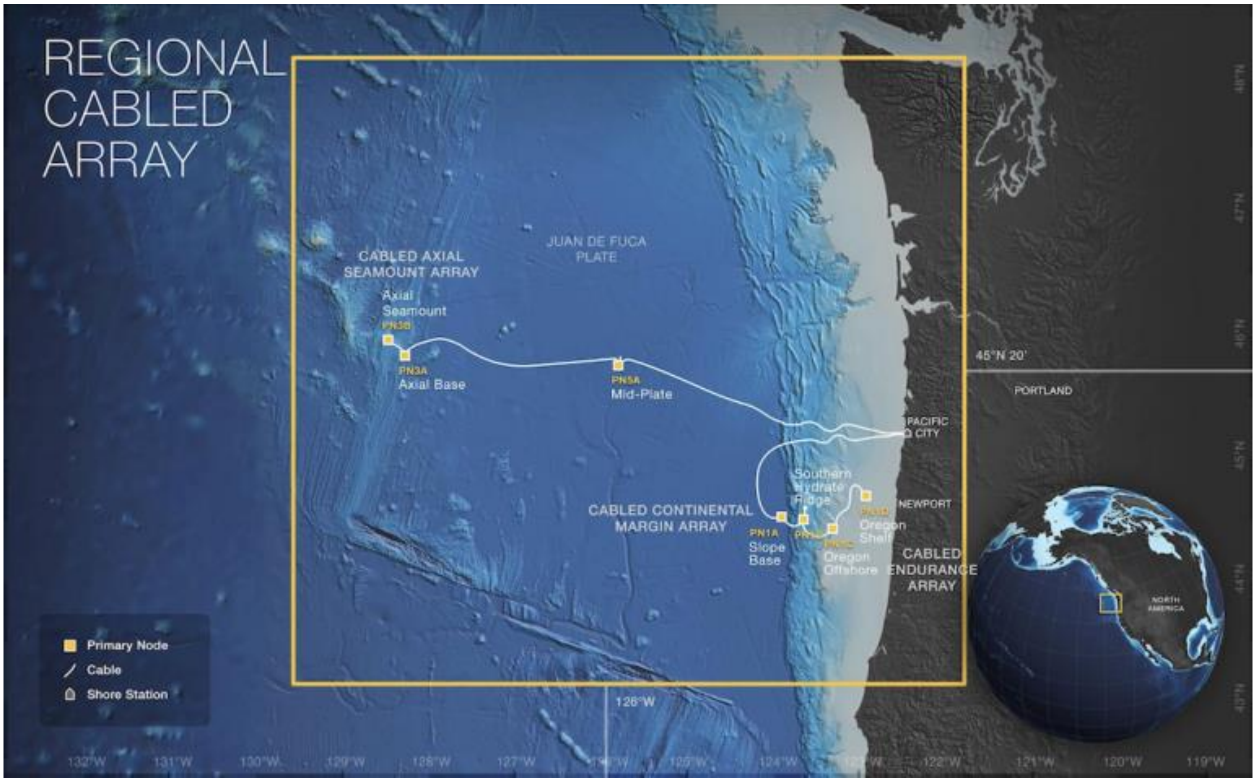


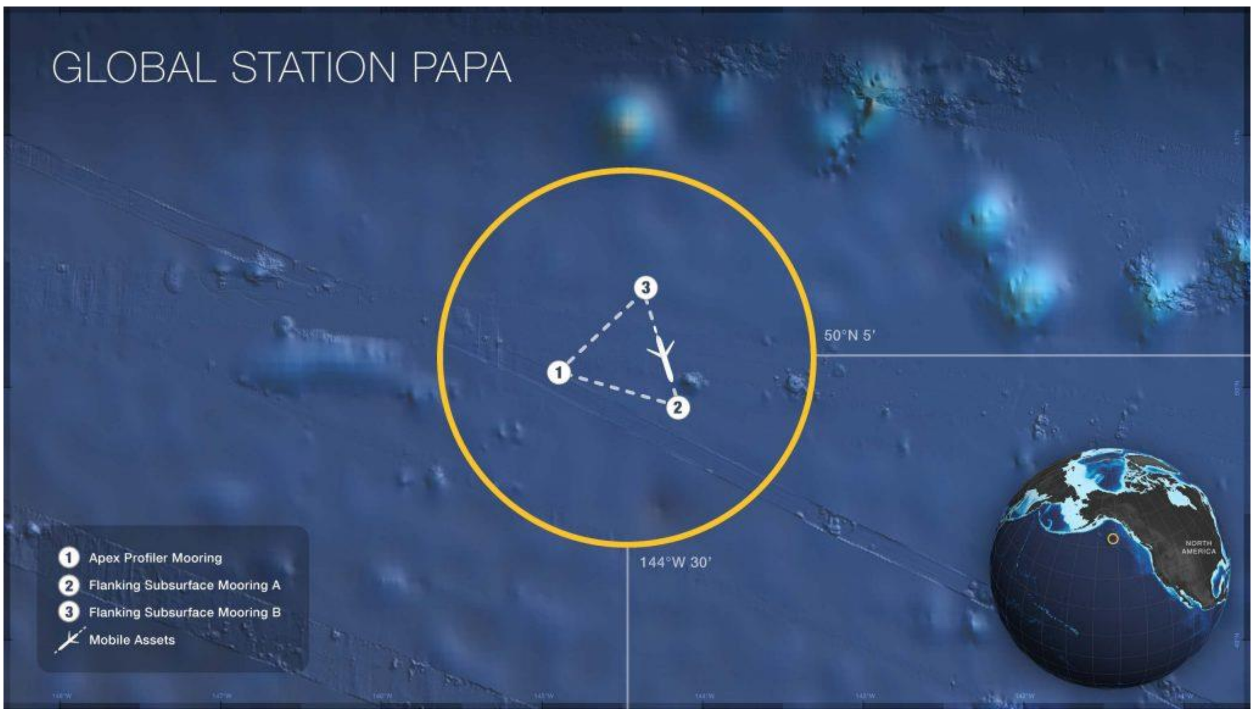
Figure 2. The California Current Marine Heatwave Tracker, an experimental tool for tracking marine heatwaves (Courtesy of A. Leising and S. Bograd, SWFSC, NOAA; https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-projects-blobtracker).

U. S. National Science Foundation's Ocean Observatories Initiative (OOI) (also described under Agenda Item 10: Updates from International Organizations)

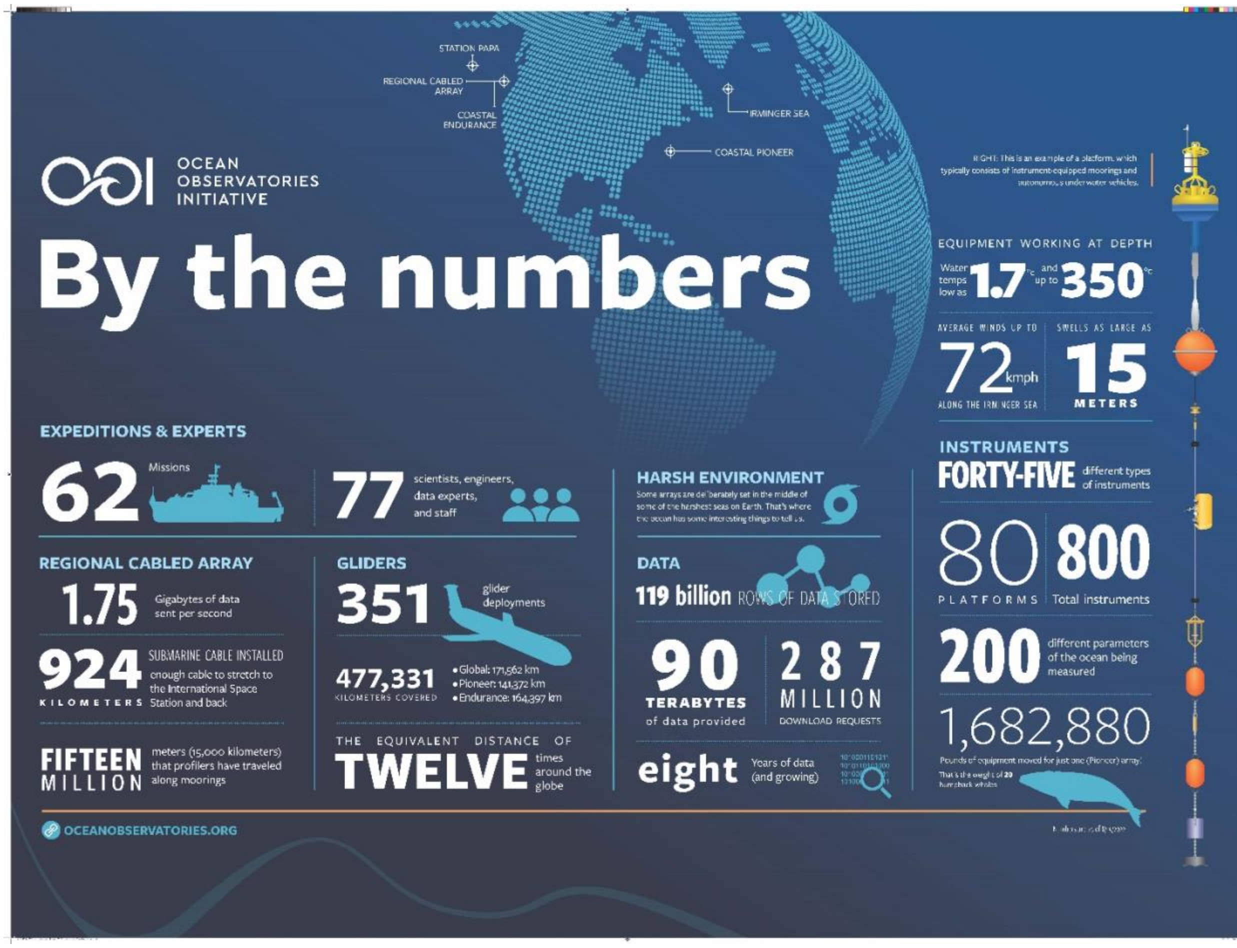
The Ocean Observatories Initiative (OOI) is a science-driven ocean observing network that delivers real-time data from more than 800 instruments to address critical science questions regarding the world's ocean. OOI data are freely available online to anyone with an Internet connection (https://oceanobservatories.org). Data can be explored and downloaded from: https://dataexplorer.oceanobservatories.org/. There are five arrays of platforms collecting continuous data including three in the Northeast Pacific: Endurance coastal array off the coasts of Oregon and Washington; Regional cabled array including Axial Seamount and Hydrate Ridge; Ocean Station Papa.







There are 800 instruments deployed, 36 different types measuring more than 200 parameters. The instruments are deployed on 80+ platforms consisting of cabled and uncabled moorings, cabled instruments, and autonomous vehicles. To date, there were 287 million requests for data, 90 terabytes of data provided including 119 billion rows of data stored.



In the second half of 2021 into 2022, the OOI team conducted the following cruises to maintain the OOI observing arrays:

Endurance Array off Oregon and Washington

- 6 Sep - 23 Sep 2021 aboard the *R/V Thomas G. Thompson* (Newport, Oregon - Newport)
- 21 Mar - 2 Apr 2022 aboard the *R/V Sikuliaq* (Newport - Newport)
- 21 Sep - 6 Oct 2022 aboard the *R/V Thomas G. Thompson* (Newport - Newport)

Regional Cabled Observatory

- 30 Jul - 3 Sep 2021 aboard the *R/V Thomas G. Thompson* (Seattle, Washington - Newport)
- 8 Aug - 16 Sep 2022 aboard the *R/V Thomas G. Thompson* (Seattle - Newport)

Station Papa

- 18 Jul - 2 Aug 2021 aboard the *R/V Sikuliaq* (Seward, Alaska - Seward)
- 12 May - 1 Jun 2022 aboard the *R/V Sikuliaq* (Seward - Seattle)

As an example of data from the mooring array off Oregon, here's a plot of temperature and dissolved oxygen during 2022 showing the onset of seasonal upwelling in mid May with lower water temperatures and low dissolved oxygen.

Examples of participation in the UN Decade of Ocean Science for Sustainable Development

On June 8, 2022, World Oceans Day, the United Nations Educational, Scientific and Cultural Organization designated the Ocean Observatories Initiative (OOI) as a UN Endorsed Action as part of the UN Decade of Ocean Science for Sustainable Development 2021-2030.

Jack Barth (Oregon State University, MONITOR, AP-NPCOOS) is serving as a member of the Ocean Decade Collaborative Center for the Northeast Pacific Advisory Committee

<u>Survey Monitoring Efforts</u> <u>on the</u> *<u>US West Coast, 2021-2022</u>*

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

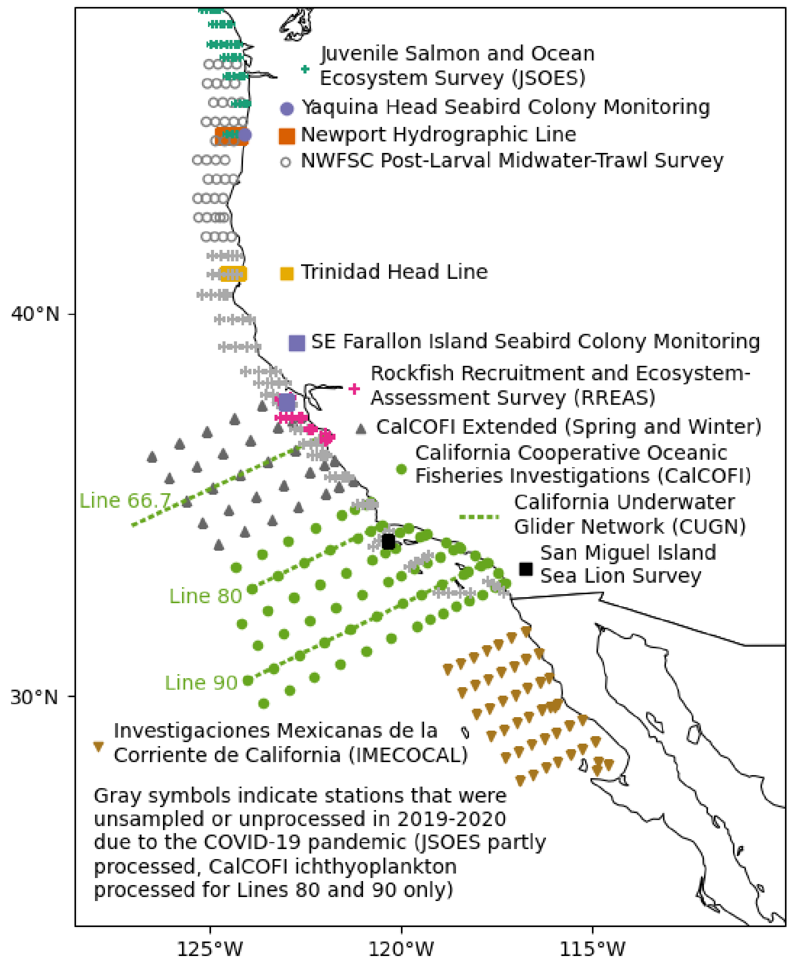


Figure 1. Hydrological and biological surveys used to assess the state of the California Current ecosystem. From the State of the California Current Report by E. Weber, NOAA Fisheries, SWFSC.

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 1.

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) each March (https://www.pcouncil.org/documents/2022/02/h-2-a-cciea-team-report-1-2021-2022-california-current-ecosystem-status-report-and-appendices.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 2) 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.

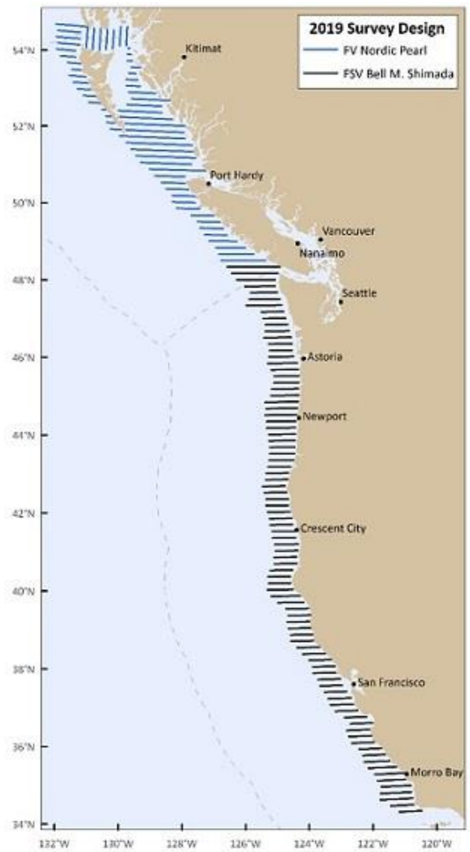


Figure 2. Acoustic-trawl survey transects for the NOAA Ship Bell M. Shimada (black, NWFSC) and the chartered vessel Nordic Pearl (blue, DFO).

Groundfish surveys have also been conducted over the shelf and slope (55 – 1280 m) annually by the NWFSC since 2003 (except in 2020) from the border with Mexico to Canada. The summer-fall 2022 (Figure 3) consists of Pass 1 from May 16 – July 26: 294 stations from US/Canada to US/Mexico with some sites not sampled due to delays caused by COVID-19 and the remainder not sampled due to a high number of cells with untrawlable bottom when searched. The second half of the survey began with Aug. 27, 2022 with plans to sample 376 sites and again cover the entire area from US/Canada to US/Mexico at depths of 55 -1280 m. The survey is scheduled to end October 27.

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 4).

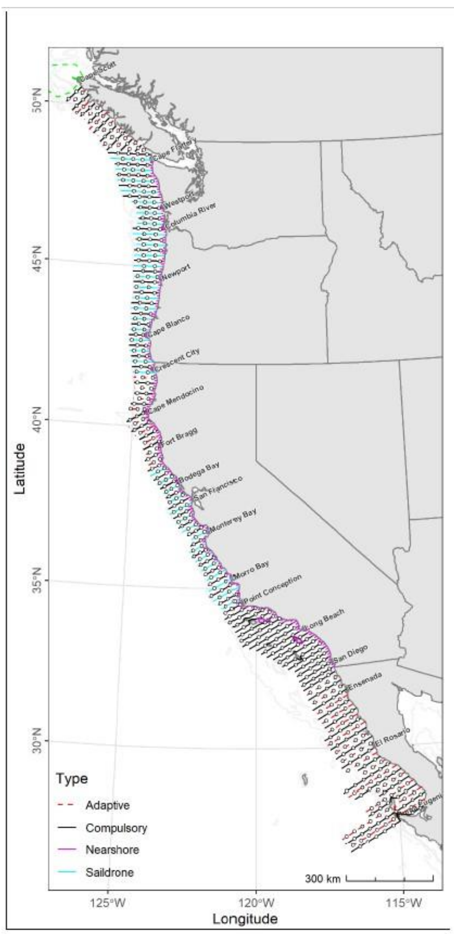


Figure 4. Planned transects for the NOAA SWFSC survey for coastal pelagic species.

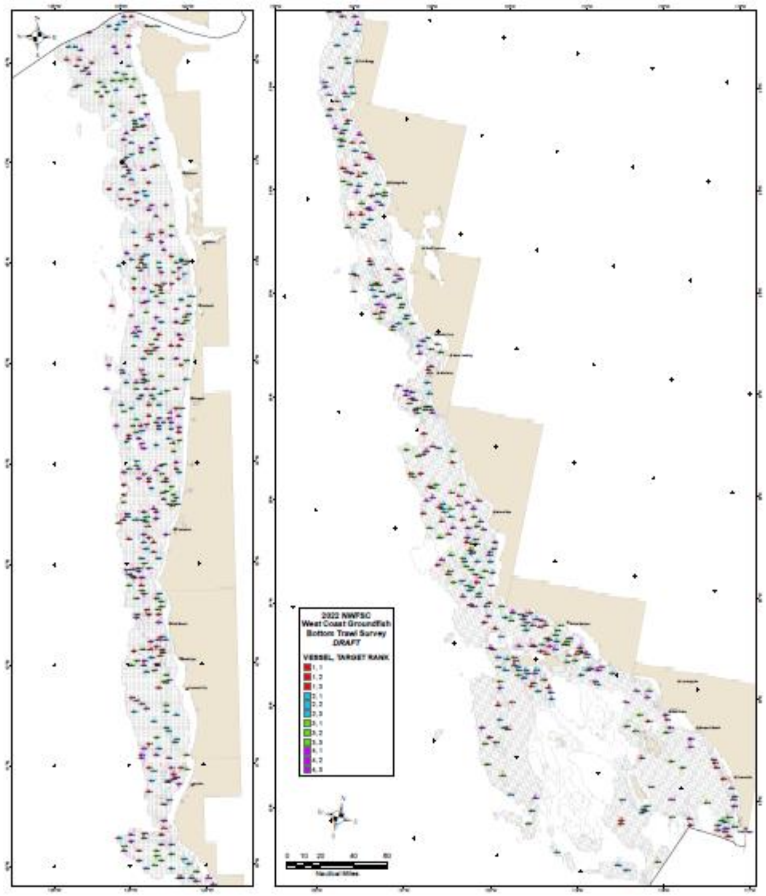


Figure 3. Target stations for 2022 NOAA groundfish survey off U.S. west coast. Left panel = northern Washington State through northern California. Right panel = northern California through southern California.

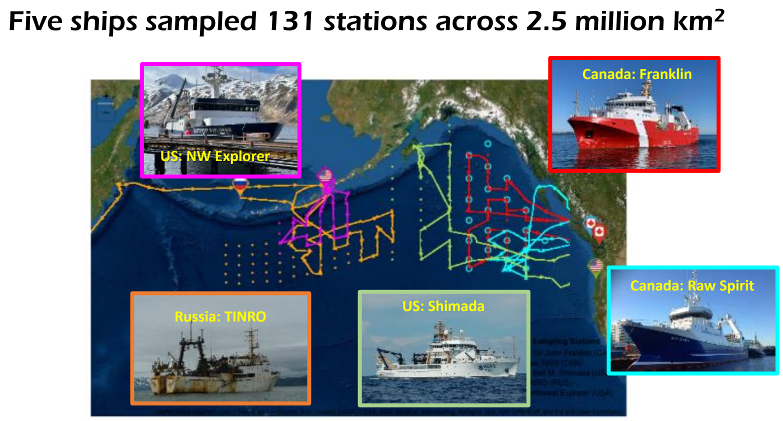


Figure 5. Ship sampling in winter of 2022 Year of the Salmon Pan-Pacific Winter High Seas Expedition

In the winter of 2022 the international collaborative efforts of five ships surveyed the high seas Pacific salmon habitats across the North Pacific Ocean (Figure 5). In addition to trawling for salmon and their predators, physical and other biological oceanographic measurements were taken. Results are forthcoming and more information can be found at https://yearofthesalmon.org/high-seas-expeditions/

The following highlights (and select figures) of conditions observed from surveys in 2021 include information from the CCIEA report to the PFMC (https://www.pcouncil.org/documents/2022/02/h-2-a-cciea-team-report-1-2021-2022-california-current-ecosystem-status-report-and-appendices.pdf/). Additional highlights are included as early season 2022 conditions.

- West Coast research efforts in 2021 were less impacted by the COVID-19 pandemic than in 2020.
- La Niña conditions and a negative PDO remained throughout 2021. These conditions are generally associated with higher productivity in the CCE.
- The 7th largest marine heatwave since 1982 observed in the North Pacific occurred in 2021, but stayed mostly offshore and outside of the US EEZ.
- Above average upwelling season, with coolest shelf conditions since 2013 providing a good nutrient supply to the base of the food web.
- Signs of concern included widespread near-bottom hypoxia off Oregon and Washington from May through October of 2021.
- Blooms of the diatom *Pseudo-nitzschia* spp. can produce domoic acid, a toxin that can affect coastal food webs and lead to shellfish fishery closures when shellfish tissue levels exceed regulatory limits. Domoic acid levels in shellfish were generally improved for most of the West Coast in 2021 compared to 2020 (Figure 6), perhaps related to the cooler temperatures associated with a negative PDO and La Niña; however, elevated levels associated with a persistent northern California "hotspot" (Trainer et al. 2020) were again observed. *Pseudo-nitzschia* cell counts varied around typical levels along most of the coast, except off Oregon where they were more abundant than normal; however, for the most part, cells produced only small amounts of domoic acid. Even so, exceedances of domoic acid were detected in razor clams from northern California to the Canadian

border in early 2021 (Figure 6.), due to legacy toxin from a fall 2020 HAB event that had not yet depurated from shellfish tissues.

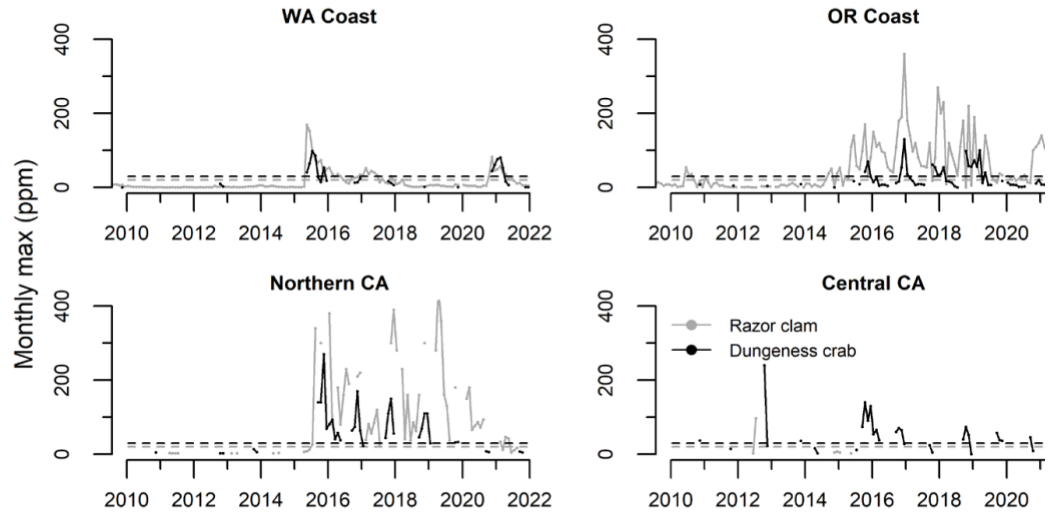


Figure 6. Monthly maximum domoic acid concentration (ppm) in razor clams (gray) and Dungeness crab viscera (black) through 2021 for WA, OR, northern CA, and central CA. Horizontal dashed lines are the management thresholds of 20 ppm (clams in gray) and 30 ppm (crabs in black). (https://www.pcouncil.org/documents/2022/02/h-2-a-cciea-team-report-1-2021-2022-california-current-ecosystem-status-report-and-appendices.pdf/).

- In 2021, 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 2021 before their regular seasonal transition in the fall (Figure 7). The spring-summer anomaly was among the highest of the time series. This trend continued again in the spring and early summer of 2022, along with an early transition to a northern copepod community in mid- April of 2022.

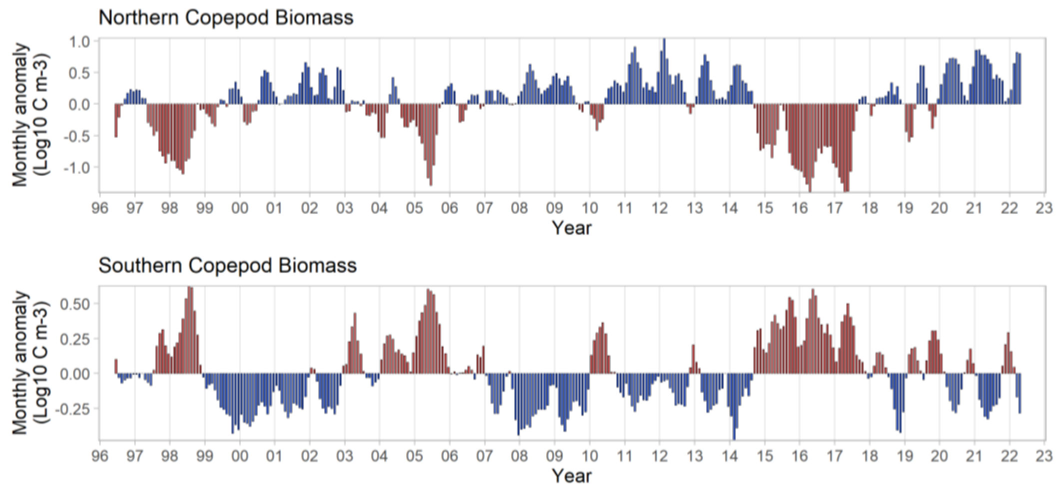


Figure 7. Three-month running mean of anomalies of biomass of northern and southern copepod taxa recorded off Newport, OR at NH05: Peterson Zooplankton Lab, NOAA, NMFS, Newport, OR.

- Off northern California, *Euphausia pacifica*, the key krill species, is sampled year-round off Trinidad Head. Mean length of adult *E. pacifica* is an indicator of productivity at the base of the food web, krill condition, and energy content for predators. *E. pacifica* lengths in spring and summer of 2021 were above average, then fell below average in fall (Figure 8, top). *E. pacifica* biomass in 2021 was mostly within ±1 s.d. of the time series average, but down from the exceptionally high biomasses of the summer of 2020 (Figure 8, bottom).

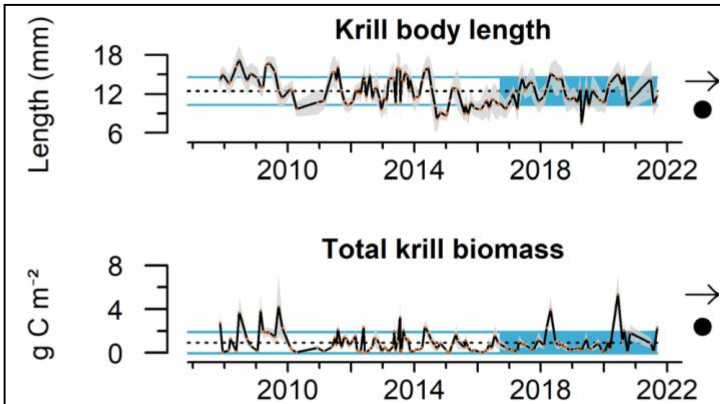
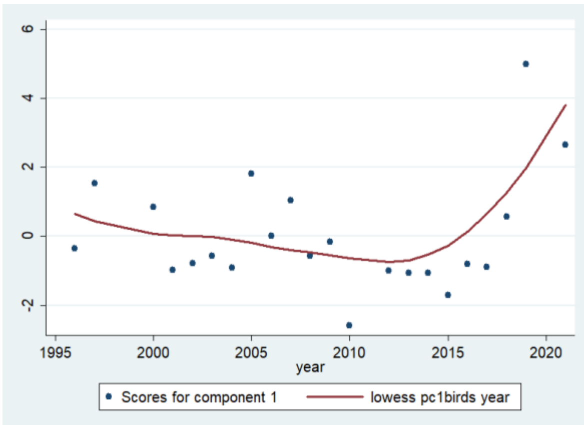


Figure 8 . Monthly mean E. pacifica length (top) and total *E. pacifica* biomass (bottom) off Trinidad Head, CA, 2007-2021. Gray envelopes indicate ± 1.0 s.d.

- Foraging conditions in 2021 appeared to be above average, based on measures of the zooplankton community, continued high abundance of anchovies in surveys and predator diets. Also positive trends in productivity and growth rates of sea lions in the southern CCE were observed as well as for seabirds in the central and northern CCE.
- The Northern CCE survey off Washington and Oregon targets juvenile salmon in surface waters, and also samples surface-oriented fishes, squid and jellies. In 2021 catches of juvenile subyearling Chinook salmon, juvenile yearling Chinook salmon, and juvenile yearling coho salmon were all very close to time series averages. Catches of market squid in 2021 returned to the time series average, down from the very high catches from 2018 to 2020. Similarly, catches of pompano (butterfish), which peaked in 2016, have declined to just below the time series mean. In the core area of the Central CCE catches of YOY rockfish, sanddabs and Pacific hake increased in 2021 from the very low levels observed in 2019 and 2020, although they remained well below the peak abundance levels that occurred during and shortly after the 2015-2016 large marine heatwave. The relative abundance of adult northern anchovy remained at very high levels observed in recent years. Forage data for the Southern CCE come from CalCOFI larval fish surveys. Catches of larval anchovy in spring 2021 were the highest in the time series for this region, and larval anchovy numbers continued their strongly significant increase in recent years. Larval California smoothtongue (a mesopelagic species) also continued a strongly increasing trend and had record high catches in 2021. Other notable results include that larval rockfish catches in 2021 were the highest since 2012, and that catches of larval sardines remained very low.
- There were positive trends in productivity and growth rates of sea lions in the southern CCE and seabirds in the central and northern CCE. Seabirds and marine mammals are surveyed annually on the NMFS Rockfish and Ecosystem Assessment Survey (RREAS). The time series is now 22 years in length starting in 1996, and ending in 2021, but 4 years were missed (1998-1999, 2011, and 2020). Surveys using standard techniques are made in May and early-mid June each year. The scatterplots and corresponding locally-weighted regression lines (Figures 9) show trends in seabird densities (individuals/km2) and mammal encounter rates (individuals/km) as synthesized using Principle Components Analysis (PCA). The eigenvalue for the seabird data (Figure 9 top panel), representing the densities of 8 species, was 2.72 and explained 30% of the variation. The PC loaded on locally-breeding species in the southern and central CCS including Brown Pelican (loading = .48), Brandt's Cormorant (.48), Comm Murre (.48) as well as one long distance migrant, the Sooty Shearwater (.42). These linear combination of densities for these species showed a decline though time, followed by a steep increase in abundance in 2019 and 2021. The abudance of these species was also relatively high (3rd highest in the time series) in 2005. We attribute the high abundances in seabirds in these years to abundant forage fish resources, particularly to a large biomass of the central stock of northern anchovy (CSNA) of about 2 Million MT in each of these years. The trend in abundance in 4 species of marine mammals is shown in Figure 9 bottom panel, and reflects the relative abundance of Humpback Whale (loading=.58), Blue Whale (.45), Pacific White sided Dolphin (.64) and Risso's Dolphin (.23). The linear combination of encounter rates for these species shows an increasing trend with a slight decline in 2019 and 2021, which we believe is probably short-term. We attribute changes in Humpback and Blue whale relative abundance to recovery of these populations from over-exploitation. Changes in whale and dolphin populations may also be influenced by changes in forage fish and krill (euphausiid crustacean) resources. Contact: Bill Sydeman (Farallon Institute)



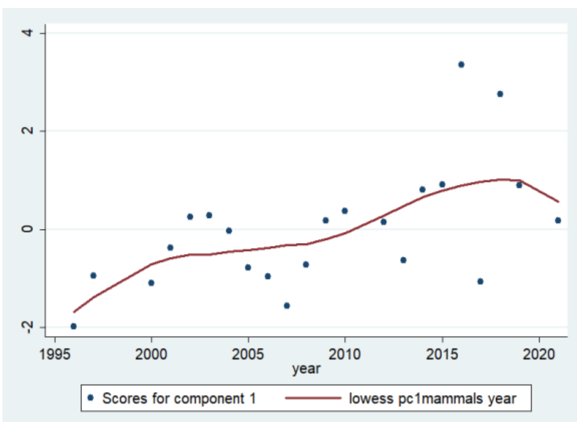


Figure 9. Scatterplot and locally-weighted regression lines of seabird densities (individuals/km2) of 8 species and mammal encounter rates (individuals/km) synthesized using Principle Components Analysis (PCA). Courtesy Bill Sydeman/Farallon Institute.

References:

Harvey, C., T. Garfield, G. Williams, and N. Tolimieri, eds., 2022. California Current Integrated Ecosystem Assessment (CCIEA) California Current Ecosystem Ecosystem Status Report, 2022. https://www.pcouncil.org/documents/2022/02/h-2-a-cciea-team-report-1-2021-2022-california-current-ecosystem-status-report-and-appendices.pdf/).

Trainer, V.L., *et al.* 2020. Pelagic harmful algal blooms and climate change: lessons from nature's experiments with extremes. *Harmful Algae* 91:101591.

Alaska

Alaska fisheries oceanography surveys and observations for 2021-2022

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

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For this report we focused primarily on fisheries and ecosystem surveys in the eastern Bering Sea since many NOAA AFSC surveys are conducted every other year, with more Bering Sea surveys in even years and more Gulf of Alaska surveys in odd years.

Time series of fisheries and oceanographic data and ecosytem evaluations can be found at https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands.

Bering Sea

Climate

Fall 2021- Spring 2022: During the period of October 2021 through March 2022, the western and eastern portions of the Bering Sea experienced different atmospheric forcing relative to climatological norms. A map of surface air temperature anomalies for this period (Fig. 1) shows that it was relatively warm over the western Bering Sea with the greatest departures from normal (> 1˚C) over the western Aleutian Islands. This was the 6th warm year in a row for this time of year relative to the climatological average over the years 1981-2010, with 2016-17 representing the extreme over the historical record back to 1948-49. In contrast, the eastern Bering Sea had near-normal to cool surface air temperatures, with the coldest anomalies just offshore the coast of western Alaska near 60˚N. This was quite a departure from the air temperatures that prevailed in recent years, with 2012-13 being the last year that was as cold over the southeast Bering Sea shelf.

The combination of warmth in the western portion and cooler temperatures in the eastern portion of the Bering Sea is consistent with the overall pattern of sea level pressure (SLP) anomalies for October 2021 through March 2022. As shown in Fig. 1, the SLP anomaly distribution featured a ridge of higher than normal pressure extending from the central North Pacific Ocean across the eastern part of the Aleutian

Islands to the eastern tip of Siberia. The surface winds with this distribution included anomalies from the southeast of 1-1.5 m s-1 in the western Bering, and hence a tendency for more air masses of mild, maritime origin. The wind anomalies were from the northwest at 1-2 m s-1 over the southeastern Bering Sea shelf, accounting for its relatively cold weather, as noted above. Relatively high SLP south of the eastern Aleutians during the months of October through March is common during La Nina, as was the case in 2021-22. But important details in the atmospheric patterns from a Bering Sea perspective vary between these events; the previous winter of 2020-21 also included La Nina but in that case the SLP anomaly pattern resulted in wind anomalies from the southwest over the southeastern Bering Sea shelf and relatively warm weather. From a sub-seasonal perspective, the eastern Bering Sea shelf experienced particularly cold air temperatures during the last part of November 2021 and the second week of February 2022; it was much warmer than normal during the last two weeks of December 2021.

The months of April and May 2022 included a transition in the regional atmospheric circulation pattern, as indicated in 2-month SLP anomaly map (Fig. 2). This pattern resulted in warm weather for the Northern Bering Sea, and a relatively rapid retreat of sea ice (see *Sea Ice Extent*) after a short period of cold winds from the north in early April 2022. The wind anomalies for the southeastern Bering Sea shelf for April through late May were from the east, implying that the advection of near-surface passive drifters (such as some zooplankton and icthyoplankton) was directed more off-shelf than typical.

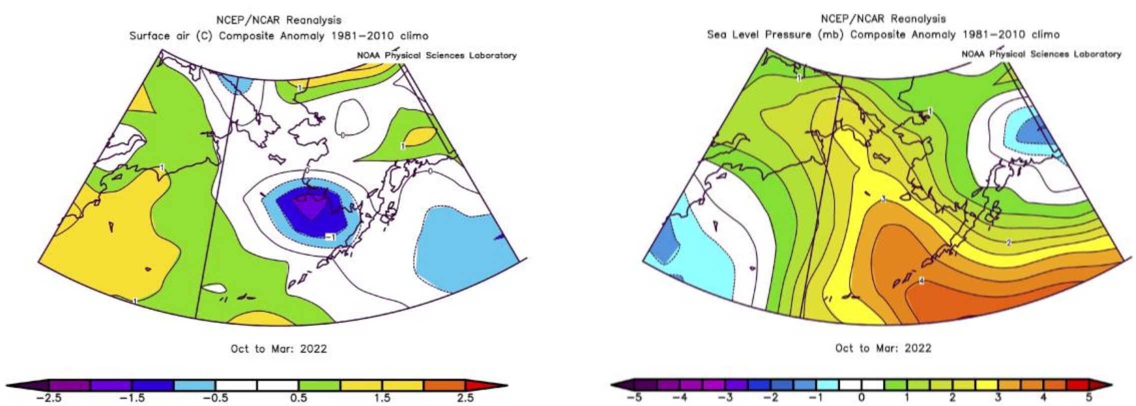


Figure 1. Mean surface air temperature anomalies (°C, left) and mean sea level pressure (SLP) anomalies (mb, right) from the NCEP/NCAR Reanalysis for October 2021 - March 2022. Figure courtesy of Nick Bond, University of Washington (UW)/ Cooperative Institute for Climate, Ocean, and Ecosystem Studies (CICOES).

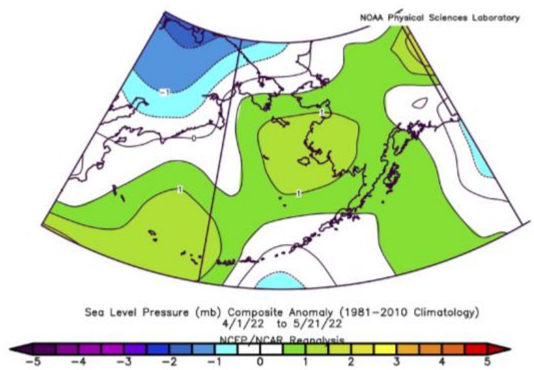


Figure 2. Mean sea level pressure (SLP) anomalies (mb) from the NCEP/NCAR Reanalysis for 1 April - 21 May, 2022. Figure courtesy of Nick Bond, UW/CICOES.

Sea Surface Temperature (SST)

Satellite-derived estimates of SST for the Bering Sea were compiled by Matthew Callahan (NOAA AFSC). In fall and winter (December 2021-March 2022), SSTs were similar to the long term mean/baseline (1985-2015, Fig. 3). The northern Bering Sea and southeastern Bering Sea experienced SSTs warmer than baseline starting April and May/June, respectively, with a return to near-baseline values in August. The time series graphs and SST data for the Bering Sea (and the Gulf of Alaska) can be updated daily at https://shinyfin.psmfc.org/ak-sst-mhw/

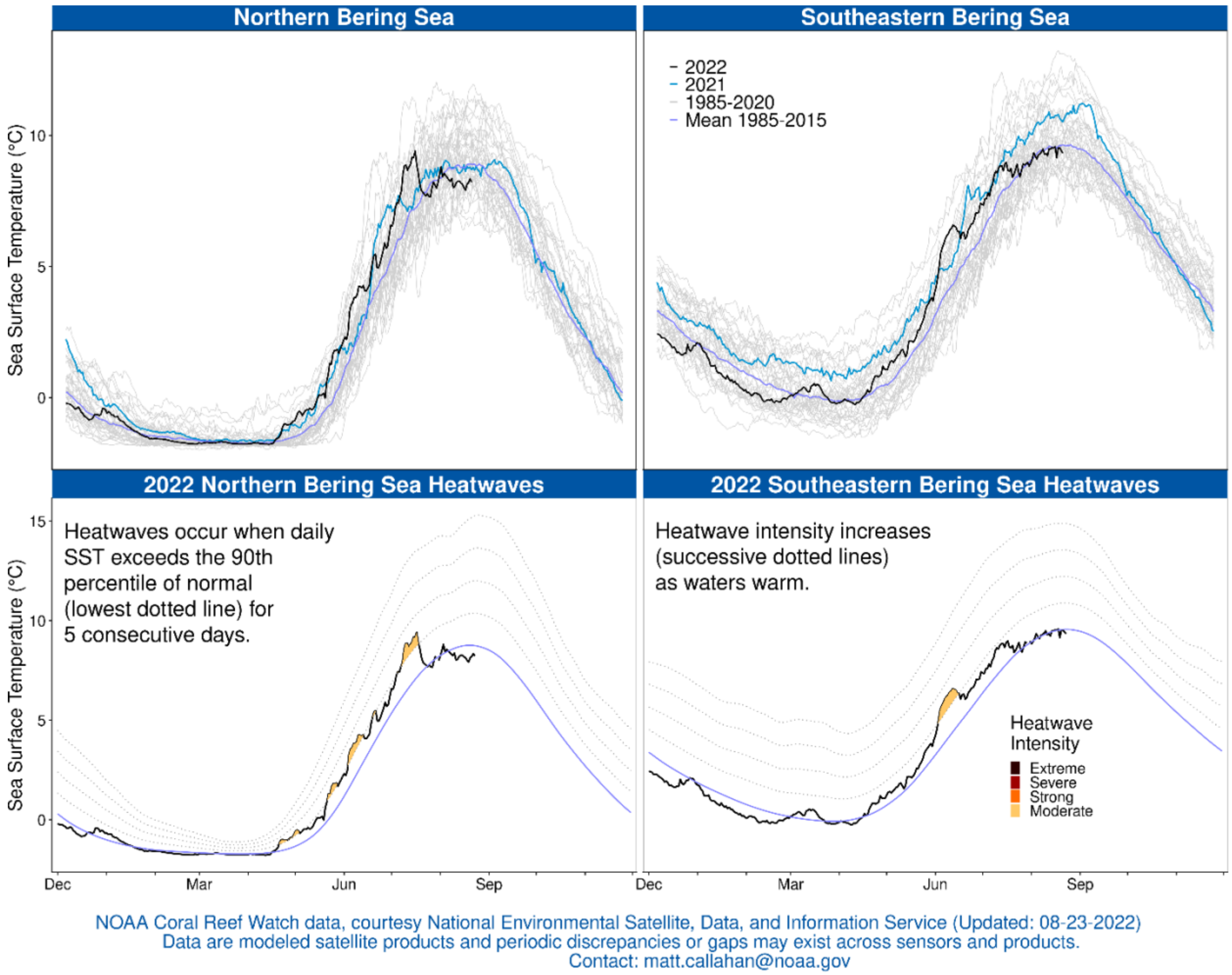


Figure 3. Daily mean SST for 2022 and 2021 compared to means for 1985-2015 for the northern Bering Sea (north of 60°N) and southeastern Bering Sea (south of 60ºN) from satellite analysis. Courtesy of Matt Callahan, NOAA AFSC.

Sea Ice Extent

Bering Sea ice extent in 2021/2022 was compiled by Rick Thoman (https://uaf-accap.org/). Sea ice formation near the Alaska Coast was accelerated by a record cold November, followed by normal variability in sea ice cover December – March, with a very rapid decline in April (Fig. 4). Repeated strong winds from the E-NE led to repeated reformation of ice on the NE shelf as the existing ice was blown away from shore. This process led to very thin ice in the eastern Bering Sea compared to the median over the last 11 years (Fig. 5).

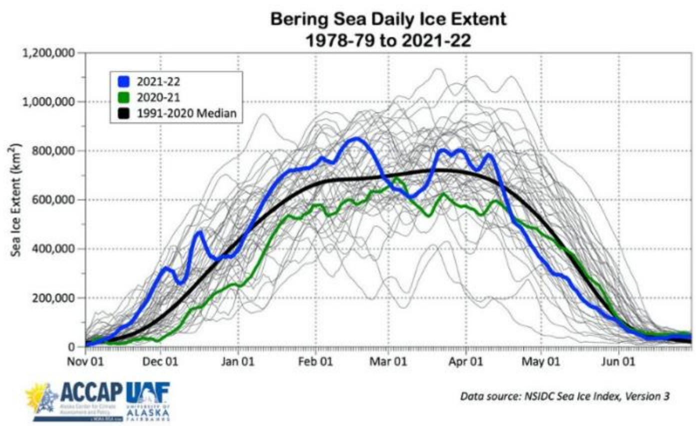


Figure 4. Sea ice thickness for late March 2022 as a percent of the median over 2011-2021. Figure courtesy of Rick Thoman, ACCAP.

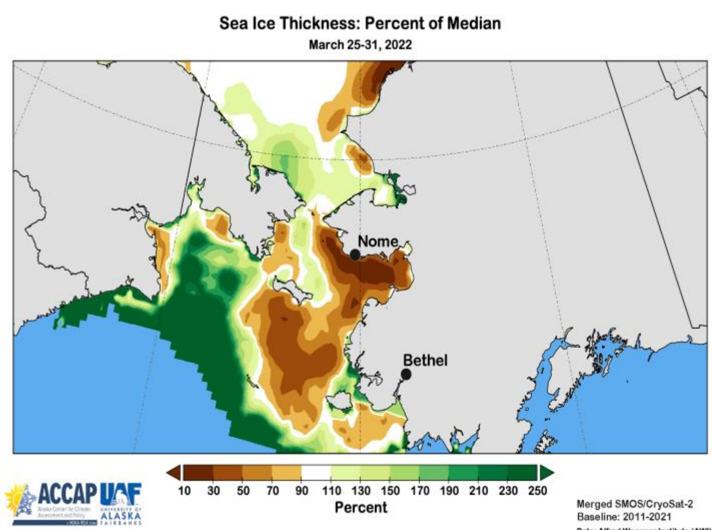


Figure 5. Sea ice thickness for late March 2022 as a percent of the median over 2011-2021. Figure courtesy of Rick Thoman, ACCAP.

Spring phytoplankton blooms

Satellite chlorophyll-a (chl-a) data, a proxy for phytoplankton biomass, allows analysis of large scale patterns in phytoplankton dynamics. Near real time satellite chl-a for spring 2022 (8-day composites) from VIIRS (https://coastwatch.pfeg.noaa.gov/erddap/griddap/erdVHNchla8day.html) show noticeable ice edge blooms in April followed by open water blooms in the southeastern Bering Sea in May (Fig. 6). This pattern of ice associated blooms followed by open water blooms is likely related to the rapid decline in sea ice cover from 10 to 20 April (Figs. 4, 6).

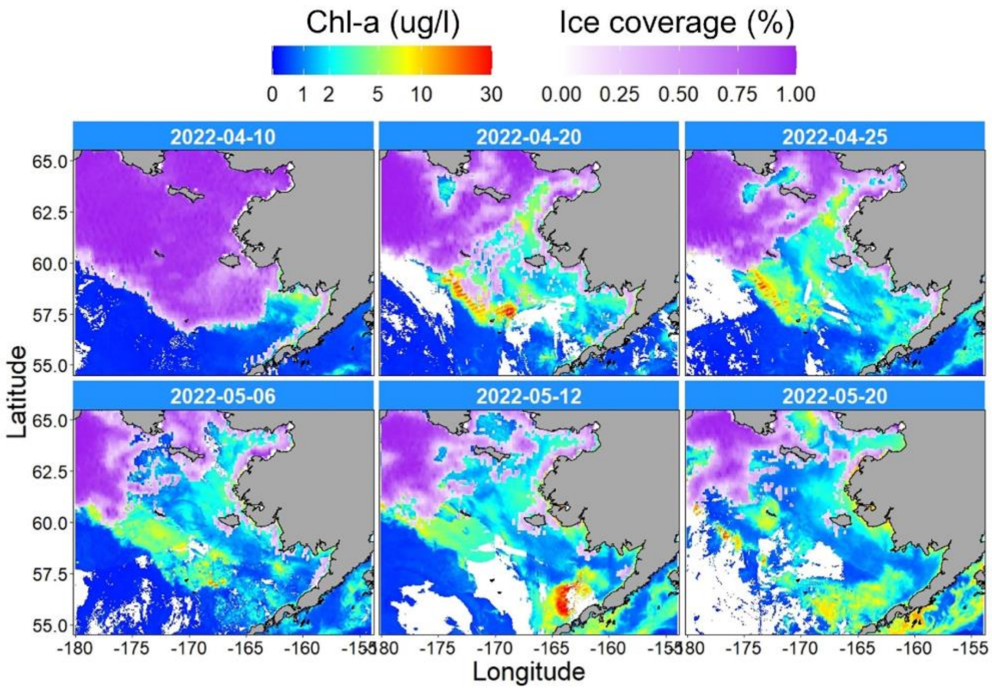


Figure 6. Satellite near real time chl-a data (µg/l) from VIIRS -8 day composites (last day of composite listed for each plot), April through mid-May 2022 in the eastern Bering Sea. Figure courtesy of Jens Nielsen, UW/CICOES.

Harmful algal blooms (HABs)

HABs occur when certain phytoplankton species proliferate and negatively impact humans or wildlife. Organizations conducting HAB sampling in Alaska are members of the Alaska Harmful Algal Bloom (AHAB) Network – a statewide platform for communicating and coordinating HAB awareness, research, monitoring, and response. This collaborative work is crucial to better understanding HABs and mitigating their impacts in the Bering Sea and throughout Alaska. To learn more about the work being done on HABs and to access a data portal with links to relavant data sets, visit the Alaska Harmful Algal Bloom network website (Fig. 7).

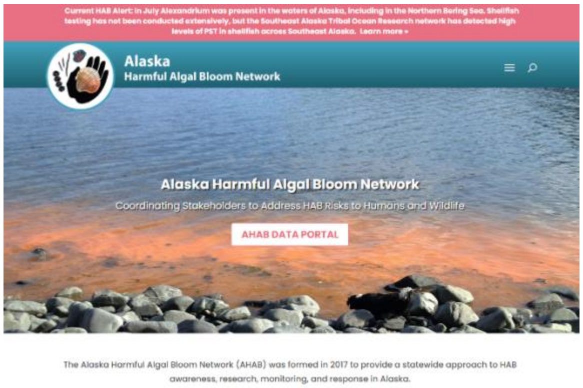


Figure 7. AHAB network website, https://ahab.aoos.org/.

2022 surveys in the Bering Sea

Many of the 2022 AFSC and Pacific Marine Environmental Lab (PMEL) surveys in the Bering (and Gulf of Alaska) are described (with maps) in the link: https://test-www.fisheries.noaa.gov/alaska/science-data/2022-alaska-fisheries-science-center-field-season. Information and excerpts from this site are also included in the list below. Credit: NOAA Fisheries.

Ice seal survey in the eastern Bering Sea on the R/V Oscar Dyson, 5 - 25 April. The Polar Ecosystems Program (PEP) conducted a research cruise to the marginal zone of the pack ice to study the habitat requirements and ecological relationships with sea ice of ribbon and spotted seals (collectively termed ice seals) in the core of their Bering Sea breeding area (Fig. 8). The seals' movements, haul-out behavior, diet, genetic population structure, and health will be investigated and monitored. The three survey goals were: 1) to capture ribbon and spotted seals to instrument them with satellite-linked tags to examine seasonal movements, foraging behavior, and timing of haul-out; 2) to collect measurements and tissue samples to assess seal health and condition; and 3) to use uncrewed aerial systems (UAS) to investigate impacts of changing ecosystems (Fig. 9). A particular focus of the work in 2022 is on health and condition of young-of-the-year seals and their mothers, and potential impacts of diminishing sea ice. Contact: Michael Cameron (AFSC).

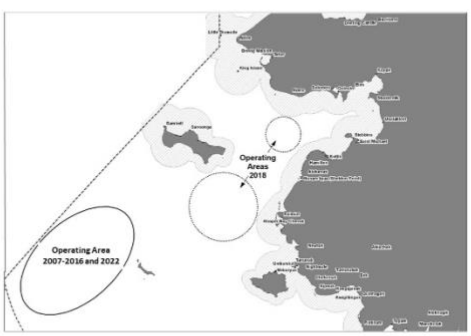


Figure 8. Ice sea marginal ice zone survey areas in the Bering Sea, 2007-2016 & 2022 (lower oval) and 2018 (circles). Figure courtesy of Heather Ziel, NOAA AFSC.

Figure 9. (Left) the UAS on a flight (photo credit Michael Cameron NOAA AFSC). (Right) an image taken by the UAS of a ribbon seal female and her pup (photo credit NOAA AFSC).

Oceanographic biophysical mooring and hydrographic surveys (PMEL/AFSC EcoFOCI) in the eastern Bering Sea on the R/V Oscar Dyson, 10 - 19 May (spring) and 16 September – 08 October (fall) (Fig. 10). The overall research objective for both surveys is to determine how varying biological and physical factors influence the Bering Sea marine ecosystem. The objectives of the survey are: 1) service oceanographic and passive acoustic moorings that measure water column and sea ice properties and detect marine mammals and sounds from human activities; 2) sample the water column for zooplankton, larval fish, and bottom-dwelling organisms; 3) deploy drifters to measure currents; and 4) deploy sonobouys to monitor marine mammal presence in real time. Contact: Phyllis Stabeno (PMEL) and Libby Logerwell (AFSC).

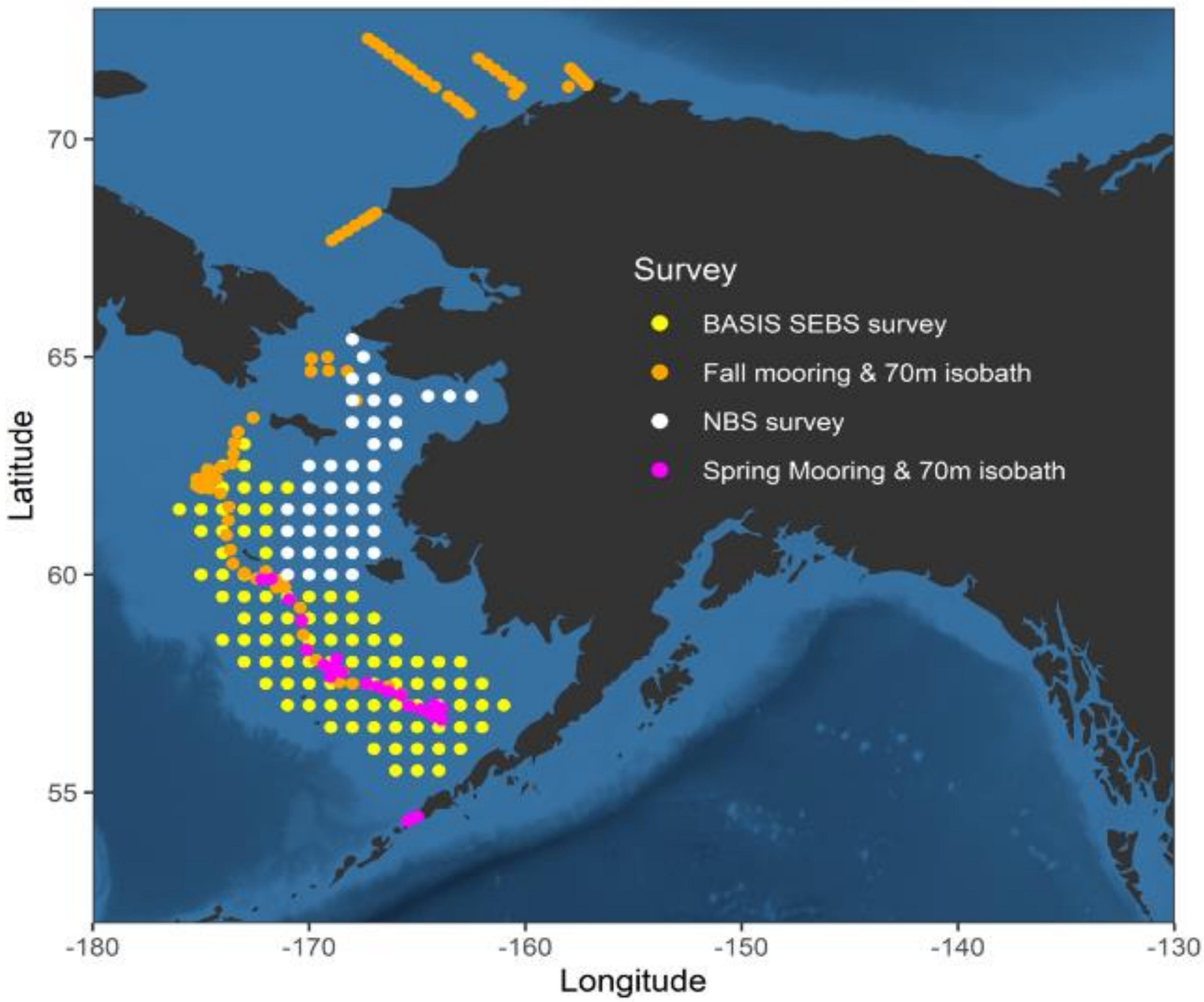


Figure 10. EcoFOCI oceanographic and mooring survey stations (spring, pink), BASIS southeastern Bering Sea and northern Bering Sea surface trawl and ecosystem survey stations (fall, yellow and white). The fall mooring survey (orange) was canceled.

Groundfish and invertebrates (crab) summer bottom trawl survey in the eastern Bering Sea and northern Bering Sea on the F/V Vesteraaelen and F/V Alaska Knight, 26 May - 30 July and 1 - 23 August, respectively (Fig. 11, left). Temperature sensors attached to the trawl net recorded bottom temperature throughout the Bering Sea (Fig. 11, right, as of 08 Aug 22). The primary goal is to estmate the distribution and abundance of crab, groundfish, and other bottom-dwelling species in the Bering Sea. These data are used for ecosystem monitoring and to aid in the management of commercially important species in Alaska. NOAA Fisheries has conducted the eastern Bering Sea Shelf survey annually since 1975, and formally standardized the survey in 1982. Since then, we have only missed one opportunity to survey the eastern Bering Sea in 2020 due to the COVID-19 pandemic. The northern Bering Sea Shelf survey has only been surveyed in 2010, 2017, 2019, 2021 and 2022. Contact: Duane Stevenson (AFSC).

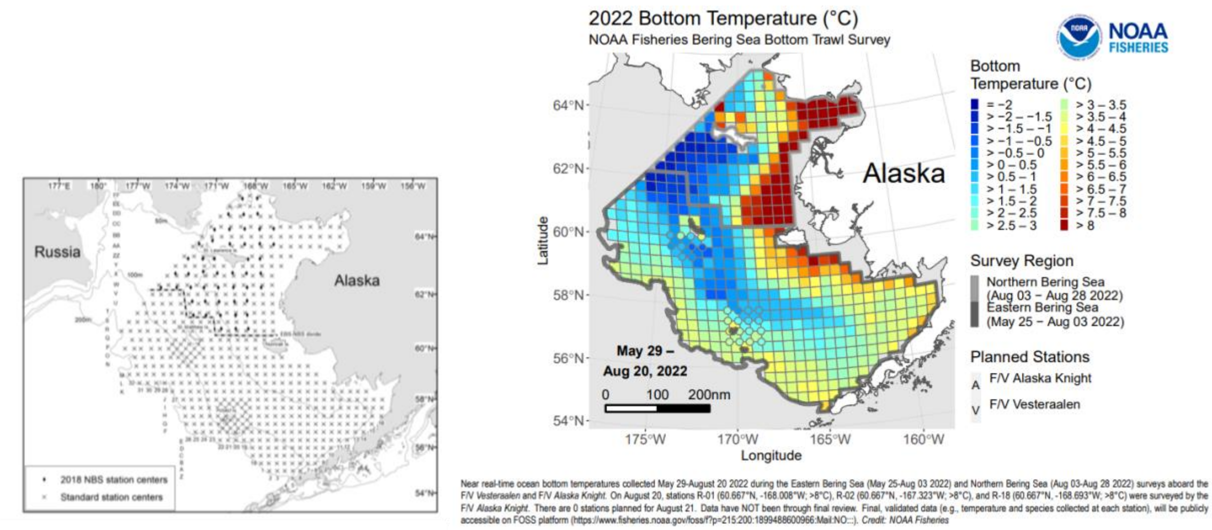


Figure 11. Bottom Trawl locations in the southeastern Bering Sea and northern Bering Sea (left) and bottom temperature (right). For details see https://www.fisheries.noaa.gov/alaska/climate/near-real-time-temperatures-bering-sea-bottom-trawl-surveys-2022.

Acoustic trawl survey in the eastern Bering Sea on the R/V Oscar Dyson, 27 May - 6 August. Eastern Bering Sea shelf walleye pollock (*Gadus chalcogrammus*) midwater abundance and distribution were assessed from Bristol Bay to the U.S.-Russia Convention Line. Contact: David McGowan (AFSC).

Beluga whale aerial abundance survey in the Norton Sound region of the eastern Bering Sea, 20 June - 2 July. The overall objective is to obtain an abundance estimate for the population of the eastern Bering Sea stock of beluga whales. Contact: Megan Ferguson & Kim Sheldon (AFSC).

Surface trawl and ecosystem survey in the southeastern Bering Sea (SEBS) on the R/V Oscar Dyson, 12 August – 11 September (Figs. 10, 12). Multiple gear was used including a CTD with rosette water sampler, bongo nets, surface and oblique trawls, Methot trawl, small mesh beam trawl, and a Van Veen benthic grab. An integrated flow cytobot (IFCB) was deployed in line to measure phytoplankton community composition in surface waters. This research is focused on improving and reducing uncertainty in stock assessment models of important commercial fish species in the Bering Sea through the collection of acoustics information, fish and zooplankton samples, and fisheries oceanographic indices.

Preliminary results indicate:

- Large coccolithophore bloom over inner and middle shelf in the SEBS;
- HAB species *Alexandrium* sp. noted at serval stations using IFCB;
- Large copepod density was low compared to recent cold period (2006-2011), small copepods were low, more similar to recent cold period, and euphausiids were slightly higher than in recent warm and cold periods;
- Large catches of age-0 Atka Mackerel near Pribilof Islands;
- More age-0 Pacific cod than usual;
- Large catches of age-0 pollock;
- Large catches of juvenile sockeye, and the jellyfish, *Chrysaora melanaster* (age-0 pollock are a major food source for juvenile sockeye salmon during warm years).

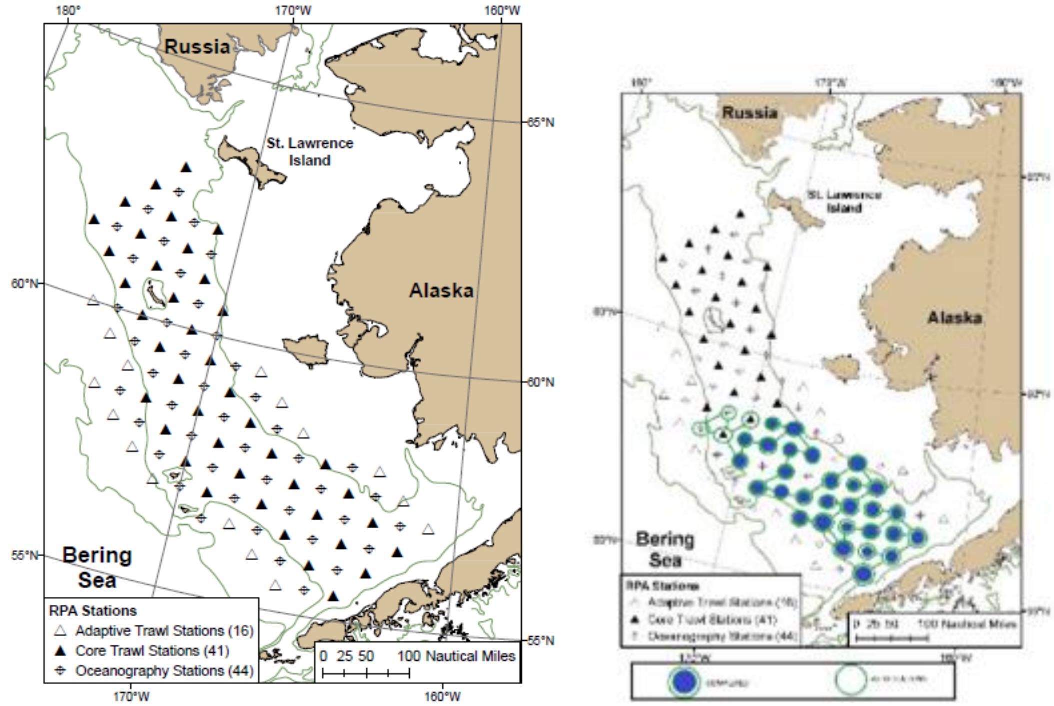


Figure 12. Map of planned stations (left) and completed stations (right, blue circles) for BASIS survey, 2022. Map courtesy of Alex Andrews, NOAA AFSC.

Contacts (AFSC): Ed Farley, Alex Andrews, and David Kimmel (zooplankton data).

<u>Surface trawl and ecosystem survey in the northern Bering Sea</u> on the F/V Northwest Explorer, 27 August – 20 September (Fig. 10). The survey included multiple sampling gear types, including a CTD with rosette water sampler, bongo nets, surface trawl, small mesh beam trawl, and a Van Veen benthic grab. Optical data (e.g., radiometer) and samples for phytoplankton pigments, absorption, dissolved organic material, etc. were collected over the northern portion of the survey grid. The survey will support a wide range of research activities, including stock-specific juvenile salmon abundance estimates, the pelagic food web, fish condition, oceanographic conditions, zooplankton distribution and abundance, seabird densities, harmful algal bloom toxins, essential crab habitat, environmental DNA, salmon shark migration, and the carbon cycle of the Yukon River plume.

Preliminary results indicate:

- Herring dominated catches, age-0 herring atypically large;
- Capelin catches up from previous years;
- Jellyfish down considerably from previous years;
- Salmon catches atypical, mostly in northern stations, juv chum and pink were very low.

Contacts (AFSC): Ed Farley, Jim Murphy.

<u>Arctic oceanographic research in the north Bering and Chukchi seas</u> was planned on the R/V Oscar Dyson and R/V Aquilla, late September – early October. The Dyson survey was canceled after a few days of sampling. Contact: Phyllis Stabeno (PMEL).

Gulf of Alaska

Sea Surface Temperature (SST)

Satellite-derived estimates of SST for the GOA were compiled by Matthew Callahan (NOAA AFSC). The western and eastern GOA SST data indicate temperatures were generally cold during winter, near average during spring, and warm during summer (1985-2015 baseline) with marine heat waves observed in June, particularly in the eastern GOA (Fig. 13). The eastern GOA heat wave was brief but strong and covered >99% EGOA area. Overall, SSTs were persistently cooler and closer to the long-term mean than the previous few years.

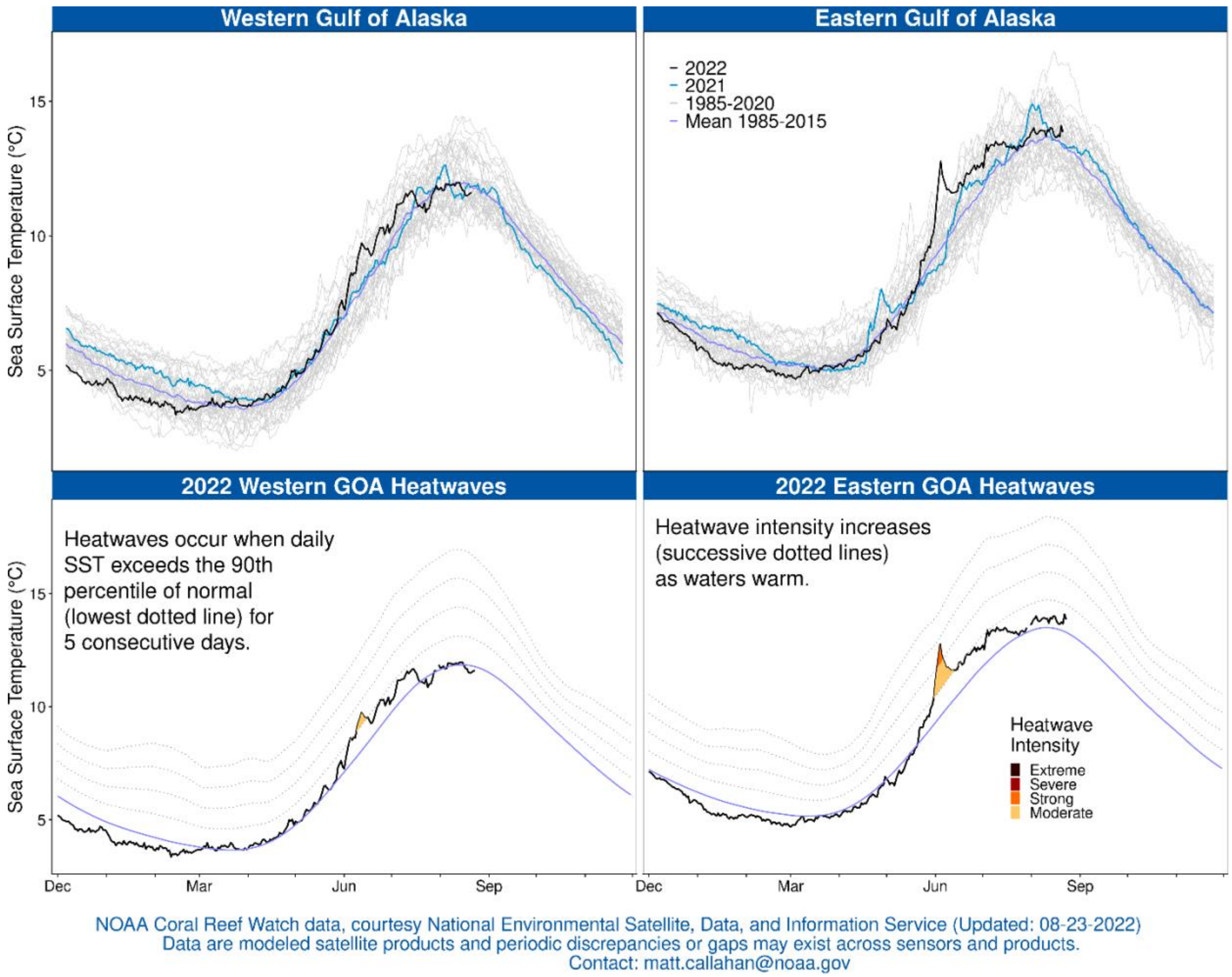


Figure 13. GOA SST for the western and eastern GOA for 2022 and 2021 compared to means for 1985-2015 from satellite analysis. Courtesy of Matthew Callahan.

2022 survys in the Gulf of Alaska

As stated earlier, many of the Gulf of Alaska surveys are described in the link: https://test-www.fisheries.noaa.gov/alaska/science-data/2022-alaska-fisheries-science-center-field-season. Information and excerpts from this site are also included in the list below. Credit: NOAA Fisheries.

Harbor porpoise monitoring in southeast Alaska near Juneau, 28 February -11 March. Passive acoustic moorings will be depluted to monitor the presence and movement of harbor porpoise. Data collected in 2022 will be used to determine the best placement of moorings in 2023 to deter harbor porpoise and protect them from injury and mortality in commercial fisheries. Contact: Kim Goetz (AFSC).

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 & Northern GOA Long Term Ecological Research (LTER) programs conduct surveys in the northern GOA (Fig. 14).

Preliminary results in spring show that the chla was relatively high, the highest chl-a was in the west (compared to the east in 2021), wind mixing pushed chl-a > 100 m deep in contrast to the upper 20 m in 2021, and the high chl-a was mostly in large cells (chain forming diatoms) (Fig. 15). The GAK1 temperature was below average, and integrated temperatures over 0-100 m were cooler across and beyond the shelf (Fig. 15, bottom 2 panels). Moderate numbers of large copepods were observed. Contact: Rob Suryan (AFSC), Suzanne Strom (WWU), Seth Danielson (UAF), Russ Hopcroft (UAF).

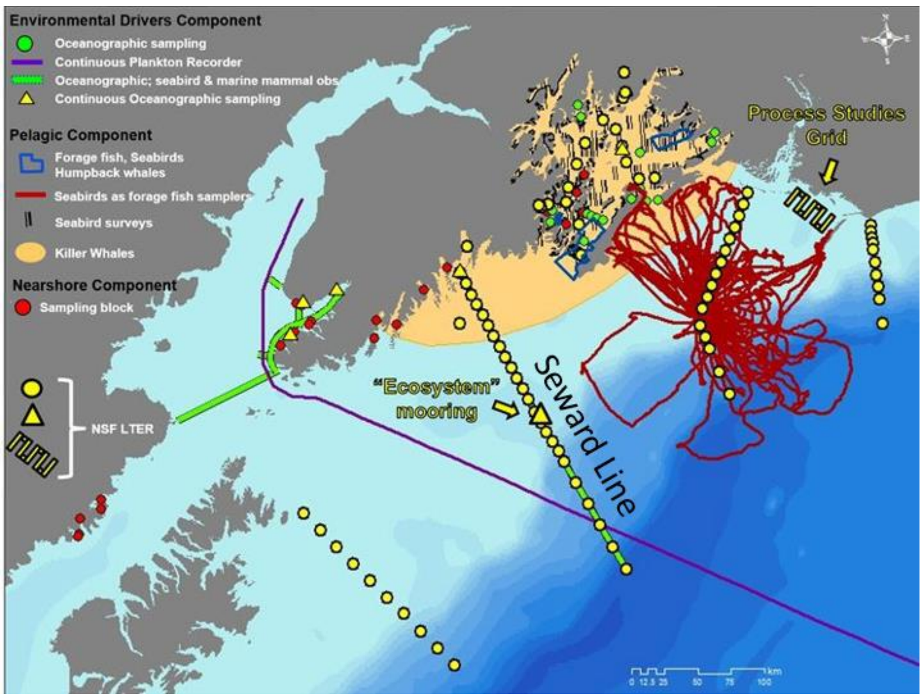
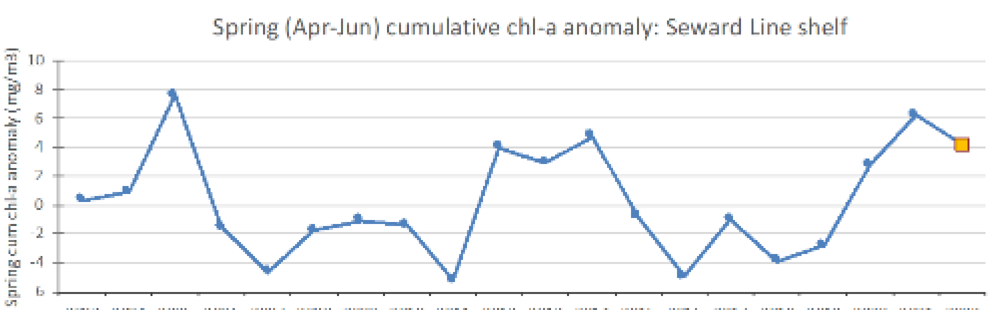


Figure 14. Gulf Watch Alaska and N. GOA Long Term Ecological Research (LTER) surveys.



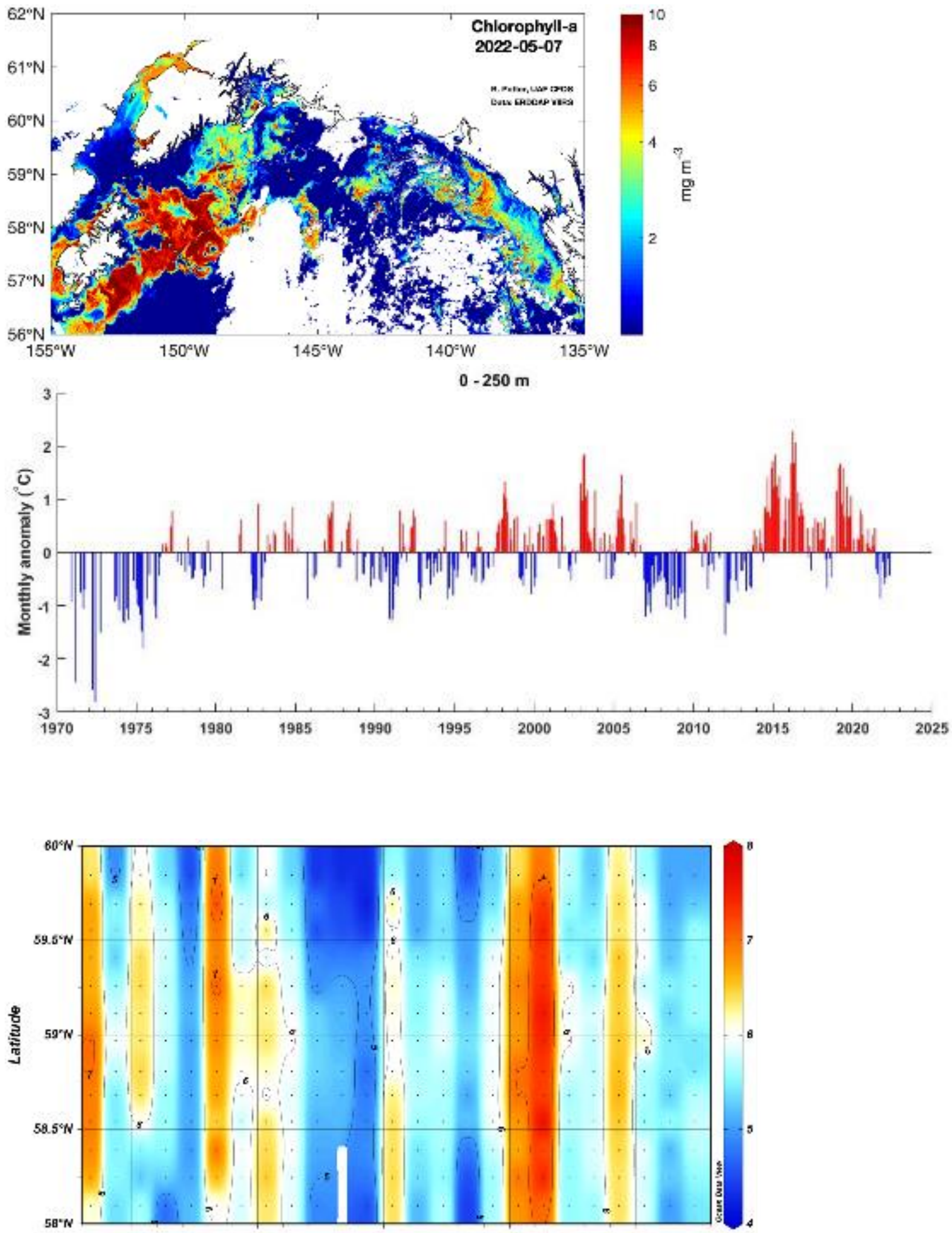


Figure 15. (Top) Spring chl-a 2022, (Middle top) Satellite Chl-a, (Middle bottom) GAK1 thru April 2022 temperature anaomalies over the top 250 m, (Bottom) 1998-2022 0-100-m integrated temperatures. Figures courtesy of Suzanne Strom (WWU), Seth Danielson (UAF), Russ Hopcroft (UAF).

Seabird diets at Middleton Island in the central GOA are used to understand changes in forage fish. In 2021 age-0 sablefish size was below average with few sablefish in diets (n=5). In contrast, in 2022 there were many more age-0 sablefish in diets (n > 100). In 2022 there was a positive trend for sand lance, but surprisingly very few capelin. Contact: Yumi Arimitsu, Scott Hatch.

Longline Survey in the Aleutian Islands and GOA on the F/V Alaskan Leader, 01 June – 28 August (Fig. 16). The main objective of the survey is to collect relative abundance information for sablefish and other groundfish species, including GOA Pacific cod, shortspine thornyhead, rougheye/blackspotted rockfish, shortraker rockfish, spiny dogfish, and grenadiers. Scientists fish 8,100 hooks/day at depths from 150-1000 m. Contact: Pat Malecha (AFSC).

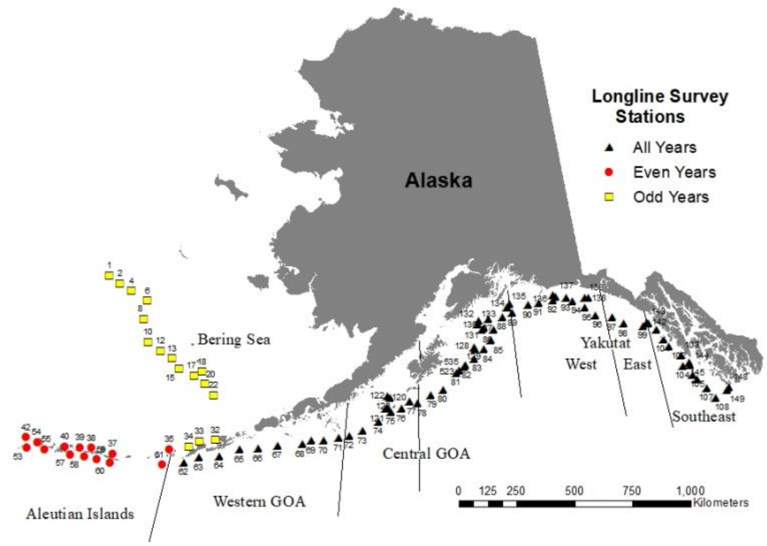


Figure 16. 2022 longline stations (red dots and black triangles) fished for sablefish and other groundfish. Figure courtesy of Pat Malecha (NOAA, AFSC).

Beluga whale aerial abundance survey in Cook Inlet, 05-20 June. The overall research objective is to obtain an abundance estimate for the endangered population of beluga whales in Cook Inlet, Alaska. Contact: Kim Sheldon & Paul Wade (AFSC).

Aleutian Islands summer bottom trawl survey on the F/V Alaska Provider and the F/V Ocean Explorer, 06 June – 18 August (Fig. 17). The overall objective is to characterize the ecologically and economically important fish, crab, and other resources that live on or near the seafloor. The precise fishing methods of the survey yields observations of species, their densities, and biological characteristics such as length, gender, age, and food habits. These observations are turned into abundance time series used in stock assessments and ecological models. Real time bottom temperature data for this survey can be found at this link: https://www.fisheries.noaa.gov/alaska/climate/near-real-time-temperatures-aleutian-islands-bottom-trawl-survey-2022?utm_medium=email&utm_source=govdelivery. Contact Wayne Palsson (AFSC).

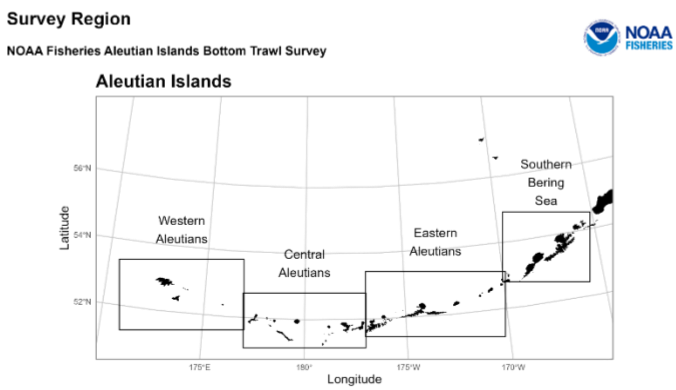


Figure 17. Locations of summer Aluetian Island bottom trawl survey 2022.

<u>Coral Settlement Plate Recovery and Deployment</u> in the Gulf of Alaska (Fairweather Ground off southeast Alaska) onboard the R/V Solstice, 09-20 June. Goals include estimation of reproductive ecology in Alaskan deep sea corals and sponges. Contact: Jerry Hoff (AFSC).

<u>Validation of coral & sponge distribution modeling</u> in the Gulf of Alaska, onboard the R/V Woldstad, 10 June – 15 July. Researchers visited ~ 300 randomly selected stations from Unimak Pass to Southeast Alaska to estimate density and size for deep sea coral and sponge, and document species associations with fish and other invertebrates. Data collected from this project will be used to refine species distribution models and maps for the Gulf of Alaska and inform management of regions of high coral and sponge density and diversity. Contact: Pat Malecha (AFSC).

<u>Aerial survey for Steller sea lions</u> in the Aleutian Islands, 23 June – 12 July. Marine mammal biologists conducted an aerial survey to collect digital images of Steller sea lions in the Aleutian Islands (western Distinct Population Segment). Survey images will be use to count adults, juveniles, and pups. Contact: Tom Gelatt & Katie Luxa (AFSC).

<u>Southeast Coastal Monitoring (SECM)</u> survey (26 year time series) in the eastern GOA inside waters during May, June, and late July/ early August (Fig. 18). Surface trawl for juvenile salmon, age-0 gadids (Pacific cod, saffron cod, pollock), and sablefish and oceanographic sampling (CTD, zooplankton tows) to evaluate onshore-offshore gradient of juvenile gadid growth and energetics, feeding ecology of southern coastal age-0 groundfish, and HABs. Preiminary results indicate copepod density above averageand, juvenile salmon average size, except chum slightly above average (Fig. 19). Contact: Wes Strasburger (AFSC).

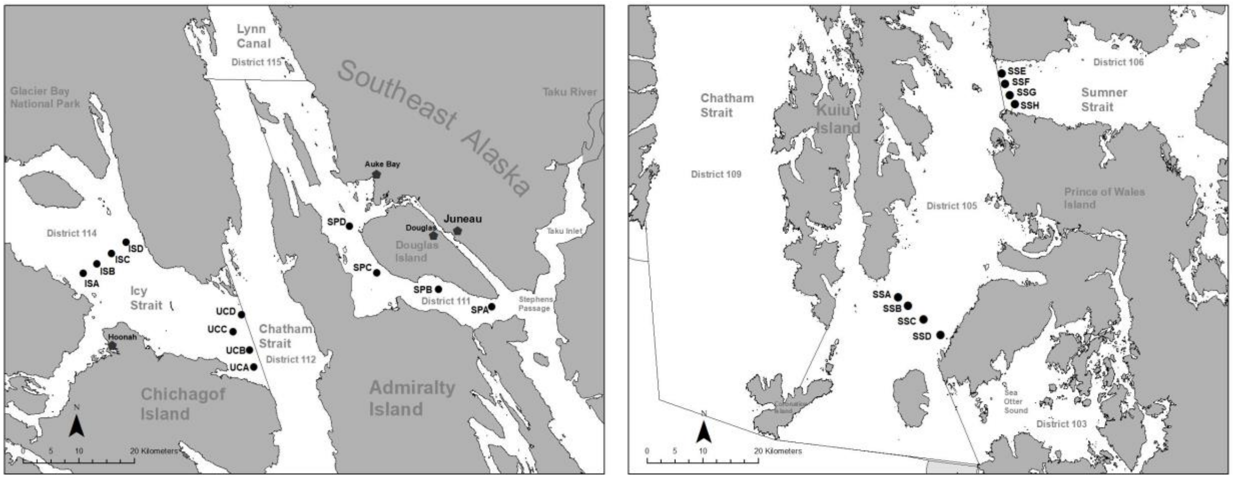


Figure 18. SECM survey in southeast Alaska, 2022. Icy Strait (IS*), Upper Chatham Strait (UC*), and Stephens Passage (SP*) stations (left) and Sumner Strait (SS*) stations (right) aboard the R/V Medeia during June and late July/early August. Icy Strait and Upper Chatham Strait stations sampled for oceanography only (no twaling) in May 2022.

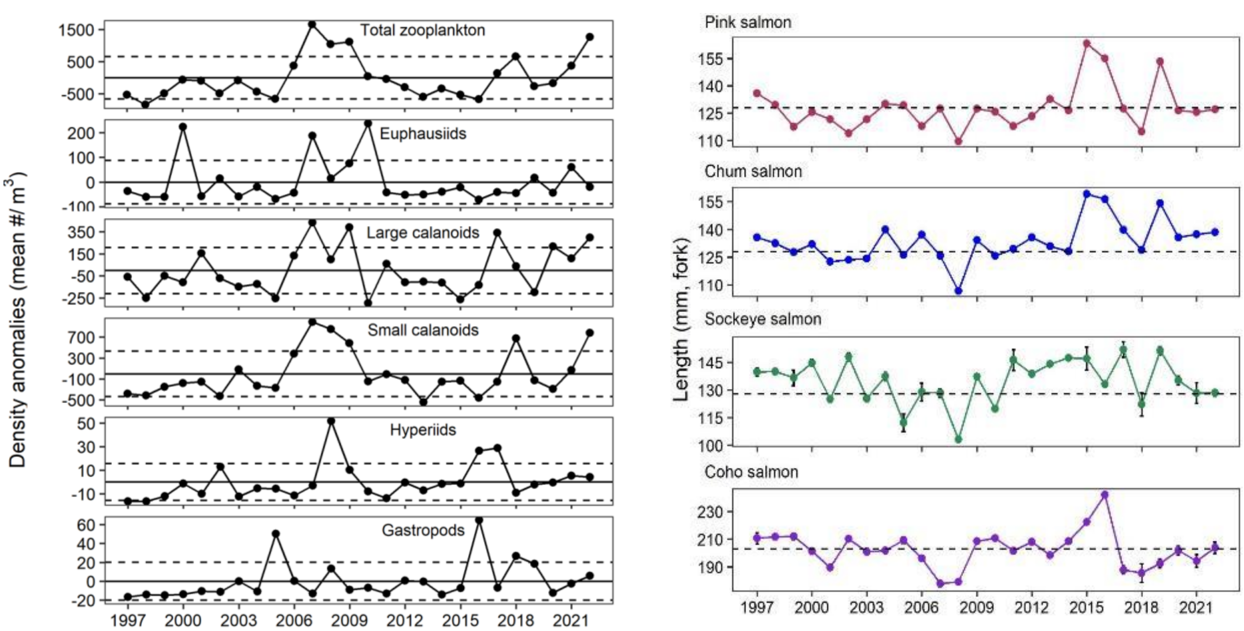


Figure 19. SECM observations 1997-2022. Figures courtesy of Wes Strasburger, Emily Fergusson, Andrew Gray (AFSC).

Western GOA Summer Beach Seine in Kodiak: July/Aug (4 surveys, 16 sites across 2 bays) 2006-2022 Expanded WGOA: July/Aug (75 sites across 14 bays) 2018-2022 (Fig. 20). Operations: Beach seine, CTD, baited cameras. Indicators: abundance & size, genetics, diets, temperature, salinity, oxygen. Preliminary results indicate 2022 Age-0 Pacific cod abundance significantly higher than long-term log mean, and 2022 age-0 pollock abundance relatively high, but spatially variable. Contact: Ben Laurel, Mike Litzow, Alisa Abookire.

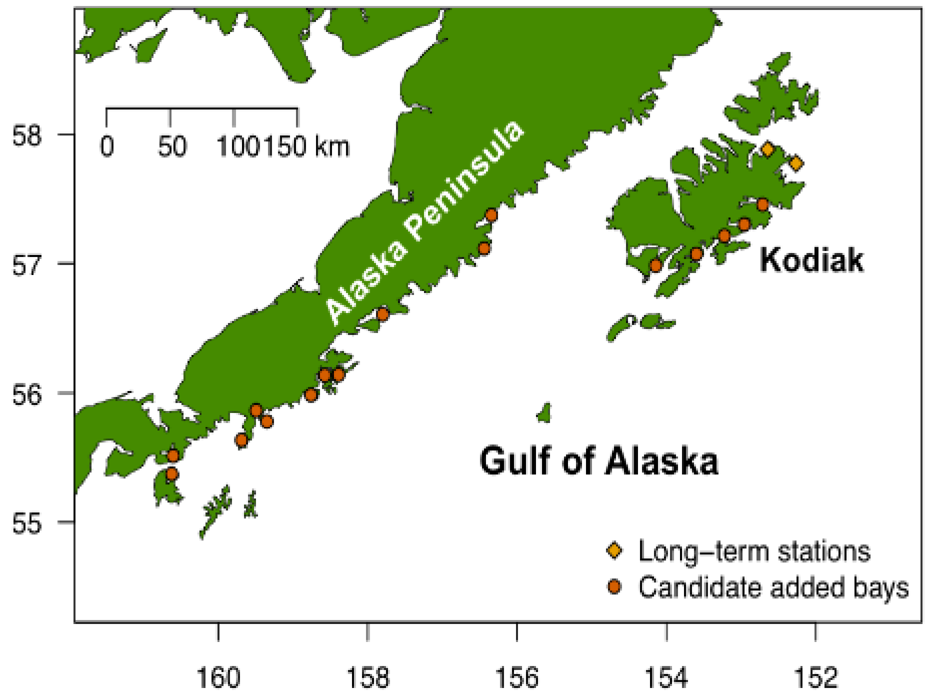


Figure 20. Beach seine station locations in 2022.

Pacific Ocean Whale and Ecosystem Research Programme (POWER) Survey in the US EEZ south of the Aleutian Islands from Samalga Pass to the Russian border, 09 August -19 September. International Whaling Commission-sponsored collaborative survey between NOAA and the Government of Japan. Visual line transect survey for marine mammals with passive acoustics via sonobuoys, with a possibility of finding North Pacific Right Whales (critically endangered). Photo-ID and biopsy samples will be collected from high priority species. AFSC contact: Jessica Crance.

3. Republic of Korea

1. National Institute of Fisheries Science (NIFS)

Marine Heatwaves (MHWs) monitoring in the Korea Waters

In summer of 2022, the 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 1~3°C. 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.

Real-Time observation system using Ferry vessel

To study the physical oceanic condition of the surface layer around Korea Waters, real-time observation system using ferry vessel is operating. The main observation factor is water temperature and salinity, and total 3 vessel is in operation. Especially, the regular route of vessel around Busan-Jeju and GangWon-Ulleung Island is useful to understand distribution and diffusion of low saline water around Korea waters.

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 Meteorological Administration (KMA)

Ocean weather observation system around the Korea Peninsula

KMA is operating 26 ocean data buoys to observe wind, atmospheric pressure, humidity, water temperature, wave height, and wave direction in Korean waters. This year, two large 10-meter discus ocean data buoys will be installed in the East Sea and in the center of the East China Sea.

3. Korea Hydrographic and Oceanographic Agency (KHOA)

KHOA operates 138 ocean observation facilities year-round to produce and provide marine information necessary for systematic management of Korea waters

and prevention of marine disaster. Ocean observation facilities consist of 55 tidal stations, 3 ocean stations, 36 ocean buoys and 44 HF-radars. The facilities observe tidal level, marine weather, seawater flow, and water temperature at 1, 30, or 60 minutes intervals. This information is provided through the website.

4. Japan

National report from Hokkaido University, Japan (by Hiroto Abe at Faculty of Fisheries Sciences)

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

Hokkaido university have two training ships, one is *Oshoro-Maru* and the other is *Ushio-Maru*. The former has contributed to monitoring open ocean/marginal seas in the North Pacific including Bering Sea over the decades, while the latter has monitored coastal areas around Hokkaido island, Japan. We reported in the previous national report that many of scheduled cruises in 2020 and 2021 for both education and research purposes were canceled due to the outbreak of COVID2019. In 2022, cruise schedules have not been seriously influenced by the COVID2019. Coastal monitoring in Tsugaru Strait by training ship *Ushio-Maru* has been quarterly conducted with researchers from Mutsu Institute for Oceanography (MIO) JAMSTEC since 2009 (Fig. 1). Figure 2 shows cross section of temperature and salinity in eastern mouth of the Tsugaru Strait in May 2022 as an example. This is the region where warm saline water originating from Kuroshio via Sea of Japan and cold less-saline water from Oyashio and Okhotsk Sea meet and combine. Clear meridional contrast of water mass property is observed. Compared to those in 2010–2017 temporal mean, this year was relatively cold in lower layer, whereas relatively warm and saline in upper layer in this season. The data will be made available online after all arrangements are finalized.

Sea surface temperature observations by satellites

Map of monthly-mean sea surface temperature (SST) is shown in Fig. 3, 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 2022. As mentioned in last year's national report, the remarkable positive SST anomalies (> +2°C) extending from Sea of Japan to Pacific coast of Japan islands were observed in July 2021. The last one year does not show such a widespread and dominant SST anomalies in all season. Time series of SST was created using the satellite data with focus on the region west and east of Hokkaido island (Fig. 4, see Fig. 3 for location of the box region). Regions A and B show interannual to decadal variability of SST anomalies. Compared to the last couple of years, positive SST anomalies are less represented in the last one year.

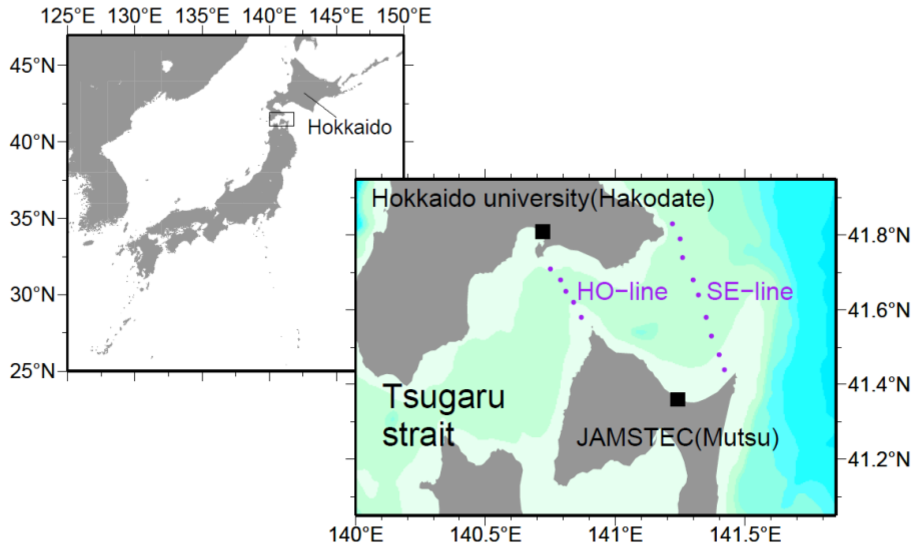


Fig. 1. Location of Tsugaru strait with SE (Shiriya-Esan) line and HO (Hakodate-Ooma) line.

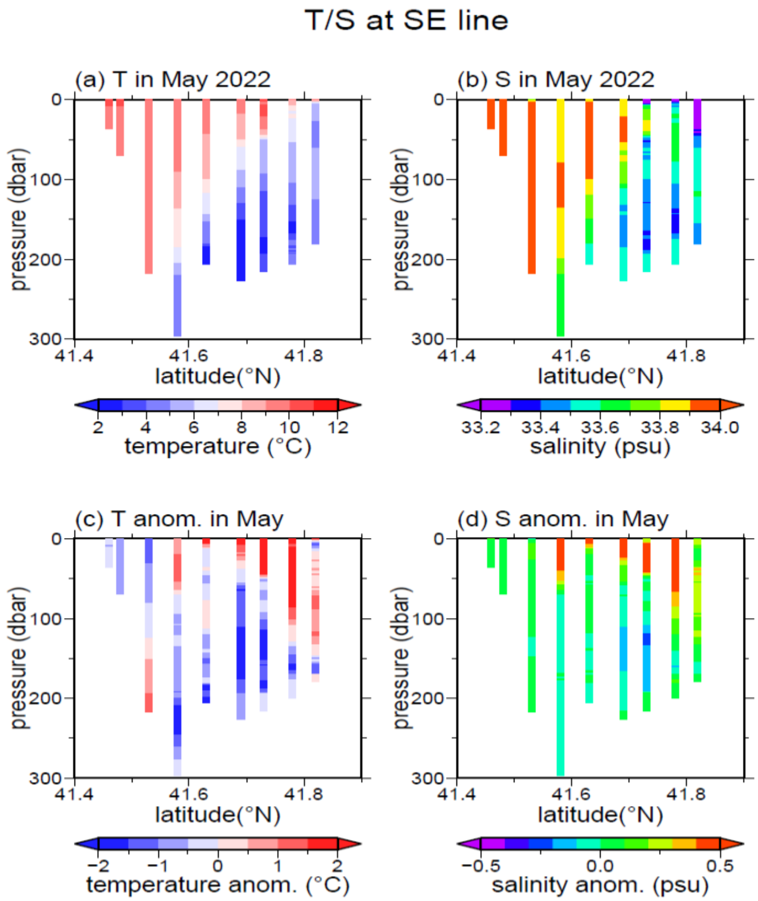


Fig. 2. Vertical section of (a) temperature and (b) salinity profiles measured at SE line in May 2022 (See Fig.1 for its location). (c) and (d) are temporal anomalies of (a) and (b) with respect to temporal means of those measured in May 2010 – 2017.

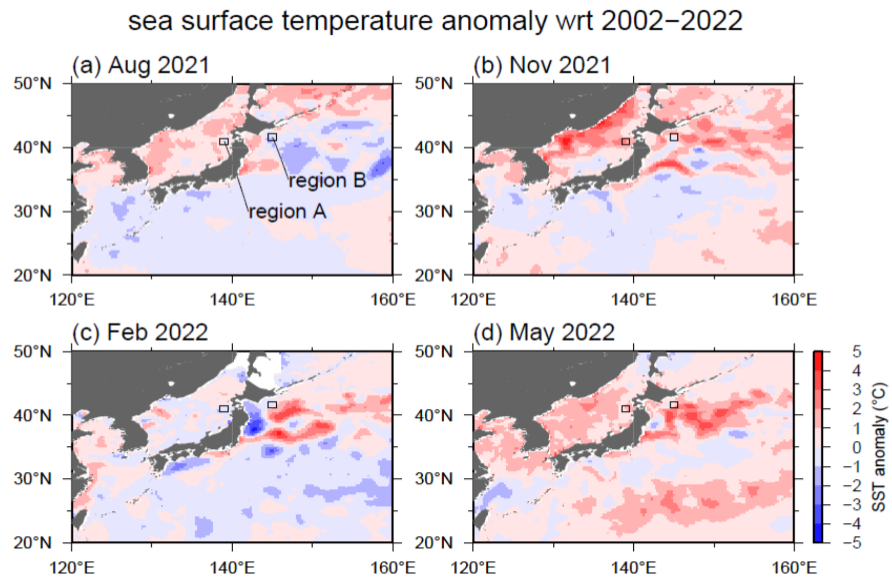


Fig. 3. Maps of monthly-mean SST anomaly in (a) August, (b) November, (c) February, (d) May of the last one year with respect to monthly climatological SST over 2002–2022. SST data observed by satellites (Aqua/AMSR-E and GCOM-W/AMSR2) have been used. SST data were downloaded from G-Portal, data server of JAXA (Japan Aerospace Exploration Agency).

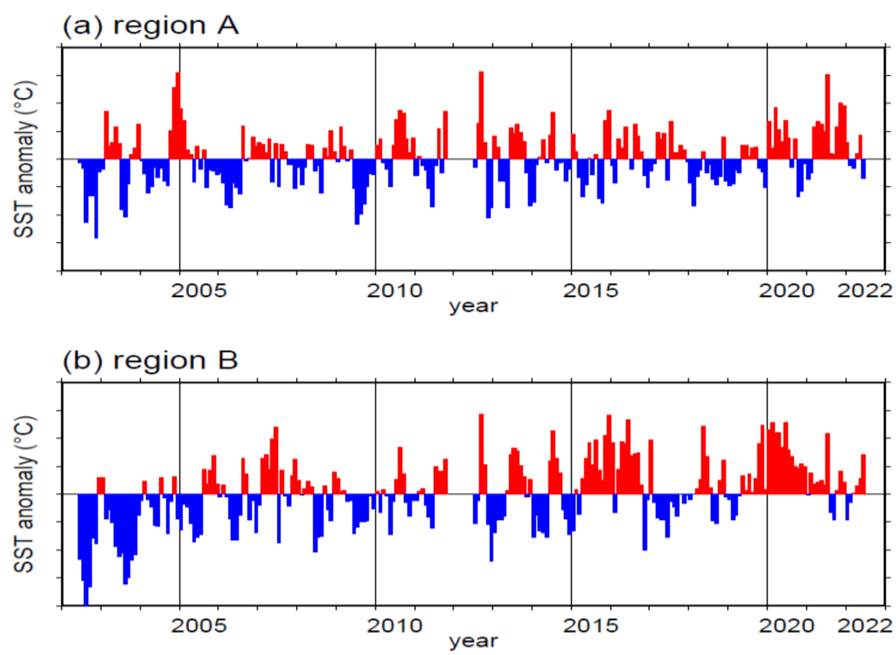


Fig. 4. Time series of monthly-mean SST anomaly with respect to monthly climatological SST over 2002 – 2022 averaged over the box regions shown in Fig. 3. SST data observed by satellites (Aqua/AMSR-E and GCOM-W/AMSR2) have been used. SST data were downloaded from G-Portal, data server of JAXA.

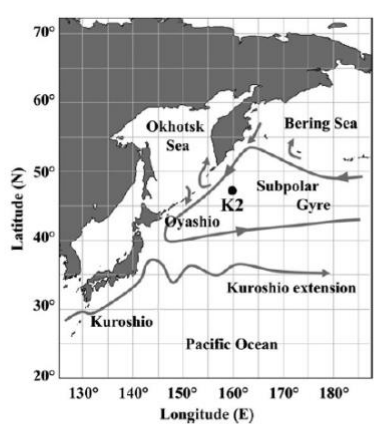
Report from Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

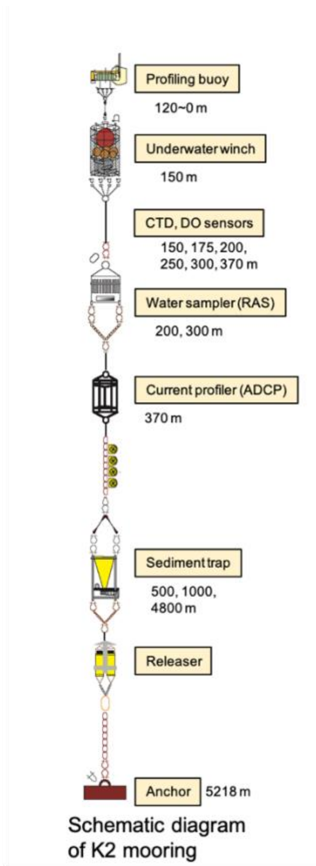
Minoru Kitamura, RIGC JAMSTEC

JAMSTEC is in charge of variety of ocean observation programs. In 2022, there were outbreaks of COVID19 at several vessels of JAMSTEC. These programs, however, are under operation.

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

The 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 trap moorings have been deployed in this station since 2001. In the current mooring system, an underwater winch is installed. 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, 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 are attached.





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.

The mooring system was recovered and redeployed in May 2022. Hydrographic observations were also conducted during the cruise.

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

The Kuroshio Extension Observatory (KEO; 32°18′N, 144°36′E) is a mooring station maintained under NOAA's Ocean Climate Stations Project. The KEO mooring has meteorological instruments as well as sensors to measure upper ocean environments. JAMSTEC deployed other mooring system with sediment traps near the KEO since 2014. From 2014 to 2019, only a sediment trap was moored. After 2019, two sediment traps were installed at 1800 and 4900 m in depths in the mooring system. In January 2022, the mooring system was successfully recovered, and time-series samples of the sinking particles were collected from the two depths. After the sample recovery, the sediment trap mooring was redeployed in January 2022.

3. Argo JAMSTEC

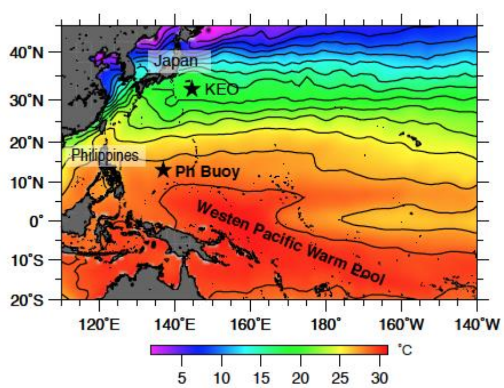
The Pacific Argo Regional Center (PARC) has been established as a joint collaboration between the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the International Pacific Research Center (IPRC) at the University of Hawaii, and the Commonwealth Scientific and Industrial Research Organization (CSIRO). 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. To contribute to the OneArgo (one of the UN Decade Projects), JAMSTEC with other institutes in Japan have deployed the many types of profiling floats (core Argo floats, BGC float, Deep float) primarily in the north Pacific Ocean. From September 2021 to August 2022, total of 24 floats were deployed by Japan.

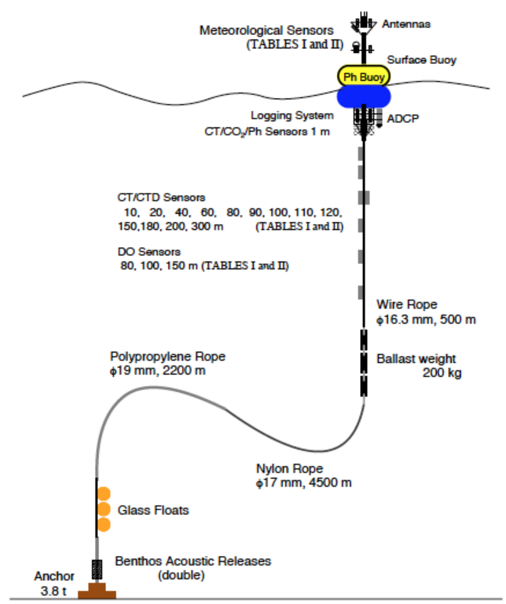
4. Deep NINJA: Deep ocean observation by deep-sea float

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. Total of 31 Deep NINJA floats had deployed since 2012, primarily in the Southern Ocean. Among the 31 floats, one float is active as of August 2022. And a float will be deployed in end of 2022. A new type of Deep NINJA installed turbulence sensor is in under development by University of Tokyo and Tsurumi-Seiki Co. Ltd. Technical life of the Deep NINJA is also under improvement by the manufacturer.

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

A time-series observation station was established at the Philippine Sea (13ºN, 137ºE) in 2016. To obtain real-time air-sea data, a surface buoy system (Ph buoy) has been deployed in 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 bottom of the buoy or the mooring wire rope above 300 m in depth. Current buy system was deployed in June 2021. And recovery and redeployment of this buoy system will be conducted in 2023 summer.





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

1. Zooplankton sample collection of Japan Fisheries Research and Education Agency

FRA has collected zooplankton samples from 1950s to present. The sampling gears are NORPAC net, Bongo net, Larval net, Neuston net, MTD net, VMPS, IKMT, MOHT etc. Total number of sample is 231228 at August 23, 2022. The samples are preserved by 5% buffered formaldehyde. The zooplankton samples are stocked in dedicated storage building at FRA Fishery Resources Institute of Shiogama field station (Fig. 1),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 2. Although sample number is 1981 in 1950s, it increased decade by decade. The number reached 83192 in 2010s. A part of the sample were collected by Dr. Kazuko Odate and it is well known as Odate collection. Those samples had 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). Web site: https://ocean.fra.go.jp/plankton/hyohon_home.html (only Japanese)

(a)

(b)

Fig. 1 Sample storage building at Shiogama field station of FRA Fishery Resources Institute. Exterior (a) and inside (b) of the Building.

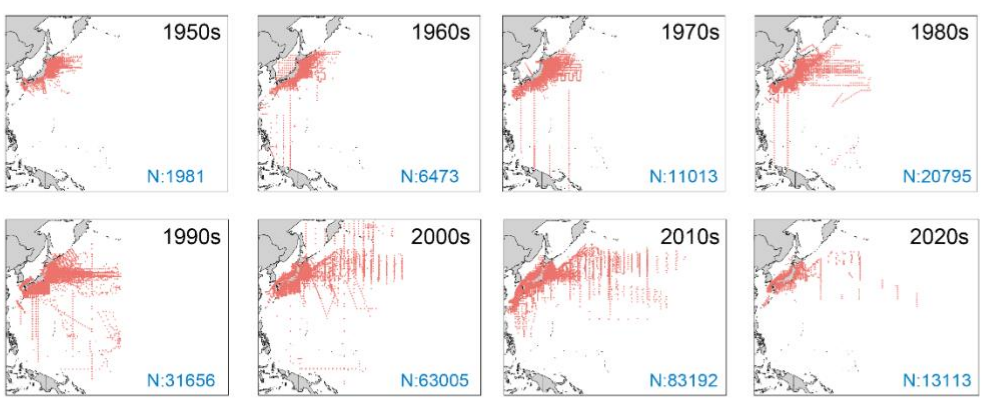


Fig. 2 Sampling location and number of zooplankton collection for the each decade

2. Observation of Monitoring lines

FRA have carried out oceanographic observation monitoring at 6 lines around Japan (Fig. 3). Detail of the observation is described as below.

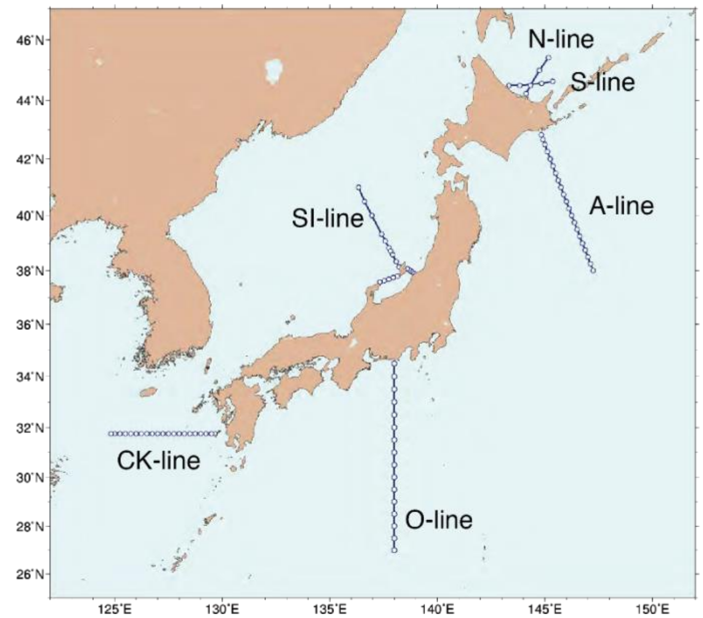


Fig. 3 6 monitoring lines around Japan has been conducted by Fisheries Resources Institute of FRA

<u>A-Line</u>

Shiogama and Kushiro field stations of 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. In recent year, 5 times observations were carried out in January, March, May, July, and October throughout a year. Observation items are CTD, water sampling by Niskin bottles, NORPAC net, and Bongo net. The oceanographic data are opened and available from the website (Fig.4). Period of published data are from 1990 to 2020 for CTD and from 1990 to 2016 for others.

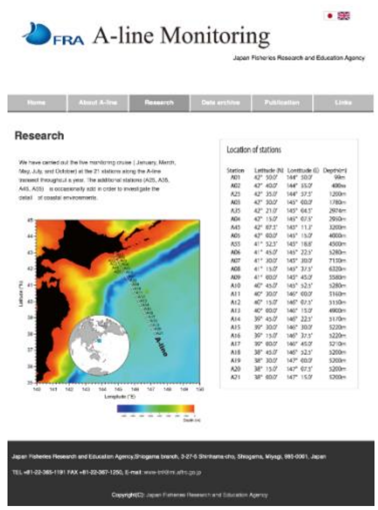


Fig. 4 Website of A-line monitoring (https://ocean.fra.go.jp/a-line/a-line_index2.html)

<u>O-line</u>

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

<u>CK-line</u>

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

<u>SI-line</u>

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

<u>N-line, S-line</u>

Kushiro field station of Fisheries Resources Institute, FRA have carried out the monitoring from 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.

3. Monitoring of stock assessment project commissioned by FRA

The observations have been carried out at 760 stations (Fig. 5) in the waters around Japan except with Okinawa and Hokkaido from 1972. The frequency of the observation is monthly except with the station in the Sea of Japan. In the Sea of Japan, the 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 of CTD and abundance of egg, larvae, juvenile of pelagic fish are archived in the database of FRESCO (Fisheries Resource Conservation) system managed by JAFIC (Japan Fisheries Information Service Center).

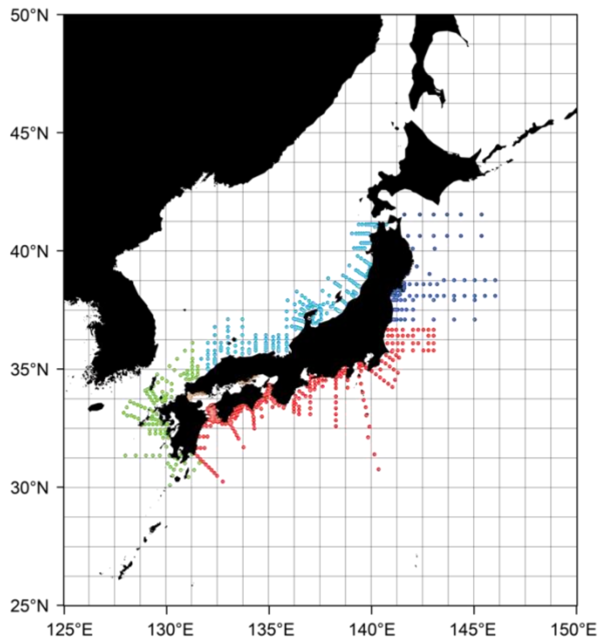


Fig. 5 Sampling location of the Monitoring of stock assessment project

4. Fish eggs, larvae, juvenile sample collection

Yokohama head quarter of Fisheries Resources Institute, FRA started to collect the samples (Fig. 6) from 2015. The samples were mainly collected by monitoring of stock assessment project commissioned by Fisheries Agency of Japan. Now the recent samples are collecting, however the historical samples will collect in immediate future.

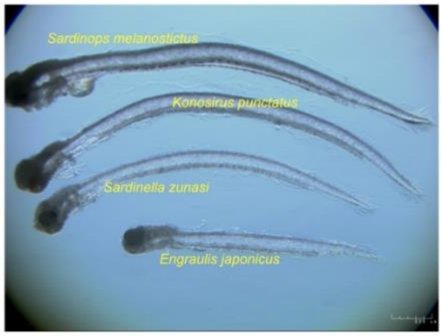


Fig. 6 Fish larvae specimen samples

5. Fish specimen sample collection

Nagasaki head quarter of Fisheries Technology Institute (Fig.7), FRA have collected fish specimen samples. The number of species is about 1200, and the total number of sample is about 32000. The samples are mainly preserved by isopropyl alcohol. DNA samples were also collected from a part of the sample.

Fig. 7 Sample storage building (above) for the fish specimen collection, and the specimens (below)

References

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

5. Russia

Report on the monitoring activity in Russia by POI FEB RAS (V.Lobanov)

V.I.Il'ichev Pacific Oceanological Institute of the Far Eastern Branch of Russian Academy of Sciences (POI FEB RAS) has been continuing its monitoring programs in 2021-2022 under the following projects:

1. Primorye upwelling system and its impact on Peter the Great Bay. One of the mooring site is located near Vladivostok, to the south of Russkiy Island at the 22 m depth (Fig. 1). Observations of temperature and salinity in the bottom layer have been implementing every summer-fall seasons since 2008. Since 2019 the observations cover whole year cycle (24 month). In 2022 a CTD sections across the bay was added (Fig. 1). Motion of the benthic front, a border between warm and low salinity shelf water and colder and more saline and rich in oxygen water of open sea, is important for changing situation on the shelf of peter the Great Bay and ventilation of the Peter the Great Bay water in the beginning of Fall season.

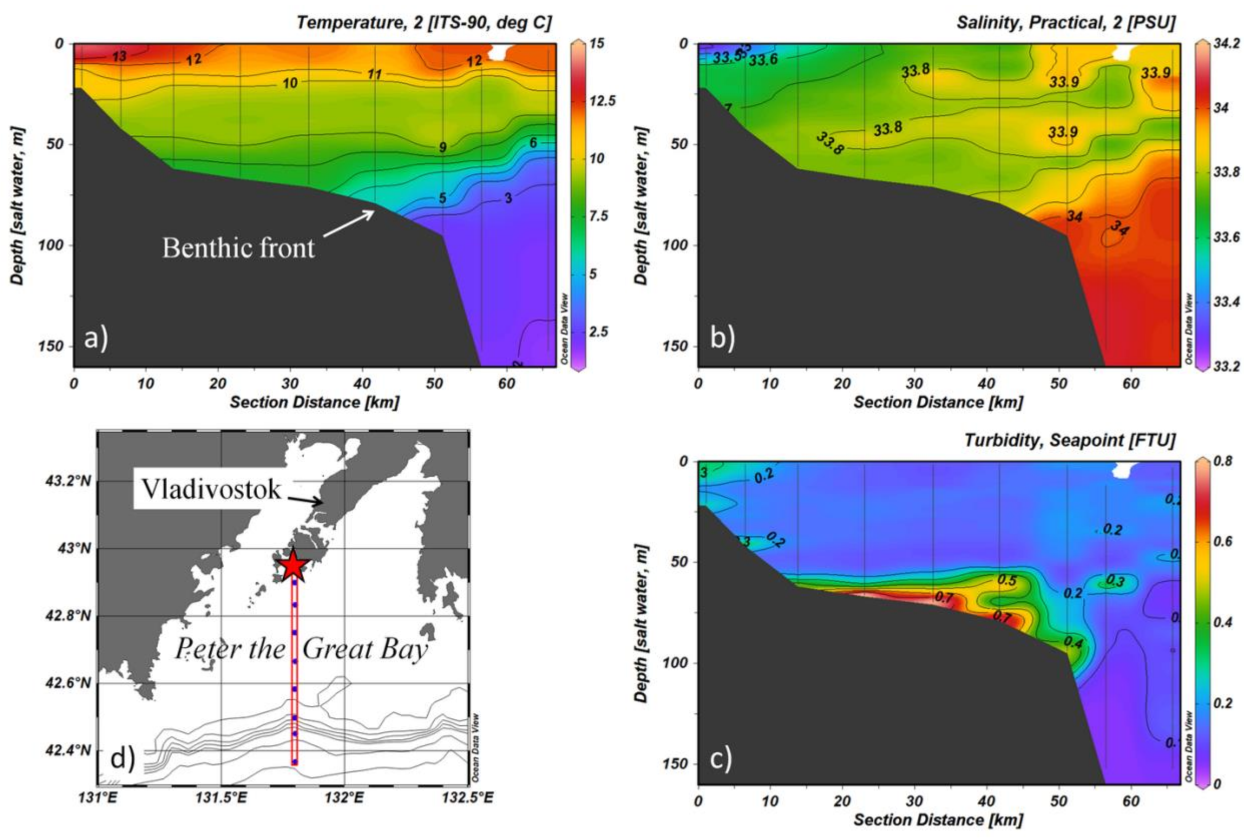


Fig. 1. Peter the Great Bay monitoring site of POI FEB RAS at the southern coast of Russkiy Island is shown by red star (d). Distribution of (a) water temperature, (b) salinity and (c) turbidity along meridional section (d) across the shelf of Peter the Great Bay in June 2022

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 SNU (Korea) and NEAR-GOOS line (along 134E) implemented jointly with JMA (Japan). CREAMS line was started in 2001 and is observed every 1-3 years. The last time in 2019. NEAR-GOOS line is observed every fall season since 2011 and was observed last time in December 2021.

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

4. Monitoring of seals behavior jointly with Cetaceans Research Institute of NIFS (Rep. Korea) was continued in 2022 by marking Largha Seal in the Peter the Great Bay. The seal has shown quite a standard behavior by migrating along the coast of Primorye to the north-east up to Tatar Strait and then turned to the south-east to Sakhalin Island in late June, where she stayed for a few months in the area around Krillion Cape making foraging migrations between Sakhalin and Hokkaido (Fig. 2). This area is known as a permanent upwelling zone caused by divergence along Soya Current front and tidal mixing. It is expected that the seal will come back to the Peter the Great Bay for wintering by the end of the year, as it was observed in previous experiments.

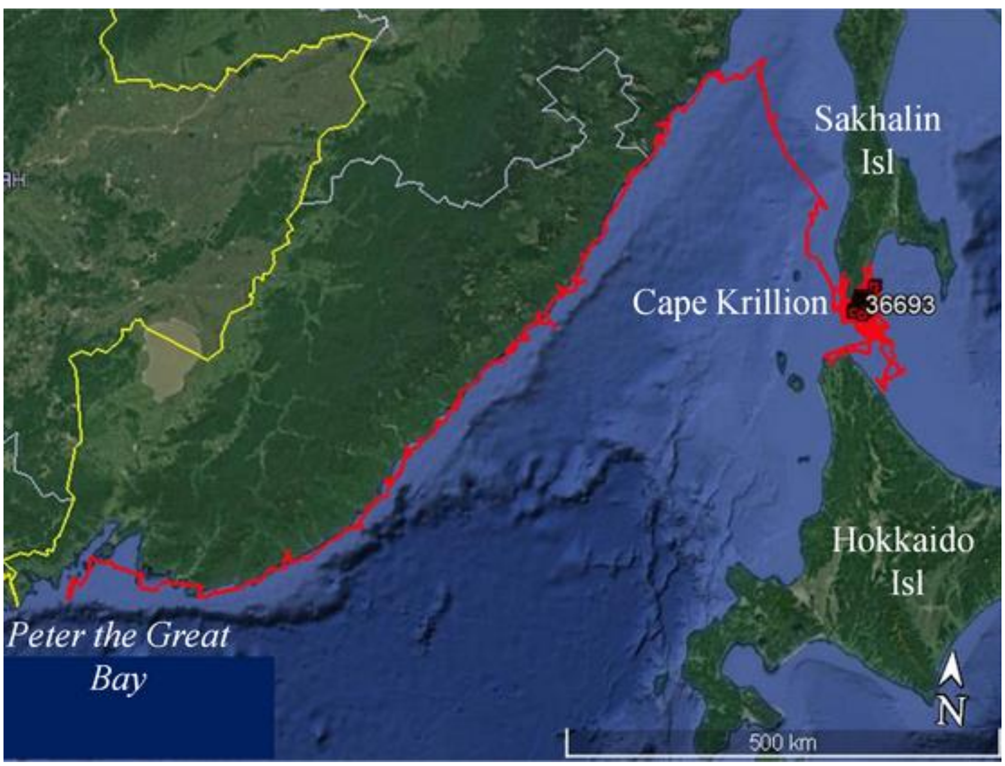


Fig. 2. Track of the Largha Sea marked by satellite tag in Peter the Great Bay from May till September 2022 (Aleksey Trukhin et al., personal)

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 1078 midwater trawls during fishery-independent surveys in the Northern part of the Pacific Ocean in 2021 (Fig. 1). 77 of those trawls were conducted in the high seas.

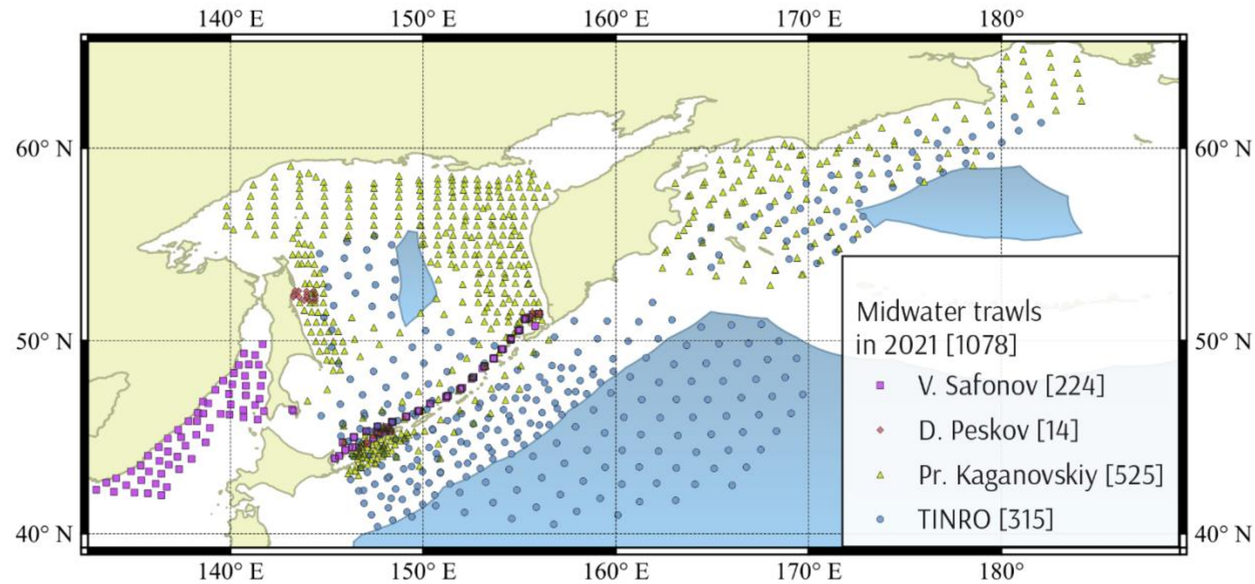


Fig. 1. Midwater trawls, conducted by TINRO's R/V in 2021

There were 541 midwater trawls conducted by R/V of TINRO in the Northwestern part of the Pacific Ocean in 2022, which have been processed already (Fig. 2). In the high seas there were 50 trawls (excluding 32 trawls in the North-Eastern Pacific under the International Year of the Salmon).

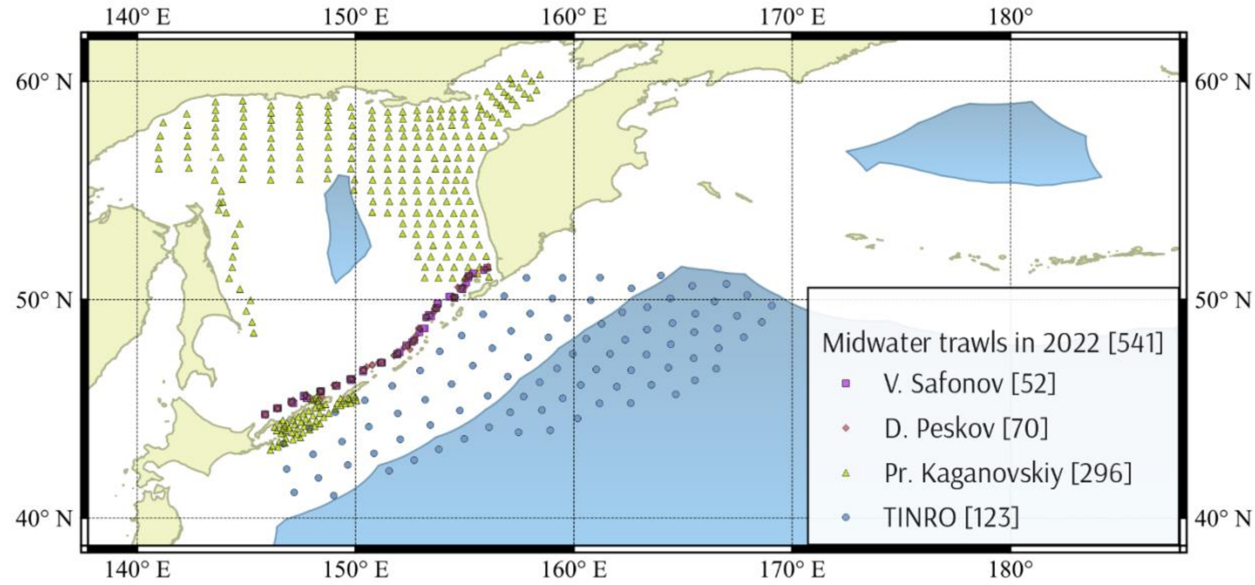


Fig. 2. Midwater trawls, conducted by TINRO's R/V in 2022 so far (the figure will be updated in 2023)

There were 744 bottom trawls conducted by R/V in 2021, which were imported into the database in TINRO (Fig. 3).

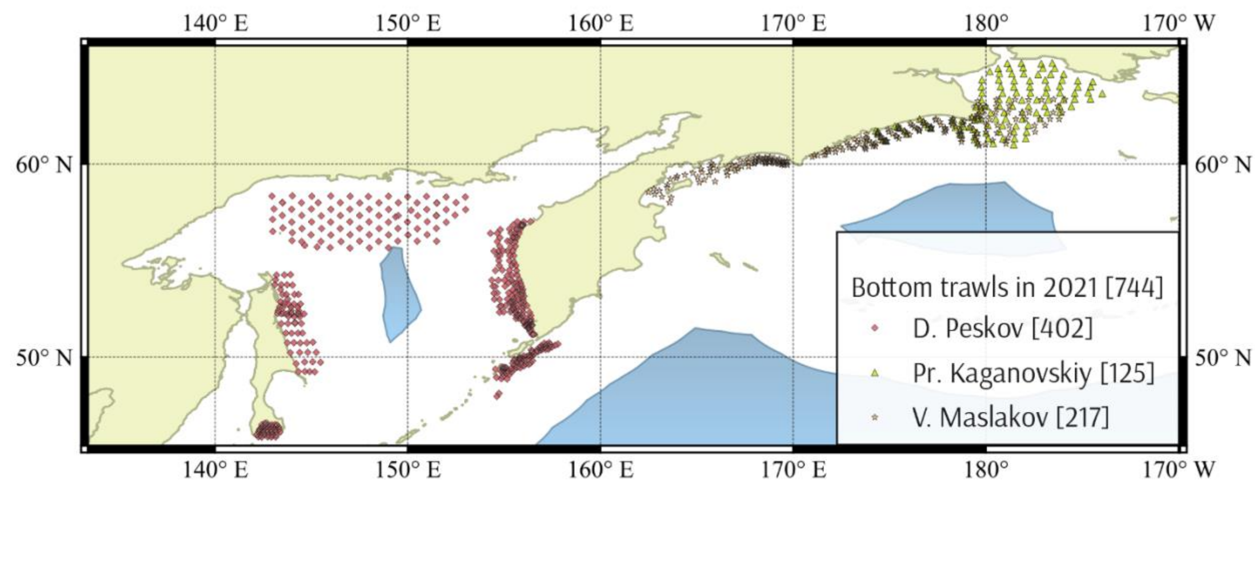


Fig. 3. Bottom trawls conducted by TINRO's R/V in 2021

In 2022 the Division for fishing statistics and databases has processed fully only 2 surveys with 322 bottom trawls (Fig. 4).

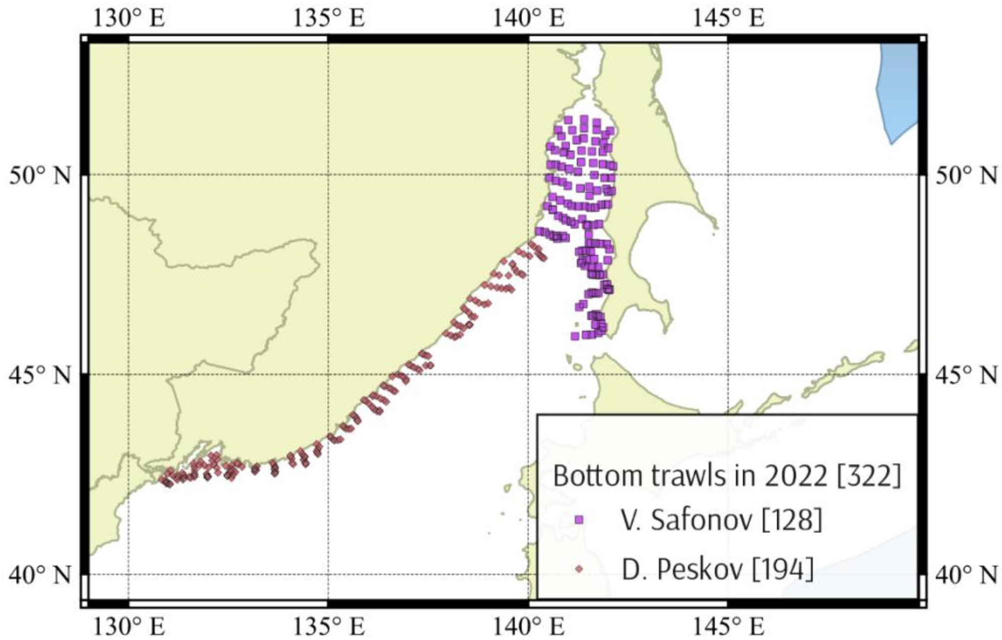


Fig. 4. Bottom trawls conducted by TINRO's R/V in 2022, which have been processed so far (the figure will be updated in 2023)

Other surveys are in progress or have not been processed yet (e.g. near the West coast of Kamchatka).