Ecosystem Studies of the Subarctic and Arctic Seas (ESSAS)

2018 Annual Science Meeting and SSC meeting
Fairbanks, Alaska, June 12-14, 2018

The Ecosystem Studies of the Subarctic and Arctic held its Annual Science Meeting at the Wedgewood Resort in Fairbanks, Alaska. A major theme of the 2018 meeting was the use of satellites in studying high-latitude marine ecosystems. The Fairbanks location was chosen in part because it is home to the Alaska Satellite Facility (ASF) and a desire to raise awareness within the ESSAS community about tools and capabilities for processing, mapping and analyzing satellite data available through ASF.

The Annual Science Meeting attracted 39 scientists from seven countries and included the following sessions and a workshops (see also attached program):

Session 1: Novel applications of remote sensing in Subarctic and Arctic marine ecosystems

Chairs: Sei-Ichi Saitoh, Hajo Eicken, Taka Hirata

Subarctic and Arctic marine ecosystems are undergoing rapid environmental changes and satellite observations have played a crucial role in documenting and understanding these changes, in particular changes in ice cover, surface temperatures (and more recently surface salinities), and primary productivity. Satellites and other remote sensing technologies are also used to track vessels, monitor zooplankton, fish, and whales, and to provide real-time observations or operational forecasts for marine traffic and science operations, emergency responses, fisheries and other uses.

This session included 8 oral presentations and several posters on the use of satellites in high-latitude marine ecosystems. Scientific highlights include:

- A variety of remote sensors, both satellite-based and airplane-based, are available and have been used to detect oil spills in Arctic environments, but Arctic marine waters pose special challenges for detecting oil, including the presence of newly formed ice (Garron).
- The use of MODIS satellite data in combination with in situ measurements shows that ice-edge associated blooms can be detected both at the surface and at the bottom of the water column in the Chukchi Sea. These vertical fluxes, along with strong northward currents through Bering Strait, fuel a hot spot of high benthic productivity in the southern Chukchi Sea (Abe et al.).
- The occurrences of fall blooms has increased in northern parts of the Pacific Arctic region (Chukchi Sea) and decreased south of Bering Strait (Northern Bering Sea). Fall blooms appear to be composed of smaller phytoplankton compared to the spring (Waga and Hirawake).
- By applying a missing value algorithm (DINEOF) to Aquarius data, Mizobata et al. were able to substantially reduce errors in predicted salinity. Aquarius-based estimates of sea-surface salinity were then used to track Pacific summer water in the Chukchi Sea and show the variable position of the salinity front over Hanna Shoal.
- Models of species distribution in the Pacific Arctic Gateway (eastern Bering Sea and Chukchi Sea) suggest that shifts in the distribution of fish species lags behind changes in climate and the pace of change differs substantially among species (Alabia et al. 2018).
- Saitoh et al. developed an operational model that incorporates a habitat suitability index for neon flying squid based on archived and near-real time satellite data to predict potential fishing zones.
- Tibbles et al developed a very different habitat suitability model for identifying viable whitefish habitat

in Arctic lagoons using interferometric synthetic aperture radar imagery (InSAR) for distinguishing bottomfast and floating ice.

- Satellites are a critical tool for tracking animal movements using tags. Using simultaneously tagged killer whales and narwhals (2009) or killer whales and bowhead whales (2013), Breed et al. showed how the presence of killer whales induces persistent changes in the behavior of their prey, which shifted to using areas covered by sea ice (bowhead) or very nearshore areas (narwhals) when predators were present.
- One emerging use of satellite technology is the development of algorithms for synoptic and frequent observations of ocean acidification using satellite remote sensing. Sabia et al. outline a promising approach for estimating surface ocean pH based on satellite-derived estimates of total alkalinity, partial pressure of CO_2 and/or dissolved inorganic carbon. Comparisons of predicted pH with in situ observations in ongoing.

In addition to brief research presentations, Scott Arko provided an overview of tools and capabilities for processing, mapping and analyzing satellite data available through the Alaska Satellite Facility (ASF). Participants also got an opportunity to visit the ASF facilities at the University of Alaska Fairbanks and get a close-up view of the AFS satellite tracking ground station, which operates three antennas on behalf of NASA. Data distribution is focused on but not limited to synthetic aperture radar (SAR) data.

This session attracted fewer participants than hoped for. The main reasons for the relative lack of interest are likely to be twofold: First, while ESSAS research has often included the use of satellite data, this has not been a strong focus in some time and we have not specifically reached out to the 'satellite community'. Second, we were somewhat surprised to find that, while UAF houses the Alaska Satellite Facility, there are currently few researchers working in satellite oceanography or other marine applications of remote sensing. As a result of the ESSAS meeting, this has now been recognized as an important gap in the College of Fisheries and Ocean Sciences.

Session 2: Integrated Ecosystem Assessments in the Subarctic and Arctic

Chairs: Alan Haynie, Libby Logerwell, Benjamin Planque

Integrated Ecosystem Assessments (IEAs) have emerged as an important means to integrate and communicate marine and terrestrial science in the Arctic, sub-Arctic, and elsewhere. There are multiple definitions of an IEA, but in general they attempt to integrate scientific data across different human uses and ecosystem characteristics to improve resource management. In the Protection of the Arctic Marine Environment (PAME) process, IEAs are one component of the Ecosystem Approach. In other areas IEAs have different approaches, goals, and primary content.

This session featured 8 presentations on various aspects of Integrated Ecosystem Assessments, followed by an open discussion of how to move forward an IEA in the Arctic.

- Libby Logerwell presented an overview of activities related to developing IEAs in the Arctic, including activities of the 'Ecosystem Approach Expert Group' (EA-EG) established by the Arctic Council (under the 'Protection of the Arctic Marine Environment' (PAME) working group) in 2007 and currently chaired by Libby Logerwell and Hein Rune Skjoldal. The EA-EG has conducted a series of workshops and this session was in part intended to solicit additional input. Another ongoing PAME activity relevant to ESSAS is the ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment (IEA) of the Central Arctic Ocean, which is co-chaired by the outgoing ESSAS Co-Chair Sei-Ichi Saitoh (Hokkaido University, Japan), along with Hein Rune Skjoldal (IMR, Norway) and John Bengtson (NOAA, USA) and has produced an outline for a Central Arctic Ocean IEA.
- Benjamin Planque (for Arneberg et al.) presented an overview of ongoing efforts to support the move towards ecosystem-based (fishery) management in the Norwegian and Barents Seas using an IEA

approach. To date, these efforts have largely focused on compiling environmental and biological time series to describe ecosystem status and trends. Several multivariate approaches, including dynamic factor analysis and structural equation models, as well as ecosystem models are currently explored to provide a better understanding of the drivers of ecosystem change and the dynamics of the system. The absence of social scientists and economists in these efforts was highlighted as a weakness.

- To address the need for including social scientists in IEAs, Haynie et al. provided some lessons from a large-scale integrated project in the Bering Sea (BSIERP) that will be useful in better integrating the human dimension in IEAs. He highlighted the central role of humans in marine ecosystems that is increasingly being recognized as being essential to informing management decisions.
- As a successful example of how to better integrate the human dimension into ecosystem studies and assessments, Haynie et al. provided an overview of the Alaska Climate Integrated Modeling project, which seeks to enhance the capacity of the fishery management system in Alaska to better adapt to changing environmental and economic conditions. He highlighted the need for developing shared socio-economic pathways for evaluating the consequences of future management options (equivalent to emissions pathways for evaluating the consequences of future climate trajectories) and proposed an approach to predicting how managers may set quotas in the future
- Other presentations focused on how results from integrated research efforts can be used to inform IEAs with a focus on fish (Baker et al.) and seabird (Hunt et al.) communities, highlighting the importance of integrated ecosystem research across disciplines and across boundaries, and the value of regional comparisons. Both presentations highlighted recent changes in the Bering Sea associated with the loss of sea ice and the retreat of the cold pool.
- One aspect of marine ecosystems that has rarely been considered it an integrated assessment context is the underwater soundscape. Moore et al. made a strong case for including sound in IEAs as the soundscape connects ecological variability (marine mammals and other animals that use or are sensitive to sound), economic pressures (shipping, resource extraction, tourism) and local communities that depend on marine resources.

Session 3: Biology, ecology and paleoecology of Arctic gadids

Co-chairs: Franz Mueter, Benjamin Laurel, Caroline Bouchard, John Nelson, Brenda Norcross, Haakon Hop

Following a successful workshop on Arctic Gadids held in conjunction with the ESSAS Annual Science Meeting in Copenhagen in 2014 (Special Issue in Polar Biology, Vol. 39, Issue 6), this session synthesized recent advances in our understanding of the biology, ecology, and dynamics of Arctic gadids around the circumpolar North in the context of a rapidly changing Arctic. The session featured 13 oral presentations and 3 posters, primarily focused on Arctic/Polar cod (*Boreogadus saida*, 14 presentations), but several presentations took a comparative approach or focused on species including saffron cod (*Eleginus gracilis*) Pacific cod (*Gadus microcephalus*), walleye pollock (*G. chalcogrammus*), Atlantic cod (*G. morhua*) and saithe (*Pollachius virens*).

Two pan-Arctic reviews highlighted the growing body of knowledge on the biology and ecology of Arctic (Hop – Invited Speaker) and the relative lack of information from the Central Arctic Ocean that is receiving increasing attention due to a recently negotiated agreement on the prevention of unregulated fishing in the Central Arctic Ocean (CAO) and the need for monitoring (Mueter & Flores).

Several presentations focused on the distributional dynamics and movements of Arctic cod in the Pacific Arctic Gateway: Marsh & Mueter suggested that temperature is the main driver of distributional shifts at the southern limits of their range, but competition and predation also play a role in constraining their distribution as subarctic species expand northward with warming. Arctic cod in the Chukchi Sea occurred primarily in Anadyr and Bering Sea water masses as well as in Chukchi Winter Water on muddy substrates, while saffron cod were largely restricted to the Alaska Coastal Current waters on sandy substrates (Logerwell et al.). A modeling study suggest

that high densities of juvenile Arctic cod typically found in the northern Chuckchi Sea may originate from spawning in the Bering Strait region, but the presence of small larvae suggests that some spawning may also occur in or near Barrow Canyon (Vestfals et al.). Forster et al. documented ontogenetic shifts in distribution that suggest that Arctic cod in the Chukchi and Beaufort seas move into nearshore nursery areas after the early juvenile phase before disperse offshore at larger sizes. To help resolve the origin and movement of larval and juvenile Arctic cod, Levine et al. propose a novel approach to track movements on the Northeast Chukchi shelf using a series of moored echosounders, combined with saildrone-based acoustic surveys in summer.

Increasing borealization and the potential for interactions between subarctic species and Arctic cod is also evident in the Atlantic Arctic, including in winter (Priou et al.). While capelin has often been described as a main competitor of Arctic cod, Priou et al. found that small herring, juvenile redfish and Atlantic cod to have the largest diet overlap with Arctic cod. Modeling the drift of Arctic cod in the Barents Sea shows a clear link between hypothesized spawning locations and age-0 Arctic cod in the fall and suggests the possibility of multiple spawning locations (Huserbraten et al.).

The successful husbandry of Arctic cod in several laboratories has greatly enhanced our understanding of the early growth and survival of Arctic cod and other gadids under different temperature and food conditions. Several presentations contributed to this understanding, demonstrating the age- and temperature dependence of age-0 overwinter survival (Lauren & Copeman); higher growth potential of both first-feeding and later stage Arctic cod compared to walleye pollock and high mortality at temperatures above 5°C (Koenker et al.); and the sensitivity of larval Arctic cod to very low levels of oil exposure (Bender et al.).

Field-based evidence from an extensive diet database of larval Arctic cod demonstrates the importance of prey quality - in particular the importance of large, energy-rich *Calanus glacialis* - to the feeding success of Arctic cod (Bouchard et al.). Nickel and Ólafsdóttir examined diets of the juveniles of two gadids, Atlantic cod and saithe, in nearshore waters and found a high potential for competition during the settlement period but differentiation of their diets soon after settlement as evident in a pronounced shift from a pelagic to a benthic diet in Atlantic cod.

Special Issue in Polar Biology
There was sufficient interest among participants to prepare manuscripts for submission to a special issue on Arctic Gadids in Polar Biology. Following the meeting, we broadened the call for manuscripts to collaborators and others working on Arctic cod and tentatively solicited a total of 22 manuscripts. Submission is open until May 31, 2019.

Session: Ocean Acidification and other climate stressors in high-latitude systems

Co-chairs: Samuel Rastrick, Kumiko Azetsu-Scott

The polar ocean is experiencing one of the most rapid shifts in biogeographic boundaries on the planet due to rapid warming, resulting in polar and tundra ice melt, and coupled with acidification - that affect the ecology of marine organisms. Still, our knowledge on the likely effects of climate change and acidification on northern ocean chemistry and ecosystems is inadequate. As it is based mainly on limited oceanographical obviations and single-species, rapid perturbation experiments on isolated elements of the ecosystem that focus on a limited number of carbonate chemistry drivers. It is difficult to extrapolate from such studies to larger scales, as these are generally too short-term to reveal how organisms may adapt/acclimatise, have often set steady pCO2 levels (which are unrealistic), and use organisms that are separated from their natural suite of food, competitors, predators, and facilitators.

Three presentations examined processes related to ocean acidification the chemistry and potential

consequences of ocean acidification on ecosystems in high latitude regions of the Pacific and Atlantic. Azetsu-Scott reviewed the chemistry of ocean acidification for non-chemists and the potential consequences for shell-forming organisms, highlighted the vulnerability of the Arctic Ocean to acidification, before summarizing spatial patterns and recent changes in aragonite saturation state in the Canadian Arctic. There is a gradient from more acidic (undersaturated) waters in the Arctic to less acidic waters in the Atlantic across the Canadian Archipelago, Baffin Bay and Davies Strait. Arctic outflow has spread further east recently, expanding the volume of undersaturated water in Davis Strait (sub-surface). Rastrick et al. summarized outcomes from the AnalogueART workshop during the 2017 Trømso meeting, which have been submitted as a synthesis manuscript to a special issue in ICES Journal of Marine Science. The manuscript and presentation highlighted the advantages and challenges of using natural analogues to investigate physiological, ecological and evolutionary effects of climate change. Examples of natural analogues were provided that are useful to studying species and community responses to acidification (e.g. CO_2 vents in the ocean) and the capacity for adaptation and acclimatisation (e.g. reciprocal transplant and common garden experiments). Finally, Pilcher et al. illustrated the impacts of local biogeochemical processes and climate variability on ocean acidification in the Bering Sea using a spatially explicit Ocean Acidification model. The model suggests that productivity and freshwater runoff drive spatial heterogeneity in aragonite saturation state but the increase in atmospheric CO_2 is the dominant mechanisms for changes in aragonite undersaturation, which is decreasing by 0.2 per decade.