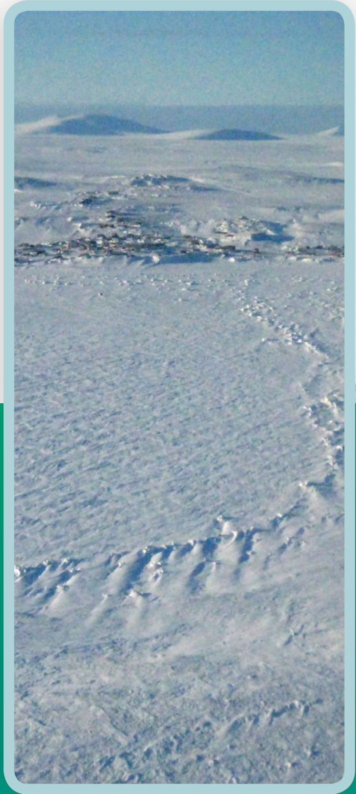
State of the Arctic Coast 2010

Scientific Review and Outlook





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Land-Ocean Interactions in the Coastal Zone

Arctic Monitoring and Assessment Programme

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2.2. Ecological State of the Circum-Arctic Coast

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Key Findings

- Arctic coastal habitats are the prime lifeline for Arctic communities and provide a wide range of ecosystem services.
- They support very large populations of fish, mammals and birds that are harvested by Arctic and non-Arctic communities.
- The Arctic coastal zone provides habitat to an estimated 500 million seabirds alone.
- Arctic coastal habitats are highly vulnerable to changing environment conditions, including climate change and growing human activities such as oil and gas exploration and development.
- Arctic river deltas are biological hotspots on the circumpolar Arctic coast. They have high biodiversity and are extremely productive in relation to adjacent landscapes. The high biodiversity remains poorly understood, but may be related to the complex natural patterns of water level fluctuation that occur in these vast lake-rich systems.
- Arctic ice shelf microbial mat cryo-ecosystems are severely threatened by ice shelf collapse, with some of the richest examples already lost.

The assessment of coastal aquatic and terrestrial biodiversity is an important component of coastal zone management and the design of marine protected areas (Cogan 2003). This report aims to assess the available knowledge from previous regional and global assessments and more recent published literature on the status, trends and prognosis of Arctic coastal ecosystems. Sources include the Arctic Climate Impact Assessment (ACIA, 2005), the AMAP Oil and Gas Assessment (AMAP, 2007), the Arctic Marine Shipping Assessment (PAME, 2009a), the Millennium Ecosystem Assessment (UNEP, 2003, 2005), and the Arctic Biodiversity Trends -2010 (CAFF, 2010), as well as a selection of global assessment reports and the Circumpolar Biodiversity Monitoring Programme (CBMP) (AMAP, PAME, and CAFF being working groups of the Arctic Council - see Section 3.4.2).

The CBMP is an international network of scientists and local resource users working together to improve detection, understanding and reporting of important Arctic biodiversity trends. To achieve these objectives, it is developing a number of ecosystem-based, pan-Arctic integrated monitoring plans to coordinate Arctic biodiversity monitoring. The CBMP is the cornerstone program of the Arctic Council's Conservation of Arctic Flora and Fauna Working Group (www.caff.is) and represents the biodiversity component of the Sustaining Arctic Observing Networks initiative. The CBMP aims towards an integrated and sustained monitoring program and is based largely on a network of networks approach with expert monitoring groups, organized by biomes, including the coastal biome (Gill and Zöckler, 2008).

2.2.1 State of knowledge – habitats and species

Coastal seas

Much of the Arctic coast borders coastal seas or inter-island passages with varying degrees of enclosure, in some cases quite shallow with significant inputs of fresh water,

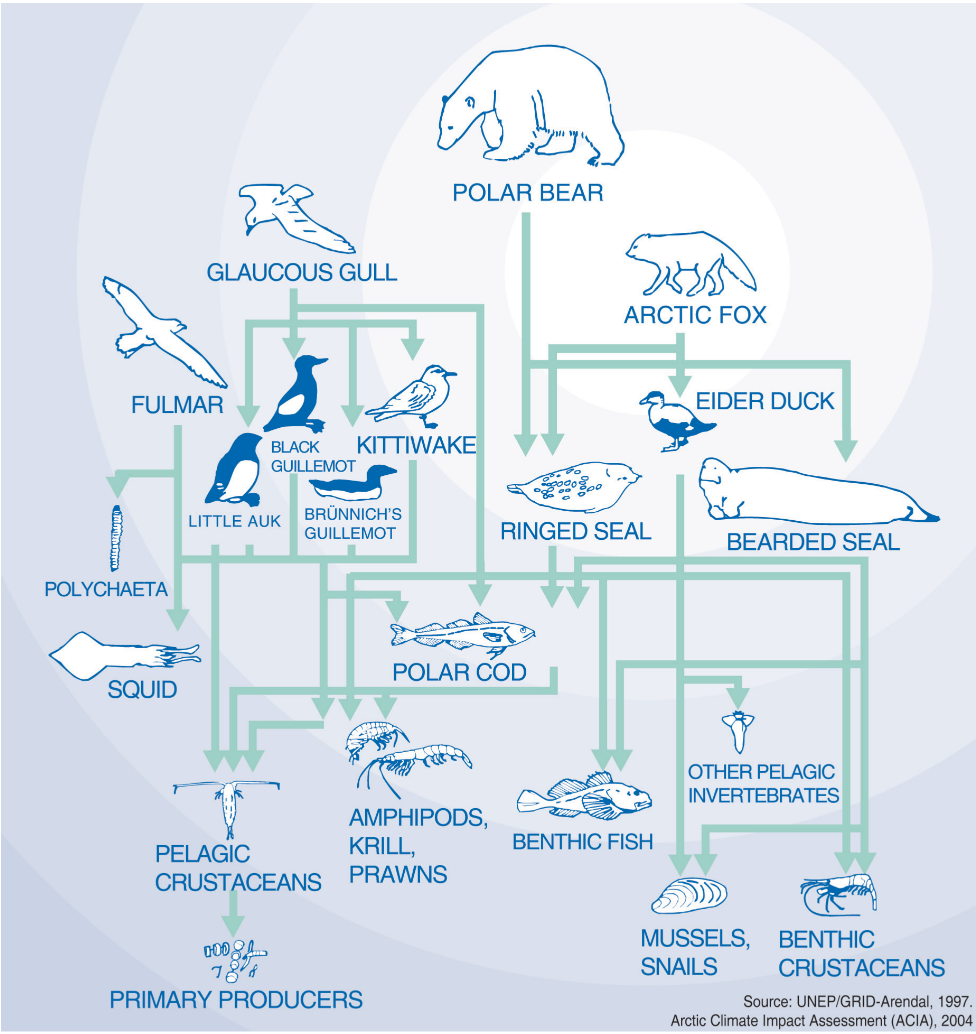


Figure 20. The coastal Arctic food web is closely related to drift ice conditions and seasonal use of shorelines by both terrestrial and marine mammals. Numerous species depend upon each other and on the transport of food between marine, coastal, and inland habitats.
Source: UNEP/GRID-Arendal.

nutrients, carbon, sediment, and contaminants (AMAP, 1997, 2002; Rachold et al., 2000). These coastal waters are critically important for northern coastal ecology and can be highly productive (Table 1) (e.g. Carmack and Macdonald, 2002; Clarke and Harris, 2003). Changes in circulation, temperature, salinity, productivity, and sea ice, among other factors, may have important implications for species success or survival, species invasion, ecological function, and biodiversity. Changes in sea ice, in particular, may also have impacts on ice-dependent or ice-limited species (Loeng et al., 2005; Mueter and Litzow, 2008) (Fig. 20).

Projected salinity changes in the Nordic Seas are generally small, except for areas influenced by coastal runoff and the melting of sea ice. If warming occurs within the Barents Sea over the next hundred years, thermophilic species (i.e., those capable of living within a wide temperature range) will outcompete others and become more prevalent. This is likely to force changes in the zoobenthic community structure and, to a lesser extent, in its functional characteristics, especially in coastal areas (Loeng and Drinkwater, 2007; Cochrane et al., 2009). Similar concerns have been identified for Baffin Bay and other Arctic coastal waters.

Area (103 km^2)	Total primary production (g C/m^2)	New primary production (g C/m^2)	Grazing rate of zooplankton (g C/m^2)
Alaskan coastal	50 –75	<20	32–50
Siberian coastal	>400	>160	>90

Table 1. Estimated levels of primary production, defined as the integrated net photosynthesis (corrected for respiration) over at least 24 hours, plus the grazing rate of mesozooplankton (compiled by Sakshaug, 2004, on the basis of data from several authors).

Past changes in northwest Atlantic circulation related to the North Atlantic Oscillation (NAO) have resulted in warmer water in southern Baffin Bay in the 1920s and associated recruitment and local spawning success of Atlantic cod (*Gadus morhua*), followed by a change of sign in the NAO, resulting in cooler temperatures, diminished spawning success, and less recruitment of juvenile cod from the 1970s to 1990s (Vilhjálmsson, 1997), with major impacts on the commercial fishery and economies of coastal communities (Hamilton et al., 2003).

Coastal wetlands (salt marshes, laida, estuaries and intertidal flats)

Coastal wetland habitats of open coasts, deltas, and river estuaries are an important element of the overall Arctic ecosystem (Martini et al., 2009). Representing the littoral halophytic floristic complex, salt marsh communities are among the most sensitive to environmental change. The most likely drivers of change in this region include rising sea level and the introduction of sediments and biogeochemical components due to coastal erosion from storm surges and warming-induced permafrost degradation (Rachold et al., 2000; Lantuit et al., 2009). Studies of the interactions between abiotic and biotic processes enable us to determine the impacts of development on coastal biology and geomorphology, facilitating efforts to project the response of the Arctic coastal zone to future changes.

Arctic coastlines are subject to extensive disturbance through processes such as thermal abrasion, wave erosion, storm-surge flooding, and sea ice grounding in the shore zone, with implications for species distribution and abundance. Genetic, range, or other adaptations by plant and animal populations require time. If environmental

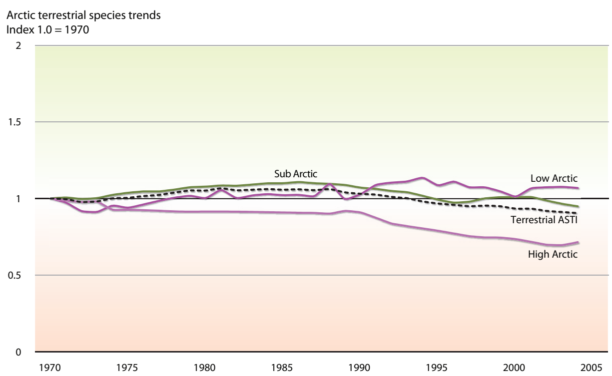
The Arctic Species Trend Index: A Barometer for Arctic Wildlife

Michael J. Gill, Christoph Zöckler, Louise McRae, Jonathan Loh and Ben Collen

The CBMP is the cornerstone program of the Arctic Council's Conservation of Arctic Flora and Fauna Working Group (www.caff.is). The Arctic Species Trend Index (ASTI) is a headline indicator for the CBMP and was developed to provide a pan-Arctic perspective on trends in Arctic vertebrates. Tracking this index will help reveal patterns in the response of Arctic wildlife to growing climatic, encroachment, development and landscape change pressures. It is also envisioned that the ASTI could be used to facilitate our predictive understanding of trends in Arctic ecosystems. A total of 965 populations of 306 species were used to generate the ASTI (see map), of which 390 relate to coastal and marine populations. Overall, the average population of Arctic species rose by 16% between 1970 and 2004, although this trend is not consistent across biomes, regions or groups of species (see graph). Although both freshwater and marine indices show increases, the data behind the freshwater index are currently too sparse in terms of species and populations, while the marine index is not spatially robust. More trend data are required, especially from marine and coastal areas in the Atlantic and central High Arctic coasts in both North America and Siberia.

Location of datasets in the Arctic Species Trend Index.

Index of terrestrial species disaggregated by Arctic boundary for the period 1970-2004. (High Arctic, n=25 species, 73 populations; Low Arctic, n=66 species, 166 populations; Sub Arctic, n=102 species, 204 populations)



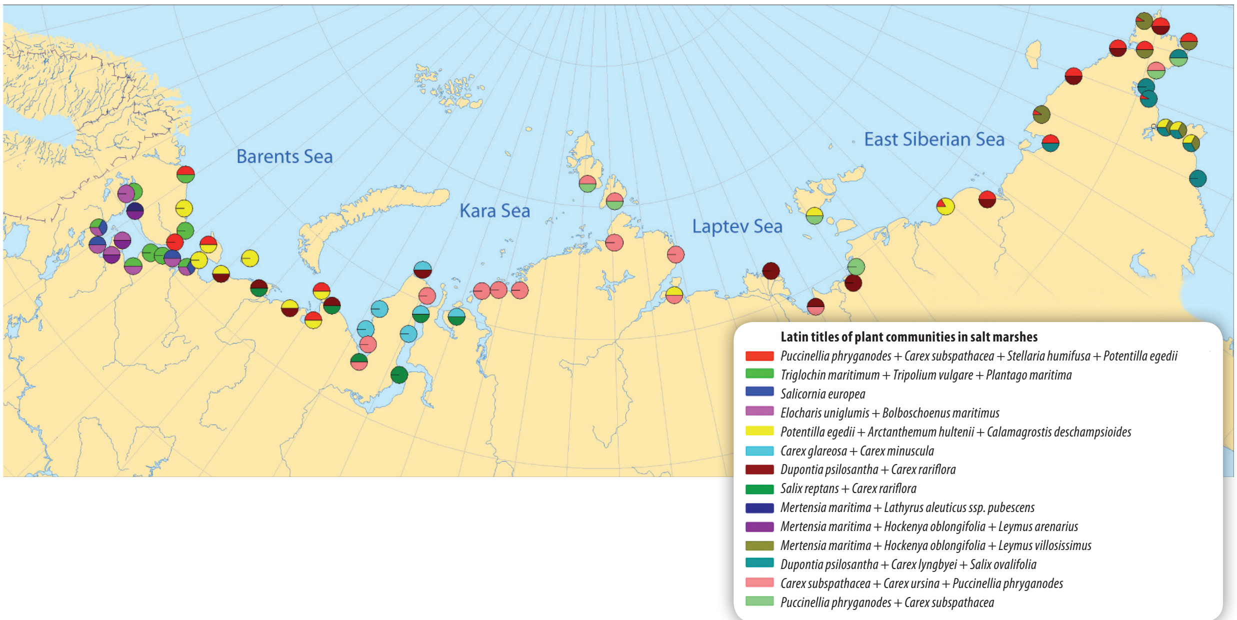


Figure 21. Distribution of salt marshes in the Russian Arctic. Colours represent variability in salt-marsh plant communities.
Source: L. Sergienko, unpublished data, 2009.

changes occur too rapidly, a population may be unable to adjust by migrating or altering its reproductive behaviour. This, in turn, could lead to deleterious changes in ecosystem functioning if the population in question is a keystone species. The total number of coastal species in various Arctic regions ranges from 18 in the plains of the Lena region to 58 species in the Kola Peninsula (L. Sergienko, pers. comm., 2009). Regions with fewer species may be more susceptible to climate changes.

During the Last Glacial Maximum, salt marshes spread along the unglaciated coasts of Chukotka and Alaska at lower sea levels. During this time, surviving coastal communities consisted only of the cold-tolerant Arctic forms. These mainly adapted to the northern climate by growing in the relatively warm estuarine zones of Arctic rivers. In the vicinity of the Taymyr Peninsula, such species as *Arctanthemum arcticum, Mertensia maritima, Senecio pseudoarnica, Salix ovalifolia, Saxifraga arctolitoralis,* and *Saxifraga bracteata* disappeared from the salt marsh communities. Under present-day conditions, some characteristic Arctic coastal species have been transferred from the Chukchi Sea to the Pacific Ocean by cold currents and spread mostly along the eastern coast of Chukotka. At the same time the warmer current from the Bering Sea transports boreal warm-preference species of salt marsh communities along the Alaska coast to spread to the coast of Siberia (Fautin et al., 2010).

The full distribution of Arctic salt marshes has not been documented, although a few regional overviews exist. Some regions with minimal tidal range, such as parts of the Beaufort Sea coast and the Canadian Arctic Archipelago have minimal salt marsh development, largely confined to low deltas and supratidal marshes (inundated during storm surges) along the margins of estuaries and thermokarst embayments (Forbes et al., 1994; Hill and Solomon, 1999). These are often dominated by *Puccinellia* spp. (Martini et al., 2009). Figure 21 shows the distribution of salt marshes across the Russian Arctic coast.

Flooding of coastal buffer zones is already occurring in some areas. Accelerated sea-level rise could lead to further destruction or rapid redistribution of existing salt marsh

Figure 22. **Inundated polygonal tundra, western Banks Island, Arctic Canada.**
Source: D.L. Forbes, Geological Survey of Canada

complexes (or both). The limited species diversity of the Arctic coastal zone means that the ecosystem is extremely vulnerable to rapid changes whether they are induced by climate change, resource development or a major spill. Over the past 4000-5000 years, some coastlines of the Russian Eastern Arctic have retreated as much as 30 to 50 km (Romanovskii et al., 2005; Overduin et al., 2007). The coastline of the Yamal Peninsula for the same period receded about 18 to 20 km. Deltas of the Dvina and Pechora rivers no longer expand outward. Similarly, the delta front of the Mackenzie River in the western Canadian Arctic is predominantly erosional (Solomon, 2005) (see Section 2.1.7).

Changes in species composition due to sea-level rise will be experienced most in buffer zones (sandy and silty supratidal meadows, mud flats and marshes) periodically inundated at high tides. Circumpolar saline margin species such as *Puccinellia phryganodes* and *Carex subspathacea* will migrate slowly landward with marine transgression (Martini et al., 2009). Although many salt marshes in temperate regions keep pace with slow sea-level rise through inorganic sedimentation and organic production (e.g. Allen, 1990; Plater et al., 1999), there are many observations of flooded tundra along Arctic coasts, where vertical accretion is clearly not keeping pace (Fig. 22). It is important to determine the dynamics of these processes and their responses to a changing climate if we wish to understand the nature and rate of adaptation in salt marsh communities. In some places, species or communities that cannot respond to change may disappear or be replaced by more hearty adaptors or perhaps by invasive species.

Biogeochemical responses to changing ocean and coastal dynamics are equally important. For example, changes in pH or chloride concentration in lower marshes lead to increased success for grasses and sedges, such as *Carex* spp. During colonization of the mudflats ancient species with different levels of ploidy prevail. Ploidy, the number of chromosomes in a plant, is dependent on the evolution and hence the co-evolution of the vegetation. Thus it is indicative of the species richness and, perhaps, its viability in evolving ecosystems. Based on the diversity and density of coastal species and on their floristic composition we can determine the origins of the coastal and estuarine biogeochemical characteristics and can make assessments of the timing of coastline formation in the Arctic.

Apart from the salt marsh and supratidal marsh habitats described above, Arctic intertidal habitats cover a wide range of environments from wide silt and sand flats in the vicinity of large deltas or other areas of abundant sediment supply to boulder-strewn tidal flats in other areas with tidal ranges from <1 m to 16 m (Lauriol and Gray, 1980; Nielsen, 1994; Samuelson, 2001; Zajaczkowski and Włodarska-Kowalczuk, 2007). There is a modest body of research on benthic communities in Arctic intertidal habitats (e.g. Aitken et al., 1988; Ambrose and Leinaas, 1988; Weslawski and Szymelfenig, 1997; Samuelson, 2001; Powers et al., 2002; Bick and Arlt, 2005). Reworking by sea ice has been proposed as one explanation for low productivity (Hamel and Mercier, 2005), a view challenged by some (e.g. Weslawski and Szymelfenig, 1997). Nevertheless the Arctic intertidal benthos has limited biodiversity, with typically 30 to 50 species (Loeng et al., 2005). Soft-bottom tidal flats are found locally in a wide range of settings from Hudson Bay embayments to Svalbard fjords to Chukotka (Fig. 23). In areas of rapid isostatic uplift, former intertidal flats emerge slowly and the upper limit of marine flooding gradually recedes seaward (Hansell et al., 1983). Bottomfast ice can develop over tidal flats with limited tidal range, while areas with higher tidal range may see the formation of an icefoot at the landward margin of the flats and mobile ice to seaward. On boulder-strewn tidal flats, the ice moves boulders, rearranging and disturbing the substrate (see references in Forbes and Taylor, 1994).

Deltas

Arctic river deltas support highly productive ecosystems (Squires et al. 2009) with high biodiversity (Lesack and Marsh, 2010; Galand et al., 2006) compared to the surrounding landscape. The high biodiversity may result, in part, from the complex natural patterns of water level fluctuations that occur in these vast lake-rich systems, with their complex networks of interconnecting channels (Lesack and Marsh, 2010). Rising sea levels and delta subsidence with limited overbank sedimentation are driving progressive inundation of some delta areas and likely contributing to delta-front retreat (see Section 2.1.7).

Other habitats

It is important to note here the unique microbial mat communities and other ecosystems on Arctic ice shelves, as well as those associated with sea ice (Vincent et al., 2004). Given the 90% loss of ice shelf extent along the north coast of Ellesmere Island over the 20th century (Vincent et al., 2001) and the more precipitous loss in recent years (Fig. 11), these remarkable cold-adapted communities are highly vulnerable (see Section 2.1.4). Recent losses include complete disappearance of the Ayles Ice Shelf in 2005 and the Markham Ice Shelf in 2008 (Copland et al., 2010). Just four years before its demise, Vincent et al. (2004) described the Markham Ice Shelf as having the richest of the Arctic ice shelf cryo-ecosystems, with a total standing stock of 11 200 tonnes (11.2 Gg).

Marine mammals (seals, polar bears, whales)

In the Arctic coastal zone, many marine mammals form a direct connection between land and sea. They link the ocean and land in the summer and the sea ice and land in winter. Their viability is dependent on nutrient flows between coasts, upwelling and river discharge and its food chains. Different species respond in different ways to disturbance, either induced by climate or human development (Laidre et al., 2008; Sjare and Stenson, 2010). The Polar Bear *Ursus maritimus* is a top-level predator, an iconic Arctic marine and coastal species that is particularly vulnerable to changes in sea ice because it is fundamentally dependent upon the ice as a platform for hunting seals, traveling, finding mates, and breeding (Regehr et al., 2007). Changes in the distribution, duration, and extent of sea ice cover and in the patterns of freeze-up and break-up have the potential to significantly influence the population ecology of polar bears (Stirling and Derocher 1993; Derocher et al. 2004).

It has been established that the timing of sea ice development, river discharge and nutrient flow has shifted markedly. Seasonal ice forms later in the fall and multiyear floes are smaller and retreat farther offshore in the summer (Serreze et al., 2002; Stroeve et al., 2005). As such, climate change poses risks to marine mammals in the Arctic that are dependent on the ice ecosystem for survival. With ports remaining ice free for longer and with potential shipping routes opening as summer ice extent decreases there will undoubtedly be an increase in human traffic and development in previously inaccessible, ice-covered areas. This poses additional stresses for ice-associated mammals. Bearded seals use regions of thin, broken sea ice over shallow areas with appropriate benthic prey communities (Burns, 1981). Their distribution, density, and reproductive success are dependent on the maintenance of suitable sea ice conditions in shallow, often coastal, areas. Walruses, another predominantly benthic feeder, also have quite specific sea ice requirements. They overwinter in areas of pack ice where the ice is sufficiently thin that they can break through and maintain breathing holes (Stirling et al., 1981), but is sufficiently thick to support the weight of groups of these highly gregarious animals. Ice retreat may result in much of the remaining Arctic sea ice being located over water that is too deep for these benthic foragers. Bowhead whales are known to inhabit the boundary between landfast ice and pack ice 2 km off the coast of Barrow, Alaska. This ecologically rich coastal zone also includes ringed seals, birds and fish. Native Alaskans have inhabited the Barrow area for about one thousand years because of this close proximity to ice-dependent subsistence foods.

In East Greenland, the narwhal together with minke whale, walrus, polar bear and ringed seal, bearded seal, harp seal, and hooded seal, are the most important living marine resources for the communities of Scoresby Sund and Angmagssalik (see Section 2.3.4). This hunt is shore-based and takes place in coastal waters. Many of these animals are bound to the ice pack. In West Greenland, the quota species humpback and fin whale are hunted. As the bowhead stock is increasing, it may also be possible that Inuit will receive a quota for bowhead in the near future. Ringed seal is hunted mostly for dog food, which is economically important because polar bear hunting requires the use of dogs.

Harp, ringed and harbour seals are hunted from shore, boats, or the floe edge in various other parts of the Arctic and these animals are dependent on the ice edge. Harp and hooded seals are hunted by Norwegians around Jan Mayen; harp, ringed, and bearded seals are taken in Svalbard. Beluga and narwhal are important species for Inuit communities

Figure 23. Tumlat mudflat in Chukotka, Russia.
Source: C. Zöckler, UNEP

in Arctic Canada. Minke whales (quota 650 per year) are hunted by Norwegians (from the whaling station Skrova Westfjorden, Lofoten) and Icelanders in the North Atlantic Ocean. Fin whales are hunted by Icelanders (from the whaling station located in Hvalfjörður).

Fish distribution and changes in species diversity and abundance

The Arctic marine coastal zone is largely inhabited by Arctic fish fauna consisting mainly of euryhaline species. Eleven of these are of circumpolar distribution, including *Lycodes pallidus, L. polaris, Artediellus scaber* and some endemic to the Arctic such as *Triglops nybelini, Lycodes jugoricus, Artediellus scaber* (Chernova 2003).

Inside the circumpolar Arctic marine coastal zone, estuaries of numerous large and small rivers host specific ecosystems. Fish complexes inhabiting these zones include about 20 anadromous, and semi-anadromous fishes, as well as those freshwater species which can enter brackish estuarine waters (Fig. 24). These fish (*Acipenser baeri baeri, Coregonus autumnalis, Stenodus leucichthys nelma* and others) usually do not occur in the waters of higher salinity.

The littoral zone in the high Arctic is a harsh environment because of ice presence most of the year. Benthic species predominate in the Arctic. In the high Arctic mid-water so-called cryopelagic fish species, depending on sea ice, are widely distributed (*Boreogadus saida, Arctogadus borisovi*). Only a few of the Arctic species have very large populations, and most of those are heavily exploited by marine fisheries.

Changing water temperatures, water levels and ocean currents are expected to alter fish migration patterns and new species will likely enter Nordic and Arctic seas (e.g. Reid et

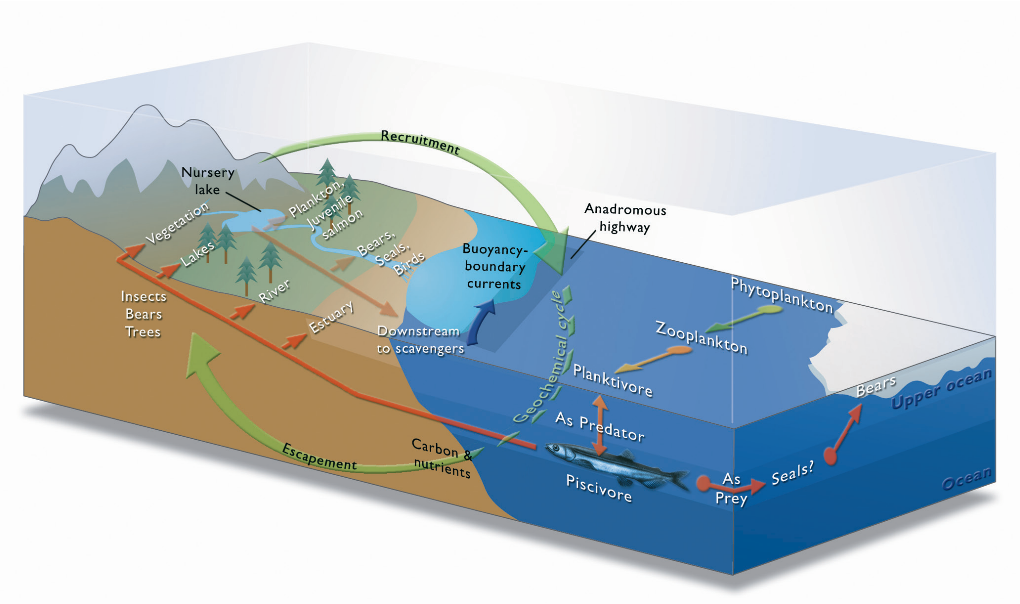


Figure 24. Schematic portrayal of the use of estuaries and the keystone role of anadromous fish in the trophic dynamics of Arctic nearshore estuarine and marine ecosystems.
Source: Wrona et al. (2005), © Arctic Climate Impact Assessment, 2005

al., 2007). In the northern Bering Sea, a change from ice-dominated Arctic conditions to sub-Arctic conditions with more open water tends to favor pelagic species like pollock (*Theragra chalcogramma*) over benthic and bottom-feeding species. With the recent shift to a cold period, the pollock population in 2009 is in collapse (Grebmeier et al., 2006; Overland, 2009). Global analyses of marine biodiversity response to projected climate change suggest the potential for substantial changes in the distribution of numerous exploited fish and invertebrate species, with the most intense species invasions at high latitudes (Arctic and Southern Ocean); these changes may entrain species turnovers of as much as 60% of present biodiversity, with impacts on marine and coastal ecosystems and potential disruption of ecosystem services (Cheung et al., 2009). In Hudson Bay and the Canadian Arctic Archipelago, some important food species such as Arctic char (*Salvelinus alpinus alpinus*) may see contracted distributions, with diminishing numbers in the southern part of the present range and limited expansion to the north (Cheung et al., 2010). The ice-dependant Arctic cod is projected to suffer severely by climate change as modeled for the next 30 years. Although not a harvested fish itself it is an important prey for larger fish important for human consumption (Bluhm and Gradinger, 2008). Anadromous species such as char integrate climate change effects between freshwater and marine environments and the impacts will vary between regions in the Arctic as a function of numerous factors affecting habitat suitability, growth, and survival (Reist et al., 2006a, 2006b, 2006c; Todd et al., 2008).

Freshwater fish relate to coastal waters in a different way than salt water fish. Deltas and estuaries have a complicated relationship with ice that controls salinity. If ice is present during spring melt flooding, it helps drive freshwater and nutrients offshore. This process and the water temperatures of the rivers and coastal ocean control stratification which in turn drives the deposition and assimilation of nutrients into the coastal zone. This has ramifications for fish such as Arctic char, as well as waterfowl, shorebirds and marine mammals that are part of the food web (e.g. Gaston et al., 2002; Chaulk et al., 2007; Dawe et al., 2007; Gaston, 2008; Regular et al., 2009). Many anadromous fish (Arctic cisco, Dolly Varden, rainbow smelt) may overwinter in freshened coastal or estuarine waters and then migrate upstream in the freshwater systems to spawn. Thus the fish are a transfer mechanism for nutrients linking coastal and inland ecosystems. Figure 24 depicts the coastal and terrestrial linkages driven by freshwater with a focus on fisheries and how climate change may affect fisheries dynamics. The figure suggests that many unknowns remain in predicting the future response to climate warming across a broad range of parameters.

Seabirds (breeding and non-breeding concentrations)

Seabirds comprise mostly cliff-breeding birds on rocky outcrops and islands or on low coastal wetlands. They nest in huge coastal colonies, often on remote islands free of ground predators. They are among the most numerous colonies in the Arctic, if not at a global scale. Some account for several million birds, like the little auk (*Alle alle*) in Greenland or the Puffin (*Fratercula arctica*) in Iceland. In the North Atlantic between Greenland and Svalbard alone an estimated 50 million pairs of seabirds (Bakken et al., 2006) nest in the coastal zone of this area, comprising in total more than 100 million seabirds that use the North Atlantic waters. Similar numbers are estimated for the Eastern Barents and Bering Sea (Isaksen and Gavrilo, 1996; Dragoo et al., 2010), followed by fewer numbers in the Kara, Laptev, Chukchi and Beaufort Sea, totalling an estimated 500 million seabirds nesting at Arctic coasts.

Indirect changes in the food chain can be expected through changes in salinity and temperature, with implications for diversity and abundance of invertebrate and fish prey (Durant et al., 2003). These may severely impact seabird communities in critical locations relative to breeding grounds. Sea surface temperatures impact the abundance of seabirds (Irons et al., 2008) with warming waters pushing the distribution of some such as the thick-billed murre to the north (Fig. 25).

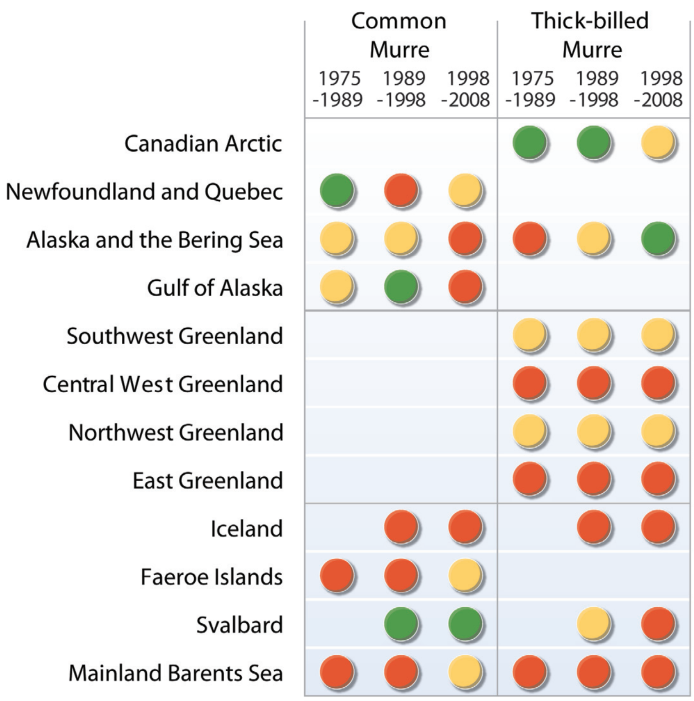


Figure 25. Changes in murre populations since 1975 by region and 'decade' (as defined by regime shifts in the Pacific Decadal Oscillation; see Irons et al., 2008). Green indicates positive population trends, yellow indicates stable populations, and red indicates negative population trends (http://web.arcticportal.org/en/caff/cbird).

Those seabird species that predominantly breed in coastal lowlands, such as eider ducks, gulls and terns may lose some breeding habitat to rising sea levels and may experience breeding failures from storm surges, but are likely to be able to adapt. Additionally, common eiders and other species have been subjected to over-harvesting in many parts of the Arctic (e.g. Merkel, 2004) (Table 2).

Table 2. Status and trends of seabird harvest in the Arctic (including sea ducks).
Information from Merkel and Barry (2008)

Country/ Region	No. of species harvested	Most important species	Est. annual seabird harvest	Est. annual egg harvest	Overall trend in harvest	Reason for change
USA/ Alaska[1]	>25	Auklets, Murres	30,000 (2001-2005)	145,000 (2001-2005)	Variable annually, no trend evident (1995-2005)	Survey methods may not be comparable
Canada	8	Murres, C. eider	260,000 (2002-2008)	Some	Decreasing (1980-2002)	Regulation and fewer hunters
Faroes	9	fulmar, puffin	65,000-240,000	1,000-12,000	Decreasing (1980-2006)	Regulation and fewer hunters
Finland	6	oldsquaw, C. eider	31,000 (2000-2004)	Banned since 1962	Decreasing (1995-2005)	Regulation and fewer hunters
Greenland	19	C. eider, dovekie terns? (eggs)	153,000-220,000 (2002-2006)	6,600 (2006)	Decreasing (1993-2006)	Regulation and fewer hunters
Iceland	19	puffin, C. murre, C. eider (down, eggs)	158,000-285,000 (2002-2007)	Many	Decreasing[2] (1995-2007)	Decreasing pop[2].
Norway/ Svalbard	5/4	gulls/ B. guillemot	4,000/150 (1995-2008)	Some	Stable (1995-2008)	-
Russia West	~10	Eiders, murres, gulls	?	Some 1000s (<10,000) (illegal)	Increase in 1990s, now stable or decreasing	Changing law enforcement and social-economic situation
Russia East	~20	Eiders, alcids, gulls, terns, comorants	Eiders (50-62,000), other seabirds (~100,000, mainly illegal)	~100,000 (mainly illegal)	Decrease in early 1990s and gradual increase in 2000s	Changing law enforcement and social-economic situation

Shorebirds and waterfowl

Arctic and sub-Arctic intertidal mudflats serve as vital feeding and stopover sites for migratory waders (shorebirds) (e.g. Gill and Handel, 1990). Gill and Senner (1996) identified 15 sites of hemispheric importance in Alaska. Other sites in northern Norway and on Kolguev Island in the Russian Arctic serve as stopovers for thousands of migrating shorebirds (Kruckenberg et al. 2008). For such migratory species, the greatest challenges may relate to climate change, development pressures on habitat, or contaminants encountered at critical sites along the migration routes or in the southern winter range (Boyd and Madsen, 1997; Baker et al., 2004).

Many swans, geese, ducks, waders (shorebirds), loons (divers) and other water birds

[1]Studies focused on coastal zone management are exceptions here.

rely on salt marsh habitats for breeding and for accumulating body mass and nutrients to sustain them on their winter migration. Swans, geese, and other waterfowl and shorebirds in the outer Mackenzie Delta (including the Kendall Island Bird Sanctuary) occasionally experience breeding failure caused by early summer storm surges. In the long term, a more serious threat may come from loss of habitat through delta front erosion combined with sea-level rise and delta subsidence (Forbes et al., 2010). The brent (brant) goose (*Branta bernicla*) with an almost circumpolar distribution makes extensive use of coastal salt marsh habitats (Zöckler, 1998), which the high Arctic goose also uses on migration in temperate Europe, America and Asia. Barnacle geese (*Branta leucopsis*) have similar characteristics and their 400,000 strong Russian population relies on salt marsh habitats for breeding and grazing in the Arctic. Likewise, the emperor goose (*Anser canagica*), endemic to Beringia, is entirely confined to coastal salt marshes in northeastern Siberia and Alaska. Among the loons (divers), the red-throated loon (diver) (*Gavia stellata*) has its maximum distribution in Arctic salt marsh areas and deltas. The Sabine's gull (*Xema sabini*) and to some extent the Ross's gull (*Rhodosthetia rosea*) breed predominantly in salt marshes. The globally critically threatened spoon-billed sandpiper (*Eurynorhynchus pygmeus*) breeds exclusively near coastal habitats utilizing salt marshes and mudflats (Tomkovich et al., 2002). All of the aforementioned water birds are examples of species highly vulnerable to sea-level rise and other coastal changes, including changes in vegetation that alter the breeding habitat, so that populations either abandon or shift their distribution. This has already been noticed for the site-faithful spoon-billed sandpiper, which abandoned some of its most southern breeding territories due to vegetation changes in its coastal habitats (Zöckler et al. in press).

2.2.2 Ecosystem services

Ecosystem services have been defined by the Millennium Ecosystem Assessment (UNEP, 2005) as provisioning, cultural, supporting, regulating and preserving services for human well being. These services refer to the Arctic local people but also to the global community (e.g. carbon sequestration and mitigation). From an Arctic coastal perspective, fish stocks are most prominent and also coastal breeding birds and other coastal animals that are regularly harvested. From a cultural perspective, the variety of peoples and traditional lifestyles as well as the touristic value of coastal habitats and their communities are of great importance (Huntington et al., 2009a; Huntington and Pungowiyi, 2009). Coastal zones also provide services in protecting the coast line and buffering the impact of storm surges and ice flow. These services are expected to be in greater need with warming seas and increased storminess. Seabirds are an excellent example to illustrate the regional differences but also the challenges, when it comes to managing the harvesting of coastal biodiversity.

The common eider (*Somateria mollissima*) is a coastal breeding bird with an almost circumpolar distribution. This duck and two other Arctic eider species of the same genus are highly valued living resources in the Arctic. The birds or their products are harvested throughout most of the circumpolar region. As the largest duck in the Northern Hemisphere, the eider is important for traditional food and lifestyle in many Arctic communities (Merkel and Barry, 2008; Syroechkovskiy and Klokov, 2007). In some countries, especially Iceland, down feather collection constitutes a significant commercial industry (Bédard et al., 2008). Common eiders have a circumpolar distribution and are dependent on benthic organisms in shallow marine waters for food throughout the year, making them a potential indicator of the health of marine coastal environments (http://maps.grida.no/go/graphic/distribution-of-common-eider-breeding-and-wintering- ranges-in-the-arctic).

Table 3 summarizes the various ecosystem services in relation to coastal ecosystems.

Table 3. Examples of ecosystem services provided by different Arctic coastal habitats (✓ indicates the habitat provides a significant amount of the service, modified after UNEP, 2005).

Ecosystem services

	Estuaries and Marshes	Lagoon and salt ponds	Intertidal mudflats	Kelp	Rock and shell reefs	Seagrass	Inner Shelf
Biodiversity	✓	✓	✓	✓	✓	✓	✓
Provisioning services							
Food	✓	✓	✓	✓	✓	✓	✓
Fibre, timber, fuel	✓	✓					✓
Medicines, other resources	✓	✓		✓			
Regulating services							
Biological regulation	✓	✓	✓		✓		
Freshwater storage and retention	✓	✓					
Hydrological balance	✓	✓	✓				
Atmospheric and climate regulation	✓	✓	✓		✓	✓	✓
Human disease control	✓	✓	✓		✓	✓	
Waste processing	✓	✓				✓	
Flood/storm protection	✓	✓	✓	✓	✓	✓	
Erosion control	✓	✓				✓	
Cultural services							
Cultural and amenity	✓	✓	✓	✓	✓	✓	✓
Recreational	✓	✓	✓	✓			
Aesthetics	✓	✓	✓				
Education and research	✓	✓	✓	✓	✓	✓	
Supporting							
Biochemical	✓			✓			
Nutrient cycling and fertility	✓	✓	✓	✓	✓		✓

2.2.3 Processes, drivers and pressures

Compared to global coasts in general, Arctic coasts largely still escape the pressure of human impact. Based on a global research effort evaluating the impact of 17 combined anthropogenic marine stressors, including coastal runoff and pollution, warming water temperature due to human-induced climate change, oil rigs that damage the sea floor, and five different kinds of fishing, most of the Arctic coastline shows low to very low impact (Halpern et al., 2008). However some areas in the Barents Sea and Bering Sea are considered highly or even very highly impacted and the sea around West Greenland shows a medium high impact.

Tourism is increasing across the Arctic and the number of cruise ships has been growing rapidly in recent years, particularly in the Canadian Arctic, Labrador, and Greenland, but also in longstanding cruise destinations in Svalbard and northern Norway (Hall and Saarinen, 2010a, 2010b). Tourists are now landing in places where they have never landed before, placing added stress on popular sites and increasing ship traffic with concomitant added risks of accidents, oil spills, and biological invasion (Hall, 2010; Hall et al., 2010).

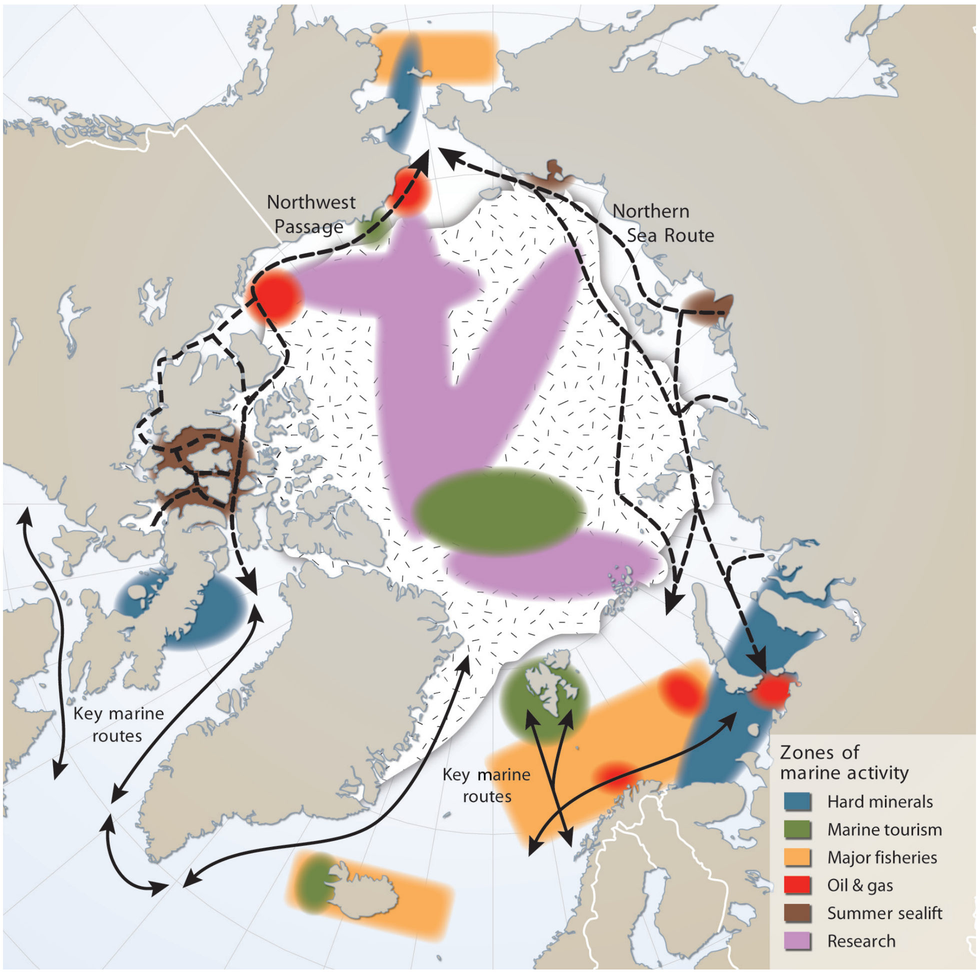
Oil spills present the greatest anthropogenic risk for the marine and coastal environment in the Arctic. Seasonality is a major driver for how pollutants can affect ecosystems. The impact of an oil spill on ice covered waters is of particular concern due to limited options in containing or responding to a spill in open or shifting pack ice. In the event of a spill in the open ocean the oil will inevitably end up at the coast when winds and currents drive it in a predominant direction. The dispersion of an oil spill would inevitably lead to extensive contamination of coast line as was evident in the Exxon Valdez spill in Alaska's Prince William Sound. Birds and other animals are most affected by a spill if they are physically coated with oil. Seals and whales are not as sensitive due to their blubber coating. Oil spills in aquatic environments are particularly dangerous because they can spread over large areas and distances. Clean up of any oil spill in the Arctic would be difficult due to the remoteness. Ice-edge communities would be the most difficult to remediate.

Climate change is likely to open or expand shipping routes, particularly north-east and north-west trans-Arctic shipping routes, or ever 'over-the-top' trans-ocean routes (Fig. 26). This, in turn, expands the range of locations where spill, recovery, and rescue response will be required. Seasonal patterns of migration and breeding determine vulnerability in Arctic systems and add importance to the timing of oil and gas activities and their impacts. Following breeding, shorebirds, ducks and geese congregate in coastal habitats where they feed and prepare for their southbound migration. Many indigenous cultures rely on the harvesting of these seasonal migrators. Near shore facilities and ship routes pose a great risk for coastal impacts. The timing of spills in relation to when fish are spawning or marine mammals are present is thus of major importance. The marginal ice zone is a location where animal aggregations are common.

Overfishing and over-exploitation of coastal marine resources pose another increasing threat (UNEP, 2007; ICES, 2008). With increasing accessibility and more and more modern technology even remote regions can be accessed for fishing and hunting, leaving more limited areas for recovery. Strict law enforcement and fishery and hunting restriction are required but not always implemented across the Arctic region (see also Table 2).

For many Arctic mammals and seabirds, changes in the extent and timing of sea-ice cover over the past several decades (Stirling and Parkinson 2006; Gaston et al. 2005) are leading to changes in phenology and reproduction with adverse consequences on breeding success. These changes seem likely to intensify. Aside from climate change, problems also include fisheries interactions, contaminants, and oil spills (PAME, 2009b) and hunting (CAFF, 2009). Levels of some contaminants, especially mercury, have increased in seabird eggs in the North American Arctic since the 1970s, although they remain at sub-lethal levels (Braune et al. 2001). If climate change leads to increased shipping and oil and gas exploitation in Arctic waters, the increased risk of spills would pose an additional stress and potential hazard to coastal marine biodiversity (Wiese and Robertson, 2004; AMAP, 2007; PAME, 2009a, 2009b) , some of which are extremely susceptible to mortality from oil pollution.

Figure 26. Current marine shipping uses in the Arctic.
Source: PAME (2009a)



Reductions in sea ice extent, duration, and thickness will likely increase human presence and activities in the Arctic (Hovelsrud et al. 2008, Ragen et al. 2008). Longer ice free seasons and reduced ice coverage could increase shipping activity and enhance resource exploration, development, and production impacting vulnerable coastal species, such as polar bears, walrus, seals and many seabird species. Potential effects of shipping include pollution, noise, physical disturbance related to ice-breaking, and waste. The number and range of cruise ships moving further north, reaching coastal areas previously untouched, may also increase the pressure on coastal ecosystems (Hall, 2010; Hall et al., 2010). Potential effects of increased tourism include pollution, disturbance, and increased risk of defence kills and biological invasion. The Arctic Marine Shipping Assessment (PAME, 2009a) mapped the distribution of shipping activities under various use classes (minerals, oil and gas, major fisheries, summer sealift, marine tourism, and research) (Fig. 26).

2.2.4 Management responses

Oil spill response facilities spaced along transportation corridors and near port facilities

Oil spill response is a major challenge, especially where ice is present. Many coastal locations that are vulnerable have limited response equipment available. Increased tanker traffic and platform installation, particularly in the Norwegian and Russian fields, is likely to continue. It is desireable that transportation and infrastructure development use the best environmental and engineering practices; be designed using adequate methods for the potential location(s) affected; and be designed to reduce the risk of marine and terrestrial spills but particularly spills on or near sea ice.

The loss of sea ice is likely to improve access to locations in the Arctic (including current port facilities) and to lengthen the shipping season. A negative consequence of having more open water is the potential for increased wave action and coastal erosion. Coastal and offshore based facilities thus must be designed to withstand the predicted increase in wave and erosion energy and activity.

PAME (2009b) developed a set of guidelines for Arctic offshore oil and gas exploration. These comprise safety management, compliance monitoring, methods, practices and standards as well as operating practices and training requirements and the level of preparedness for spill response. As is evident in the response to the Gulf of Mexico oil rig explosion and spill in 2010, oil spills in readily accessible areas can pose substantial control and remediation challenges. A similar mishap in an Arctic marine location with sea ice could be far more challenging.

Coastal Protected areas

Protected areas are still considered a key element for maintaining and conserving Arctic biodiversity and the functioning landscapes upon which species depend. Arctic protected areas have been established in strategically important and representative areas, helping to maintain crucial ecological processes, habitats and species, e.g., caribou migration and calving areas, shorebird and waterfowl staging and nesting sites, seabird colonies, and critical components of marine mammal habitats. Arctic marine and coastal areas are increasingly protected, yet still cover less than 5% of the Arctic coast line and below the average of all the other Arctic habitats (see Box).

Coastal zone management

By the early 1990s common eiders along with other eider species had generally declined over the past two to five decades, and the need to stabilize and manage eider populations was increasingly recognized. As part of the Arctic Environmental Protection Strategy, signed in 1991, the Circumpolar Seabird Working Group under CAFF developed a Circumpolar Eider Conservation Strategy and Action Plan (CSWG 1997). The factors behind several eider population declines reported in the 1980s and 1990s were often unknown, but in some cases involved human disturbances, excessive harvest, and severe climatic events (Robertson and Gilchrist, 1998; Suydam et al., 2000; Merkel, 2004). The current trend of common eider populations varies but at least some populations in Alaska, Canada, and Greenland are now recovering with improved harvest management as a likely contributing factor (Chaulk et al. 2005, Gilliland et al. 2009).

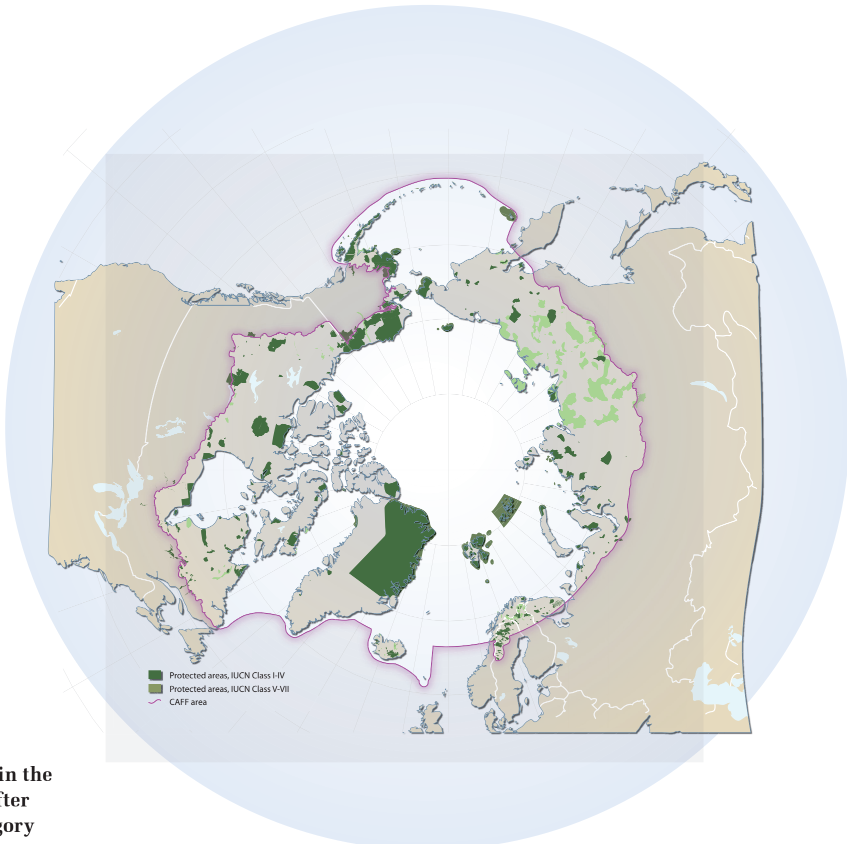
Further details on institutional arrangements for Arctic coastal zone management can be found in Section 2.3.7 below.

Protected Coastal Areas *C. Zöckler (UNEP)*

The first protected areas dataset for the Arctic was created by the Conservation of Arctic Flora and Fauna (CAFF) Working Group of the Arctic Council in 1994. It has recently been updated as part of CAFFs ongoing Arctic Biodiversity Assessment (ABA) (www.caff.is/aba), which is a follow-up to ACIA (2005). The term 'Protected areas' is included in the suite of indicators included within the first ABA report, *Arctic Biodiversity Trends 2010: selected indicators of change.* This new dataset contains data officially submitted by each of the Arctic Council countries (Canada, Sweden, Norway, Denmark, Greenland, Faeroe Islands, Iceland, Finland, Russia, USA).

A key finding from the *Arctic Biodiversity Trends 2010* report was that, since 1991, the extent of protected areas in the Arctic has increased, although marine areas remain poorly represented. The analysis found that 11% of the area of the Arctic as defined by CAFF (see map) has protected status. This represents a doubling of the area protected in the last 30 years. The initial results also indicate that over 40% of the protected areas recorded have a coastal component. However for the majority of these areas it is not possible at present to determine the extent to which they incorporate the adjacent coastal/marine environment. To redress this gap in knowledge, CAFF has launched a project led by Iceland to consider the extent that protection extends into the coastal environment. This project will further develop the information on these areas and compile a dataset detailing the nature and extent of the protection afforded.

This project reflects but one aspect of CAFFs activities addressing protected areas in the Arctic. Other activities include establishment under the Circumpolar Biodiversity Monitoring Programme (CBMP) of an expert group with members from all Arctic countries to develop an Arctic Protected Areas Monitoring Plan. In addition, CAFF is actively following up on the Arctic Marine Shipping Assessment (AMSA) recommendations to consider marine sensitive areas in the Arctic and is also cooperating with the International Union for Conservation of Nature (IUCN) to address related aspects of protection in the coastal/marine environment.



Protected areas in the Arctic classed after their IUCN category