Theme session P

Arctic ecosystem services: challenges and opportunities

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The Arctic environment is changing rapidly. In the Arctic, surface temperatures are rising twice the global average rate, and sea ice cover is declining dramatically. From the rapidly changing climate to the increase in human activities, there are many challenges affecting Arctic marine ecosystems. These challenges are being addressed in three Arctic regions in the ongoing Arctic Council project "Adaptation Actions for a Changing Arctic (AACA)."

The Arctic Monitoring and Assessment Programme (AMAP), a working group of the Arctic Council, and EU Horizon 2020 Coordination and Support Action EU-PolarNet co-sponsored this session. The session was well attended and consisted of 13 oral presentations and three poster presentations.

Presentations, P:450, P:502, and P:433, highlighted the role of heterogeneity of the Arctic with respect to hydrography, bathymetry, productivity regimes, and biodiversity. An important point that emerged from this session was that because of this heterogeneity; climate-warming effects will vary across the Arctic ecosystems. P:450 highlighted how variations in the response of hydrography differed between sub-regions within the Kara Sea, but, overall, ice condition was found to be the most important variable affecting hydrography. P:502 highlighted how differences in the resilience of Arctic benthos to perturbations, such as invasions, varied among five Arctic regions, with the two northernmost regions (i.e., the North Water Polynya and the Canadian Archipelago) being more resilient to invasions but less resilient to loss of ice-associated organisms such as sea-ice algae. The benthic communities of the Chukchi, Amundsen, and Beaufort Sea displayed less resilience. The authors of paper P:433 examined whether domain, temperature, and latitude matter with respect to climate change impacts on fish by studying six shelf domains. The Bering and Barents Seas were the most productive of the shelfs, whereas the Chukchi and Beaufort Seas were less productive. The models indicated the biggest changes are expected in the 2080-2100 time period. The authors concluded if we do nothing to mitigate the causes of climate change, we will see significant warming.

Presentations P:178, P:644, and P:129 presented evidence that species and whole community sensitivity to perturbations (e.g., temperature increase or invasive species) from climate warming will vary throughout the Arctic. For example, saffron cod and polar cod, although in the same family of fishes, have different temperature sensitivities and optima for growth and will respond differently to climate change. Whole communities may be more or less resilient or sensitive to perturbations, such as invasive species. Also, fish eggs may have different sensitivity to oil. P:178 showed food availability, temperature, and fishing are important drivers of Icelandic cod stocks. During warm-water regimes, food availability becomes an even more important driver, indicating that as the high-latitude ecosystems continue to warm, this effect may become even more pronounced. Even if fishing effort was removed from the model, there was still a significant effect of temperature. P:644 illustrated that gadoids have unique thermal responses, implying growth efficiencies are temperature-dependent and climate warming will not affect all gadoid species in Arctic waters equally. A laboratory experiment showed saffron cod performed well at higher temperatures. The most negative effect from climate warming will be on polar cod (*Boreogadus saida*), a key species in the marine Arctic, which provides a unique and valuable ecosystem service by efficiently channeling rich lipid energy to higher trophic levels at cold temperatures. P:129 described how continued warming and loss of sea ice is projected to shift the Chukchi Sea ecosystem from a benthic-dominated system to a more pelagic-dominated system. The authors conducted integrated ecosystem surveys during August to September in 2007, 2012, and 2013 in the U.S. Chukchi Sea. More juvenile pink salmon were captured in 2007, a warmer year, which likely increased pelagic productivity that led to larger (i.e., higher marine survival) and more abundance of juvenile pink salmon compared to the colder years of 2012 and 2013.

Scientists estimate the ocean is 30% more acidic today than it was 300 years ago. Because the waters of the Arctic are both old and cold, scientists expect the Arctic to experience the effects of ocean acidification faster and more seriously than lower latitudes. Data are currently lacking regarding effects of ocean acidification in the region. The authors of P:248 used biological and economic models to determine what may happen in the Baffin Bay/Davis Strait shrimp fishery as a result of ocean acidification. However, at this stage, it is hard to say whether shrimp in Greenland are affected by ocean acidification. P:268 described a study looking at the effect of food concentration on Atlantic cod survival and found no effect. The authors also described preliminary results regarding temperature effects on the western Baltic stock of Atlantic cod. The correlative analyses revealed strongest impact of temperature on recruitment in November and March. They found the stock collapsed even before a 2^{o} Celsius increase, and, with increasing temperatures, profits are likely to decrease.

With diminishing sea ice, anthropogenic activities such as shipping and oil and gas exploration and development have increased in the Arctic. Presentations P:647, P:280, and P:445 described the risks associated with various anthropogenic activities and presented risk management and assessment tools. Using the Lofotens and Barents Sea, Norway, Howell *et al.* (P:647) developed a risk management tool to predict a range of possibilities regarding impacts of oil development on fish species in the region, running the model in hind cast. The model is still being developed and tested. They found that haddock eggs are more vulnerable to potential oil spills than cod eggs. Therefore, key species need to be investigated separately.

An increase in shipping leads to the increased possibility of oil spills and the spread of invasive species. To date, most risk assessments have only focused on single species and are qualitative. Nevalainen *et al.* (P:280) developed a model using a holistic food-web approach.

Species are not equally sensitive to oils spills, but data are limited. Therefore, models should focus on key functional groups instead of individual species. The models should be probabilistic to take uncertainty into account. Warming Arctic conditions and increased shipping favor the establishment of temperate invasive species in the region. Howland *et al.* (P:445) are using models to determine the likelihood of suitable habitat for invasive species in areas of the Canadian Arctic, with a focus on benthic species in port areas. They found sea surface temperature, ice concentration, and bathymetry to be the most important variables for species spread, and nearly all species exhibited future poleward gains. Currently, they are conducting screening level risk assessments to rank 30 species through a rapid assessment tool.

It became evident during the session that lack of data of the Arctic marine ecosystems is a major issue. In some cases, there truly are no data regarding a certain region or resource; however, in other cases, data have been collected but are not readily available. Both are problematic. Researchers have been reviewing logbooks of United Kingdom expeditions to the Arctic conducted between 1930 and 1977 (P:559) with data from the logbooks of 1930-1959 already digitized. They have uncovered data from cod catches and cod diet studies that will allow comparisons with today's data and conditions. The final paper (P:405) discussed the importance of filling the data gap in the central Arctic Ocean. There are data on the physical oceanography, lower trophic levels, and seabirds and marine mammals, but there are relatively little to no data available for fish in the Arctic Ocean. With the signing of a declaration by the five Arctic coastal states in July 2015 and the continuing negotiations between the five Arctic coastal states, China, the European Union, Iceland, Japan, and Korea to sign an agreement that they will not fish in the central Arctic Ocean until more fish data are available, it is crucial to fill the data gap. International collaboration on the science will be key to filling in the "missing middle."

Paper P:502 (Friscourt *et al.*) won Best Oral Presentation by an Early Career Scientist.