Environmental Considerations and Impacts

Marine shipping, if not properly managed, poses a threat to natural ecosystems. This is especially true for the Arctic. Whether it is the release of substances through emissions to air or discharges to water, accidental releases of oil or hazardous cargo, disturbances of wildlife through sound, sight, collisions or the introduction of invasive alien species, the Arctic marine environment is especially vulnerable to potential impacts from marine activity.

Vulnerability of Arctic Species and Ecosystems

Extreme cold temperatures, ice and strong seasonal variability characterize the Arctic. These extremes have resulted in a range of adaptations among Arctic animals including the ability to store energy when food is plentiful and fast when it is not; highly insulating outer layers such as feather, fur or blubber to keep warm; and a high degree of seasonal migration to and from the region, especially among marine mammals and birds.

The extensive seasonal migrations of marine mammals and birds into and out of the Arctic are key features that determine the vulnerability of Arctic ecosystems. Seabirds, shorebirds and waterfowl move north to breed and feed during the short Arctic summer, exploiting the burst of productivity in the northern ecosystems. Whales and seals have similar migrations to northern feeding areas. Many species aggregate throughout the circumpolar north in very large numbers to feed, mate, give birth, nurture their young and molt. During the periods when Arctic species gather and in the areas where they do so, they are particularly vulnerable to potential environmental stresses, such as accidental discharges from ships and various types of disturbances that ships can cause.

Disturbance during critical stages could disrupt the short feeding season for Arctic species, causing some animals to not get enough food to provide the energy needed for the long migrations they face and for breeding and raising their young. Arctic species, which are reliant on feathers and fur to insulate against the cold, are especially vulnerable to contamination from oil that will compromise their insulating layers, leaving them exposed and at risk of hypothermia and death. It is the unique adaptations of the various species which live in and migrate to the Arctic that make them vulnerable to potential adverse impacts as a result of shipping and other vessel activities.

The degree of oil pollution in the Arctic marine environment is low, according to the recent Arctic Council Assessment of Oil and Gas Activities, with natural seeps being the largest source of input of oil hydrocarbons. Accidental oil spills were seen as the largest threat. While the Arctic environment is still relatively clean for many types of contaminants, recent assessments by the Arctic Monitoring and Assessment Programme (AMAP) have shown that persistent organic pollutants (POPs) occur at high levels and pose a threat to top predators in marine food chains, including humans. Heavy metals such as mercury, cadmium and lead are also seen as issues of concern in some parts of the Arctic.

Arctic Species: Interactions with Shipping

Arctic marine mammals such as bowhead, beluga, narwhal, walrus and several species of seals migrate south in fall to spend the winter in the southern areas of seasonal ice. In spring, they move north again, using systems of polynyas and leads, often before the break-up of the ice. At this time, these mammals reproduce and give birth to their young. Important wintering areas for marine mammals are in the broken pack ice in the northern Bering Sea, Hudson Strait, Davis Strait and southeastern Barents Sea. From these areas, the mammals follow leads and openings north through the Bering Strait and the Chukchi Sea; north through Baffin Bay into Lancaster Sound, into Hudson Bay and Foxe Basin; and north and east into the Kara and Laptev seas. The leads and openings in the ice are also used by seabirds, eiders and other marine birds on their spring migration to the northern breeding areas.

As climate and sea ice conditions continue to change, the timing and movements of the animals' activity will also be modified, making predictions of the potential interactions between shipping and animals increasingly complex.

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The migration corridors used by marine mammals and birds correspond broadly with the main shipping routes into and out of the Arctic. Currently, there is limited overlap during the spring migrations as all shipping activity will typically occur later in the spring than the animal migrations. In the fall, there is likely more opportunity for interaction between ships and migrating species, as both are leaving the Arctic ahead of the formation of the pack ice. As the Arctic climate continues to change, it is very likely that the shipping season could extend earlier in the spring and later into the fall. The spring migration corridors are particularly sensitive and vulnerable areas to oil spills, ship strikes and disturbances, and could be a time of vulnerability for marine mammals and birds. In the future there will be a need to consider the potential risk and interaction between ships and animals during this vulnerable period.

The geographic area covered by this assessment spans a wide range of environmental conditions, from pack ice in the Arctic Ocean to open subarctic waters in the Bering Sea and the Nordic seas in the northeastern Atlantic. The volume of current shipping traffic also varies considerably across the Arctic. Currently, there is significant year-round traffic along the subarctic coast of Norway, around Iceland, on the southeast coast of Greenland and out of the Yenisei River and Pechora Sea to the port of Murmansk in northwest Russia. There is a moderate amount of seasonal shipping to and from destinations in the North American Arctic, and no established trans-Arctic traffic. Risk of negative interaction between vessels and wildlife varies across the region. The North Pacific Great Circle Route between western North America and eastern Asia is a high volume shipping lane that swings through the Unimak Pass in the Aleutian chain, passing in close proximity to important marine mammal haul-outs, rookeries and nesting sites of marine mammals and seabirds, close to active commercial fishing grounds and one of the largest protected essential fish habitats in the world.

The Arctic is Changing

The Arctic climate is warming. The effects of this are now being seen in the retreating sea ice, melting permafrost and the changing timing of the onset of fall and spring, as well as the increasing variability within each season. These changes are affecting Arctic species and ecosystems. Where caribou used to migrate across frozen rivers, they now have to wade. Polar bears swim farther to find food and wait longer in the fall for the pack ice to reform, extending their fasting. Pacific walrus are now hauling out on land in the Chukchi Sea, where they used to haul out mainly on sea ice.

Arctic species and ecosystems are, by nature, highly evolved in function and finely tuned with the timing of seasonal events. Although some species will benefit from the changes, there are many that are now under stress as a result and, for some, at risk of steep decline. For many species, any potential impacts as a result of current or future shipping activity will be in addition to the stress they are already under due to the changes occurring in their environment. It is beyond the scope of the current assessment to examine the interaction between effects from climate change and effects from future shipping activities. This is in part because of the intrinsic difficulties and the many uncertainties about the future.

Climate experts are projecting that the main change in sea ice will be decreasing ice coverage in the summer along the coastal Arctic seas with the formation of first-year ice occurring later in the fall. Even with a warmer climate, the Arctic Ocean will still remain ice-covered for most of the year. As climate and sea ice conditions continue to change, the timing and movements of the animals' activity will also be modified, making predictions of the potential interactions between shipping and animals increasingly complex.

Ship Based Impacts

Accidental Discharge

The accidental release of oil or toxic chemicals can be considered one of the most serious threats to Arctic ecosystems as a result of shipping. The release of oil into the Arctic environment could have immediate and long-term consequences. Some Arctic animals are particularly sensitive to oil because it reduces the insulating properties of feathers and fur and they can quickly die from hypothermia if affected. This is the case for seabirds, including eiders and other sea ducks, and also polar bear and seal pups. Concentrated aggregations of birds and mammals, often in confined spaces such as leads and polynyas, increase the risk to the animals in the case of an oil spill in the Arctic. Crude and refined oils, including fuel oils used by ships, vary much in their physical and chemical properties. This, in addition to other factors such as temperature, light, waves and ice, plays a major role in the behavior of oil in the environment and the extent of biological effects.

Other potential problems from released oil include the transfer of oil to nests by sea birds landing on oil slicks and the ingestion of oil by animals while preening. This can lead to death or other biological effects both in the short and long term. Even small spills can have large consequences if they occur where marine birds are concentrated.

Chronic seepage of residual oil after a spill can affect the entire food chain in an area because hydrocarbons are taken up by bottom feeding invertebrates, which then end up as prey for sea birds and

Environmental Impacts and Disturbances from Cruise Ships

The number of cruise ships operating in the Arctic is rapidly increasing. These ships are traveling to the region for the scenery and to actively seek out areas of special interest, including exceptional wildlife viewing opportunities. Wildlife is a primary attraction for polar tourists. Polar ecosystems, particularly in coastal environments, and wildlife migratory events provide tourists with opportunities to view many species of land and marine mammals as well as a remarkable diversity of birds. However, because cruise ships are specifically seeking out such events and opportunities, the potential is created for significant impacts on concentrations of wildlife due to disturbance from the ship.

There are numerous ways passenger ships can cause environmental harm. Emission of substances to the local air and ocean, possible incidents including sinkings and groundings, ship operations unsuitable for polar conditions and the inappropriate behavior of passengers ashore are the most prominent impacts. The 2004 U.S. Commission on Ocean Policy reported that, while at sea, the average cruise-ship passenger generates about eight gallons of sewage per day and an average cruise ship can generate a total of 532,000 to 798,000 liters of sewage and 3.8 million liters of wastewater from sinks, showers and laundries each week, as well as large amounts of solid waste (garbage). The average cruise ship will also produce more than 95,000 liters of oily bilge water from engines and machinery a week.

Sewage, solid waste and oily bilge water release are regulated through MARPOL. There are no restrictions on the release of treated wastewater. MARPOL restrictions typically prescribe the allowed distance from shore and rate at which wastes can be released or requires ships to deposit them in shore-side reception facilities. However, the Arctic region lacks infrastructure to adequately dispose of bilge water, sewage and solid waste. Many Arctic communities do not even have sufficient facilities to deal with the waste of their own communities, let alone that of tourist vessels. When ships are forced to stockpile wastes onboard where reception facilities are lacking, the risk of illegal or accidental release into sensitive areas is heightened. The alternative to depositing waste into onshore facilities is onboard incineration, a practice that also brings with it concerns about localized air pollution.

The extent of the impacts on different Arctic species from cruise ships is difficult to assess due to the lack of Arctic-specific baseline information on wildlife and the relatively recent increase in cruise ship activity. The cruise ship industry has a vested interest in maintaining healthy wildlife populations; however, there are currently no common best practices for the circumpolar Arctic as there is in the Antarctic through the International Association of Antarctica Tour Operators. The Arctic's one cruise organization, the Association of Arctic Expedition Cruise Operators, is limited in scope with its geographic range in the Svalbard, Jan Mayen and Greenland area. Cooperation among cruise ship operators, in partnership with academic and regulatory bodies, is necessary to ensure more sustainable eco-tourism in the Arctic.

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other animals, causing effects higher up the food web. Arctic animals are also particularly vulnerable to spills in certain areas and at certain times of the year when animals aggregate in large numbers to breed, nest, bear young and molt.

The Arctic is an extreme environment with a range of weather, light, hazards and with little human infrastructure. Responding to oil spills in these conditions is a major challenge, especially where ice is present. There are currently limited methods for recovering spilled oil in an ice-covered environment. The options currently available for oil spill recovery in the Arctic include mechanical methods, bio-remediation, dispersants and/or in-situ burning. Consequently, strong prevention measures must be of primary concern, while response measures, being both unreliable and untested, should be secondary. The risk of accidental release of oil and other contaminants increases with any increase in shipping activity that involves the use or transportation of oil or other chemicals.

Regular Discharges to Water

As a part of normal operations, ships produce a range of substances that must eventually be eliminated from the ship through discharge into the ocean, incineration or transfer to port-based reception facilities. Referred to as regular discharges these include oil, ballast water, bilge water, tank washings (oily water), oily sludge, sewage (black water), garbage and grey water. Regular ship discharges are regulated through the IMO's *International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto* (MARPOL 73/78) and other IMO conventions, as well as through domestic regulation by coastal states (See page 59). MARPOL has effectively reduced pollution in the marine environment by regulating the release of regular discharges. However, it has not eliminated discharges into the world's oceans altogether.

Ship Category	Ship Sub-category/ Use	Ship Type–Specific Pollution Sources
Government Vessels and Icebreakers	Coast guard vessels, research icebreakers, private icebreakers, government icebreakers, other research vessels	Accident/incident recovery-produced contaminants, emergency dumping oil/fuel, nuclear icebreaker radiation contamination, explosives/munitions, impacts due to icebreaking activity (disruption of ice formation, marine mammals, etc).
Container Ships	Cargo transport	Hazardous goods in transit, convoy collision hazard, grounding hazard (uncharted waters, lack of experienced ice navigation).
General Cargo	Community re-supply vessels, roll on/roll off cargo	Hazardous goods in transit, accidental cargo release, contaminated cargo.
Bulk Carriers	Timber, merchant, oil, ore, automobile carriers	Release of metal contaminants, radiation contamination from cargo, hazardous goods in transit.
Tanker Ships	Oil tankers, natural gas tankers, chemical tankers	Liquid Nitrogen Gas contamination, chemicals and hazardous goods in transit, spills from oil transfer.
Passenger Ships	Cruise ships, ocean liners, ferries	Large volumes of black and grey water release, garbage disposal, cleaning contaminants, disturbance of wildlife through viewing activities, automotive contaminants w/ vehicles ferries .
Tug / Barge	Re-supply vessels Bulk cargo transport	Increased accident hazard (non-propelled), hazardous goods in transit, spills during oil transfer, heavy emitters of air contaminants (black carbon).
Fishing Vessels	Small fishing boats, trawlers, whaling boats, fish processing boats	Increased fire hazard, introduction of pathogens and other contaminants from released fish offal, accidental release of invasive species/related biological contaminants, release of plastics, ghost nets and other fishing debris, seafloor damage from bottom trawlers, depletion of marine species (if not managed), accidental release of refrigerant contaminants.
Oil and Gas Exploration/Exploitation Vessels	Seismic exploratory vessels, oceanic and hydrographic survey vessels, oil drilling vessels, oil and gas storage vessels, offshore re-supply, portable oil platform vessels, other oil and gas support vessels	Hazardous cargo, explosives, acoustic impacts from seismic activities, oil/hydrocarbon contamination, contamination from extraction chemicals, accidental loading/offloading spillage, fire hazards.

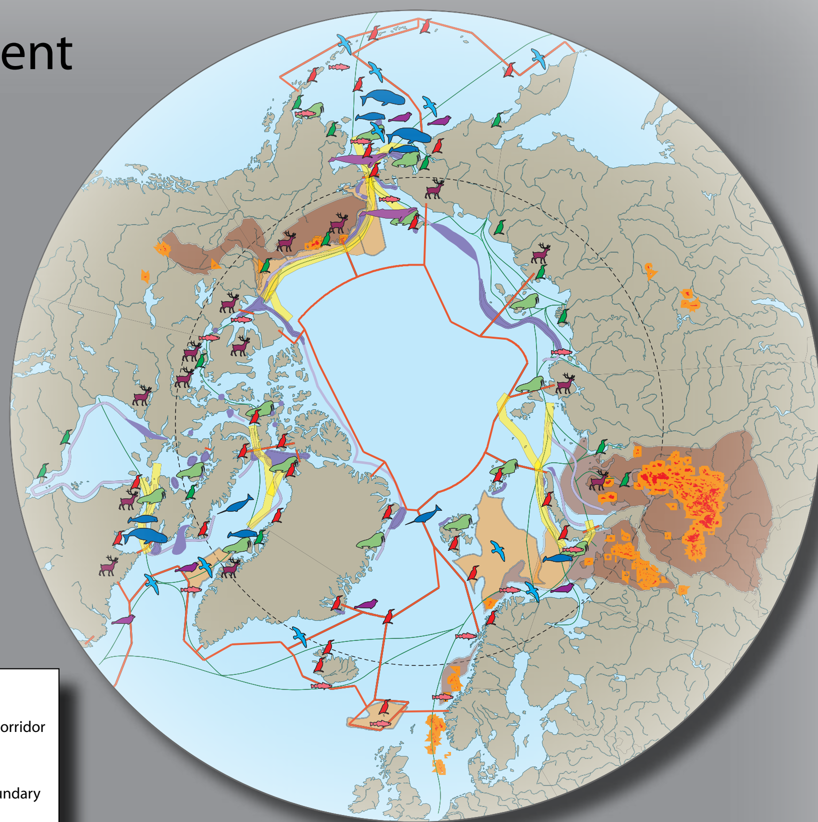
Table 8.1 A range of potential environmental impacts linked to ship types operating in the Arctic. *Note: All ships will have certain impacts linked to the release of grey water, sewage, ballast and bilge water; air emissions; regular and accidental discharge of fuel/oil; introduction of noise and other acoustics such as sonar; and possible strikes on animals. Those listed above are in addition to these and specific to the vessel type. Source: AMSA*

Oil is released with bilge water with a maximum allowed concentration of 15 parts per million (15 mg per m^3) after treatment with an oil separator. Oil is also released with water used for tank washings after required treatment and with restrictions on amount and rate of release to avoid formation of oil film at the surface (i.e., blue shine). Oily sludge, consisting of high molecular hydrocarbon substances, accumulates in fuel tanks in fairly large amounts, constituting typically 1-5 percent of the amount of fuel consumed. Oily sludge must not be released but stored on board and brought to reception facilities in ports.

A recent study of regular discharges from ships in the Norwegian and Barents seas provides an example of the level of discharge expected to be released in an area that has some of the heaviest ship traffic in the Arctic or subarctic region. In this study it was estimated that the amount of oil released via bilge water and tank washings that the MARPOL allowed 15 ppm totaled about two tons of oil per year, a relatively small amount. However, the study found ship operations generate about 13,000 metric tons of oily sludge annually.

Arctic Oil and Gas Assessment

A comprehensive assessment of the oil and gas activities in the Arctic was carried out in 2007 by the Arctic Council under the leadership of the Arctic Monitoring and Assessment Programme working group. This assessment summarized information on the history, current and projected oil and gas activities in the Arctic, and examined socio-economic and environmental effects associated with these activities. The assessment included a detailed description of the main features and species of the Arctic ecosystems and their vulnerability to oil spills and disturbances from oil and gas activities. An illustrative circumpolar map of vulnerable areas based on aggregations of mammals, birds, and fish was produced as an outcome.



- Caribou/reindeer calving grounds
- Seabird colonies
- Staging area - birds
- Wintering area - birds
- Feeding area - grey whale
- Wintering area - bowhead
- Wintering area - narwhal
- Wintering area - beluga
- Walrus aggregations
- Whelping area - seals

- Spawning area - fish
- Marine mammal migration corridor
- Shipping route
- Large Marine Ecosystem boundary
- Major shore lead polynya
- Concentrations of polynyas
- Producing fields
- Production areas
- Basin/province with production
- Major exploration basins

An illustrative map from the Arctic Oil and Gas 2007 assessment of areas in the Arctic indicating where selected birds, mammals and fish form major aggregations to breed, stage, migrate or overwinter. When oil and gas activities including transportation occur in such areas, such aggregations are vulnerable to disturbances and oil spills. *Source: AMAP*

1.0%

The 2004 Arctic shipping contribution of CO_2 emissions to the total from the global shipping fleet.

Wild Card – Ship Stack Emissions – NOx, SOx, Black Carbon and Ozone

Ships are powered by engines and fuels that, like other transportation modes, emit CO_2 and water vapor, nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO) and particulate matter (including black carbon [BC]). Most oceangoing ships burn low-quality residual fuels that tend to contain high amounts of particulates from soot (black carbon), sulfur aerosols, ash and heavy metals.

These are pollutants specifically quantified in the inventory of emissions from Arctic shipping in this assessment. These pollutants are linked with specific environmental effects, and complex interactions occur among these substances in the regional and global atmosphere. For example, NOx is a gaseous contributor to tropospheric ozone formation; SOx gases form particles that contribute to acid rain and cloud effects on regional climate; and other fine particles like black carbon impact air quality, visibility and climate change.

Shipping's contribution to regional and global impacts from emissions such as CO_2, NOx and SO_2 have been evaluated by scientists and shown to be significant enough to motivate policy action. However, environmental and climate effects of NOx and ozone, sulfur aerosols and clouds, and black carbon particles in the Arctic are only beginning to be understood. Black carbon has been proven to have significant climate forcing effects, in addition to its effects on snow and ice albedo, accelerating the retreat of Arctic sea ice.

Background levels of NOx, the precursor to ozone, are very low in the Arctic and recent studies have found that seasonal increases in ozone are closely linked to seasonal increases in shipping activity. Surface ozone is known to have harmful effects on plant growth and human health and is the basis for photochemical smog.

Ship stack emissions in and near the Arctic will increase along with growth in shipping activity, except where regulations like MARPOL Annex VI require steep reductions in sulfur emissions through fuel sulfur limits or pollution reductions in specially designated regions. The specific benefits of reducing impacts in the Arctic through control of ship emissions need to be further studied, and the AMSA inventory for 2004 provides a good baseline inventory to evaluate scenarios that may achieve these benefits.

Based on AMSA findings, the report recommends continued study of ship-based emissions and trends. Climate change policy is currently focused on CO_2 from ships and the potential climate response to lower ship sulfur emissions is becoming recognized. NOx emission controls may mitigate some of the Arctic regional ozone impacts suggested by one international study and the AMSA inventory provides an opportunity to update previous research findings.

More recently, scientists are recognizing that black carbon particles have potentially significant impacts on the vulnerable Arctic environment and climate that need to be quantified. The AMSA contribution to further research may be very important, given that recent studies suggest that reduction of the positive climate forcing due to BC would decrease both global warming and retreat of the sea ice and glaciers and would therefore provide an opportunity for effective short term mitigation of global warming.

The release and deposition of black carbon in the Arctic region is of particular concern because of the effect it has on reducing the albedo (reflectivity) of sea ice and snow.

Table 8.2 Estimated emissions in the Arctic for 2004 by ship type. *Source: AMSA*

Emission amounts were calculated using the AMSA marine activity database (See page 70), which is based on information reported by Arctic Council member states. Baseline information was provided in different formats and to different degrees of detail between states.

Vessel Category	Fuel Use (kt/y)	CO_2 (kt/y)	BC (t/y)	NOx (kt/y)	PM (kt/y)	SOx (kt/y)	CO (kt/y)
Bulk	354	1,120	122	26.9	17.9	18.6	2.57
Container	689	2,170	239	52.5	35.0	36.2	5.01
General Cargo[1]	590	1,860	202	44.9	29.9	31.0	4.29
Government Vessel	117	368	40.1	8.89	5.92	6.13	0.85
Other Service Vessel	3	11	1.19	0.26	0.18	0.18	0.03
Passenger Vessel	349	1,100	120	26.6	17.7	18.3	2.54
Tanker	269	848	92.5	20.5	13.7	14.1	1.96
Tug and Barge	17	54	3.38	1.32	0.88	0.91	0.13
Fishing[2]	1,020	3,230	363	78.0	52.0	53.8	7.4
Total	**3,410**	**10,800**	**1,180**	**260**	**173**	**179**	**25**

1. A review and comparison of the AMSA estimated fuel use by General Cargo vessels with recent activity-based inventories completed by Norwegian researchers at DNV suggest that this category may be overestimated, due to the world fleet characteristics for general cargo ships reflecting larger vessels with more installed power than typical for Arctic operations.

2. A review and comparison of the AMSA Fishing vessel data with more direct activity-based estimates completed by DNV for Norwegian fishing vessels suggests that this first estimate may be in the range of three to four times higher than what was found by DNV. This is likely because the AMSA fishing vessel estimates are based primarily on days at sea, which assumes the vessel engine runs at varying capacity for the entire period at sea and may overestimate fishing vessel emissions and fuel use.

The amount of legally discharged oil under MARPOL in the Norwegian study indicates that current amounts of legally discharged oil should not pose a significant threat to the local ecosystem so long as the laws are strictly followed. MARPOL requires oily sludge to be disposed of in port-based reception facilities. Norway is unusual in the Arctic region in that it has good port reception facilities in all of its Arctic ports, but that is not the case in many other areas of the Arctic. In some areas, limited port side infrastructure as well as the cost of disposing of waste using port reception facilities provide incentive for illegal dumping of wastes produced on board.

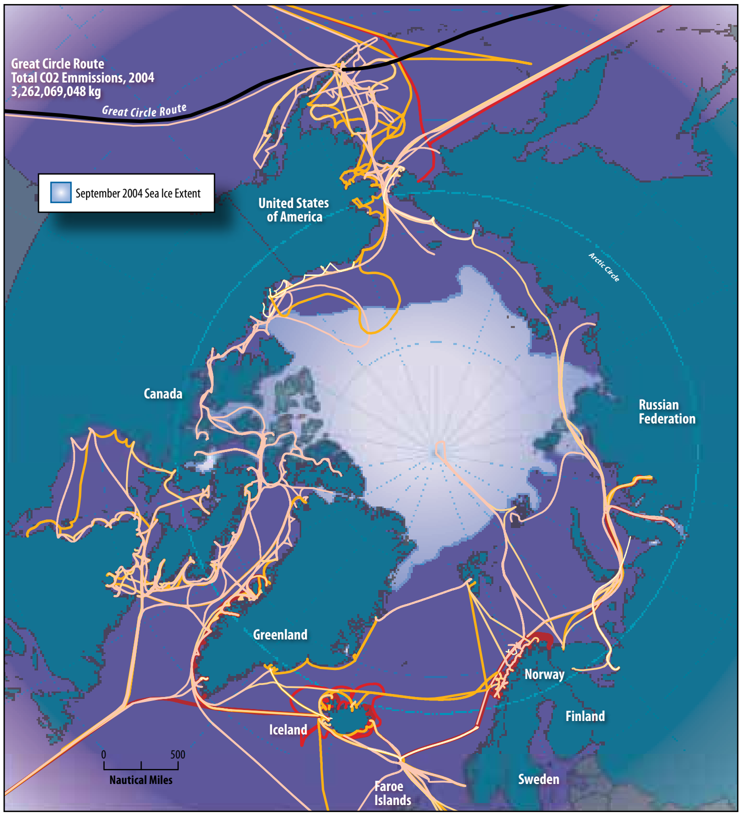
Considering the sheer volume of oily sludge produced in Norwegian waters alone, it would take only a small percentage of the oily sludge produced to be illegally discharged for it to cause environmental damage. Illegal release of oil and oily sludge can cause oiling of animals and birds, can be toxic to marine and terrestrial ecosystems and extremely difficult to clean up. Contamination can last for years in ocean sediment and other compartments of the marine environment, sometimes presenting contaminated prey upward within marine and coastal food chains. Oily sludge is not the only regular discharge that can end up in the ocean. Under MARPOL it is legal to discharge garbage and raw sewage into the water once a ship is a certain distance from shore. The presence of significant amounts of garbage and other debris in the ocean can result in a number of environmental impacts. These range from damage to marine habitat, entanglement of wildlife, introduction of bacteria and disease (from untreated human sewage) and the ingestion of plastics and other unsuitable items by marine mammals and birds. As vessel activity increases in the Arctic, the management of regular discharges from all vessels will need to be seriously considered so that environmental impacts are minimized.

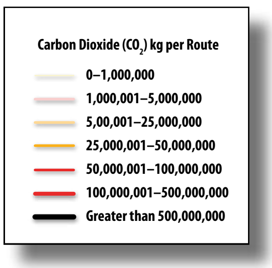
Ship Emissions to Air

Studies assessing the potential impacts of international shipping on climate and air pollution demonstrate that ships contribute significantly to global climate change and health impacts through emission of GHGs (for example, carbon dioxide [CO_2], methane [CH_4], chlorofluorocarbons [CFC]), aerosols, nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO) and particulate matter (PM). Air quality impacts may result from the chemical processing and atmospheric transport of ship emissions. For example, NOx emissions from ships can combine with hydrocarbons in the presence of sunlight to produce ozone pollution, which can potentially affect visibility through haze, human and environmental health and has been associated with climate change effects.

The AMSA has developed the world's first activity-based estimate of Arctic marine shipping emissions using empirical data for shipping reported by Arctic Council member states. Emissions were calculated for each vessel-trip for which data was available for the base year 2004. The 515,000 trips analyzed represent about 14.2 million km of distance traveled (or 7.7 million nautical miles) by transport vessels; fishing vessels represent over 15,000 fishing vessel days at sea for 2004. Some results could be an underestimation of current emissions, given potential underreporting bias and anecdotal reports of recent growth in international shipping and

Map 8.1 Arctic shipping emissions map. *Source: AMSA*





Emission amounts were calculated using the AMSA marine activity database (See page 70), which is based on information reported by Arctic Council member states. Baseline information was provided in different formats and to different degrees of detail between states.

trade through the Arctic. Researchers at DNV recently completed a similar activity based emissions inventory for Norwegian waters (*Operational emissions to air and sea from shipping activities in Norwegian sea areas. DNV Report No. 2007-2030*). A review and comparison of the DNV results with the Norwegian portion of the AMSA results showed good agreement for all vessel types, except for general cargo and fishing vessel estimates. The AMSA results for Norway were sometimes greater than, and sometime less than, the DNV results, generally falling within 10 percent to 30 percent confidence. The AMSA evaluates ship emissions of greenhouse gases and air quality pollutants that may have regional or local impacts; however it does not directly conduct the detailed studies needed to determine the level of impact (Table 8.2).

Results show CO_2 emissions from international shipping in the Arctic region to be approximately 10,800 kilo tons per year tons (kt) CO_2 per year. Given that total CO_2 emissions from international shipping globally are about 1,000 MMT CO_2 per year, Arctic contributions for 2004 amount to about 1 percent of total ship CO_2 emissions, not an amount that would cause significant effects in the global context. However, pollutants such as black carbon (BC), particulate matter, nitrogen oxide (NOx), carbon monoxide (CO) and sulfur oxide (SOx), which may be small contributors to global inventories on a mass basis, may have regional effects even in small amounts. Current IMO regulations under MARPOL Annex VI that place requirements on the sulfur content of marine fuels, once implemented, will dramatically reduce SOx emissions from global shipping. As a result, observable impacts from SOx should decline and there may be indirect effects on the climate forcing properties of other air pollutants such as NOx and BC.

Black carbon is a component of particulate matter produced by marine vessels through the incomplete oxidation of diesel fuel. The release and deposition of BC in the Arctic region is of particular concern because of the effect it has on reducing the albedo (reflectivity) of sea ice and snow. When solar radiation is applied, reduced albedo increases the rate of ice and snow melt significantly, resulting in more open water, and thereby reducing the regional albedo further. In the Arctic region in 2004, approximately 1,180 metric tons of black carbon was released, representing a small proportion of the estimated 71,000 to 160,000 metric tons released around the globe annually. However, the region-specific effects of black carbon indicate that even small amounts could have a potentially disproportionate impact on ice melt and warming in the region. More research is needed to determine the level of impact this could have on ice melt acceleration in the Arctic and the potential benefits from limiting ships' BC emissions when operating near to or in ice-covered regions. The potential impacts of black carbon should also be a point of consideration when weighing the costs and benefits of using in-situ burning of oil in spill response situations.

As part of the AMSA emissions inventory, the amounts of carbon dioxide and black carbon emitted were mapped using the GIS database of shipping routes and areas of fishing vessel activity reported by Arctic states (Map 8.1).

The CO_2 emitted by all vessels was mapped according to the location of activity; emissions from transport vessels (non-fishing vessels) were assigned to reported routes and fishing vessel emissions were assigned to the Large Marine Ecosystem in which the fishing fleet operated. The map shows that the heaviest CO_2

Regional Environment Case Study

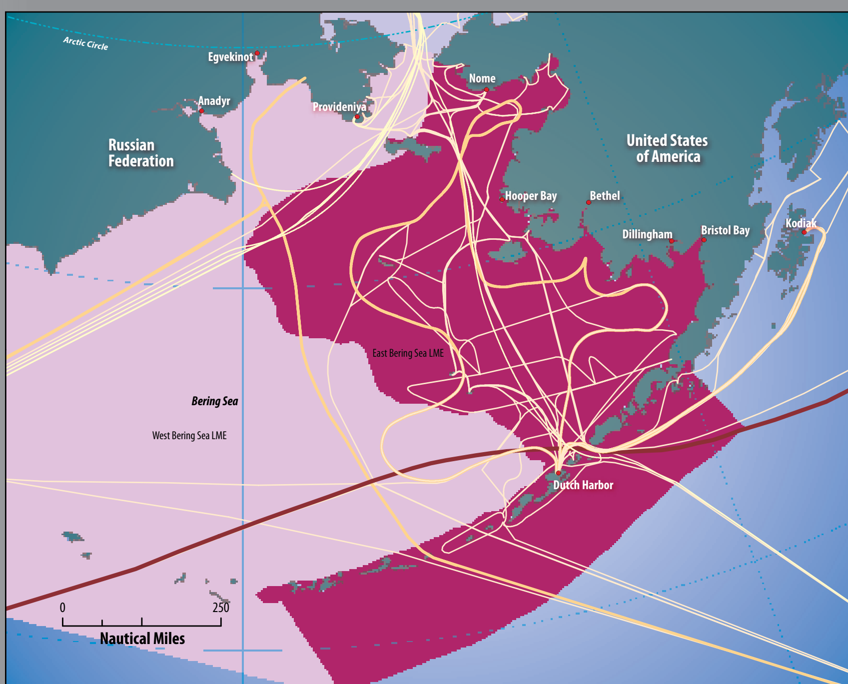
Aleutian Islands/Great Circle Route

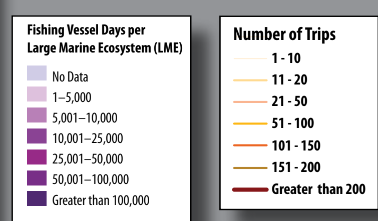
The North Pacific's Great Circle Route is the most economic pathway for commerce between northern ports of the west coast of North America to ports in eastern Asia. The segment of this route considered in this analysis is the portion that extends from the western Gulf of Alaska, westward offshore from the Alaska Peninsula and through the Aleutian Islands including the passes at Unimak Pass and the Rat Islands. This portion of the route traverses two Arctic Large Marine Ecosystems (LMEs), the East Bering Sea LME and the West Bering Sea LME.

The East and West Bering Sea LMEs are characterized by their subarctic climate and are strongly influenced by a persistent atmospheric low pressure system that produces intense storm activity and strong ocean currents, particularly through the Aleutian Island passes. The marine and coastal environment in the region where the Great Circle Route passes includes rocky shorelines, fjords and tidal wetlands. This region seasonally supports populations of shorebirds, nesting seabirds, herring and other marine resources as well as millions of salmon during their migrations to streams of origin.

The route also passes through the U.S. Alaska Coastal Maritime Wildlife Refuge, which provides nesting and foraging habitat seasonally for millions of seabirds and year-round habitat for thousands of marine mammals. The populations of several marine species in this region are depressed, declining or otherwise considered particularly sensitive and in danger of potential extinction. Commercial fisheries in the region where the Great Circle route passes provide a large proportion of the annual landings by the U.S. fishing industry. Salmon, halibut, herring, crab, groundfish and many other fisheries are pursued annually in the region. In 2004, Alaska fish landings were 2.43 million metric tons, valued at $US 1.17 billion.

The AMSA estimates that approximately 2,800 vessels passed along this route in 2004. Environmental impacts due to shipping, which are of the most concern in the region of the Arctic where this route passes, include the potential for vessel strikes on marine mammals, particularly the Pacific right whale; the discharge of oil and other pollutants both from routine ship discharge and accidents; and the introduction of invasive species into local ecosystems.





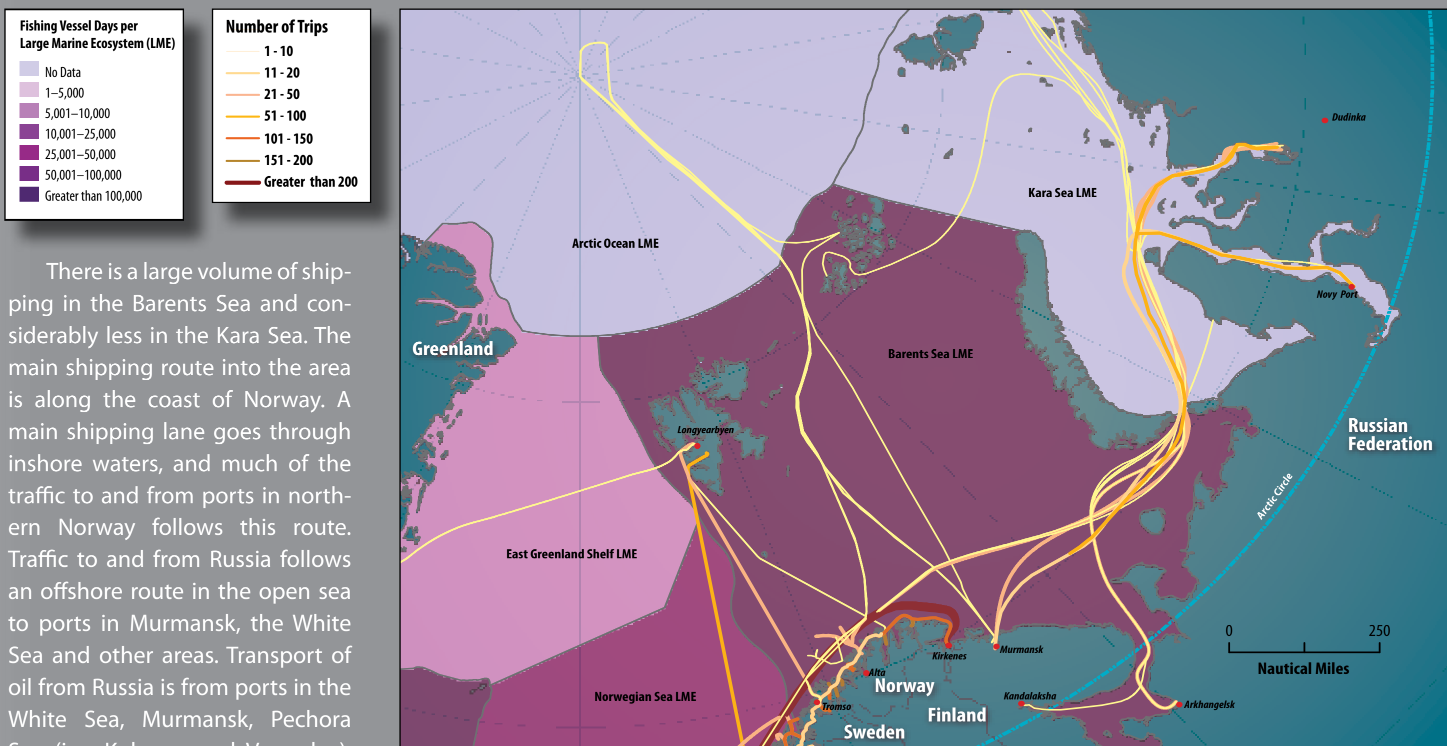
Map 8.2 Aleutian Islands regional traffic and LME map. *Source: AMSA*

13,000

Metric tons – The approximate amount of oil sludge generated annually by ships operating in the Norwegian and Barents seas.

Regional Environment Case Study

Barents and Kara seas



Map 8.3 Barents and Kara seas regional traffic and LME map. *Source: AMSA*

There is a large volume of shipping in the Barents Sea and considerably less in the Kara Sea. The main shipping route into the area is along the coast of Norway. A main shipping lane goes through inshore waters, and much of the traffic to and from ports in northern Norway follows this route. Traffic to and from Russia follows an offshore route in the open sea to ports in Murmansk, the White Sea and other areas. Transport of oil from Russia is from ports in the White Sea, Murmansk, Pechora Sea (i.e., Kolguev and Varandey), and Ob' and Yenisei estuaries in the Kara Sea. There is also year-round shipping of nickel ore by Norilsk Nickel from a port in the Yenisei estuary. In the western Barents Sea, there is a shipping route to Svalbard with seasonal traffic of cargo ships supplying the communities, bulk carriers transporting coal and cruise ships. There is also a substantial number of fishing vessels that operate year round in the ice-free part of the southern and central Barents Sea, while there is little fishing activity in the Kara Sea.

In 2006, Norway adopted an integrated management plan for the Norwegian part of the Barents Sea and adjacent waters off the Lofoten Islands. In the preparatory work for this plan, an assessment of environmental impacts from shipping was carried out and valuable and vulnerable areas were identified. The plan established a forum on environmental risk management headed by the Norwegian Coastal Administration, which is tasked with providing better information on risk trends in the area, especially as regards acute oil pollution from ships and other sources. In July 2007, the IMO established regulations that require larger cargo vessels and tankers transiting the Norwegian coast of the Barents Sea to operate further away from the coast than in the past. This requirement is intended to allow a longer response time in case of accidents that could impact the Norwegian coastal environment and resources.

Vulnerable areas in the Barents and Kara seas have been identified in relation to oil and gas activities, based on where there are aggregations of animals that could potentially be impacted by oil spills or disturbances from activities. The Barents Sea holds more than seven million pairs of breeding seabirds, with major colonies on Svalbard, the western section of Novaya Zemlya off the coast of northern Russia and along the coast of northern Norway. The oceanographic polar front and the ice edge in the western and central Barents Sea is a concentrated zone of life in spring and summer with aggregations of seabirds and seals. The polar front area is also the wintering area for the large Barents Sea capelin stock and for seabirds such as thick-billed murre. Svalbard and Franz Josef Land in the northern Barents Sea are important breeding and feeding areas for seabirds, walrus and seals, and denning areas for polar bear. The southern and eastern Barents Sea is a wintering area for many seabirds and sea ducks that breed further east in the Russian Arctic. The Pechora Sea area and the southern Kara Sea lie adjacent to tundra and wetlands that are important breeding grounds for geese, ducks and shorebirds. Many of these use coastal habitats for staging during spring migration and after breeding when they prepare for the fall migration out of the Arctic.

The southern Barents Sea is a rich fisheries area with large stocks of cod, haddock, capelin, juvenile herring and shrimp. A major stock of polar cod spawns under ice in the Pechora Sea region, and this region is also the main wintering area for white whales of the Karskaya population that is migratory between the Barents, Kara and Laptev seas. The smaller White Sea beluga population has its wintering area in the Voronka and Gorlo area at the entrance to the White Sea. The Barents Sea harp seal population has its whelping and molting areas on the ice also at the entrance to the White Sea. The Novaya Zemlya population of Atlantic walrus has its wintering area in the pack ice in the Pechora Sea region. White whales and walrus migrate north in spring following lead systems west of Novaya Zemlya, and the white whales continue east through the northern Kara Sea and into the western Laptev Sea in early summer. There are two subpopulations of polar bears in the Barents and Kara seas with seasonal migrations following the ice.

There are no documented negative impacts on animals in this area from shipping activities. Accidental oil spills have occurred and have been associated with high local mortality of seabirds. However, these incidents have not had material impacts at the population level for the affected species. Ship strikes of whales could occur in some areas but there are no reports to suggest that the level of impact is significant. The greatest concern is the threat from accidental oil spills that could have a large impact on seabirds and other marine birds, and also on marine mammals such as polar bear and on spawning polar cod. If shipping activities increase in the future, potential disturbance of wintering marine mammals and ship strikes of whales will become a concern.

and black carbon emissions were found in the Bering Sea region, around Iceland, along the Norwegian coast and in the Barents Sea. There are also moderate emissions along the western coast of Greenland.

Potential Disturbances from Ships and Shipping Activity in the Arctic

Sound and Noise Disturbance

All vessels produce sound as a by-product of their operation. Typically, vessels produce low frequency sound from the operation of machinery onboard, hydrodynamic flow noise around the hull and from propeller cavitation, which is typically the dominant source of noise. The sound a vessel produces relates to many factors including size, speed, load, condition, age and engine type. The larger the vessel and/or the faster it is moving, the more noise it produces. Many vessels also employ hydroacoustic devices such as commercial sonar, echosounders, side scan sonar for navigation, depth finding, seafloor mapping or to detect biologics as a regular part of their operations. These types of devices produce short pulses and use frequencies ranging from low to high, depending on their utility.

For most marine vertebrates, making, hearing and processing sounds serve critical biological functions. These include communication, foraging, reproduction, navigation and predator-avoidance. In particular, toothed whales have developed sophisticated biosonar capabilities to help them feed and navigate; large baleen whales have developed long-range communication systems using sound in reproductive and social interaction; and pinnipeds (i.e., seals, sea lion, walrus, etc.) make and listen to sounds for critical communicative functions. Many fish utilize sounds in mating and other social interactions.

The introduction of noise into the environment can adversely affect the ability of marine life to use sound in various ways and can induce alteration of behavior; reduction of communication ranges for social interactions, foraging, and predator avoidance; and temporary or permanent compromise of the auditory or other systems. In extreme cases, too much noise can lead to habitat avoidance or even death. Noise can also affect physiological functions and cause more generalized stress. Determining when impacts of noise exposure from any source become biologically significant to a species is often difficult. Nevertheless, this is an area where additional research is ongoing and needed in key areas.

Many environmental effects resulting from ship disturbances can be effectively mitigated through the use of best practices and the implementation of management measures.

Where there is an overlap between potential noise sources and the frequencies of sound used by marine life, there is particular concern as to how sound sources can interfere with important biological functions. The predominately low frequency sounds associated with large vessels is similar to the general hearing sensitivity bandwidths of large whales and many fish species. The ambient noise environment in the Arctic is more complex and variable than in many other ocean areas due to the seasonal variability in ice cover. In addition to natural sources contributing to background levels, anthropogenic sources, like vessel traffic, can also have a profound impact on these levels. In most regions in the northern hemisphere, shipping noise is the dominant source of underwater noise below 300 hertz.

Many environmental effects resulting from ship disturbances can be effectively mitigated through the use of best practices and the implementation of management measures. With regard to noise disturbances, such measures could include rerouting to avoid some areas in sensitive periods, lower speed, and alternative engine and hull designs to make ships more silent. There may be a need to plan potential future shipping lanes in the Arctic so as to avoid large seabird colonies, marine mammal haul-outs and other areas where animals are aggregated. In late 2008, the IMO's Marine Environment Protection Committee (MEPC) formed a correspondence group that is now working to identify and address ways to minimize the introduction of incidental noise into the marine environment from commercial shipping in order to reduce the potential adverse impact on marine life. This group aims to develop non-mandatory technical guidelines for ship-quieting technologies, as well as potential navigation and operational practices for all IMO member states. This work will be aimed at the global shipping industry and is not likely to contain Arctic specific considerations.

Icebreakers and Disturbance

All icebreaking operations, whether by independent commercial icebreaking ships or government icebreaker escort, can potentially cause disturbances to wildlife and local communities both through the noise they create and the trail of open water left astern. Compared to other vessels, icebreakers produce louder and more variable sounds. This is because of the episodic nature of the icebreaking, which involves ramming forward into the ice and then reversing to begin the process again. Some icebreakers are equipped with bubbler systems to aid in clearing ice from the vessel's path and these can create an additional noise source. Noise from bubbler systems and propeller cavitation associated with icebreaker movement has the potential to alter animal behavior and to disrupt the hearing ability and vocalization of marine mammals.

Wildlife has been found to exhibit a range of behavior in the presence of icebreakers. For example, beluga whales were found to be aware of the icebreaker vessels presence at distances of more than 80 kilometers away, and exhibit strong avoidance response at 35 to 50 km away. However, narwhal whales were found to display only subtle responses to the same disturbance.

The opening of channels through the ice by icebreaking vessels can impact Arctic residents and alter animal behavior. Open water channels take time to freeze and this can disrupt the movements of animals and people over the ice. In many areas of the Arctic in winter, the only naturally occurring ice openings are polynyas caused by winds or ocean currents. Artificially opened water channels can be problematic for marine mammals and other species, which confuse them for polynyas and can get trapped too far from the ice edge as the channel eventually refreezes.

Vessel Strikes on Marine Mammals

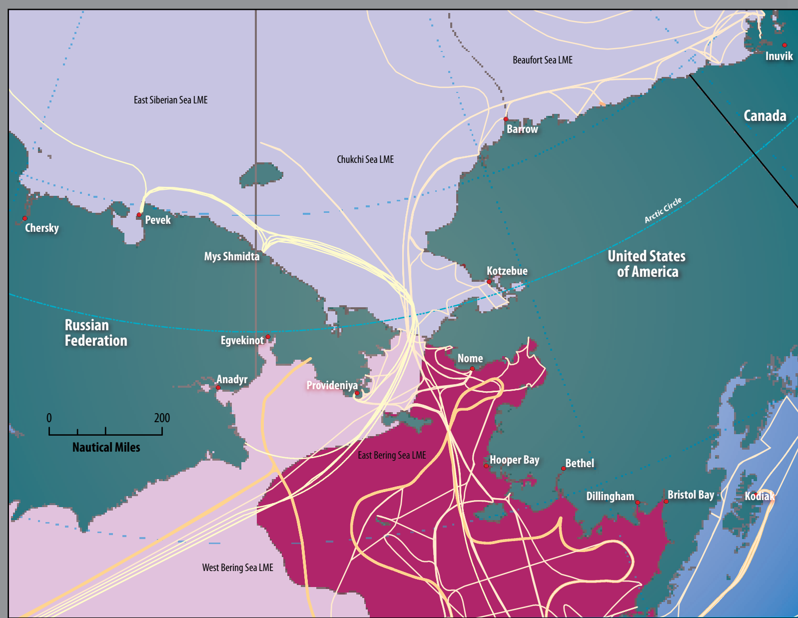
Vessel collisions, resulting in death or serious injury of marine mammals, are a threat to marine organisms worldwide. Vessel collisions or ship strikes occur mainly with large whale species, small cetaceans (i.e., dolphins, narwhal, beluga), marine turtles and sirenians (i.e., manatees, dugongs). Records indicate that nearly all large whale species are vulnerable to ship strikes. Vessel collisions with marine mammals can result in death, massive trauma, hemorrhaging, broken bones and propeller wounds.

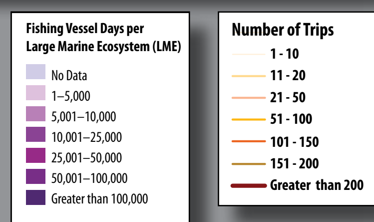
Databases have been constructed which track the number of ship strikes occurring. These report more than 750 known cetacean vessel strikes through the world's oceans, including nearly 300 incidents involving large whales. Virtually all motorized vessel types, sizes and classes are represented in these databases. It should be noted, however, that any database will likely underestimate the number

Regional Environment Case Study

Bering Strait

Map 8.4 Bering Strait regional traffic and LME map. *Source: AMSA*





Current shipping activity in the Bering Strait and Chukchi Sea predominately comprises community re-supply and destinational traffic.

Traffic plying the Bering Strait, one of the narrowest sea lanes in the world, also traverses remote areas with difficult access for incident response, rescue and contaminant or debris cleanup. The U.S. Beaufort Sea coast has no port facilities or harbors suitable for refuge for medium to deep draft vessels and there are also very limited facilities on the Russian side of the strait. Given its restricted geographic nature, confounded by ice movement and strong ocean currents, the Bering Strait area is a major chokepoint for vessels transiting the region. The Aleutian Low creates persistent high winds and stormy conditions that elevate risk to vessels and cargo transiting the Aleutian and Commander islands area. These severe weather patterns may reduce the effectiveness of response to spills or other incidents.

This region includes four of the Arctic Large Marine Ecosystems: the Beaufort Sea LME, the Chukchi Sea LME, and East and West Bering Sea LME. Increased vessel traffic in the Beaufort and Chukchi seas may result in greater incidents of damage to the environment from ships, including pollutant discharges, and an increase in the risk of disturbance effects such as ship noise and ship strikes on migrating and foraging bowheads or other marine mammals. Any vessel incidents in this region would also have the potential to adversely affect major populations of nesting shorebirds, waterfowl and other birds that utilize breeding, nesting and foraging habitat along the coastal Beaufort and Chukchi seas and along the coast of western Alaska.

The eastern Bering Sea supports some of the largest commercial fisheries in the world. Increased vessel use of the eastern route that traverses the eastern Bering Sea may increase potentially adverse interactions with this region's rich fishery resources, fishing communities and hundreds of fishing vessels and support vessels. Spills due to accidental or illegal discharge from vessels could drift ashore to western Alaska areas where seasonal herring and salmon fisheries occur.

The western Arctic stock of bowhead whales seasonally migrates through the Bering Strait, Chukchi and Beaufort seas. In the Bering Strait, they are physically constricted to a relatively small corridor, exposing them to increased interactions with vessels transiting this area during spring and fall. Bowhead whale migration could also potentially be disrupted by icebreakers. Whales could move further offshore following the open leads created by icebreaking vessels, putting them out of reach of coastal whaling communities. Any disruption of the spring and fall hunts, or any injury or mortality to bowheads would be considered a major issue to coastal Alaskan and Siberian communities.

Ice-dependent marine mammals in this region, such as polar bear, walrus and seals, already stressed due to sea ice retreat, may be at increased risk from any additional ship-sourced stressors or contamination, as populations will become increasingly concentrated around retreating sea ice.

Regional Environment Case Study

Canadian Arctic

For many years shipping has been the main link to the outside world for remote Arctic communities in Canada and yearly sealifts remain the key source of goods and necessities for many communities. Shipping in the Canadian Arctic has been occurring in a safe and relatively environmentally sustainable way for many years. This has been due to the historically low level of activity, as well as the regulatory restrictions that have been in place to protect Canadian Arctic waters from shipping since the 1970s in the form of the *Arctic Waters Pollution Prevention Act*. The types of shipping activity occurring in the Canadian Arctic during 2004 can be grouped into the following activities: community re-supply (i.e., tug-barge, cargo, fuel tankers), Canadian Coast Guard and research activity, cargo and re-supply support for resource development operations, cargo shipments in and out of the Port of Churchill and tourism.

The Canadian Arctic remains one of the last frontiers for natural resources and one of the last areas of relatively pristine wilderness on earth. It is a region with virtually no roads, no rail lines and where air services are infrequent and very costly. The lack of infrastructure and the extreme climate have, until recently, made this region uneconomical for large-scale resource development. Rising prices of oil, gas and other commodities and the changing climatic and geographic restraints may combine to allow significant and rapid increases in resource development

Map 8.5 Canadian Arctic regional traffic and LME map. *Source: AMSA*

activity in the Canadian Arctic, which would lead to increased destinational shipping traffic in the region and intra-regional traffic. How this potential increase may impact the local environment is not known. However, any increase in activity brings with it a corresponding increase in the risk of damage to the environment both from normal ship operations and accidents or emergencies. Due to the current relatively low levels of shipping activity occurring in the Canadian Arctic, any increase in activity in this region will be significant.

Currently four of the Arctic's 17 Large Marine Ecosystems occur in Canadian waters: Hudson Bay, Baffin Bay/Davis Strait, Arctic Archipelago and Beaufort Sea. The Canadian Arctic is home to a diverse range of wildlife that thrives across this variety of ecosystems. These populations are now under stress to varying degrees due to the changes occurring in the Arctic environment as a result of global climate change.

Areas that are vulnerable to new developments include wintering areas of bowhead and beluga in Hudson and Davis straits, spring migration routes for those whales into Hudson Bay and Foxe Basin and north into Lancaster Sound. Seabird breeding colonies and staging areas for migratory waterfowl and shorebirds occur in several locations throughout the region.

Specific adverse impacts associated with shipping activity that are of the most concern in the Canadian Arctic include the discharge of pollutants into the marine environment and the disruption or disturbance of migratory patterns of wildlife that would, in turn, impact indigenous hunting activity. In this region, icebreakers leave behind open water channels that may disrupt the movements of wildlife and people traveling on the ice. Icebreakers or other ships traveling through ice-covered waters where seals are whelping can impact nearby seals through flooding dens and wetting baby seals with their wakes. Marine mammals are known to congregate in shallow bays and migrate through the Canadian Arctic Archipelago. As shipping traffic increases in this region there will be increased potential for conflict between ships and marine mammals in narrow and geographically restrictive areas. Other ship impacts outlined in this section such as noise impacts, introduction of invasive species and ship emissions are also of concern.

of actual occurrences because many go either undetected or unreported. In some cases carcasses are found, but because injuries are internal or due to advanced decomposition, it may be difficult to determine cause of death. When large vessels are involved, the mariner may not be aware that a strike has occurred.

There are relatively few known incidents of Arctic or ice-adapted marine mammal species being involved in ship strikes. The relatively infrequent occurrence is a result of relatively lower vessel traffic in high latitudes as compared to major trading routes and human population centers in lower latitudes. However, of consideration is that certain Arctic species, such as the bowhead and Pacific right whale, have features that make them potentially vulnerable to ship strikes, particularly as vessel traffic increases in their waters. Arctic toothed whales, namely narwhals and beluga whales, are probably less vulnerable to ship strikes, given their greater maneuverability and social behavior that lends them to aggregating in large groups enhancing their detection. It should be noted, however, that records of roughly comparable mid-sized species such as pilot whales, killer whales and various species of beaked whales also appear in ship strike databases.

Vessel speed has been implicated as a key factor in the occurrence and severity of vessel strikes with large species. Several independent studies indicate that vessel speeds of 10-14 knots increase by one-half or greater the probability that a whale will survive a collision with a ship.

As vessel traffic increases in the Arctic, modifications to customary vessel operation in key cetacean aggregation areas or vessel speed restrictions can be an effective measure to mitigate potential impacts on vulnerable species such as bowhead whales and, to a lesser extent, narwhals, beluga whales and other Arctic marine organisms. Where feasible, vessel routing measures may also be applied in order for ships to avoid known cetacean aggregation areas. A number of steps have been taken by some states outside the Arctic region to reduce the threat of ship strikes to endangered large whale species, including shifting shipping lanes and applying to the IMO to establish a vessel "Area to be Avoided." The IMO's MEPC is currently working on development of a non-mandatory guidance document for minimizing the risk of ship strikes on cetaceans which will be aimed at the global maritime industry.

Light Disturbance

Birds of all species appear to be attracted to lights. This puts them at risk of collision with lighted structures. The attraction to light and resulting risk of collision varies depending on the weather, season and the age of the bird. The fall migration in the Arctic is when most bird attraction and collision issues emerge, as young birds are traveling for the first time and inclement weather becomes more frequent. Light attraction of marine birds is not yet a significant issue in the Arctic. This is because most birds are in the Arctic in the summer months to breed, when there is little or no darkness; and most Arctic-breeding seabirds are diurnal and, therefore, less active at night.

Despite these factors, there are still risks. During the non-breeding period in ice-free waters and as the presence of lighted ships and structures increases, risks are heightened. A wide variety of nocturnal species nest in the North Pacific, especially in the Aleutian Islands. Storm-petrels are vulnerable in late summer and early fall, when hundreds have been known to pitch on a vessel during foggy conditions. These problems are not unique to the smaller nocturnal species. Common and king eiders, both large ducks, have collided with large shrimp vessels in waters off western Greenland, causing injury or death.

Introduction of Invasive Species

The introduction and spread of alien invasive species is a serious problem that has ecological, economic, health and environmental impacts, including the loss of native biological diversity worldwide. Although the introduction of invasive species into the Arctic environment has been minimally studied, it is an issue that deserves further study in the context of a changing climate and potential increased shipping in the Arctic region.

The risk of introduction of invasive species will increase as shipping volume increases in this region. As with ship operations in non-Arctic areas, the threat of introduction comes from four sources: ballast water discharge, hull fouling, cargo operations and casualties or shipwrecks.

- **Ballast Water**
  The IMO's *International Convention for the Control and Management of Ships Ballast Water & Sediments* addresses ballast exchange and treatment. As of November 2008, 16 states including Norway, representing about 3.6 percent of the world's merchant shipping, have ratified this convention. Under the IMO convention standard, a small percentage of viable organisms will still be discharged.
- **Hull Fouling**
  In subarctic waters, transfer of aquatic invasive species on the hulls of ships has become a serious threat to the environment, rivaling ballast water discharge. However, hull coatings on ice-capable vessels may be effective antifouling agents, as would the scouring effects of passage through ice.
- **Cargo**
  Most international movements of goods are regulated by fumigation and biosecurity provisions to prevent the movement of invasive species in cargo. This is also applicable to the Arctic region. Much of the sealift and re-supply movements into the Arctic are palletized, increasing the potential for unwanted organisms to be entrained in the cargo.

Research Opportunities

- ❑ Investigate the effects of ship noise and physical presence, including avoidance behavior on Arctic marine animals at the individual and population level. Such research would contribute to determining distances at which animals are disturbed from ships, the potential for ship strikes and assessment of the need for mitigation strategies if adverse effects are predicted.
- ❑ Complete regional modeling of ship emissions in order to investigate the current and potential impacts from these emissions along major routes and near key port regions in the Arctic. This will contribute to more accurate assessment of regional impacts on air quality, pollution, haze and visibility, and climate forcing due to the release and deposition of black carbon and other aerosols.
- ❑ Conduct baseline surveys of aquatic species in major recipient ports in the Arctic region and research the potential survival of species introduced through different vectors. Carry out a risk assessment of invasive species introduction under current international standards in order to determine the need for Arctic specific protections.
- ❑ Conduct further research on the transport, fate and effects of oil in ice-covered waters, and on technology, methods and procedures to clean-up and remove spilled oil to reduce environmental impacts.

MARPOL 73/78

Regular ship discharges are regulated through the IMO's *International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto*

- **Casualty**
  Ship accidents and sinkings can introduce invasive species into the local environment. As an example, shipwrecks in the Aleutians have caused significant ecological damage through the introduction of predatory rat species onto islands that have large aggregations of nesting seabirds.

Due to climate change and the potential increase in shipping activity, the introduction of invasive species may require more attention than it has received in the past. In particular, trans-Arctic shipping between the North Atlantic and North Pacific could potentially represent a vector for transfer of species in ballast water or on hulls to new areas where the environmental conditions resemble those in their home waters. Introduction of rodent species to islands harboring nesting seabirds, as evidenced in the Aleutian Islands, can be devastating. With limited baseline data on what species might actually be at risk from ship operations such as ballast water discharge, the use of the precautionary approach and proactive preventative actions are encouraged.

Green Ship Technology in the Arctic

Technology has a role to play in the mitigation of environmental impacts in the Arctic and elsewhere. Many of the potential impacts from shipping that have been discussed in this assessment can be effectively reduced or eliminated through the use of current or developing technologies, as well as best practices. Examples include stack scrubbers that remove harmful substances such as sulfur and black carbon from a ship's emissions; water treatment systems for sewage, bilge water, ballast water and other discharges; technologies that harness wind or solar power to reduce fuel consumption; or the use of cleaner fuels that emit less harmful substances when burned. Given the sensitivity of the Arctic environment and the potential impacts from shipping, the development and application of green ship technologies should be a priority. These new technologies can be expedited through industry incentives, such as the green ship technology fund in Norway; or regulatory requirements, such as the IMO *International Convention for the Control and Management of Ships Ballast Water & Sediments.*

Selendang Ayu Impact

On December 8, 2004, the cargo ship *M/V Selendang Ayu* lost power as it was transiting the North Pacific's Great Circle Route and eventually came ashore near Dutch Harbor in the Aleutian Islands, where it broke into two sections (See page 88). Operations to rescue the crew from the *Selendang Ayu* resulted in loss of life for both rescuers and crew, increasing the adverse effects of this incident. Despite removal and recovery efforts, the ship eventually discharged its cargo of 66 million metric tons of soybeans, an estimated 1.7 million liters of intermediate fuel oil, 55,564 liters of marine diesel and other contaminants into the environment.

For three weeks the weather delayed response to the environmental hazards of the incident. Strong winds, rough seas and the remoteness of the spill stalled the clean-up and search for oiled animals.

To study the impact of the spill on shorebirds, the U.S. Fish and Wildlife Service released 162 bird-size blocks of wood from the grounding site more than a month after the incident. The blocks helped determine where contaminated dead birds might have drifted. The exercise led to the immediate recovery of 29 oiled birds, 19 that were dead or dying and 10 that were recovered and released. During the course of the clean-up, 1,603 bird carcasses and six sea otter carcasses were recovered. Because of the delay in the recovery efforts, it is likely the number of wildlife impacted was greater. By mid-February 2005, 38,000 bags of oily solid waste had been reclaimed. The clean-up effort was ongoing until June 2006, and the long term impacts on local populations are yet to be fully assessed. This information was drawn from a recent U.S. Fish and Wildlife Service report on the incident.

Findings

1] From an environmental point of view, Arctic shipping poses a threat to the region's unique ecosystems. This threat can be effectively mitigated through careful planning and effective regulation in areas of high risk.

2] Release of oil into the Arctic marine environment, either through accidental release, or illegal discharge, is the most significant threat from shipping activity.

3] Ship strikes of whales and other marine mammals are of concern in areas where shipping routes coincide with seasonal migration and areas of aggregation.

4] The introduction of invasive species into the Arctic marine environment from shipping can occur and the risk may be enhanced due to changing climate, possibly making conditions more favorable to some species. The most risk exists where a transfer of organisms from ecosystems of similar latitudes and conditions can occur. Of particular future concern is the transfer of organisms across the Arctic Ocean from the North Pacific to the North Atlantic or vice versa.

5] There are certain areas in the Arctic region that are of heightened ecological significance, many of which will be at risk from current and/or increased shipping. Many of these areas are located in geographically restrictive locations or chokepoints where much shipping activity also occurs, such as the Bering Strait, Hudson Strait, Lancaster Sound, Pechora Sea and the Kara Port.

6] Migratory marine mammals such as bowhead, beluga, narwhal and walrus have wintering areas in the southern extent of the sea ice and spring migration routes into the Arctic through systems of leads and polynyas also used by many seabirds, ducks and other marine birds during spring migration. These migration corridors correspond broadly to the current main shipping routes and travel through geographic chokepoints.

7] The black carbon emitted from shipping in the Arctic could have significant regional impacts by accelerating ice melt.

8] Ship emissions including greenhouse gases (GHGs), Nitrogen Oxides (NOx), Sulfur Oxides (SOx) and Particulate Matter (PM) may have negative effects on the Arctic environment and will increase in the Arctic region proportionately with increased shipping activity. Effective reduction of ship emissions can be achieved through the application of feasible and best available technologies, through air emissions reduction techniques and, most importantly, through effective implementation of relevant IMO regulations.

9] Sound is of vital biological importance to marine mammals and anthropogenic noise produced through shipping and other vessel activity can have various adverse effects on Arctic species.

10] Subarctic seas support some of the richest fisheries in the world in the Bering Sea and the Barents Sea. These two areas are also the location of the heaviest shipping traffic now occurring in the Arctic region. A potential accidental spill of oil or other hazardous and noxious substances in these areas could have large economic, social and environmental impacts.

11] Environmental effects on marine mammals, seabirds and fisheries from ship sourced disturbances, noise, or potential accidental/illegal release of oil and other hazardous and noxious substances may impact culturally and economically significant subsistence harvests of these animals.

12] The most immediate impacts of climate change in the Arctic will be the reduction of summer sea ice, longer open water seasons in the fall and the reduction of the year-round presence of multi-year ice. These changes may have far reaching implications for Arctic ecosystems and will also result in the lengthening of the current shipping season. Shipping in the future may be occurring much later into the fall and possibly earlier in the spring, thereby increasing the possibility of interaction between migrating and calving species and ships.