Report of the Technical Committee on Monitoring

The Technical Committee on Monitoring (hereafter MONITOR) met twice in Victoria, Canada: 1) 18:00 to 20:00 on Sunday, October 20, 2019 and 2) 14:00 to 18:00 on Wednesday, October 23, 2019. Prior to the meetings, a MONITOR briefing book, containing the draft agenda and information regarding agenda items, was circulated to MONITOR members. The briefing book was updated and recirculated as new information was provided.

MONITOR meeting participants (from left to right) front row: Jennifer Boldt, Sanae Chiba, Tetjana Ross, Sonia Batten, Vyacheslav Lobanov, Sung Yong Kim; back row: Hiroto Abe, Lisa Eisner, Kym Jacobson, Jack Barth, Vladimir Kulik, Kazuaki Tadokoro, Eok Dong Kim, In-Seong Han; missing: Sei-Ichi Saitoh

Sunday, October 20, 2019

AGENDA ITEM 1
Welcome and introductions

MONITOR Chair, Dr. Jennifer Boldt, called the meeting to order, participants introduced themselves, and the agenda was reviewed and adopted (***MONITOR Endnote 1*** *and* ***MONITOR Endnote 2***).

AGENDA ITEM 2
PICES-2019 information and judges

a. Topic Sessions and Workshops

MONITOR sponsored PICES 2019 Topic Session S9 "*Coastal Ocean Observing Systems, Essential Biological Variables, and community-based monitoring*":

Duration: 1 day
Convenors: Charles Hannah (Canada), corresponding, Sung Yong Kim (Korea), Kim Juniper (Canada)
Invited Speakers: Sanae Chiba (Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Eric Peterson (Hakai Institute, BC, Canada)

b. Judges for the best presentation award (MONITOR members)

MONITOR was tasked by the Science Board Chair to judge one MONITOR-sponsored Topic Session. Only ECS are eligible for Best Poster Presentation for Sessions and Workshops. Only ECS are eligible for Best Oral Presentation for Sessions. ECS who make oral presentations at workshops will not be judged, and are not eligible for Best Oral awards.
MONITOR members volunteered to judge presentations and posters in S9 and provided their rankings to the MONITOR chair.

Best Oral Presentation was awarded to early career scientist, Erin Satterthwaite, for her talk titled "*Developing a biological Global Ocean Observing System: Qualities, attributes, and readiness of existing biological Essential Ocean Variable networks*". Best Poster was awarded to early career scientist, Patrick Pata, for his poster titled "*Sensitivity analysis on zooplankton bioregionalization of British Columbia*" (see Best Presentations at PICES-2019).

AGENDA ITEMS 3, 7
Relations with international organizations

a. CPR Survey at the Marine Biological Association and GACS

Dr. Willie Wilson, representing the CPR Survey at the Marine Biological Association, updated the MONITOR committee on the MBA and the Continuous Plankton Recorder (CPR) program. The MBA has a Royal Charter and over 1,700 members worldwide, with a mandate to provide an authoritative and independent voice on behalf of the marine biological community.
Dr. Wilson provided some highlights about the CPR program:

- Most geographically extensive and longest running marine biological survey in the world (since 1931);
- Currently tow 10,000 nautical miles/month;
- Almost 7-million nautical miles towed to date with over 550,000 plankton samples;
- Data freely available. Physical archive of stored filters back to the 1960s – resource for molecular ecology research;
- Impact of CPR Survey research influences policy, climate change, human health, plastics, fisheries, biodiversity, pathogens, invasive species, ocean acidification.
- 30–50 high impact papers/year;
- CPR fleet being modernised with autonomous instrumentation, optical and eDNA tools.

Dr. Wilson noted that 2019 marks the 20th anniversary of the North Pacific CPR program which has resulted in:

- 30,000 samples collected and archived;
- 8,000 samples analysed;
- 30 papers published; data freely available, contribution to ocean assessment reports.

Dr. Wilson also discussed the Global Alliance of CPR Surveys (GACS) and the GACS data portal. The current focus of GAS is on improved products and integration of data to improve research, and to develop models to better extrapolate across time and space.

For more information on MBA, CPR, or GACs, see www.mba.ac.uk.

b.) POGO

Dr. Willie Wilson provided an update on POGO activities. POGO is a consortium of major oceanographic institutes around the world, represented by their Directors. Their mission is to:

- Lead innovation and development of the crucial components of the ocean observing system,
- Identify and contribute to the development of key skills, capabilities and capacities,
- Work with governments, foundations and industry, to articulate the benefits to society and required funding to build and sustain the system.

The three main pillars of POGO are:

- Promoting ocean observations by conducting research and undertaking scientific oceanographic observations;
- Development of worldwide capacity for oceanographic observations by supporting training and knowledge transfer;
- Outreach and advocacy – from improving "ocean literacy" within the general population, through to influencing policy-makers by speaking with a common voice on behalf of the marine science community.

Some of the ways POGO supports such innovation and development is through:

- Annual Workshops held during POGO Annual Meetings.
- Working Groups funded by POGO, selected from proposals submitted by the members in response to a call.
- Working in partnership with other organizations, with a long-standing collaboration with IOC and SCOR. POGO helped to launch Argo and OceanSITES programs and provided financial support to those programs in the beginning. POGO also created the Blue Planet Initiative within the Group on Earth Observations (GEO) in 2011.

Current POGO projects include:

- OpenMODS: To conceive/identify an easy-to-use, flexible and affordable core set of ocean sensors and platforms;
- SAGITTA: a project of the NF-POGO Alumni Network for Oceans (NANO): to implement a citizen science approach for consistent and regular temperature profile data collection in the coastal ocean;
- Bio Obs WG: workshops on Artificial Intelligence/Machine Learning for biological oceanographic observations (imaging, acoustics, genomics) in 2019 and eDNA in 2020.
- WG on DNA sampling tools for the global CPR survey: Workshop planned for November 2019.

In 2017, POGO launched a dedicated web portal for shipboard training –students can apply online, and there is a short profile/CV of every participant.

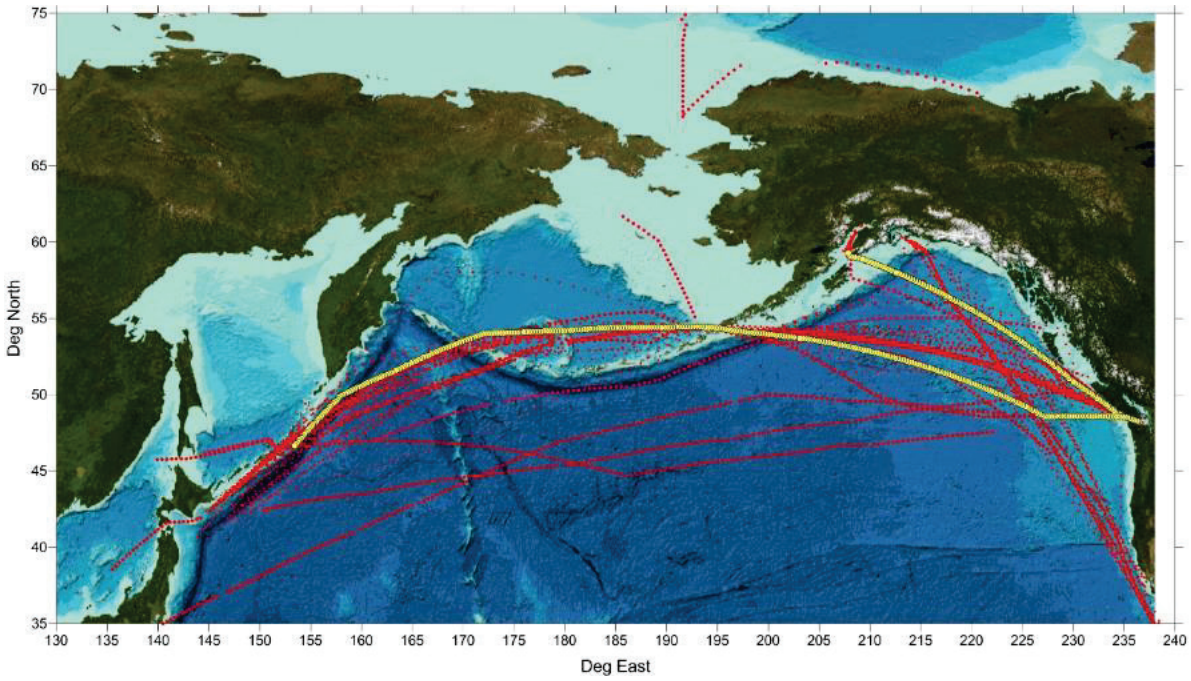
POGO support for the CPR survey/GACS includes:

- POGO has provided financial support for scientists from developing countries (Argentina, India, Brazil, South Africa) to attend training courses (phytoplankton identification, CPR survey operations, silk analysis, data analysis/interpretation) at SAHFOS/MBA (2012, 2016) and in Australia (2019).
- A POGO Visiting Professorship was awarded to a scientist from MBA to teach a course in South Africa on "Molecular mining of the CPR and other archived datasets" in 2013.
- A CPR was towed during a NF-POGO shipboard training transect in 2015, teaching 25 students from around the world about the CPR instrument and program.
- A Working Group on "DNA sampling tools for the global CPR survey" has been funded by POGO, with a workshop due to take place in Australia in November/December.

AGENDA ITEM 4
Reports from MONITOR groups

North Pacific CPR Survey

Dr. Sonia Batten, *ex officio* member, representing the CPR Survey at the MBA, reported that 2019 year marked the 20th consecutive year of data collection. The figure below shows the sample coverage:



There are additional transects to be added to the figure for 2019 once sample processing has been completed. The Bering Sea shelf and the western Arctic were sampled for the first time in 2018 and these transects have been repeated in 2019 but the ship is still at sea and the samples not yet off-loaded.

To celebrate the two-decade milestone a ½-day PICES workshop (W5) on "*Celebrating two decades of North Pacific CPR sampling, and future directions*" was convened and held on October 18 at PICES-2019. There were four speakers (one invited, three contributed), one poster, and some discussion on future directions. The outcomes of this workshop were summarized in PICES Press, 2020, Vol 28, No.1 . There will also be a poster summarizing the survey's first two decades at the poster session and in addition to the CPR talks in the workshop Dr. Batten also gave an oral presentation entitled "*Marine heat wave impacts on lower trophic levels in the northern Gulf of Alaska*" in Topic Session (S2), "*Marine heatwaves in the North Pacific: Predictions and impacts in coastal regions*".

Funding remains consistent and there have been no major issues with ships or equipment so far this year.

Transfer of equipment and outstanding samples for the Western Pacific was made this year to Dr Atsushi Yamaguchi at Hokkaido University who has now taken over the Western Pacific CPR survey activities from Dr Sanae Chiba.

AP-NPCOOS

Drs. Jack Barth and Sung Yong Kim, AP-NPCOOS Co-Chairs, provided an update on AP-NPCOOS activities. At their annual meeting, AP-NPCOOS members discussed how to fulfill their revised Terms of Reference, received reports on the FUTURE Scientific Steering Committee, 2020 PICES Spring School (see below), OceanObs'19 (including Integrated Ocean Observations, Essential Ocean Variables), as well as reviewed the PICES Inventory Data Policy, and proposed a Topic Session for PICES-2020.

AP-NPCOOS has helped organize an upcoming PICES Spring School with WG 37:
Date: March 4–8, 2020
Venue: Kagoshima University – a 5-hr trip from Tokyo-Narita, Japan
Scope: What is the Deep Scattering Layer (DSL) in the coastal region?
Goals: To identify DSL by various sampling gears and data analysis
Local organizers: N. Yoshie (AP-NPCOOS), T. Kobari (WG 37) and G. Kume
Lecturers: N. Yoshie, D. Hasegawa and A. Tachibana
Participants: 20 persons from various countries.

AGENDA ITEM 5
MONITOR Chair and Vice Chair election

The PICES Secretariat ran the election for MONITOR Chair and Vice Chair. Dr. Jennifer Boldt and Dr. Sanae Chiba have completed two terms as Chair and Vice Chair, respectively. MONITOR elected Dr. Sung Yong Kim as Chair and Dr. Lisa Eisner as Vice Chair.

AGENDA ITEM 6
Other

a.) POMA

At ISB-2019 Science Board asked that MONITOR and TCODE consider broadening the scope of the POMA award to include new and innovative technologies that advance ocean monitoring. MONITOR members provided feedback on suggested re-wording prior to PICES-2019. At MONITOR's business meeting members then discussed the edits and added more edits to address concerns. Overall, there was support for the edits; however, there was some concern about "diluting" the award and some desire to advertise this award more broadly. The final edits were provided to the Science Board and TCODE for discussion and consideration.

b.) MONITOR Action Plan

MONITOR's Action Plan was updated to reflect the current PICES organizational structure and science program and the goals of PICES' new Strategic Plan. An initial draft was circulated to MONITOR members on August 24, 2019 and feedback was received from 5 committee members. This feedback was incorporated into a new draft (see ***MONITOR Endnote 3***).

c.) PICES Data Policy and inventory review

PICES has adopted a PICES Data Management Policy https://meetings.pices.int/about/PICES-Policy. The policy outlines the roles and responsibilities of Science Board and expert groups, including Committees. Basically, this policy requires that expert groups:

1. Identify any data developed during the activities of the expert group and inform TCODE and PICES Secretariat.
   - This can be accomplished by reviewing the PICES Data Inventory on a regular (annual) basis and ensuring that the contents are complete and accurate. Any deficiencies should be reported to the Chair of TCODE and the PICES Secretariat.
   - A copy of this inventory was provided to MONITOR.
2. Develop, with assistance from TCODE, strategies or options for managing data used by the expert group.
   - In the event that deficiencies are noted in the management of data produced under the operations of a PICES expert group, the responsible groups are required to develop (with TCODE) some options for correcting the deficiency for approval by Science Board and Governing Council.
3. Revise Terms of Reference (if/as required) to include this as part of the regular business of the group.
   - Add a TOR: "Review the PICES Data Inventory, and identify data and/or data products developed under the direction of the [name of expert group] not currently recorded in the Data Inventory and inform [parent committee], the TCODE Chair and the Secretariat."

MONITOR reviewed the Policy and data inventory and added a Term of Reference to their Action Plan to address the above requirements.

d.) Other

MONITOR members were asked to:

i. Submit the following to the MONITOR Chair by October 23, 2019:
   - Any proposals and requests for funding, including travel, publications, *etc*. (*e.g*., summer school),
   - Proposals for new expert groups, with suggested members and recommended Co-Chairs (if known),
   - Changes in expert group membership.

ii. Please remember to advertise PICES capacity building events to their member nation students and post-docs.

iii. Start reviewing PICES-2020 submitted topic session and workshop proposals for MONITOR's Wednesday meeting.

Wednesday, October 23, 2019

AGENDA ITEM 8

Welcome, Introductions, and Sign-in

MONITOR Chair, Dr. Jennifer Boldt, called the meeting to order, participants introduce themselves, and the agenda was reviewed and adopted.

AGENDA ITEMS 9, 12

Reports from MONITOR groups and FUTURE SSC, *continued*

WG 35 (NPESR3)

Mr. Peter Chandler, Co-Chair of WG-NPESR, provided an update on WG 35 activities. He noted that the WG-NPESR synthesis report is expected to be finished by spring 2020 and the regional reports by fall 2020. They are also considering a 2 to 4 page communications pamphlet to coincide with the publication of the synthesis report. The WG requested a ½-day business meeting at PICES-2020 to develop recommendations for NPESR4.

FUTURE SSC

Dr. Vyacheslav Lobanov summarized FUTURE SSC activities, which included:

- A FUTURE synthesis paper: Bograd, S.J., S. Kang, E. Di Lorenzo, T. Horii, O.N. Katugin, J.R. King, V.B. Lobanov, M. Makino, G. Na, R.I. Perry, F. Qiao, R.R. Rykaczewski, H. Saito, T.W. Therriault, S. Yoo, H. Batchelder, 2019. Developing a social-ecological-environmental system framework to address climate change impacts in the North Pacific. *Frontiers in Marine Science*, 6:333, doi:10.3389/fmars.2019.00333.
- Revisions to provide better FUTURE web presence at www.pices.int;
- A FUTURE outreach video;
- A contribution to PICES Special Publication 5 (Ocean Acidification and Deoxygenation in the North Pacific Ocean);
- The development of new priority SEES (Social-Ecological-Environmental Systems) Case Studies;
- Plans for future PICES integrative science programs;
- UN Ocean Decade North Pacific Planning Workshop;
- Planning for next FUTURE Open Science Conference.

AP-CREAMS

Dr. Vyacheslav Lobanov, AP-CREAMS Co-Chair, provided an update on AP-CREAMS activities:

- Inter-sessional meeting of the AP-CREAMS, May 21–22, 2019 at the East Sea Fisheries Research Institute, a branch of National Institute of Fisheries Science (ESFRI/NIFS) in Gangneung, Korea. Six members of the AP and 4 observers attended the meeting. The agenda included:
  - National reports on activities and plans related to the AP-CREAMS Program,
  - Report and discussion on AP-CREAMS publications (EAST-II Publication and NPESR-3),
  - Status report and discussion on international cooperation (Korea-Russia joint cruise on December 2018, Korea-EAST cruises,
  - Ferryboat monitoring program,
  - participation of Korea side in the Japanese Nagasaki-maru cruise and Korea-US NRL joint cruise for ocean mixing study planned in 2020),
  - CREAMS-3.0 planned new program of cooperative experiments,
  - Proposal for CB in 2020 (Ocean mixing Summer 2019, Qingdao, China),
  - Workshop (W4) on "*Circulation, biogeochemistry, ecosystem, and fisheries of the western North Pacific marginal seas: Past and future of CREAMS*" at PICES-2019, and
  - proposals for the future AP activities.

During PICES-2019, AP-CREAMS successfully convened a 1-day workshop mentioned above, and a ½-day business meeting. Plans for future activities of the AP were discussed extensively, including proposals for CREAMS 3.0 international experiments. It was suggested that an inter-sessional workshop be organized jointly with other programs developed in the area of North Asian Marginal Seas to discuss a closer collaborations. The workshop could be organized in Vladivostok, Russian for May–June 2020.

Requests:

- a 5-year extension of AP-CREAMS;
- A satellite remote sensing training course is being organized by NOWPAP; it will likely be held in Japan during the summer of 2020;
- ½-day meeting at PICES-2020.

AGENDA ITEM 10
Proposals for PICES-2020

Members discussed and ranked proposals for PICES-2019 topic sessions, workshops, and inter-sessional workshops.

AP-NPCOOS members identified a gap in proposed workshop subjects that could address one of FUTURE's recommendations. Dr. Barth suggested a workshop that could work towards mapping PICES to the UN Decade of the Ocean. The AP recognized there is a topic session, but recommend that more work could be accomplished in a workshop (in addition to the topic session). MONITOR sent a request to the PICES Secretariat and FUTURE SSC Chairs to ask if the FUTURE SSC would be interested in such a workshop and could it be considered for PICES-2020.

Although, there were many excellent proposals, the ones that were ranked as pertinent to MONITOR and the FUTURE were identified as:
Topic Sessions:
- *Predictions of extreme events in the North Pacific and their incorporation into management strategies*;
- *Applications of artificial intelligence to advance the understanding of North Pacific ecosystems*;
- *FUTURE Plenary slot on PICES role in UN Decade of Science;*
- *Global warming patterns and multiscale climate variability in the North Pacific;*
- *Upper ocean energetics from mesoscale, submesoscale to small-scale turbulence in the North Pacific;*
- *Using environmental indicators to assess baselines, targets, and risk of plastic pollution in the North Pacific*.

Workshops:
- *The social-ecological-environmental dynamics of climate extremes in Pacific coastal systems*;
- *How does the Pacific Arctic gateway affect the marine system in the Central Arctic Ocean (CAO)?*
- *Can we link zooplankton production to fisheries recruitment?*

Intersessional workshops:
- *Fifth meeting of ICES/PICES/PAME Working Group for Integrated Ecosystem Assessment of the Central Arctic Ocean – WGICA*;
- *Research priorities for understanding the population dynamics of small pelagic fish*;
- *FUTURE SSC inter-sessional.*

AGENDA ITEM 11
ICES ASC 2020 sessions

MONITOR members were also asked to rank the proposed 2020 ICES Annual Science Conference theme sessions and send them to the MONITOR Chair before Friday. It was noted that if some sessions were approved, there are MONITOR members who are interested in co-convening them:
1. *Can technology-based monitoring deliver timely, cost-effective and high quality fishery-dependent data?*: Jack Barth
2. *Past, present and future of marine plankton assemblages and communities*: Sonia Batten

AGENDA ITEM 13
Relations with PICES, international, and national organizations and programs *continued*

SCOR Working Group (P-Obs)

Dr. Batten represents PICES as an Associate Member of the SCOR WG "Integration of plankton-observing sensor systems to existing global sampling programs". She provided an update on the activities of this group. The main goal of the WG is to "Identify best practices (technologies and sampling protocols) and technical feasibility" to incorporate plankton measurements into global ocean observing platforms (initially GO-SHIP and for expansion into the mooring array of OceanSITES).

This year has seen a focus on GO-SHIP and just prior to the OceanObs'19 meeting in September there was a 1-day workshop to finalise the WG's recommendations which were then presented to the GO-SHIP committee. Recommendations included hull mounted sensors (*e.g.*, quantitative echosounders), instruments that could be fixed to the CTD rosette (such as the Underwater Vision Profiler or UVP) and sensors that could be added to the flow-through system on the ship (such as flow cytometers). The WG identified resource requirements (personnel time and cost) for each recommendation. The final year of the WG will see the focus move towards OceanSITES.

GOOS Biology and Ecosystems Panel

Dr. Sonia Batten provided an update on activities of the GOOS Biology and Ecosystems Panel. PICES is represented on the Panel by Drs. Batten and Chiba. The Panel's work this past year has been to continue the implementation of the biological EOVs (Essential Ocean Variables) and seagrasses/mangroves and microbial EOVs have had recent focus.

The OceanObs'19 meeting in September 2019 was a key event for the Panel this year, with contributions to 10 of the community white papers (***MONITOR Endnote 4***). The Panel also contributed to three breakout sessions on integrating ocean observations.

The Panel is also involved in Pegasus, a Future Earth-funded project to design an observing system for these EOVs. The first meeting was in March 2019 where more than 20 international, multidisciplinary experts met to:

(1) Identify the monitoring backbone for each biological EOV by reviewing existing major networks or communities of practice which have facilities, platforms, and programs providing information on regional trends that can feed into a global perspective.
(2) Identify goals and material extensions to the existing backbone that could be reasonably achieved in the next 10 years
(3) Develop criteria to define biological observing networks that would be effective in a global system
(4) Identify and prioritize implementation activities within specified timelines to ensure that products support monitoring progress against the Convention on Biological Diversity 2050 Vision, Agenda 2030 and other critical international agreements, and contribute to the UN Decade of Ocean Science for Sustainable Development.

A summary of the workshop can be found at https://eos.org/meeting-reports/designing-the-global-observing-system-for-marine-life. The second workshop will take place in December 2019.

World Ocean Assessment II

Dr. Chiba provided an update on progress of the WOA II. The writing team members and reviewers for most of the total 31 chapters who have been identified among the Pool of Experts (PoE) and invited by the Group of

Experts (GoE), were approved by the Bureau (the officer group from the selected States). But the GoE is still struggling to find the appropriate writers and reviewers for some chapters, particularly in the areas of human dimension and management, *e.g.*, human health, maritime industries, marine special planning, tourism. Recruitment of PoE in these areas is ongoing through the National Focal Points of each State while the reviewing process must speed up to realize the scheduled publication of WOA II in FY2020.

Given that WOA is the one of the core projects of the United Nation Oceans alliance, GoEs agreed that the contents of WOA II should be carefully designed to align activities/projects of the major UN Oceans initiatives: The UN Decade of Ocean Science for Sustainable Development.

The planning and brainstorming for the 3rd process (WOA III) has already started. Although the process is quicker and much more organized in WOA II compared to WOA I, there will be still much improvement needed, which might be helped by allocating a budget to hire a full-time staff with 100% effort on WOA.

OceanObs'19

Dr. Sanae Chiba gave an overview of the OceanObs'19 conference. The decadal conference series, OceanObs'19, was held from September 16–20, in Honolulu, USA – a first time in a PICES member country. The OceanObs has expanded its community and disciplines since the 1st conference was held in 1999, from climate and physical oceanographers to biogeochemistry and biological oceanographers. From the start, its aim has been to establish an ocean observation system to deliver a useful service for the global society. OceanObs'19 emphasized "Community dialogue/building" and "Co-design" of ocean observing and reached out to broader communities and multiple-stakeholders to join, from social scientists, private sectors, decision makers, funders, NPOs. This resulted in 1,368 participants from 74 countries, which is more than double that of OceanObs'09, with marked improvement in geographical and gender balances in participants and plenary speakers/panelists.

Nearly 140 Community White Papers (CWPs), which represent the wisdom of the ocean observing community, from a total of ~2,500 experts from 74 countries, were published as an OceanObs'19 Special Issue in *Frontiers in Marine Science* in advance of the conference. For a synthesis of the CWPs, please see http://www.oceanobs19.net/wp-content/uploads/2019/09/OceanObs19-White-Paper-Synthesis_FINAL_v1.pdf.

To enhance among-community dialogue/building, OceanObs'19 organizers asked CWP authors and Breakout Session leads to organize the papers and/or sessions in a transdisciplinary manner, rather than focus on strategic planning of specific projects/frameworks. This was challenging and time-consuming for scientists, but it helped involve various stakeholders in co-designing ocean observing in the next decade. Recognition of the traditional knowledge of the coastal indigenous communities in ocean observing system was particularly highlighted through the conference. Fifty representatives were invited from small island countries and coastal Arctic regions all over the world, and "AHA HONUA Coastal Indigenous People's Declarations at OceanObs'19" was issued on the last day.

One of the new logistic features of OceanObs'19 was the use of a web-based Q&A and polling platform, Sli.do, to effectively collect questions and responses from a wider audience to talks, panels and recommendations proposed by session conveners through a mobile and/or PC application. In the coming year, OceanObs'19 organizers, together with the session conveners and CWP author groups, will evaluate and prioritize the recommendations considering the voices of the audience, and design action plans of ocean observing toward OceanObs'29, which will be held in Qingdao, China, another PICES member country.

Argo

Dr. Tetjana Ross provided an update on Argo activities, including updates on Argo status and the future:

1. Core array remains healthy (though deployment numbers are decreasing);
2. Argo beyond 2020: a full-depth, global and multidisciplinary array;
3. Status of Argo enhancements:
   a. Deep: deep pilots are expanding, progress on sensor testing and development is promising. How to manage 4000dbar/6000dbar mix is a challenge – Deep Mission Team,
   b. Equatorial: clear recommendation of doubling (+/- 10o) from TPOS2020 - implementation stalled, but possible progress soon,
   c. Western Boundary Current (WBC): design still needs work, implementation spotty,
   d. Polar: Antarctic array has stalled ~ 50%; Arctic pilots are increasing and some floats have over-wintered,
   e. Biogeochemical (BGC): regional pilots expanding, active Mission Team. EEZ issue is largely solved providing programs follow Argo guidelines. Major new US proposal is still alive, but high sensor prices are an impediment to several nations,
   f. Marginal seas: progress remains spotty – largely due to EEZ and capacity issues.

North East Asian Regional GOOS (NEAR-GOOS)

Dr. Vyacheslav Lobanov, representing IOC/WESTPAC Coordinating Committee for NEAR-GOOS, provided a summary of NEAR-GOOS (***MONITOR Endnote 5***): Developing sustained ocean observations for enhanced services in the northeastern Asian marginal seas

PACON-2019

Dr. Vyacheslav Lobanov, President of PACON International, provided a summary of the PACON-2019 conference.

The 26th International Conference of the Pacific Congress on Marine Science and Technology (PACON-2019) was held at the campus of Far Eastern Federal University (FEFU) in Vladivostok, Russia on July 16–19, 2019. Support of the conference was discussed at the MONITOR and AP-CREAMS, and was approved by Science Board and Governing Council at PICES-2018. PICES provided travel support for 13 early career scientists from Russia, China and Japan to attend the conference.

The theme of PACON-2019 was “Marine science and technology for sustainable development”, and included 11 themes (and sessions):
T01- Ocean dynamics and climate (3)
T02- Marine geology and geological resources (3)
T03- Ocean environment and ecosystem (2)
T04- Ocean and sustainability of human life (1)
T05- Polar ocean research and exploration (2)
T06- Ocean engineering, marine constructions and renewable energy (6)
T07- Undersea vehicles, robotics, acoustics (2)
T08- Ocean hazards (1)
T09- Fisheries and aquaculture (2)
T10- Ocean observations (3)
T11- Sustainable economy, ocean policy making and education (2)

Oral presentations were presented at 27 special sessions, 4 plenary sessions and one poster session. A total of 262 participants from 11 countries presented 13 plenary, 178 oral, 43 poster talks. A panel discussion on “How

to save our oceans: exchange of the best practice in the Pacific", with participation of experts from China, Indonesia, Philippines, Russia, and USA was organized with invitations to the press and general public. The summary discussion was related to the UN Decade of Ocean Sciences. The conference was successful and was well attended by many local marine scientists.

Northwest Association of Networked Ocean Observing Systems (NANOOS)

Dr. Jack Barth provided an update of NANOOS activities in the U.S. National report (***MONITOR Endnote 7***).

Alaska Ocean Observing System (AOOS)

Dr. Lisa Eisner provided a summary of AOOS activities. The presentation provided by Carol Janzen, AOOS (***MONITOR Endnote 6***).

Ecosystem Study on the Sub-Arctic and Arctic Seas (ESSAS)

Dr. Franz Mueter spoke about the Ecosystem Studies of the Subarctic and Arctic Seas (ESSAS) program which is a regional program of IMBeR (Integrated Marine Biosphere Research) that focuses on the impacts of climate variability and change on high-latitude marine ecosystems. ESSAS takes a comparative approach across ecosystems and in recent years has specifically focused on documenting and comparing changes in the Atlantic and Pacific Arctic Gateways. ESSAS scientists are involved in ongoing monitoring activities in these regions, for example the Alaska Marine Biodiversity Observing Network (AMBON) in the Chukchi Sea and many other ongoing research projects. These projects will be useful in the development of an Integrated Ecosystem Assessment for the Northern Bering Sea/Chukchi Sea (a proposal for new working group is being submitted to PICES Science Board) as well as the Central Arctic Ocean IEA (e.g., WGICA/PICES WG 39). The next ESSAS Annual Science Meeting on "Linking past and present marine ecosystems to inform future fisheries and aquaculture" will take place in Sapporo, Japan June 1–3, 2020.

WGICA (IEA of Central Arctic Ocean)

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

WGICA is a joint Working Group including: ICES – International Council for Exploration of the Sea Science and Advice, PICES – North Pacific Marine Science Organization (PICES), and PAME – Protection of the Arctic Marine Environment (AC working group). WGICA was established in 2015 by ICES and PAME. PICES joined the WG in 2016 (WG 39; 2016–2018). The WG was extended for 3 years (2019–2021) to complete an Integrated Ecosystem Assessment for the Central Arctic Ocean. They convened their fourth meeting in Sapporo, Japan, May 8–10, 2019. A 5th WGICA/WG 39 meeting will be convened in Tromsø, Norway, April 27–29, 2020. WG 39 proposed a workshop for PICES-2020 on "*How does the Pacific Arctic gateway affect the marine system in the Central Arctic Ocean (CAO)?*"

AGENDA ITEM 14
National reports

See ***MONITOR Endnote 7*** for national reports.

The MONITOR meeting adjourned at 18:05

MONITOR Endnote 1

MONITOR participation list

Members

Jennifer Boldt (Canada, Chair)
Sanae Chiba (Japan, Vice-Chair)
Hiroto Abe (Japan)
Jack Barth (USA)
Sonia Batten (CPR Survey at the MBA *ex officio*)
Lisa Eisner (USA)
Kym Corporon Jacobson (USA)
In-Seong Han (Korea)
Sung Yong Kim (Korea)
Vladimir Kulik (Russia)
Vyacheslav Lobanov (Russia)
Tetjana Ross (Canada)
Sei-Ichi Saitoh (Japan)
Kazuaki Tadokoro (Japan)

Members unable to attend

China: Honghui Huang, Zhifeng Zhang, Xianyong Zhao
Japan: Minoru Kitamura
Korea: Jung Hyun Kim

Observers

Eok Dong Kim (Korea)
Franz Mueter (ESSAS)
Willie Wilson (MBA)

MONITOR Endnote 2

MONITOR meeting agenda

October 20, 2019, 18:00-20:00

1. Welcome, introductions, and sign-in
2. PICES-2019 information and judges
3. Relations international organizations
   a. Status of Pacific Continuous Plankton Recorder (CPR) program and activities of Sir Alister Hardy Foundation for Ocean Science (SAHFOS) and GACS (Batten)
4. Reports from MONITOR groups:
   a. Status of the North Pacific CPR program – Batten
   b. Activities of AP-NPCOOS (Barth and Kim)
5. MONITOR Chair and Vice Chair election
6. Other
   a. POMA - discuss wording of award
   b. MONITOR Action Plan –discussion on updates
   c. PICES Data Policy and inventory review
   d. Other
7. Relations with international organizations
   b. POGO - Wilson

October 23, 2019, 14:00-18:00

8. Welcome, introductions, and sign-in
9. Reports from MONITOR groups, *continued*
   c. Activities of WG-NPESR –Chandler/Yoo
10. Proposals for PICES-2020
11. ICES ASC 2020 sessions
12. Reports from MONITOR groups and FUTURE SSC, *continued*
   d. Report from FUTURE SSC –Lobanov
   e. Activities of AP-CREAMS –Lobanov
13. Relations with PICES, international, and national organizations and programs *continued*
   c. SCOR WG (P-Obs) – Batten
   d. GOOS Bio-Eco Panel – Batten
   e. World Ocean Assessment II (WOA II) – Chiba
   f. OceanObs'19 – Chiba
   g. Argo – Ross
   h. NEAR-GOOS – Lobanov
   i. PACON 2019 – Lobanov
   j. NANOOS – Barth (moved to US national report)
   k. AOOS – Eisner
   l. ESSAS – Mueter
   m. WGICA (IEA of Central Arctic Ocean)– Saitoh
14. National reports – Written and Oral
15. Other business

MONITOR Endnote 3

MONITOR Action Plan (2020-2025)

Mission

1. Identify principal monitoring needs of the PICES region, and develop recommendations to meet these needs, including training and capacity building;
2. Serve as a forum for coordination and development of inter-regional and international components of the North Pacific Ocean Observing Systems, including the Global Ocean Observing System (GOOS). Facilitate method development and inter-comparison workshops to promote calibration, standardization and harmonization of data sets;
3. Contribute to the development of the North Pacific Ecosystem Status Report (NPESR), advising editors and lead authors on monitoring issues, identifying the need for particular time series and their continuities, the period on which they need to be updated for PICES Science Programs, and recommend to Science Board that they endorse the need to establish or maintain particular time series;
4. Review and advise Science Board on outcomes and annual operations of the North Pacific Continuous Plankton Recorder (CPR), including providing technical advice on parameters to be measured and possible linkages to other marine monitoring initiatives and programs in the North Pacific and elsewhere;
5. Provide annual reports to Science Board and the Secretariat on monitoring activities in relation to PICES;
6. Interact with TCODE on management issues of monitoring data.

To implement its mission, the MONITOR Committee will address each of the six main goals of the PICES Strategic Plan (https://meetings.pices.int/About/PICES-Strategic-Plan-Oct-2016.pdf):

PICES Strategic Plan Goals:

1. Foster collaboration among scientists within PICES and with other multinational organizations
2. Understand the status and trends, vulnerability and resilience, of marine ecosystems
3. Understand and quantify how marine ecosystems respond to natural forcing and human activities
4. Advance methods and tools
5. Provide relevant scientific information pertinent to North Pacific ecosystems that is timely and broadly accessible
6. Engage with early career scientists to sustain a vibrant and cutting edge PICES scientific community

Goal 1: Foster collaboration among scientists within PICES and with other multinational organizations

Action 1.1 Promote collaboration and communication among Ocean Observing Systems internal and external to the PICES region.

Task 1.1.1 Define PICES' role, assist, and participate in the implementation of international programs (e.g. GOOS).

Action 1.2 Promote the process of creating regular NPESRs as a way to gain collaboration among organizations, scientific programs, and stakeholders.

Task 1.2.1 Establish and maintain dialogue with organizations, programs, and stakeholders on potential ways to increase the value of NPESR to scientists, industry, government, and communities.

Task 1.2.2 Seek input from intergovernmental regulatory organizations on the content, format, and value of NPESR.

Goal 2: Understand the status and trends, vulnerability and resilience, of marine ecosystems

Action 2.1 Promote the use of Global (GOOS), GOOS Regional Alliances (e.g., IOOS, CIOOS, NEAR-GOOS), and other ocean observing systems as tools to understand the functioning of marine ecosystems.

Task 2.1.1 Identify and describe the major observing systems and programs (present and proposed) in the PICES region.

Task 2.1.2 Provide a forum at annual PICES meetings for exchange of information on ocean observing systems and programs among PICES member countries.

Action 2.2 Promote the use of the PICES NPESR to understand the functioning of marine ecosystems.

Task 2.2.1 Conduct sessions and workshops at the PICES annual meetings.

Task 2.2.2 Contribute to the production of the NPESR.

Task 2.2.3 Evaluate the report and contribute to improving the process used to create it.

Goal 3: Understand and quantify how marine ecosystems respond to natural forcing and human activities

Action 3.1 Linked to the PICES Science Program activities, understand and quantify the impacts of climate on marine ecosystems.

Task 3.1.1 Solicit advice from member countries, scientists, and stakeholders for what type of information is needed for NPESR to be useful to understand and quantify impacts

Task 3.2.1 Develop a strategy for promoting and funding PICES observing activities, and actively communicating their relevance and utility. For example, i) North Pacific Continuous Plankton Recorder transects. ii) ocean observing systems, iii) international surveys (e.g., EAST-I area Joint Korea-Russia cruise, ferry-box monitoring between Donghae and Vladivostok , EAST-II area Joint Japan-China-Korea cruise), iv) North Pacific seabird and marine mammal transects.

Goal 4: Advance methods and tools

Action 4.1 Use MONITOR's resources and involvement in global and regional Ocean Observation Systems to provide advice on methods and guide scientific activities.

Task 4.1.1 Propose sessions or workshops for the PICES annual meeting to address emerging issues in ocean observing science.

Task 4.1.2 Encourage nominations and vote for recipients of the POMA.

Action 4.2 Use NPESR as a forum for providing information on current status of ocean observing to guide scientific activities.

Task 4.2.1 Provide a recommendation on emerging information needs and critical issues in methodology to multiple stakeholders, including scientists, industry, government and communities.

Goal 5: Provide relevant scientific information pertinent to North Pacific ecosystems that is timely and broadly accessible

Action 5.1 Create and oversee expert groups to support PICES Science Programs and activities.

Task 5.1.1 Make recommendations to the Science Board on the establishment of new expert groups to support PICES Science Program and activities.

Task 5.1.2 Delegate representatives as members of the PICES Science Program Advisory Panels to enable communication among groups.

Task 5.1.3 Review the PICES Data Inventory, and identify data and/or data products developed under the direction of the MONITOR not currently recorded in the Data Inventory and inform the TCODE Chair and the Secretariat.

Action 5.2 Publish reports and workshop proceedings on a timely basis.

Action 5.3 Review the current MONITOR web page and identify new web-based products to support committee's communication with members and stakeholders.

Goal 6: Engage with early career scientists to sustain a vibrant and cutting edge PICES scientific community

Action 6.1 Use PICES involvement in Ocean Observing Systems as a means for promoting collaboration among scientists.

Task 6.1.1 Conduct collaborative workshops and summer schools.

Task 6.1.2 Recruit scientists from under-represented groups to participate

Action 6.2 Use the North Pacific Ecosystem Status Report as a tool or means to promote collaboration and communication among PICES scientists.

Task 6.2.1 Conduct collaborative workshops for authors, whenever possible, as part of the process that creates the report.

Task 6.2.2 Recruit scientists from under-represented groups to participate.

MONITOR Endnote 4

GOOS Bio-Eco Panel Community White Paper contributions from OceanObs'19

- Anderson *et al*. (2019). Scaling Up From Regional Case Studies to a Global Harmful Algal Bloom Observing System. Front. Mar. Sci. https://doi.org/10.3389/fmars.2019.00250
- Batten *et al*. (2019). A Global Plankton Diversity Monitoring Program. Front. Mar. Sci. doi: 10.3389/fmars.2019.00321
- Bax *et al*. (2019). A Response to Scientific and Societal Needs for Marine Biological Observations. Front. Mar. Sci. doi: 10.3389/fmars.2019.0039
- Canonico *et al*. (2019). Global Observational Needs and Resources for Marine Biodiversity. Front. Mar. Sci. doi: 10.3389/fmars.2019.00367
- Duffy *et al*. (2019). Toward a Coordinated Global Observing System for Seagrasses and Marine Macroalgae. Front. Mar. Sci. doi: 10.3389/fmars.2019.00317
- Harcourt *et al*. (2019). Animal-Borne Telemetry: An Integral Component of the Ocean Observing Toolkit. Front. Mar. Sci. doi: 10.3389/fmars.2019.00326
- Lombard *et al*. (2019). Globally Consistent Quantitative Observations of Planktonic Ecosystems. Front. Mar. Sci. doi: 10.3389/fmars.2019.00196
- Newman *et al*. (2019). Delivering sustained, coordinated and integrated observations of the Southern Ocean for global impact. Front. Mar. Sci. doi: 10.3389/fmars.2019.00433
- Obura *et al*. (In revision). Coral Reef Monitoring, Reef Assessment Technologies, and Ecosystem-based Management. Front. Mar. Sci. Manuscript ID: 436982
- Tanhua *et al*. (2019). What have we learned from the Framework for Ocean Observing: evolution of the Global Ocean Observing System. Front. Mar. Sci. doi: 10.3389/fmars.2019.00471

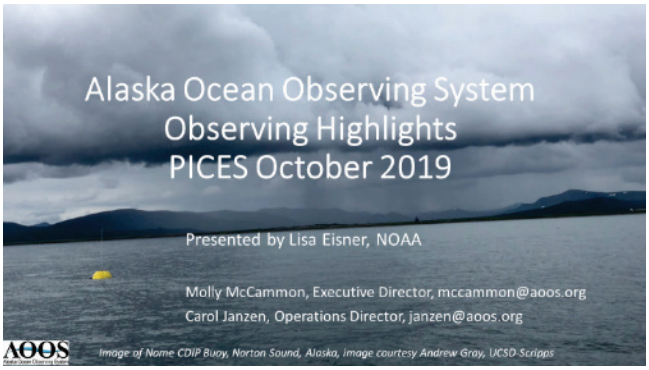
MONITOR Endnote 5

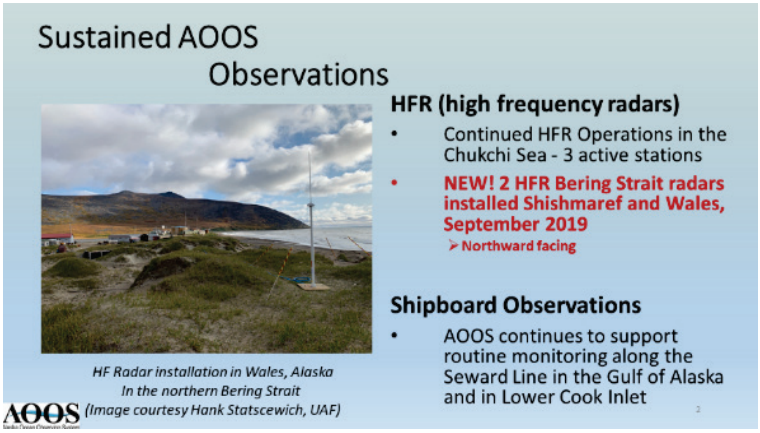
North-East Asian Regional-Global Ocean Observing System (NEAR-GOOS)

The North-East Asian Regional-Global Ocean Observing System (NEAR-GOOS) is the first regional pilot project of GOOS. This presentation describes its success and challenges over the last 20 years. Initiated in 1996, NEAR-GOOS aimed to facilitate the sharing of oceanographic data in the marginal seas bordered by the partner countries: China, Japan, Korea and Russia. Its development has been coordinated by the UNESCO/IOC Sub-Commission for the Western Pacific (IOC/WESTPAC) through its Coordinating Committee for NEAR-GOOS. The major achievement of NEAR-GOOS at its first phase features the establishment of a network of real-time and delayed mode databases accessible online free-of-charge, with these databases being operated by designated national agencies. Despite some restrictions on oceanographic data exchange in some member states, NEAR-GOOS archives now contain 59 types of data with total volume of 211 GB (as of September 2019). A challenge for NEAR-GOOS at its second phase (after 2003) was to advance from data management to jointly developing sustained regional integrated ocean observations and delivering enhanced services, for a wide range of users in the region. This advancement requires not only continued improvements of the existing data and information exchange mechanisms, but also an enhancement in its observations, and delivering more user-friendly services in the region and beyond. Currently, NEAR-GOOS has three working groups on data management, products, and ocean forecasting system (OFS). Recent NEAR-GOOS projects include Cross Basin Climate Monitoring Section implemented by Japan and Russia since 2011, enhancement of OFS since 2016, and ferry box monitoring since 2018. Next meeting of NEAR-GOOS Co-ordinating committee is scheduled for 21–22 November 2019 in Gangneung, Korea.

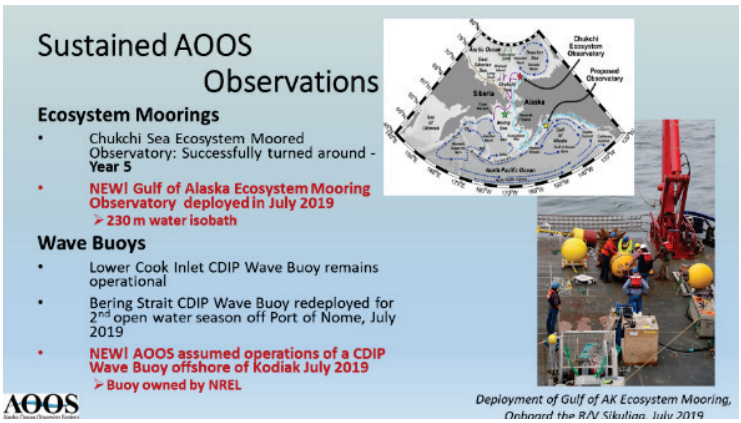
MONITOR Endnote 6

Alaska Ocean Observing System highlights

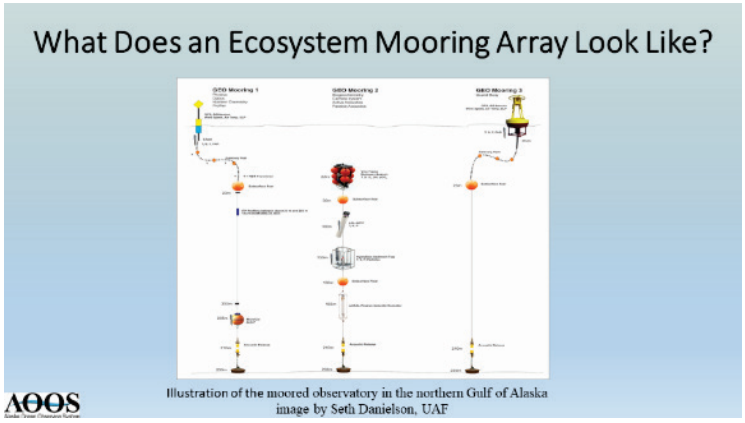


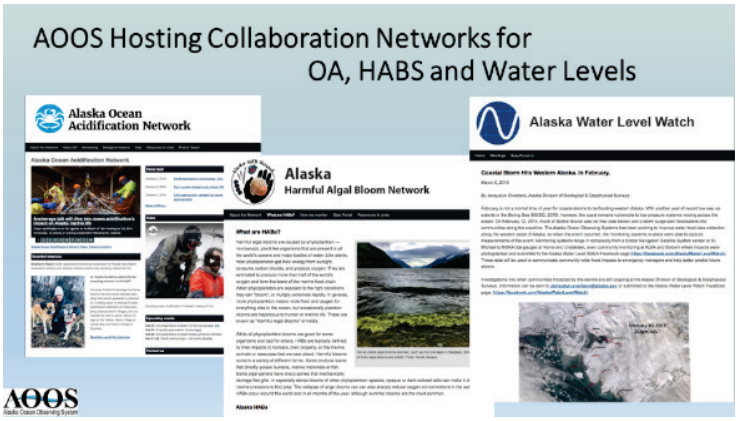


AOOS continues to support ongoing observing activities throughout Alaska.



In July 2019, Seth Danielson (University of Alaska) announced the commissioning of our moored Gulf of Alaska Ecosystem Observatory, representing a new node of the pan-Alaska network of ecosystem moorings. The array consists of three moorings. Funding for this GOA mooring array comes from the M.J. Murdock Charitable Trust, AOOS, UAF, EVOSTC, NSF.





AOOS continues to host 3 collaborations for sharing and promoting OA information, HABS and Water Level observing initiatives in Alaska.

Network webpages are now available on the AOOS website at https://aoos.org/. The webpages share information about the state of affairs regarding HABS and Water Levels in the region, ongoing activities and initiatives, monitoring, results, and contact information.

MONITOR Endnote 7

Country Reports for 2019

Canada

I. Highlights from 2018

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 2019 (for conditions in 2018) is available at: http://waves-vagues.dfo-mpo.gc.ca/Library/40717914.pdf.

Highlights below are taken from this report:

- The NE Pacific marine heat wave of 2014-2016 diminished; however, in 2018 the effects on lower trophic levels remained and new heat waves were observed in the fall of 2018 due to delayed and reduced winter cooling. In 2018, there was a transition from a weak La Niña to a weak El Niño.

- In 2018, both surface and subsurface temperatures were near normal until the fall, when marine heat waves were observed offshore and on the shelf with varying spatial and temporal scales (Fig. 2; Ross and Robert 2019, Hannah *et al*. 2019).

Fig. 1. Map of areas reported on in the State of the Ocean report, including Line P, and Ocean Station Papa. Source: Boldt *et al*. (2019).

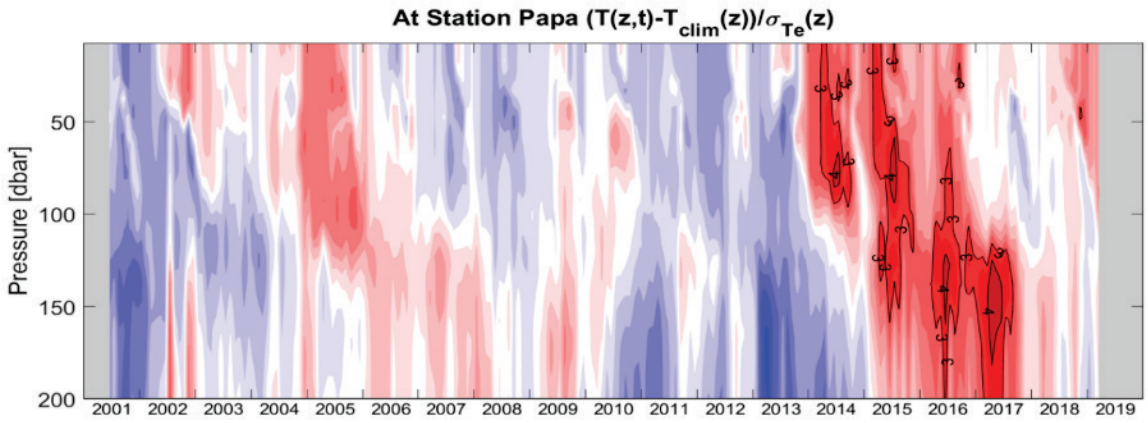


Fig. 2. False colour plot of temperature anomalies relative to the 1956–2012 seasonally-corrected mean and standard deviation (from the Line P time series), as observed by Argo floats near Station Papa (P26: 50° N, 145° W). The cool colours indicate cooler than average temperatures and warm colours indicate warmer that average temperatures. Dark colours indicate anomalies were large compared with the 1956–2012 standard deviations. The black lines highlight regions with anomalies that were 3 and 4 standard deviations above the mean. Source: Ross and Robert, section 6. Source: Ross and Robert (2019).

- The upwelling of cool nutrient rich waters along the west coast of Vancouver Island (WCVI) in 2018 started earlier than usual but was not as intense as previous years, implying mixed conditions for productivity and fish growth (Fig. 3; Hourston and Thomson 2019).

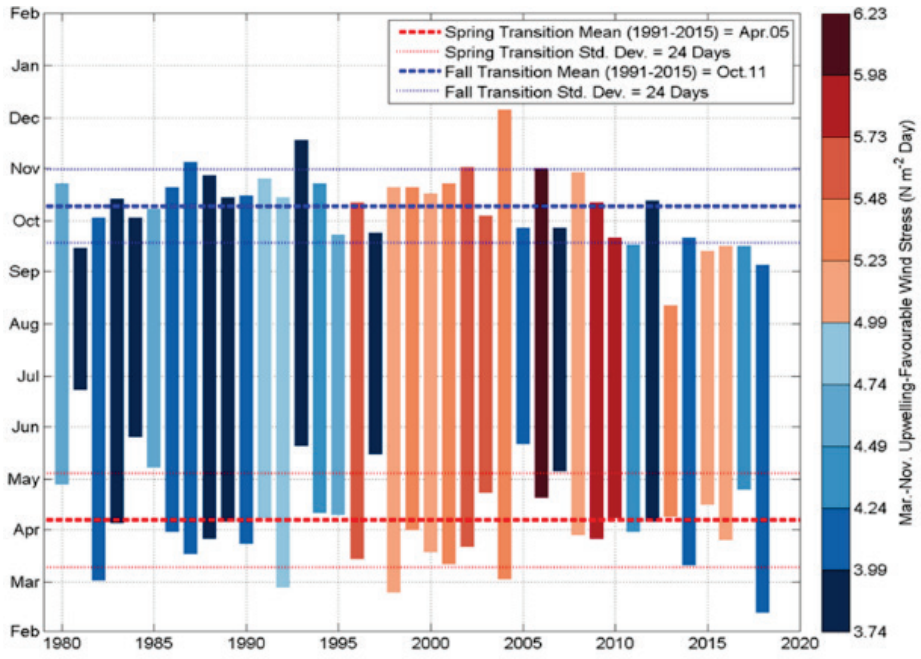


Fig. 3. The upwelling index for the west coast of British Columbia. Bar plot showing Spring and Fall Transitions and upwelling-favourable wind stress magnitude. The length of the bar corresponds to the duration of the upwelling season, coloured by the intensity of the upwelling (red indicates intense upwelling, blue indicates weak upwelling). Bold dashed lines indicates 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: Hourston and Thomson (2019).

- Zooplankton distribution off the WCVI (Fig. 4 and 5) still reflects the effects of the 2014-2016 marine heatwave (Galbraith and Young 2019). The abundance of southern copepod species was high and subarctic copepods low; southern species were still present, consistent with reduced winter cooling.

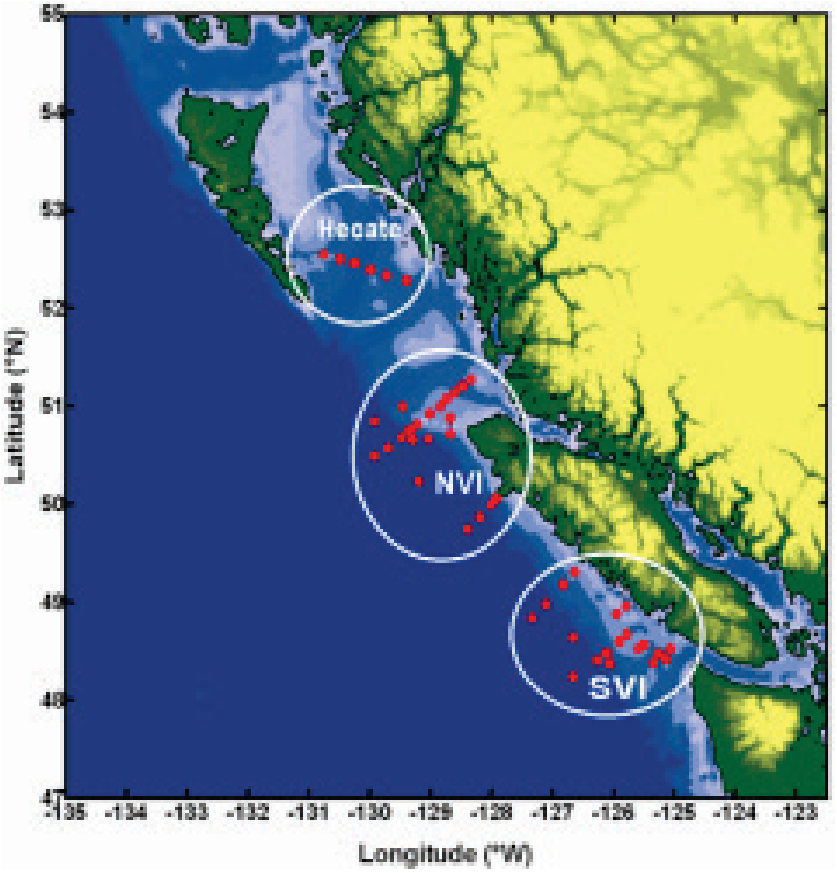


Fig. 4. Zooplankton time series sampling locations (red dots) in B.C. marine waters. Data are averaged for samples within each area; the SVI and NVI regions are further classified into shelf and offshore subregions. Source: Galbraith and Young (2019).

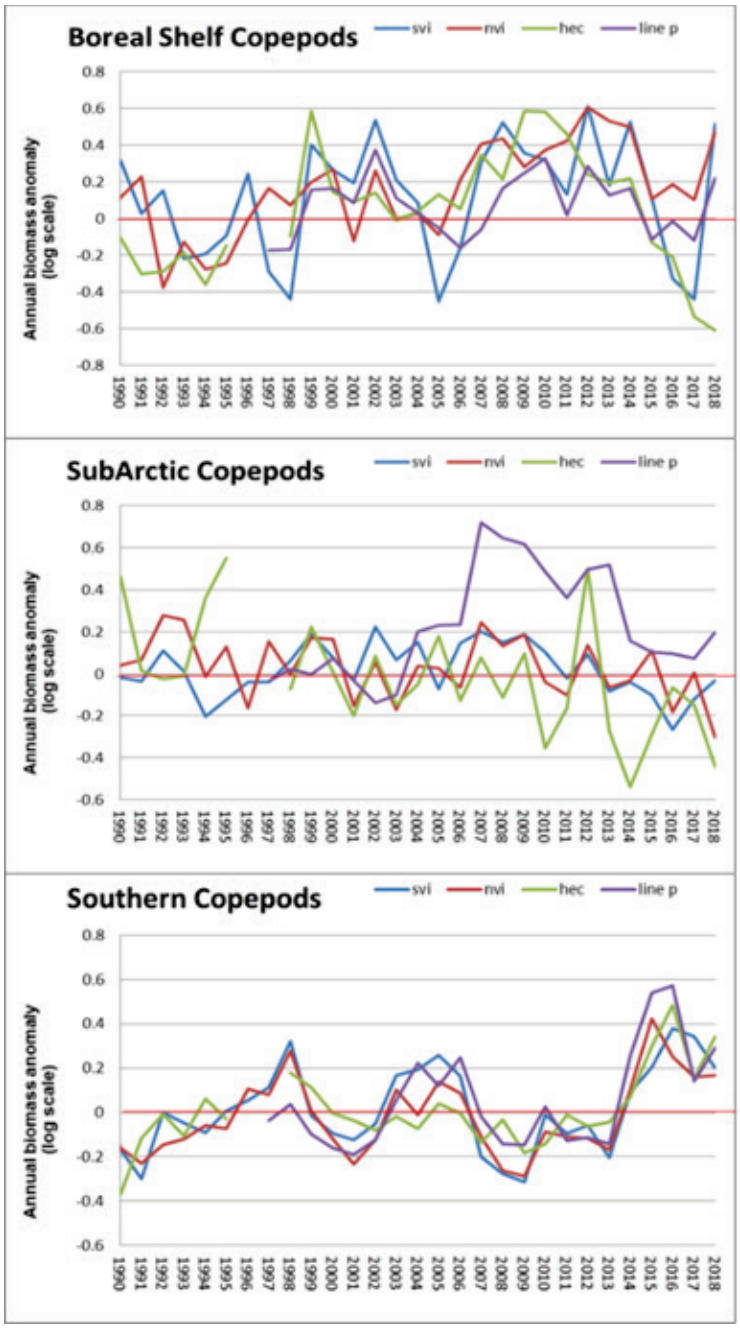


Fig. 5. Zooplankton species-group anomaly time series for the regions shown in Figure 4. Line graphs are annual log scale anomalies. Southern Vancouver Island (SVI) blue; Northern Vancouver Island (NVI) red; Hecate Strait (HEC) green; Line P – purple for all graphs. Note the y-axis changes with each taxonomic group. Source: Galbraith and Young (2019).

- Multi-species small-mesh bottom trawl surveys conducted annually in May off the WCVI (Fig. 6) indicate pink shrimp biomass in 2018 continued to decline from its peak in 2014, with anomalies now below the average biomass levels observed since the survey began in 1973 (Fig. 7; Perry et al. 2019).

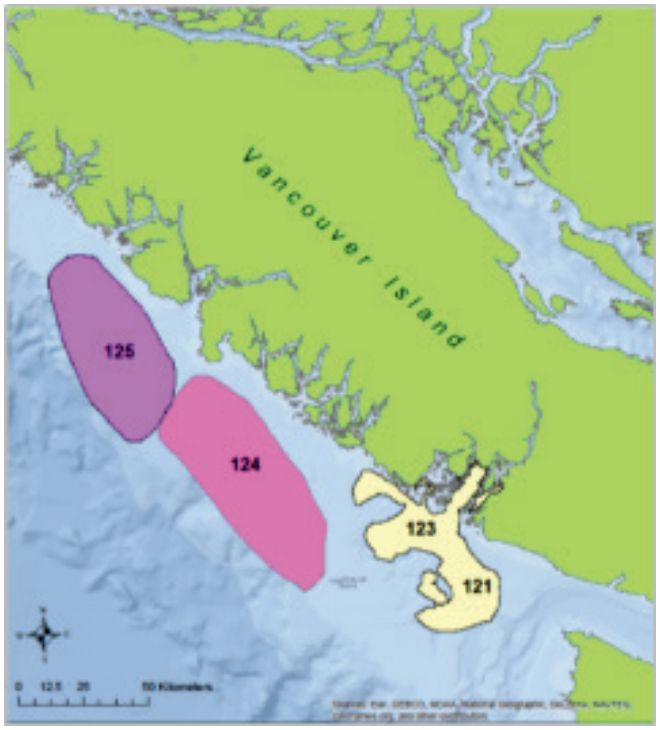


Fig. 6. Map showing the three main shrimp (*Pandalus jordani*) fishing grounds and survey areas off Vancouver Island. The Nootka (Area 125) and Tofino (Area 124) Grounds have been surveyed since 1973. The area off Barkley Sound (Areas 23, 121 and 123) has been surveyed since 1996. Source: Perry *et al*. (2018)

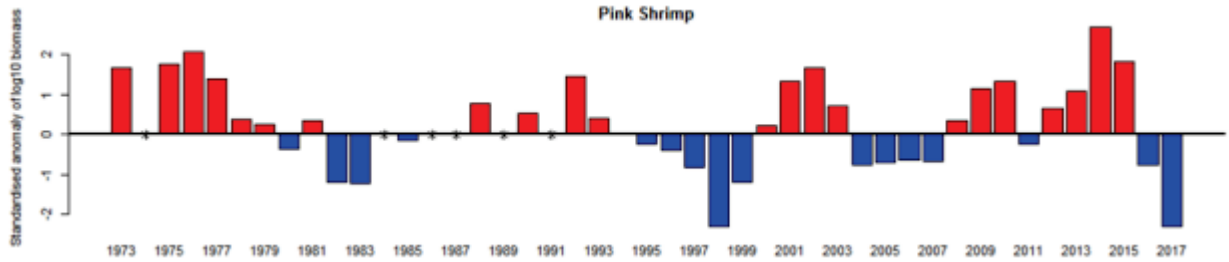


Fig. 7. Standardised (by the standard deviation) anomalies of log10 species biomass for pink shrimp in the WCVI small-mesh multi-species bottom trawl surveys. Climatology period is 1981–2010. Source: Perry *et al*. (2018).

- Over the last 8 years, Pacific Herring biomass estimates increased in the Strait of Georgia; however, over the last 2 to 5 years, the biomass of other stocks was either stable (West Coast of Vancouver Island) or decreased (Central Coast, Haida Gwaii, Prince Rupert) (Figs. 8 and 9; Cleary *et al*. 2019).

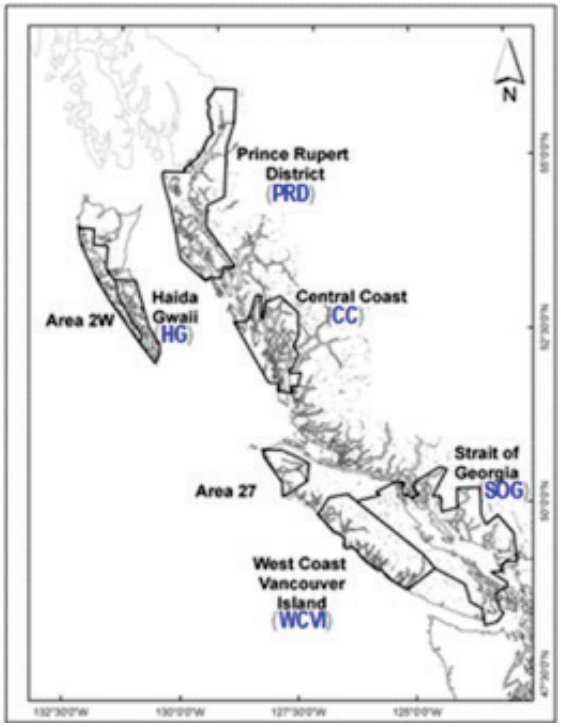


Fig. 8. Location of the five major (Strait of Georgia, West Coast of Vancouver Island, Prince Rupert, Haida Gwaii, and Central Coast) as well as two minor (Area 2W, and Area 27) Pacific Herring stocks in BC. Source: Cleary *et al*. (2019).

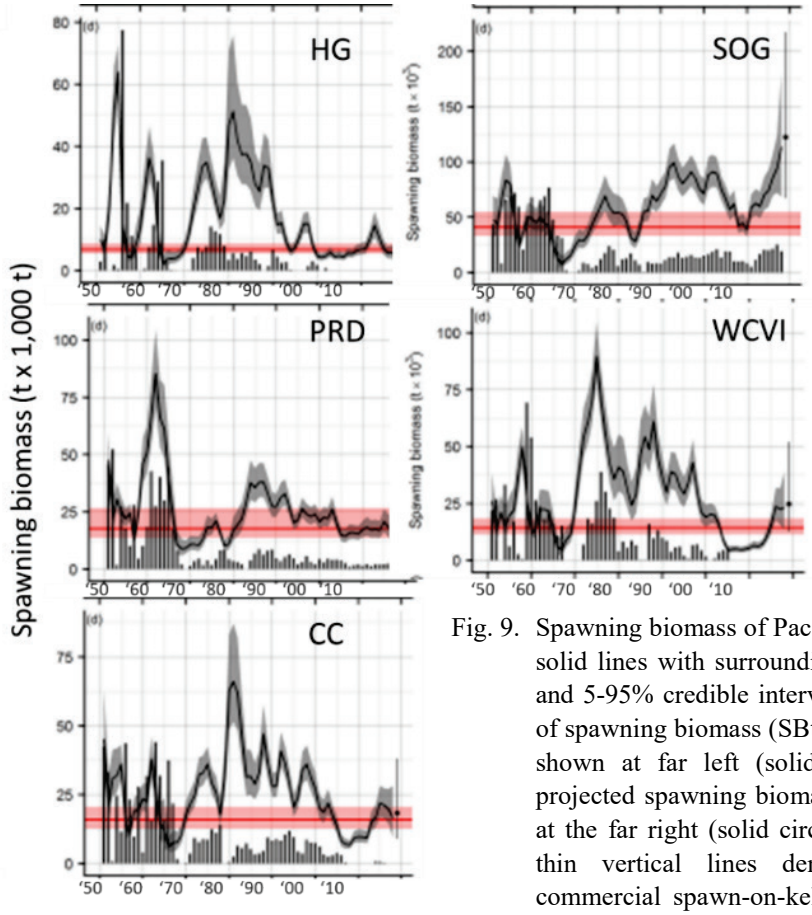


Fig. 9. Spawning biomass of Pacific Herring from 1951 to 2018, where solid lines with surrounding grey envelopes represent medians and 5-95% credible intervals. Also shown is the reconstruction of spawning biomass (SBt) for each year t, with unfished values shown at far left (solid circle and vertical lines) and the projected spawning biomass given zero catch (SB2019) shown at the far right (solid circle and vertical lines). Time series of thin vertical lines denote commercial catch (excluding commercial spawn-on-kelp). The horizontal red line indicates the LRP= limit reference point. Figure adapted from DFO (2019). Source: Cleary *et al*. (2019).

- During 2018 in the Strait of Georgia (SoG), spring and summer temperature and salinity conditions were near-normal, but as the year progressed temperatures at all depths became warmer than normal (Chandler 2019). During the fall and winter, lower than normal oxygen levels were widespread with the exception of the deep SoG. There was an early, rapid and high volume Fraser River freshet.
- After a three-year absence from the Strait of Georgia, a harmful algal bloom (*Heterosigma akashiwo*) occurred in early June, resulting in high aquaculture fish mortality in Jervis Inlet (Esenkulova and Pearsall 2019, Haigh and Johnson 2019, Nemcek *et al*. 2019). This bloom was linked to the early and high Fraser River freshet and hot weather in May-June.
- An index of Eulachon spawning stock biomass in the Fraser River was estimated to be at a moderately high level (similar to 2015), compared with most other years from 2004–2017 which were relatively low (Flostrand 2019).
- Total Fraser River Sockeye Salmon (*Oncorhynchus nerka*) productivity and returns have declined since the mid-1990s (Fig. 10; Grant et al. 2019a). Although most populations in the Fraser River, such as Chilko and Stellako, have exhibited declining trends since the 1990s, some populations, such as Late Shuswap, have not exhibited any persistent trends, and the Harrison River population has increased in productivity.

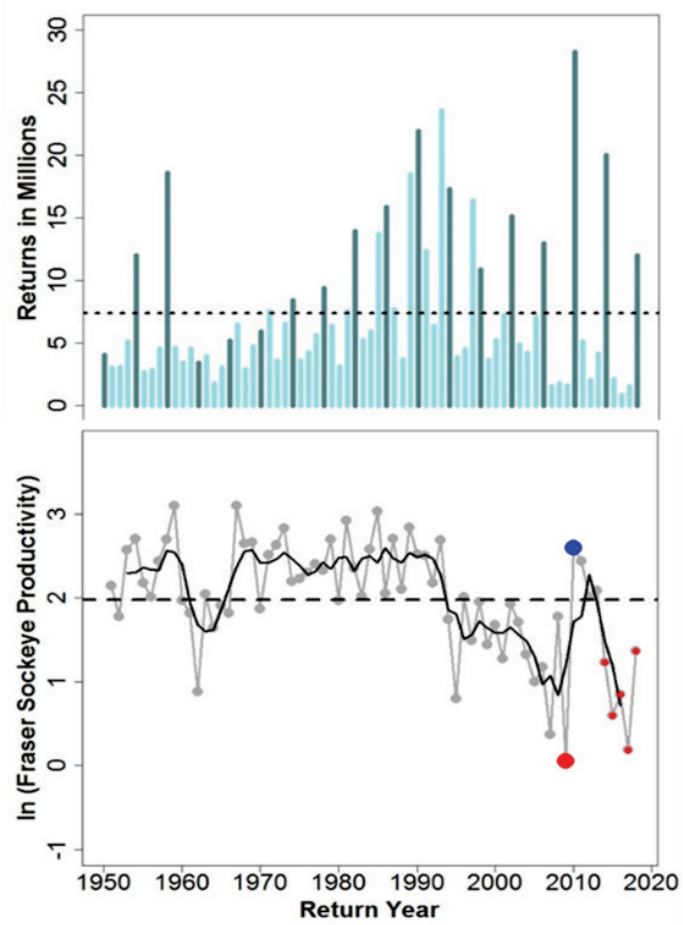


Fig. 10. Total Fraser Sockeye annual returns (dark blue vertical bars for the 2018 cycle and light blue vertical bars for the three other cycles) (top panel). Recent returns from 2016 to 2018 are preliminary, and 2018 (the last data point) is an in-season estimate only. Total Fraser Sockeye productivity (loge (returns/total spawner)) up to the 2018 return year (bottom panel). The grey dots and lines represent annual productivity estimates and the black line represents the smoothed four year running average. For both figures, the dashed line is the time series average. Source: Grant *et al*. (2019a).

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, O_2, T, S, pH), and their links to climate variability and trends (Fig. 4). 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, with intensified sampling in 2010 and 2011. Areas of emphasis: hydrography and circulation, nutrients, phytoplankton, vertical flux of organic matter and 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. 11). 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. 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. 11). 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 (Fig. 6): 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, 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) 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) 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.
   - 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. 12). 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).
   c) 2017, 2019 – Survey of the Offshore Area of Interest (AOI) (Fig. 13). 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
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. 2019b), (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

F. Argo profiling drifters

Canada has been very active in this successful international program. Since the start of the program, Canada has deployed many floats (see http://www.argo.ucsd.edu/).

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 Sonia Batten on some of the analyses and publications (see http://pices.int/projects/tcprsotnp/).

H. Ocean observatory networks (Ocean Networks Canada)

The 'inland seas' component has operational undersea cabled observatory nodes and coastal radar (VENUS network) in the Strait of Georgia (since 2008) and in Saanich Inlet (since 2006). The installation of sensor platforms on ferries on three routes between Vancouver and Vancouver Island was completed in 2015. An ocean glider program, initiated in 2014, provides additional mobile observing capacity for coastal waters. Five community-based cabled observatories are currently operating in coastal locations, one on Vancouver Island, three on the British Columbia mainland, and another in the Canadian Arctic at Cambridge Bay, Nunavut. Additional community-based cabled observatories are being installed at four coastal British Columbia sites, with completion expected in late 2019. 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 provides real-time information on surface ocean conditions and vessel traffic.

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. Autonomous oceanographic moorings (since 2012) in the Salish Sea provide continuity between the VENUS and NEPTUNE observing systems.

ONC's Oceans 2.0 data system also archives and delivers ocean data partner observing systems in Atlantic Canada and the eastern Arctic. Beginning in early 2019, ONC will be hosting the Pacific node of the Canadian Integrated Ocean Observing System.

For more information see http://www.oceannetworks.ca/.

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 (http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/index-eng.html).

J. Hakai Institute autonomous instrumentation

Fixed autonomous stations include (Fig. 11):

- Burke-o-later (BoL) for determining T, S, pCO_2 and TCO_2 in Hyacinthe Bay, near Quadra Island since 2015;
- Multiple temperature sensors at fixed nearshore locations throughout the central coast near Calvert Island since 2015;

- A MApCO_2 buoy near Calvert Island that measures S, T, surface seawater and atmospheric pCO_2, and meteorological data since 2018;
- A cabled observatory called the Limpet has measured T, S, and oxygen at the seafloor in Hyacinthe Bay off Quadra Island since 2015;
- A string of moored temperature and salinity sensors has collected T data every 10 minutes in 10 m intervals since 2017;
- The Alaska Marine Highway System M/V *Columbia* has collected T, S, O, and seawater and atmospheric pCO_2 since 2017.

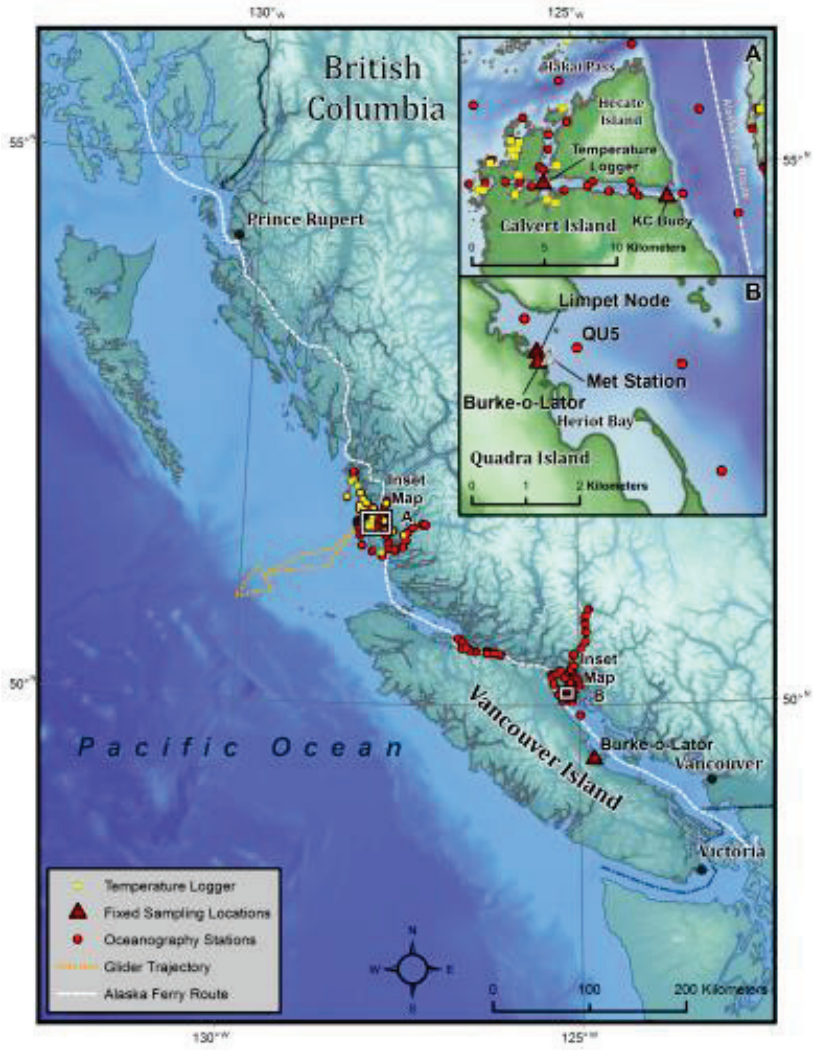


Fig. 11. Locations where the Hakai Institute collects ocean data in British Columbia. Hydrographic stations (red circles) are where physical, biological and chemical measurements are made at bi-weekly to monthly frequencies. High frequency data from fixed sampling locations (red triangles) and temperature 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).

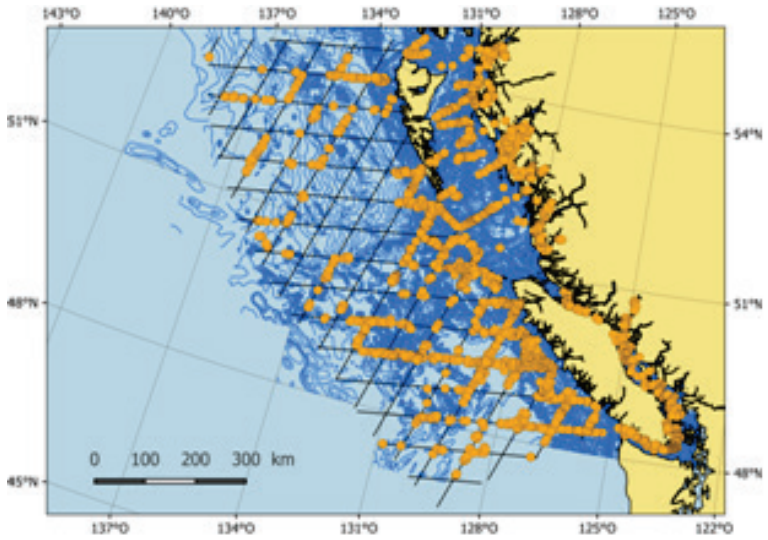


Fig. 12. 2018 Pacific Region International Survey of Marine Megafauna (PRISMM). Visual and acoustic detections were made along 17,000 km of pre-determined systematic line transects. The survey resulted in over 2800 sightings of marine mammals, mostly concentrated in inshore passages and inlets, on the continental shelf and shelf break, as well as around some seamounts offshore. Source: Thomas Doniol-Valcroze (DFO).

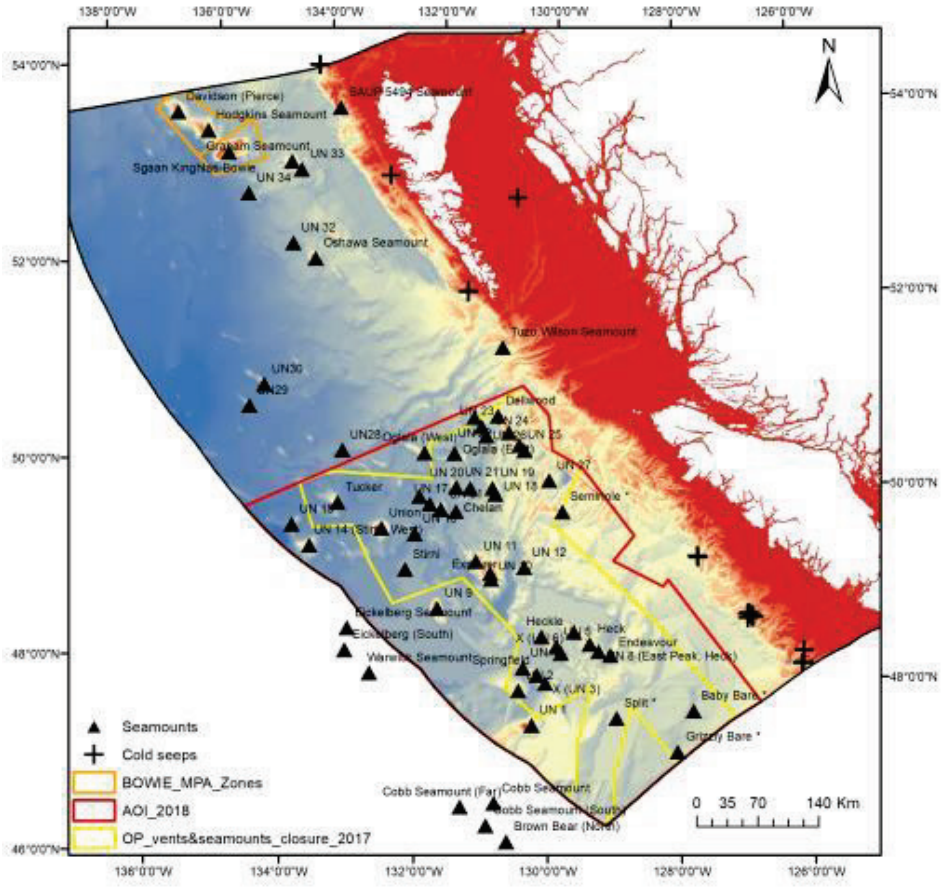


Fig. 13. 2019 Survey of the Offshore Area of Interest (AOI). Source: Tammy Norgard (DFO).

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Japan

I. Report from JAMSTEC (by Sanae Chiba, RIGC JAMSTEC)

1. Highlights in 2019: JAMSTEC has launched a Marine Plastics Research Group

1-1. Marine Plastics Monitoring in the western North Pacific garbage patch

The Microplastic Research Group was newly launched in April 2019 (Fig. 1). The group plans to conduct extensive monitoring of marine plastics particularly next couple of years in the regions known as the western North Pacific gyre where are estimated as the major accumulation area of plastics released from south-east and east Asian countries, and the observation data are nevertheless scarce. The project particularly emphasizes the investigation of macro- and microplastics on the deep-sea floor and in sediments where they hypothesized as one of the major sinks of the missing global marine plastics. The research took places in August to September 2019, and samples from sea floor up to over 9000 m below and adjacent of the gyre are collected. The research outcome will be published in due course.

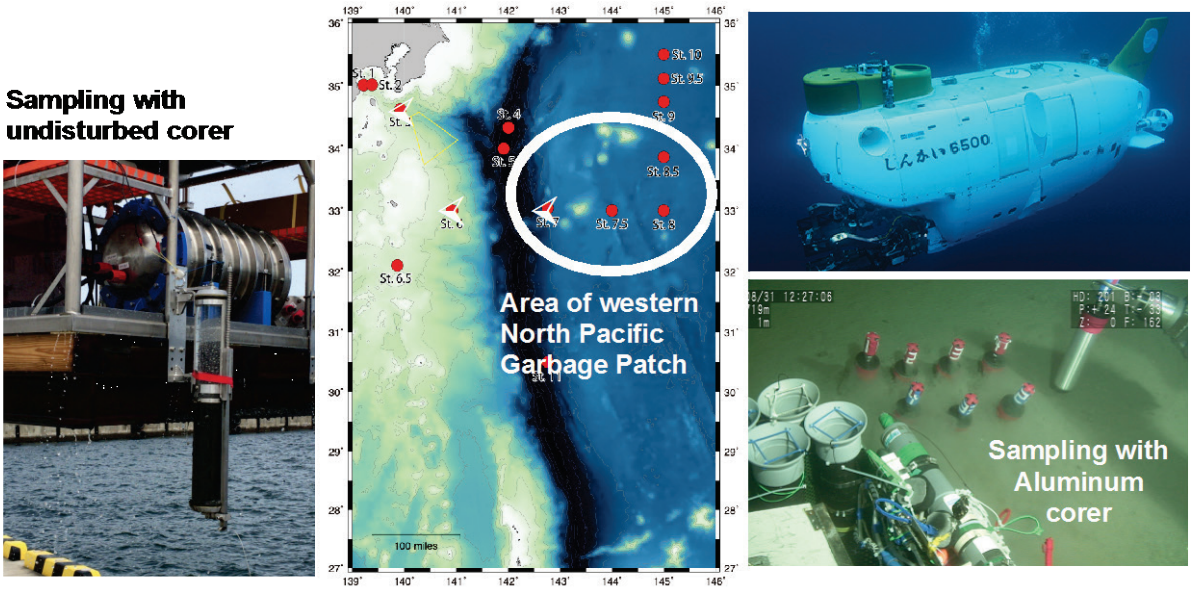


Fig. 1. JAMSTEC Marine plastics research cruise, August 28, 2019 to September 14, 2019.

1-2. Microplastic Monitoring

The group also plans to conduct microplastic monitoring under the collaboration of Japan-Palau Goodwill and Friendship Yacht Race organizer which will take place in December-January, 2019 (Fig. 2). They equip the semi-automated microplastic samplers (SubCTech, Co.) on a race yacht and the escort ship “Miraihe” to collect size fluctuated microplastics across the race route over 3000 km. The ocean literacy programme is also planned for school children and their families who will be on board the escort ship. This is the first JAMSTEC project that is co-designed with non-academia and conducted by non-research vessels, thus opens the door for the citizen science to join the JAMSTEC’s observation in future, and for JAMSTEC to enhance its activities in ocean literacy.

http://www.jamstec.go.jp/e/jamstec_news/20190730/

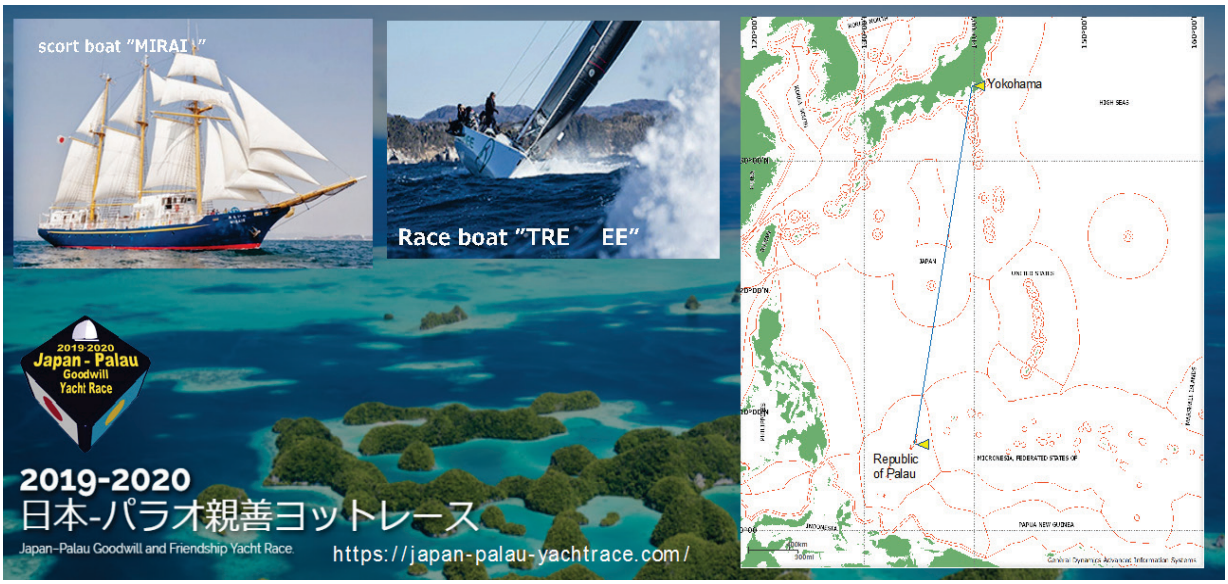


Fig. 2. Planned microplastic monitoring under the collaboration of Japan-Palau Goodwill and Friendship Yacht Race organizer will take place in December 2019–January 2020.

2. Update on Conventional Observation Programs of Research Center for Global Change

RCGC (Research and developmental Center for Global Change) is in charge of variety of ocean observation programs. Conventional monitoring projects as shown below are succeeded and under operation by RCGC. These projects yet are mainly limited to physical, chemical and atmospheric observation.

2-1. Argo JAMSTEC

http://www.jamstec.go.jp/ARGO/argo_web/argo/?lang=en

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). PARC is taking on the responsibility to validate all float data in the Pacific through rigorous scrutiny and to derive regional products based on these floats.

The global data point map of temperature and salinity was updated was updated (data up to August 2019). The map of gridded mixed layer depth with its related parameters (MILA GPV: MIxed Layer data set of Argo, Grid Point Value) was updated (data up to September 2019; Fig. 3). Download and visualization services of Argo gridded dataset "MOAA GPV" and "MILA GPV" have started from the JAMSTEC GODAC data site.

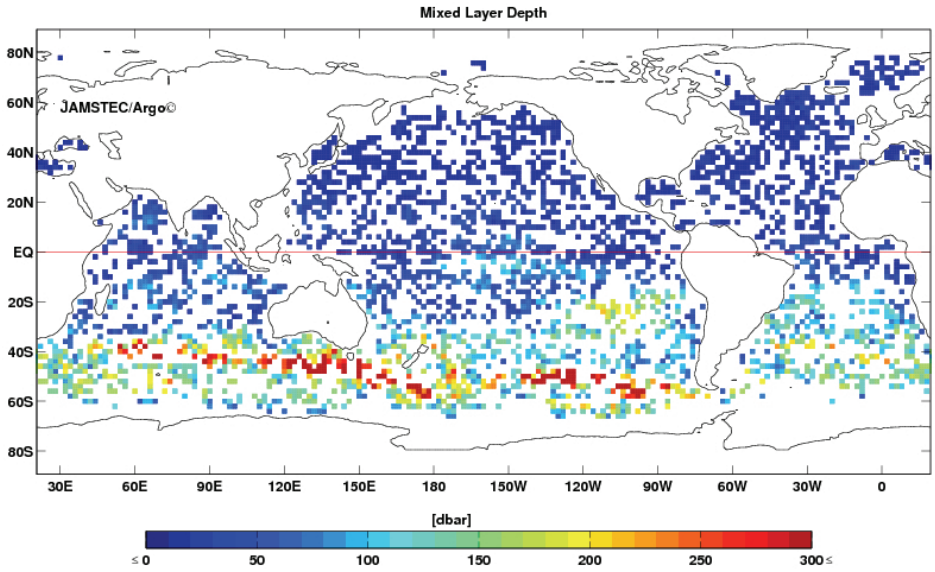


Fig. 3. Planned Mixed Layer properties (depth definition : $\Delta\sigma\theta$= 0.125km/m^3 & ΔT = 0.5℃) August 2019.

2-2. Deep NINJA: Deep ocean observation by deep-sea float

http://www.jamstec.go.jp/ARGO/deepninja/

JAMSTEC has deployed 31 Deep NINJA floats in collaboration with Tsurumi-Seiki Co., Ltd, primarily in the Southern Ocean up to January 2019. Additional two Deep NINJA floats were deployed off the Adelie Coast of Antarctica in December 2018 and January 2019 to measure deep profiles under sea ice throughout an Antarctic winter and continued to observe seasonal changes of the deep/bottom waters. Another float was deployed in the Eastern Pacific Ocean December 2018 (Fig. 4).

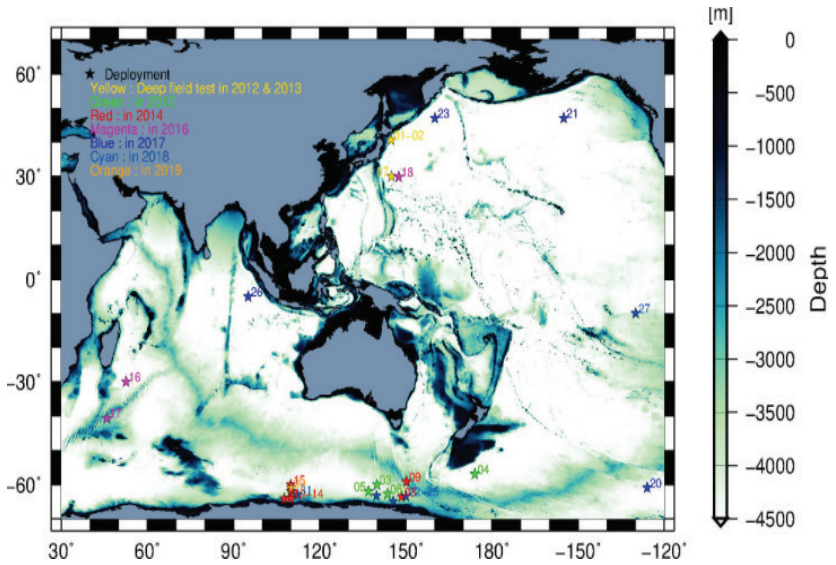


Fig. 4. Deployment map of Deep NINJA floats.

2-3. TAO and TRITON project

http://www.jamstec.go.jp/jamstec/TRITON/real_time/

TRITON (TRIangle Trans-Ocean buoy Network) is a mooring array of ocean buoys designed to obtain real-time air–sea data in the equatorial western Pacific and eastern Indian Ocean for improved detection, understanding and prediction of El Niño and La Niña. The data on the portal site were updated October 2019.

2-4. IOMICS project

http://www.jamstec.go.jp/iorgc/iomics/

IOMICS (Indian Ocean Moored buoy network Initiative for Climate Studies) developed a new type of moored buoy which observes sea surface heat flux components and ocean temperature and salinity in the upper layer to understand the mechanism of the Indian Ocean's variation and its importance for the global climate system under a cooperative framework among surrounding countries. The data on the portal site were updated October 2019.

2-5. Post-WOCE hydrography

http://www.jamstec.go.jp/iorgc/ocorp/data/post-woce.html

Repeat hydrography is carried out along the WOCE (World Ocean Circulation Experiment) observation lines. It encompasses observations of chemical tracers, total alkalinity, pH, Ω, and nutrients to accurately quantify the influence of global warming and ocean acidification on marine ecosystems, as well as to depict changes of the ocean heat content and the distribution of substances in seawater. The data on the portal site were updated for the 2017 winter cruise.

II. Report from Fisheries Research Agency (FRA) (by Kazuaki Tadokoro, Tohoku National Fisheries Research Institute)

1. Observation at monitoring lines

A-Line

Tohoku and Hokkaido National Fisheries Research Institutes have carried out oceanographic monitoring from 1987 to the present at the A-line transect in the Oyashio and Kuroshio-Oyashio transition waters (Figs. 5 and 6). In recent years, observations have been carried out 5 times throughout the year, in January, March, May, July, and October. Observations include CTD, water sampling by Niskin bottles, Norpac nets, and Bongo nets. In 2019, 5 cruises were carried out. The oceanographic data are open and available from the A-line website. Published data are from 1990 to 2017 for CTD and from 1990 to 2014 for other types of data.

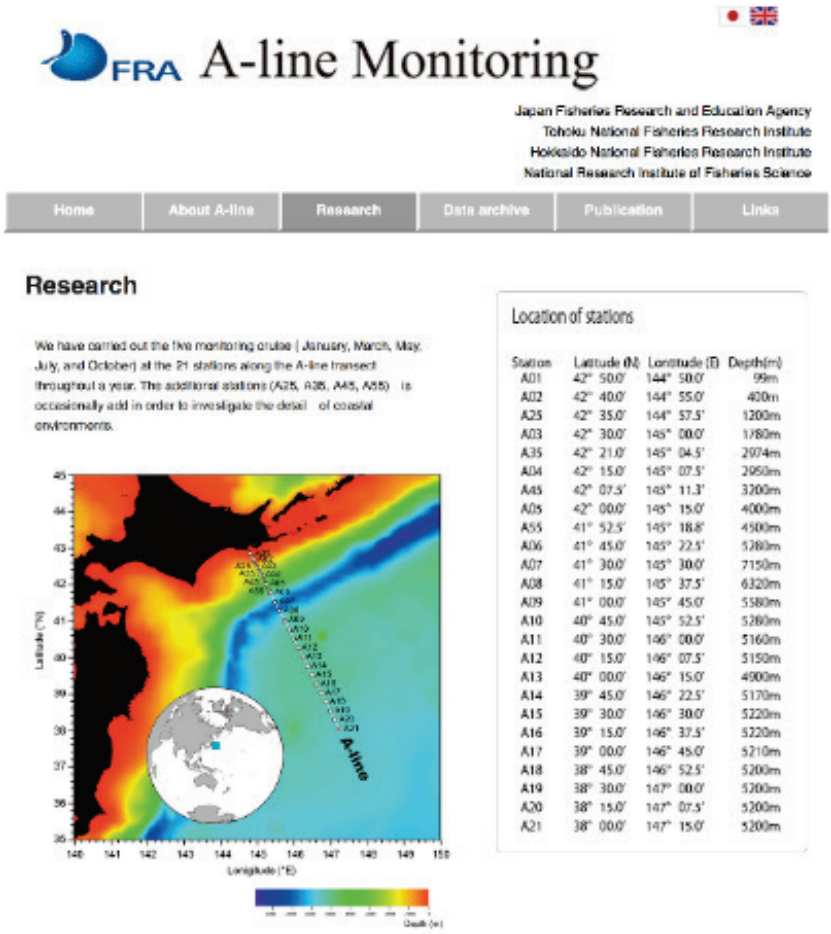


Fig. 5. A-line monitoring website.

O-Line

The National Fisheries Research Institute has carried out monitoring from 1999 to the present at the O-line transect (138°W, 27°N to 34.30°N) in the Kuroshio waters (Fig. 6). The observations are carried out in January, March, May, August, and October. Observations include CTD, water sampling by Niskin bottles, and Norpac net. In 2019, 5 cruises were carried out.

CK-line

The Seikai Fisheries Research Institute have carried out the monitoring from 2002 to present at a transect CK-line in the East China Sea (Fig. 6). The observations are carried out throughout the year, in February, March, June, July, and October. Observations include CTD, water sampling by Niskin bottles, and Norpac net. In 2019, 5 cruises were carried out.

SI-line

The Japan Sea National Fisheries Research Institute has carried out monitoring from 2016 to the present in the Sea of Japan (Fig. 6). Observations are carried out throughout the year, in February, April, June, and September. Observations include CTD, water sampling by Niskin bottles, and Norpac net. In 2019, 5 cruises were carried out.

N-line, S-line

The Hokkaido National Fisheries Research Institute has carried out monitoring from 2000 to the present in the Sea of Okhotsk (Fig. 6). The observations are carried out in May and September. Observations include CTD, water sampling by Niskin bottles, and Norpac net. Five cruises were carried out in 2019. See the N-line website.

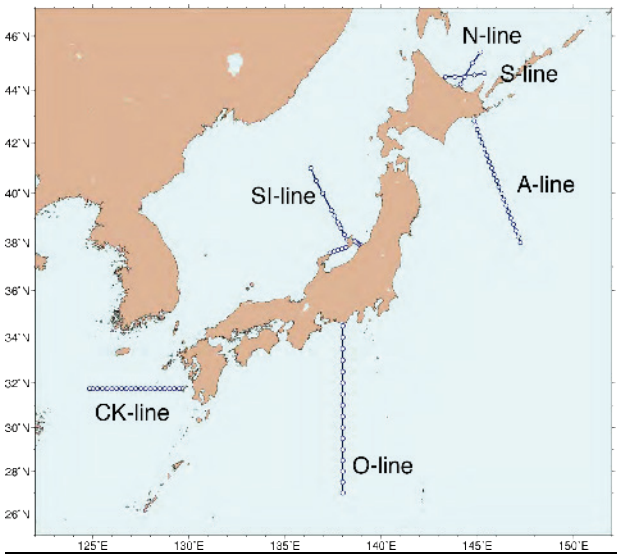


Fig. 6. Monitoring lines of FRA.

2. Meta genomic and HPLC sample collecting

To understand the biodiversity and biomass of plankton around Japan, FRA has collected metagenomic samples of mesozooplankton and phytoplankton at monitoring lines (A-line, O-line, CK-line, SI-line, N-line, S-line). Mesozooplankton samples are collected by NORPAC net (mouth diameter: 45cm, mesh size: 0.1mm). Phytoplankton are collected by nuclerpore membrane filter (pore size: 0.2 μm, and 3 μm) and GF/F filters. We are also collecting the HPLC samples for the CHEMTAX analysis. The samples were collected by GF/F filter.

3. Monitoring of stock assessment project commissioned by the Fisheries Agency of Japan

Observations have been carried out at 760 stations in the waters around Japan, except Okinawa and Hokkaido, since 1972 (Fig. 7). The frequency of the observations is monthly except with the stations in the Sea of Japan. In the Sea of Japan, observations are carried out during spring and autumn. Annual sampling number is about 7,000. The prefectural fisheries institutes mainly carry out the monitoring. Observation items are CTD and Norpac net. CTD data and abundance of egg, larvae, and juvenile pelagic fish are archived in the database of the FRESCO (Fisheries Resource Conservation) system managed by JAFIC (Japan Fisheries Information Service Center).

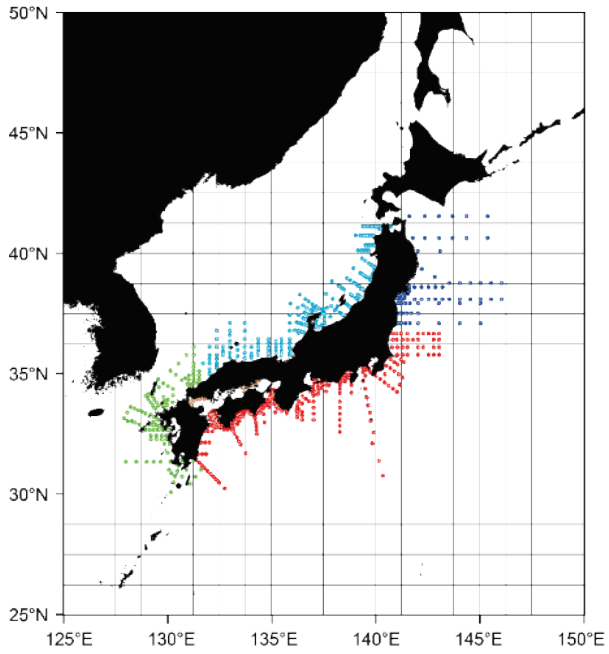


Fig. 7. Observation stations for monitoring during the stock assessment project.

4. Zooplankton sample collection

The Tohoku National Fisheries Research Institute has been collecting zooplankton samples from 1951 to the present (Fig. 8; see http://tnfri.fra.affrc.go.jp/seika/plankton/hyohon_home.html). The total number of samples is more than 180,000 at present (October 1, 2019). The samples are preserved by 5% buffered formaldehyde. The sampling area is mainly in the waters around Japan. However, the samples have also been collected in the western North Pacific, central North Pacific, and Peruvian waters. Samples are collected by FRA, prefectural fisheries institutes, Japan Meteorological Agency, and university. The inventory of the sample is archived to the closed database.

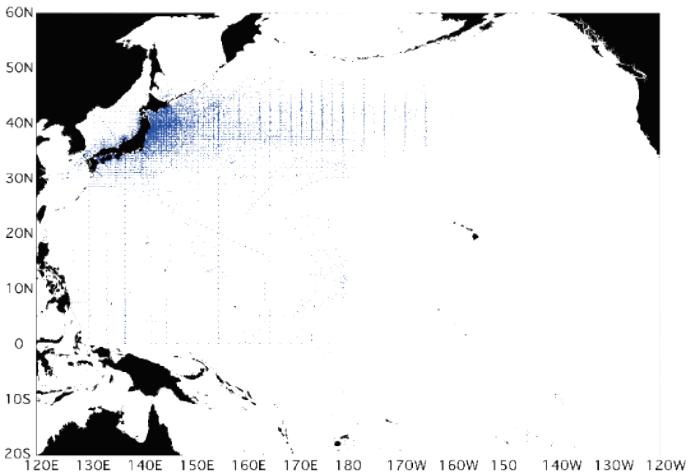


Fig. 8. Sampling locations of zooplankton

5. Zooplankton photo, sketch, and genomic information library

To analyze zooplankton to species level we have started to collect genomic information (COI, 18S, *etc*.) of mesozooplankton around Japan. We are also collecting morphological information (photos and sketches) of mesozooplankton at the same time (Fig. 9). Up to the present, we collected samples and photos from 3 cruises (western north Pacific subtropical waters, western north Pacific tropical waters, Kuroshio-Oyashio Transition waters). This program is collaboration with SCOR Working Group 157 (MetaZooGene).

Fig. 9. Mesozooplankton.

6. Fish eggs, larvae, juvenile sample collection

The National Fisheries Institute started to collect samples starting in 2015 (Fig. 10). The samples were mainly collected during the stock assessment project commissioned by the Fisheries Agency of Japan.

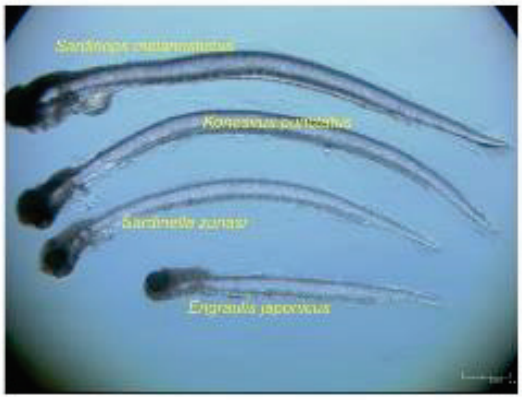


Fig. 10. Fish larvae specimen samples

7. Fish specimens sample collection

The Seikai National Fisheries Research Institute has a total number of about 32,000 samples (Fig. 11). They are mainly preserved by isopropyl alcohol. DNA samples have also been collected from a part of the samples.

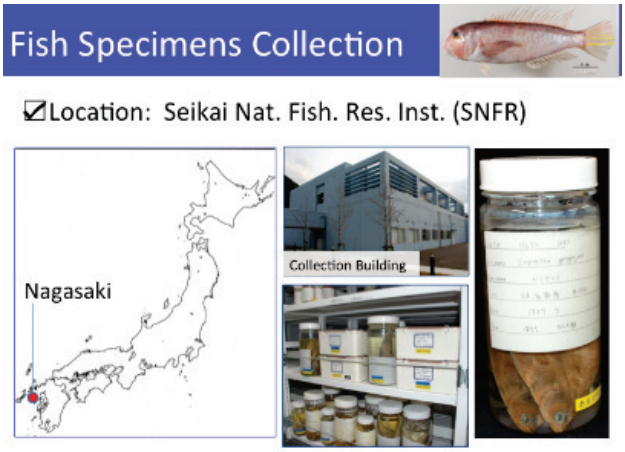


Fig. 11. Location, collection building and specimens of fish samples.

III. Report from Hokkaido University (by Hiroto Abe and Sei-Ichi Saitoh, Faculty of Fisheries Sciences, Hokkaido University)

1. Coastal monitoring by T/S Ushio-Maru in Tsugaru Strait

Tsugaru Strait, located between Hokkaido and main island of Japan (Fig. 12), is known as major fishing area of Squid and Tuna in Japan. Recently, volume of squid caches is on declining trend and this has been becoming serious social concern in this area. In addition, long-term observation on the coast indicates warming trend of water temperature. Based on this background, Hokkaido University and Mutsu Institute of Oceanography (MIO) of JAMSTEC have made effort for quarterly monitoring physical and chemical water property across the Tsugaru strait since 2009 until this year using T/S *Ushio-Maru* (Fig. 13). The observation items include CTD, nutrient, and pH. Further, three High Frequency (HF) radars were deployed by JAMSTEC at both sides of coast in Tsugaru Strait, and have monitored surface currents since 2014. Validation effort using near-surface current velocity from the *Ushio-Maru* ADCP and moored current meters by JAMSTEC guarantee the accuracy of HF radar surface current velocity at a certain level (Fig. 14). This radar system has/will have been a vital tool for environmental monitoring in this area.

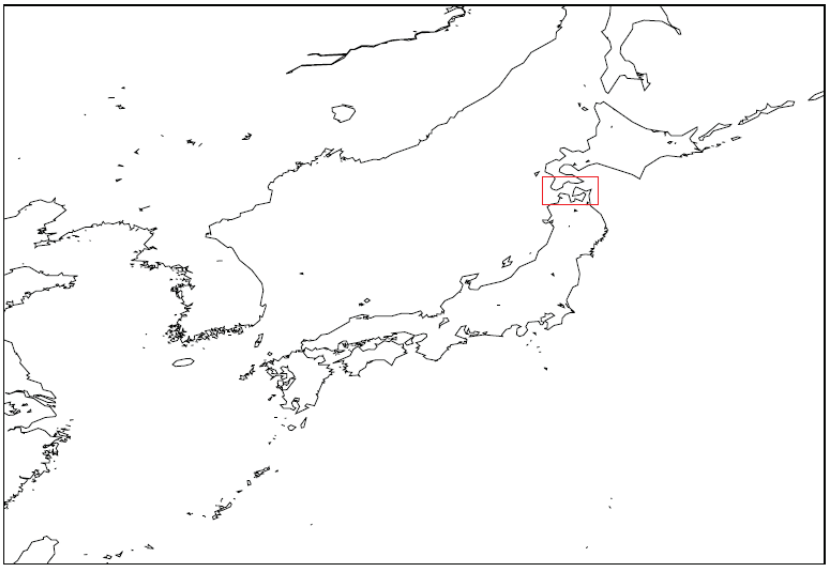


Fig. 12　Location of Tsugaru Strait.

Fig. 13. Photo of the T/S *Ushio-Maru*, Hokkaido University.

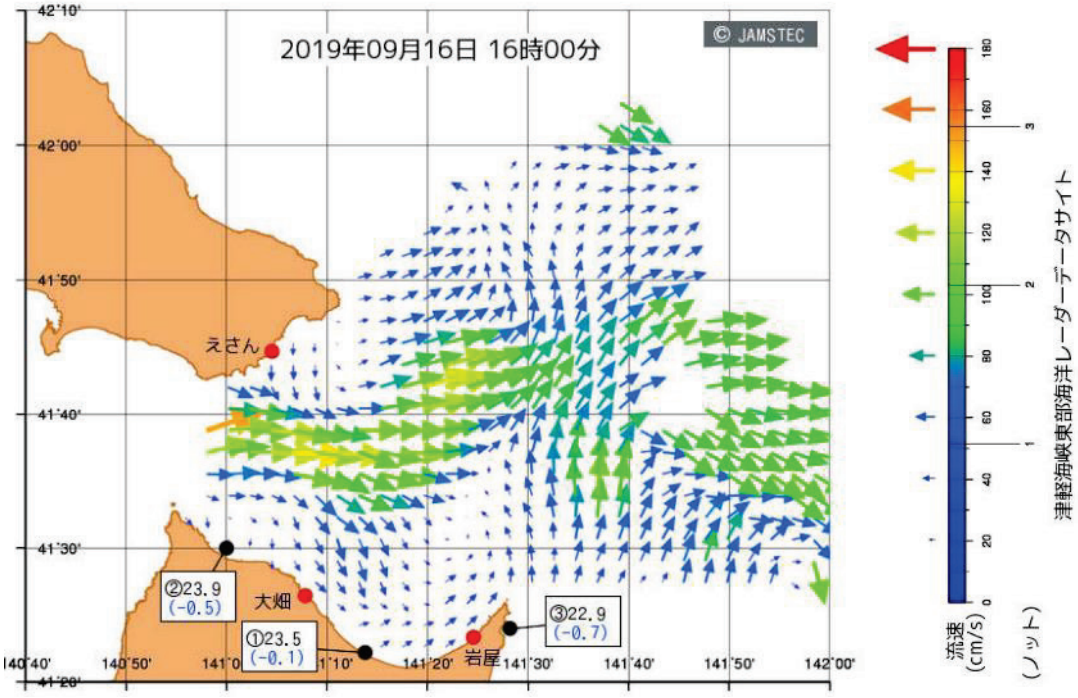


Fig. 14. Surface current map in the Tsugaru Strait measured by JAMSTEC's HF radar. See http://www.godac.jamstec.go.jp/morsets/e/top/.

2. Saloma-ko lagoon sea ice observation

Saroma-ko Lagoon is located on the Okhotsk Sea coast of Hokkaido, which has two inlets that connect to the Sea of Okhotsk, allowing fresh–sea water exchange (Fig. 15). During winter, most of the lagoon surface is covered with sea ice. This place is safe for observation and relatively easy access from a populated area. This lagoon attracts many researchers from various countries for testing devices, education, and training for polar research.

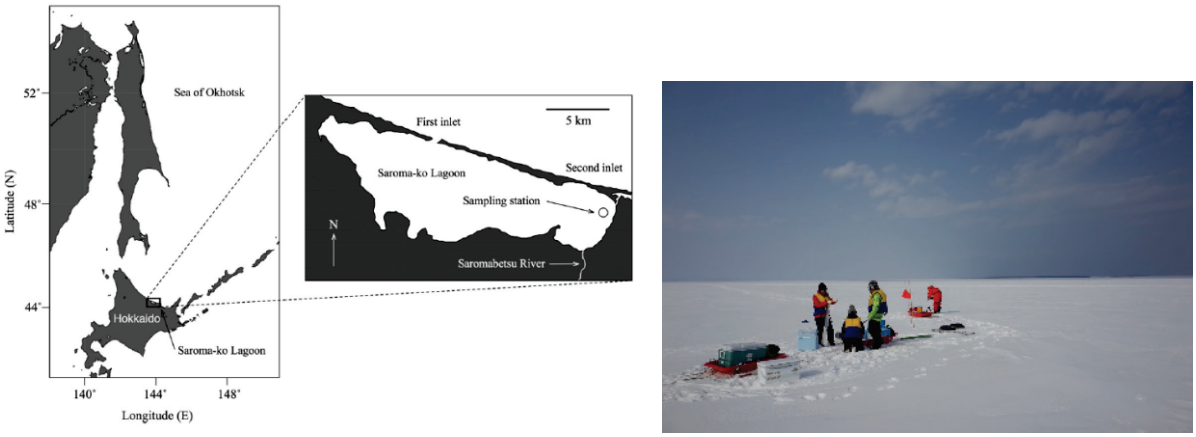


Fig. 15. Location of Saloma-ko Lagoon (left), and photo of field campaign (right).

3. Ice sheet/glacier–ocean interaction in Greenland

Through the ArCS project, we carried out coastal observations in Greenland (Figs. 16 and 17).

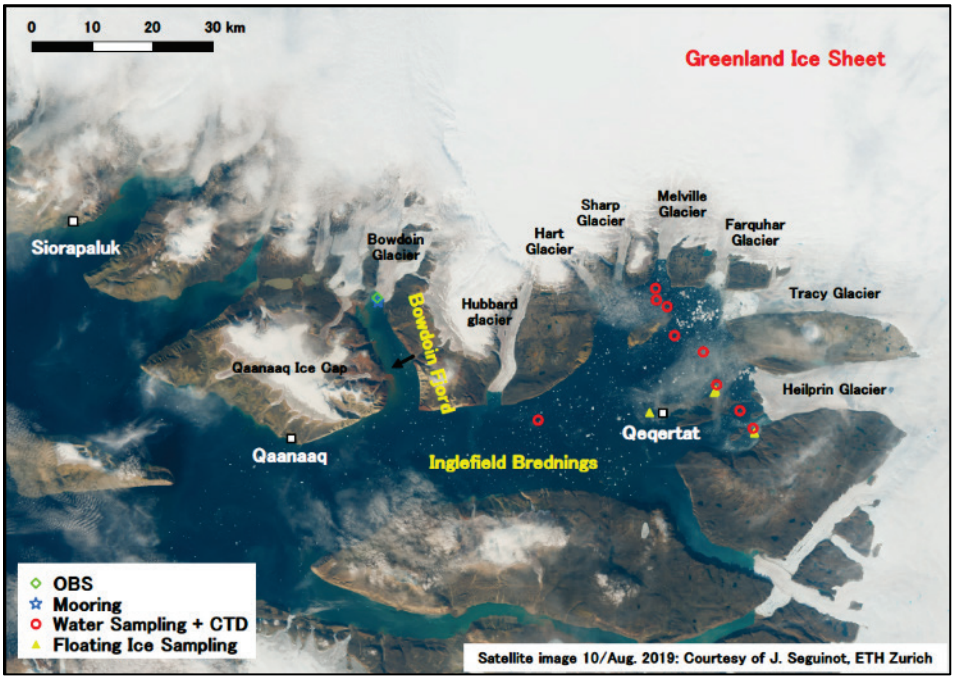


Fig. 16. Observation stations and mooring stations in Inglefield Gulf, northwestern Greenland.

Fig. 17. A researcher taking a water sample using a CTD just off the glacier's edge.

Korea

I. Report from National Institute of Fisheries Science (NIFS)

1. Marine Heatwaves (MHWs) monitoring in Korean waters

Since 2016, Marine Heatwaves (MHWs) were frequently occurred around the Korean coastal area in the Yellow Sea and Northern East China Sea every summer. SROCC (Special report on Ocean and Cryosphere in a Changing Climate) by IPCC (Intergovernmental Panel on Climate Change) has been published by adding the Yellow Sea and Northern East China Sea as MHWs occurring ocean areas. Fisheries damage by MHWs around the Korean coastal area in the Yellow Sea and Northern East China Sea was also described in this special report. NIFS operates 105 real-time water temperature monitoring system to observe the abnormal water temperature including MHWs around the Korea coastal area. 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.

2. Marine ecosystem structure surveys (2018~2022) in Korean waters

NIFS carries out the marine ecosystem structure surveys with pelagic and benthic ecosystems in the Korea Waters from 2018 with 5 years plan. These surveys are monitored and measured more than 60 items with the physical items like water temperature and salinity, the chemical items like dissolved oxygen, nutrients, Chl-a, organic Carbon, Total nitrogen etc., and the biological items like bacteria, phyto- and zoo-plankton, ANF, HNF etc. NIFS have a plan to obtain more than 20,000 samples related to marine ecosystem structure every year.

3. Wave-glider and ocean glider survey in Korean waters

To understand the behavior of low salinity water and clarify the satellite algorism of salinity distribution, wave-glider survey was carried out the East China Sea during summer in 2019 around the Northern East China Sea. Frontier observation with ocean glider across the East Sea was carried out in the East Sea. This ocean glider survey plans to examine the possibility of replacing the vessels survey in the long-term.

II. Report from Korea Institute of Ocean Science and Technology (KIOST)

Operating ocean research stations

KIOST has constructed and operated 3 sites of ocean research stations in the Yellow Sea and northern East China Sea since 2003. The data obtained by these stations were usually used to improve the comprehensive ocean and weather observations and provide for the global environmental change studies. KIOST registered these 3 sites of ocean research station to the first shallow water observatories for OceanSITES in August 2018. From the acceptance by OceanSITES, shallow water pilot project should be contributed to understand the propagation of ocean signals shoreward to the continental shelf regions.

III. Report from Korea Meteorological Agency (KMA)

Ocean weather observation system around the Korea Peninsula

KMA operates 17 ocean data buoys around the Korea Peninsula to observe the wind, air pressure, humidity, water temperature, wave heights and wave direction etc. They will install 2 large scale ocean data buoys in the center of Yellow Sea to obtain the available ocean and atmosphere data in this region. They also operate 59

coastal wave buoys near the coast of Korea to observe the wave heights and water temperature. Among them, 44 coastal waver buoys were used to minimize the fisheries damage in connection with real-time water temperature information system of NIFS since 2018.

IV. Report from Korea Hydrographic and Oceanographic Agency (KHOA)

Operation Korea Ocean Observing Network

KHOA operates Korea Ocean Observing Network (KOON) that consists of tidal stations, ocean research stations, ocean buoys and surface currents stations. KOON is providing the real-time ocean information with improved data quality for the needs of oceanic industry, military and general public. KHOA currently operates 50 tidal stations, 3 ocean research stations, 32 moored ocean buoys and 44 HF radar systems. They will install 1 tidal station and 1 ocean buoy, which will be detected to rip current, in the end of this year.

V. Report from Korea Advanced Institute of Science and Technology (KAIST)

Data quality assurance and quality control

KAIST conducted the hind-cast quality assurance and quality control (QAQC) procedure of hourly radial velocity maps for a one year (2018) obtained from 23 high-frequency radars (HFRs), operated by KHOA, and quantified the uncertainty of radial velocity data along with the spatial and temporal data availability maps. The developed QAQC procedure will advance the operational HFR observing system and enhance the efficiency of internal and external data flows.

Russia

I. Monitoring Activities (fishery-independent surveys) at the Pacific branch of VNIRO (TINRO) (by Vladimir Kulik)

TINRO-Center conducts fishery-independent surveys in all Far Eastern Seas and the Northwestern part of the Pacific Ocean. The information from trawls and CTD stations has been stored in the Laboratory "Regional Data Center" for 43 years (Volvenko, 2015). The laboratory was renamed in 2018 to "Laboratory for Fishing Statistics and Databases". Employees at TINRO can organize their datasets as they wish, but they are obliged to share copies with the Division for Fishing Statistics and Databases if the data are gathered in expeditions organized by TINRO. Thus, we prepare and store the data in the PostgreSQL database for the usage by authorized users.

TINRO dispatched the R/V *Professor Kaganovskiy* to the Sea of Okhotsk in 2018, and the R/V *TINRO*, similar to the former one, in 2019. The target was to estimate walleye pollock abundance in spring and all other species caught by trawl. Environmental conditions were also monitored as it is usually done in TINRO's complex expeditions. There were 220 midwater trawlings made from April 15, 2018 to May 26, 2018 and 279 midwater trawls conducted from April 6, 2019 to May 27, 2019. The number of stations increased in the East Sakhalin Subzone (Figure 1).

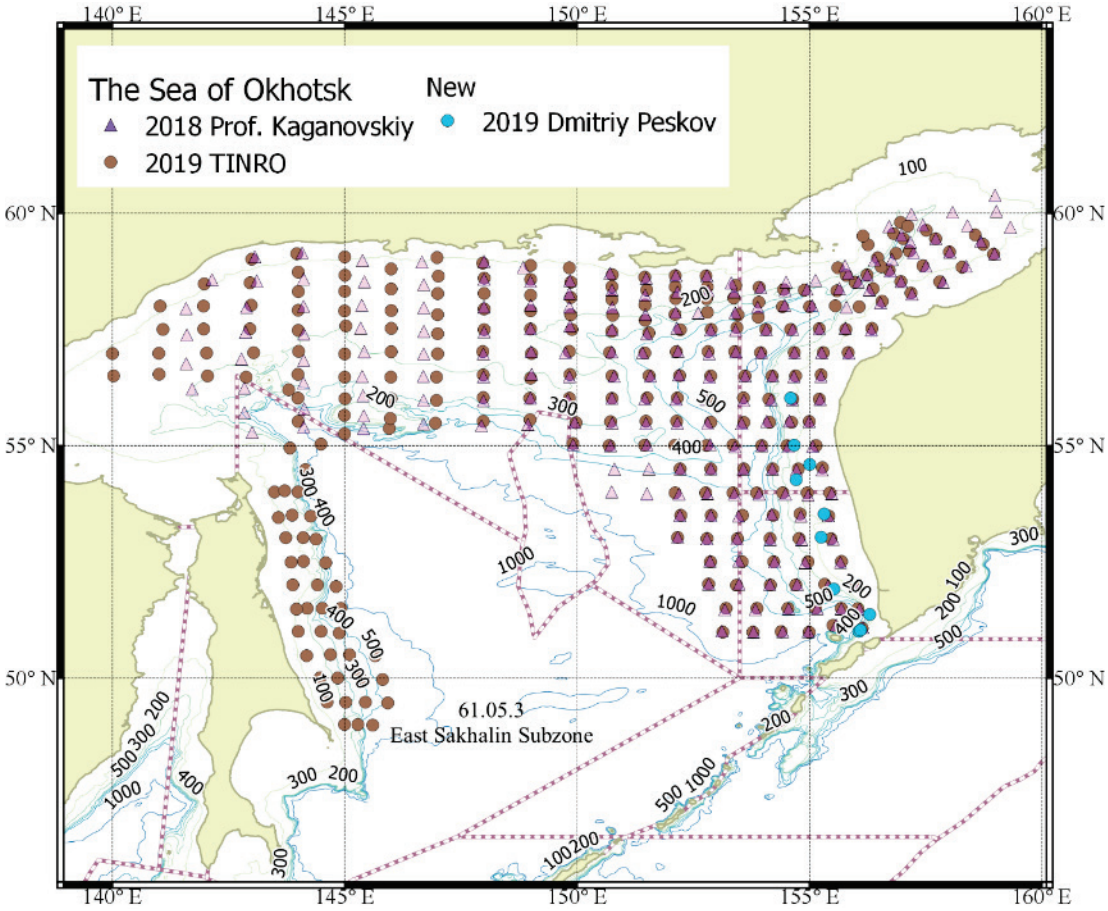


Figure 1

At the same time (from April 6, 2019 to May 8, 2019) the R/V *Dmitriy Peskov* conducted additional research including 10 midwater trawls (See Figure 1).

The R/V *Professor Kaganovskiy* conducted 30 trawls from April 6, 2018 to April 11, 2018and the R/V *TINRO* conducted 38 trawls from March 24, 2019 to April 3, 2019 in the Northwestern part of the Pacific Ocean (NWPO). All of them were targeted mainly to estimate walleye pollock stock as usual. The R/V *Buhoro* conducted 95 bottom trawls from July 13, 2018 to July 30, 2018 (Figure 2)

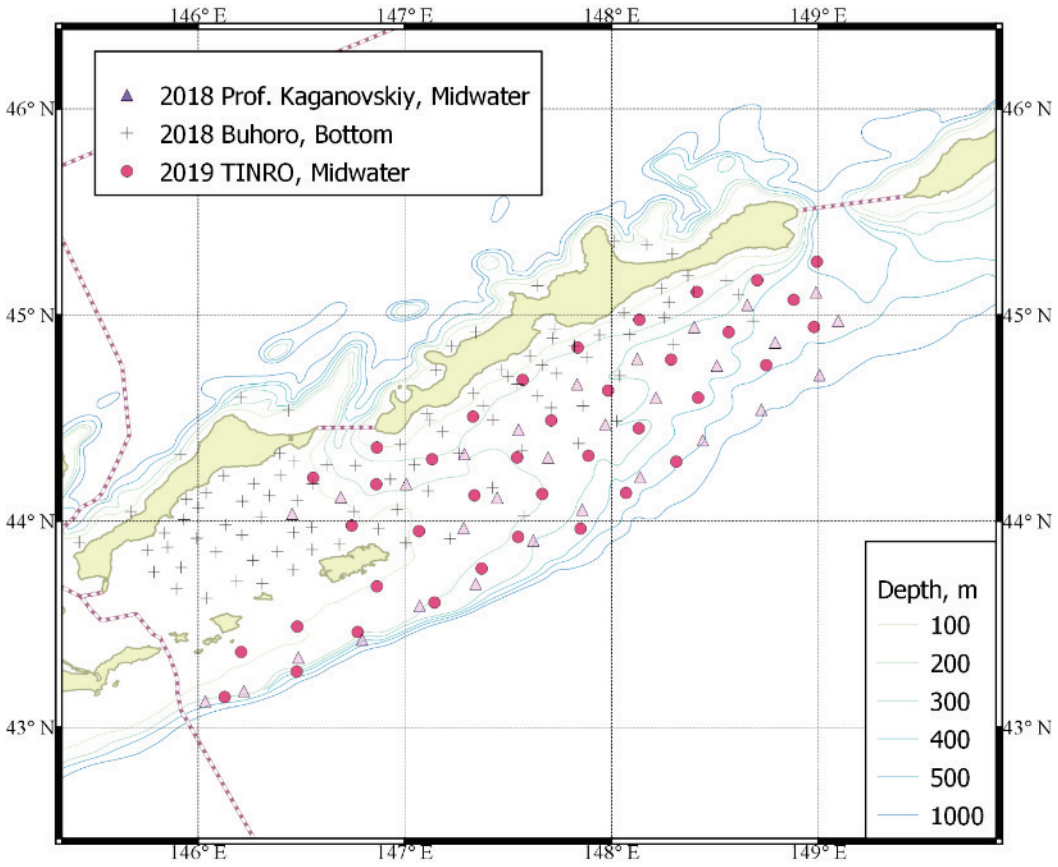


Figure 2

The R/V *TINRO* conducted bottom trawls close to Western Kamchatka in Summer (mostly June) from coast down to 211 meters depth (from May 28, 2018 to July 3, 2018there were 220 trawlings) As usual. But in 2018 it also conducted bottom trawls in deeper places (from April 14, 2018there were 171 trawlings). Maximum depth of bottom trawling was 972 m. The R/V *Professor Kaganovskiy* conducted 218 bottom trawls close to Western Kamchatka from June 11, 2019 to July 12, 2019 between 12 and 275 m depth. The R/V *Dmitriy Peskov* made 49 bottom trawlings in the shelf and slope areas of the Northern Kuril Islands from March 1, 2019 to March 27, 2019 between 60 and 500 m depth. The year before (from May 25, 2018 to September 10, 2018), the R/V *Professor Levanidov* worked in the same area and made 89 bottom trawlings twice deeper: between 120–1024 m depth (Figure 3).

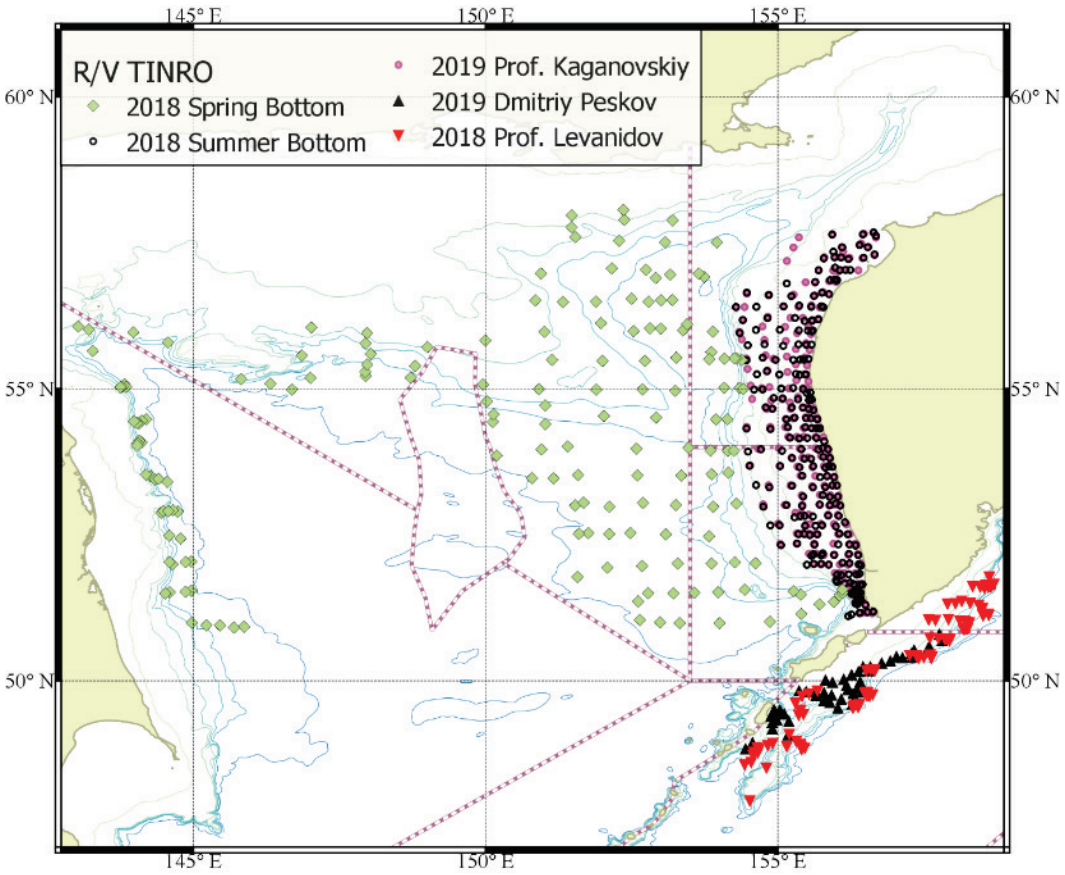


Figure 3

In the Bering Sea, the R/V *Professor Levanidov* conducted 72 bottom trawlings from September 13, 2018 to September 28, 2018 between 88 and 968 m depth and 79 midwater trawlings from July 31, 2018 to August 18, 2018 (Figure 4).

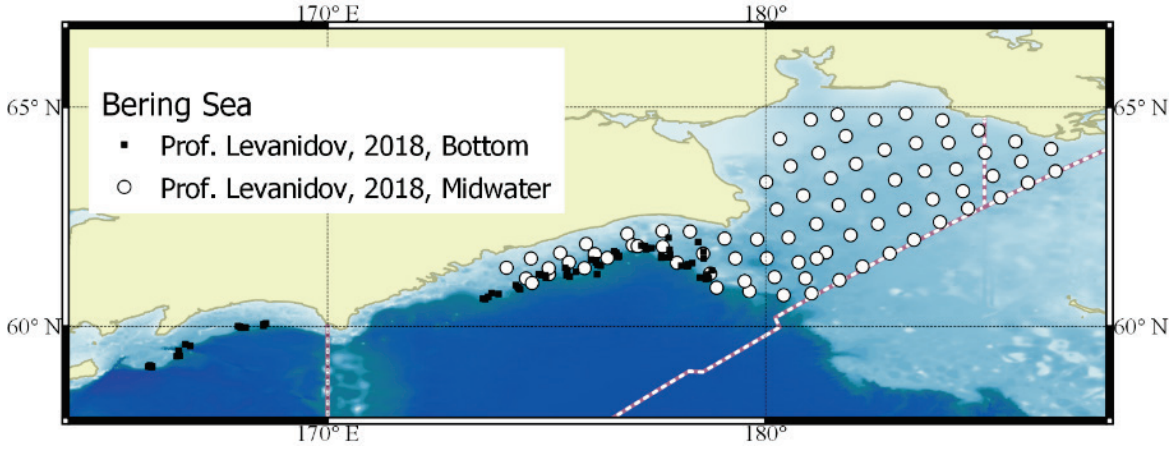


Figure 4

The upper layer of pelagic waters are usually studied in Fall to count mainly juveniles of salmon. The R/V *Professor Levanidov* and R/V *TINRO* conducted 183 trawls totally on the routes of salmon migration in Fall of

2018. The adults of salmon (mature and immature) are the main targets during scientific surveys in Summer in the offshore waters of the NWPO. The R/V *Professor Kaganovskiy* conducted 88 trawls from May 31, 2018 to July 7, 2018 and the R/V *TINRO* conducted 85 trawls from May 28, 2019to July 3, 2019, almost in the same places (Figure 5).

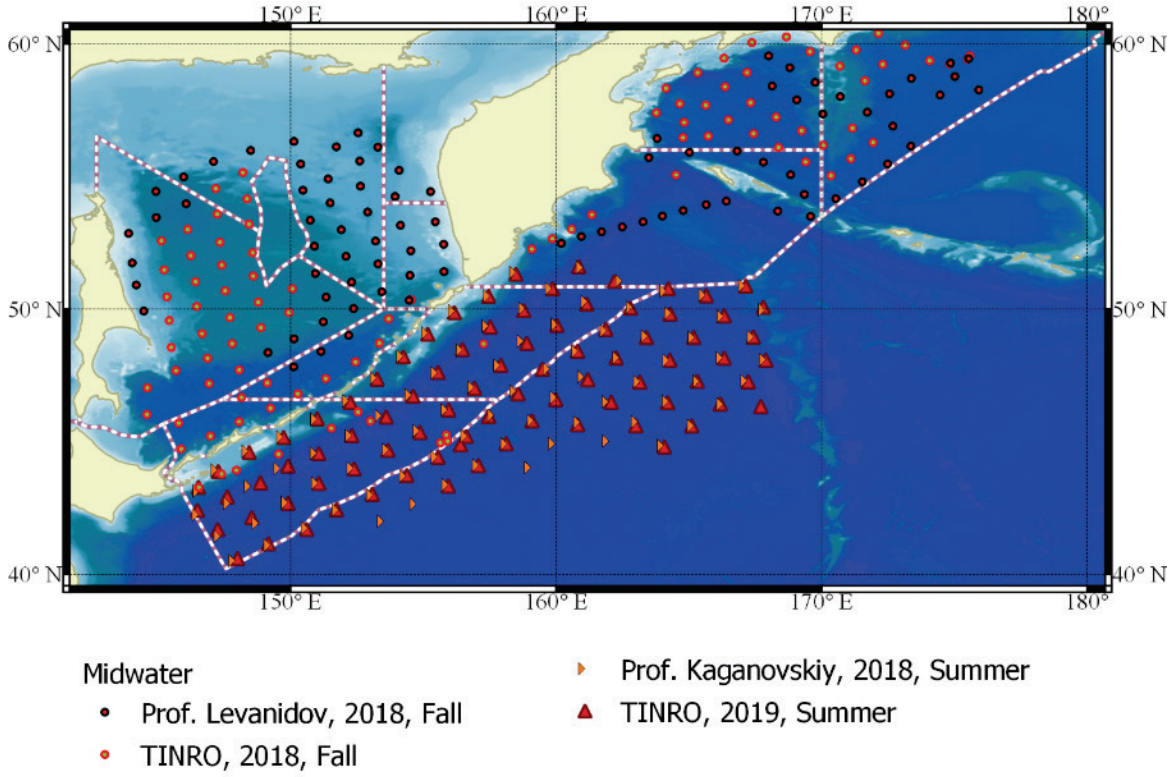


Figure 5

The R/V *Professor Kaganovskiy* took onboard the international expedition composed of 21 scientists from Canada, Japan, Korea, Russia and the United States of America for the International Year of the Salmon Program in 2019 (Figure 6).

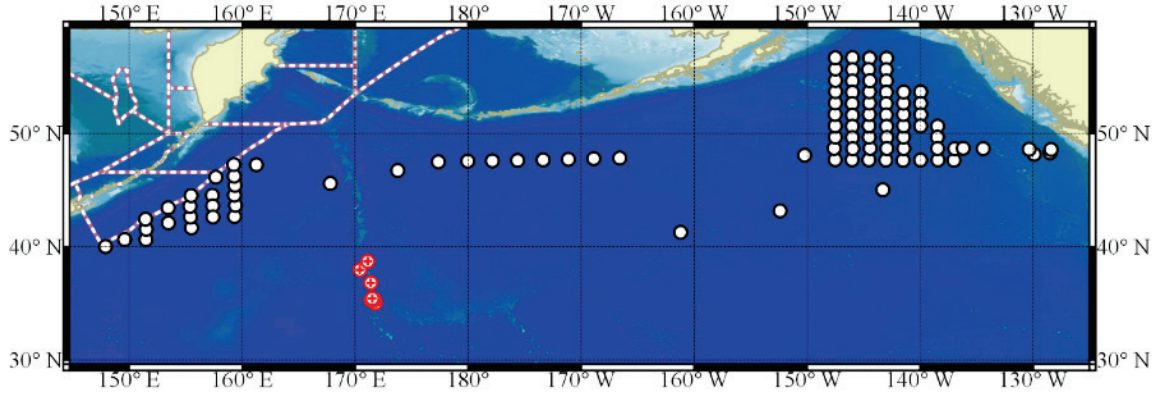


Figure 6

The R/V *Buhoro* conducted 224 bottom trawls from April 20, 2018 to June 17, 2018 in the northwestern part of the Region 19 and 100 bottom trawls from June 20, 2018 to July 11, 2018 in the northeastern part of the Region 19 (Figure 7).

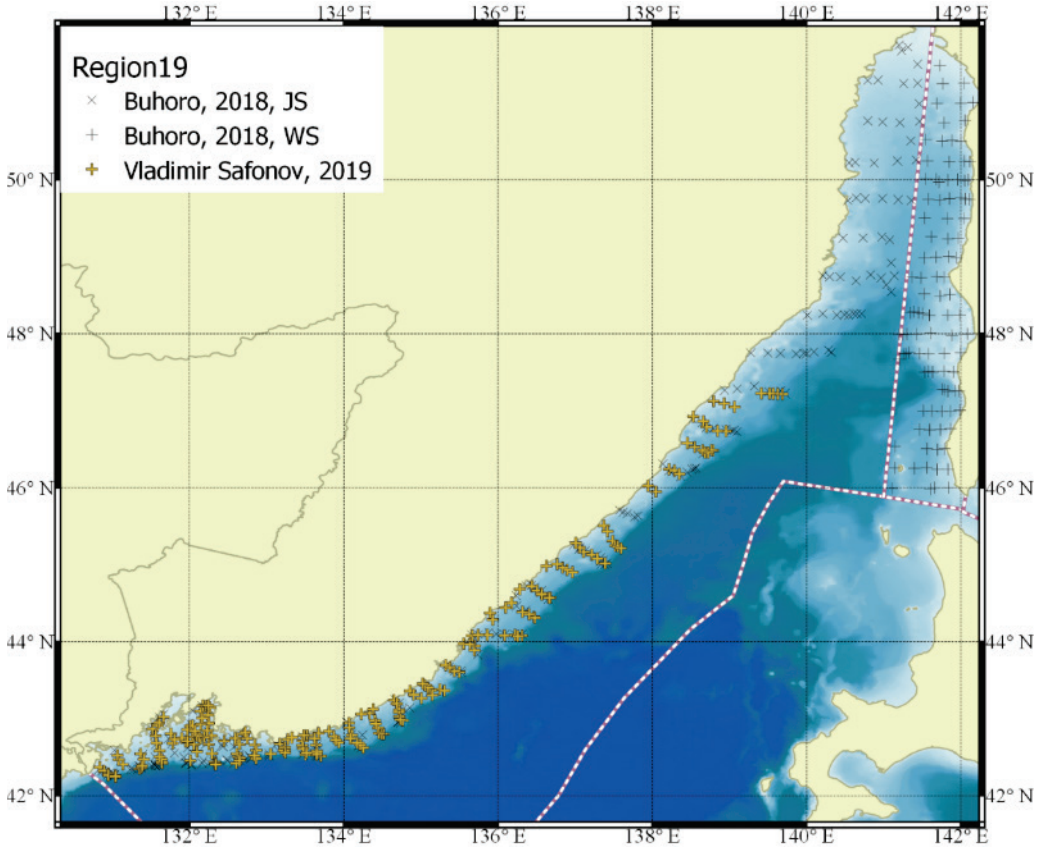


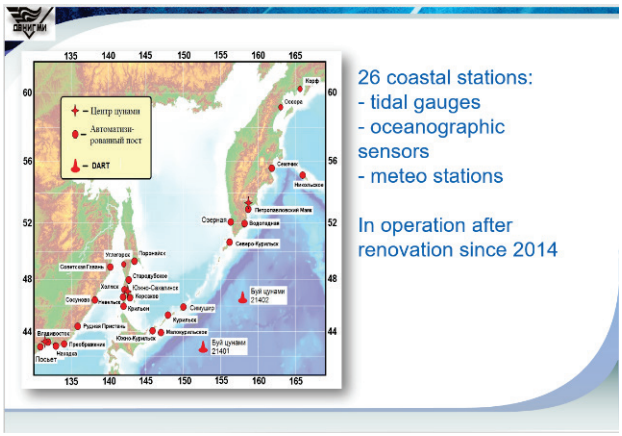
Figure 7

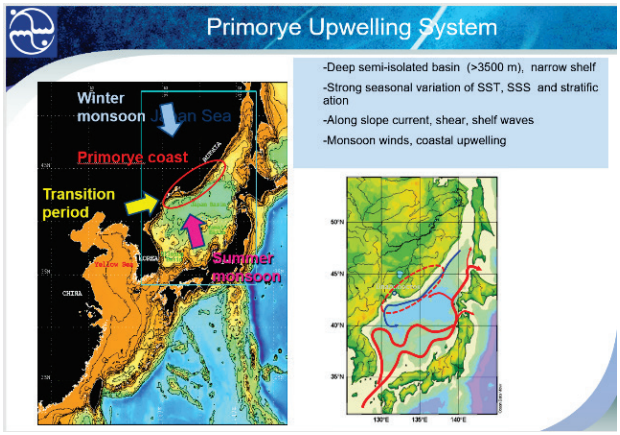
There are some other expeditions in process of conducting or checking. A full list of expeditions, conducted in 2019, will be available in 2020 only.

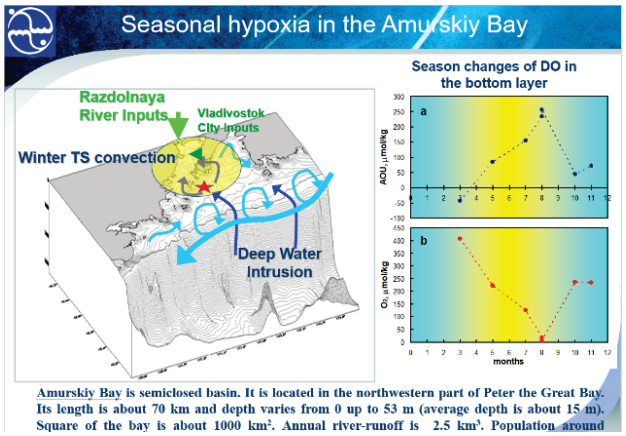
Reference

Volvenko, I. V. (2015). The Role of the Regional Data Center (RDC) of the Pacific Research Fisheries Center (TINRO-Center) in North Pacific Ecosystem and Fisheries Research. *International Journal of Engineering Research & Science*, 1 (November 2015), 47–54.

Main monitoring activities in Russia by POI in 2018–2019 (by Vyacheslav Lobanov, V.I. Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences)

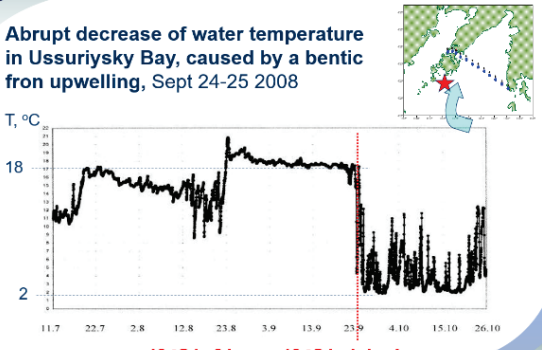






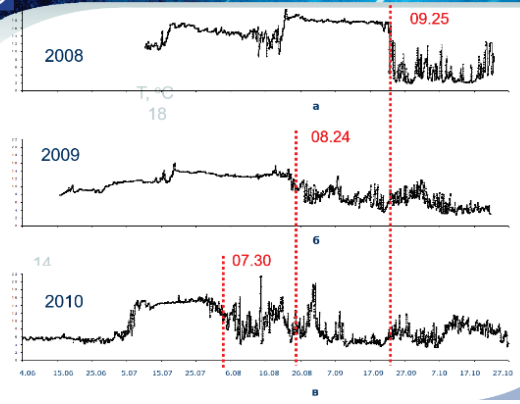
PGB Upwelling monitoring 2008-2019

Abrupt decrease of water temperature in Ussuriysky Bay, caused by a bentic fron upwelling, Sept 24-25 2008

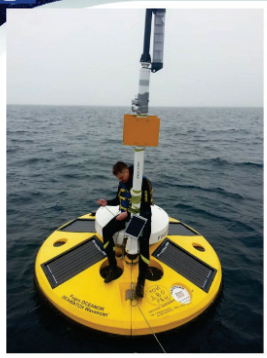


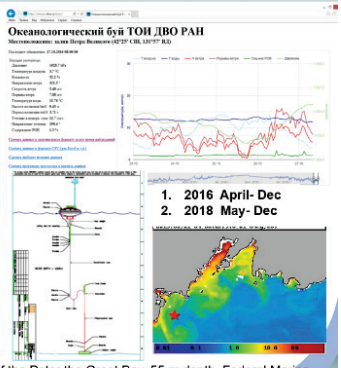
10 °C in 6 hours, 16 °C in 1 day !

Inter-annual Variability of the PGB Upwelling



Peter the Great Bay Observing System

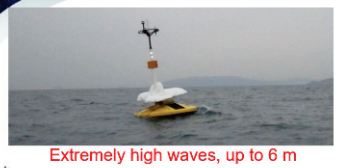




Wavescan Oceanographic Buoy at SW part of the Peter the Great Bay, 55 m depth, Federal Marine Preserve, operation data transfer via GSM every hour: meteo, currents, waves, T, S, Chl, CDOM etc.

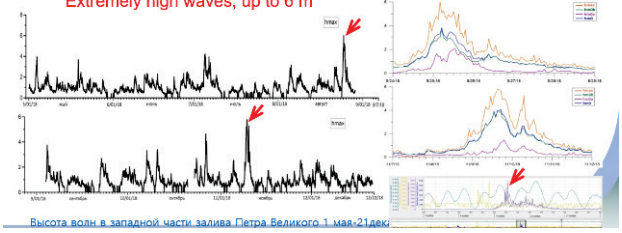
Cleaning the sensors of the buoy (August 2018)

New extremes of Hydormet regime of PGB



Extremely high waves, up to 6 m

hm0a (м)	Mean	Max
May-18	1.0	3.9
Jun-18	0.9	2.5
Jul-18	0.8	4.2
Aug-18	1.2	**6.0**
Sep-18	0.8	3.8
Oct-18	1.0	4.6
Nov-18	0.9	**5.8**
Dec-18	0.9	2.6
May-Aug	1.0	6.0
Sep-Dec	0.9	5.8



Высота волн в западной части залива Петра Великого 1 мая-21 дек

Hot summer, strong winds in Autumn, strong currents

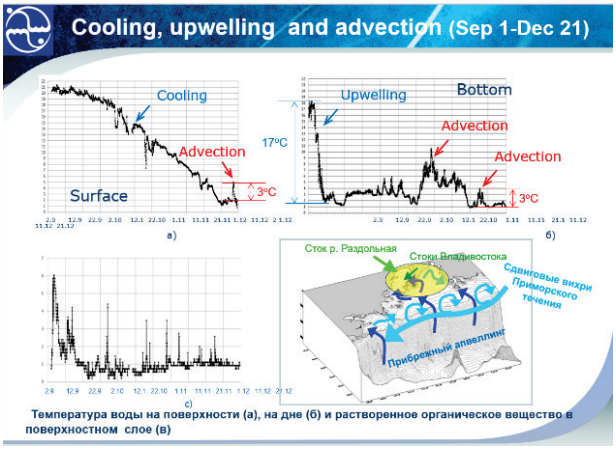
Wind (м/с)	Mean	Min	Max	Max f
май.18	3,7	0,2	12,4	18,0
июн.18	3,8	0,1	10,5	13,4
июл.18	3,4	0,1	9,2	13,0
авг.18	4,3	0,1	12,9	**22,5**
сен.18	4,7	0,4	11,5	17,3
окт.18	6,4	0,2	14,9	20,4
ноя.18	6,1	0,2	17,0	**24,7**
дек.18	7,1	0,2	17,2	**22,9**
май-авг	3,8	0,1	12,9	**22,5**
сент-дек	5,6	0,2	17,2	**24,7**

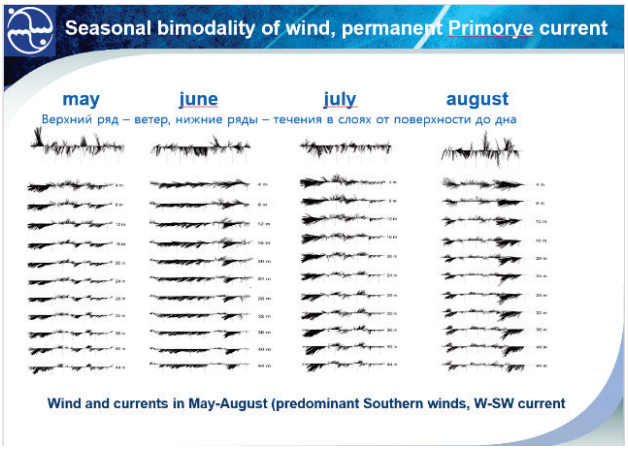
Air T (°C)	Mean	Min	Max
май.18	8,5	3,9	17,0
июн.18	14,0	10,0	23,3
июл.18	18,4	13,0	**28,2**
авг.18	22,0	18,2	**29,6**
сен.18	18,6	12,9	23,4
окт.18	13,0	3,1	20,6
ноя.18	5,1	-6,2	13,6
дек.18	-2,7	-12,3	6,4
май-авг	15,7	3,9	29,6

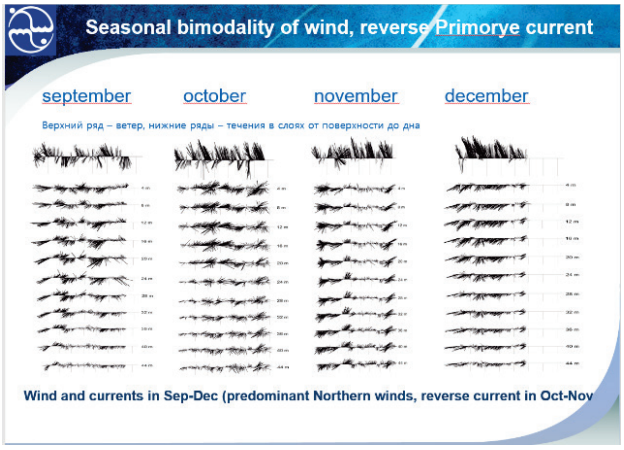
Currents velocity 4 м (см/с)	Mean	Max
май.18	17,6	54,5
июн.18	18,8	44,5
июл.18	16,8	**73,2**
авг.18	17,3	**77,9**
сен.18	17,5	55,7
окт.18	20,1	58,6
ноя.18	15,5	61,5
дек.18	15,5	46,9
май-авг	17,6	77,9
сент-дек	17,2	61,5

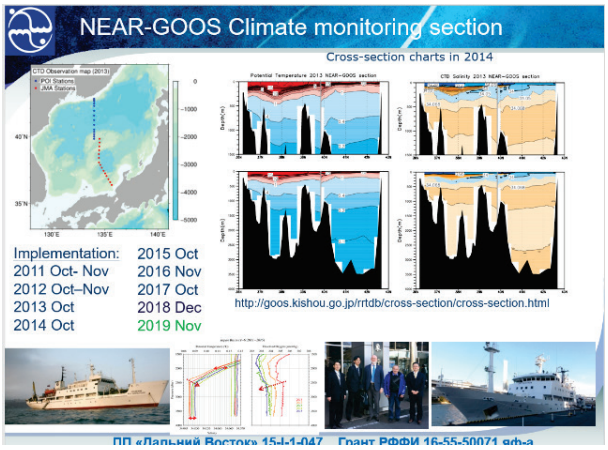
Currents velocity 44 м (см/с)	ср	макс
май.18	11,8	41,0
июн.18	11,2	31,1
июл.18	11,3	49,8
авг.18	10,9	41,6
сен.18	8,5	32,2
окт.18	10,6	32,8
ноя.18	14,7	44,5
дек.18	10,8	42,8
май-авг	11,3	49,8
сент-дек	11,2	44,5

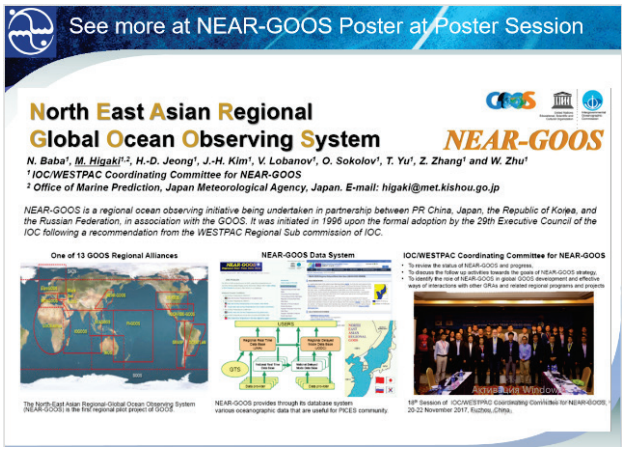
SST (°C)	Mean	Min	Max
май.18	6,9	2,8	11,3
июн.18	13,7	10,0	17,8
июл.18	18,5	13,5	**26,5**
авг.18	22,4	20,2	**27,5**
сен.18	20,0	18,6	21,3
окт.18	15,6	7,9	19,1
ноя.18	8,8	3,7	12,0
дек.18	2,9	1,1	5,5
май-авг	15,4	2,8	27,5
сент-дек	11,8	1,1	21,3

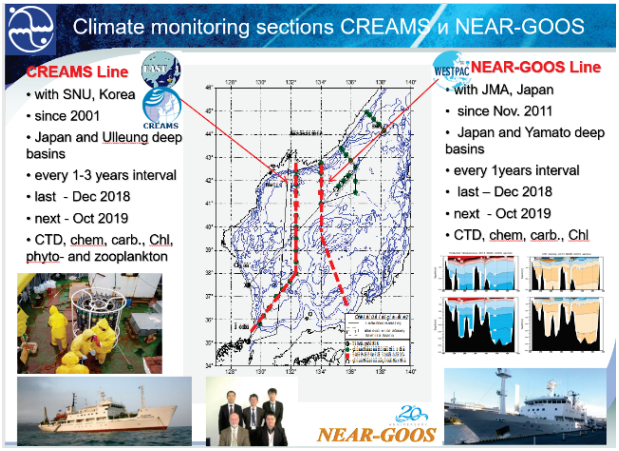

Cooling, upwelling and advection (Sep 1-Dec 21)
Cooling
Advection
Surface
17°C
3°C
Upwelling
Bottom
Advection
Advection
3°C
а)
б)
Сток р. Раздольная
Стоки Владивостока
Сдвиговые вихри Приморского течения
Прибрежный апвеллинг
c)
Температура воды на поверхности (а), на дне (б) и растворенное органическое вещество в поверхностном слое (в)

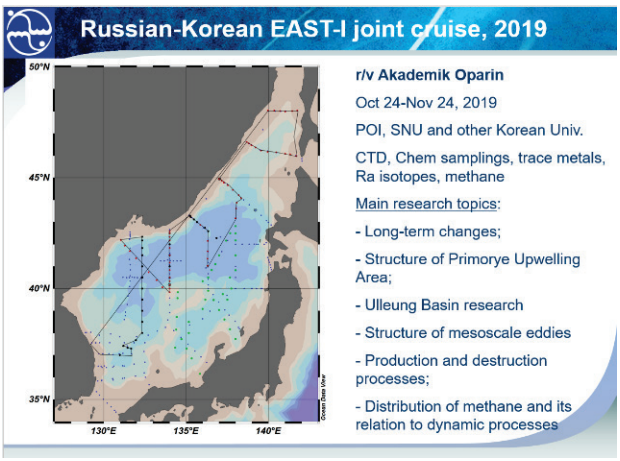

Seasonal bimodality of wind, permanent Primorye current
may
june
july
august
Верхний ряд – ветер, нижние ряды – течения в слоях от поверхности до дна
Wind and currents in May-August (predominant Southern winds, W-SW current

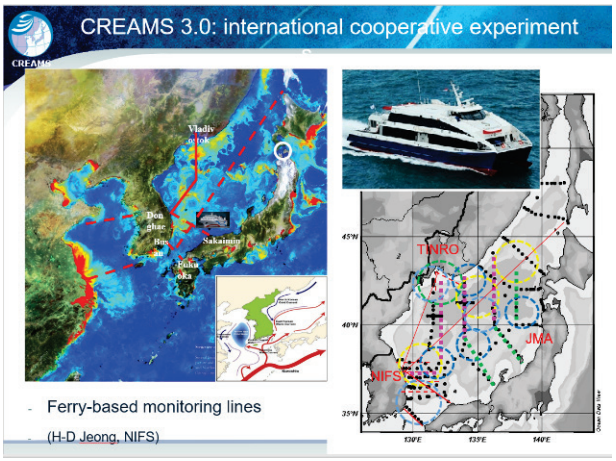

Seasonal bimodality of wind, reverse Primorye current
september
october
november
december
Верхний ряд – ветер, нижние ряды – течения в слоях от поверхности до дна
Wind and currents in Sep-Dec (predominant Northern winds, reverse current in Oct-Nov

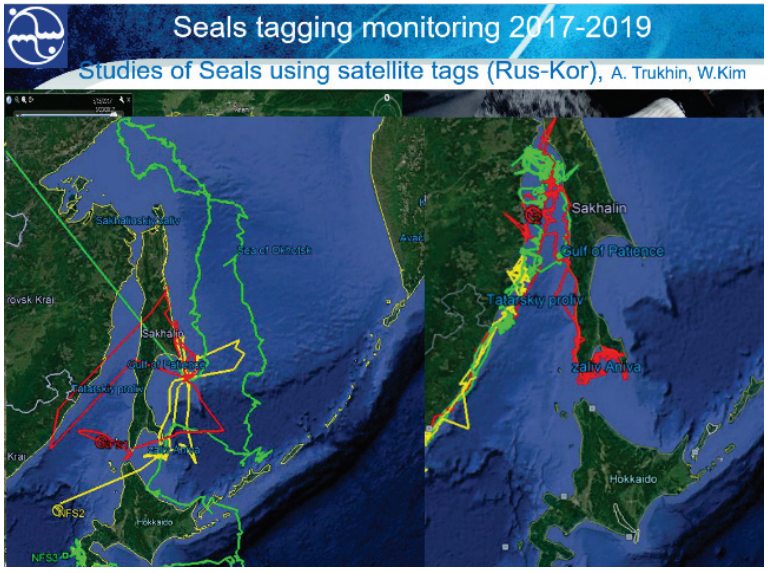

NEAR-GOOS Climate monitoring section
Cross-section charts in 2014
Implementation:
2011 Oct- Nov
2012 Oct–Nov
2013 Oct
2014 Oct
2015 Oct
2016 Nov
2017 Oct
2018 Dec
2019 Nov
http://goos.kishou.go.jp/rrtdb/cross-section/cross-section.html


See more at NEAR-GOOS Poster at Poster Session
North East Asian Regional Global Ocean Observing System
NEAR-GOOS
N. Baba¹, M. Higaki[1,2], H.-D. Jeong¹, J.-H. Kim¹, V. Lobanov¹, O. Sokolov¹, T. Yu¹, Z. Zhang¹ and W. Zhu¹
¹ IOC/WESTPAC Coordinating Committee for NEAR-GOOS
² Office of Marine Prediction, Japan Meteorological Agency, Japan. E-mail: higaki@met.kishou.go.jp
NEAR-GOOS is a regional ocean observing initiative being undertaken in partnership between PR China, Japan, the Republic of Korea, and the Russian Federation, in association with the GOOS. It was initiated in 1996 upon the formal adoption by the 29th Executive Council of the IOC following a recommendation from the WESTPAC Regional Sub commission of IOC.
One of 13 GOOS Regional Alliances
NEAR-GOOS Data System
IOC/WESTPAC Coordinating Committee for NEAR-GOOS


Climate monitoring sections CREAMS и NEAR-GOOS
CREAMS Line
• with SNU, Korea
• since 2001
• Japan and Ulleung deep basins
• every 1-3 years interval
• last - Dec 2018
• next - Oct 2019
• CTD, chem, carb., Chl, phyto- and zooplankton
NEAR-GOOS Line
• with JMA, Japan
• since Nov. 2011
• Japan and Yamato deep basins
• every 1years interval
• last – Dec 2018
• next - Oct 2019
• CTD, chem, carb., Chl
NEAR-GOOS


Russian-Korean EAST-I joint cruise, 2019
50°N
45°N
40°N
35°N
130°E
135°E
140°E
r/v Akademik Oparin
Oct 24-Nov 24, 2019
POI, SNU and other Korean Univ.
CTD, Chem samplings, trace metals, Ra isotopes, methane
Main research topics:
- Long-term changes;
- Structure of Primorye Upwelling Area;
- Ulleung Basin research
- Structure of mesoscale eddies
- Production and destruction processes;
- Distribution of methane and its relation to dynamic processes

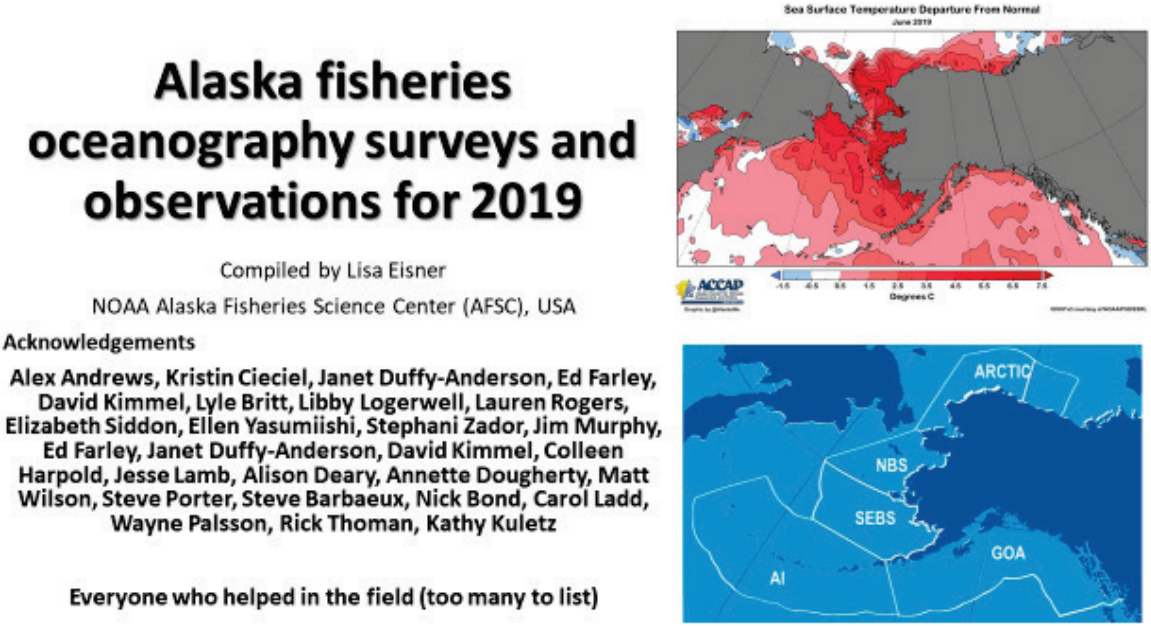

CREAMS 3.0: international cooperative experiment
Vladivostok
Donghae
Sakaminato
Fukuoka
Ferry-based monitoring lines
(H-D Jeong, NIFS)
TNIRO
JMA
NIFS

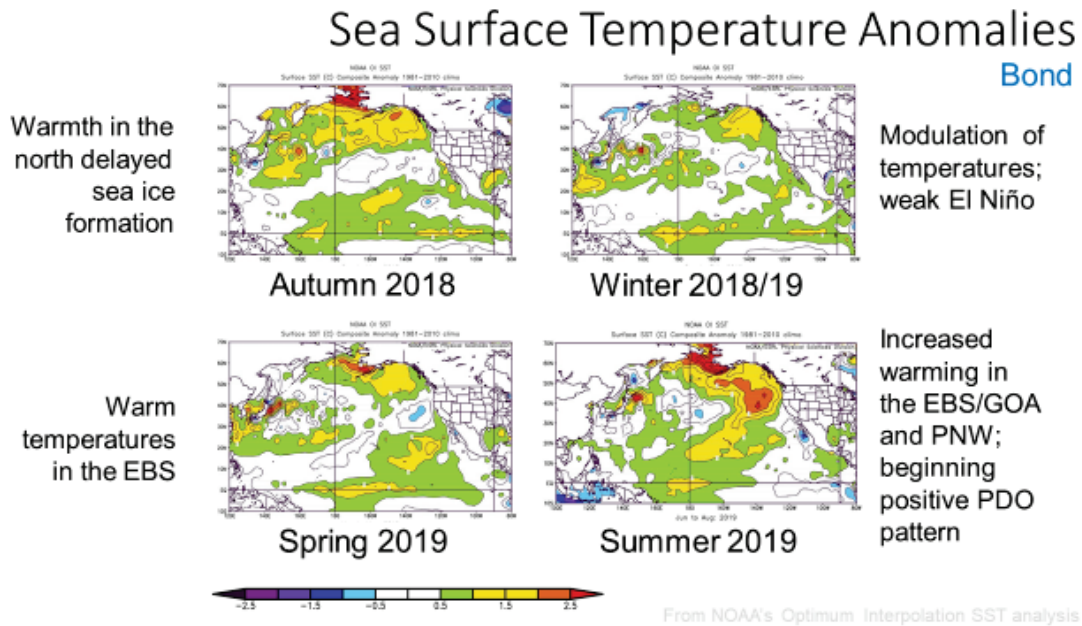

Seals tagging monitoring 2017-2019
Studies of Seals using satellite tags (Rus-Kor), A. Trukhin, W.Kim
Sakhalin
Gulf of Patience
Tatarsky proliv
Zaliv Aniva
Hokkaido
NFS2
NFS3

USA

US country report for Alaska (primarily NOAA surveys and observations) for 2019 (compiled by Lisa Eisner)

Slides kindly provided by Stephani Zador, Elizabeth Siddon, and Ellen Yasumishii at the NOAA Alaska Fisheries Science Center (AFSC) from presentations at the NPFMC Council Team meeting October, 2019 in Homer, Alaska. Many individual scientists contributed information for this report (please see author/contact listed on each slide)..

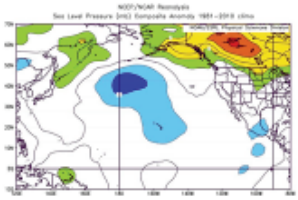




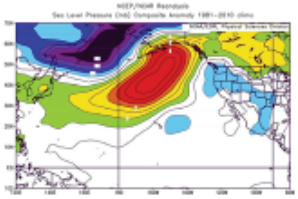
Sea Level Pressure Anomalies

Bond

Suppressed storminess in the GOA related to development of warm SSTs



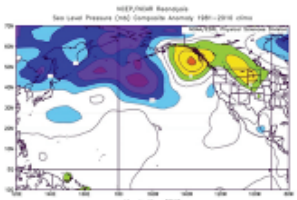
Autumn 2018



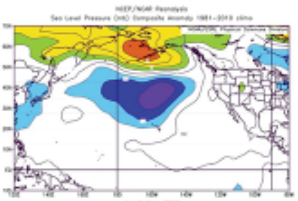
Winter 2018/19

Highly unusual pattern with El Niño. Strong southern winds across the

Continuation of warm air flow from the south over the EBS and WGOA



Spring 2019



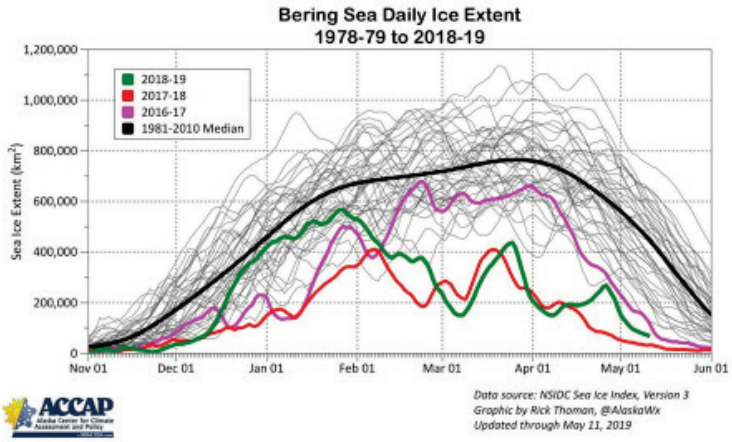
Summer 2019

Suppressed storminess in the EBS/GOA contributing to warmth

From the NCEP/NCAR Reanalysis project

Bering Sea sea ice extent

Thoman, Bond

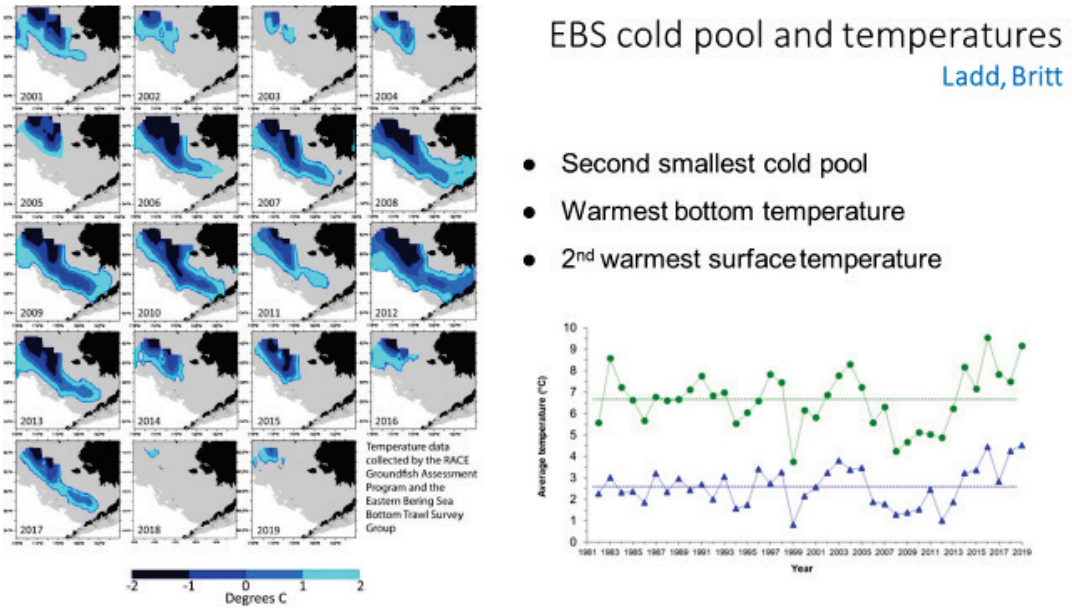


ACCAP Alaska Center for Climate Assessment and Policy

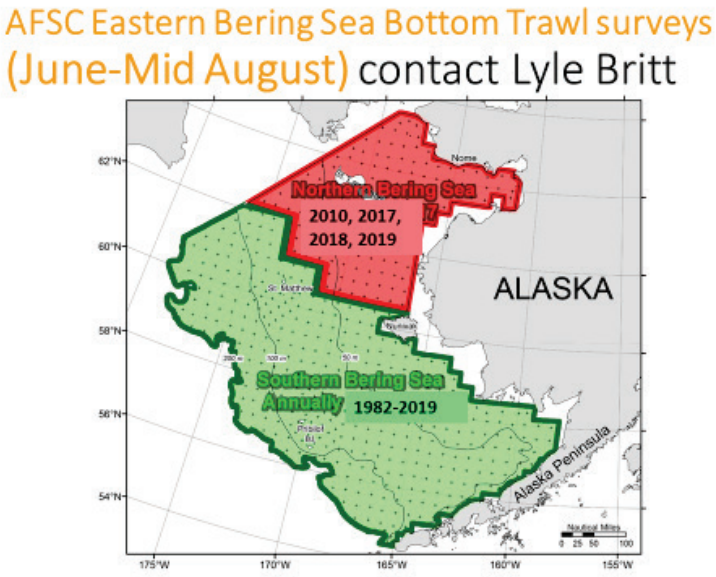
double whammy!

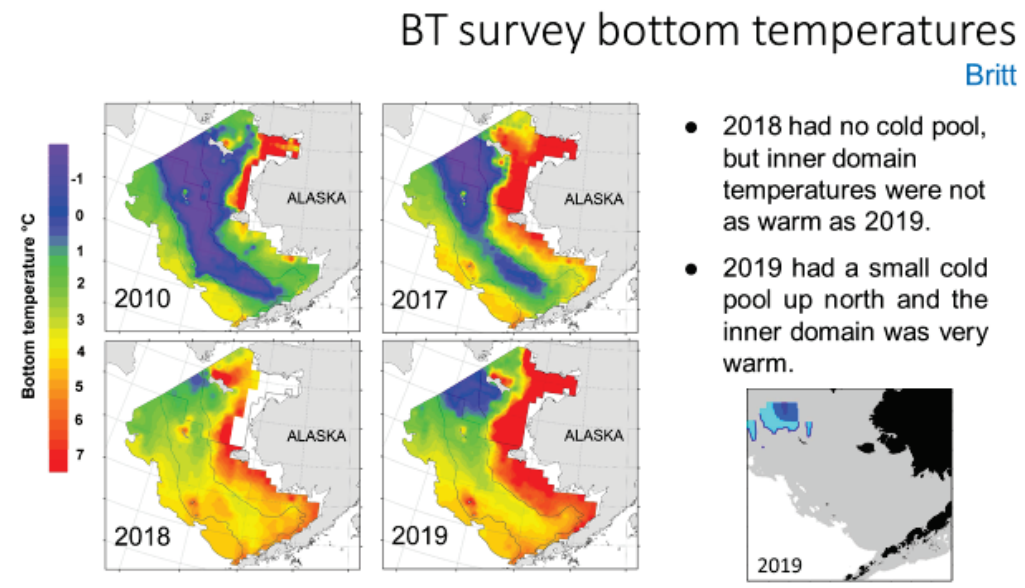
2nd winter of low sea ice in the Bering Sea.

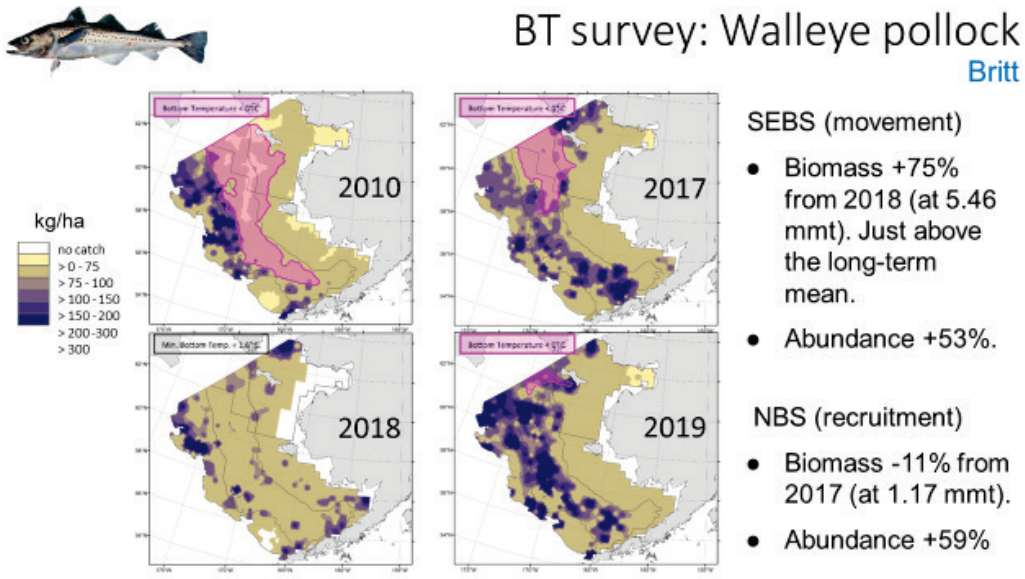
Early winter ice, but southerly winds in Feb caused retreat.



Bottom Trawl (BT) surveys have been conducted by the Alaska Fisheries Science Center (AFSC) since 1982, with surveys extended north in 2010, 2017, 2018, 2019.



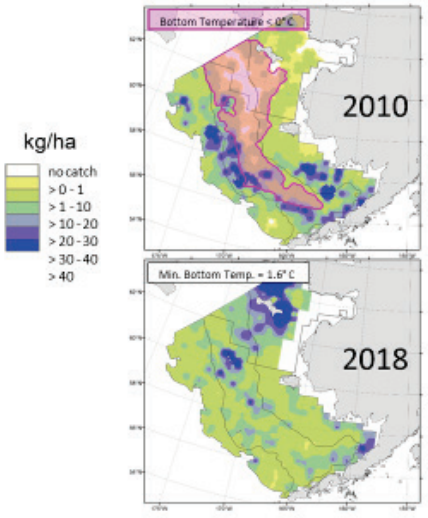




The 0°C contour seems to exclude adult pollock.

BT survey: Pacific cod

Britt



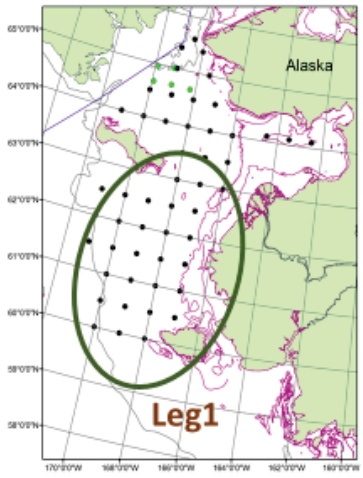
- Biomass +2% from 2018 (at 517K mt). Below the long-term mean.
- Abundance +112%.

NBS

- Biomass +30% from 2017 (at 368K mt).
- Abundance +52%.

Similar to adult pollock, the 0°C contour seems to exclude adult Pacific cod.

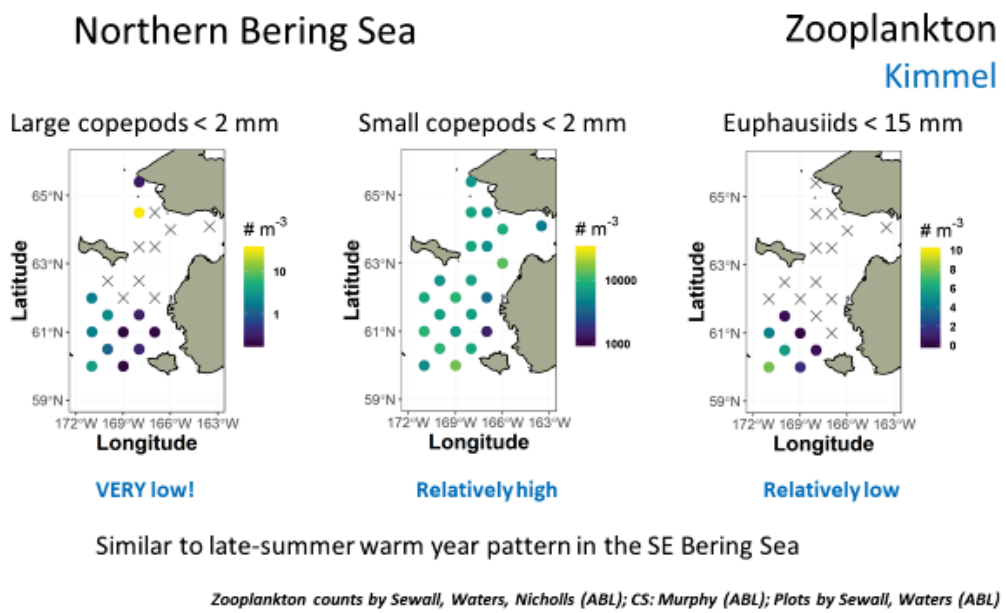
Ecosystem surveys have been conducted by the Recruitment Processes Alliance (RPA)in the northern Bering Sea every year (with exclusion of 2008) from 2002–2019. The results in the first slide are only for leg 1 (the area circled). Zooplankton data in the second slide include both leg 1 and leg 2. Similar surveys are conducted in the southeastern Bering Sea in even years (next survey in 2020)..



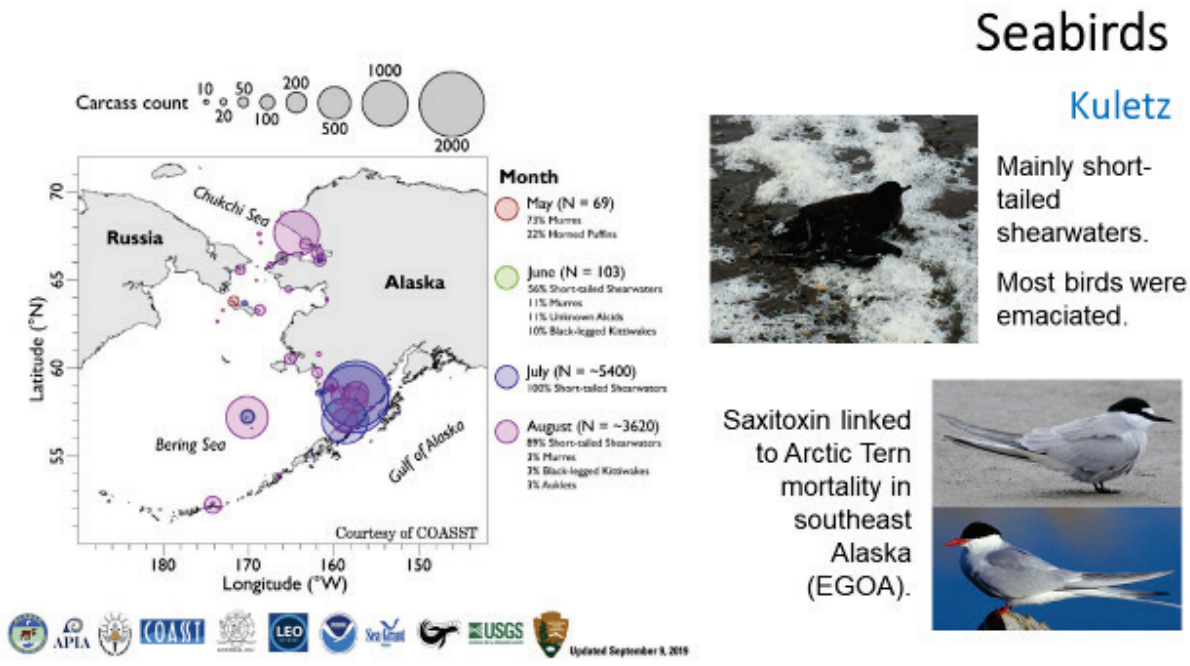
Northern Bering Sea Survey

Aug/Sep 2002-2019 Murphy

- SST ranged 8 – 13 °C (likely warmest since 2002)
- Lower than expected catches of age-0 pollock given a warm year.
- No age-0 saffron cod (usually catch 1000s).
- Lots of herring.
- No capelin (not unusual in a warm year).
- Low catches of juvenile Chinook salmon.
- Very high catches of juvenile pink and sockeye salmon
- Few auklets, puffins, murres, and shearwaters compared to 2018.



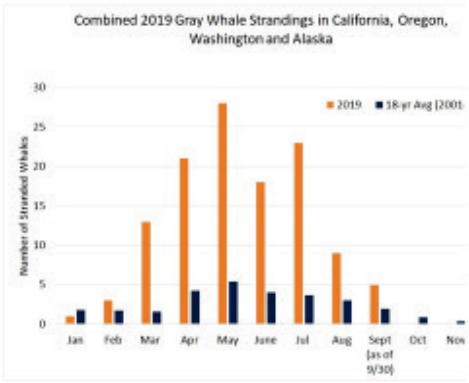
Large copepods in the northern Bering Sea are very, very low. Small copepods are in quite high abundance. Abundance of large and small copepods look very similar to the SE Bering Sea in the late summer/fall of warm years. Euphausiid numbers are low overall, but higher than what was observed in the north for the spring.



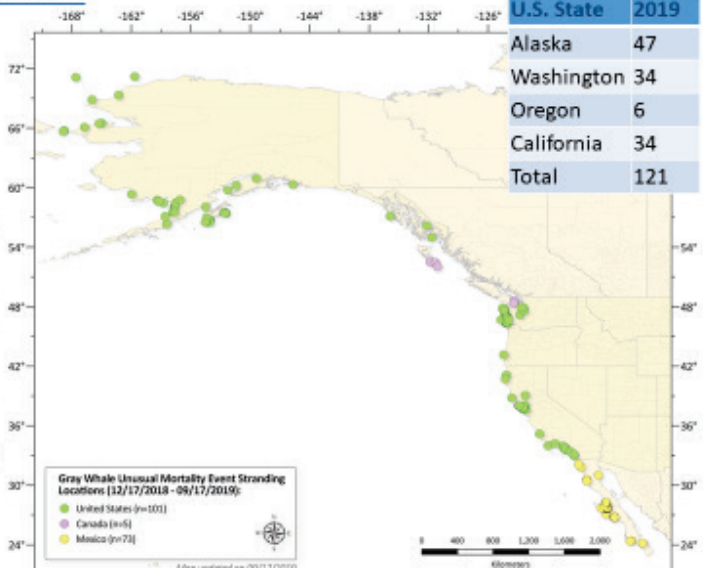
Map by Tim Jones of COASST (Coastal Observation and Seabird Survey Team). Acknowledgements: COASST volunteers (that walk certain beaches regularly), USFWS & Refuges, National Park Service, various communities and tribes, Alaska Sea Grant, and other citizens.

Gray Whale Unusual Mortality Event (UME)

https://www.fisheries.noaa.gov/national/marine-life-distress/2019-gray-whale-unusual-mortality-event-along-west-coast



U.S. State	2019
Alaska	47
Washington	34
Oregon	6
California	34
Total	121



EBS: Implications

Siddon, Yasumiishi, Zador

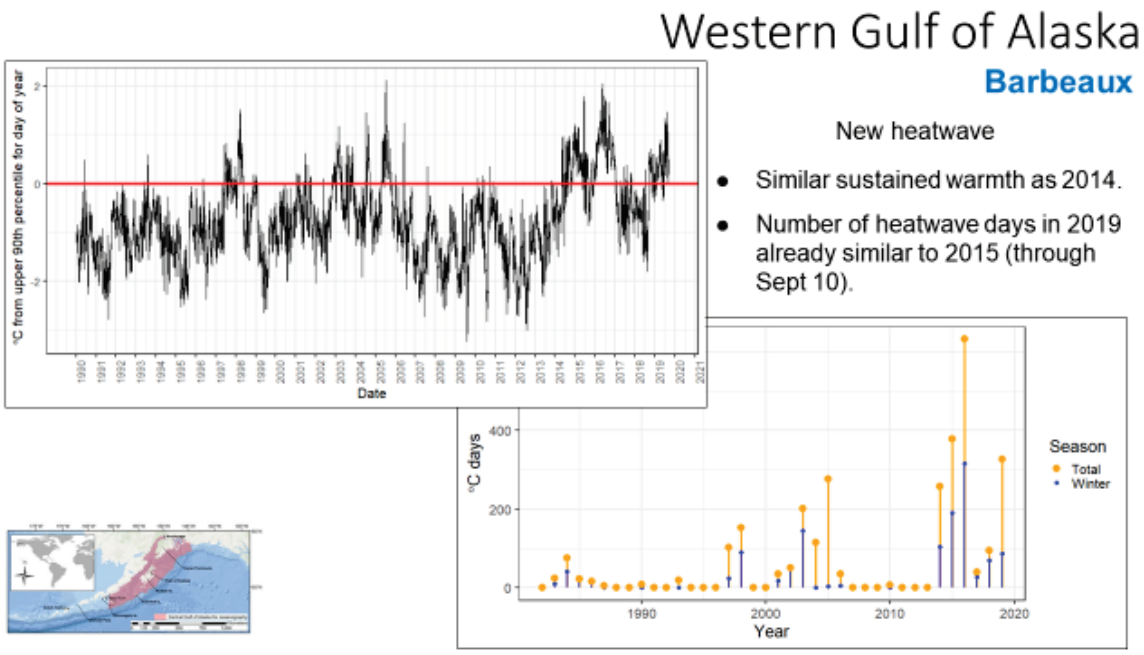
2nd winter of low sea ice in NBS; unprecedented warm inner domain. Impacts to fish distribution.

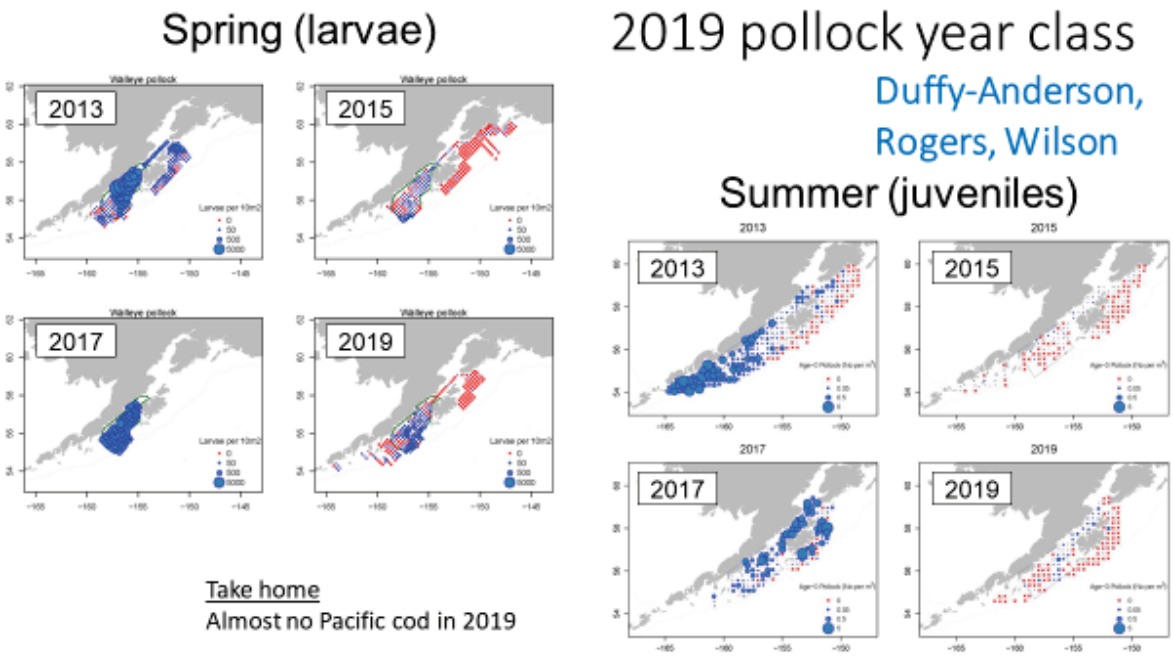
Zooplankton prey base dominated by small, lipid-poor copepods; low abundances of large copepods and euphausiids.
Impacts to carrying capacity throughout the system.

Pollock increase represents movement of adult fish into SEBS; PCod biomass continues to increase in the NBS.

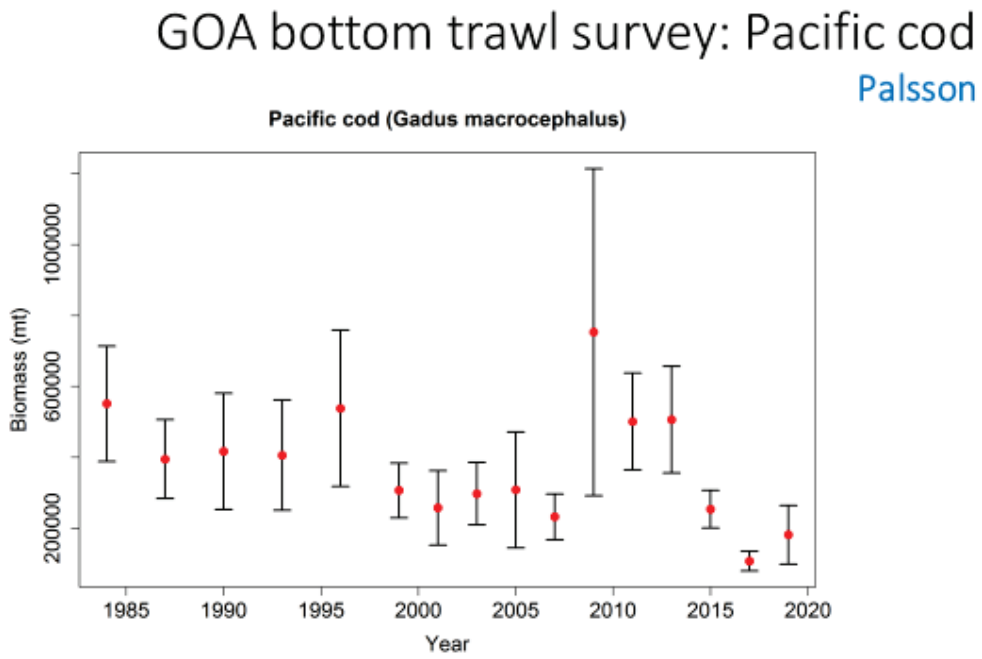
Seabird die-off (mainly short-tailed shearwaters) attributed to starvation. Concerns about food security in NBS. Seabirds at colonies did better than expected.

Gray whale UME.

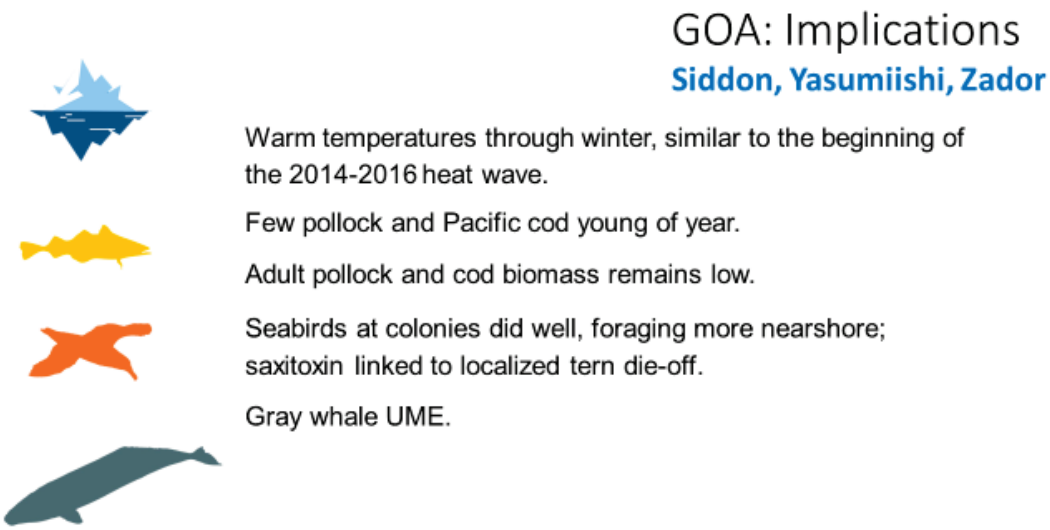


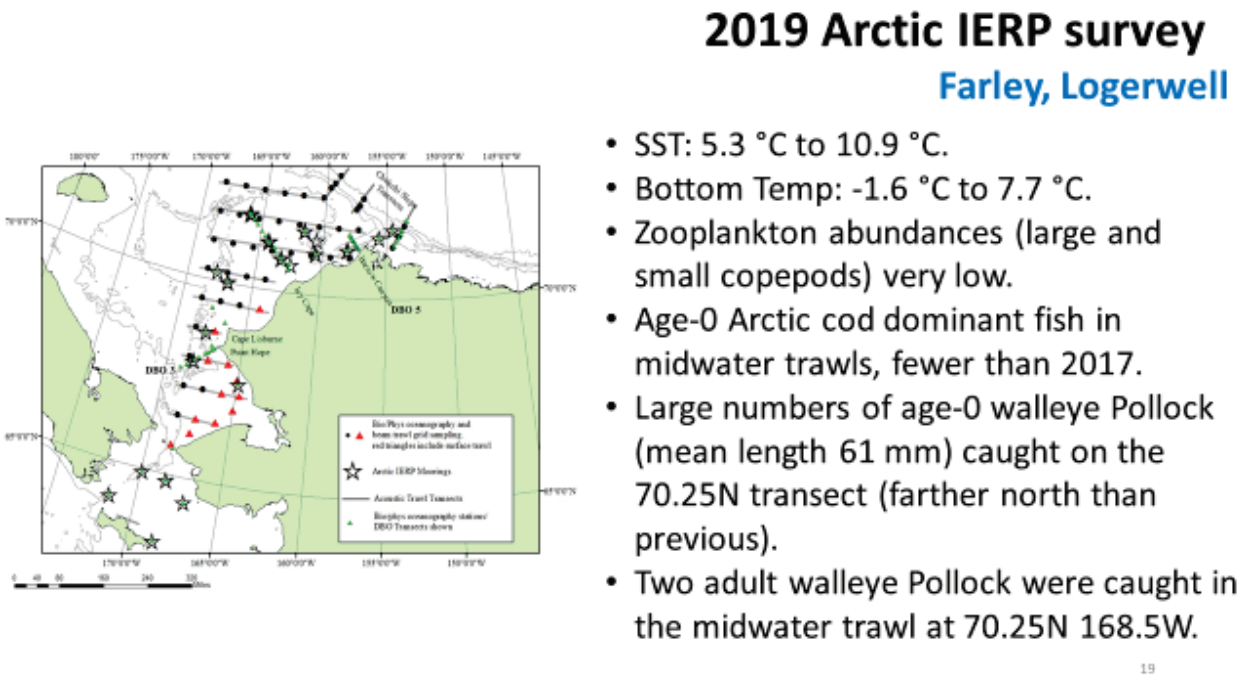


2019 had similar distributions as 2015 (also a heat wave) of larval and juvenile (age 0) walleye pollock.



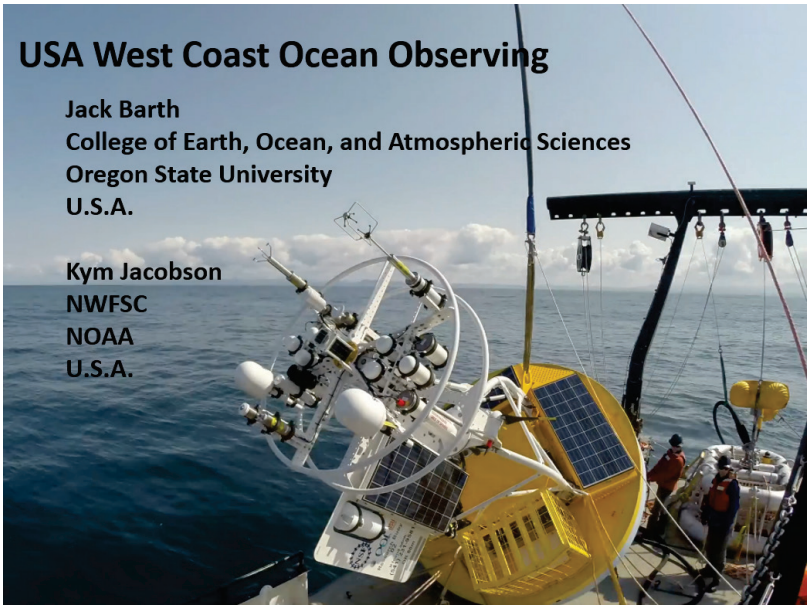
Low numbers of adult Pacific cod in 2019 in the western Gulf of Alaska. Bottom Trawl Data collected only in odd years.





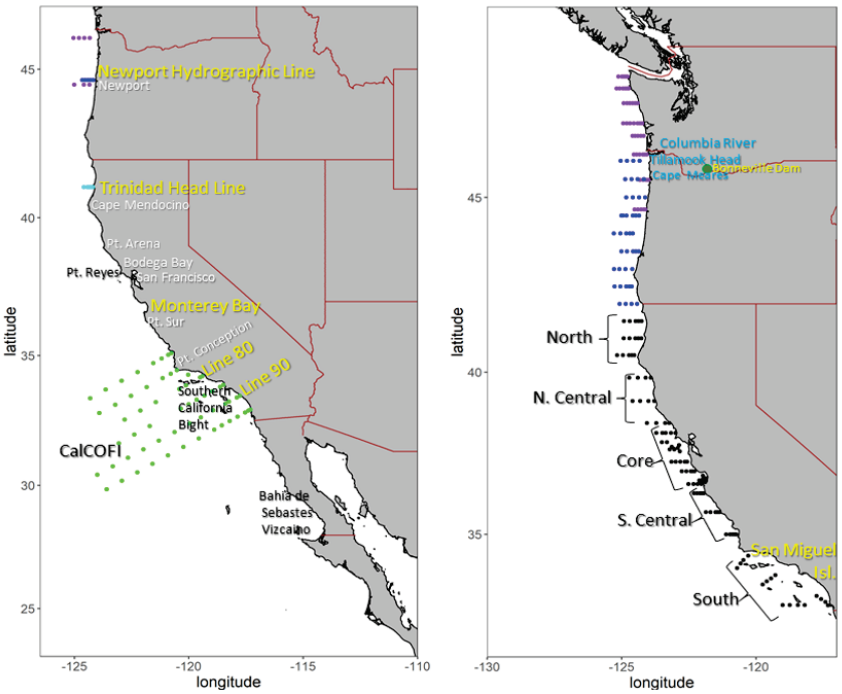
A similar survey was also conducted in 2017 as part of the North Pacific Research Board (NPRB) and Bureau of Ocean and Energy Management (BOEM) funded Arctic Integrated Ecosystem Research Project (Arctic IERP).

USA West Coast Ocean Observing (by Jack Barth, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, U.S.A. and Kym Jacobson, NWFSC, NOAA, U.S.A.)



A wide range of coastal ocean observing off the US Pacific coasts

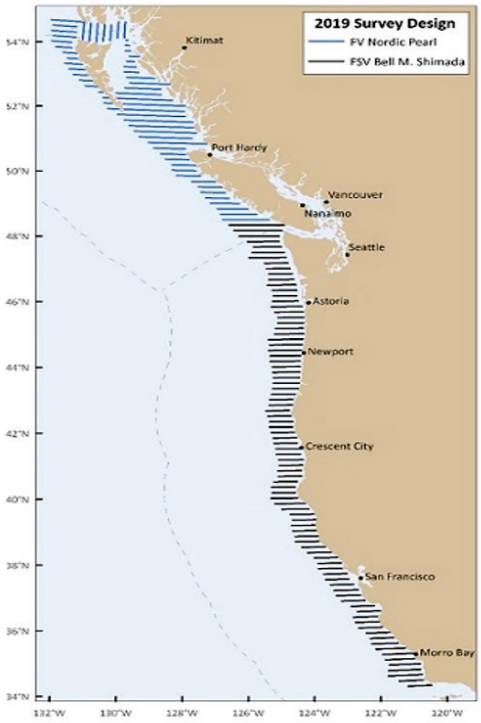
- US Integrated Ocean Observing System (NOAA)
- NOAA fishery surveys (groundfish, hake, sardine)
- Long-term hydrographic and zooplankton lines: CalCOFI, Newport Hydrographic, Trinidad Head
- Moorings, hydrographic and biogeochemical sampling off Monterey Bay, California
- Gliders
- Wave buoys and wave models
- Rocky intertidal biodiversity and recruitment
- Carbon chemistry (pCO2, pH) (NOAA, university)
- National Science Foundation's Ocean Observatories Initiative (OOI)
- First Nations and Native American

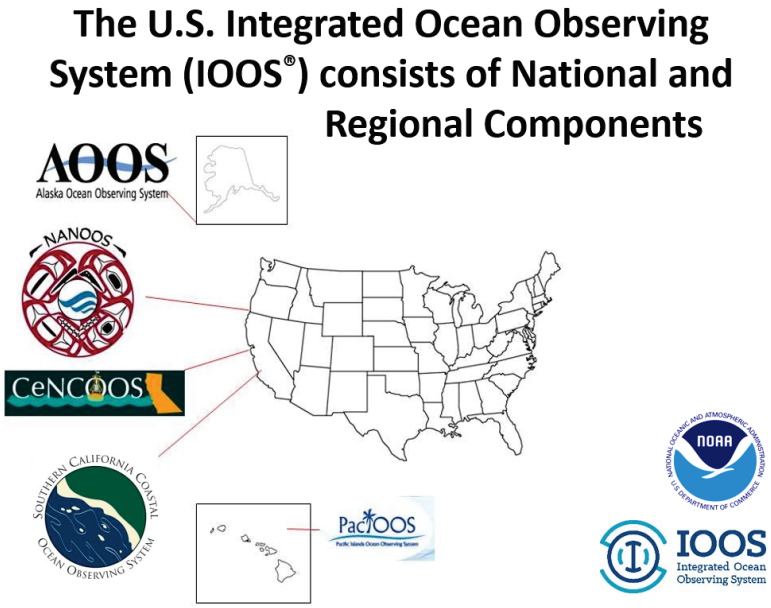


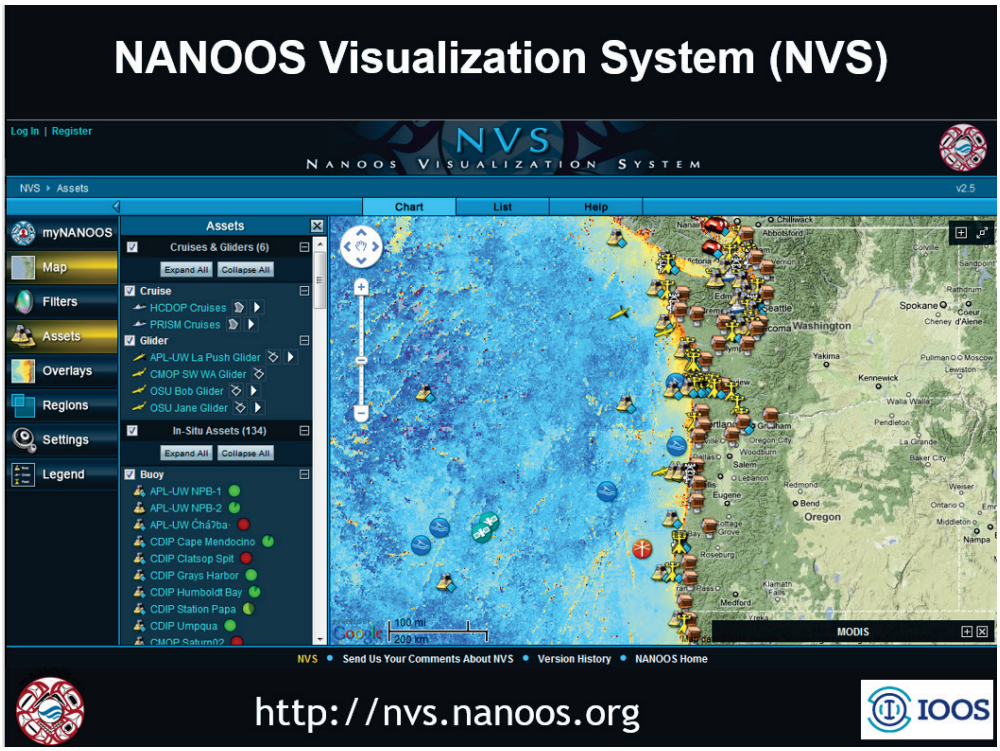
Maps depicting NOAA Fisheries surveys that included bongo tows (left) versus rope trawls and fixed observations for marine mammals (right). Figure modified from the State of the California Current Report by A. Thompson, NOAA Fisheries, SWFSC.

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

https://www.nwfsc.noaa.gov/news/features/pacific_hake_survey/index.cfm







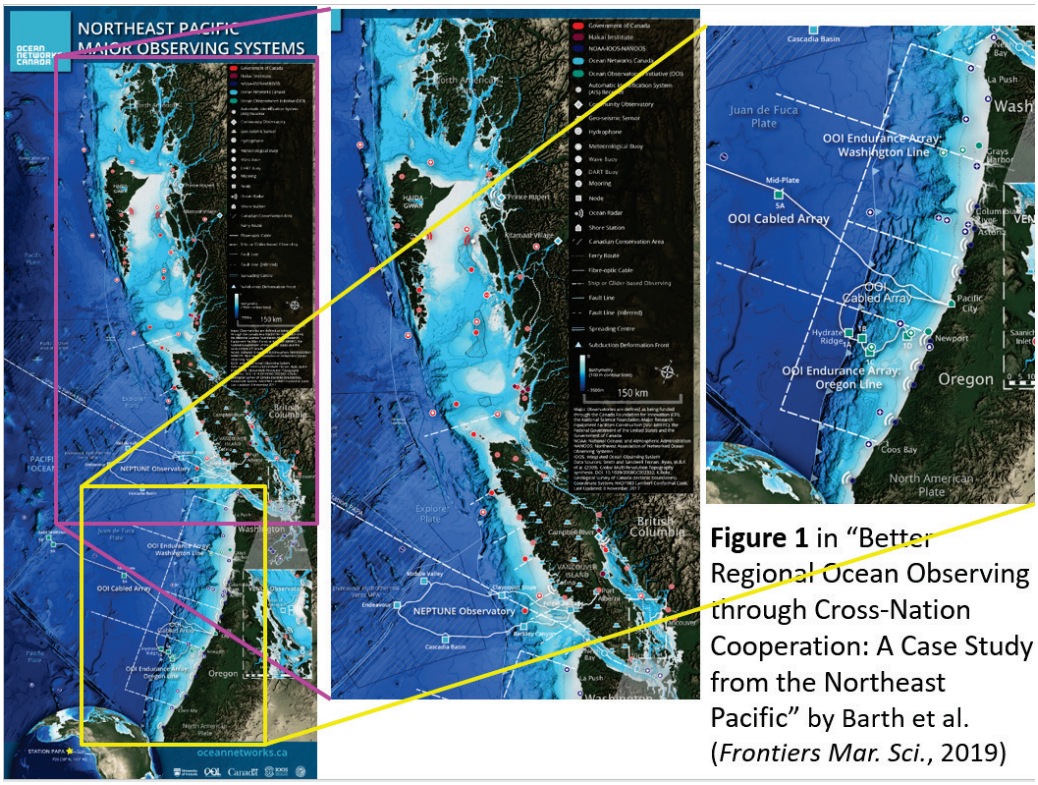


Figure 1 in "Better Regional Ocean Observing through Cross-Nation Cooperation: A Case Study from the Northeast Pacific" by Barth et al. (*Frontiers Mar. Sci.*, 2019)

NANOOS
Northwest Association of Networked Ocean Observing Systems
Washington - Oregon - Northern California
IOOS Integrated Ocean Observing System

High Frequency (HF) Radar

Currently in Place

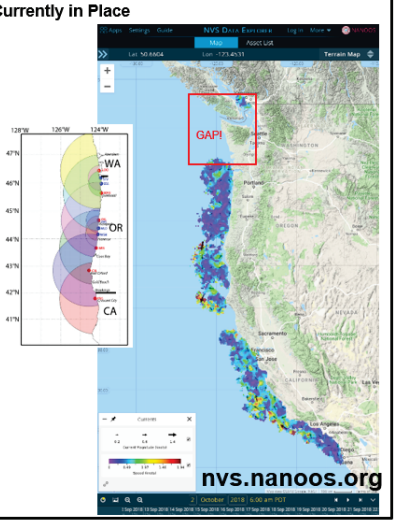
NANOOS HF surface current mapping

Mike Kosro, PI
Anne Dorkins, Erik Arnesen

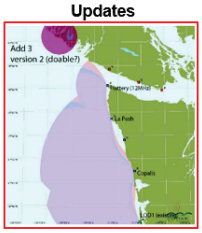
- 11 HF surface current mapping sites (Codar Seasondes):
- 6 Long-Range (4.785 MHz, 150km range, 6km range resolution)
- 5 Standard-Range (12-13 MHz, 50km range, 2km range resolution)

Each site measures "radial" currents in a semicircular region (1-D currents toward/away from site)

Where measurements from two separate sites are available, can determine the 2D surface current.



Updates

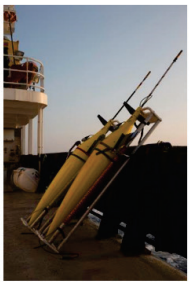


Need sites in
- S. Wash: Copalis area
- C. Wash: La Push
- N. Wash: Cape Flattery

NANOOS received funds for 2 HF radars to fill the GAP!

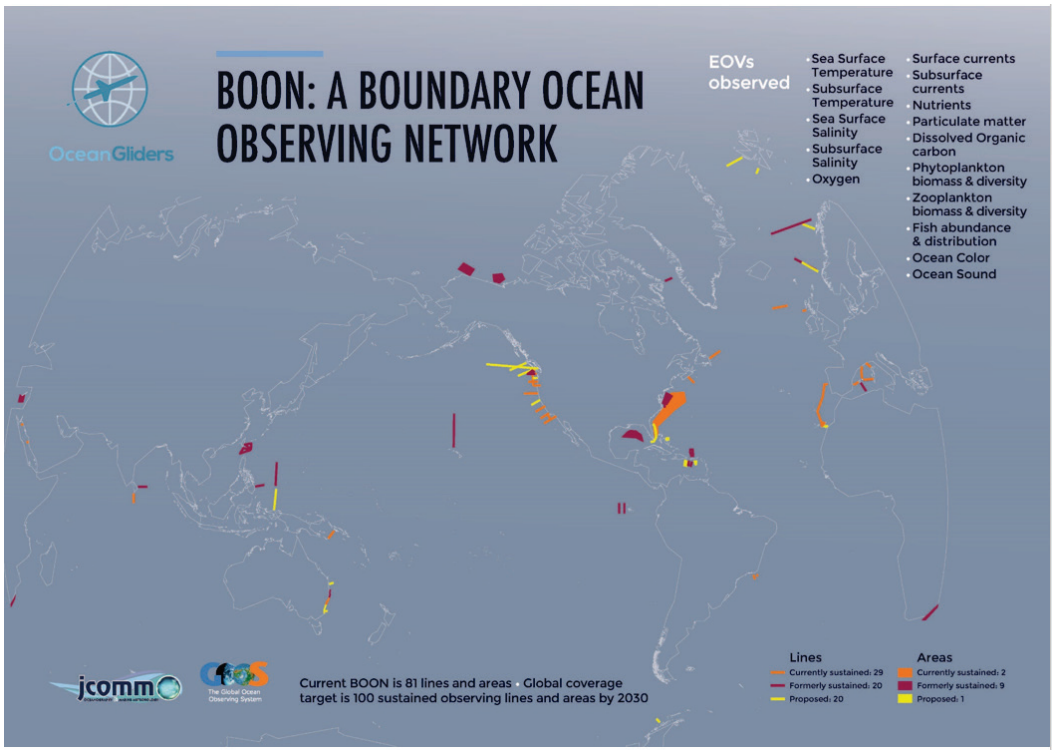
Currently working on siting, though some difficulties:
- Remote coast
- Lack of power
- Obstructing headlands
- Wide beaches
- Cars on beaches

West Coast Underwater Glider Network

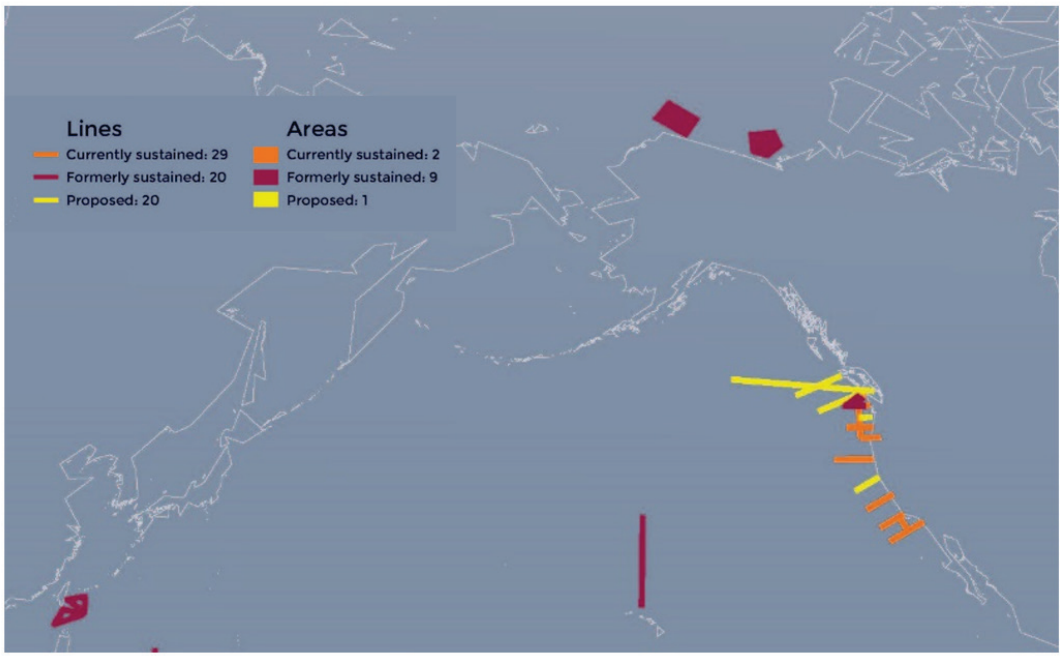


NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

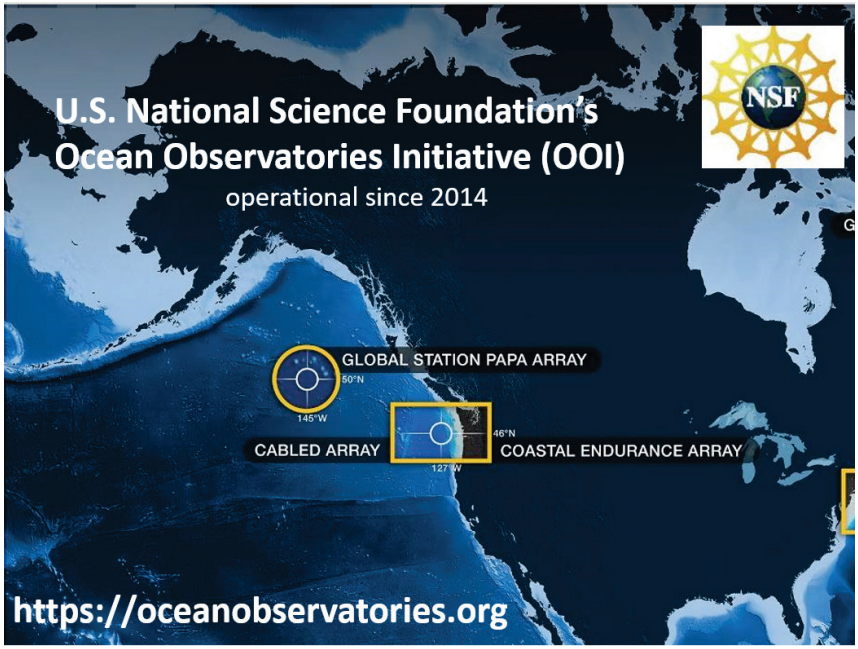
NSF

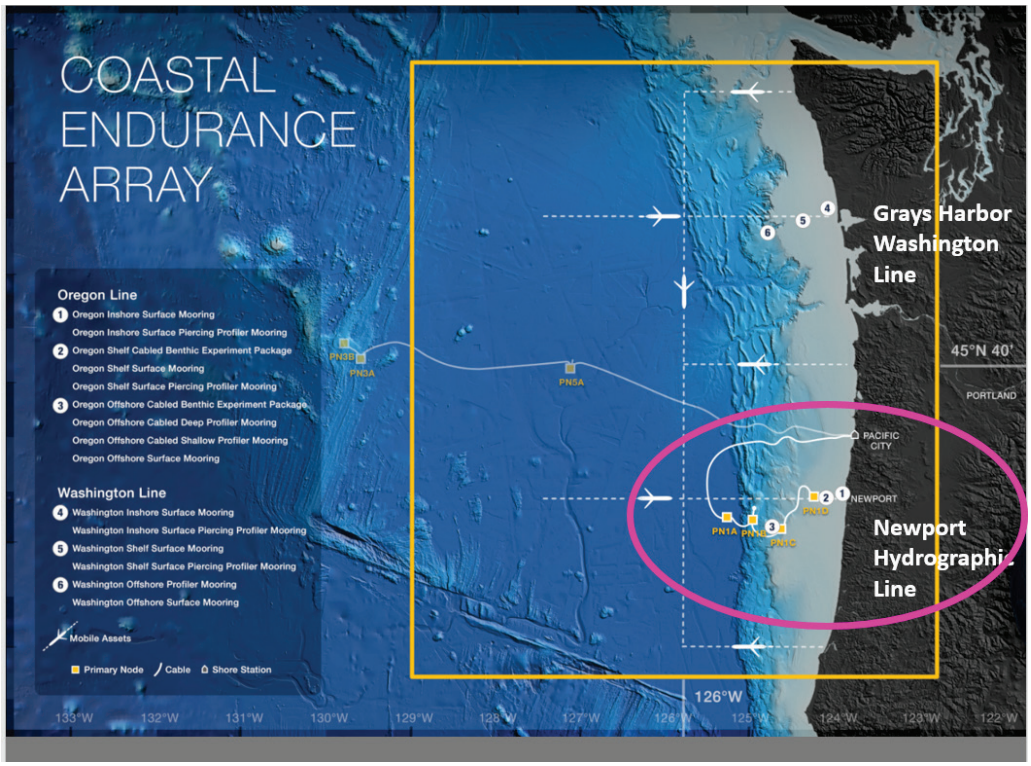


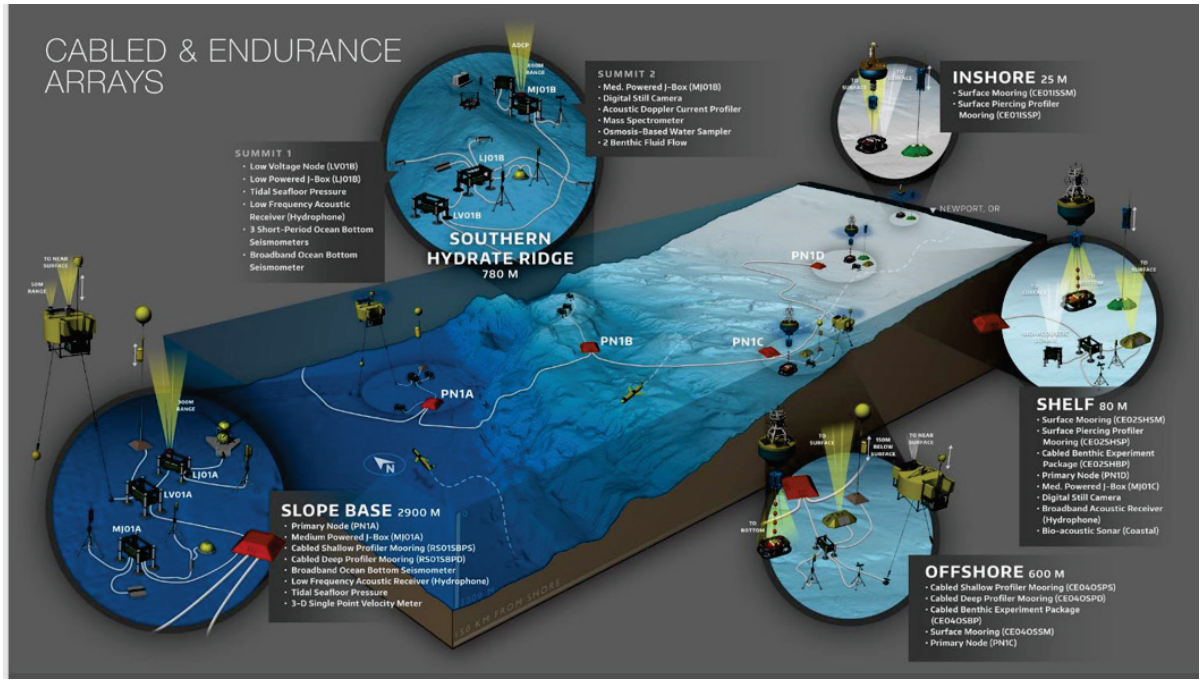
BOON: A Boundary Ocean Observing Network (zoom in on North Pacific)




U.S. National Science Foundation's
Ocean Observatories Initiative (OOI)
Installation complete
Operate and use the data!
https://oceanobservatories.org
NSF


U.S. National Science Foundation's
Ocean Observatories Initiative (OOI)
operational since 2014
NSF
GLOBAL STATION PAPA ARRAY
50°N
145°W
CABLED ARRAY
46°N
127°W
COASTAL ENDURANCE ARRAY
https://oceanobservatories.org


COASTAL ENDURANCE ARRAY
Oregon Line
1 Oregon Inshore Surface Mooring
Oregon Inshore Surface Piercing Profiler Mooring
2 Oregon Shelf Cabled Benthic Experiment Package
Oregon Shelf Surface Mooring
Oregon Shelf Surface Piercing Profiler Mooring
3 Oregon Offshore Cabled Benthic Experiment Package
Oregon Offshore Cabled Deep Profiler Mooring
Oregon Offshore Cabled Shallow Profiler Mooring
Oregon Offshore Surface Mooring
Washington Line
4 Washington Inshore Surface Mooring
Washington Inshore Surface Piercing Profiler Mooring
5 Washington Shelf Surface Mooring
Washington Shelf Surface Piercing Profiler Mooring
6 Washington Offshore Profiler Mooring
Washington Offshore Surface Mooring
Mobile Assets
Primary Node
Cable
Shore Station
Grays Harbor Washington Line
Newport Hydrographic Line
PN3B
PN3A
PN5A
PACIFIC CITY
NEWPORT
PN1A
PN1C
PORTLAND
45°N 40'
126°W
133°W
132°W
131°W
130°W
129°W
128°W
127°W
126°W
125°W
124°W
123°W
122°W


CABLED & ENDURANCE ARRAYS
SUMMIT 1
Low Voltage Node (LV01B)
Low Powered J-Box (LJ01B)
Tidal Seafloor Pressure
Low Frequency Acoustic Receiver (Hydrophone)
3 Short-Period Ocean Bottom Seismometers
Broadband Ocean Bottom Seismometer
SUMMIT 2
Med. Powered J-Box (MJ01B)
Digital Still Camera
Acoustic Doppler Current Profiler
Mass Spectrometer
Osmosis-Based Water Sampler
2 Benthic Fluid Flow
SOUTHERN HYDRATE RIDGE
780 M
MJ01B
LJ01B
LV01B
INSHORE 25 M
Surface Mooring (CE01ISSM)
Surface Piercing Profiler Mooring (CE01ISSP)
NEWPORT, OR
PN1D
PN1B
PN1C
PN1A
SHELF 80 M
Surface Mooring (CE02SHSM)
Surface Piercing Profiler Mooring (CE02SHSP)
Cabled Benthic Experiment Package (CE02SHBP)
Primary Node (PN1D)
Med. Powered J-Box (MJ01C)
Digital Still Camera
Broadband Acoustic Receiver (Hydrophone)
Bio-acoustic Sonar (Coastal)
LJ01A
LV01A
MJ01A
SLOPE BASE 2900 M
Primary Node (PN1A)
Medium Powered J-Box (MJ01A)
Cabled Shallow Profiler Mooring (RS01SBPS)
Cabled Deep Profiler Mooring (RS01SBPD)
Broadband Ocean Bottom Seismometer
Low Frequency Acoustic Receiver (Hydrophone)
Tidal Seafloor Pressure
3-D Single Point Velocity Meter
OFFSHORE 600 M
Cabled Shallow Profiler Mooring (CE04OSPS)
Cabled Deep Profiler Mooring (CE04OSPD)
Cabled Benthic Experiment Package (CE04OSBP)
Surface Mooring (CE04OSSM)
Primary Node (PN1C)

Coastal Endurance Array Platforms & Instruments

Coastal Gliders

Instrument	Data Products
CTD	Salinity, Temperature, Depth, Density
Dissolved Oxygen	Dissolved Oxygen Concentration
3-Wavelength Fluorometer	Chlorophyll, Turbidity, CDOM
PAR	Photosynthetically Available Radiation
ADCP	Water Velocity Profile

Cabled Deep Profiler Mooring

Instrument	Data Products
CTD	Salinity, Temperature, Depth, Density
Dissolved Oxygen	Dissolved Oxygen Concentration
2-Wavelength & CDOM Fluorometers	Chlorophyll, Turbidity, CDOM
3-D Single Point Velocity Meter	Turbulent Point Water Velocity

Coastal Surface-Piercing Profiler Moorings

Instrument	Data Products
CTD	Salinity, Temperature, Depth, Density
Dissolved Oxygen	Dissolved Oxygen Concentration
3-Wavelength Fluorometer	Chlorophyll, Turbidity, CDOM
Spectral Irradiance	Downwelling Irradiance
Nitrate	Nitrate Concentration
PAR	Photosynthetically Available Radiation
Spectrophotometer	Optical Absorption & Attenuation
Single Point Velocity Meter	Mean Point Water Velocity

Coastal Profiler Mooring

% only on OR Shelf

Instrument	Data Products
CTD	Salinity, Temperature, Depth, Density
Dissolved Oxygen	Dissolved Oxygen Concentration
3-Wavelength Fluorometer	Chlorophyll, Turbidity, CDOM
PAR Sensor	Photosynthetically Available Radiation
3-D Single Point Velocity Meter	Turbulent Point Water Velocity

Coastal Endurance Array Platforms & Instruments

Cabled Shallow Profiler Mooring

Instrument	Data Products
Bio-acoustic Sonar	Multi-frequency Acoustic Backscatter
CTD	Salinity, Temperature, Depth, Density
Dissolved Oxygen	Dissolved Oxygen Concentration
3-Wavelength Fluorometer	Chlorophyll, Turbidity, CDOM
Spectral Irradiance	Downwelling Irradiance
Nitrate	Nitrate Concentration
PAR Sensor	Photosynthetically Available Radiation
Seawater pCO_2	Partial Pressure of CO_2
Seawater pH	pH
Spectrophotometer	Optical Absorption & Attenuation
Single Point Velocity Meter	Mean Point Water Velocity

Cabled Benthic Experiment Packages (BEPs)

Instrument	Data Products
Bio-acoustic Sonar*	Multi-frequency Acoustic Backscatter
CTD	Salinity, Temperature, Depth, Density
Digital Still Camera	Still Image
Dissolved Oxygen	Dissolved Oxygen Concentration
Broadband Hydrophone	Acoustics Pressure Waves & Frequency
Seawater pCO_2	Partial Pressure of CO_2
Seawater pH	pH
Spectrophotometer	Optical Absorption & Attenuation
ADCP	Water Velocity Profile
3-D Single Point Velocity Meter	Turbulent Point Water Velocity

**only located on the Oregon Shelf BEP*

Coastal Surface Moorings

Instrument	Data Products
Air-Sea Interface pCO_2*	Partial Pressure of CO_2 in Atmosphere & Surface Seawater, Air-Sea CO_2 Flux
Bio-acoustic Sonar*	Multi-frequency Acoustic Backscatter
CTD	Salinity, Temperature, Depth, Density
Digital Still Camera*	Still Image
Dissolved Oxygen	Dissolved Oxygen Concentration
3-Wavelength Fluorometer	Chlorophyll, Turbidity, CDOM
Spectral Irradiance	Downwelling Irradiance
Meteorological Instrument Package*	Water Temperature & Salinity, Precipitation, Atmospheric Pressure, Air-Sea Heat Flux, Wind Velocity, Humidity, Air Temperature, Downwelling Longwave & Shortwave Irradiance
Nitrate	Nitrate Concentration
Direct Covariance Flux^	Air-Sea Heat Flux, Wind Velocity, Air Temperature
Seafloor Pressure^	Seafloor Pressure
Seawater pCO_2^	Partial Pressure of CO_2
Seawater pH	pH
Surface Wave Spectra*	Wave Properties
Spectrophotometer	Optical Absorption & Attenuation
ADCP	Water Velocity Profile
Single Point Velocity Meter	Mean Point Water Velocity
3-D Single Point Velocity Meter^	Turbulent Point Water Velocity