PART III

Arctic Marine Living Resourcese

4. Arctic Marine Living Resources

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INTRODUCTION

The whole Arctic marine ecosystem has been in flux in recent decades because of changes in the physical and chemical processes that drive atmospheric and ocean circulation, the loss of sea ice, changes in precipitation and runoff, all of which affect nutrient distribution and availability. These changes result in alterations in ocean microbiology and primary and secondary production which are processes that transfer impacts onto fisheries, marine mammals and seabirds and thereby onto patterns of human activities dependent on them. Increasingly, new human activities made possible as a result of loss of summer sea ice are permitting oil, gas and mineral development, seasonal shipping, and marine tourism in addition to well-developed fisheries in the far North Atlantic and subsistence fisheries throughout the Arctic region. While these changes may have an impact on summer breeding and feeding areas for migratory seabirds and marine mammals in the Arctic region, the interplay continues in their winter range far from the region. Indeed, even indirect influences originating geographically outse the Arctic result in transport of toxic materials into the Arctic ecosystem that may exacerbate changes in living marine resources in the Arctic (Bard 1999). Many of these influences provide evidence of the extent of economic globalization on Arctic resources. It is clear that these influences affect demand for living marine resources as well as oil, natural gas, and minerals in addition to transportation services for commerce and tourism. The Arctic region is clearly a northerly expression of the concept of the Anthropocene (Crutzen and Stoermer 2000, Economist 2011).

This examination is focused on the present and future use and management of living marine resources in the Arctic and the impacts of climate change and other forcing mechanisms on Arctic marine ecosystems. I first discuss the physical drivers, and other drivers, that form the context that influences the distribution and abundance of living marine resources in the Arctic Ocean and adjacent northern seas. I next discuss existing marine fisheries and their management and then I examine potential marine fisheries and issues associated with their management. Finally, I focus on the Arctic as a region of marine biodiversity by extending discussion to marine mammals, seabirds, and polar bears and issues relating to management for maintaining and protecting marine biodiversity. Additional topics touched upon briefly include possible aquaculture developments and impacts of changes in the freshwater regimes in the Arctic and their implications for freshwater fisheries.

Most of the discussion to this point assumes a rapid but incremental change in Arctic marine ecosystems. Significant concern and increasing evidence point in the direction of possible abrupt climate change occurring which would alter the incremental change scenarios in ways that are hard to predict. I discuss the implications of abrupt change and conclude with a general discussion of prospects for cooperation in governance of the Arctic in terms of living marine resource management.

This treatment can provide a background for planning by North Pacific Rim and other countries to promote informal consultation and to consider how to convey the results of these consultations into various Arctic forums.

CONTEXT: PHYSICAL AND ENVIRONMENTAL DRIVERS AFFECTING ARCTIC LIVING MARINE RESOURCES

The Arctic Ocean is a unique and extreme environment. It is an ice-covered enclosed sea and its low temperatures, restricted circulation, huge variation in seasonal light, and great depths surrounded by shallow shelves make it a tough crucible for living marine resources (Gradinger 1995). The narrow and shallow Bering Strait in the west and the deep and wide Fram Strait in the east serve as the main connections to the rest of the world's oceans. The land and water of the Arctic region accounts for approximately 17% of the total area of the world. The Arctic Ocean is 4.3% (15.6 million square kilometers) of the world's oceans by area but only 1.4% of the volume because it has the shallowest average ocean depth (1,205m). Its deepest area is 5,567m (http://www.ngdc.noaa.gov/mgg/global/etopo1oceanvolumes.html). The Central Arctic Ocean is outside of currently designated Exclusive Economic Zones (EEZs) of adjacent countries and constitutes an estimated area of 2.8 million square kilometers, roughly the same size as the Mediterranean Sea (www.oceansnorth.org/arctic-fisheries-letter). Freshwater inflow from land plays a large role in ocean structure in the Arctic Ocean—especially the circulation in the Western Bering Sea but also as a result of glacial melting in Iceland and Greenland. The Central Arctic Ocean outside national jurisdictions is a deep basin with extensive, although diminishing, sea ice for all or some parts of the year.

The primary dominating feature of the Arctic has been its ice cover which has been largely seen as a year-round constant. In recent decades the ice dynamics have been studied and there have been significant changes on a timescale much faster than imagined (Stroeve et al. 2007). The summer melting of sea ice, the thinning of sea ice and the melting of glaciers in Greenland has also accelerated (Kjaer et al. 2012).

Arctic marine ecosystems are quite varied and complex. The physical features of the Arctic region include broad areas of continental shelf, narrow passages like the Bering Strait, less prominent areas of the continental shelf in the Arctic Ocean and the deep basin of the Arctic Ocean. There are numerous islands, inlets, bays and passages. These features are critical in understanding the basis for water circulation and potential productivity distribution in the Arctic Region. Atmospheric circulation is also a critical element to understand as a driver of ecosystem processes (Dessler and Parson 2006; Häkkinen, S., P. Rhines, and D. Worthen 2011). Finally the type, extent and variability in sea ice and its progressive loss (Stroeve et al. 2007; Perovich and Richter-Menge 2009; Carmack and Melling 2011) has significantly altered the global view of the future of the Arctic as a potential source of fish production (Grebmeier 2012, and more generally with respect to marine biodiversity, Doney et al. 2012). There is growing consensus on the nature of change in Arctic freshwater and marine ecosystems (more precipitation, warmer temperatures, changes in quantity and timing of productivity). Thus, there is mounting evidence that as a result of the velocity of climate change-shift in isotherms and seasonal timing and productivity in the marine Arctic, "give a complex mosaic of predicted range shifts⋯ that deviate from simple pole ward migration and earlier springs or later falls." These factors "emphasize conservation concerns, because areas of high marine biodiversity often have greater velocities of climate change and seasonal shifts" (Burrows et al. 2011: 652).

Vastly different processes affect microbial (Lovejoy et al. 2011, Poulin et al. 2011), algal and zooplankton processes in the sea ice realm, the under-ice realm, the pelagic realm in terms of species and production processes (Gradinger 1995, Li et al. 2009). The organisms that inhabit the Arctic Ocean have evolved over thousands of years to survive in these harsh conditions. Fundamental change in the amount and timing of ice cover is expected and with it will vary with the rate of change—terrestrial change apparently occurring faster than change in marine environments (Gradinger 1995, Gilg et al. 2009) although in northern subarctic waters change in the marine biota can be as fast or faster (Pinsky 2012). It is not entirely clear how changes in biology will affect the CO_2 pump in the Arctic. To the extent that reduction in sea ice cover happens there may be an increase in biological productivity which would result in biological carbon fixation and increase in sedimentation. Thus, the role of the Arctic in sequestering carbon may increase (Gradinger 1995, Chapin et al. 2000). Concomitantly, the rate of ocean acidification would increase as well although this process and its impacts are not well understood.

Ocean acidification is a growing concern in many parts of the world ocean. The extent to which the Arctic may be affected is unclear and the impacts on Arctic marine living resources is even murkier, although it is not unreasonable to anticipate similar effects for the Arctic as found in other ocean regions. Modeling the likelihood of ocean acidification in the Arctic based on a global coupled carbon cycle-climate model suggests that acidification is imminent (Steinacher et al. 2009). Direct monitoring of upwelling coupled with sea ice melt in the Beaufort Sea indicate that aragonite undersaturation, an indicator of ocean acidification, is occurring (Yamamoto-Kawai 2009).

In fact, the polar regions may be more vulnerable and susceptible to ocean acidification than other regions "because cold water absorbs CO_2 more readily, lowering the pH, added melt-water may force an uptake of CO_2, reduced sea-ice coverage results in more seawater exposure to and uptake of atmospheric CO_2 and expanded ocean-surface area may in turn alter the production and decomposition of organic carbon, a complex process that plays an important role in ocean chemistry" (http://coastal.er.usgs.gov/ocean-acidification/polar.htm). There appears to be scientific debate about CO_2 sequestration processes for the Arctic with some predicting a decrease in the CO_2 uptake capacity in an ice-free Arctic Ocean basin (Cai et al. 2010) and precautionary notes about the ability to generalize about impacts of climate change on how species will respond (Denman et al. 2011).

Release of methane from the sea floor due to sea floor warming is another potential source of increased acidity (Biastoch 2011). Research is underway to assess the impacts of ocean acidification on the Arctic (Robbins 2012, IFM-GEOMAR 2012, Robbins et al. 2011). Despite the high cost of research, especially experimental research in the Arctic, some have recommended that a framework for research be adopted that, "considers the effects of multiple stressors associated with a changing climate on the 'thermal window' of activity of marine animals" (Denman et al. 2011).

Species of marine organisms dependent on a permanently ice-covered region, such as ice seals and polar bears, will likely decrease. Seabirds that occupy rookeries in the vicinity of the ice edge may benefit or lose depending on how the biological foodweb restructures itself with reduced sea ice. Marine mammals highly dependent on the ice edge and the platforms in multi-year ice flows may experience significant harmful effects (Gradinger 1997, Moore and Huntington 2008, Ragen et al. 2007). Arctic freshwater systems are also strongly influenced by weather and climate and the impact differs with respect to flowing water in rivers and estuarine waters, standing water in lakes, ponds and wetlands, as well as the frozen water in permafrost, freshwater ice and snow cover (Prowse et al. 2006).

Critical to the discussion in this chapter is definition of the Arctic domain. There are numerous definitions—geographical, biological, physical and political—that exist as illustrated by Figure 4.1 below (Osherenko and Young 1989). Based on the stated intent to engage with the on-going efforts of the existing entities working on Arctic policymaking, I have chosen to select the most common Arctic Council definition of the Arctic because it illustrates the transition zone from temperate/sub-Arctic to high Arctic. This captures the adjacent seas and existing management efforts for living marine resources. These adjacent seas are all largely within national jurisdictions. For fisheries, these adjacent areas also represent areas with commercial fisheries having the highest harvests and values in the Arctic. In addition, I think it useful to identify separate, delineated Large Marine Ecosystems (LMEs) for the Arctic region as well as their tributary freshwater ecosystems (See Figures 4.2 and 4.3). Seventeen LMEs have been elaborated by the Arctic Council's Protection of the Arctic Marine Environment (PAME) in a multiyear process (PAME 2009).

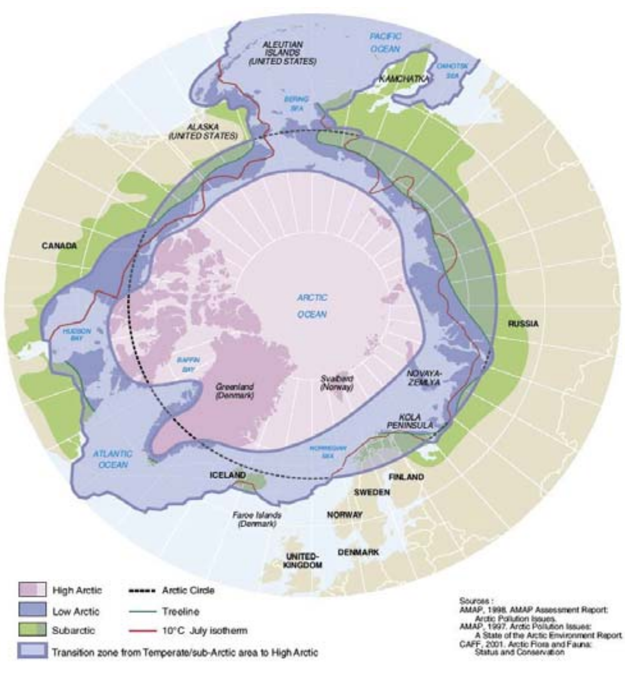

Figure 4.1. Alternative Definitions of the Arctic

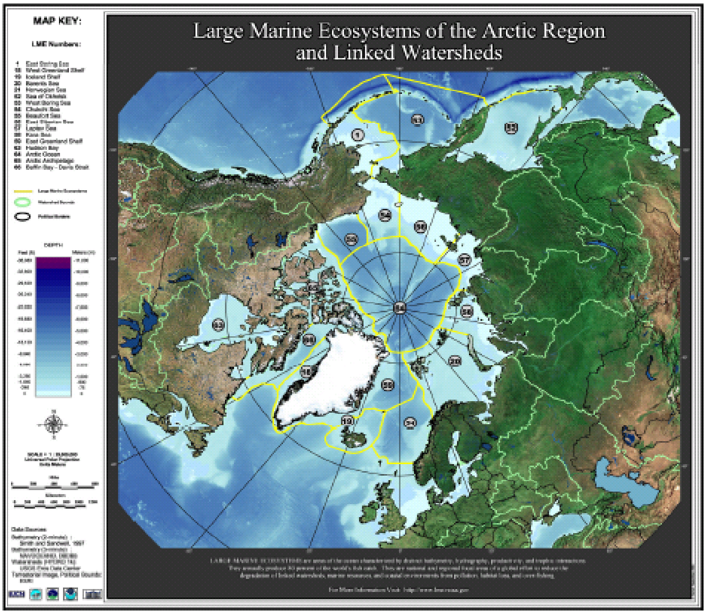

Figure 4.2. The 17 Large Marine Ecosystems and Freshwater Ecosystems of the Arctic

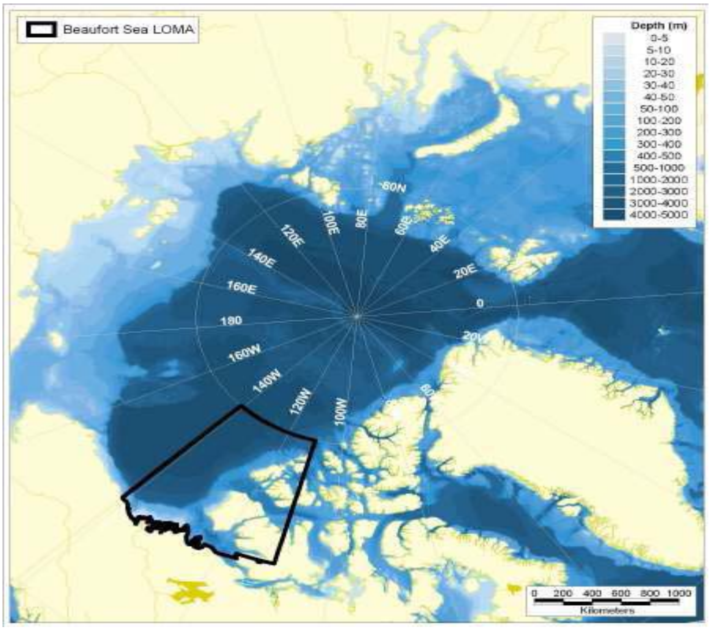

Figure 4.3. Western, Eastern Arctic and Central Arctic Ocean

EXISTING FISHERIES AND THEIR MANAGEMENT

The Arctic Ocean is not known for extensive fisheries per se, however its neighboring subarctic seas are among the sources of the largest fisheries in the world. Despite the fact that large scale commercial fisheries do not exist in the Arctic Ocean is not to diminish the roles that marine and freshwater fish (as well as marine mammals and seabirds) have played and continue to play in the subsistence economies and nutrition of indigenous peoples surrounding the Arctic Ocean (Booth and Watts 2007, Booth and Zellner 2008, Zellner et al. 2011, Pauly and Swartz 2007).

It is useful to understand that there are existing major world fisheries occurring in the northern portions of adjacent seas and the sub-Arctic. Major fisheries are evident in the form of the Russian and United States Bering Sea fisheries. Norwegian, Russian, Icelandic, Canadian and Greenland-Denmark fisheries are significant players in the North Atlantic and Barents and Norwegian Seas. Fisheries regions are characterized by the Arctic Climate Impact Assessment (ACIA) report (2005) as the four ecosystems, i.e., Northeast Atlantic (Barents Sea and Norwegian Seas), Central North Atlantic (Iceland and East Greenland), Northeast Canada (Newfoundland and Labrador Seas) and the North Pacific (Russian and US Bering Sea) for boreal fisheries (Livingston and Tjelmeland 2000). The ACIA Fisheries report did not focus on the Central Arctic Ocean (Food and Agriculture Organization (FAO) fisheries reporting Area 18) which is where current international attention appears to be riveted. This is because there is a dearth of commercial fisheries in the Arctic Ocean basin. For purposes of this article the Central Arctic Ocean (CAO) is a fifth regional ecosystem with an emphasis on the very significant subsistence fisheries, potential fisheries and especially on fisheries considerations for the areas outside limits of national jurisdiction.

There are significant differences between what might be termed the Western Arctic Ocean, the Central Arctic Ocean and the Eastern Arctic Ocean with respect to living marine resources that are important to recognize (See Figure 4.3). The open Eastern Arctic Ocean is already occupied by high latitude large scale commercial fisheries. The species composition of fisheries is considerably greater in the Eastern Arctic Ocean than in the Western Arctic as a result of its openness to the North Atlantic. Subsistence fisheries by indigenous peoples occur around the rim of the Arctic Ocean on shallow continental shelf ecosystems and in tributary freshwater aquatic systems. So far, surveys of fish in the Arctic Ocean show greatest abundance and variety of fish on these continental shelf ecosystems because of the seasonal patterns of ice melt and the ability to retain nutrients in the water column and advection of nutrients from the south through the Bering and Fram Straits. The

Central Arctic Ocean remains ice-covered year round so lack of light and nutrients limits productivity and, of course, ability to fish if there were sufficient abundance of fish (which there does not appear to be).

Quite a few significant fish species in the Arctic Ocean region are diadromous while most of the species of commercial importance are anadromous, e.g., salmon and Arctic char. This justifies developing an understanding the land/sea interface because changes in hydrography as a result of climate change may alter conditions for some species during the freshwater portions of their lives (Finstad and Hein 2012, Prowse et al. 2006).

In addition to the large scale fisheries in the four areas outlined above, there are much smaller scale fisheries occurring in Canada, Greenland, Norway, Russia and the United States as seen in mostly non-commercial subsistence fisheries that are of critical importance to indigenous communities in the Arctic (Zeller et al. 2011). Figure 4.4 shows the various regions of the Arctic Ocean region and displays the commercial fishing intensity in the areas mentioned above.

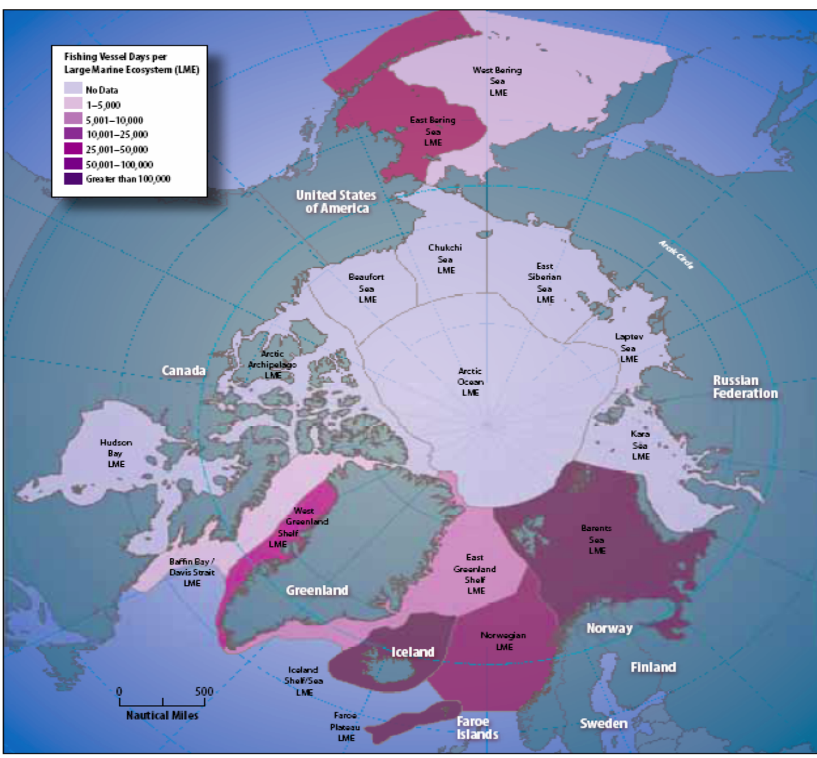

Figure 4.4. Fishing Vessel Activity in the Arctic Region by Large Marine Ecosystem. Source: AMSA

NE Atlantic fisheries by Norway, Russia, Iceland Greenland and Canada focus on Atlantic cod, Greenland halibut, polar cod, northern shrimp, capelin, herring, and blue whiting. Snow crab in Greenland and Canada are a valuable invertebrate species. While many more species are caught these are the principal species of interest.

These fisheries represent well studied species with variability to climate change as evidenced by past variability in stocks associated with shifts in ocean temperature and circulation (ACIA Chap. 13; Schrank 2007, Stige et al. 2006). The key point is that these are, in general, large scale, commercial fisheries that have been prosecuted for extensive periods of time from diverse fishery-dependent communities spaced around the NE Atlantic. Changes in abundance in the past have been much more heavily influenced by fishing pressures and at times overfishing has occurred, however, this practice is abating. The legacy effects of overfishing pressure persist in some stocks.

The fisheries in the Bering Sea are generally of more recent origin than the NE Atlantic. They are also large scale, commercial fisheries; however, the locus of the base of fishing operation involves larger communities often based outside the Arctic region per se. It should be noted that in recognition of the non-coastal nature of these fisheries (except for salmonids), an innovative Community Quota Development program has been devised to provide benefits of the fishery to small fishing communities in Coastal Alaska through six regional organizations. (NRC 2005). Whether or not this model is suitable for Arctic Ocean fisheries would depend on their being large scale commercial fisheries developing in the area which this author deems unlikely.

Principal species harvested in the Eastern Bering Sea are walleye pollock, salmonids, Pacific cod, Pacific Ocean perch, yellowfin sole, rock sole, Pacific halibut, king crab, and snow crab (ACIA 2005). Strong evidence of regime shifts in the species composition and abundance of the catch in the Bering Sea has generated significant interest in the fisheries management communities about the impacts of climate change on fisheries (Mantua et al. 1997, Hare and Mantua 2000, Mantua and Hare 2002, Grebmeier et al. 2006). Access to comparable information and assessments from the Western Bering Sea is acknowledged (Mathisen and Coyle 1996, NRC 1996, ACIA 2005, PICES 2010).

A sense of the quantities and distribution of fish harvests in the Arctic (mostly sub-Arctic) can be observed from Figure 4.5 which summarizes catches by broad categories and location.

Aquaculture, except for Norway's farming of salmonids, does not appear to be a significant factor in other countries at the present but it is conceivable that Arctic char and perhaps other select species might be suitable for consideration. The harvest of marine mammals and seabirds is discussed below. It is acknowledged that pursuit of fisheries in the Arctic may affect the prey base for marine mammals and seabirds (Brown et al. 2010) but these interactions are incompletely known.

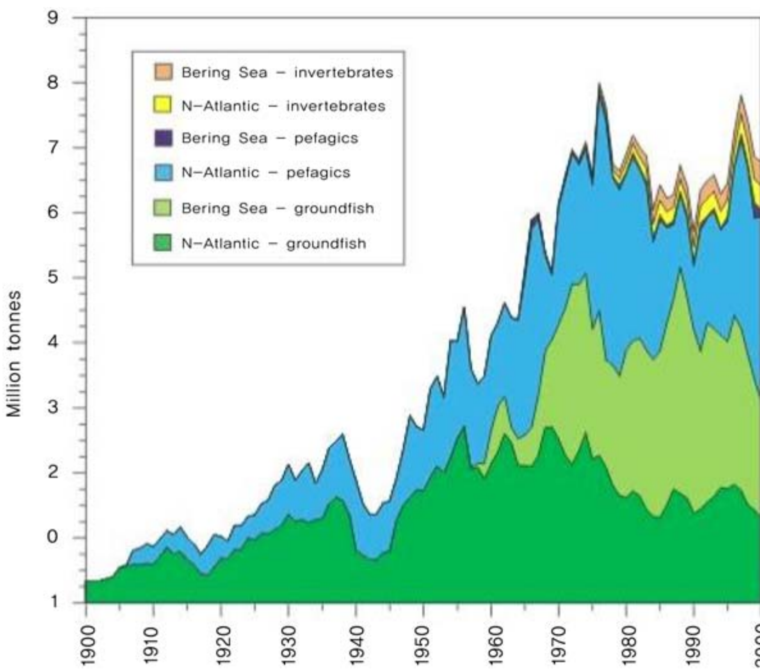

Figure 4.5. Distribution of fish harvests in the Arctic (Source: Encyclopedia of the Arctic, edited by Mark Nuttall, 2004).

In the Western Arctic Ocean, fish harvests have been documented by a series of studies from the University of British Columbia. In a summary paper, Zellner et al. (2011) reconstruct Arctic Ocean catch histories in Russia, Canada and the United States from 1950 to 2006 and find that total catches averaged 24,100 tons per year in 1950 but declined to 10,200 tons per year in 2006. The harvests were predominantly whitefishes in Siberia, salmonids in Alaska and Arctic char in Canada. Zellner et al. (2011) make the point that these catches are not accurately reported in the national statistics for FAO Area 18. While conditions vary across the Western Arctic, the reasons for decrease in these subsistence catches do not include overfishing, rather they indicate changing demographics and technology, most notably the substitution of mechanical transport for dog sleds. Thus, there is a decrease in the need to harvest fish to feed sled dogs. Other factors that affect demand for fish may reflect dietary choices in circumpolar peoples where there is a switch from traditional locally obtained to foods "imported" from outside the area (Pauly and Swartz 2006, Booth and Scott 2008). In the Eastern Arctic, the early openings and late closing of leads have interfered with traditional resource harvesting practices.

These changes in traditional practices and potential fisheries make for a very uncertain future for indigenous peoples of the Arctic. Loss of sea ice and changes in patterns of use constrain hunts in usual and accustomed areas. While some income is garnered from guiding of hunting and fishing as well as providing lodging and meals for tourists, these activities are not part of traditional pattern but are increasing. Most agree that there can be substantial adaptation to new circumstances within indigenous communities and that alternative mechanisms can be substituted to traditional sharing of resources, responsibility of hunting, etc. however it is also agreed that climate change will exacerbate increased interaction among regional and global economies (Berkes and Jolly 2001).

How are existing fisheries managed?

Indigenous fisheries appear to be locally managed by the resource users themselves in Canada and the United States. There is little effective oversight or monitoring by government agencies, i.e., Alaska Department of Fish and Game for Alaska and Department of Fisheries and Oceans for Canada. Stronger engagement between the state and local fisheries exists through co-management institutions in Norway. Commercial engagement of indigenous people in local fisheries is so mixed that this presents a particular case (Hersoug 1997). The Russian management approach is unknown.

Resources of the continental shelves inside EEZs of Arctic coastal states are managed by national entities charged with that responsibility. They consist, as best can be discerned, of modest oversight of subsistence fisheries by traditional communities. There is not a regional fishery management organization (RFMO) for the western Arctic or the Central Arctic Ocean at the present time, whereas one exists in part of the eastern Arctic in the form of Northeast Atlantic Fisheries Commission. This situation is largely as a result of the lack of apparent need for a RFMO given the nature of present bilateral arrangements of the EEZs in the Western Arctic and the ice dominated area of the areas beyond EEZ jurisdiction in the Arctic. Perceptions of the need for and timing of development of a RFMO or other more comprehensive arrangements are discussed later.

In the Northeast Arctic the Atlantic fisheries RFMOs are developed to manage fisheries outside of coastal state EEZs, for example, the

Northeast Atlantic Fisheries Commission (NEAFC) www.neafc.org, and Northwest Atlantic Fisheries Organization (NAFO) www.nafo.org. The International Council for Exploration of the Seas (ICES) provides scientific advice to the North Atlantic (and Baltic Sea) convention areas and provides advice to North Atlantic governments www.ices.dk/. In the North Atlantic Salmon Conservation Organization (NASCO) measures are taken to manage salmon fisheries in the North Atlantic www.nasco.org. The European Union manages fisheries in these areas on behalf of its members. For all practical purposes, coastal states in the northern part of the NEAFC area manage the fisheries because they occupy continental shelf areas inside of EEZs with only small set asides or quotas offered to other states.

By comparison fisheries management organizations in the Western Arctic Ocean area are represented by the EEZs of Canada, Russia and the United States (Molenaar and Corell 2009). In the North Pacific the North Pacific Anadromous Fish Commission (NPAFC) www.npafc.org and the North Pacific Marine Science Organization (PICES) www.pices.int are not management institutions but for fisheries they play a significant role in the development of knowledge of the North Pacific ecosystems and their variability. They are largely focused on the sub-arctic.

There are multiple perceptions of the nature of the central Arctic Ocean basin potential for fisheries outside the limits of national jurisdiction leaving aside the questions of delimitation that remain unresolved. These differences are quite important in terms of understanding engagement in Arctic Ocean fisheries policies and arrangements to be later addressed.

North Atlantic for Atlantic cod and herring and Bering Sea fisheries for walleye pollock constitute some of the world's largest fisheries and arguably they are among the best managed fisheries with Norway, USA, Canada, Iceland and Denmark among the top ten countries in terms of compliance with the FAO Code of Conduct for Responsible Fisheries (Mora et al. 2009). Similarly, these countries are among the most capable when it comes to maintaining and rebuilding fisheries (Worm et al. 2009). Using yet other standards for implementation of ecosystem-based management of fisheries these same countries were rated as among the best in the world (Pitcher et al. 2009). The point in this recitation of capacity is to emphasize that these same coastal states can be expected to apply high standards for any commercial fishery likely to commence in the Arctic region.

Disparate other fisheries not highlighted in the above discussion of groundfish are also important. Fisheries for salmon, multiple species of crab, Pacific cod, Atka mackerel, small pelagics, etc. are important as generating income and nutritional products. In these fishing areas it is safe to say that fisheries are mature, fully developed with strong integration into national management programs. In addition where transboundary or straddling stock fisheries are shared by countries, bilateral and multilateral arrangements for sustainable fisheries have been developed. Eight bilateral boundary areas exist where transboundary fish stocks or other fisheries issues may be important. See Table 4.1.

Table 4.1. Bilateral Boundaries in the Arctic Relative to Fisheries

1. Russia–US: Bering and Chukchi Seas	Unresolved – delimited but not ratified –Donut Hole Convention 1992 [multilateral]
2. US–Canada: Beaufort Sea	Unresolved – active research and discussions to resolve
3. Canada–Denmark/Greenland: Davis Strait	Treaty 1973
4. Denmark/Greenland– Iceland: Fram Strait	Treaty 1997
5. Denmark/Greenland–Norway: Jan Mayen	IJC Decision 1993 – Treaty 1995
6. Denmark/Greenland– Norway: Svalbard	Boundary Agreed–based on equidistance
7. Iceland–Norway: Jan Mayen	1980 Treaty Fisheries/1981 Treaty EEZ
8. Norway – Russia: Barents Sea	Treaty 2011

FAO 1998. FAO's Fisheries Agreements Register (FARISIS). Rome. Updated by Author 2011.

Key to this status is coastal state management of fisheries within respective EEZs. This can be seen in the assignment of levels of fishing effort in the Arctic region in Figure. 4.3 above. While there is no regional fishery management agreement for the Bering Sea, much less the Arctic Ocean, transboundary and shared stocks are, arguably, under adequate management or have not developed into significant management disputes in the area. Norway and Russia, for example, have developed extensive cooperation in the Barents Sea (Hønneland 2012). See Figure 4.6.

Finally, there are arrangements, in some cases multilateral, to deal with the three Arctic areas outside of national jurisdiction (besides the CAO), i.e., the "Donut Hole" in the Bering Sea (Wespestad 1993, Bailey 2011), the "Banana Hole/ Herring Hole" in the Norwegian Sea and the "Loophole" in the Barents Sea (Hoel 2009). In the area termed the "European Wedge" in the Central Arctic Ocean the Northeast Atlantic Fisheries Commission has a mandate over part of the currently ice covered portion of the high seas in the Arctic Ocean (north of 36 degrees north latitude and between 42 degrees west longitude and 51 degrees east longitude) even though at the present time commercial fisheries are precluded by the ice (Molenaar and Corell 2009). This leaves the Western portion of the high seas in the Arctic Ocean, also ice covered, without formal agreement. In this Western region commercial fisheries are almost non-existent in coastal state EEZs and non-existent in the ice covered areas (Booth et al. 2008). The United States has taken formal action to develop a Fishery Management Plan for its Arctic EEZ which closes the area to fishing until adequate scientific understanding of the potential fisheries is obtained (NPFMC 2009). See Figure 4.7.

Figure 4.6. Fisheries management zones in the Northeast Atlantic – Norway/Russia.

Similar actions have been taken for closures of the northeastern Bering Sea in US waters as a Northern Bering Sea. See Figure 4.8.

In the NE Atlantic the Convention on the Protection of the Marine Environment in the North-East Atlantic (OSPAR Commission) and its Annex IV on the assessment of the quality of the marine environment plays a major role (www.ospar.org). The full listing and description of North Atlantic arrangements for the marine environment affecting fisheries and other resources is beyond the scope of this treatment.1 In the broadest sense there are numerous international agreements with respect to regional governance under the Law of the Sea Convention (LOSC) that apply to fisheries and numerous bilateral arrangements among coastal states and with the European Union (Airoldi 2008, Hoel 2009, Molenaar and Corell 2008, Koivurova et al. 2009, Koivurova and Molenaar 2010) that apply to fisheries science and management.

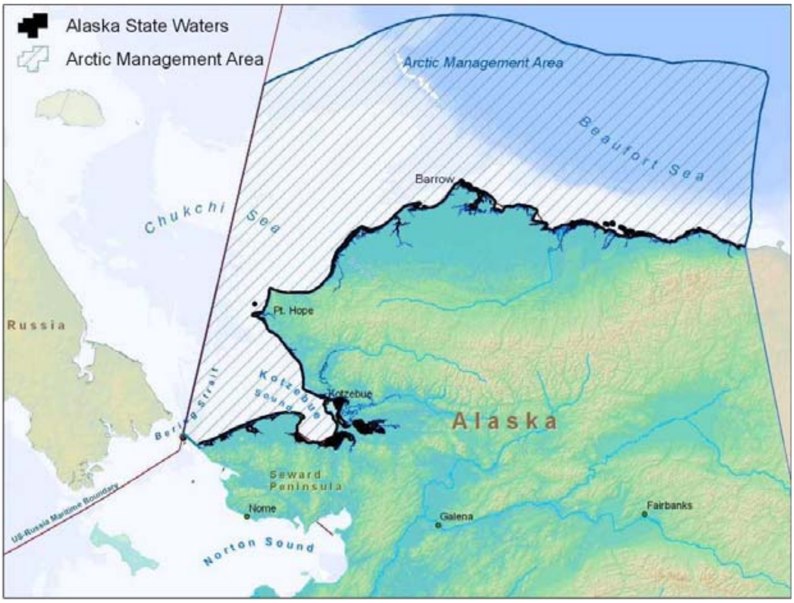

Figure 4.7. Closed to fishing area in US EEZ under Arctic Fisheries FMP

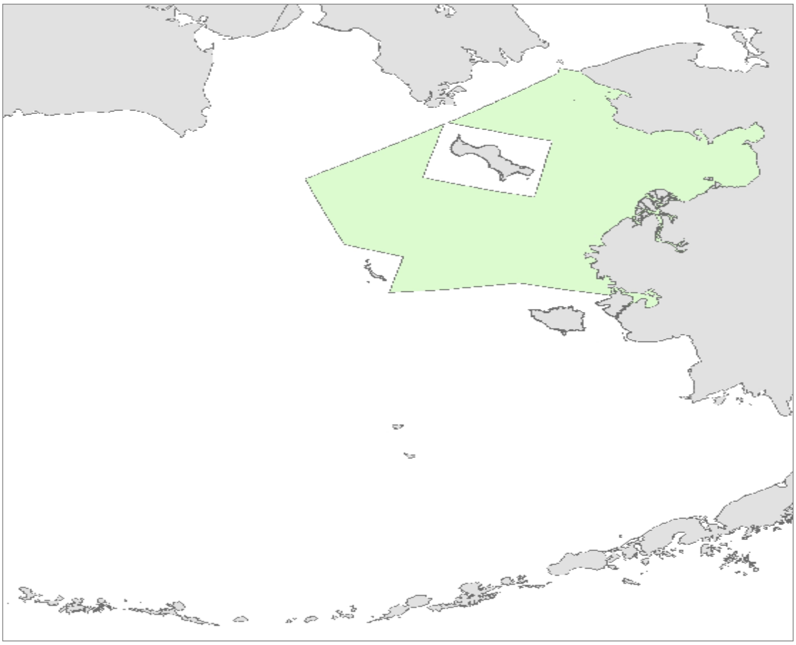

Figure 4.8. Research area where only limited experimental fishing is permitted

What are potential arctic fisheries?

Potential Arctic fisheries are here posited as fisheries that result from 1) projected changes in existing Arctic fisheries, 2) changes anticipated as a result of northward extensions of species ranges, and 3) changes in productivity because of reduction of sea ice and an extended ice free Arctic season. Potential fisheries can result in stock sizes larger and smaller than current fisheries and locations of abundance may shift. Predictability of these changes is low so the uncertainty surrounding these estimates is crucial to recognize. It is likely that the first order of action is to monitor and assess scientifically the potential for fisheries to develop (Fluharty 2010). This precautionary approach has been established by some Arctic coastal states namely the United States and Canada in their respective EEZs whereas other states (Norway, Iceland, Greenland/Denmark and Russia) maintain conservatively managed fisheries which also are subject to scientific research and monitoring.

Besides the biological availability of a commercial size fishery, economic viability of potential fisheries must take into account the extreme distances (8,000-12,000 km. one way) that must be transited by fishing entities from Asia or the United States, the lack of local support infrastructure and processing capacity, the lack of search and rescue and aids to navigation and, last but not least, the relatively low value of the projected resources in terms of the species and type of fishing activity expected especially in the Western Arctic region. A project to perform mid-water and bottom trawling in the Northern Bering and Chukchi was undertaking during the summer 2012.[2] It was funded by the Bureau of Ocean Energy Management and performed by the National Marine Fisheries Service along with a number of other players and sought to determine the nature of the fisheries resources in that region.

Changes in fisheries abundance are likely highest along the continental shelves where existing fisheries are taking place and where subsistence fisheries by indigenous peoples is a high priority in maintaining cultural integrity and livelihoods (Carmack et al. 2012). Potential fisheries of the Arctic Ocean will most likely occur on the continental shelves inside EEZs claimed by coastal states and, therefore, fishery management is expected to remain largely at the discretion of the coastal states. Any potential fishery on the High Seas Central Arctic Ocean is likely to be slow to develop because of the continued presence of sea ice. Sea ice forms again over the continental shelf each winter so fish populations will have to be tolerant of low temperatures because winter wind mixing and brine formation make this area vertically homogenous. Potential fisheries are likely to be pelagic rather than demersal in nature due to the extreme depth of the Arctic Ocean main basin and the nature of wind and water circulation not to mention accessibility under sea ice

(Augstí et al. 2010). Finally, the seasonal low intensity of light to fuel primary production will mean that potential fisheries will be slow growing and with reproductive and evolutionary strategies that are long-lived.

Various authors have noted major shifts in distribution of catches, abundance of fish stocks and changes in the size composition of stocks of fish in the Arctic region. Grebmeier et al. note that "[c]hanges in biological communities are contemporaneous with shift in regional atmospheric and hydrographic forcing. In the past decade, geographic displacement of marine mammal distributions has coincided with a reduction of benthic prey populations, an increase in pelagic fish, a reduction in sea ice and an increase in air and ocean temperatures" (2006:1461). A survey of literature (51 studies) on climate change in the Arctic marine ecosystem revealed that there were examples of range shifts, changes in abundance, growth/condition, behavior/phenology and community/regime shifts (Wassman et al. 2011). The authors lament that evidence of changes in planktonic and benthic systems is low and that losses of endemic species were difficult to evaluate given the paucity of information. Likewise, lack of information on invasive species is limited by the same monitoring problems. There were significant gaps in information from certain regions like Siberia (Wassman et al. 2011). The main conclusion by Wassman et al. (2011) was that considerably more research was needed to document changes occurring in the Arctic region marine ecosystems. Given the expense of Arctic monitoring and research, behavioral models are being developed to provide a common framework to predict impact of environmental change (Satterthwaite and Mangel 2012).

Results of research on modeling and monitoring of freshwater species response to climate change, show potential and actual changes in species distribution and abundance in a northward shift. In northern Canada studies reveal that if the temperature suitable for smallmouth bass, for example, would expand northward (and increase by as much as 18 degrees C by 2100) it would have the potential to alter lake ecosystems significantly (Sharma et al. 2007). Similar studies in Northern Norway point to a change in species distribution between Arctic char and brown trout as lake systems warm because the more aggressive and dominant brown trout may outcompete the more biophysically efficient Arctic char favored in cold water low productivity lakes (Finstad et al. 2011, Finstad and Hien 2012).

Actual estimates of change in climate on potential fisheries production for the Arctic are extremely rare and are full of caveats about the uncertainties of the climate change scenarios, response of the fish to climate change signals, how the ecosystem would evolve, and how to incorporate effects of ocean acidification among other things. I find the work of Cheung et al. (2010) to provide the most compelling effort to model these responses on a consistent global basis. Their results for potential maximum fisheries catch potential for the EEZs of Arctic coastal states show increases ranging from Canada at 5% to Norway at about 45% (Table 4.2).

Table 4.2. Projected changes in 10-year averaged maximum catch potential from 2005 to 2055 in Arctic nation EEZs

Norway (95)	45% increase
Greenland (37)	27% increase
US (Alaska) (43)	25% increase
Russian Federation (Asia) (75)	21% increase
Iceland (54)	20% increase
Canada (125)	5% Increase

These changes in maximum catch potential do not identify which species gain or lose in abundance or range to produce the net effect although these details can be teased from the model. One caveat should be made. It cannot be presumed that the increases are necessarily in high value fish or the species preferred in the market. Note that these values are for EEZs (more or less corresponding to the LMEs in Figure 4.1 above). There is no estimate of a maximum fish catch potential in the Arctic Ocean high seas area. Fisheries development in this area is generally considered small at this time and, in the view of many, the international interest in this area is misplaced at best in terms of potential fisheries.

Cheung et al. (2010) have attempted to project impacts of change on global ocean fish stocks. Their regional results for Arctic Ocean fish stocks distribution by decade from 2010-2050 have been presented at the International Arctic Fisheries Symposium (IAFS) held in Anchorage, Alaska, 19-21 October 2009 and available at (www.nprb.org/iafs/2009—last accessed January 20, 2012). They found polar cod distribution, for example, does not appear to change significantly, however its abundance decreases over its whole current range by 2055. Greenland cod appears to increase in distribution in limited areas, however, there are both increases and decreases in local abundance estimated.

Field research and monitoring results as reported by Logerwell at IAFS (www.nprb.org/iafs/2009) appear to provide evidence of the kinds of changes consistent with the Cheung et al. (2009, 2010) early model results. Logerwell (see above) reviewed the US portion of the Arctic using expert opinion to preliminarily assess the likelihood of range extensions and increase in abundance of fisheries for 30 the major species of groundfish, shellfish and anadromous species, salmon, herring, and forage fish in the Arctic as shown in Table 4.3.

On top of all the previously described impacts, ocean acidification is expected particularly to be an issue in the Arctic due to the ability of cold water to absorb carbon dioxide. The Arctic is expected to be one of the regions most vulnerable to effects of ocean acidification although the mechanisms and processes are yet to be determined (Doney et al. 2009, Mathis et al. 2011, Duarte et al. 2012).

MARINE BIODIVERSITY AND MANAGEMENT

This section reviews potential shifts in seabirds, marine mammals, polar bears and marine biodiversity in general. For each of the four elements, I consider the best available information on the processes of climate change that are likely produce impacts on each and I report overall management approaches at the national and international levels.

Seabirds

Seabirds are an important component of the Arctic and sub-arctic. Because of the extreme seasonality of the Arctic most birds exhibit a strong migration northward in the spring and southward in the fall. Research has shown that some species of seabirds (thick billed murres and common murres) show strong neg ative trends with respect to large temperature shifts both warmer and cooler than average (Irons et al. 2008). While conditions along seabird wintering areas and flyways are critical (e.g., Wilson 2010), the strong pulse of productivity in the Arctic permits feeding for all and breeding for many. It appears that the start of marine productivity and processes associated with presence of sea ice are changing, causing the opening of much larger areas in the Arctic for seabird access which may affect seabirds positively and negatively depending on species (Van Der Jeugd et al. 2009). The North American brant, for example, experience a strongly degraded wintering habitat which makes their Arctic habitats extremely important with respect to breeding and nutrition (Ward et al. 2005).

In contrast, the European pink-footed geese which has expanded in population size due to conservation and land use measures in the temperate zone may actually reduce carbon stocks and sink strength in tundra systems in Svalbard where they spend their summers (Van Der Val et al. 2007). Prey and forage availability in freshwater can be important as well [likely in offshore areas too] and this has differential impacts according to species (Tulp and Schekkerman 2008, Renner et al. 2012).

Table 4.3. Major species of fish and shellfish in trawl samples in the US Arctic EEZ and Preliminary Expert Assessment of Fishery Potential

Common Name	Present	Unlikely	Maybe
Coho salmon		X	
Chinook salmon		X	
Chum salmon	X		
Sockeye salmon		X	
Pink salmon	X		
Broad whitefish	X		
Least cisco	X		
Doll varden	X		
Arctic char	X		
Arctic grayling	X		
Pacific herring	X		
Capelin	X		
Arctic cod	X		
Walleye pollock		X	
Pacific cod		X	
Saffron cod	X		
Yellowfin sole			X
Greenland turbot (halibut)	X		
Arrowtooth flounder		X	
Kamchatka flounder	X		
Bering flounder	X		
Rock sole		X	
Flathead sole		X	
Alaska plaice	X		
Pacific Ocean perch		X	
Northern rockfish		X	
Snow crab	X		
Red king crab			X
Tanner crab		X	

Logerwell, E. 2009. Arctic Fisheries Research. NOAA Fisheries Service. Presentation to the IAFS Anchorage, AK, October 19 ppt. presentation (www.nprb.org/iafs/2009).

How seabirds (Arctic terns) disperse has been shown to be associated with changes the North Atlantic Oscillation such that natal dispersal may influence gene flow (Møller, Flensted-Jensen and Mardal 2006).

It has proven to be difficult to obtain a synoptic view of how seabird dynamics are affected by climate change in the Arctic. Given the vastly different life histories and adaptations, seabirds present an uncommonly difficult group of species about which to generalize. Suffice it to say that across all species there is considerable diversity. Modelers are attempting to construct frameworks that can help sort through the myriad scenarios (Satterthwaite and Mangel 2012).

This makes efforts for management of seabirds in light of climate change particularly problematic. All of the major flyways converge for certain species in the Arctic, especially the continental shelf areas, as the ice covered center is inhospitable (see Figure 4.9). These highly migratory species receive various degrees of national and international protection (CMS 2011). For the Arctic seabirds the Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) group provides the principal forum for cooperation through the CAFF Circumpolar Seabird Group.[3] European treaties like the Convention for the Protection of Birds Useful to Agriculture (Paris 1902) and the International Convention for the Protection of Birds (Paris 1950) are still in force but the European Union (EU) Habitat Directive and Birds Directive are the primary ways the EU implements the Convention on Migratory Species

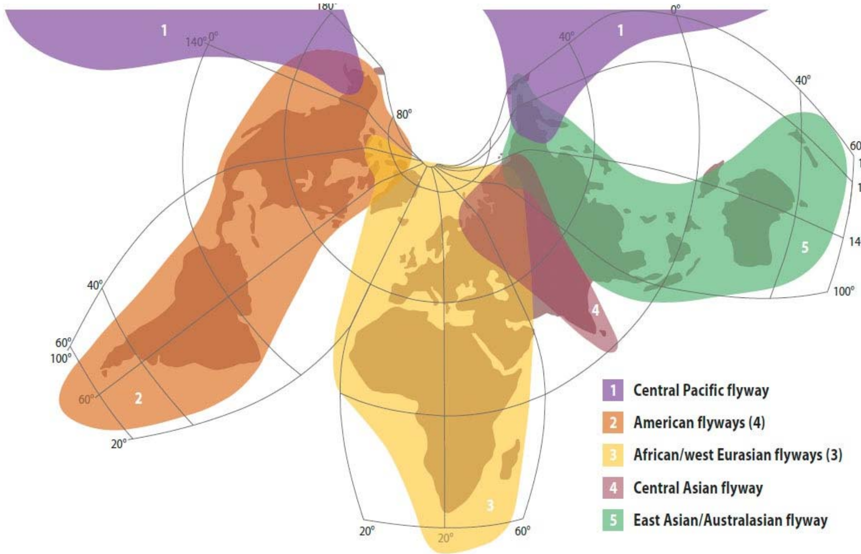

Figure 4.9. Major Flyways for Arctic Birds. Source: International Wader Study Group. 1998.

1979 and the Agreement of Conservation of African-Eurasian Migratory Waterbirds 1995. However it should be remembered that the CMS builds off of the Ramsar Convention for Wetlands of International Importance especially as Wildfowl Habitat 1971. Now the Convention on Biological Diversity provides the global overarching framework for migratory bird management. In North America, Mexico, the United States, and Canada have agreed in the Migratory Bird Treaty Act (1918) to cooperate in the management of the full migratory corridor. A similar bilateral agreement has been agreed between Japan and Russia, Russia and South Korea, US and Japan, US and Korea, for the Asian-Pacific Flyway.

Marine mammals

The constellation of year round Arctic marine mammals includes three species of whales (narwhal, beluga, and bowhead) and three seal species (walrus, ringed, and bearded seals) and the polar bear (in a separate section below). In addition, there are five whale species (fin, humpback, minke, gray and orca) and four seal species (harp, ribbon, hooded and spotted) that occupy the Arctic Ocean seasonally. Sea ice is a critical component for the survival of each of these species whether it is as a platform, an environment for ice-adapted species or simply as a seasonal barrier to certain migrant species (Moore and Huntington 2008). While it is extremely difficult to predict, it appears that some ice-obligate species can survive through 2050 in refugia, but others may adapt to ice free conditions. Some ice-associated species may be able to shift locations and prey and therefore adapt to expanded foraging opportunity afforded by a longer season. Finally, Arctic resident species may face increased competition from seasonally migrant species (Moore and Huntington 2008, Huettman et al. 2011). Killer whale sightings in the eastern Canadian Arctic increase in periods with low ice cover possibly generating predator-prey trophic cascades across the region (Higdon and Ferguson 2009).

The marine mammal complex that exists year round in the United States Arctic waters may be vulnerable or challenged by habitat modifications (Laidre et al. 2008) ecosystem alteration, i.e., change in food composition (Bluhm and Gradinger 2008), organismal health (Burek, Gulland and O'Hara 2008) and human impacts (Hovelsrud 2008) according to Moore and Huntington (2008). Systematic estimation of the sensitivity to climate induced change for resident marine mammals is problematic (Laidre et al. 2008). The regional availability of food for resident marine mammals is derivative of many physical and biological processes and therefore difficult to specify although scenarios can be built using existing information to partially inform and predict which species might be advantaged or disadvantaged (Bluhm and Gradinger 2008). These concerns can be summarized as shown in Table 4.4. Health of any marine mammal is a complex interaction with physical and biological factors and some may be direct via air and water temperature, amount of sea ice and human harvests, and indirect via changes in pathogen transmission, shifts in the prey base, and exposure to toxicants (Burek, Gulland and O'Hara 2008). As economic activities like oil and gas exploration and development and shipping expand, these activities can have direct and indirect effects as well. Direct management actions taken to utilize a precautionary approach as has been done in the US Arctic for fisheries (Stram and Evans 2009) and other activities can be compromised by the lack of similar actions in other sectors (Reeves et al. 2012).

Management of pinniped populations is relegated to national governments. While management for conservation can take action with respect to restrictions on hunting, protection of habitat, and reduction of incidental take is possible these efforts are a stopgap effort if there are not ancillary actions to stop the loss of sea ice (Ragen, Huntington and Hovelsrud 2008). The North Atlantic Marine Mammal Commission (NAMMCO) established by agreement among North Atlantic nations in 1992 focuses on the marine ecosystem and the roles of marine mammals in it. It provides a regional forum for exchange of scientific information on marine mammal management including hunting practices and makes recommendations on conservation measures. Global management of cetaceans fall in large part under the International Whaling Commission Treaty (1946)[4] and the IWC. Most of the IWC attention in the Arctic is focused on setting quotas for harvests by indigenous peoples because of the global moratorium on whale harvests, allowing a certain number of bowhead whales to be taken by Native Alaskans and gray whales by indigenous people in Russia. Norway currently sets a quota of 700 minke whales for its commercial harvests under its formal and legal objection to the moratorium under section V(3) of the International Convention for the Regulation of Whaling. Iceland harvests minke whales as well.

Polar bears

Polar bears have become the iconic species of charismatic mega-fauna for climate change in the Arctic (O'Niell et al. 2008). They are circumpolar located in the nearshore ice shelf where the rate of disappearance of seasonal ice is most rapid. The polar bear's preferred prey is seals. Shifts in the pattern of sea ice are likely to make them less accessible to predators in several ways. A decline in the abundance of ice seals and greater dispersal of pack ice will likely make polar bear movement more difficult. While life history traits demonstrate a fair amount of plasticity, that is, adaptability to change, it is expected that polar bears in a warming climate will not fare well (Derocher, Lunn and Stirling 2004). However, predicting the rate of decline is difficult and even experts vary in their perspectives (O'Niell et al. 2008, Stirling and Derocher 2012). Most would agree that the rate of ice loss in the Arctic sets the pace for decline in polar bear abundance (Stirling and Parkinson 2006).

Table 4.4. Ice-associated marine mammals, linkages to sea ice and sensitivity to sea-ice conditions

Species	Linkages	Sensitivity
Pinnipeds		
Walrus	Mate, Birth, Rearing, Forage far from shore	Broadens feeding distribution/ Possible increase in abundance
Ringed seal	Needs ice for breeding, pupping, resting, ice–associated prey/ summer ice for resting	Stable snow on ice for lairs
Bearded seal	Same as above	Sea ice over shallow water rich benthic community
Ribbon seal	Breeds in ice pack	Pack ice in late winter early spring in regions where food is available for young.
Spotted seal	Breeds in pack ice	Lack of pack ice
Harp seal	Breeds in pack ice	Lack of pack ice
Hooded seal	Breeds on heavy large floes of pack ice late in season	Lack of pack ice
Cetaceans		
Bowhead	Highly ice adapted	Sea ice structures ecosystem and influences prey availability
Beluga	Associated with ice year round	Noise from seismic operations
Narwal	Associated with ice year round feed in pack–ice on benthos in winter	Noise from seismic operations
Polar bear	Principal hunting platform/ transportation for females with cubs	Short ice season means longer period of fasting

Polar bears are managed by national governments under the 1973 Agreement on Conservation of Polar Bears. The coastal state signatories to the agreement have obligated themselves to protect the ecosystems of which polar bears are a part and to manage those ecosystems consistent with conservation and use of the best available scientific data (Stirling and Parkinson 2006). Polar bears are also subject to bilateral agreements between the United States and Canada (Inuvialuit-Inupiak) and United States and Russia (Alaska Chukotka). The latter agreement called for a commission to be established for coordination of measures taken and one was set up in 2008. Greenland, Canada, and Nunavut signed a Memorandum of Understanding for polar bears in 2009. The Convention on International Trade in Endangered Species under Annex II covers species which are not threatened with extinction but may become so if international trade is not restricted. Polar bears are both revered and feared by native peoples in the Arctic. They are also valued by big game hunters as trophies and guided hunts for them produce substantial revenues in regional economies.

Marine ecosystem biodiversity

Understanding how the Arctic marine ecosystem is structured and functions at a time of rapid climate change is a daunting enterprise. Ecological and evolutionary responses to recent climate change are of critical interest (Parmesan 2006, Hop et al. 2011). Besides their scientific interest Arctic living marine organisms may have unusual adaptations to cold and other factors and these genetic inheritances may have commercial values as well (Leary et al. 2009). "Effects of climate change on future biodiversity operate at the individual, population, species, community, ecosystem and biome scales, notably showing that species can respond to climate change challenges by shifting their climatic niche along three non-exclusive axes: time (e.g., phenology), space (e.g., range) and self (e.g., physiology)" (Bellard et al. 2012, p 183). Polar regions have been generally considered to be depauperate in species compared to the tropics and this seems to be a fairly constant feature (Yasuhara et al. 2012). Only recently have we realized that micro algae are a significant part of the ecosystem and have barely begun to chart their role in the Arctic ecosystem (Lovejoy et al. 2006, Lovejoy et al. 2011). Thus, understanding the Arctic marine ecosystem from its physical and chemical constituents and how they translate into biological productivity and eventually into resources available for human use and or protection is a critical task. Some progress is being made with understanding the patterns of zooplankton (Kosobokova, Hopcroft and Hirche 2011) and benthic (Bluhm et al. 2011) diversity in the Arctic Ocean's central basins but there remains much to be learned.

Recent discoveries are being made that may significantly alter our understanding of productivity in the Arctic. Researchers from the US National Aeronautics and Space Administration have reported massive phytoplankton blooms under the sea ice that apparently have not been observed previously and whose mechanism is not understood (Arrigo et al. 2012). Foodweb changes in response to climate warming are little understood (Quinlan, Douglas and Smol 2005). We are seeing evidence of rapid biogeographical plankton shifts in the North Atlantic (Beaugrand, Luczak and Edwards 2009). The timing of phytoplankton blooms appear to be occurring earlier in the Arctic (Kahru et al. 2011) in some cases affecting algal food quality (Søreide 2010). Climate shifts the interaction web in marine plankton communities and they lead to further changes (Francis et al. 2012). These changes in fundamental primary production processes may be having impacts terrestrially as well as marine through predator-prey relationships (Gild, Sittler and Hanski 2009).

If the Cheung et al. (2009) scenarios are borne out over the next decades, the Arctic will be gaining species and the ecosystem will be adjusting to these new circumstances in contrast to the projected losses of biodiversity in most other global systems (Reich et al. 2012, Naeem, Duffy and Zavaleta 2012). As discussed earlier, potential fish assemblages are likely to shift and we expect loss in abundance of most seals, cetaceans and polar bears. What are the consequences for marine ecosystem-based management in terms of scientific and governance challenges (Ruckelshaus et al. 2010)? What are the roles of refugia (Stewart et al. 2010)?

A key factor is the rate of change in the marine ecosystems (Lenton et al. 2012). Hitherto we have tacitly assumed that the change occurring will be gradual and incremental. Review of the emerging literature shows that climate change can be abrupt as a result of such processes as rapid melting of glaciers and ice sheets, changes in hydrology, change in the Atlantic meridional overturning circulation and increased release of methane from clathrate hydrates due to sea floor or terrestrial warming (US Climate Change Science Program 2009).[5] Abrupt climate change has been defined as "A large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades, and causes substantial disruptions in human and natural systems" (US Climate Change Science Program 2009:1).

Applying the US Climate Change Science Program definition of abrupt climate change, others have started to focus on what might be termed Arctic tipping points exceeded by anthropogenic global warming (Lenton 2012, Duarte et al. 2012, Wassman and Lenton 2012). A tipping point in an ecosystem context occurs when a small change in a parameter leads to a qualitative change in its future state. Lenton (2012) regards sea ice loss, permafrost thawing, and insect outbreaks as evidence that abrupt climate changes are already taking place and that they are irreversible. What flows from this high level statement in practical terms is almost unimaginable. We are only beginning a discourse on the implications, however, the Arctic ecosystem is probably among the ecosystems most susceptible to abrupt change (along with coral reef ecosystems in the tropics). Still, when extreme events are factored in, such as unprecedented rainfall, winds or temperatures the impact on society as a whole might be more costly and widespread than what might be imagined in the Arctic (Martens et al. 2010).

The implications for governance of the kinds of abrupt change or "surprises" observed so far call for anticipatory responses (Young 2012). This means monitoring to develop an early warning to both physical and biological shocks but also to shocks to society (Carmack et al. 2012). For society, this "prompts discussion characterized by a nervous anticipation of a future shaped by dramatic, far-reaching, and irreversible climatic, environmental, economic, political and social change" (Nuttall 2012: 97). Failure to think about, respond to, adapt to, or avoid tipping points is seen as increasing the cost of impacts and reducing the options for Arctic and global society (Huntington, Goodstein and Euskirchen 2012).

Cheung et al. (2009) explored impact of climate change scenarios on intensity of species extinctions and species invasions in the global oceans for 1066 species of fish world-wide. Their results for the Arctic and Subarctic regions (latitude equal to or greater than latitude 65 degrees N.) found there were 160 species from 68 families with landings data out of 420 species from 100 families in the total area as reported by FishBase. A recent review of the taxonomy and zoogeography of arctic marine fisheries found 242 species (Mecklenburg, Møller and Steinke 2011). Species richness is higher on continental shelves in the Arctic than in the Arctic Ocean basin and is considerably higher in the Eastern Arctic than the Western Arctic (www.nprb.org/iafs/2009). Cheung et al. (2009) projected invasions, primarily from the Northeast Atlantic could raise the species richness in 2050 to twice the current status despite a number of species going extinct as a result of the poleward shift and other factors. Others have reported on the invasion potential of mollusks from the Bering Sea into the Arctic and eventually to the Atlantic (Vermeij and Roopnarine 2008). These incipient trends are consistent with the evidence of Arctic biodiversity trends being monitored (CAFF International Secretariat 2010, Reid et al. 2007).

The management of living marine resources in the Arctic is difficult enough as it is due dynamic change in many components. However, living marine resource management can be affected by other economic activities new to the Arctic, especially oil and gas exploration and development (see chapter by Arild Moe this volume), and shipping (See chapters by Sung-Woo Lee and David VanderZwaag this volume). Marine tourism and associated transportation requirements present additional concerns especially with the increase in cruise ship activity without sufficient search and rescue capabilities. National security and defense activity is of continuing interest although the shape of activity may be shifting from Cold War capabilities to other operational patterns and open areas where there was once heavy sea ice. These activities are ramping up quite rapidly, and while there may be management capacity and regulations to deal with interaction and conflict between industrial uses and living marine resource management at the national level, it is not clear how well these arrangements can serve in the extremes of the Arctic environment and with the challenges the Arctic presents in terms of infrastructure and accident response in the case of oil spills, scientific monitoring of impacts, etc.

PROSPECTS FOR COOPERATION IN LIVING MARINE RESOURCE DEVELOPMENT AND PROTECTION

The treatment so far has focused on the nature of the Arctic ecosystem, management of its marine living resources and biodiversity and discussion of how these may respond to a changing Arctic climate. What is next is to review that information in light of concerns and interests of coastal and non-coastal states in Arctic fisheries, especially North Pacific Rim countries. Hoel (2009) reviews fisheries among other uses in asking if a new legal regime is needed for the Arctic Ocean. His perspective is that the immediate need in fisheries is for continued improvement in domestic management of fisheries and in developing appropriate arrangements for transboundary fisheries among coastal states where these presently do not exist. Similar views are expressed by Molenaar and Corell (2009) who observe that in some of the bilateral arenas development of bilateral and multilateral arrangements has not been necessary due to the presence of sea ice and the lack of fishery development. These authors recognize the potential need for intra-sectoral bilateral arrangements for fisheries in the near term and, over the longer term, the need for multilateral agreements with respect to the Arctic Ocean basin. In addition, these authors all recognize that the regime for a summertime ice-free or mostly ice-free Arctic involves issues other than fisheries. In order to protect potential fisheries from possible negative externalities generated by shipping, oil and gas development, tourism, etc. it may be necessary to consider a broader framework for action taking.

Others, such as Potts and Schofield (2008), argue that now is the time to deal comprehensively with Arctic Ocean issues. Similarly, the WWF and other environmental non-governmental organizations with concerns about protecting the vulnerable Arctic ecosystems are particularly interested in comprehensive environmental protection agreements for the Arctic and have assessed the gaps in the current management approaches in the region (Koivurova and Molenaar 2010). They argue that comprehensive environmental protection agreements would reflect the broad international interests in the Arctic and would mirror the agreements for the Antarctic while respecting the different conditions imposed by coastal state interests and presence of indigenous peoples. However, their perspectives would necessarily constrain economic development relative to fisheries, oil and gas, shipping, etc. in favor of protecting marine biodiversity and a functioning Arctic Ocean ecosystem.

The Arctic Ocean is an enclosed sea with adjacent subarctic seas where the living marine resources are under the EEZ jurisdictions and management of coastal states. While the multilateral Northeast Atlantic Fisheries Commission has modest jurisdiction into the Arctic no similar regional fisheries management body exists in the western Arctic. The Convention on the Conservation and Management of Pollock Resources in the Bering Sea does play an international role but one that does not extend north of the Bering Strait. The differences between the Antarctic and the Arctic make for widely different management circumstances. The Antarctic is a continental system with a terrestrially dominant core surrounded by the Southern Ocean, while the Arctic is an oceanic system with a deep central basin. The presence of inter-annual sea ice over the Central Arctic Ocean and strong seasonality of sea ice extent in its coastal margins is a major difference from the Antarctic system.

What is to be managed, how to manage, and who to manage are also important differences between the Antarctic and Arctic situations. Management for the Southern Ocean living marine resources is outside the national jurisdiction of any country (leaving aside putative interests of Antarctic claimants). In the Antarctic an inclusive approach is taken with respect to participation and resources are shared under conservative management guidelines. In the Arctic more than 80% of the area falls under national jurisdictions of five coastal states. The CAO basin outside of national jurisdiction is currently covered with ice year round and not subject to exploitation. In fact, it is not clear when ice conditions would allow fishing to take place assuming that there would be commercial quantities and values of fish to catch.

The five coastal states have signed the Ilulissat Declaration (2008) asserting their sovereign rights and affirming their intent to maintain coastal state jurisdictions over their EEZ under the 1982 United Nations Convention on the Law of the Sea (Berkman and Young 2009). In view of the approximately 20 per cent of the Arctic Ocean ecosystem that lies beyond limits of national jurisdiction, the parties to the Ilulissat Declaration state their view that, "This framework (of existing national and international laws) provides a solid foundation for responsible management by the five coastal states and other users of the Ocean…" and continues, "We therefore see no need to develop a new comprehensive international legal regime to govern the Arctic Ocean. We will keep abreast of the developments of the Arctic Ocean and continue to implement appropriate measures." Thus, there is confidence that for living marine resources, the components of the existing framework (LOSC, CITES, CBD, FAO Agreements, etc.) are, taken together, an adequate framework for management.

It is possible to construct multiple scenarios on how to manage marine living resources in the Arctic Ocean (e.g., Brigham 2007). Certainly, coastal states with their extensive EEZs will want to have a very strong say in whatever arrangements are proposed for the CAO and they are not likely to be receptive to non-coastal state involvement in their EEZs unless there is a clear scientific, economic, or political advantage. Besides their proprietary interests and other obligations under international law (which also reserves their rights in the EEZ) it is unlikely that coastal states will welcome other nations to their waters. Indeed, as is seen in the approaches to the other areas of high seas areas in the Arctic surrounded by coastal state jurisdictions, there is a very strong interest to restrict "foreign" activities for purposes of conservation and allocation.

Do non-coastal state interests want direct access to fisheries resources? The answer is probably no for a number of very practical reasons. First, the likely cost of participating in Arctic Ocean fisheries is high and so are the risks. Second, there is high uncertainty about the nature of the resources to be exploited and their abundance. Indirectly, it is possible that non-Arctic coastal states may want to assert their readiness to participate in Arctic living marine resource management from a scientific perspective as contributing to the acquisition of knowledge about the global oceans as is evident in contributions by such states in Antarctic affairs.

It might be appropriate to view the interest of North Pacific Rim states in potential fisheries as quite logical in terms of current fisheries in the Bering Sea and how they might change as a result of climate change. China, Japan, and Korea are major markets and consumers of the current suite of fisheries harvests in the Bering Sea, for example. In addition, it is entirely appropriate for them to want to anticipate changes in abundance or distribution from potential new fisheries that would affect consumption and economic activity. It is not clear that Pacific Rim nations expect opportunities to develop that would allow direct harvesting of living marine resources. However, it is likely that they might be willing to contribute to scientific research and monitoring in the Arctic and to the provision of equipment and infrastructure to track changes in availability of fisheries resources for consumption. Within the realm of accepting the roles of engagement in developing scientific understanding of the interacting Arctic ecosystem, Pacific Rim states could have considerable roles to play.

With respect to the development of scientific understanding, North Pacific Rim states have demonstrated significant commitments and resources to attempting to understand the change in walleye pollock abundance in the "Donut Hole" area in the central Bering Sea (Bailey 2011). Hokkaido University's R/V Hakuho Maru representing Japan has been a consistent and innovative research and monitoring partner in the Eastern Bering Sea for many years. There have been important official and informal arrangements for marine research that have benefited scientific understanding in the western subarctic and Arctic. The Pacific Arctic Group (PAG) notes members from North Pacific states and documents scientific contributions including the construction of icebreakers for research by Japan (RV Mirai Maru) Korea (RV Araon) and China (RV Xuelong) and Japan's investment in a four-year Arctic ecosystem program.[6] The PAG has been working collaboratively with the Marine Working Group of the International Arctic Science Committee (IASC) has been linking international Arctic programs for the past decade, with recent connectivity with PICES through the Ecosystem Studies of Sub-Arctic Seas (ESSAS) program.

The formation of PICES through the efforts of North Pacific Rim nations has brought significant focus on North Pacific ecosystem research and attention is shifting to the Arctic as well through joint engagement among PICES scientists and their ICES counterparts (ICES/PICES 2010).

An important question needs to be answered with respect to North Pacific Rim engagement in marine science in the Arctic. That is, should the North Pacific Rim be the focus or should the focus be broader as seen in the previous Arctic Ocean Sciences Board (now the Marine Working Group of IASC) where all Pacific Rim nations are represented along with their European counterparts? Similarly, are there other countries, namely Brazil and India who want to be players in the Arctic but are not part of any of these endeavors so far? How should they be engaged? The point here is that it is unlikely that participation in scientific and other enterprises can or should be limited to any particular suite of states. If open to all, what framework is productive and equitable for scientific progress irrespective of access to any commercial resource?

One approach for non-coastal states is to apply for status as an observer for the Arctic Council. Observer status is available to non-Arctic states, inter-governmental and inter-parliamentary organizations, global and regional as well as non-governmental organizations. In addition, an observer role is available if the governments or organizations meet certain criteria and this status allows them certain limited roles. Nine intergovernmental organizations have been granted observer status as well as eleven non-governmental organizations. So far there are six non-Arctic countries that have observer status however not one of them is from the North Pacific rim. North Pacific states have applied for this status but have not been approved to date.

North Pacific Rim nations are members of PICES and have had significant roles to play in development of scientific understanding of the North Pacific (Bering Sea) and the Arctic Ocean (PICES 2010). Similarly, all Pacific Rim Nations are members of the Arctic Ocean Sciences Board (AOSB) (now the Marine Working Group of IASC). Through actions of the (AOSB) Pacific Rim Nations are able to join their European counterparts in developing scientific proposals, research and action to influence scientific considerations.

It goes without saying that Pacific Rim Nations can take initiative individually or as a group to organize scientific enterprise in the Arctic Ocean High Sea area or to collaborate with coastal states in performing research and assessments within coastal state jurisdiction. Regardless of any official sanction, Pacific Rim States can advocate for specific issues [to be determined] in any Arctic forum to which it is invited or has a stake.

Within fisheries management, sectoral management at the national level is likely to remain critical. It can be argued that coastal state and international arrangements under the Law of the Sea Convention III are adequate for dealing with future management needs in the near term and possibly the long term. Some initiatives are being taken, e.g., the United States (not a signatory of the LOSC) is promoting a coastal state regional fisheries management organization for highly migratory and transboundary fish stocks in the Arctic (Senate Joint Resolution 17 110th Congress, 1st Session, August 7, 2007). The European Union and others have suggested that NEAFC could be expanded into an International regional fishery management organization for the Arctic. There has been talk of a UN General Assembly resolution on the Arctic Ocean as well as suggestions that a regional seas approach (broader than just fisheries) could be considered. Thus, the field is broadly open for discussion and debate over the pros and cons of different approaches for management in the fisheries sector.

The views expressed above by the five coastal states in the Ilulissat Declaration are not shared universally. Young (See chapter 6 by Young this volume) terms the stance of the Arctic States as untenable. Potts and Scholfield (2008) and the World Wildlife Fund (Koivurova and Molenaar 2010) argue along other lines that there are serious gaps in the management approach to the Arctic in the different national regulations and in necessary international cooperation. Besides, the interests of non-Arctic states in protection of the Arctic from inappropriate development are not considered.

There is no objective answer to this divide over whether a new comprehensive Arctic Convention is needed or if existing arrangement and modifications to them would suffice. Proponents of the comprehensive-inclusive approach state that such an approach is proactive in light of the rapid environmental change occurring in the Arctic Ocean and the surge in new resource uses. They argue that such a treaty would lead to a better balance of interests and avoid conflicts. More philosophical claims are made about the Arctic Ocean being part of the common or natural heritage of mankind.

To these claims others reply that the transaction costs of reaching agreement would be too high, that national sovereignty would be diminished, that all problems and conflicts cannot be anticipated or resolved, etc. Further, much of the high-level debate moves forward without recognition of the engagement of indigenous peoples and the impacts of proposed measures, such as development or protection, on their livelihoods and communities. I think it fair to observe that the more closely one is engaged in day-to-day management of any Arctic resource, the less excited one is a bout comprehensive management approaches and the less one has to do with management, the more attractive comprehensive solutions appear.

One very interesting development along the lines of comprehensive or integrated management is the development at a national or sub-national regional level of marine spatial plans. Norway has marine spatial plans for the Barents[7] and Norwegian Seas[8] and Canada has recently instituted a Large Ocean Management Area for the Beaufort Sea[9]. The United States is embarking on ecosystem-based management framework for the Alaska Arctic[10] (ELI 2008). It is not known to the author if such plans are being developed in Russia or Greenland. These planning processes are consistent with the development of the necessary Arctic Ocean regime that is being advised (See chapter by Young this volume). Would the sum of the parts of a national marine spatial plan equal a successful national or coupled-international regime for Arctic management? That is an interesting question which can be answered in many ways. In any case, such an approach would appear to be movement in the direction of more coordinated management of different sectors in the Arctic than at present.

When considering more comprehensive type arrangements for development and conservation in the Arctic Region, the Arctic Council is frequently examined as a core institution to “grow” into larger roles. Even its strongest supporters are not sanguine about it being able to move from a convener and consensus building advisory body into a regional management authority. That would require amendment of its fundamental agreement. Others suggest it necessary to jettison the Arctic Council and to develop a new legal and institutional authority legally binding across multiple sectors and involving a broad international community of states in decision making (Koivurova and Molenaar 2010).

If comprehensive management approaches are not agreed upon as either desirable or necessary by all parties, can there be agreement on measures taken at the sector level and across sectors that will improve management by implementing a long-term sustainable ecosystem-based management approach? Berkman and Young (2009) offer the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) as a partial precedent for the Arctic Ocean ecosystem because of the applicability and interest in ecosystem-based management and precautionary approach. The goal and commitment of parties to scientific cooperation under CCAMLR is seen as appropriate but other factors appear to mediate against fully adopting the CCAMLR approach for the Arctic Ocean. Therefore, Berkman and Young (2009) advocate that, "One useful approach in developing effective governance for a rapidly changing Arctic may be to treat the Central Arctic Ocean as an international space and to draw a clear distinction between the overlying water column and the seafloor. Ecologically and legally distinct from the seafloor, the overlying water column and sea surface of the central Arctic can remain an undisputed international area in which the interests of Arctic and non-Arctic states alike play a role in effective governance" (340).

In this way, it would appear that recognition of an emerging regime complex as defined by the number of issues being addressed through different but related governance arrangements could increase participation, transparency, and coordination but would not engage in management decisions per se. Important official and informal arrangements for marine research, for example have benefited scientific understanding of living marine resources and their management in the Arctic Ocean. Perhaps the best documentation of such progress across the Arctic Ocean is in the report "Best Practices in Ecosystem-based Oceans Management in the Arctic" (Hoel 2009). The Pacific Arctic Group (PAG) is another example where its members are from North Pacific states that engage in scientific contributions including the construction of icebreakers for research by Japan (R/V Mirai Maru, Korea (R/V Araon) and China (R/V Xuelong) as well as Japan's investment in a four-year Arctic ecosystem program.[11] The PAG has been working collaboratively with the Marine Working Group of the International Arctic Science Committee (IASC) which has been linking international Arctic programs for the past decade, including the recent connectivity with PICES and ICES through the Ecosystem Studies of Sub-Arctic Seas (ESSAS) program.

As noted by Young (See chapter by Young this volume) informal consultation mechanisms might be used to foster the dialogue required to engage a broad spectrum of users, managers, scientists and interested citizens in the development of the conditions for a regime complex. A formal Arctic Ocean Forum could serve to promote and accommodate this function. The analytical and pragmatic question that continues to nag is whether or not the Arctic five states (A5) would be willing to participate in such an inclusive forum as opposed to designing its own forum centered on national sovereignty in living marine resource management. With the Ilulissat Declaration it appears the A5 group has indicated its preference.

If comprehensive new arrangements are not seen as feasible and an inclusive participatory approach to developing a complex regime is not accepted by the Arctic Ocean coastal states, it is useful to review how existing arrangements are working for the management of living marine resources in the Arctic Ocean and subarctic seas.

Relative to fisheries, it should be recalled that coastal state management of EEZ fisheries among the A5 shows that in general management is ranked highly on a global standard. This is not to say that there is no room for improvement. Presently there is evidence that fisheries managers in areas where sea ice is receding are adopting proactive measures to limit or prohibit fisheries until scientific research is available to identify appropriate management measures. This is consistent with the goal and approach identified as desirable under CCAMLR even though developments may be more ad hoc and uncoordinated across Arctic Ocean states. Existing subsistence fisheries and hunting are likely to continue to the extent they make sense as traditional practices, climate change does not significantly impact them, and globalization does not alter local economy. Local knowledge of these hunting and fishing practices is needed to assess their status and likelihood to change across the Arctic region.

Three examples of how a living marine resources portfolio regime might evolve have been proposed including negotiation of a Central Bering Sea pollock conservation type approach for long term precautionary management of the Central Arctic Ocean high seas area; a community development quota approach for coastal indigenous peoples and; bi—or multilateral fisheries agreements in the Western Arctic.

Central Arctic Ocean high seas

It is fairly clear that Arctic Ocean coast states are unlikely to invite others to participate in their EEZ fisheries. Whether or not there will be commercial quantities of fish in the CAO is a matter of considerable speculation. If it is decided that some kind of international mechanism is useful in terms of conservation of fish stocks in the area outside of national jurisdiction in the Arctic it might be seen that a Central Bering Sea "Donut Hole" agreement might emerge where coastal states agree to regional management subject to shared and straddling stock agreements under the LOSC and FAO arrangements. While the EU has suggested an expansion of NEAFC as a management entity in the CAO, I doubt that expansion of NEAFC authority would be considered appropriate—especially by Western Arctic interests. The starting point for such a CAO agreement would be quite different from other similar arrangements in the subarctic because the incentive to conserve existing transboundary fish stocks does not exist. Should a modified form of the Central Bering Sea agreement be considered, the main point would be the incentive to participate in and funding for research and monitoring of a changing Arctic Ocean to determine when commercial fisheries could be opened, if at all. Such an arrangement would ensure transparency in the science and allow participation by any state willing to assume certain scientific responsibilities.

The Central Bering Sea pollock convention is predicated on the idea that the super abundant pollock stocks in the region prior to the time of negotiation will eventually reappear. This hope has persevered and the annual scientific meetings have been a principal way international science has been focused on that area. A strength of the Central Bering Sea convention is that it sets forth decision rules about when there is sufficient resource abundance for a fishery to take place. How this could be done under the uncertainties of climate change is daunting.

If purposive scientific research on the potential fisheries in the CAO is to the primary intent of a high seas agreement, one must ask if that is the best way to organize scientific collaboration. Given the circumpolar ecosystem interaction, the Arctic Council and other organizations with longstanding roles and working groups may provide a better institutional structure than a separate scientific agreement on the CAO. Continued investment in Arctic Ocean ecosystem science might be more successful if the fisheries questions—especially transboundary and emerging fisheries—are a "bycatch" of more integrated scientific cooperation across scales.

Community development quota-inspired indigenous fisheries

The Community Development Quota (CDQ) Program is a place-based approach to fishery management that links the interests of small coastal communities along the Bering Sea coast with commercial fishing enterprises for the large scale fisheries of the Bering Sea. At present, this quota is 10% of the total allowable catch for each managed species in the Northeast Bering Sea. This program is seen as highly successful (NRC 1999b). However, to apply this to the Arctic is unrealistic for a number of reasons. The short answer is that there are no commercial fisheries in the Arctic Ocean at present. However, a dedicated anticipatory approach for fisheries that allows coastal communities a preference in development of commercial fisheries might be contemplated. The place-based and subsistence nature of current fisheries and the local knowledge of Arctic communities would be invaluable if significant fisheries abundance develops in coastal areas. In addition, if opportunities to develop guided and chartered operations for recreational fisheries and tourism occur, consideration of a place-based preference might work to the benefit of indigenous communities.

Bilateral-multilateral agreements for the Western Pacific

Transboundary and straddling stocks of fish in the Arctic Ocean are poorly known–largely due to the difficulty of performing research in the Arctic and the short seasonal nature of the window for research cruises. Cooperative research is underway between the US, Canada and Russia to better understand these relationships. The open Arctic sea areas between Norway and Russia and the significant and well-documented transboundary movements of fish have produced effective bilateral management under treaties. Should a need arise, the Norway-Russia model could be useful for similar arrangements in the Western Arctic.

Other living marine resource management approaches

Other living marine resources like seabirds, marine mammals and polar bears and the other components of marine biodiversity illustrate other ways that Arctic Ocean coastal states working with others might evolve an effective regime.

From the standpoint of seabirds, there appears to be a loosely organized and somewhat effective system of protection of feeding and breeding habitat throughout their international flyways. Current international agreements link northern countries with southern countries largely incorporating the flyways as an organizing principle, e.g., Migratory Bird Treaty (US/Canada/Mexico). Already, national and international monitoring of seabirds is well-organized for the Arctic in the Circumpolar Biodiversity Monitoring Program as part of the biodiversity working group Conservation of Arctic Flora and Fauna (CAFF) of the Arctic Council. However, I am not confident that monitoring is adequate for the southern portion of the range. The critical question appears to be how well states adhere to their obligations–especially the commitment to protect important habitats for feeding and breeding and areas along migratory corridors. It is not apparent that new agreements are necessary at this time as much as ensuring the capacity and engagement of countries along the flyways to maintain and monitor the habitats. While the climate changes affecting seabirds in the Arctic may be dramatic, they may be less of a threat to seabird survival than other drivers of habitat change in other parts of the range like pollution and loss of habitat.

Marine mammals receive significant protections by Arctic Ocean coastal states and harvests are strictly controlled. In the North Atlantic, NAMMCO provides a forum for international engagement whereas no similar organization exists in the Bering Sea or Western Arctic. Scientific research and monitoring is performed at the national level and internationally through CAFF. Some of the results of this monitoring point to serious declines in some species, such as walruses, Steller sea lions, and ice dependent seals. Management action at the national level appears capable to address the impacts of direct harvest and harassment, but indirect impacts from climate change and toxic contaminants require international attention. While the proximate drivers of marine mammal populations may be adequately managed by the existing national regime, a broader international interest in protection of the Arctic marine mammals might not be welcome if it would interfere with continued harvest of seals for fur and other commercial uses, the culling of seals as a fishery management measure, or the determination of what constitutes optimum populations.

Cetaceans in the Arctic Ocean are more mobile than the seals and with changing climate more northern species of whales may migrate into the Arctic Ocean. The IWC was set up to manage these species throughout their range and perform that function for indigenous whaling in the Bering Sea. Commercial whaling by Norway and Iceland is managed by those countries. The IWC quota management system appears to be scientifically robust with respect to the Arctic whales. In the Southern Ocean, IWC is involved in efforts to establish whale sanctuaries and other large marine protected areas but because of the EEZs of Arctic Ocean coastal states such protection areas fall under national jurisdictions. Thus, there does not seem to be a specific need for a comprehensive treaty in the Arctic Ocean to manage whales although as with seals potential differences among risk tolerance or value preferences in the broader international community may exist.

Polar bears are protected in Arctic Ocean coastal states by international convention. While polar bears are seen internationally as icons of the Arctic and there is great concern being expressed about their fate as a result of climate change, there does not appear to be a strong demand for changing the polar bear treaty or substituting some other form of management. The Arctic Ocean coastal states would assert that this shows that polar bears are well-managed. Of course, it is also possible to think that under a comprehensive international treaty there could be differences of opinion over harvest management.

With respect to marine biodiversity in the Arctic Ocean it is possible to examine management from at least two perspectives. First, and the one with which we are the most comfortable, is a static view of the Arctic and its living marine resources. The second, with which we have not come to terms, is what research and modeling is insisting will be the future of Arctic biodiversity, i.e., vast changes in the species and the populations of existing species. From either standpoint, Arctic Ocean coastal states are not in much of a position to manage these changes by management measures to maintain the status quo. However, management must adapt to changes. The largely nation-based management of marine biodiversity among Arctic Ocean coastal states incorporates specific conservative measures and monitoring for fisheries, marine mammals, seabirds, and cumulatively for marine biodiversity. Such measures make for a more resilient approach to detecting and coping with rapid change in the Arctic Ocean.

In wrapping up this section, it is critical to understand that management measures for living marine resources are not adequate to protect marine biota from a catastrophic oil spill or other pollution associated with increased economic activity in the Arctic. Thus, the question of how to ensure protective and balanced management across all sectors is why some advocate for a comprehensive Arctic Ocean agreement. Earlier, we discussed the response of Arctic Ocean coastal states to utilize marine spatial planning within their EEZs to accomplish this purpose. It seems a more likely response by these countries than agreement on a new comprehensive treaty.

In conclusion, the purpose of this chapter is to provide a background for planning for North Pacific Rim countries to promote informal consultation and to consider how to convey the results of these consultations to other Arctic forums. In this examination, the opportunity for coastal and non-coastal states to perform research and monitoring of the Arctic Ocean ecosystem is clearly a most active and productive way to engage. Major changes are likely in the subarctic seas and the Arctic Ocean in ways that affect fisheries production, seabirds, marine mammals, polar bears, and marine biodiversity. Active monitoring is a good way to provide transparency in developments in the Arctic ecosystem with respect to commercial uses however the likelihood of major new fisheries developing is marginal especially within the CAO.

With respect to management of the living marine resources in the Arctic, coastal state signatories of the Ilulissat Declaration have sought to inform the international community that it can trust in the management measures they have and can further develop. Promoting formal and informal mechanisms for performing research and monitoring is a good way for the international community to evaluate whether or not that trust is warranted. When over 2,000 scientists from 67 nations signed on to a letter calling for the international community to develop an international fisheries agreement to protect the CAO in advance of prospective fisheries[12] the high level of scrutiny and interest was clearly communicated. Some saw this as a building block toward broader protection measures for the Arctic regions (Rogers 2012). The response from governments has been slow and muted.

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Notes

1. See Koivurova and Molenaar (2010) for a recent detailed accounting and Brander (2007) for a global context
2. http://www.commerce.state.ak.us/dca/planning/cciap/ArcticEcosystemintegrated Survey.htm
3. http://caff.arcticportal.org/expert-groups/seabird-group-cbird
4. www.iwcoffice.org
5. Natural disasters like a huge volcanic eruption or comet impact could also precipitate abrupt climate change.
6. http://pag.arctiporal.org/
7. www.regjeringen.no/../updated-version-of-the-integreatee-management-plans.html/
8. www.fisheries.no/resource-management/Area-management/Integrated-management-plan/
9. www.beaufortseapartnership.co/
10. www.doi.go/new/pressreleasesMarch 6, 2012
11. http://pag.arctiportal.org
12. Pew Environmental Group www.oceansnorth.org/arctic-fisheries-letter, last ac cessed August 1, 2012

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Comments on Chapter 4: Scientific perspective

Alf Håkon Hoel

INTRODUCTION

There are currently no fish stocks of commercial interest in the Central Arctic Ocean. The reasons for this include ice cover, low water temperatures, and low primary production. In the sub-Arctic seas surrounding the Arctic Ocean, there are commercial fisheries of global importance (Hoel and Vilhjamsson 2005). These areas comprise the Bering Sea and the Aleutian Islands, the Northwest Atlantic between Canada and Greenland, the waters around Greenland and Iceland, the Norwegian Sea, and the Barents Sea. The marine ecosystems in these oceans are subject to substantial natural variability (Arctic Ocean Review 2011), as well as to major fisheries. In a global perspective, most of the major commercial fisheries in these areas are currently well managed.

There are six littoral states to the Arctic and the sub-Arctic oceans: Russia, the US, Canada, Denmark/Greenland/Faroe Islands, Iceland and Norway. Except for areas of high seas (areas beyond national jurisdiction), the northern oceans are under the jurisdiction of these countries. The high seas areas are in the Bering Sea, the Northwest Atlantic, the Norwegian Sea, and the Barents Sea. There is also an ice-covered area of high seas in the central Arctic Ocean, where the coastal states are the US, Canada, Denmark/Greenland, Norway and Russia.

THE FISHERIES

Some of the world's largest commercial fisheries take place in the oceans surrounding the Arctic. Alaska (walleye) pollock Theragra chalcogramma in the Bering Sea and Aleutian Islands has TAC levels in 2012 of approximately 1.2 million tons. In the Barents Sea, North Atlantic cod Gadus morhua have a TAC in 2012 of 750,000 tons, with up to 1 million tons indicated for 2013. Herring Clupea harengus in the Norwegian Sea has a TAC in 2012 of 833,000 tons. Other important species include redfish Sebastes spp., saithe Pollachius virens, and haddock Melanogrammus aeglefinus. There are also important crab, shrimp and shellfish fisheries in these oceans, as well as a number of marine mammal species.

Due to the warming influence of the Atlantic current, commercial fisheries in the Northeast Atlantic occur up towards the Svalbard Archipelago. In the northwest Atlantic cold currents from the north keep fisheries at more southerly latitudes, while the commercial fisheries in the Bering Sea are limited to the area south of the Bering Strait at 65° N. The fisheries are regionally concentrated and occur mostly in the waters under the jurisdiction of coastal states.

It has been estimated that in the four last decades of the 20th century, the annual average landings of fish from Arctic and sub-Arctic waters were about six million tons (Hoel & Vilhjamsson 2005). In comparison, the total for global marine capture fisheries is now about 80 million tons (FAO 2012). Commercial fisheries in the seas surrounding the

Arctic are therefore globally significant. These fisheries constitute a major economic activity in the high North of these countries, and in many regions they are critical to the economy of local communities (ACIA 2005). The fisheries in the Bering Sea and the Aleutian Islands, for example, provided a value of two billion USD in 2008 (Plan Team 2009).

Commercial and indigenous exploitation of marine mammals takes place in several Arctic countries. In Norway, minke whales and harp seals are exploited, in Iceland minke whales and fin whales are hunted, and in Canada in the Northwest Atlantic harp seals are hunted. In Russia harbor seals in the White Sea are harvested. Inuit in the US, Russia, Alaska, and Greenland hunt a number of whale and seal species.

Aquaculture is of increasing importance in the North. Globally, aquaculture will in the course of the next few years produce more fish than capture fisheries. In Norway, the export value of aquaculture products (mostly salmon) is now larger than those of capture fisheries. With warming oceans and increasing global demand for seafood, we are likely to see an expansion of aquaculture in the North (ACIA 2005). Similarly, marine bioprospecting is likely to increase substantially in importance over the coming years.

THE MANAGEMENT REGIMES

Living marine resources are subject to a comprehensive management regime, with global, regional and national components.

The international legal foundation for fisheries management is the 1982 United Nations Convention on the Law of the Sea (United Nations 1982). The Convention gives coastal states sovereign rights over the natural resources in an Exclusive Economic Zone (EEZ) of 200 nautical miles (370 km), a duty to conserve and the right to utilize fish stocks, and a duty to cooperate with other countries on the management of transboundary fish stocks.

The global fisheries regime has been enhanced by the 1995 UN Fish Stocks Agreement (United Nations 1995), which provides for a precautionary approach in management, improved regional cooperation in the management of fisheries on the high seas, and stricter enforcement of regulations. Also, the UN Food and Agriculture Organization (FAO) has adopted a number of binding as well as non-binding global instruments pertaining to various aspects of fisheries and their management. The most recent is the 2009 Port State Agreement which aims to stop illegal fishing though prevention of landings from such fisheries (FAO 2009). For large cetaceans the International Convention for the Regulation of Whaling has a global application. A number of other global instruments are also relevant for the management of living marine resources in the

Arctic (Arctic Ocean Review 2011).

This global framework applies also in the Arctic, and is implemented by all Arctic Countries (the US, though not a party to the Law of the Sea Convention, nonetheless implements its provisions). The global framework provides principles for management, as for example Maximum Sustainable Yield (MSY), guidelines for deep water fishing, the precautionary approach, the ecosystem approach to fisheries, and more.

At the regional level, a number of important fish stocks in the sub-Arctic are transboundary and shared by two or three countries. In such instances countries cooperate through bilateral agreements on fisheries management, as for example Norway and Russia do in the Barents Sea (Hønneland 2012). Such bi- and trilateral cooperation is a very important feature of the regime complex, and critical decisions on management strategies and annual TAC levels are decided in these bodies.

Where fish stocks also occur on the high seas, regional fisheries management organizations or arrangements (RFMOs/RFMAs) have to be established. In the Northeast Atlantic, the Northeast Atlantic Fisheries Commission (1963/1982) has authority over the high seas areas, including areas beyond national jurisdiction in the European sector of the Arctic Ocean. Salmon fisheries are regulated by the North Atlantic Salmon Organization (NASCO) and marine mammals are managed by the North Atlantic Marine Mammals Commission (NAMMCO). Other regional fisheries arrangements or bodies in the Arctic/sub-Arctic include: The Northwest Atlantic Fisheries Organization (NAFO), and the agreement covering the so-called “Donut Hole” in the Bering Sea.

Fisheries management essentially entails three functions, the implementation of which is critical to the success of resource management:

a) the development of scientific understanding of the stock in question, so as to be able to estimate stock size, assess impacts of the fishery, and provide scientific advice on catch levels,
b) the establishment of regulations in a fishery, so as to limit the impact of the fishery on the resource and the ecosystem, and
c) the enforcement of these regulations.

The ways in which these three functions are institutionalized vary greatly between countries, depending on political systems, whether fish stocks are owned by one state or are transboundary, and regulatory traditions in the coastal states.

In the north Atlantic, the International Council for the Exploration of the Sea (ICES) (1902) plays a critical role in the provision of scientific advice. Based on the work of the marine science institutions in its member states, the North Atlantic coastal states, it provides an international scientific review process and scientific advice on management of the marine environment and its living marine resources to its members, the EU Commission, and the regional fisheries management organizations in the region. (The corresponding organization in the North Pacific, the North Pacific Marine Science Organization, or PICES, does not provide management advice for fisheries.)

As to the regulation of fisheries, the total allowable catches (TACs) are set by the coastal states in the case of exclusive fish stocks (found in the waters of one state). In the case of transboundary fish stocks TACs are set by the various arrangements for international cooperation, as pointed out above. The most important in the oceans surrounding the Arctic Ocean is the Norway-Russia bilateral fisheries commission, which sets quotas for cod, haddock, and capelin (Hønneland 2012), as well as Greenland Halibut. There are a number of such arrangements among the coastal states in the region, as well as regional fisheries management organizations for the high seas areas.

The actual regulation of fisheries is carried out by the coastal states, by regulations limiting participation fisheries, restricting quantities that can be caught, and by providing restrictions on how, when and where a fishery can occur. All Arctic states have comprehensive legislation pertaining to their living marine resources and their management.

The enforcement of fisheries regulations is carried out by the coastal state in the waters under their jurisdiction and by the state whose flag a vessel is carrying on the high seas. Generally enforcement systems have been much strengthened over the last decade, with increased international collaboration and the introduction of satellite-based vessel monitoring systems. Illegal, unregulated, and unreported (IUU) fisheries have in the past been significant in the Arctic, in particular in the high seas areas. Following developments in the Law of the Sea and a substantial improvement in international cooperation, as well as in domestic implementation, IUU fishing now appears to be on the decline in the oceans surrounding the Arctic Ocean. In the Barents Sea, for example, estimated unreported catches have fallen from 90,000 tons in 2002 to 15,000 tons in 2008, and has been close to zero since 2009.

These three management functions of science, regulations, and enforcement are well institutionalized in the Arctic coastal states. While the effectiveness in implementation may vary over time and from country to country, each has developed the institutional structures associated with effective resource management. In particular, each has devised arrangements for rights-based management, providing for allocation of fishing rights among the participants in a fishery. In a recent global study this was found to be a critical determinant of effective fisheries management (Costello et al 2008).

In a global perspective, the major Arctic commercial fisheries currently appear to be relatively well managed. While the status for many commercial stocks (about one third) globally leaves a lot to be desired (FAO 2012), the status of the major sub-Arctic fish stocks is generally good. The reports of the International Council for the Exploration of the Sea in the case of the Barents Sea and Norwegian Sea demonstrates this for major fish stocks such as cod, and haddock (ICES 2012). For the Bering Sea and Aleutian Islands the report of the Plan Team preparing the scientific groundwork for the North Pacific Fisheries Management Council states that "Overall, the status of the stocks continues to appear relatively favorable. No groundfish stocks are overfished" (Plan Team 2009). Also, several major fisheries (e.g., Alaskan pollock and Norwegian spring-spawning herring) in the oceans surrounding the Arctic Ocean are certified by the Marine Stewardship Council, which provides an independent, science based assessment of fisheries.

There are, however, also examples of management failure in the seas surrounding the Arctic Ocean. In the late 1960s Norwegian spring-spawning herring was heavily overfished, necessitating a more than 20-year re-building period before the stock recovered. Today it is one of the world's largest fish stocks and sustains one of the world's largest fisheries. Another example of management failure is that of northwest Atlantic cod, which collapsed in the early 1990s and has not since recovered. In the Barents Sea, for example, cod was severely overfished in the 1980s, leading to an extended rebuilding period.

The lesson learnt from this was that fishing pressure had to be reduced, by employing a precautionary approach to management and reducing the catch capacity of the fishing fleet. A recent challenge to management regimes are alien species. One example is king crab, which is not an endemic species in the Northeast Atlantic. It was introduced into Russian waters in the 1960s and in recent years the stock has expanded vastly, providing for a substantial coastal fishery as well as causing changes in near-shore ecosystems.

FUTURE DEVELOPMENTS

The Arctic Climate Impact Assessment (ACIA 2005) had two broad conclusions regarding the future development of living marine resources and fisheries in the Arctic: one was that of a general expansion of fisheries due to increased growth, including a northward expansion. The other was that the critical factor in determining the future development for fisheries was fisheries management.

In the years that have passed since, the research into these issues has grown exponentially, and the understanding of our ignorance has grown correspondingly. Uncertainties abound, and the complexity of the questions involved is substantial. It is therefore simplistic to assume that there will be a simple, linear response in fish stocks to increased temperatures. The effects of climate change on marine ecosystems are manifold and complex. Major changes in density and distribution of species can trigger significant changes in ecosystem structures, with positive or negative consequences for commercial fisheries (Loeng 2008). In the Arctic, marine ecosystems are subject to large natural variability. This variablity, and the added stress induced by anthropogenic influences such as climate change, affects plankton, fish, and marine mammals. So not only fish, but also the prey fish feed on as well as those animals that feed on fish are affected. The effects of such pressures on the geographic distribution of living marine resources depends upon a number of factors, such as bottom topography (see the map, below), climatic parameters as temperature, salinity, and ice distribution, the availability of food, distance to spawning grounds, and others.

In the face of such complexities, robust predictions of future developments are difficult. What we do know, based on past experience, is that the geographical distribution of fish stocks tend to change over time, and we know that climatic factors are associated with such changes (Toresen and Østvedt 2000). One example, discussed in the fisheries chapter of the Arctic Climate Impact Assessment (Vilhjamsson and Hoel 2005), is from Greenland. A warm climate during the 1930s and 1940s led to a substantial cod fishery off Greenland. With the onset of a cooling climate in the 1960s this fishery disappeared. Another example of a fish stock with major changes in its geographical distribution over time is Norwegian spring spawning herring (Holst et al 2004). We do expect that such changes will continue. All major stocks are fully exploited and likely to remain so even though their geographical distribution changes.

As regards the other ACIA prediction, that the critical factor in the future development of fisheries in the North will be the robustness and performance of management regimes, the current development towards ecosystem-based management of the marine environment in general, and towards ecosystem approaches to fisheries in particular, are important. At the general level, ecosystem-based management holds considerable promise as a strategy to confront the challenges to oceans management associated with climate change (Hoel and Olsen 2012).

The development towards an ecosystem approach to fisheries (FAO 2003) essentially means that its management has to be considered in relation to its environment: how the environment affects the fish stock in question, and how the fishery affects the environment (Pikitch et al 2004). Ecosystem-based fisheries management is a process of developing new practices on the basis of existing ones, rather than devising entirely new approaches in a short time. Many countries are now in the process of developing their policies in this regard and implementing them (Murawski 2007).

In the Arctic countries, fisheries management is therefore gradually being developed to take ecosystem considerations into concern. This has implications for the management functions addressed above:

The science underlying the management of a fish stock are expanded so as to include information on how environmental factors are likely to affect a fishery, as well as information on how the fishery will impact on its environment. Research surveys, which used to be oriented towards monitoring the status of specific commercial fish species, nowadays routinely monitor a whole suite of environmental parameters, non-commercial species, as well as commercial species. The Norway-Russia annual ecosystem surveys of the Barents Sea are a case in point.

For the regulation of a fishery, an ecosystem approach likewise entails that the restrictions set on a fishery have to be configured so as to take the impact of environmental factors into account, as for example changes in water temperatures. At the same time, the impacts of the fishery on the ecosystem have to be minimized, for example by placing restrictions on the type of gear that can be employed in a given area. For bottom trawling, for instance, this means that its impact on benthic communities has to be considered when establishing management measures. An example of how this is done in practice can be found in the scientific background material for the Bering Sea, which contains explicit ecosystem considerations (Witherell et al. 2000, Plan Team 2009). Also, countries are becoming increasingly restrictive with regard to trawling in vulnerable marine ecosystems (VMEs). The Northeast Atlantic Fisheries Commission, for example, has introduced a series of measures to protect VMEs in the high seas in that region the last decade.

These developments in management approaches take place in the context of ambitious schemes to develop ecosystem-based oceans management. This is a global process, and the Arctic countries are at the forefront of these developments (Hoel 2009). At the ministerial meeting of the Arctic Council in April 2009, a set of "Observed Best Practices in Ecosystem-based Oceans Management in the Arctic Countries" was endorsed. At the 2011 ministerial an ecosystem management expert group was appointed, to look into ways to develop ecosystem-based management in Arctic regions further.

The reduction of sea ice in the Central Arctic Ocean has brought speculation that substantial fisheries may develop there. In discussing such a scenario, the following elements should be borne in mind:

- The Central Arctic Ocean will remain ice-covered for most of the year.

- Most of the Arctic Ocean is under the jurisdiction of the coastal states, and subject to an extensive management regime complex.
- The high seas area beyond national jurisdiction is subject to the law of the sea as well as a number of global instruments, both legally binding and non-binding. The European sector of the high seas is a NEAFC regulatory area, while the western Arctic high seas area does not have a regional fisheries management body.

In 2009, in the margins of the biannual meeting of the FAO Committee of Fisheries, a meeting was held to discuss Arctic fisheries upon the initiative of the US. The US also hosted a conference on Arctic fisheries in the fall the same year. In 2010, the five Arctic coastal states to the Central Arctic Ocean met in Oslo to discuss the future of the management of living marine resources in the Arctic, in light of their responsibilities as coastal states. The main conclusion of that meeting was it was necessary to have a better understanding of the status of marine ecosystems in the Central Arctic Ocean and the living marine resources there.

As a follow-up of the Oslo meeting, a scientific workshop was convened in Anchorage in 2011 to discuss the status of knowledge of these issues, on-going scientific efforts, and research priorities. The workshop demonstrated that while some areas in the sub-Arctic have been subject to intensive scientific research for many decades, others are not as well covered. As regards the Central Arctic Ocean to the north of the continents, the status of scientific understanding is limited. The number one priority identified by the workshop was the establishment of baseline data (at a pan-Arctic level) on plankton, fish, invertebrates, and marine mammals as well as associated physical factors. The scientific cooperation on such issues will be pursued in a number of forums. ICES and PICES will be the most prominent, ICES in particular given its advisory role in the management of living marine resources in the Northeast Atlantic and the role of its Arctic Fisheries Working Group in that regard. There are also a number of other forums where the scientific aspects of climate and fisheries in the Arctic is pursued, such as ESSAS program,[1] as well as others.

CONCLUSIONS

We have reviewed the status of fisheries in the Arctic, and pointed out that while there are virtually no commercial fisheries in the Central Arctic Ocean, the sub-Arctic seas have globally significant commercial fisheries. These fisheries are subject to comprehensive management, through a regime complex consisting of global, regional and national components. The performance fisheries management in the Arctic and sub-Arctic is generally good, and stands out in a global perspective.

Future developments are difficult to predict, but possible changes in geographic distribution of fish stocks are likely–such changes have been occurring throughout known history. The ability of the Arctic states to meet such challenges in the future will require further development of management regimes. Further development of the ecosystem approach to fisheries is critical in that regard. The Arctic coastal states have also initiated a process to study the developments of living marine resources and associated elements of marine ecosystems in the Central Arctic Ocean, and ICES and PICES as well as other scientific forums will have important roles in that regard.

Beyond this, the future of Arctic living marine resources management is likely to be increasingly affected by the growing importance of aquaculture, which may well at some point become more important than capture fisheries in terms of economic value. This would be a reflection of a global trend, already evident in Norway. Also, marine bio-prospecting is growing in economic importance and may well become the third, major area of living marine resources management in the North.

Notes

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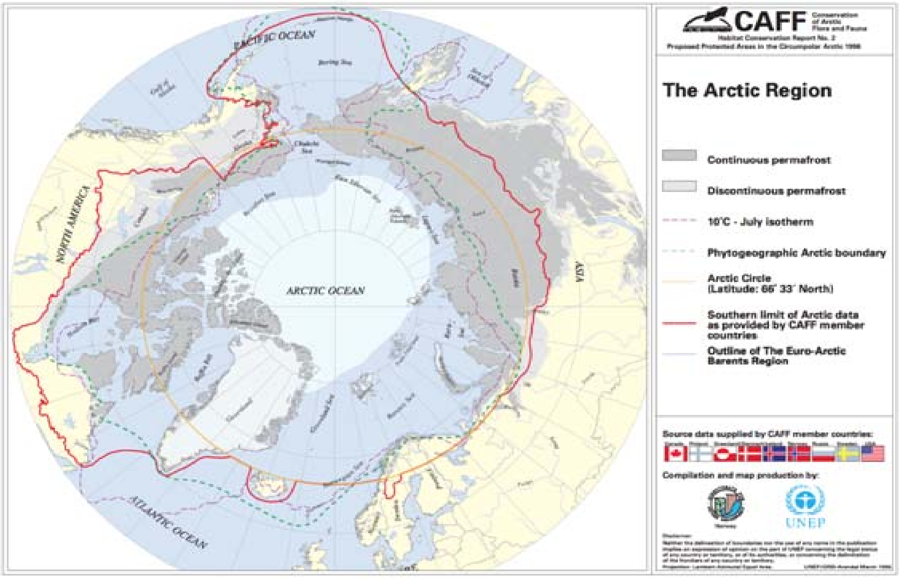

Comments on Chapter 4: Ecosystem and Inuit perspective

Trevor Taylor

Since the advent of the factory freezer trawler in the late 1940s, the development of the industrial deep-sea fishing fleets has left few areas of the world's oceans off limits. The transformation was rather swift for fisheries that were for the most part prosecuted by fixed gear, primarily in the shallower water areas of the continental shelves. Those somewhat seasonal fisheries in northern regions were available to access during that part of the year when the ocean was not covered by ice, but are now fisheries prosecuted to the depths of fish habitation, limited only by the determination of the vessels masters.

Most fisheries conducted during the 1950s, 1960s and 1970s took place in the absence of significant scientific research of the sort that provides accurate stock abundance estimates, recruitment projections and interspecies dependencies. They also took place in the absence of almost any effective management and regulatory oversight.

In the late 1970s as many coastal states declared their 200 mile exclusive economic zones (EEZ's), the situation started to change. With a few notable exceptions the 200-mile EEZs captured most of the continental shelves adjacent to the coastal states and increased regulation, scientific research and management began to take shape.

The areas outside the EEZs however continued to be subject to little research and regulation. Deep sea distant water fleets continued their unregulated fishing in these international waters with little regard for stock status or conservation. In many cases stocks were depleted before adjacent coastal states could convince the offending parties of the need for catch limits aimed at the long term preservation of the stock and thereby the fishery. In this region we need look no further than the Bering Sea Donut Hole between the USA and Russia to see the effects of unregulated fishing on pollock in international waters. Only after the stock was depleted could the various nations involved agree to put a management regime in place to protect what was left of a once great stock of fish.

Fortunately, during this period of intense unregulated fishing in international waters one region of the world's oceans has remained off limits. Covered by permanent sea ice for most of the last 800,000 years, the international waters of the Central Arctic Ocean have been protected from incursion by fishing fleets in search of new grounds and new stocks of fish. The protection of permanent sea ice has allowed an ecosystem to survive and produce some of this world's most fascinating and awe inspiring animals. The abundant Arctic cod have provided the narwhal, bowhead, beluga, humpback and polar bears with the nourishment to survive in one of the world's harshest environments. In turn, these marine mammals have provided sustenance, clothing, shelter and means of transportation for the Arctic marine peoples, the Inuit of Northern Canada, Alaska, Greenland, Russia and Siberia. It is hardly an overstatement to say that the Inuit of the Arctic could not have survived in this region without the continued health of the living marine resources of the Arctic Ocean.

The Arctic and its ocean, however, are changing. The high seas area of the Arctic Ocean, (that is, the area outside the northern maritime boundary of the five Arctic coastal states), encompasses 2.8 million square kilometers, an area the size of the Mediterranean Sea. Over the course of a decade, the international waters of the Arctic Ocean have gone from a virtually impenetrable block of multi-year sea ice to a low point in 2007 where 40% of the area was open water. That area of open water was 1.1 million square kilometers, roughly the size of the Norwegian Sea. The trend towards more open water in this area is expected to continue into the future. Significant areas of fishable depth, particularly the Chukchi Plateau, north of the territorial waters of Russia, the United States, and Canada have seen the most open water at the end of the summer melt season. At its low point in 2007, the open water area included 476,000 square kilometers of ocean that could be considered of fishable depth, (less than 1000 meters depth). Most of this area is adjacent to the rich fishing grounds of the Bering Strait and it is reasonable to expect that in the future, fishing fleets will explore these depths for fishing opportunities. Already, at the other end of the globe, fishing fleets are pursuing fisheries for the bottom of the food chain, fishing for krill in the waters off Antarctica.

While the rapid deterioration of the polar sea ice raises somewhat abstract concerns for many in the south, more direct concerns emerge for Inuit. What effect would a commercial, industrial fishery in Arctic waters have on the ecosystem? Who would, who should, and should anyone pursue this type of endeavor in this fragile area? Is there any surplus biomass for fleets to harvest over and above that which is needed to support the marine ecosystem? Under whose oversight would fisheries be conducted, whether experimental, exploratory, or fully commercial? These are but a few of the many questions that should be answered prior to the advent of high seas fishing in this area.

Many have hypothesized, and the evidence thus far confirms, that environmental change as a result of climate change will be most visible and most dramatic in the polar regions. There is no consensus on what effect a melting ice pack will have on the productivity of the Arctic Ocean generally and there is even less agreement on what will happen in the international waters of the Arctic Ocean. What will be the effect on plankton bloom? Will there be more or less? Will the occurrence of Arctic cod increase or decrease? Will new species move north to the area from adjacent fishing grounds?

Of all the questions that can be asked however, from a fisheries perspective arguably the biggest one is this: Can the Arctic Ocean ecosystem sustain an unregulated, unscientific, unmanaged, industrial fishery in the midst of the tremendous uncertainties associated with the climate change that will allow the area to be opened to commerce?

I propose that the answer to that question is quite easily found by reviewing our record in other oceans. Almost without exception where the fishing fleets of the world have engaged in unregulated, industrial, high seas fisheries the result has been overfishing, followed by stock depletion and in many cases collapse. All evidence suggests the Arctic Ocean would find a similar fate.

So then what should be done? Is it fair to simply allow history to repeat itself in the Arctic Ocean? Well, no, it is not. Is it fair to say that regardless of the circumstances, absolutely no fishing should ever take place in the high seas of the Arctic Ocean? No, again.

The solution lies in gathering the required information to determine if and under what circumstances a fishery is possible. It requires the establishment, should it be determined that a fishery can take place, of an appropriate fisheries management regime. And it requires the complete engagement of the Inuit, the people who from time immemorial have relied on the bounty of the Arctic Ocean to sustain them and their culture. If we are truly interested in sustainable development in the Arctic these three basic principles must be our guides.

The Arctic Ocean ecosystem and the Inuit who depend on it are undergoing tremendous change as a result of global warming. While this causes tremendous uncertainty about the future, there is one certainty: unregulated, high seas, industrial fisheries lead to stock depletion, confrontation, adverse impacts for the adjacent coastal peoples, and almost always a formal management agreement after the damage is done. In the Arctic Ocean, let us identify the rules before their absence once again becomes the problem.

Comments on Chapter 4: Chinese perspective

Zhou YingQi

Global climate change may increase the primary productivity of living resources in the Arctic marine area as those resources become more abundant due to sea water the temperatures rising and more direct sunlight because of melting ice cover. These changes might also have effects on the migration routes and distribution of the Arctic fish stocks in space and time, which might provide certain possibilities for commercial fishing in the future, but up to now the most of these opportunities are uncertain.

Because of cold weather and harsh environmental conditions, the Arctic, compared to other oceans, has experienced less human activity and influence during the past hundred years. However, the Arctic and Antarctic influence the Earth, as a home to all of us, and feedback on current activities in these regions should also not be ignored. Atmospheric circulation and climate change, as well as storage and regulation of water resources all are important to human society and its development and as such these issues have an important and meaningful significance in many areas of scientific research.

Despite the harsh Arctic environment, the ice melts and new technologies developed may gradually increase the possibilities to access the area of the Arctic and the living and non-living resources found there. We should realized that the Arctic remains one of the most pristine areas on the planet and the combined effects of climate change and human activities will increase the risks living resources might encounter. We must remain very cautious about development and utilization of resources in the Arctic.

It is well known that the ecosystem in the Arctic has never been disturbed before by human activities and it should be mentioned that the ecosystem, despite the harshness of its temperatures and other conditions, is a biologically very vulnerable system. In order to be attentive to these vulnerabilities, any activities in the area should only be conducted for scientific purposes. If there is to be fishing in the Arctic, it should be managed through an international organization under agreement or convention, which should be open to the states interested. Eliminating illegal, unreported, and unregulated fishing is a continual challenge around the world and should not be allowed to happen in the Arctic area.

A conference or forum could be established as a platform for exchanging views about the Arctic and discussing issues amongst interested participants.

FISHERIES RESOURCES AND VULNERABLE ECOSYSTEM IN THE ARCTIC WATERS

The availability of some species of fish in the waters of the Arctic Ocean and adjacent seas have led to the development of a world-class commercial fishing industry. Commercial fish stocks in the Arctic waters are mainly Arctic trout, Arctic cuttle fish, butterfly fish, and capelin, among others. The Barents Sea, Norway Sea, and Greenland Sea are the most famous fishing grounds in the world, with catches approximately 8 to 10% of the total world catch. In the Bering Strait Alaska pollack has been the largest single species fishery in the world.

Scientists in China are very concerned about the biological resources in Arctic waters and have conducted scientific research programs related to the Arctic area. For example, in July 2010, the Chinese scientific research vessel Xue Long (meaning “Snow Dragon”), carried out her fourth Arctic survey and expedition, depicted in the photographs of Figure 4.10. The main target of this voyage was the investigation of the effects of rapid change in the Arctic, as well as ecological, environmental and climate research. Forty-seven stations were covered during the survey on the slope of Bering Sea, including projects with physics, chemistry, biology, geology, optics, the atmosphere and more. Some findings from the voyage are interesting. For instance, in the area of N60.55, W177.38 degrees in the continental slope of Bering Sea, within half an hour of underlying biological trawling collected nearly one ton of benthic organisms, through which sampling and investigations showed to represent quite abundant benthic biomass. During the eighty-two days-long voyage more than 800 samples were collected, including around 100 benthic species from 24 stations in three months. These species included crabs, starfish, sea urchins and similar organisms, mainly from the Bering Sea, the Chukchi Sea and Canada basin, collected from sampling depths of 20 or 30 meters to 1,500 meters. In addition, more than 100 bottles of plankton samples have been collected.

One of targets of the survey was to collect data for understanding the Arctic food web. The project was called "The Relationship Between the Structure of the Arctic Marine Food Chain and Sea Ice Changes," and aimed at the relationship between the plankton and the species on the top of food chain and the nutrition structure in the ecological system. Researchers explored the factors influence the food chain directly and considered those with the geographic data from acquisition stations, looking for certain indications of the distribution patterns and mechanisms of the Arctic biology.

Figure 4.10. R/V Xue Long in the Arctic region

Arctic ecosystems are tough but also vulnerable. In the Arctic Ocean region, summer is short, with a long and cold dark winter. As a result, marine animals have been very tenacious in order to survive and adapt to harsh natural conditions through years of evolution. Because of the relatively simple food chain, if any of these organisms are destroyed it will be enough to cause the collapse of the entire ecosystem. Under such extremely harsh environmental conditions as found in the Arctic, the original ecosystem structure and function is extremely difficult to recover. Degraded ecosystems not only lead in turn to the deterioration of the environment, but will result in the extinction of species and the reduction of biodiversity.

However, even as the animals have adapted to natural conditions in recent years, a rapidly changing environment poses a new challenge to polar organisms and animals including fishes. It is hard to predict whether organisms can ultimately survive, therefore, ecosystems in the Arctic should be considered extremely vulnerable. This extreme vulnerability should be noticed as the first priority when conducting any human activities in the Arctic in order to guarantee the practices of sustainable development and utilization. The ecosystem approach and management which has been proposed by the FAO should be a key guideline.

As the Arctic sea ice continues to shrink, and the time length of ice melting becomes longer, freshwater increasingly enters the system causing changes in Arctic Ocean currents, circulation, structure, and distribution, having serious consequences for living marine resources. Rapid melting of sea ice has caused ice algae, a major source of food for many fish and plankton in Arctic, to decline drastically. The results are that some populations of Arctic cod began to shrink, having a strong influence on the Arctic coast fishery economy.

Arctic microbes such as bacteria and fungi and microfauna (flagellates such as nematodes) are already struggling to survive, without much of an ability to reproduce. Since the Arctic ecosystem itself is fragile and vulnerable, so are microorganisms's ability for self-modification or self-recovering.

CONSERVATION, PROTECTION OF MARINE LIVING RESOURCES IN ARCTIC WATERS

Ocean science is an "observation science" in that the observation is still a major activity for marine science. As such, observations are currently the major activities of marine science and studies on the polar marine ecosystem. Because polar ecosystems, biological life history and ability to adapt to the environment, as well as the population and distribution of marine living resources are poorly understood, we must take care while undertaking any actions in the area. Currently, the Arctic waters do not provide favorable conditions for any commercial fishing activities. This is not the case because there are not fishing technologies and capacities, but rather because our understanding of polar marine living resources is too limited. At this point, only scientific studies and surveys should be considered in our action plan, ultimately strengthening scientific study as means for cooperation for interested parties.

In current research on the Arctic, many fundamental scientific questions persist which have not been answered clearly yet, such as those on the interference between the Arctic sea surface, icebergs, and the atmosphere, and how each plays a role in the global climate system. There are still many questions about the history of the Arctic ecological system and the impact human activities have on the system, as well as how flora and fauna in the Arctic react to climate changes and so on.

A range of factors and issues might affect the polar ecological system. Primary among these issues is pollution, including noise pollution, chemical pollution, and their impacts on migratory routes. Besides fishing operations, we are more concerned with varied human activities, in particular shipping which damages polar marine biological resources. For instance, two of the world's richest fisheries in the Bering and Barents Seas are located in Arctic areas but involve extensive shipping. Therefore, necessary institutions and mechanisms must be established for the strengthened supervision and management of monitoring chemicals discarded in the Arctic, to increase efforts to reduce persistent organic pollutants, heavy metals and other contaminants (including land pollution sources), to support removal of harmful chemicals accumulated in the Arctic, and reduce the risk of release of radioactive substances.

According to the results of current research, noise produced by ships and engineering construction already created certain degree of harm to the marine animals and aquatic organisms, including fishes, whales, and marine mammals. The noise might drive or frighten fish schools away from their favorable migration routes or habitats and might introduce other risks. Increasing ship traffic has the potential to increase pollution and the risk of oil or waste water spills, as well. There is a need for effective international regulatory arrangements to enhance marine safety and protect the environment. It is suggested that there be an allocation of professional experts or observers on board for monitoring and preventing pollution from ships engaged in shipping in Arctic waters. Therefore, regulations in the Arctic region must be established related to the assessment of human activities, the impacts of noise on marine mammals, and established rules and standards for protection based on scientific research. So more surveys and investigation are required in the future plan.

With the growth of potential mineral resources, energy, and biological resources in the Arctic, the contradictions between countries and peoples of the surrounding areas are growing at the same time. Moreover, in conflicts between modern industrial economic development and environmental protection in the Arctic, the contradictions between modern civilization and the ancient culture of the local population is increasingly obvious. Scientific activity in the Arctic is closely linked to economic, military, political interests, but also to natural sciences and social sciences. These are mutually related and cannot be discussed separately.

REGULATION AND MANAGEMENT ON FISHERIES

Until now there has been no comprehensive regional fishery convention and coordinating management organization in the Arctic region, and, in light of requirements of the UN Convention on the Law of the Sea (UNCLOS) and United Nations Fish Stocks Agreement, the Arctic states and Non-Arctic states with interests in Arctic fishery resources are liable and to take responsibility to cooperate in order to conserve and manage these Arctic fisheries resources properly.

Recent changes in the attitude of the Arctic Council and divergences from mandates of several regional fishery management organizations make the prospect of Arctic fisheries complicated. The north Pacific portion of the Arctic marine areas has been deemed a potential alternative for fishing industries because of regional fishery management practices in the north Atlantic Ocean and the capability of fishing fleets.

It is suggested that the survey and biological investigation and research on Arctic marine resources by international cooperation should be a high priority. An Arctic conference could be established as a platform for exchanging views and discussing the issues participants are interested in. Some sub-groups could be set up to focus on particular problems. Such scientific inputs in Arctic fisheries will pave a way for future commercial fishing in the Arctic and might offer another new fishing ground. Marine biological scientists, whether they come from the Arctic states or non-Arctic states, should have a voice and influence in Arctic marine resources conservation and management and governance.

There are two main types of fishing in the region: an artisanal or subsistence fishery and commercial fishery. The artisanal fishery can be licensed and protected under certain regulations, but the commercial fishery should be strictly limited. The fishing activities should be within the framework set by the international fisheries management organizations under its mandate. For example, the International Whaling Commission (IWC) ensures effective protection in the Arctic region and any activities related to whaling in the Arctic region should be decided by IWC. At the same time, there should be considerations to support proposals on the management of whaling in subsistence fisheries for local aboriginal people, even if whale protection negotiations did not fully agree. Whaling should remain subject to appropriate control, catches need to be recorded and controlled within the scope of accreditation needs and continued dialogue is needed with local traditional seal hunting communities. Guided by the FAO's approach to subsistence fisheries policies, there shouls be consideration and support for a reasonable catch certificate system for seal products[1] on the market, including any import, transit, and export. However, this should not affect the economic and social interests of local communities which historically engaged in traditional hunting of seals as one of their fundamental living resources. These determinations should be made through dialogue with aboriginal groups living in the area to achieve consensus.

Fisheries management in the Arctic should be under international agreement involving states that have real interest in the area. The waters of the Bering Sea and the North Atlantic Ocean are already covered by international regional fisheries management organizations. Besides the exclusive economic zones under the national jurisdiction of coastal states, the remaining waters in the Arctic are considered the high seas, an "Arctic hole" which needs to be managed so that developing a conservation treaty for living marine resources to implement the United Nations Fish Stocks Agreement is at higher priority.

Arctic waters are a broad, complex set of marine jurisdictions and any delineation of their boundaries needs to take into account a variety of factors, particular the impacts of human activities on living resources. The Arctic Ocean is an ocean, not a sea, and certainly not a gulf. It cannot be treated as if it were an enclosed or semi-enclosed sea. Arctic affairs should be open to interested parties from non-Arctic States. Due to climate change and warming effects, there could be a tremendous impact on the living marine resources in the Arctic including the Bering Sea, North Pacific, and North Atlantic. If a fish population and their food organisms relocate or their geographical distributions obviously change, moving towards northern waters for instance, this is an issue that obviously concerns not only the coastal states, but also the interests of non-Arctic States. It is recommended that Arctic fisheries and related ecosystems develop approaches to conservation and management, and should establish a regional fisheries management organization before the start of commercial fishery.

Most fish migrate from one place to another depending on the weather, environment, and their habitat range. In doing so, some of them will cross the borders of exclusive economic zones and high seas. The Arctic states should implement the international obligations of the 1995 United Nations Fish Stocks Agreement, Item 5, Article 8, and actively promote and implement management guided by the concept of ecosystems approach, rather than the traditional sector or industry management.

The Antarctic Treaty is an example. Under the Antarctic Treaty system, the environmental protection and conservation of living marine resources are two separate treaties. Although the Arctic marine environment protection treaty already exists, a fisheries management treaty is needed. If one international organization were empowered to manage the two issues the fisheries management could be merged into considerations for the marine environment. Otherwise fisheries conservation and management requirements may not be compatible.

Due to the special geographical situation of the Arctic, the Arctic should not be managed by the Arctic states only. Of course, the eight states have a vital interest in the Arctic, however, participation should be open to non-Arctic states which have vital interests there, too. Actions taken should actively support the United Nations Law of the Sea. Further development of cooperation in the Arctic management system, should ensure (a) safety and stabilization, (b) strict environmental management, including principles of prevention, such as precluding and precaution points, (c) sustainable utilization of living marine resources, as well as open and equitable access to resources, and (d) promote broad dialogue and negotiation, support non-arctic states participating in negotiations. Instead of proposing new laws, it is suggested that there be full implementation of existing obligations. However, this should not preclude the further development of the existing legal framework to enable it to adapt to the new conditions or Arctic specificities.

One lesson that should be learned regards areas commonly known as high seas in the north Pacific nicknamed “donut holes” and “peanuts holes” because they are surrounded by exclusive economic zones. They were rich in pollock during the 1980s and declined during the 1990s. Afterward, a moratorium was placed on commercial fishing with factory trawler fleets for decades under the Convention of Conservation and Management for Pollock Resources in Central of the Bering Sea due to the collapse of pollock stocks. Those fisheries will not be re-opened until conditions are better. Monitoring systems, fisheries management, and the necessary sustainable security measures should be taken, such as setting precaution points, and eliminating illegal, unreported, unregulated fishing.

PROPOSAL FOR ACTION PLAN

A multi-sector framework for integrated ecosystem management on marine living resources could include the establishment of a set of marine protected areas, navigational specification rules, and a plan for ensuring the sustainable development of mineral resources. At the international level, there is a need to further explore all the possibilities for the protection of marine biological diversity beyond areas of national jurisdictions, including tracking the implementation of UNCLOS agreements.

To promote the International negotiations on high-latitude marine protected areas

- Arctic affairs should be arranged on high-level dialogue of Ocean Affairs,
- the possibility of establishing an Arctic information center should be explored, and
- education networks related Arctic affairs should be established.

Waters systems and environments of the Arctic will be influenced by adjacent areas and the atmosphere. The Arctic is a fragile ecological system, and humans need to be particularly careful and strictly manage their activities there. If fish are affected by environmental pollution and noise impacts, they could change their migration routes and habitats which might affect their breeding and survival.

Arctic fisheries are divided into two types: indigenous subsistence, which would be licensed and protected, and commercial fisheries. A strict management system which combats illegal fishing must be established on the basis of scientific investigations and sufficient proper management.

Scientific cooperation committees and working groups must be established, providing scientific guidance and recommendations, providing preparation and the foundation for establishing a fisheries management organization, the coordination of scientific investigation, information exchange, and cooperative activities. Additionally, organizing regular conferences or meetings of parties interested in Arctic issues to exchange information will strengthen international cooperation.

Notes

1. Some species of seals are not in the list of CITES.

Comments on Chapter 4: Korean Perspective

Jong Deog Kim

Professor Fluharty's chapter has presented a very comprehensive analysis of current issues on Arctic living marine resources including fisheries and ecosystem management. His presentation also covers some practical counter measures not only for the Arctic coastal states but non-Arctic states such as China, Japan and Korea. I believe his chapter presents a logical need for international cooperation to manage integrated and sustainable living resources in the Arctic and its adjacent sea areas.

According to the chapter, the interest of North Pacific Rim states in Arctic fisheries seems reasonable in relation to the Bering Sea. As we are well aware, China, Japan, and Korea are major global fisheries producers and consumers. Therefore, opening of the Arctic is an issue of major interest to them because it highly affects the fisheries industry and seafood supply. The three nations have good capacities in scientific surveying and monitoring on marine resources management as well. For instance, they have experience conducting scientific research on pollack in the Bering Sea Donut Hole and have their own facilities, such as icebreakers. Based on international discussion on Arctic fisheries, Korea is very willing to participate in Arctic resource surveys with its experience in the Antarctic Ocean.

Regarding the concept of "Arctic Ocean fisheries," I think there is still some confusion on the notion because of the migratory features of living resources and ecosystems in the region. A clear definition of the physical scope is important to establish new agreements on Arctic fisheries and resource management, regional fisheries agreements and other necessary governance. Given migratory fisheries resources, I think we can refer to the Antarctic Convergence in the Convention for the Conservation of Antarctic Marine Living Resources of 1980.

Generally, when we consider fisheries resources management, it is quite appropriate to conceptualize in terms of fisheries consumption and supply. I think analysis on the global supply and demand of Arctic fishes based on scientific understanding will be useful for future development. The catch of major Arctic fishes, such as halibut, cod, and other white fish has slowed down, compared to rising demand. It is highly likely that the Arctic Ocean will emerge as the major fishing ground.

As with other countries in the East Asian region, our domestic fisheries production hardly kept up with rising fisheries consumption. Accordingly, fisheries importation continued to increase, which called for development of new fishing grounds. In particular, production of pollack, halibut, and cod, the cold current species enjoyed by the Korean people, has seriously decreased. Unfortunately, major production areas for such species are the Arctic Ocean and its adjacent sea. Therefore, Arctic fisheries are more than somewhat crucial for stable seafood supply and domestic price management.

Beginning in 2013, we will seek more concrete cooperation measures with the Arctic states, including fisheries forum with industry, government, academia, NGOs, and local people for finding a more reasonable approach. I think our existing bilateral or multilateral cooperative relations with NAFO, Russia, Norway and the US, will be the foundation for this cooperation. Of course, we do not need to say that this interest should be under the international rules and coastal states' authority in the fisheries resources management. When such strategies are drawn up, applicable resource conservation measures should be considered and active consultation should follow with regional fisheries organizations and the nations who have jurisdiction over the EEZ of the Arctic.