# Navigating the North

## An Assessment of the Environmental Risks of Arctic Vessel Traffic

Ocean Conservancy®

# Acknowledgments

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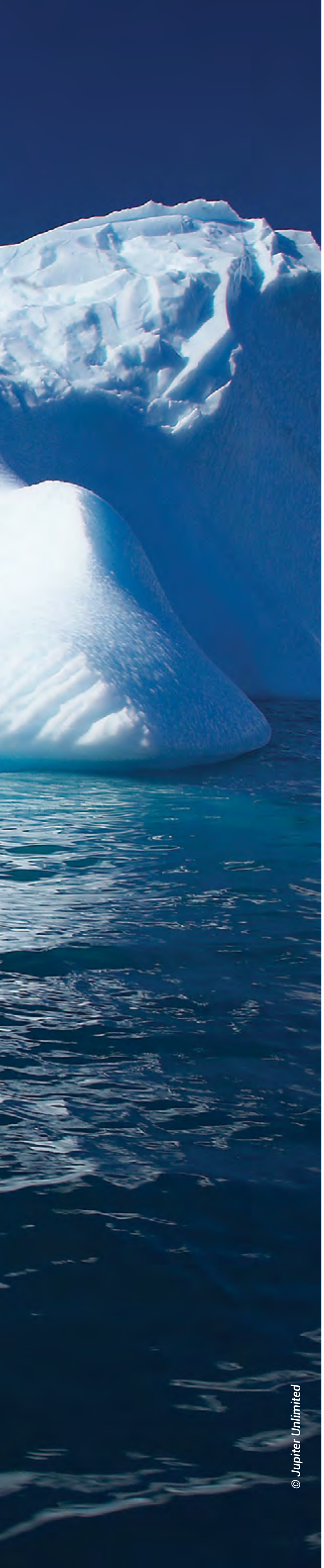


# Acronyms Table

| | |
|---|---|
| **AECO** | Association of Arctic Expedition Cruise Operators |
| **AIS** | Automatic Identification System |
| **AMSA** | Arctic Marine Shipping Assessment |
| **ASPPR** | Arctic Shipping Pollution Prevention Regulations |
| **ATBA** | areas to be avoided |
| **ATON** | aids to navigation |
| **AWPPA** | Arctic Waters Pollution Prevention Act |
| **CAFF** | Conservation of Arctic Flora and Fauna |
| **$CO_2$** | carbon dioxide |
| **DMA** | Dynamic Management Area |
| **ECA** | Emission Control Area |
| **ECDIS** | Electronic Chart Display and Information System |
| **EEDI** | Energy Efficiency Design Index |
| **EEZ** | Exclusive Economic Zone |
| **GAIRAS** | Generally Accepted International Rules and Standards |
| **GHG** | greenhouse gas |
| **GPS** | Global Positioning System |
| **GT** | gross tonnage |
| **HFO** | heavy fuel oil |
| **IMO** | International Maritime Organization |
| **LNG** | liquefied natural gas |
| **MARPOL** | International Convention for the Prevention of Pollution from Ships |
| **MDO** | marine diesel oil |
| **MEPC** | Marine Environmental Protection Committee |
| **MGO** | marine gas oil |
| **NEP** | Northeast Passage |
| **NGO** | non-governmental organization |
| **nm** | nautical miles |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **$NO_x$** | nitrogen oxides |
| **NSR** | Northern Sea Route |
| **NWP** | Northwest Passage |
| **PAME** | Protection of the Arctic Marine Environment |
| **POLARIS** | Polar Operational Limit Assessment Risk Indexing System |
| **PPR** | Pollution Prevention and Response |
| **PSSA** | Particularly Sensitive Sea Area |
| **SAR** | search and rescue |
| **SOLAS** | International Convention for the Safety of Life at Sea |
| **$SO_x$** | sulfur oxides |
| **TBT** | Tributyltin |
| **UNCLOS** | United Nations Convention on the Law of the Sea |
| **USCG** | United States Coast Guard |
| **VHF** | very high frequency |
| **VTS** | Vessel Traffic Systems |

# Introduction

The Arctic marine environment is experiencing rapid and profound changes. Climate change is having dramatic effects on this region, as temperatures are rising more than two times faster than the rest of the planet [1]. Sea level rise, habitat loss and spatial and temporal shifts of species are only a few of the many impacts the changing climate has on the Arctic environment [2, 3]. At the same time, the changing climate and melting ice have facilitated growth of industrial interests in the region, including the maritime transportation sector.

As seasonal sea ice diminishes and industrial activity in the Arctic grows, Arctic waters will experience increasing levels of vessel traffic. For example, transits of the Northern Sea Route — which connects the Atlantic and Pacific oceans via the Arctic waters north of Russia — increased dramatically from 2010 to 2013 [4]. While vessel traffic in many areas of the Arctic declined somewhat after 2014, it is anticipated to increase in future years. By 2025, vessel traffic through the Bering Strait is projected to increase anywhere from 100% to 500% relative to 2013 traffic levels [5].

Vessels operating in this region face significant challenges, including variable sea ice, severe cold, rough seas and fierce storms. In addition, the region is remote, inadequately charted, and has extremely limited maritime infrastructure [6, 7]. All these factors increase the potential for incidents that put human lives and the environment at risk. Vessel traffic-related accidents — like major oil spills — could have catastrophic impacts in the Arctic environment. Even in the absence of an accident, increased vessel traffic may have serious ecological impacts through ship strikes of marine mammals, vessel emissions, introduction of invasive species through ballast water and hull fouling, and discharges of sewage and graywater. If not managed carefully, increasing vessel traffic could also have negative impacts on commercial fisheries and maritime subsistence hunting and fishing, which is an important source of healthy food and central to the culture of Arctic indigenous peoples [8].

The potential impacts of increased vessel traffic in the Arctic on both the marine environment and communities of the Arctic have not gone unnoticed. The Arctic Marine Shipping Assessment (AMSA), published in 2009, provided the first comprehensive review of Arctic shipping. Among other things, it considered the use of ships in the Arctic, maritime infrastructure requirements, and potential impacts on people and the environment. The report advanced a variety of recommendations to enhance Arctic marine safety, protect Arctic people and the environment and build Arctic marine infrastructure [7].

Since the publication of AMSA, local, regional, national and international organizations and governments have taken steps to reduce risks posed by Arctic vessel traffic. Perhaps most notably, the International Maritime Organization (IMO) adopted the Polar Code to strengthen shipping regulations in high-latitude seas. Implementation of the Polar Code, which began in January 2017, was a critical step in promoting safe vessel operation and environmental protection in the region. Despite this progress, there remain regulatory and infrastructure gaps that hinder our ability to effectively address threats posed by increasing vessel traffic in Arctic waters.

This report synthesizes key information related to vessel traffic in Arctic waters, including the characteristics of Arctic vessel traffic, infrastructure, governance mechanisms, regulatory gaps and environmental risks. It also provides recommendations that chart a course for the next iteration of protections needed to address vessel-related threats including oil spills, air emissions, invasive species, disturbance to marine mammals and discharges of sewage and graywater.

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# 1

# Background and context

## 1.1 Geographic boundaries

The geographic definition of the Arctic varies with different policy, legal, management and regulatory contexts. One common description of the region defines the Arctic as the area north of the Arctic Circle (66° 33′ 44″ N). Definitions used by the IMO and the Arctic Council — an intergovernmental forum of Arctic governments and indigenous organizations — are broader; they include certain sea areas south of the Arctic Circle.

In general, this report uses the IMO Polar Code definition of Arctic waters (see Figure 1). Areas included in this definition generally coincide with areas where sea ice may form during at least part of the year.

In cases where this report considers areas beyond the Polar Code boundaries, it will be noted.

*Figure 1: IMO Arctic Polar Code boundaries (i.e., all waters north of the red lines). From [9], adapted from [10].*


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## 1.2 Human dimensions

One of the distinguishing characteristics of the Arctic, as opposed to the Antarctic region, is the presence of communities and people throughout the region. The Arctic Council, using a broader definition of the Arctic than the Polar Code, projects nearly four million people live in the region today [11]. Major population centers within this broader Arctic region include Murmansk, Norilsk and Tromsø. Overall, only 10% of those living in the Arctic are of indigenous descent. However, in many parts of the Arctic, indigenous populations constitute the majority of the population. For example, in Canada, 50% of the population residing in the Arctic regions is indigenous, as is nearly all of Greenland's population [12].

Inuit, Yup'ik, Saint Lawrence Island Yupi'k, Saami, Dene, Aleut, Koryak, Nenets, Dolgan, Nganasan, Entsi, Yukagir, Even and Chukchi peoples have resided in the coastal Arctic for millennia [12]. Indigenous peoples have historically resided in all Arctic states other than Iceland [13].While there are a few relatively large indigenous population centers (e.g., Nuuk, Greenland), many indigenous peoples in the Arctic live in small, dispersed communities [12].

Arctic indigenous peoples rely on a healthy marine ecosystem for cultural and economic purposes, including food security [14]. Residents of the region use marine resources as a source of clothing and equipment, as material for handicrafts, and to support their participation in a mixed-cash economy [15]. Indigenous peoples of the Arctic are highly dependent on maritime hunting and fishing due to both deeply rooted cultural practices and traditions and the high cost of other food sources [16]. In the modern mixed-cash economy, many indigenous communities, particularly those that are not connected by road systems, rely on shipments of goods and fuel from resupply vessels during ice-free months. Vessel traffic connects these remote areas with the broader economy and is vital to the region.

In the coming years, increased maritime traffic is projected to bring social and economic change to areas of the Arctic that develop shipping-related infrastructure, natural resources or tourism enterprises [7]. Growth of these sectors may provide more opportunity in terms of employment opportunities and enhanced access to trade markets [17].

At the same time, increased vessel traffic also brings threats to communities, as well as to hunting and fishing practices. Development of maritime and port infrastructure could result in social disruption of communities. Noise, pollution and other vessel-related impacts could adversely affect the marine environment and marine resources. Impacts associated with increased maritime traffic may include increased risk of collisions between large vessels and hunting craft, or displacement or contamination of wildlife that threatens food security [7, 8]. See Section 5.5 for more on these threats.

## 1.3 Biodiversity of the Arctic marine ecosystem

The Polar Code region includes the Arctic Ocean, its coastal seas and a portion of the Bering Sea and the North Atlantic Ocean. Sea ice is a dominant feature in this region [18]. Each winter, much of the ocean's surface freezes to form new sea ice, called first-year ice. Some sea ice lasts through the summer, at which point it becomes multiyear sea ice.

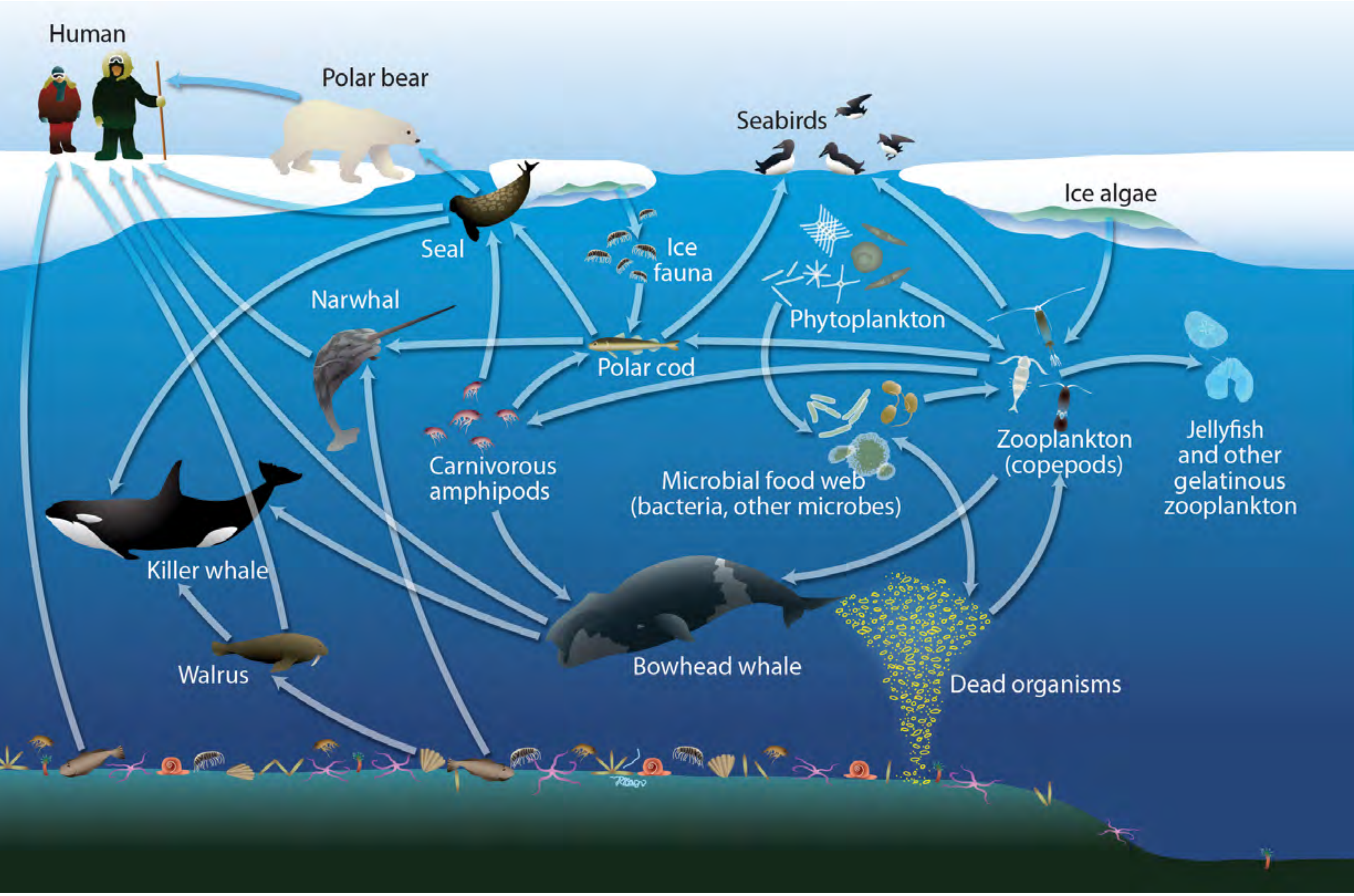
The ice-covered central Arctic Ocean generally exhibits relatively low productivity. However, the edges of the ice pack and polynyas (open leads in the ice) are highly productive. The Barents and Bering seas are some of the most productive marine areas of the world. These seas host large aggregations of fish, seabirds, marine mammals and invertebrates and are regional hotspots of high biodiversity [16].

The Arctic ecosystem hosts species that reside in conjunction with multiyear and/or first-year ice — including iconic marine mammals such as beluga and bowhead whales, polar bears, narwhals and walruses.

These resident Arctic animals have adapted to living in harsh weather conditions, seasonal light variability and limited resources [16]. The Arctic ecosystem also features species that migrate to the region for the summer season of high marine productivity. Gray whales make the longest known migration of any mammal on Earth, traveling from their wintering grounds off the coast of northern Mexico to feed in the Bering and Chukchi seas [19, 20]. Similarly, millions of seabirds migrate north to breed and feed in the Arctic. Nesting colonies on Alaska's Chukchi coast support nearly a quarter-million breeding birds, some of which may forage more than 100 miles offshore [19, 21].

Compared to temperate marine ecosystems, the Arctic food web hosts fewer species overall (Figure 2). That said, lower trophic levels in the Arctic are complex and demonstrate a high degree of diversity [22]. To date, Arctic marine ecosystems have shown substantial resilience to natural variability. However, the structure of the Arctic food web may make it particularly vulnerable to disruption. With relatively few species, each one plays an important role in the system, and adverse impacts may trigger a cascading effect throughout the ecosystem [16].

*Figure 2: Canadian Arctic marine food web. From [15].*



## 1.4 Climate change impacts on the Arctic marine ecosystem

Climate change and ocean warming are already affecting and will continue to affect the Arctic marine ecosystem. Warming in the Arctic is amplified by positive feedback loops, "including ice and snow melting that decreases surface albedo, atmospheric stability that traps temperature anomalies near the surface, and cloud dynamics that magnify change" [23]. As a result, Arctic marine ecosystems are warming more than two times faster than the rest of the planet [1].

Global emissions of greenhouse gases and short-lived climate forcers (e.g., black carbon) are increasing atmospheric and sea surface temperatures, resulting in sea ice retreat and reductions in sea-ice thickness [24]. From 1979 to 2012, data from the National Snow and Ice Data Center revealed summer sea ice extent decreased 40%. Mean sea ice thickness decreased more than 50% from 1980 to 2008 [25]. Vast reductions in multiyear ice have been observed. The amount of fresh water in the Arctic Ocean has increased and will continue to increase due to warming and increased precipitation, which results in above-average heating of surface layers in ice-free regions [23]. Some scientists predict the Arctic Ocean will be largely ice-free in the summer by 2037 [26].

Alterations in sea ice coverage, hydrographic regimes, seawater temperatures and salinity will affect the distribution of marine species by shifting suitable habitats and changing dispersal patterns [27]. Larger and longer periods of open water are increasing primary productivity, which is causing changes in the geographic distribution of some species, particularly northward shifts in range [3, 28]. In the Barents Sea, recent warming caused boreal fish communities to expand northward [29]. High-latitude coastal areas — including the Svalbard coast, the Barents Sea, the Alaskan coast, the Bering Strait, the east coast of Greenland and elsewhere — may experience the largest colonization of new fish species [3]. However, it is not yet clear whether these population shifts will result in a corresponding increase in commercial productivity in these areas [30].

While some species may experience short- or long-term benefits from sea ice loss and changes in primary productivity, many species will be adversely affected. Endemic species associated with sea ice — such as several species of amphipod, ice algae, walruses, polar bears and narwhals — will lose habitat and possibly food resources [31]. For example, polar bears are projected to lose 68% of their summer habitat by 2100 [1]. Already, walruses are increasingly hauling out on coastal areas instead of historic ice feeding grounds, resulting in disease and mass mortality events due to overcrowding [32]. Although not always the case, ocean warming generally correlates negatively with seabird breeding success and survival [33].

Warming temperatures and decreasing sea ice are not the only factors to affect the abundance, productivity and distribution of species in the Arctic; ocean acidification will also play a role. Arctic marine ecosystems will experience reduced ocean pH caused by uptake of atmospheric $CO_2$ (acidification) in the global ocean [34]. At higher latitudes, "enhanced sea ice melt, respiration of organic matter, upwelling, and riverine inputs have been shown to exacerbate $CO_2$-driven ocean acidification" [35].

Increased $CO_2$ may benefit some carbon-limited autotrophs like sea grass [36]. However, it will reduce growth and development of calciferous marine organisms such as bivalves and corals, thereby negatively affecting food sources for species at higher trophic levels [36, 37]. Overall, acidification will combine with other systemic changes to increase stress on the Arctic marine ecosystem [38].

As climate change results in retreating sea ice, the Arctic region is becoming more accessible to vessel traffic and other industrial uses. The possible cumulative effects of climate change, ocean acidification, increasing vessel traffic and other stressors in the Arctic region are not well understood. In some cases, impacts may be synergistic (i.e., a total impact greater than the sum of its parts) [39]. In evaluating these impacts, it is critical to keep in mind that the health of the Arctic marine ecosystem is of central importance to the food security, culture and economies of its indigenous peoples who live in the region.


2

# The past, present and future of vessel traffic in the Arctic

*To better understand the potential safety and environmental impacts vessel traffic may have on the Arctic region, it is important to put that traffic in context. This section considers the characteristics of Arctic vessel traffic in the past and in the present day. It also discusses projections of future vessel traffic in the region, as well as climate-based and industrial drivers. These drivers, in conjunction with other factors, have already resulted in increasing vessel traffic in most Arctic waters, a trend that is expected to continue.*

# Arctic Traffic Routes

Three principal Arctic shipping routes connect the Atlantic and Pacific: the Northwest Passage, the Northern Sea Route, and the Transpolar Sea Route.

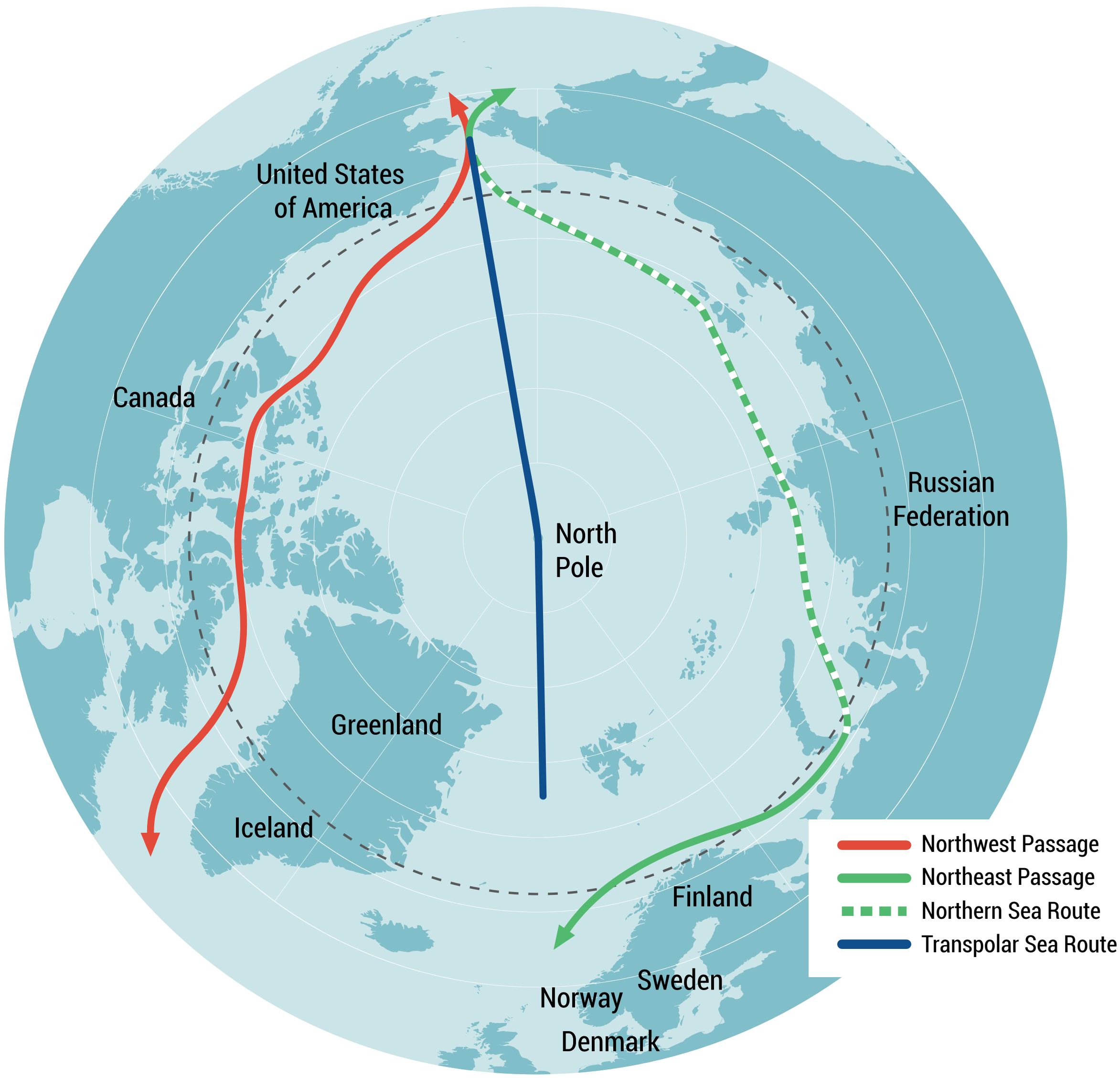
The Northwest Passage refers to a variety of routes that connect the Northern Atlantic and Pacific Oceans via the Arctic Ocean, traversing north of mainland North America. As a significantly shorter passage (up to 30% between Northwest Europe and Asia, and up to 20% shorter than a Panama Canal voyage), the Northwest Passage will become more economically viable as sea ice diminishes [40].

The Northeast Passage spans the Bering Strait to the edge of Norwegian Barents Sea via waters north of Eurasia. The term Northern Sea Route, as defined by Russian law, relates to the portion of the Northeast Passage between the Novaya Zemlya archipelago and the Bering Strait. More commonly, the notion of Northern Sea Route is used interchangeably with Northeast Passage to characterize the entire route that connects the Bering Strait to European waters [41]. It is often predicted to play an increasing role for connecting Asian and European markets as it is a significantly shorter passage (up to 40% shorter than through the Suez Canal) [40].

The Transpolar Sea Route runs directly through the North Pole and is the most direct route between the Atlantic and Pacific oceans. As sea ice continues to recede, the Transpolar Sea Route may offer substantial voyage distance savings at some point later in the century [40]. At this time, however, thick and persistent multiyear ice renders this route uneconomic.

Of the three major Arctic routes, the Northern Sea Route has the most potential to enable economic activity in the next 50 years. This will involve both transit shipping (for cargo between ports outside the Arctic) and destinational shipping (activities that begin and/or end in the Arctic) [41]. That said, sea ice will remain a navigational challenge for all Arctic routes — including the Northern Sea Route — for the foreseeable future.

*Figure 3: The Northern Sea Route/Northeast Passage, Northwest Passage and Transpolar Sea Route.*




## 2.1 Summary of historic vessel traffic in the Arctic

Indigenous peoples were the first to travel in the maritime Arctic. In addition to centuries-old indigenous use, historic Arctic shipping activities include non-indigenous exploration, supply of coastal communities, whaling and the more recent advent of global shipping [7].

Exploration of potential trade routes through the Arctic by Western explorers began centuries ago. The Northwest Passage was seen as a potential trade route as early as the late fifteenth century, but it was not until 1906 that Roald Amundsen completed the first traverse of this route (over three seasons, from 1903–1906). By the mid-twentieth century, most vessel traffic in the region had a national security-related purpose. In 1969, the U.S. oil tanker Manhattan became the first commercial ship to traverse the Northwest Passage. This voyage demonstrated that unescorted icebreaking vessels were both technologically and economically able to sail the Northwest Passage [7, 42].

The idea of a Northeast Passage route connecting the Atlantic and Pacific originated in Russia in the sixteenth century. The first transit of the Northeast Passage was completed in two consecutive seasons by Adolf Erik Nordenskiöld in 1878–1879 [7].

The Northern Sea Route section of the Northeast Passage was developed in various stages over the twentieth century, first by the Russian Empire and then by the Soviet Union. What began as a community supply route became a year-round commercial shipping route by the late 1970s. At its peak in 1987, the route saw 1,306 voyages. With the fall of the Soviet Union, traffic along the route decreased drastically. Although the Northern Sea Route opened to foreign traffic in 1991, it was only in more recent times that it attracted the attention of companies interested in exploring the potential economic benefits of the route [7].

## 2.2 Industrial activity in the Arctic as a catalyst for increasing vessel traffic

Loss of Arctic sea ice cover and advances in technology have facilitated the expansion of oil and gas extraction, commercial fisheries, mining and tourism. The following subsections briefly describe how these industrial sectors are affecting the Arctic and stimulating increasing vessel traffic in the region. Although this report addresses these sectors separately, the commercial and industrial activities that drive increases in Arctic vessel traffic do not occur in isolation from one another. Instead, they often overlap in time and/or space.

### 2.2.1 Oil and gas

Experts believe the Arctic contains some of the world's largest undiscovered petroleum reserves [43]. According to the U.S. Geological Survey, more than 80% of the Arctic's undiscovered oil and gas is found offshore. Russia in particular has abundant natural reserves — more than 40% of the undiscovered Arctic oil reserves and about 70% of undiscovered gas reserves [43]. While oil and gas operations have been conducted in some portions of the Arctic for many years, experts predict that offshore energy development will grow within the Exclusive Economic Zone (EEZ) of individual Arctic coastal states in the foreseeable future, leading to increasing levels of traffic in the region [44].

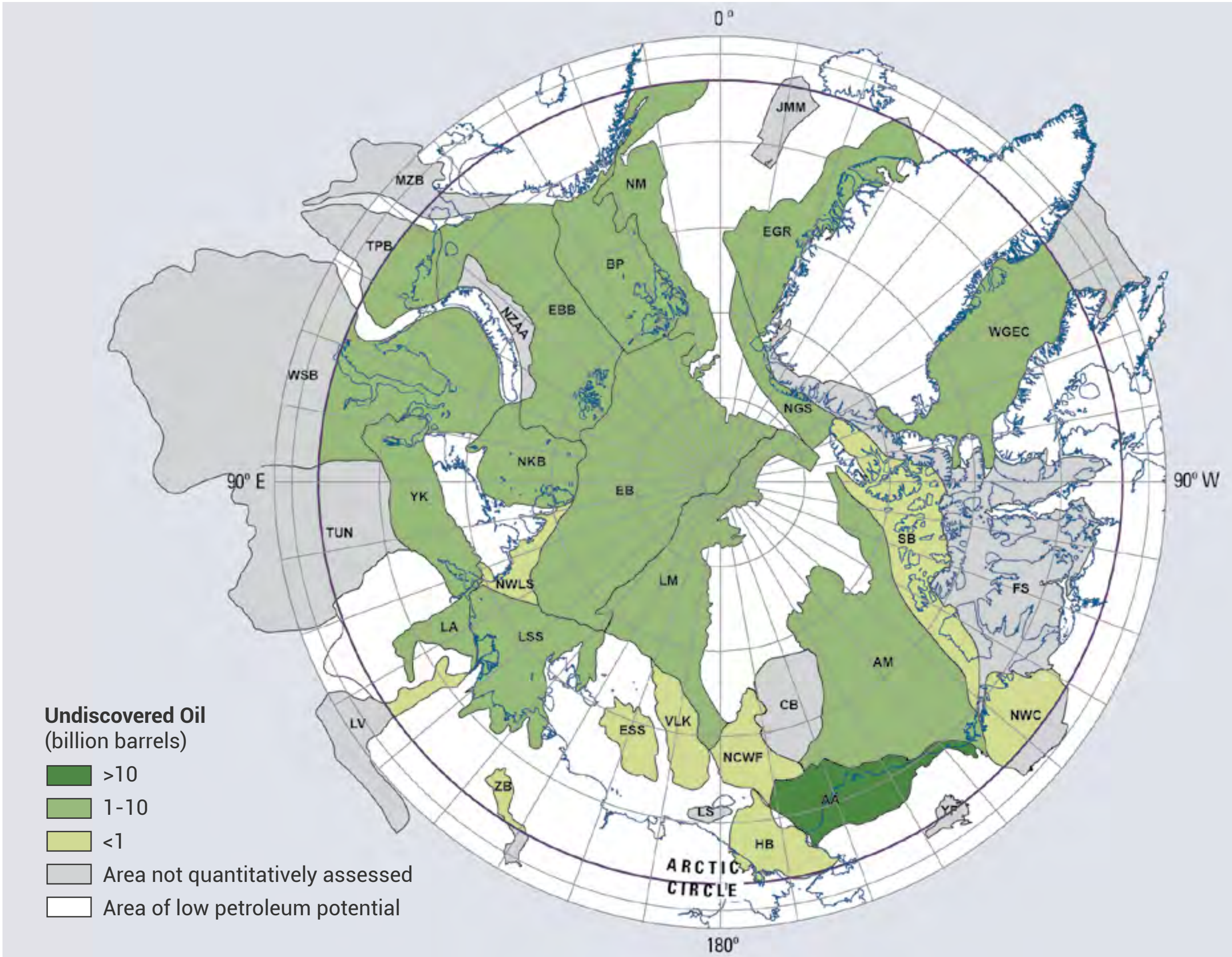
For example, Russia's Novoportovskoye Oil and Gas project began production in 2014 and launched large-scale shipments in 2016, and its Yamal LNG project is scheduled to start shipments in 2017 [45, 46]. Both projects are located on Russia's Arctic coastline. These developments rely on the Northern Sea Route to transport hydrocarbon products to the market, and are expected to generate increased vessel traffic on that route in the foreseeable future [47].

In Norway, Statoil continues to purchase offshore drilling licenses, and in 2017 the company plans to conduct operations at the northernmost well ever drilled off Norway [48]. While that project is outside the Polar Code area, it could affect adjacent marine areas.

Oil companies recently retreated from efforts to explore new fields in the U.S. Chukchi Sea, resulting in a decrease in vessel traffic relative to the years when exploration activities were occurring. However, there remains interest in other undertakings in the U.S. Arctic, such as Hilcorp's Liberty Project off Alaska's Beaufort Sea coast [49]. While the Obama administration withdrew a significant portion of the federally managed waters of the Chukchi and Beaufort seas from future oil and gas drilling, in the spring of 2017, President Trump issued an executive order that purported to revoke those protections. This action triggered an immediate legal challenge [50]. At present, the status of the Arctic withdrawals remains contested, while areas within state waters are available.

As market forces and political administrations change, oil companies are likely to pursue oil and gas in different areas of the circumpolar Arctic. Those oil and gas activities will generate more vessel traffic in the region [47].

*Figure 4: Map of estimated undiscovered oil in the Arctic. From [43].*




### 2.2.2 Commercial fisheries

Fishing grounds adjacent to the Arctic are some of the most productive on Earth [51]. The Barents Sea, for example, supports the largest cod stock in the world [51]. The vast majority of commercial fishing in the Arctic occurs in ice-free areas of the EEZ of Arctic nations, many of which occur south of the Polar Code boundary [52].

In many areas of the Polar Code region, commercial fishing is prohibited. In 2009, the United States prohibited commercial fishing in U.S. waters north of the Bering Strait until more information is known about potential impacts to Arctic fish stocks [51]. Similarly, Canada's federal government worked with the Inuvialuit indigenous peoples to protect more than 800,000 square kilometers of the Canadian Beaufort Sea from large-scale commercial fishing [53].

Nations have also taken steps to prohibit commercial fishing in the Central Arctic Ocean, the area of the Arctic Ocean that lies beyond the boundaries of individual nations' EEZ. In 2015, an agreement signed by Canada, the Kingdom of Denmark (in respect of Greenland), the Kingdom of Norway, the Russian Federation and the United States announced that those nations would ban their own commercial fleets from the Central Arctic Ocean until better scientific knowledge and regulatory mechanisms are available [54]. Currently, these countries are leading efforts to expand signatories to include other nations that would be likely to fish in the Arctic Ocean, including China, Korea and Japan [55].

Although fish species from more southerly waters are expected to move north into Arctic waters, it is not clear if this will result in increased commercial fishing in northern waters. Even if commercial fishing does expand, it is not clear how it will be managed and regulated [3, 30]. Because of these uncertainties, it is difficult to forecast whether or how fishing-related vessel traffic in Arctic waters will change in the future.

### 2.2.3 Mining

The Arctic contains vast quantities of minerals, including iron ore, copper, nickel, bauxites, zinc and phosphates [41]. The region is home to the world's largest nickel mine (Norilsk in Russia) and the world's largest zinc mine (Red Dog in Alaska). Arctic Canada is home to Baffinland iron mine and several diamond mines, and the Kvanefjeld deposit in Greenland's far south is now the target of mining operations for rare earth elements [51].

These and other mining operations account for a significant portion of shipping traffic in the Arctic. In Russia, ships servicing the Norilsk mine sail year-round from the port of Dudinka to Murmansk [7]. In the U.S. Arctic, during ice-free months, the bulk cargo ships that service Red Dog mine via the DeLong Mountain terminal account for a significant amount of deep draft vessel traffic in the region [56]. Mining operations in the Arctic are expected to rise, and as a result, mining-associated vessel traffic is also expected to increase [51].

### 2.2.4 Tourism

Tourism is a growing sector in the Arctic. Marine tourism has been on the rise for more than two decades [7]. Most tourists to the Arctic visit via cruise vessels [7, 57]. Between 2004 and 2007, cruise ship traffic in the Arctic went from 50 ships to 250, a 400% increase [6].

In recent years, larger tour vessels have undertaken longer voyages to more remote locations. In 2014, the *MS Hanseatic* (with a passenger/crew capacity of 300) became the first non-Russian cruise ship to travel the Northeast Passage. In 2016, it completed its second voyage of this route [58]. Also in 2016, the Crystal Serenity — carrying 1,700 passengers and crew — became the first large luxury cruise ship to transit the Northwest Passage. Its voyage increased popular awareness of this new frontier of tourism. Many companies have indicated growth of operations in the region, including Lindblad Expeditions, which plans to build ten new expedition ships ready to travel Arctic waters by 2019 [59].

While Arctic cruises may bring new economic opportunities to communities, it may also generate risks to people of the Arctic and the environment [60]. For example, passenger ships generate a substantial amount of sewage and graywater. Currently, international law allows ships to legally dump untreated sewage 12 nautical miles away from land (or the ice shelf, fast ice, or areas of ice concentration exceeding 1/10 when present). Discharge of graywater is not regulated by international law at all (see Section 5.3 for more details).

In addition to potential increases in harmful discharges, visits from large passenger ships can also disrupt small coastal communities and hunting and fishing practices. Some regions, like the Canadian territory of Nunavut, are considering regulations that require cruise ship passengers to enter villages in small groups and be provided educational materials about local communities [61].

## 2.3 Snapshot of 2014 Arctic vessel traffic

Analysis of recent Arctic vessel traffic is essential to understanding current operations and future growth trends in light of sea ice and global economic change.

Vessels use Arctic waters in different ways. The AMSA defined the following voyage types: (1) destination transport, in which a vessel travels to the Arctic and then leaves; (2) inter-Arctic transport, in which a vessel stays within the Arctic but moves between countries, (3) trans-Arctic transport, in which a vessel crosses the Arctic from Atlantic to Pacific (or vice versa), and (4) cabotage, in which a vessel conducts trade or transports passengers within a single Arctic country [7]. The following subsection examines vessel traffic of all voyage types in Arctic waters, using data from the year 2014 to present a snapshot of the type, size, prevalence and location of vessel traffic in Arctic waters.

### 2.3.1 Method

This analysis uses vessel traffic data from the Norwegian Coastal Administration satellite Automatic Identification System (AIS) for the year 2014 and covers the Polar Code region.

IMO's International Convention for the Safety of Life at Sea (SOLAS) requires AIS transmitters to be fitted on board vessels of 300 gross tonnage (GT) or more engaged in international voyages; cargo ships greater than 500 GT; passenger vessels and certain other vessels [62]. The AIS data used for this analysis should represent these types of vessels. Ships required to use AIS must transmit vessel identity, type, location, course, speed and status. They may choose to transmit additional information, as well.

Reliance on AIS data involves some limitations, since not all vessels carry and use AIS equipment. For example, barges are not required to carry AIS transmitters and, as a result, AIS data cannot be used to characterize barge traffic. Government and military vessels are not required to transmit AIS information at all times and may be under-represented by the data. Similarly, small vessels are not required to use AIS. That said, some vessels that are not required to carry AIS choose to do so voluntarily. Information from these "volunteer" vessels is included in the dataset.

A small portion of AIS information may be missing, inaccurate, or incomplete. If vessels stop transmitting AIS information, or if satellite or shore-based receivers stop functioning, then there will be gaps in the dataset that could affect the analysis. Despite these limitations, AIS data provides a fairly complete picture of overall vessel traffic in a given area.

### 2.3.2 Vessel type, size and quantity

Vessels operating in the Arctic are engaged in a wide range of activities, including fishing, transporting goods and raw materials, research and tourism [7]. The vessel types identified in the 2014 dataset and listed in Table 1 reflect the diversity of activity in the region.

*Table 1: Vessel types by category (based on information provided for vessels in 2014 data).*

| Vessel Categories | Description |
|---|---|
| **Bulk carriers** | Carries bulk cargoes of different types. |
| **Cargo – General** | Carries different types of cargo; also referred to as "break bulk" carriers. |
| **Cargo – Refrigerated** | Subcategory of cargo ships; separated in dataset. |
| **Cargo – Roll on/Roll off (Ro-Ro)** | Allows wheeled cargo (e.g., vehicles) to roll on and off. Subcategory of cargo ships; separated in dataset. |
| **Container ships** | Carries cargo in containers designed for transfer to truck or rail. |
| **Fishing vessels** | Commercial fishing vessels. |
| **Liquid gas carriers** | Carries liquefied natural gas (LNG) or liquid petroleum gas (LPG). |
| **Offshore supply vessels** | Serves offshore oil and gas or other facilities. |
| **Other offshore activities** | Drilling, diving, standby safety and other offshore support for oil and gas or other offshore activities such as cable-laying. |
| **Other activities** | Tugs and vessels used for patrol, pilots, and fire-fighting; fish processors; dredgers; ice breakers; research or survey vessels. |
| **Passenger** | Passenger vessels including ferries and cruise ships. |
| **Tankers – Chemical and other** | Tank vessels carrying chemicals or other liquids. |
| **Tankers – Oil** | Tank vessels primarily transporting crude or refined oil products. |
| **Unknown** | AIS dataset did not provide information for vessel type and/or size. |

Vessels vary by size as well as type. Of the 2,300 vessels for which size was identified, the 2014 vessel traffic in the Polar Code region was largely comprised of smaller vessels: those less than 1,000 GT or between 1,000 and 5,000 GT as shown in Table 2 and summarized in Figure 5. While GT is a measurement of volume typically applied to non-tank vessels, it is used here for both tank and non-tank vessels to facilitate comparison.

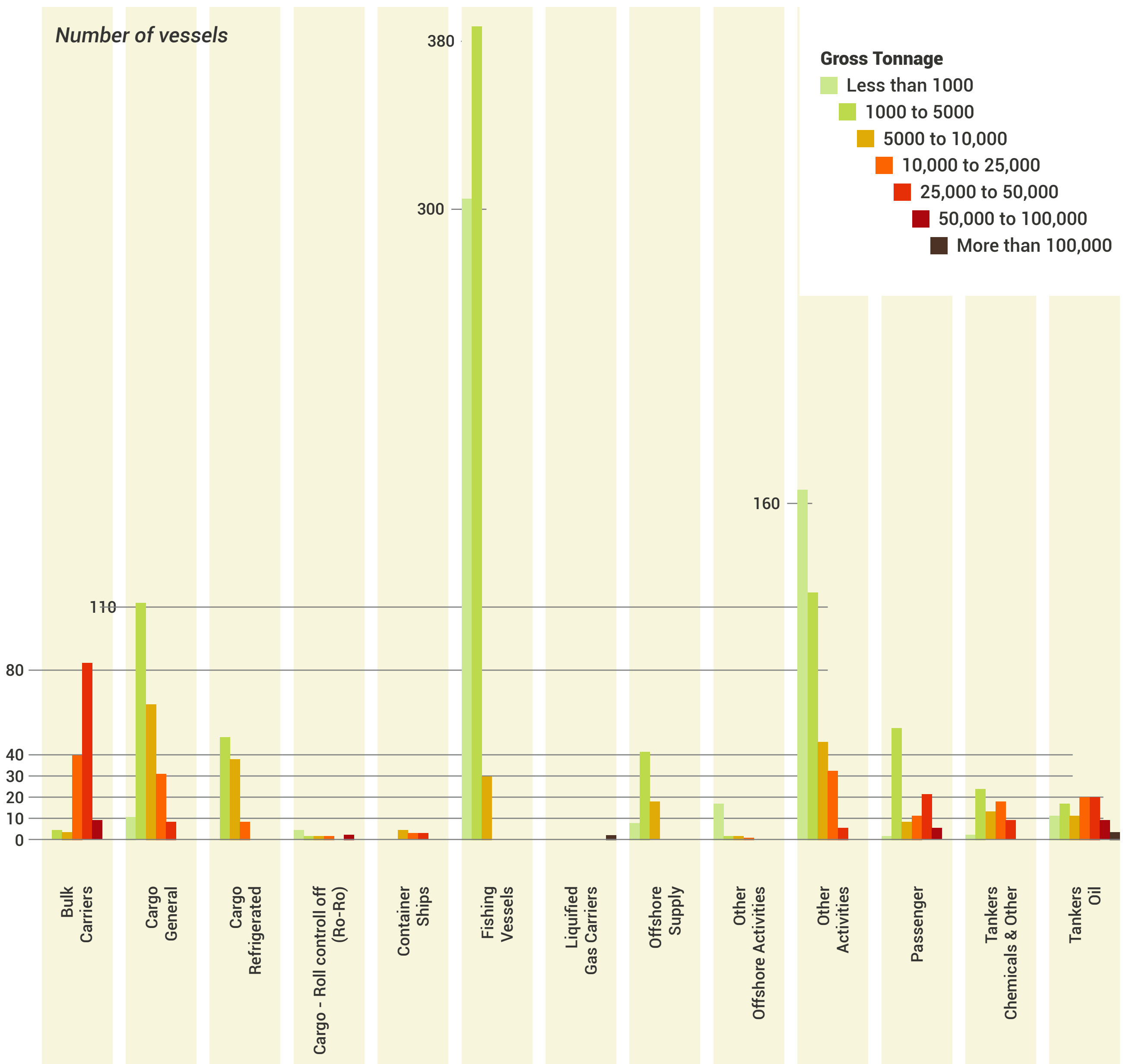
Fishing vessels were the most common type of vessel operating in Arctic waters and represented 31% of all vessels in the region. Unknown vessels comprised 17% of vessels in the region. Despite regulations specifying the need to do so, vessels do not always provide required or accurate identification information over AIS. Vessels in the "other activities" category were the third most frequent type, representing 16% of all vessels in the region. General cargo and bulk carriers were the next most common vessel type, followed by various other vessel types that comprised less than 5%, respectively.

Although 2,300 ships voyaged within the Polar Code Arctic in 2014, the volume of vessel traffic in the Arctic traffic does not approach the levels found in most other sea areas.

*Table 2: Number of vessels operating in Polar Code region in 2014 by type and size (gross tonnage).*

| Gross Tonnage (GT) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | <1000 | 1000-5000 | 5000 – 10,000 | 10,000 - 25,000 | 25,000-50,000 | 50,000-100,000 | ≥100,000 | Not known | Total |
| **Bulk carriers** | | 4 | 3 | 40 | 84 | 5 | | | 136 |
| **Cargo – General** | 11 | 112 | 64 | 31 | 8 | | | | 226 |
| **Cargo – Refrigerated** | 1 | 49 | 38 | 8 | | | | | 96 |
| **Cargo – Roll on/ Roll off (Ro-Ro)** | 5 | 2 | 2 | 1 | | 2 | | | 12 |
| **Container ships** | | | 5 | 3 | 3 | | | | 11 |
| **Fishing vessels** | 305 | 387 | 29 | | | | | | 721 |
| **Liquid gas carriers** | | | | | | | 1 | | 1 |
| **Offshore supply vessels** | 7 | 42 | 18 | | | | | | 67 |
| **Other offshore activities** | 17 | 2 | 2 | 1 | | | | | 22 |
| **Other activities** | 166 | 118 | 46 | 33 | 5 | | | | 368 |
| **Passenger** | 12 | 17 | 11 | 20 | 20 | 9 | 3 | | 92 |
| **Tankers – Chemical and other** | 2 | 24 | 13 | 18 | 9 | | | | 66 |
| **Tankers – Oil** | 1 | 53 | 8 | 11 | 21 | 5 | | | 99 |
| **Unknown** | 1 | | | | | | | 382 | 383 |
| **Total** | **528** | **810** | **239** | **166** | **150** | **21** | **4** | **382** | **2,300** |

*Figure 5: Number of vessels operating in the Polar Code region in 2014 by type and size (gross tons). The figure omits "unknown" category due to lack of tonnage information. See Table 2 for information on the "unknown" category.*



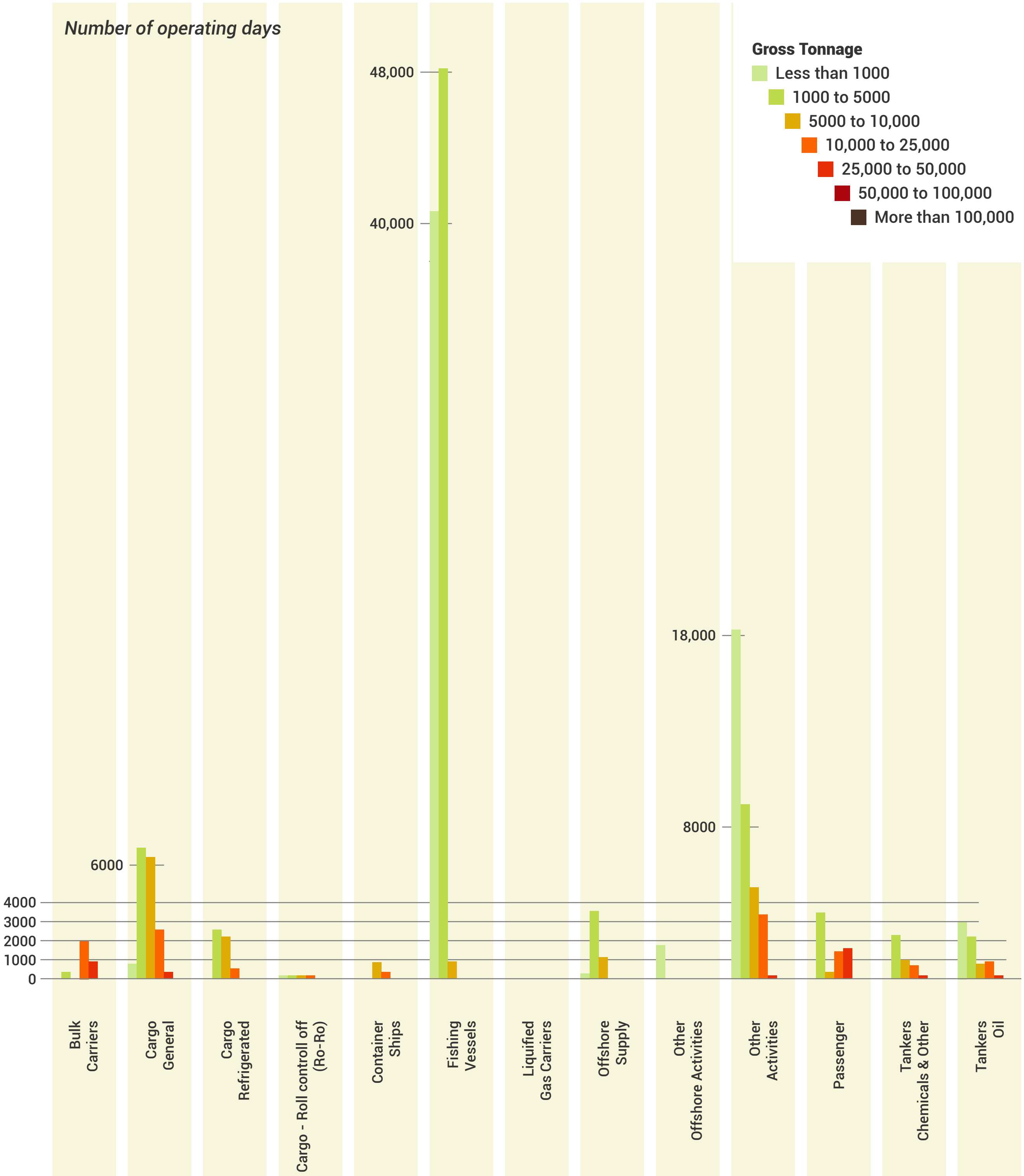

## 2.3.3 Operating days

Characterizing vessel traffic for the region requires considering not just the vessels themselves but how much time they spend in the area. Table 3 shows the number of operating days for each vessel type and size recorded in the Polar Code region in 2014. For this summary, an "operating day" represents the time, in days, that AIS data records a vessel as being in the study area. This is then aggregated by vessel type and size.

*Table 3: Operating days in Polar Code region in 2014 by vessel type and size (gross tonnage).*

| | Gross Tonnage (GT) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | <1000 | 1000-5000 | 5000 – 10,000 | 10,000 - 25,000 | 25,000-50,000 | 50,000-100,000 | ≥100,000 | Not known | Total |
| **Bulk carriers** | | 267 | 8 | 1886 | 918 | 8 | | | 3087 |
| **Cargo – General** | 700 | 6849 | 3675 | 2527 | 235 | | | | 13,987 |
| **Cargo – Refrigerated** | 23 | 2547 | 2140 | 445 | | | | | 5155 |
| **Cargo – Roll on/ Roll off (Ro-Ro)** | 239 | 159 | 65 | 101 | | 0.1 | | | 564 |
| **Container ships** | | | 737 | 391 | 0.4 | | | | 1128 |
| **Fishing vessels** | 40,605 | 48,194 | 793 | | | | | | 89,592 |
| **Liquid gas carriers** | | | | | | | 25 | | 25 |
| **Offshore supply vessels** | 189 | 3533 | 1124 | | | | | | 4846 |
| **Other offshore activities** | 1750 | 83 | 87 | 35 | | | | | 1955 |
| **Other activities** | 18431 | 9190 | 4805 | 3279 | 209 | | | | 35,915 |
| **Passenger** | 2884 | 2154 | 684 | 850 | 138 | 33 | 12 | | 6754 |
| **Tankers – Chemical and other** | 52 | 2248 | 950 | 676 | 187 | | | | 4113 |
| **Tankers – Oil** | 6 | 3464 | 415 | 1370 | 1571 | 74 | | | 6900 |
| **Unknown** | 52 | | | | | | | 19,683 | 19,735 |
| **Total** | **64,931** | **78,689** | **15,483** | **11,559** | **3259** | **115** | **37** | **19,683** | **193,756** |

*Figure 6: Operating days in the Polar Code region in 2014 by type and size (gross tonnage). The figure omits "unknown" category due to lack of tonnage information. See Table 3 for information on the "unknown" category.*



Small vessels (less than 5,000 GT) represented the majority of both vessel size and operating days (74%) in the region. Similarly, fishing vessels dominated both the vessel type and number of operating days (46%). However, the numbers of individual vessels and operating days do not necessarily correlate for a particular vessel type/size. For some vessel types, a significant component of the traffic consists of specialized, ice-classed (and relatively high-powered) ships that make multiple voyages each year within, to or from the Arctic region. For other types, the majority of individual vessels may be making a single trip to areas at the margin of the region, during a brief open water window. For example, examining tanker and passenger vessels of the same size category (25,000 – 50,000 GT), 20 oil tankers spent 1,571 operating days (1%) in the Polar Code area, while 21 passenger vessels spent 138 days (15%). In other words, even though there were roughly equal numbers of tankers and passenger vessels in this size category, the tankers spent much less time in the region.

"Other activities" and "unknown" vessel types (combined) comprised 36% of total vessel types, and operated in the Polar Code region 32% of the time (combined).

### 2.3.4 Vessel location

As previously mentioned, fishing vessels were the most common and widely distributed vessels in the area, as shown in Figure 7. By contrast, oil tanker activity in 2014 was almost exclusively conducted along the Eurasian coast. Offshore supply and other offshore service vessels are concentrated in the Barents Sea. Bulk carrier routes highlight traffic likely associated with mining activity in Svalbard in Norway and Alaska in the United States. The lone liquid gas carrier in the region traveled the Northern Sea Route connecting Western Europe to the Pacific Ocean.

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*Figure 7: Vessel tracks recorded in Polar Code region in 2014, shown by vessel type in yellow.*

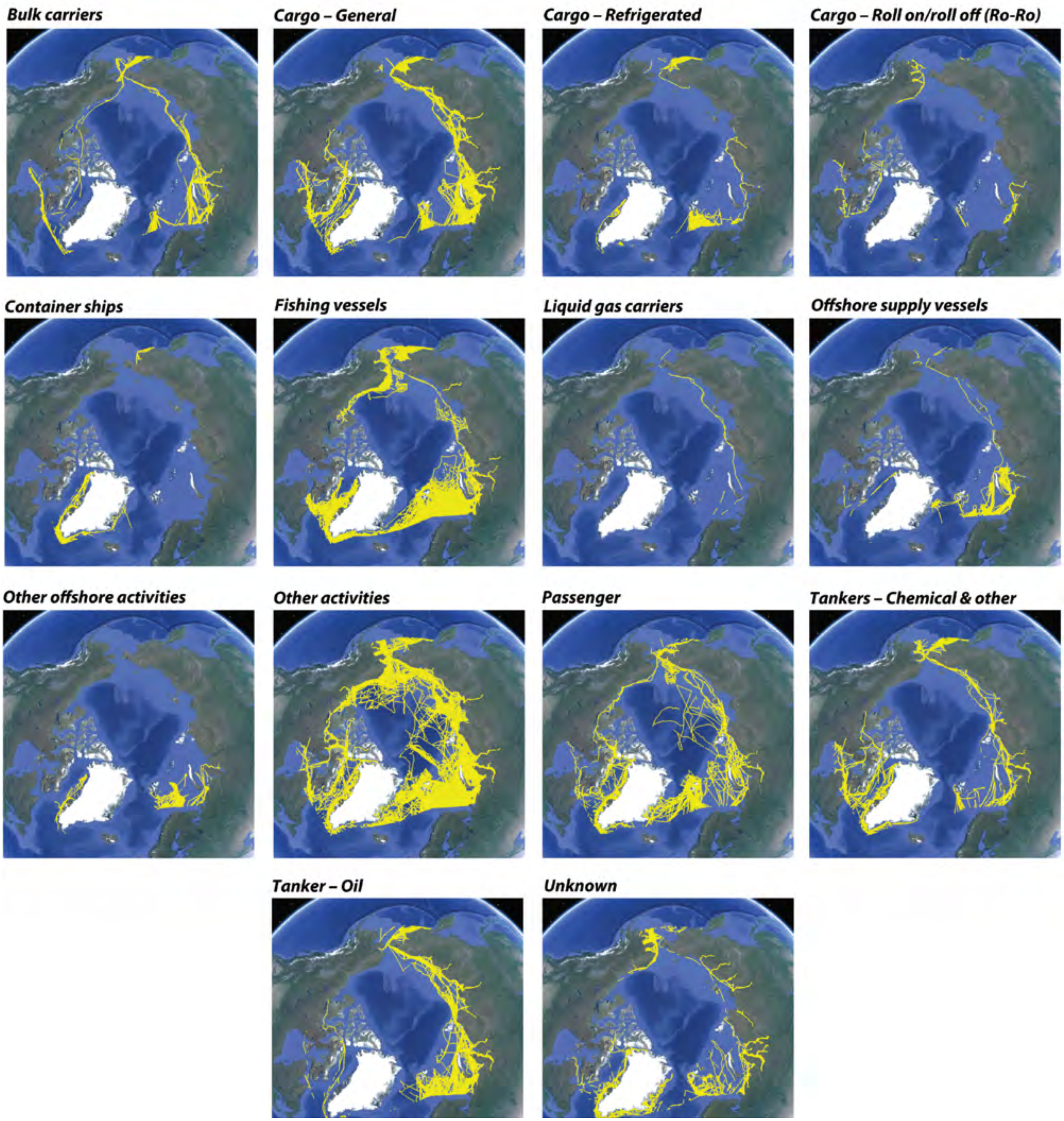
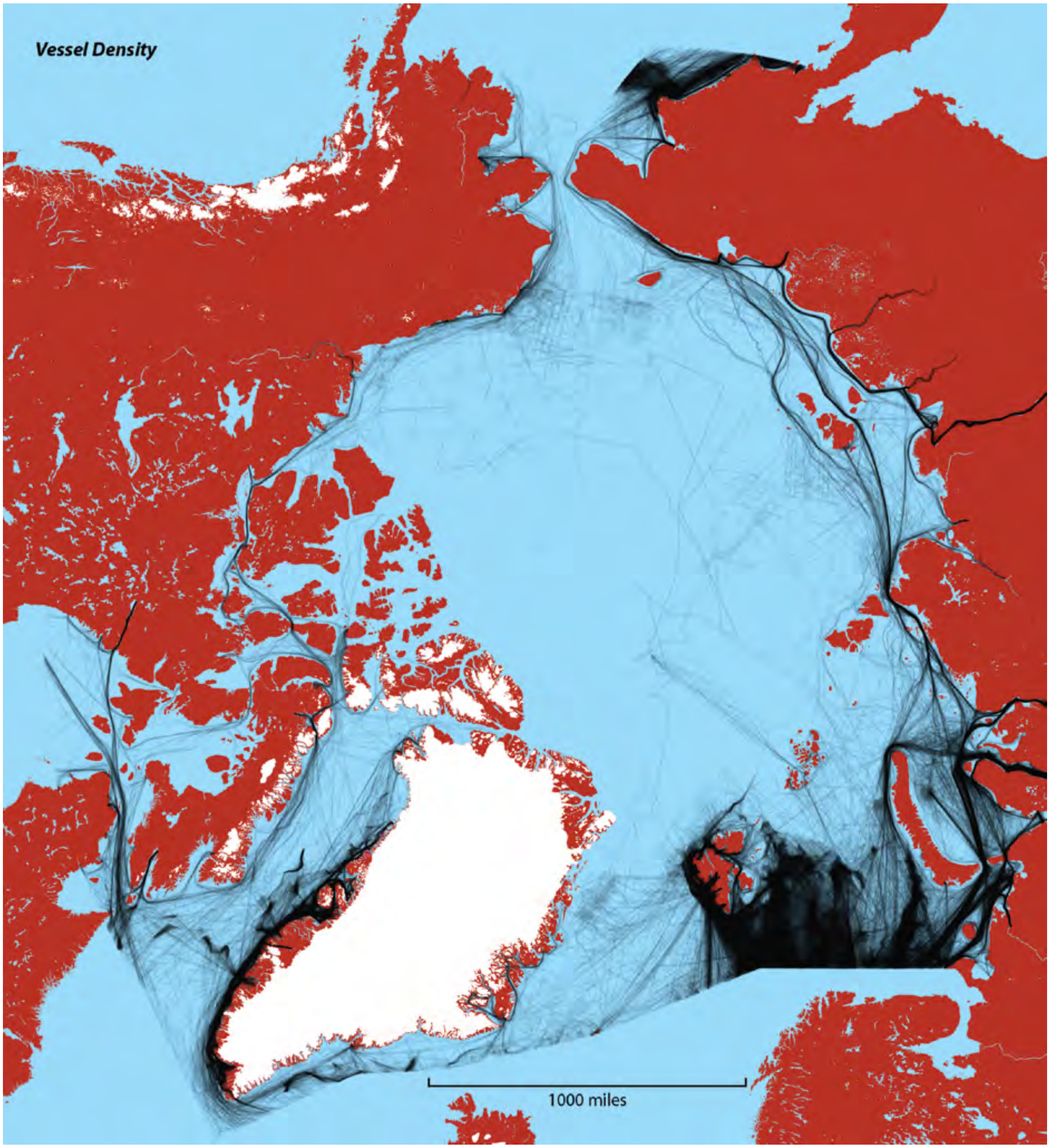


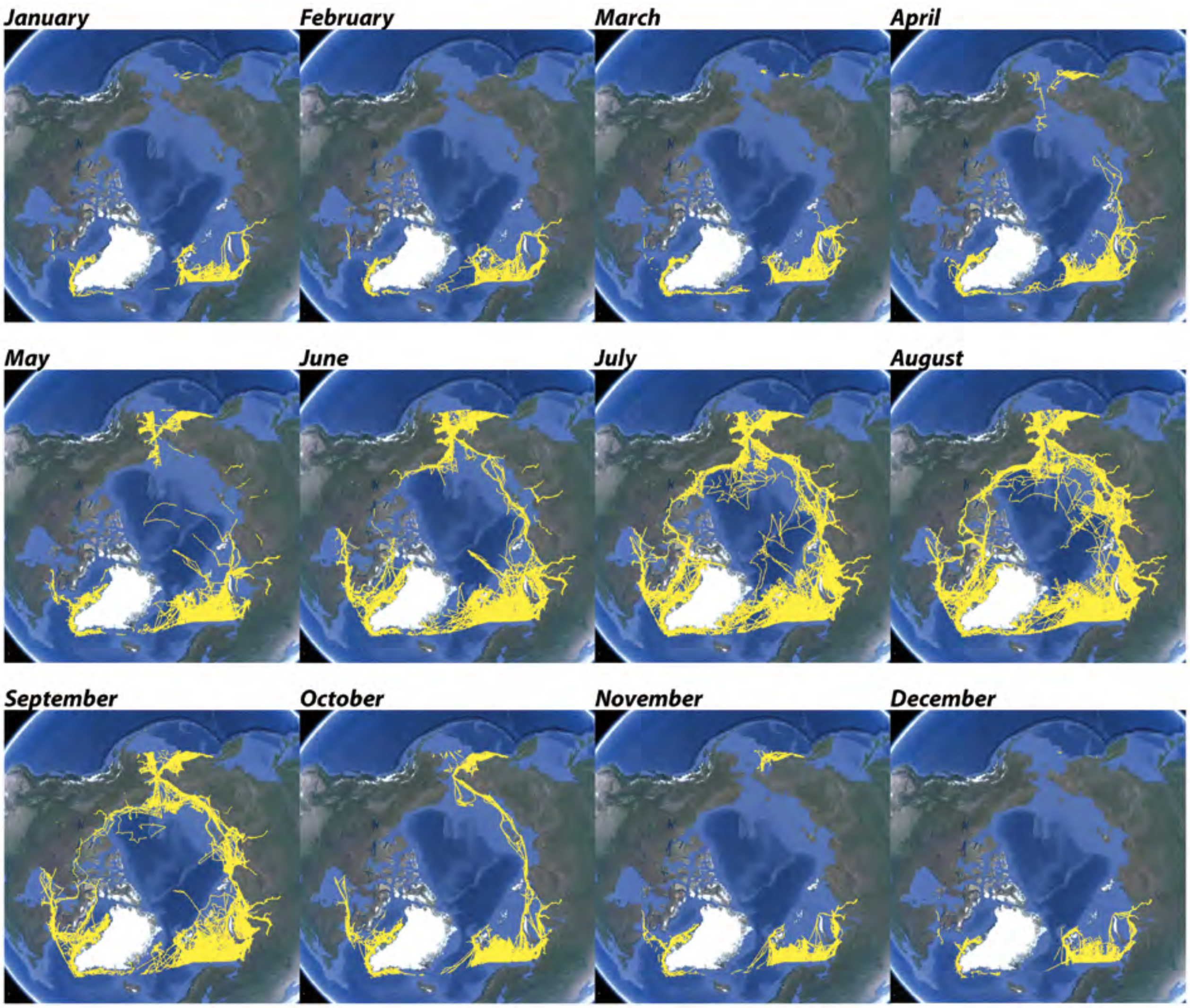
*Figure 8: Vessel traffic density for Polar Code region in 2014. Vessel tracks are shown in black.*



### 2.3.5 Seasonal variation

Figure 9 shows monthly variations in the location of vessels in the Polar Code region in 2014. Sea ice is a key driver of vessel location, with stark differences between winter and summer months. Most Arctic traffic consists of vessels with light or no ice strengthening. Vessel operators avoid ice-covered waters since ice slows forward progress. In addition, snow and ice can adversely affect propulsion by clogging or blocking machinery air and seawater intakes for cooling or firefighting systems.

*Figure 9: Vessel tracks recorded in Polar Code area in 2014, by month.*




### 2.3.6 Annual variations in traffic

While the 2014 analysis provides a useful snapshot of vessel activities in the Polar Code Arctic, vessel traffic in the Arctic varies from year to year as operations in the area evolve. For example, on the Northern Sea Route, there was steep growth in transits between 2010 and 2013, with cargo tonnage peaking at around 1.3m tons. However, transit volume experienced a sharp decline in 2014, and then slid further in 2015, to just 40 thousand tons [4]. This decreasing trend was due to a combination of global economics, commercial preferences, ice conditions and other factors. However, overall traffic levels (when considering both transit and destinational traffic) on the Northern Sea Route have increased due to inflow of construction cargoes associated with resource extraction projects [63].

Traffic levels in North American waters have also been variable in recent years. For example, in the Chukchi Sea, oil and gas exploration efforts by Shell in 2012 and 2015 resulted in traffic increases in the Alaskan Arctic and resulted in noticeable increases in Bering Strait transits [56].

## 2.4 Predictions of future Arctic vessel traffic

The navigability of Arctic vessel traffic routes will continue to change as sea ice extent and thickness continues to diminish in the coming years and decades. A 2009 study estimates that the Arctic Ocean will experience sea-ice free Septembers as early as 2037 [26]. As hazardous multiyear ice disappears and leaves weaker first-year ice, navigation by vessels with only moderate ice strengthening will become easier, the need for icebreaker escorts will decrease and the navigation season will be longer [40]. By the end of the century, some experts predict ice free passage through the Northern Sea Route for three to six months of the year and the Northwest Passage for two to four months of the year [64].

While vessel traffic growth by mid-century is a near certainty, projections of future vessel traffic volume differ widely. Models vary in focus on projections of technical accessibility and navigability, navigation season length, fuel consumption, transit time, economic viability and other factors, resulting in a broad range of future projections [65].

Future increases in vessel traffic will be heavily influenced by development within the Arctic. Destination cargo vessel traffic (e.g., oil and LNG tankers, bulk carriers) on the Northern Sea Route is expected to increase considerably with the completion of development projects for Russian hydrocarbon resources, including LNG from the Yamal region, crude oil production from several fields and coal exports. Although many other projects have been put on hold due to current low prices and technological constraints, Northern Sea Route cargo flow could still approach 100 million tons of goods a year by 2030 [66].

Studies have reached different conclusions regarding future Northern Sea Route international transit traffic. A 2011 study estimated the Northern Sea Route will be used for "480 transit voyages, or about 8% of the total container trade between Asia and Europe, in 2030, and 850 transits voyages, or about 10% of all container traffic between Asia and Europe, in 2050" [67]. Even given this growth, other studies emphasize that the Northern Sea Route will not experience vessel traffic volumes on par with those of the Suez Canal any time soon [17]. Container services may be particularly slow to use Arctic routes; they aim for tight adherence to schedules, but sea ice encountered on Arctic routes can cause unpredictable delays or interruptions to voyages [41].

The Northwest Passage has received less interest as a potential transit route than the Northern Sea Route. Due to the complexity of routes in the Northwest Passage, its shallow waters, variable sea ice that is present nine to 10 months a year and lack of physical and information infrastructure, it is not clear whether or when this route will be suitable for regular commercial transit traffic [47]. That said, destinational traffic, mostly associated with current and future mining developments, is expected to increase substantially in the Canadian Arctic [68]. The Baffinland mine alone exported roughly 3m tons of ore in 2016 and plans to increase this to 12m tons by 2020 [69].

In the U.S. Arctic, predictions show anywhere from a 100% (low-growth economic scenario) to 500% (high-growth economic scenario) increase in vessel traffic. Predictions vary greatly due to uncertainties relating to expansion of oil and gas north in the region, infrastructure development, the numbers of vessels transiting the Northern Sea Route and Northwest Passage and other variables [70].

While precise predictions of vessel traffic in the Arctic are impossible, some generalizations can be made. Resource extraction projects now in production or under development will lead to growth for bulk cargo in North America and Russia and for hydrocarbons in Russia [69]. Economic factors and the regulatory climate will dictate how and when longer term investments in new resource projects take place [44]. Supply operations for some communities in the Arctic will grow due to population growth and increases in local economic activity. Tourism-related vessel traffic and research vessels will also increase [59, 71]. Potential fishing grounds are likely to increase in extent and accessibility with changes in ice cover. Regulatory bodies and the scientific community will influence when or if this leads to increased fishing activity [72].

Overall, declining ice cover will likely make Arctic routes more attractive in the future [40, 73]. But for transit traffic to grow along the Northern Sea Route, Northwest Passage and potential trans-polar routes, the Arctic routes must be competitive with other shipping routes, including routes through the Suez and Panama canals [40]. Some factors influencing this include fuel costs, navigation fees and other regulatory costs, insurance costs, security concerns, ability to consistently adhere to shipping schedules, political considerations, development of local regulations and the relative costs of the ships themselves.

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# 3

# Overview of Arctic vessel traffic governance

*Governance of vessel traffic in the Arctic can promote safety, security and environmental protection. A variety of existing regulatory and non-regulatory measures influence Arctic vessel traffic activities. These include not only mandatory IMO regulations and treaties, binding agreements and national laws, but also recommendatory measures and best practices established by industry groups and/or various stakeholders. This section explores these governance mechanisms, as well as potential gaps that could trigger the adoption of new regulatory or non-regulatory mechanisms.*

## 3.1 United Nations Convention on the Law of the Sea (UNCLOS)

Global maritime traffic is governed by an overarching legal framework established by customary international law and the 1982 United Nations Convention on the Law of the Sea (UNCLOS). Among other things, this legal framework includes a series of maritime jurisdictional zones that balance the ability of coastal states to regulate vessel traffic and the ability of maritime powers to maintain navigational freedom. Certain areas of the ocean are subject to special rules. UNCLOS, for example, establishes a unique set of rules that apply to international straits, such as the Bering Strait. In addition, UNCLOS includes special provisions relating to ice-covered waters [74].

Customary international law, as reflected in UNCLOS, recognizes maritime jurisdictional zones ranging from internal waters to the high seas. Within each of these zones, coastal states may exercise varying degrees of authority over foreign-flagged vessels, and foreign-flagged vessels have varying degrees of freedom of navigation. One important jurisdictional zone is the territorial sea, which extends from a baseline (usually a state's coastline) outward to a distance of at most 12 nautical miles (nm). In general, a coastal state may exercise full sovereignty over its territorial sea. However, vessels are allowed to transit this region in innocent passage (see below). Another key zone is the coastal state's EEZ, which extends from the outer edge of its territorial sea seaward for a distance of no more than 200nm from the baseline. Within its EEZ, a coastal state has the sovereign right to explore, manage, conserve living and nonliving natural resources and exploit other economic activities including energy production [74].

International waters begin outside the territorial sea. As noted above, vessels from any country have the right to transit a coastal state's territorial sea in "innocent passage." In broad terms, "innocent passage" refers to continuous and expeditious travel through the territorial sea; ships traveling in innocent passage, though subject to general international laws, may not have to abide by all the laws of the coastal state whose territorial sea it is transiting. The high seas are those parts of the ocean that are outside all EEZs and territorial seas. The high seas are open to all states. In the absence of other international agreements, vessels operating on the high seas enjoy unrestricted freedom of navigation, freedom to lay submarine cables and pipelines, freedom of fishing and freedom of scientific research, among other things [74].

UNCLOS requires every vessel have a nationality, referred to as the vessel's flag state. The laws of the flag state apply on board these vessels. The flag state must ensure its ships adhere to international laws (e.g., rules regarding safety and the environment). Vessels enter ports subject to the jurisdiction of a specific nation; such nations are known as port states. Port states have the authority to impose certain regulations on foreign flagged ships entering their territorial waters with intention to access ports [7, 74].

UNCLOS includes special provisions relating to ice-covered waters. Article 234 provides that coastal states may adopt and enforce nondiscriminatory laws and regulations designed to prevent, reduce and control vessel pollution in ice-covered waters within a nation's EEZ. It applies "where particularly severe climatic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance." According to some experts, this "gives coastal states broad prescriptive and enforcement jurisdictions in the EEZ where it is ice-covered, even though for a limited purpose and subject to several restrictions [75]." Article 234 applies only to areas that are ice-covered for "most of the year," and therefore may not apply to many of the future navigable regions of the Arctic [74].

Flag and coastal states exercise jurisdiction in accordance with Generally Accepted International Rules and Standards (GAIRAS), which are the technical rules and standards adopted by regulatory bodies [75]. Broadly speaking, flag states must maintain vessel standards that are at least as strict as GAIRAS. On the other hand, port states usually cannot impose standards that are more stringent than GAIRAS. However, in areas that are ice covered most of the year, Article 234 of UNCLOS allows states to set more stringent requirements of foreign vessels, and to extend those requirements out to the boundary of their EEZ [75].

## 3.2 International Maritime Organization (IMO)

The IMO is a specialized agency within the United Nations responsible for the safety and security of shipping, as well as the prevention of marine pollution by ships. Through international conventions, the IMO sets both mandatory and voluntary regulations and standards governing international vessel traffic, which member nations are responsible for implementing and enforcing. Many national administrations authorize classification societies — non-governmental organizations (NGOs) that create, validate, and ensure maintenance of technical standards for vessels — to ensure certain aspects of implementation and compliance with IMO regulations.

### 3.2.1 International Convention for the Safety of Life At Sea (SOLAS)

One IMO instrument, SOLAS, sets "minimum standards for the construction, equipment and operation of ships, compatible with their safety" [76]. In addition to chapters addressing construction, fire protection, radio communications and carriage of dangerous goods, the safety of navigation chapter of SOLAS allows the IMO to adopt vessel traffic routing and reporting measures and require vessel communication systems that enable contact with other vessels and ports.

Routing measures are widely used to enhance navigational safety. By steering vessels into a defined traffic lane or away from particular locations, they increase the predictability of vessel movement. They can also help ensure vessels remain in well-charted waters, thus avoiding groundings and other potential accidents. Routing measures like traffic lanes and areas to be avoided (ATBAs) are also used to protect vulnerable and valuable habitats from vessel impacts such as marine mammal strikes and noise disturbance. For example, as part of a shipping study of the Bering Strait region, the United States Coast Guard (USCG) recommended a designated route for vessel traffic and a series of ATBAs to ensure that vessels steer clear of dangerous or sensitive areas, including areas where subsistence hunting occurs [77].

### 3.2.2 International Convention for the Prevention of Pollution from Ships (MARPOL)

Another important IMO convention is the International Convention for the Prevention of Pollution from Ships (MARPOL), as modified by the Protocol of 1978 and the Protocol of 1997. MARPOL addresses prevention of pollution of the marine environment by ships and includes six annexes [78].

*Table 4: MARPOL Annexes.*

| MARPOL Annex | Title |
|---|---|
| **I** | Prevention of pollution by oil and oily water |
| **II** | Control of pollution by noxious liquid substances in bulk |
| **III** | Prevention of pollution by harmful substances carried by sea in packaged form |
| **IV** | Pollution by sewage from ships |
| **V** | Pollution by garbage from ships |
| **VI** | Prevention of air pollution from ships |

Under Annexes I, II, IV and V of MARPOL, special areas may be designated to protect specific geographic areas from specified types of discharge. Under Annex VI, Emission Control Areas (ECAs) may be established to reduce emissions of sulfur oxides ($SO_X$) and nitrogen oxides ($NO_X$) in designated areas [79]. Discussions of MARPOL annexes can be found in Section 5 of this report.

### 3.2.3 The International Code for Ships Operating in Polar Waters (Polar Code)

On November 21, 2014, and May 15, 2015, the IMO formally adopted the safety and environmental provisions of the Polar Code, respectively. Formal adoption of the Polar Code came after more than 20 years of work at the IMO to promote safety and reduce potential environmental pollution from the increasing number of vessels operating in Arctic and Antarctic waters.

The Polar Code, which took effect January 1, 2017, introduced a broad spectrum of new binding regulations covering elements of "ship design, construction and equipment; operational and training concerns; search and rescue; and ... protection of the unique environment and eco-systems of the polar regions" [80]. The Polar Code added a new chapter to SOLAS to outline high-latitude safety provisions. Mandatory environmental provisions were added through the amendment of four MARPOL annexes (I, II, IV and V) relating to operational discharges of oil, noxious liquid substances, sewage and garbage. Other environmental provisions of the Polar Code (Part IIB) are recommendatory, not required [81].

A key safety element of the Polar Code is the Polar Ship Certificate. This certificate defines the vessel's polar operating capabilities and limitations, and confirms the flag state — or a recognized organization acting on its behalf (e.g., a classification society) — has inspected the vessel and determined its compliance with the relevant requirements of the Polar Code. Polar Ship Certificates classify vessels as one of the following:

**Category A –** Capable of operating in at least medium first-year ice which may include old-ice inclusions

**Category B –** Capable of operating in at least thin first-year ice which may include old-ice inclusions

**Category C –** Capable of operating in open water, or ice conditions less severe than those qualified as Category A or B ships

Generally speaking, the Polar Code applies to ships differently depending upon how a ship is constructed and how it will be operated in polar waters. The Polar Code's requirements take into account the capabilities a ship will need to carry out its intended operations safely and responsibly. These may include operation in ice, low air temperature, high latitude, extended periods of darkness, icing and so on. These conditions are highly dependent on where, when and how a ship will operate in the polar regions and what environmental conditions it will likely encounter while there.


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Not all ships traveling in the Arctic are subject to all provisions of the Polar Code. For example, non-SOLAS vessels (i.e., fishing vessels, cargo ships of less than 500 GT, ships of war, pleasure yachts not engaged in trade, ships not propelled by mechanical means and wooden ships of primitive build) do not have to adhere to the Part 1-A safety provisions of the Polar Code.

### 3.2.4 Other IMO instruments

In addition to MARPOL and SOLAS, the IMO has various conventions and guidelines that address specific environmental risks posed by vessel traffic, including a convention to address the risk of ballast-borne invasive species, voluntary measures to reduce the risk of hull fouling invasive species, voluntary vessel noise reduction guidelines and others that will be discussed further in Section 5 of this report.

One IMO instrument that can be used to address a variety of environmental concerns is a Particularly Sensitive Sea Area (PSSA) designation, which can be established for regions with "recognized ecological, socioeconomic, or scientific attributes where such attributes may be vulnerable to damage by international shipping activities" [82]. PSSA designation must be accompanied by one or multiple protective measures — called associated protective measures — such as routing measures, ships reporting systems, emissions requirements or discharge and equipment requirements [71, 82].

## 3.3 Arctic-specific national regulations

In addition to the international regulations implemented under IMO authorities, various nations have also implemented their own regulations which apply to vessels operating within their waters. Prior to the creation and adoption of the Polar Code, Canada and Russia had already implemented Arctic maritime-specific regulations and operating requirements for domestic and foreign vessels operating in their Arctic waters [7].

Canada has had its own Arctic shipping regulatory regime since 1970. With the 2017 implementation of the Polar Code, Transport Canada is in the process of integrating the Polar Code with Canada's existing Arctic shipping regulations. In doing so, some national regulations will be amended and others repealed. For example, Canada's 1970 Arctic Waters Pollution Prevention Act (AWPPA), which prohibits all foreign and domestic ships traveling in Canadian waters from depositing waste (excluding sewage) in Arctic waters, will be amended to include sewage and garbage requirements specified in the Polar Code [83]. The Canadian Arctic Shipping Pollution Prevention Regulations (ASPPR), which specify structural requirements for ships, will most likely be repealed. Canada's Arctic Ice Regime Shipping System (AIRSS), which requires ship operators to calculate ice conditions and ship capability as a measure to reduce pollution, will most likely be maintained and augmented with IMO's Polar Operational Limit Assessment Risk Indexing System (POLARIS) system [83].

Generally speaking, even after the integration of new Polar Code provisions, regulations for Canadian waters will still contain higher standards for safety and environmental protection than those established by the Polar Code. This may result in some vessels not being permitted in Canadian waters, even if they are Polar Code compliant [84].

After the collapse of the USSR in 1991, the Russian government enacted new legislation for those voyaging in the Arctic as it opened the region to international traffic. This legislation contained some environmental provisions that were more stringent than international standards, including a ban on garbage deposits and oily ballast water exchanges [7]. In 2013, the Russian government updated its Northern Sea Route regulations, relaxing some earlier restrictions regarding minimum ice class designations for navigation along the route, and established the Northern Sea Route Administration as a distinct special-purpose organization to centralize Northern Sea Route vessel traffic operations [85, 86].

The Northern Sea Route Administration manages Northern Sea Route transit applications and assesses the ice capabilities of applicants' vessels to determine required services (e.g., icebreaker assistance and pilotage) and related fees [41]. The Northern Sea Route Administration provides a variety of other services, including navigation information, to vessels [87]. As of March 2017, ships subject to the Polar Code must provide a copy of their Polar Ship Certificate to receive approval to transit the Northern Sea Route [88].

In addition to Canada and Russia's Arctic-specific maritime regulations, additional safety and environmental regulations apply in other regions of the Arctic, as well. For example, there are mandatory pilotage requirements for certain ships operating in the Svalbard region and for passenger vessels with more than 250 passengers that operate in Greenland [89, 90].

## 3.4 Arctic Council

The Arctic Council formed in 1996 to "provide a means for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic indigenous communities and other Arctic inhabitants on common issues, in particular issues of sustainable development and environmental protection in the Arctic" [91].

Most Arctic Council projects have resulted in nonbinding guidelines and reports addressing science, ecology, and social and cultural issues that inform the policymaking of member states. For instance, in 2009, the Arctic Council published the AMSA, the first comprehensive review of Arctic vessel traffic. Publication of the AMSA was a catalyst that provided recommendations to mitigate impacts from increased shipping, including by protecting areas of ecological or cultural significance, addressing impacts to marine mammals, reducing pollution from oil spills and air pollutant emissions, and increasing infrastructure in the circumpolar region [7]. Since the Assessment was published, various countries and organizations have adopted some of these recommendations, and the Arctic Council has continued to track and support the recommendations that have not yet been implemented.

More recently, the Arctic Council has also facilitated the adoption of three internationally binding agreements. The 2011 Arctic Search and Rescue Agreement delineates specific areas of the Arctic for which each party will provide search and rescue (SAR) support [42]. The 2013 agreement on Cooperation of Marine Oil Pollution Preparedness and Response in the Arctic is intended to strengthen oil pollution prevention and response coordination and mutual assistance among Arctic nations [92]. It requires each signatory to "maintain a national system for responding promptly and effectively to oil pollution incidents," and outlines specific requirements or recommendations regarding notification, monitoring, joint exercises and training, etc. [92]. These agreements provide a cooperative framework among the states, but they do little to substantively increase SAR or environmental response capabilities (i.e., resources) in the Arctic. A third Agreement on Enhancing International Arctic Scientific Cooperation was signed in May 2017.

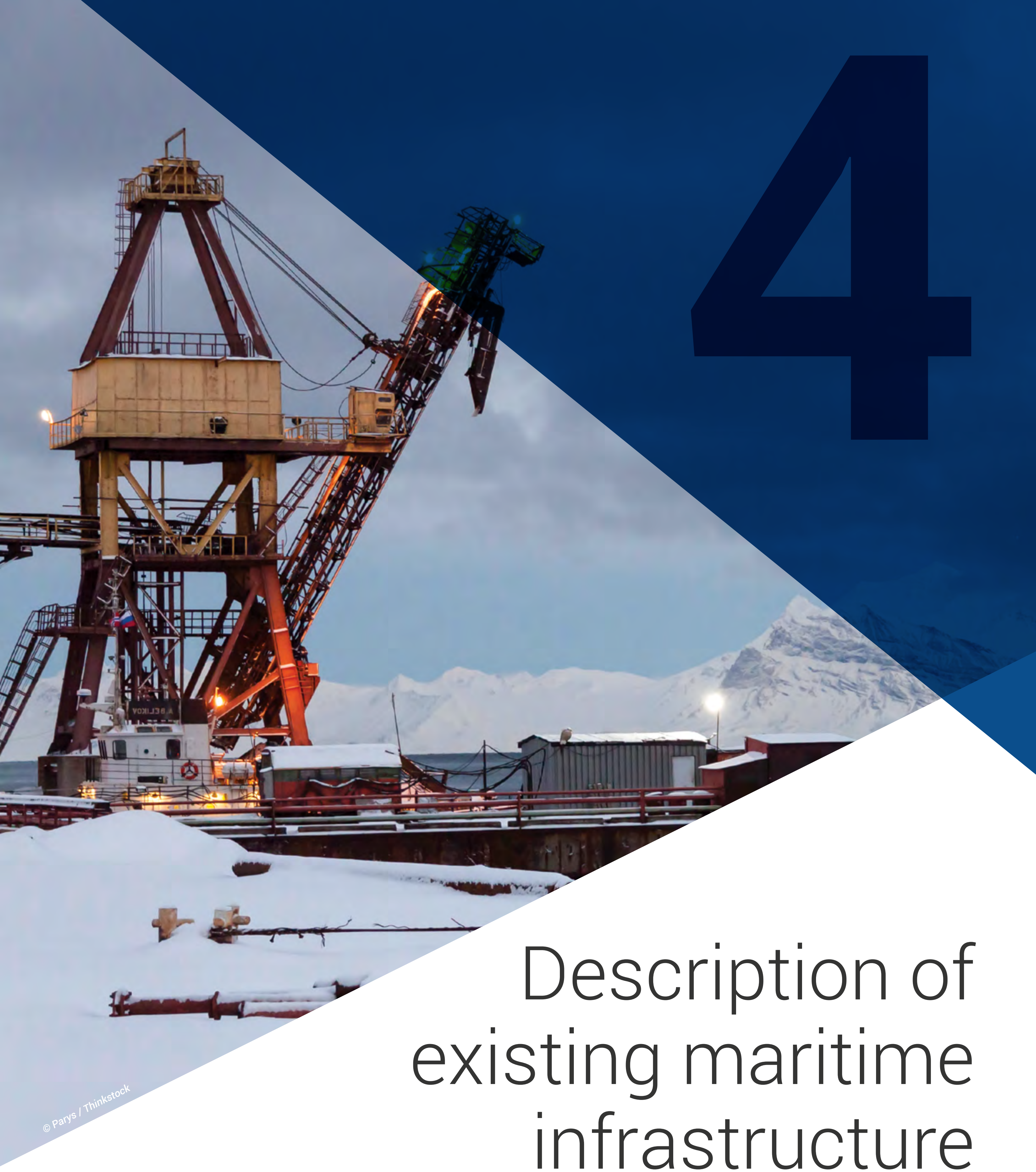
The Arctic Council has also initiated efforts to work directly with the private sector to advance best practices [41]. In 2016, the Arctic Council approved the formation of a non-regulatory "Arctic Marine Shipping Best Practices Information Forum" to create easier access to information and data required by the mandatory Polar Code. The forum is meant to facilitate exchange of technical and operational information, best practices and lessons learned to inform vessel traffic operations in the region. This will include a publicly accessible online web portal to store this information [93]. Seen as a way for the Arctic Council, the IMO and industry to collaborate with one another on Arctic shipping initiatives, the forum could help establish best practices for ships operating in the region [94]. If the forum succeeds as envisioned, it will gather and disseminate data that can help mariners comply with the Polar Code. It may also identify research and regulatory gaps and ways to address those gaps. In the future, the forum could provide feedback about the implementation of the Polar Code by generating recommendations for refinements or new safety and environmental measures.

## 3.5 Non-regulatory approaches

Other non-regulatory mechanisms include industry standards of care or best practices that can be used to promote safer and more environmentally friendly shipping practices. Responsible members of the maritime industry engage in various forms of standard setting and self-policing. Bodies representing specific sectors of Arctic maritime operations (e.g., cruise operators) can require their membership to meet or adhere to agreed standards. For example, the mission of the Association of Arctic Expedition Cruise Operators (AECO) is to "ensure that expedition cruises and tourism in the Arctic are carried out with the utmost consideration for the vulnerable, natural environment, local cultures and cultural remains, as well as the challenging safety hazards at sea and on land [95]." AECO members have agreed to follow guidelines designed to ensure that operations in the Arctic align with the organization's mission. AECO has also spoken out in favor of a phase out of the use of heavy fuel oil (HFO) in the Arctic. In general, responsible ship owners and operators are concerned with their reputations as good corporate citizens and do not want to jeopardize that reputation by having an accident in Arctic waters. Similarly, maritime insurers have financial incentive to adopt strong standards to minimize risk exposure.

Stakeholder forums are another non-regulatory tool that can help implement best practices and recommended measures in specific regions of the Arctic. For example, the Arctic Coast Guard Forum was established in 2015 as an "operationally-focused, consensus based organization" that leverages collective resources to promote safe and environmentally sound activities in the Arctic [96]. Coast Guard representatives of each Arctic nation come together to share information and best practices and conduct live tabletop exercises. In March 2017, the eight nations signed a joint statement outlining procedures and tactics in emergency maritime response and combined operations in the Arctic [97].

Stakeholders in the U.S. Arctic recently formed a different type of forum. Representatives from regional governments, the maritime industry, five regional subsistence groups and others in the region came together to form a nonprofit organization called the Arctic Waterways Safety Committee. The committee is drafting an Arctic Waterways Safety Plan intended to enhance marine safety, protect indigenous food security and promote environmental stewardship. The plan, which is being developed collaboratively, will "provide information, guidelines, and Standards of Care for marine operations in the United States (Alaskan) Arctic" [98].



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# 4

# Description of existing maritime infrastructure in the Arctic

*When compared with other regions of the world, the Arctic has relatively little physical infrastructure to support and facilitate safe maritime operations. Arctic maritime infrastructure is inadequate given current and predicted future levels of vessel traffic in the region. Port infrastructure, navigation and communication tools, SAR services and oil spill response capacity are lacking throughout most of the Arctic region. This section provides a broad overview of maritime infrastructure in the Polar Code Arctic region.*

## 4.1 Port infrastructure

Both terrestrial and maritime infrastructure in the Polar Code Arctic region is extremely limited. Few roads, limited airports and vast distances between communities, as well as a lack of ports and other coastal infrastructure, make transportation in the Arctic difficult. There are a few large, modern ports in the Polar Code Arctic, including Greenland's capital, Nuuk; the ice-free port of Murmansk in Russia; and the Port of Longyearbyen in Svalbard, Norway. Other Arctic ports may not be able to provide a full range of maritime services or meet modern standards, and vast stretches of the Arctic coastline have no infrastructure at all [7, 69].

Relative to the Northwest Passage, the Northeast Passage contains more physical port infrastructure. There are approximately 15 to 18 marine ports in the Russian Arctic. The largest port on the Northeast Passage is Murmansk, which is a deep draft, ice-free port that operates year-round. Smaller ports, located in regions of the Northern Sea Route with seasonal first-year ice, have moderate facilities. These include Tiksi, Pevek and Sabetta, which is under construction and will serve the Yamal LNG project [99]. Overall, many Russian ports in the Arctic are operated only seasonally, are shallow and have limited facilities or connecting infrastructure [100].

Lack of robust port facilities and deep draft ports is a problem in other parts of the Arctic as well. For example, the U.S. Arctic lacks any deepwater ports [6, 101]. There are three main ports: Nome, Kotzebue, and the DeLong Mountain Terminal (which is a private facility). Since none of these is a deep draft port, loading and unloading operations must be done through lightering [6]. In the Canadian Arctic, a number of mines have private deep draft terminals, and the Canadian Navy is developing a limited wharf capacity based on a closed mine terminal at Nanisivik, but there are no public deepwater ports. Work is also underway to establish port facilities in Iqaluit, the capital and largest community in the Territory of Nunavut. Until a deepwater port is established, dry cargo operations are delivered "over the beach," and bulk fuel transfer requires lightering via long and vulnerable floating hoses [69].

Establishment of deep draft ports has been identified as a key priority in the United States and other parts of the Arctic, and efforts are currently underway throughout the Arctic to develop more deep draft ports and port facilities [5]. However, building or expanding Arctic ports requires significant investment, due in part to the same harsh conditions and remoteness that make such ports desirable. Under IMO rules, new and existing ports should be equipped with port reception facilities capable of receiving operational wastes (e.g., oils, chemicals, sewage and garbage) from vessels [102]. At present, few Arctic communities have the ability to process such wastes. Building, operating and maintaining waste facilities for ports in remote areas of the Arctic is an ongoing challenge [103].

## 4.2 Information infrastructure

Most maritime regions around the world have developed substantial maritime safety enhancements. Beginning with lighthouses and buoys, navigational systems have evolved to include pilotage requirements, radio communications systems and in some areas, radar equipped Vessel Traffic Systems (VTS). Most parts of the Arctic, which have only recently opened up to modern commercial vessel traffic, do not have these risk-mitigating capabilities in place. The Arctic's remoteness, seasonality, lack of infrastructure and dynamic environmental sensitivity present greater challenges than other maritime regions.

In many areas, the Arctic lacks adequate and up-to-date charting, mapping, aids to navigation (ATON), geodetic and tidal data, and weather and sea ice forecasts [5]. For example, while more than half of U.S. Arctic waters are considered navigationally significant, less than 2% have been surveyed with modern multibeam technology [5]. Elevations relative to sea level can be more than a meter off due to the lack of the geospatial infrastructure [6]. In the Canadian Arctic, only 1% of waters are surveyed to modern standards, and only 10% of nautical charts meet modern standards [101]. In the Russian Arctic, a hydrographic survey program has been underway for several years, focusing primarily on high latitude routes and on approaches to Ob Bay, but its progress is still slow due to a limited specialized fleet [104]. Lack of proper surveys, as well as physical hazards like sea ice, make it difficult to establish physical ATONs, such as buoys. Of navigations aids in Canadian waters, only 2% are deployed north of the Arctic Circle [101]. To address the complexity of navigating a region with limited navigation information, some nations require compulsory pilotage and higher training standards, and the Polar Code sets a higher baseline personnel competency [90, 105].

Communication in the region is also a challenge because of a lack of shore-based communication systems traditionally used in navigation. These limitations are so severe that they are specifically noted in the Polar Code: "digital VHF, mobile phone systems and other types of wireless technology offer enough digital capacity for many maritime applications, but only to ships within sight of shore-based stations, and are, therefore, not generally available in polar waters" [105]. For example, on the Northern Sea Route, voice and data communications mostly rely on the geostationary INMARSAT satellites. However, INMARSAT has spatial gaps in the Russian Arctic. This leaves the Northern Sea Route, especially its high latitude portions, vulnerable to interrupted reception. The further north a vessel travels, the less reliable communications become due to the diminishing incline of line-of-site to the satellites. Functional problems arise above 70°–75° N [106]. While use of the Iridium network of low Earth orbit satellites is used as a backup technology, information critical to navigation can be lost. Iridium NEXT technologies are expected to solve this problem, but their deployment, originally planned for 2016 to 2017, has experienced delays [107].

The maritime industry is embracing the use of AIS technology and other e-Navigation technologies to aid operational efficiency. AIS integrates GPS positioning with a very high frequency (VHF) communications transceiver. A vessel equipped with an AIS transmitter digitally sends out data on the vessel's position, type, size, heading, speed, destination and other information to shore stations and nearby vessels. All of this can be displayed on an Electronic Chart Display and Information System (ECDIS) and can be made accessible via the internet for shore support activities.

By allowing vessels and onshore observers to track ships, AIS helps to avoid collisions, maintain a safe distance from maritime hazards, locate vessels in distress and assist in SAR efforts. Moreover, it makes possible vessel traffic and monitoring systems that may encourage safer maritime practices and compliance with both mandatory and voluntary regulatory measures [108]. AIS can also transmit messages concerning hazards, changes in charts and other information from shore-based stations to vessels [6]. In waters where the presence of ice prevents the setting of buoys, AIS has been used to transmit the location of "virtual buoys" that appear on a vessel's ECDIS, but do not actually exist on the water. IMO treaties and national regulations prescribe the size and types of vessels that must be equipped with AIS (see section 2.3).

Land-based AIS stations have a limited range, typically around 74 kilometers offshore [6]. AIS-equipped vessels can be tracked further offshore using satellite AIS [109]. Satellite AIS is the primary means of tracking vessels in the offshore Arctic and provides many of the same functions of land-based AIS.


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However, it provides a vessel's position to ground stations much less frequently, lacks the ability for two-way ship-to-shore communication, and may experience functional problems in the far north as discussed above [106, 110]. There will likely be further development of both AIS satellite technologies and land-based AIS stations to address existing limitations [111].

# e-Navigation

e-Navigation is an international maritime safety initiative adopted by the IMO and the International Association of Marine Aid to Navigation and Lighthouse Authorities. The purpose of e-Navigation is to apply emerging technologies to enhance maritime safety, efficiency, security and environmental protection.

Over the last several years, substantial technological advances have greatly enhanced the dissemination of navigational, safety, environmental and other information between vessels and coastal authorities [108]. The IMO is currently working on an e-Strategy Implementation Plan to develop e-Navigation solutions. Once complete in 2019, the plan will inform industry on how to design products and services needed to meet these solutions [112]. Even though IMO's e-Navigation plan is yet to be implemented, reliance on publications, paper charts, buoys and lighthouses is being gradually replaced by new technologies.

A key e-Navigation tool, ECDIS is an IMO-compliant, computer-based navigation system that displays information from Electronic Navigational Charts or Digital Nautical Charts, along with information on the vessel's position, heading and speed provided by GPS, fathometers and radar. AIS messages from other vessels and shore stations are also incorporated into a vessel's ECDIS. In addition to harmonizing various data sources on one display, ECDIS can also trigger alarms and alerts when a vessel is approaching shallow waters and/or entering restricted areas, as well as display safety and environmental information disseminated by national coastal administrations and other authorized entities [108].

Although e-Navigation is likely the future of vessel navigation, safe use of integrated e-Navigation technologies throughout the Arctic will require investment in information infrastructure discussed above (e.g., updated charts and data, expanded satellite or land-based coverage, etc). e-Navigation is still in its early stages of development. Comprehensive implementation of e-Navigation technologies will most likely occur in regions with more robust infrastructure before it is used widely in the Arctic.

## 4.3 Incident response infrastructure

Given the challenging operating conditions and navigation, communication and physical infrastructure gaps, there is considerable risk of an incident in Arctic waters. SAR networks, oil spill response capabilities and icebreakers are key components to addressing incidents once they happen. Availability of incident response tools varies by region, but generally speaking, response capabilities are inadequate even in those areas of the Arctic that have the most response infrastructure (e.g., the Northern Sea Route).

As noted above, the Arctic Council created binding agreements to coordinate mutual assistance efforts in the case of a SAR or oil spill recovery response event. On the national level, icebreakers may be necessary to address regional incident response (and prevention) needs. Many Northern Sea Route transits are required to operate with an icebreaker escort, therefore providing immediate, on-site assistance if an incident arises. Along the Northwest Passage, Canada has maintained an icebreaker in the vicinity of many of the higher profile transit voyages that have been undertaken (e.g., MS Nordic Orion, Crystal Serenity). Overall, however, the Canadian icebreaker fleet has limited capacity, as is the case for the United States, Greenland and Norway [113]. To date, in the U.S. and Canadian Arctic, vessels have relied on privately contracted icebreakers when deemed necessary. The voyage of the Crystal Serenity, for example, included a privately contracted icebreaking escort vessel, which also carried extensive emergency response equipment. Shell's exploration of the Chukchi Sea in the U.S. Arctic also involved privately contracted icebreakers and response equipment.

# Incident response on the Northern Sea Route

On the Northern Sea Route, SAR coverage is provided by the Marine Rescue Service (Morspassluzhba), with assistance from several other Russian agencies. The Marine Rescue Service has created a coordination center in Dikson (Taimyr peninsula) that operates year-round, along with two subcenters in Tiski and Pevek (central and eastern sections of Northern Sea Route), and an eastern site in Provideniya (Figure 10). All of these locations have SAR and oil spill response equipment, but these resources are limited [87].

The Marine Rescue Service currently has 12 multifunctional and supply vessels in Arctic and sub-Arctic areas, including specialized icebreaking vessels. Direct involvement of icebreakers is seen as crucial to SAR, incident prevention and response in this region. Most Marine Rescue Service vessels are located in less icy western and eastern regions, such as Murmansk, Sakhalin and Vladivostok [114]. Some of the vessels are deployed to select Northern Sea Route regions in the summer months.

Even though Russia's SAR fleet is probably the most robust of any Arctic nation, it is still insufficient and overstretched [115]. Russia has plans to narrow the gap; they focus on construction of multipurpose salvage and rescue vessels with high ice reinforcements, rescue tugs and oil spill response vessels.

***Figure 10: Marine rescue centers and emergency rescue centers in Russian Arctic. Adapted from [116], EMERCON website and other news sources.***


In parallel to the Marine Rescue Service, the Emergencies Ministry of Russia is implementing its own broad-scale Arctic program, with 10 emergency rescue centers in the Russian Arctic. Relative to the Marine Rescue Service, the Emergencies Ministry centers cover a broader range of emergencies, including land-based industrial, weather induced and other catastrophic events. Nonetheless, their remit also includes marine SAR activities. As reflected in Figure 10, the locations of several of these Emergency Ministry centers — including Tiski, Pevek and Provideniya — overlap with the locations used by the Marine Rescue Service [117].


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# 5

# Mitigating the environmental risks of Arctic vessel traffic

*As more vessels operate in the Arctic region, there will be a greater risk of incidents that adversely affect the marine environment. Threats from increased vessel traffic include, but are not limited to: oil spills, emissions, operational discharges, invasive species, noise and ship strikes on marine mammals. This section discusses these threats, the challenges to addressing them, relevant regulatory and or non-regulatory tools and next steps to mitigate risk.*

*While this report treats these topics individually, they are often inherently intertwined. For example, switching away from HFO use will both decrease the risk of oil spills and greatly decrease emissions generated by vessels. Similarly, certain governance measures may address multiple threats. ATBAs, for example, may be used to safeguard particularly valuable or vulnerable areas from many different potentially harmful activities. Minding this, it is useful to take a holistic approach toward addressing the adverse impacts of vessel traffic activities.*

## 5.1 Oil spills

### 5.1.1 Overview

An oil spill from a vessel operating in the Arctic can endanger the marine ecosystem and the indigenous communities that depend on it for subsistence. Not only can oil spills severely damage a healthy ecosystem and result in acute mortality of marine species — they also can have decades-long persistent impacts. In 2009, the AMSA identified an oil spill as the most significant threat to the Arctic marine environment [7]. While a spill of any type of oil is likely to have negative impacts, a spill of heavy fuel oil (HFO) may be especially damaging [118]. For that reason, this section places an emphasis on the particular threats associated with the use of HFO.

Most large seagoing vessels use HFO, also known as residual fuel or bunker fuel, due to its low cost. HFO is the residual product of the stock crude oil refining process. What remains is lower quality fuel with more concentrated amounts of contaminants like sulfur, ash, vanadium, aluminum, silicon, asphaltenes and other material [119]. Smaller vessels, like fishing boats, tend to use distillates that — while acutely toxic — evaporate much more readily than HFO [118]. A small percentage of vessels do not use HFO or distillate, but instead use LNG or other technologies.

In 2015, although only 925 of the 2,086 (44%) ships that operated in the Arctic operated on HFO, they represented 76% of the mass of bunker fuel (fuel used to propel a vessel) onboard [120]. In other words, although fewer ships run on HFO, those that do tend to carry significantly more fuel than the ships that run on distillates.

In addition to carrying fuels needed to propel themselves, some vessels operating in the Arctic also carry fuel as cargo for delivery to commercial markets or communities. Crude oil (unrefined petroleum) is carried to and from oil extraction sites or pipeline terminals; diesel fuel is commonly carried to parts of the Arctic for use by communities; and HFO is thought to be carried to certain communities in Russia for use ashore.

When an oil spill occurs, factors such as weathering, dispersion and level of toxicity will vary greatly depending on the type of oil, water temperature, weather and wave patterns, currents and other conditions.[56].

Unlike marine diesel, HFO emulsifies in water, is extremely viscous and breaks down very slowly in marine environments, particularly in colder regions like the Arctic [121, 122]. In a simulated spill scenario, after three days, distillate fuels disappeared from the water surface, whereas nearly all HFO remained present after 20 days [118]. Although diesel evaporates and disperses naturally in a shorter amount of time, it can leave residue (up to one-third the amount of the spill) and adhere to suspended sediments [123]. That said, an HFO spill is a much greater risk than a diesel spill; a 2011 report concluded that use of distillates instead of HFO as fuel would reduce risk to the marine environment [118]. Crude oil weathers more quickly than HFO, but otherwise exhibits many of the same acute and persistent effects of HFO [123]. Regardless of the type of oil, a spill in ice-covered waters could result in oil becoming trapped in ice, causing the oil to persist even longer, and enabling oil to transport even longer distances [118].

Exposure to an HFO or crude oil spill can result in massive die-offs [124]. For example, HFO and crude oil will adhere to the plumage of seabirds and fur of marine mammals, leading to hypothermia and subsequent death [123]. Spills can also have lasting persistent impacts that affect productivity levels and predator-prey dynamics and damage habitats that support ecosystem function [125]. For example, the 1989 Exxon Valdez crude oil spill caused both massive acute mortality within days of the spill (e.g., an estimated 250,000 seabirds died within days of the event), and persistent ecosystem effects in the area that lasted for more than a decade [126]. Long-term effects included "(i) chronic persistence of oil, biological exposure, and population impacts to species closely associated with shallow sediments, (ii) delayed population impacts by sublethal doses (comprising health, growth and reproduction), (iii) indirect effects of trophic and interaction cascades, all of which transmit impacts well beyond the acute phase mortality" [126].

Diesel spills, although not persisting in the environment in the same manner as HFO and crude oil, can have severe acute toxic impacts and pose long-term contamination impacts of intertidal resources [123]. In shallow seas of remote areas of the Arctic, diesel fuel is transferred from one vessel to another by hoses (i.e., lightered), a potentially risky practice [56].

Extremely limited response capacity and response techniques that require specific environmental conditions (e.g., good weather, low winds or ice-free waters) render a spill in the Arctic nearly impossible to clean up. If a spill were to occur near Barrow, Alaska, the nearest major port (Dutch Harbor) is 1,300 miles away by boat, while the nearest permanent USCG station (Kodiak) is a 950-mile flight away. Once responders arrive at the remote spill site (possibly days to weeks later), cleanup attempts may be hindered by intense storms, high waves, fog, sea ice and overall volatile conditions [127].

A 2014 analysis of the U.S. Arctic Ocean concluded open-water mechanical recovery of spilled oil would not be possible roughly 80% of the time (and would be nearly impossible in sea ice). In-situ burning of spilled oil may be an effective technique in both icy and ice-free conditions, and dispersants can be effective in ice-free regions. However, the utility of these options is still limited due to challenges relating to weather, availability of needed response equipment and other factors [128].

### 5.1.2 Regulatory and mitigation measures

As noted above, environmental conditions often make it impossible to even attempt to recover spilled oil. Even when environmental conditions are favorable for cleanup, recovery rates of oil — and HFO in particular — are low [128]. As a result, this section will only briefly touch on response agreements and will instead focuses on spill prevention measures — measures that will help keep oil from ever reaching the water in the first place.

The 1990 International Convention on Oil Pollution Preparedness, Response and Cooperation and the 2013 Agreement on Cooperation of Marine Oil Pollution Preparedness and Response in the Arctic form the main incident response frameworks in the region. The 1990 convention requires that ships carry an oil pollution emergency plan on board, report pollution incidents to coastal authorities, have oil spill response equipment ready for disposal and hold oil spill response drills, among other things. It also requires other parties of the convention to provide assistance in a spill event [129, 130].


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The 2013 agreement, signed by all Arctic nations, outlines the responsibilities of each signatory nation, including mandatory notification of incidents to all signatory states, coordinated response operations (including areas outside a signatory's own jurisdiction), conducting joint spill exercises and other commitments [92].

The Polar Code introduces structural spill prevention requirements for ships operating in the Arctic. For example, in certain types of ships, oil fuel tanks, cargo tanks and holding tanks must be separated from the outer shell of the vessel by a distance of at least 0.76 meters. These provisions are designed to reduce the risk of an oil release in the event of grounding, impact with ice or a collision. The Polar Code requirements are an addition to global MARPOL regulations that require oil tankers have double hulls [131]. However, the Polar Code provisions only apply to ships designed for operation in at least thin first-year ice with old ice inclusions (Category B) or at least medium first-year ice with old ice inclusions (Category A). Most ships currently operating in polar waters are designed to operate in open water or in ice conditions that are less severe than those described for Category A and B vessels (Category C), and therefore would not be subject to this portion of the Polar Code [105].

Other IMO instruments are available to reduce the risk of oil spills in the Arctic. Routing measures can be established to concentrate vessel traffic in the most appropriate areas, or divert it from hazardous or ecologically valuable or vulnerable areas [132]. Shipping lanes can be designated in well-charted areas to keep vessels from traveling through areas that have not been charted to modern standards and may contain unknown hazards. ATBAs can be established in hazardous areas or in areas of special ecological or biological significance, reducing risk of an oil spill in these regions. In the Bering Strait region of the United States, the USCG is considering designation of a shipping lane and complementary ATBAs that protect areas important for subsistence and for specific Arctic species [77].

Some proposed mitigation measures focus specifically on HFO use because an HFO poses a greater threat than a spill of distillate fuel. The simplest way to mitigate the spill of HFO in the Arctic would be to phase out its use by vessels in the Arctic. The use and carriage of HFO has already been banned in the Antarctic (south of latitude 60° S) under an amendment to MARPOL Annex I, which came into effect in 2011. Norway has also banned HFO use within its own EEZ in specific sea areas off Svalbard. During the development of the Polar Code, and following the adoption of the ban on HFO in the Antarctic, consideration was given to restrictions on HFO in the Arctic. In the end, however, the Polar Code did not mandate restrictions; it only recommended that ships not use HFO in the Arctic.

Consideration of a ban on HFO use in Arctic waters was raised in IMO discussions again in 2016. At the end of 2016, both the United States and Canada declared their intention to develop a strategy to "phase down" the use of HFO. In April 2017, the United States and Canada, with co-sponsorship from Finland, Iceland, Norway, Germany and the Netherlands, submitted a proposal for a new output in the IMO MEPC work program to develop measures to reduce risks of use and carriage of HFO as fuel by ships in Arctic waters. This proposal will be considered at the 71st session of MEPC in July 2017.

A phase out of the use of HFO would require vessels to shift to marine distillates or possibly to liquefied natural gas (LNG) or even carbon-free fuel alternatives (e.g., biofuels, batteries). As mentioned above, in the event of a spill, marine distillate breaks down and disperses more quickly than HFO, posing less of a threat [118]. An LNG spill would dissipate almost immediately, and would have the least impact if a spill were to occur [133]. However, widespread use of LNG is not likely in the near future because it requires additional port infrastructure developments and because existing vessels cannot be easily retrofitted to use LNG [134]. In addition, gas extraction and LNG production come with their own environmental risks and impacts [135]. Nontraditional fuel alternatives being explored include biofuels and battery propulsion [136].

Although not directly intended to have an impact on HFO oil spill risk, a forthcoming cap on the percentage of sulfur in marine fuels will likely result in a shift away from HFO use by some vessels in the Arctic. The sulfur cap — which was adopted by IMO and will limit sulfur content in fuel to 0.5% or equivalent emissions — will come into effect in 2020 and is worldwide in scope.

Currently, most HFOs have higher sulfur content than would be allowed under the cap. As a result, implementation of the cap will force vessels that use HFO to transition to a lower sulfur fuel (such as distillate, LNG or low sulfur HFO/distillate blends) or install sulfur scrubbing technologies that reduce HFO emission levels so that they are equivalent to those generated with low sulfur fuel. At present, it is not clear how ship owners and operators will comply with the sulfur cap. Projections show that while some vessels may shift from HFO to distillates, HFO will likely continue to be used as a marine fuel by others, either with scrubbers or in fuel blends. As a result, absent a phase out of HFO, the threat of HFO spills in the Arctic will likely remain [137].

### 5.1.3 Recommendations to mitigate risks of oil spills

- Establish routing measures to decrease the likelihood of ship groundings and other incidents, and protect ecologically valuable or sensitive areas from oil spills.
- Amend MARPOL Annex 1 to phase out the use of HFO in the Arctic.
- Conduct a study on carriage of HFO and crude oil in the Arctic region to determine the amount of heavy and medium fuels carried as cargo in the region, and explore possible mitigation measures.
- Determine the possible long-term environmental, economic and pragmatic aspects of constructing and operating LNG-operated vessels, bearing in mind both environmental benefits and drawbacks.
- Develop a long-term shipping fuel/propulsion option for vessels operating in the Arctic that mitigates the risk of spills and reduces reliance on fossil fuels.

## 5.2 Vessel emissions

### 5.2.1 Overview

The vast majority of commercial vessels are powered by diesel engines that run on HFO, distillates or fuel blends. These engines generate combustion exhaust, releasing long- and short-lived pollutants into the atmosphere. Many of these pollutants contribute to global warming and negatively impact human and environmental health.

Carbon dioxide ($CO_2$) makes up the bulk of emissions from any diesel engine. Levels of $CO_2$ emissions vary somewhat depending on the hydrocarbon being burned. As a long-lived greenhouse gas, $CO_2$ becomes well-mixed in the atmosphere and causes global warming [138]. In 2012, global vessel traffic accounted for 2.2% of $CO_2$ emissions worldwide [19].

Diesel engines produce a variety of pollutants other than $CO_2$ . The high cylinder temperatures and pressures in modern diesels mean that if anything in the fuel can burn (oxidize), it will. Accordingly, diesel exhaust streams contain oxide forms of fuel and contaminants, most notably sulfur and nitrogen. Sulfur oxides ($SO_X$) are produced by diesels in direct proportion to the percentage of sulfur included in the fuel. Nitrogen oxides ($NO_X$) are produced during the combustion process itself, from the nitrogen in the air [119].

In addition to the gaseous pollutants, diesel engines also emit various types of particulate matter, depending on the fuel quality and combustion process. Particulate matter emissions can be attributed to incomplete combustion of fuels. The breakdown of the fuel can lead to carbon particles, sulphates and nitrate aerosols being produced. Fuels with higher sulfur content, such as HFO, result in higher particulate matter emissions because some of the fuel is converted to sulfate particulates in the exhaust [119].

In contrast to long-lived greenhouse gases like $CO_2$, $SO_x$, $NO_x$ and particulate matter are relatively short-lived and localized pollutants. Even so, they are extremely potent. Recently, there has been an increased focus on the effects of black carbon, a form of particulate matter, due to its significant climate-forcing impact [138]. After $CO_2$, black carbon is the second greatest contributor to human-induced climate warming [139]. While $CO_2$ persists longer, black carbon has hundreds to thousands of times greater warming potential than $CO_2$ [138]. Black carbon is the most effective form of particulate matter, by mass, at absorbing solar energy [140]. Black carbon is of particular concern in the Arctic because, when deposited on snow and ice surfaces, it reduces albedo and increases warming. The warming impact of black carbon is increased by at least a factor of three in the Arctic region [140].

Other pollutant emissions that cause adverse effects on local air quality, acidification or human health impacts — like $SO_x$ and $NO_x$ — can be targeted for reduction/mitigation efforts. Emissions of $SO_x$ and $NO_x$ cause acidification of soil and water [141]. $NO_x$ also contributes to the formation of ground-level ozone, which is detrimental to vegetation and human health [141]. In 2012, the World Health Organization classified diesel engine exhaust as carcinogenic to humans [142]. Airborne particles in $SO_x$, $NO_x$ and particulate matter emissions enter the lungs and can trigger inflammation that can lead to lung and heart failure [141]. In fact, the IMO's recent decision to implement reductions in vessel sulfur emissions in 2020 (instead of a later implementation date of 2025) is projected to prevent 200,000 premature deaths, mainly in developing country coastal communities [143].

The quantity of emissions from vessels varies greatly depending on the type of fuel used. Many large deep-sea shipping vessels, and a significant percentage of large coastal shipping vessels, burn HFO. As previously mentioned, the exact composition of HFO can vary and includes a wide range of contaminants, including ash, water, sulfur, vanadium, aluminum, silicon, sodium, sediment and asphaltenes. As these contaminants are burned in ships' engines, they will affect the composition of the combustion exhaust gases, producing "dirtier" exhaust [119].

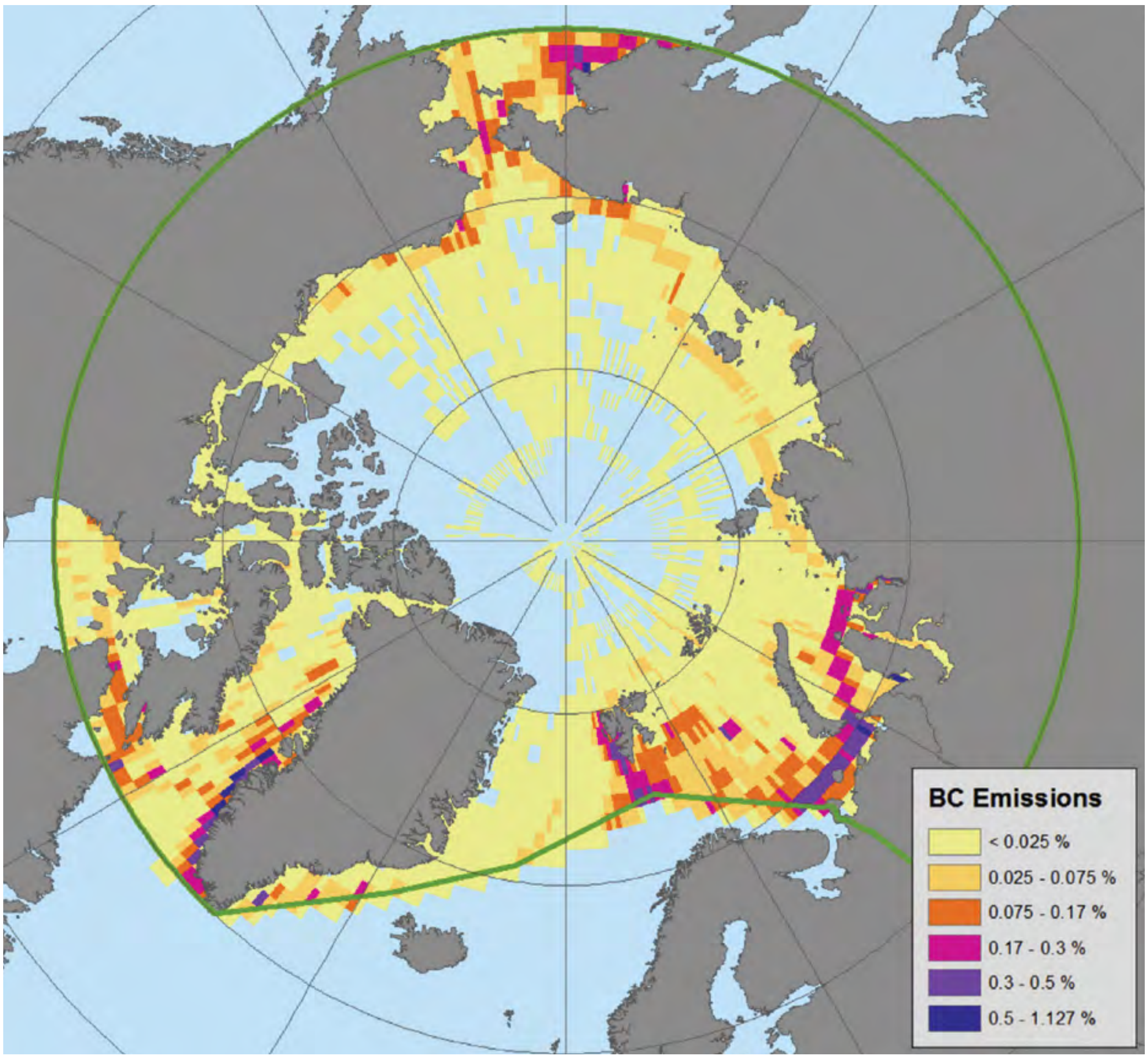
Most smaller vessels burn distillate fuels instead of HFO [118]. Distillate fuels used by shipping vessels can be divided into two categories: marine diesel oil (MDO) and marine gas oil (MGO). MDO is quite different from the type of diesel fuel used by cars and trucks. MDO may be more viscous and have more impurities including significantly higher levels of sulfur. In contrast, MGO is a more highly refined product, with lower viscosities and with various additives to improve the combustion processes [119].

Liquefied natural gas (LNG) is gaining popularity as a marine fuel. LNG drastically decreases emissions of $NO_x$, virtually eliminates emissions of $SO_x$ and particulate matter including black carbon, and can also reduce $CO_2$ emissions [133]. However, questions remain on its overall environmental impact and infrastructure requirements. In the long term, continued use of fossil fuels is seen by some as only a bridge technology to more environmentally friendly renewable sources [135].

Accurate inventories of emissions from vessels are necessary to quantify the environmental impacts of these emissions. Fuel type and amount used by vessels are key data needed to estimate emissions by vessels operating in the Arctic. Activity-based models integrating AIS data, vessel information from ship registers and other supporting data can project emission amounts from individual vessels. These models enable the development of emissions inventories and subsequent emission impact modeling, as well as projections of future vessel emissions [144].

Most Arctic vessel traffic emission inventory studies have used a broader definition of the Arctic than the Polar Code [24, 67, 145]. The main exception is the Mjelde et al. 2014 study, which applied the Polar Code definition of the Arctic to its inventory (see Figure 11). Among the other prominent studies, there is general agreement that vessel traffic emissions above 60° N accounted for about one third of total anthropogenic $SO_x$ and $NO_x$ in the region, and about 5% to10 % of total anthropogenic black carbon emissions [146, 147].

*Figure 11: Spatial distribution of 2012 black carbon emissions in the Polar Code defined Arctic. Values indicate the share of the total Arctic black carbon emissions per grid cell. From [144].*



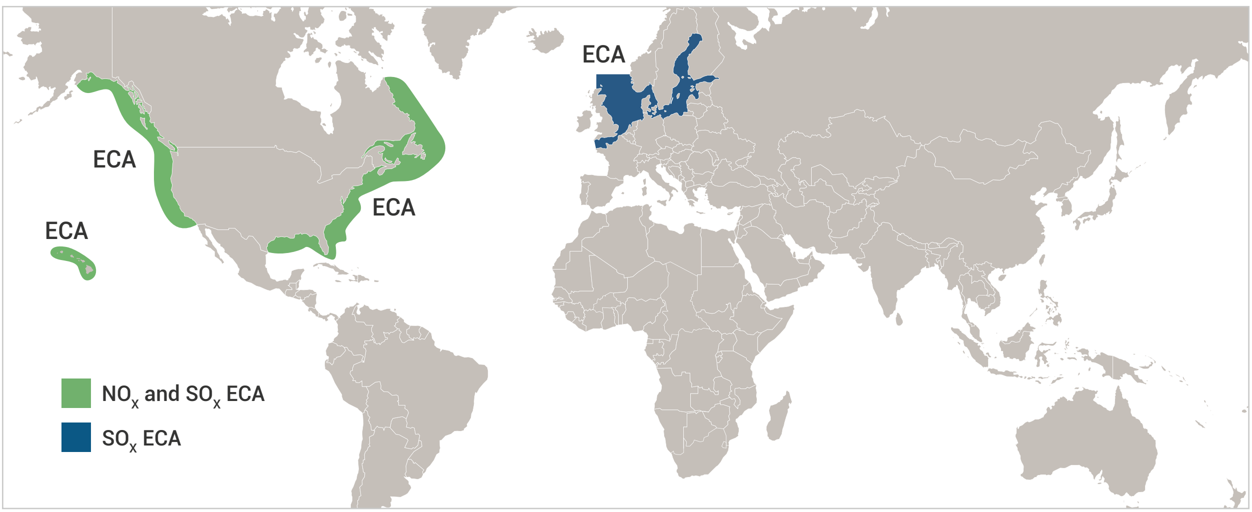

There is considerable seasonality to Arctic traffic and its associated emissions. In the peak months of August and September, traffic volumes and associated emissions are nearly 10 times the equivalent February numbers. In February, vessel traffic occurs mainly in the margins of the Arctic area [144].

### 5.2.2 Regulatory and mitigation measures

At a global level, the IMO has taken only modest steps to limit $NO_X$ emissions from vessels. IMO's limitations on $NO_X$ emissions apply to new ships only; existing ships are not subject to the emissions standards [148].

IMO has been more aggressive with respect to limits on $SO_X$ emissions, as shown in Table 5. By 2020, operators must either comply with .5% fuel sulfur content requirements or use exhaust treatments (e.g., scrubbers) to remove $SO_X$. Scrubbers have been installed on a number of vessels intended to be used within Emission Control Areas (ECAs), described in the following paragraph, to allow them to continue to use HFO.

*Figure 12: IMO ECAs. From [149].*




Nations have worked through the IMO to create — via "special area" designation — a series of ECAs that apply tighter controls on the emissions. The North American and U.S. Caribbean Sea ECAs limit both $SO_X$ and $NO_X$ emissions, while the Baltic and North Sea ECAs limit solely $SO_X$ at this time (Figure 12) [79]. However, ships built in 2021 or later will have to comply with $NO_X$ regulations in the North Sea and Baltic Sea [136].

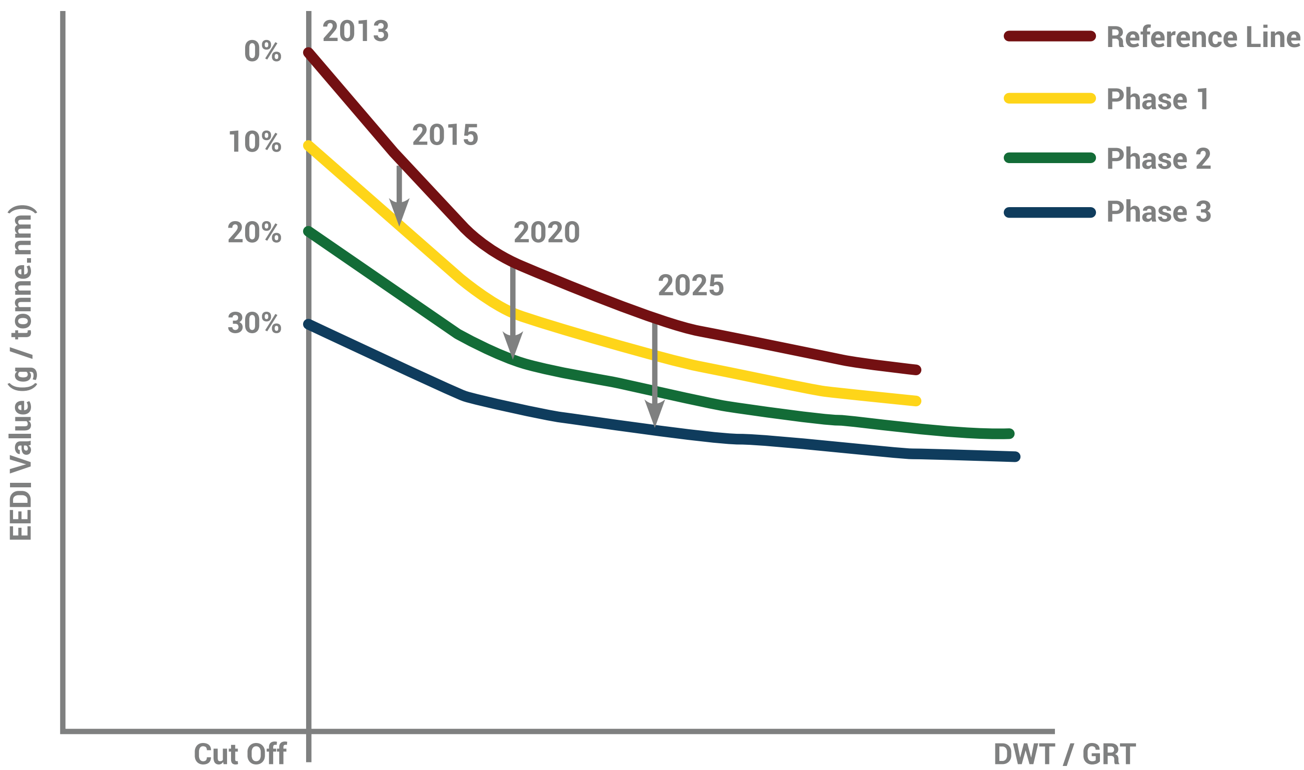
No part of the Arctic is currently included within an ECA, and the Polar Code contains no new provisions regarding air emissions. There are no IMO regulations for particulate or black carbon emissions, though the latter are currently under consideration under IMO's Marine Environmental Protection Committee (MEPC) and Pollution Prevention and Response Subcommittee (PPR) [150]. As sulfur reduction is a prerequisite for black carbon reduction, the forthcoming 0.5% global sulfur limit will reduce black carbon emissions globally. That said, the global sulfur limit is still well above the 0.1% sulfur limit established in ECAs. Moreover, even the strict sulfur limits required in ECAs are orders of magnitude greater than sulfur limits for automotive diesel fuels in North America.

*Table 5: Marine fuel permissible sulfur content, outside and inside ECAs, from [151].*

| Locations | Dates | Fuel Oil Maximum Sulfur Content |
|---|---|---|
| **Outside ECA-$SO_x$** | From 1 January 2012 | 3.50% |
| | From 1 January 2020 | 0.50% |
| **Inside ECA-$SO_x$** | From 1 January 2015 | 0.10% |

Looking beyond limits on $SO_x$ emissions, IMO has also taken measures to reduce overall greenhouse gas emissions from shipping through its Energy Efficiency Design Index (EEDI) [152]. EEDI starts with baseline (reference line) values for energy use by different ship types, based on historical information. Going forward there is a requirement to improve the efficiency of new ships by up to 30% by 2025, as shown in Figure 13 [153]. This is a performance requirement to be met by whatever means an owner/operator wishes to consider, some of which are discussed below.

*Figure 13: Progressive implementation of EEDI. From [119].*




Critics of the EEDI point out that it is easy for newly constructed ships to greatly surpass EEDI requirements, calling into question whether the standards are stringent enough to promote the acquisition of new technologies or drive efficiency improvements [154]. The IMO has also been criticized for moving slowly in adopting a comprehensive greenhouse gas reduction strategy that would contribute to the United Nations' Paris Agreement, which did not include greenhouse gas reductions from the shipping sector [155]. The 2016 approved roadmap for developing a comprehensive IMO strategy on reduction of greenhouse gas emissions from ships sets a goal for an initial IMO greenhouse gas reduction strategy to be adopted in 2018 [153].

Individual vessels can use a variety of techniques to reduce their emissions. By switching from HFO to distillates, LNG, or incorporating zero or low emission auxiliary propulsion (e.g., battery power), and/or by purifying heavy fuels to remove impurities, emissions can be greatly reduced. Increasing hull and propulsor efficiency, and slow steaming can be effective emissions reducing techniques as well (although vessels breaking ice may not be able to slow steam efficiently) [156]. Ships can improve exhaust quality by altering engine combustion technology or using exhaust stream treatments like scrubbers and filters [119]. Vessels can also increase engine efficiency or reduce emissions through various voyage planning considerations (e.g., taking the shortest possible route to a destination) [156].

These mitigation measures can be used individually or in combination. That said, not all measures are appropriate for all vessels or voyages, and some measures may have other environmental drawbacks. For example, scrubbers consume additional energy, causing additional fuel to be burned. If scrubbers are used in an open loop system, they generate potentially harmful discharges. LNG is very "clean" and has low carbon content per unit energy, but the process involved in extraction, liquefaction and transportation can in some cases result in higher $CO_2$ emissions than would be the case for distillate [69]. Diesel particulate filters (DPFs) can reduce black carbon emissions, but use of anything other than low ash fuels (i.e., extremely low sulfur distillates) will clog filters and preclude their use [152].

### 5.2.3 Recommendations to mitigate risks of vessel emissions

- Pursue establishment of an Arctic ECA to address the magnified warming impacts of black carbon in Arctic regions.
- Encourage the IMO to commit the shipping sector to expedited greenhouse gas reductions that align with the goals of the Paris Agreement.
- Amend MARPOL Annex 1 to phase out the use of HFO in the Arctic to mitigate its emissions impacts.
- Establish a long-term vision for fuels used by vessels operating in the Arctic and the usage of technical and operational measures that reduce harmful emissions.

## 5.3 Discharges (sewage and graywater)

### 5.3.1 Overview

Vessels may intentionally discharge garbage, sewage, graywater and other substances into marine environments. The Polar Code prohibits discharges of oil and oily mixtures, noxious liquid substances and harmful chemicals, and also establishes relatively stringent trash disposal regulations. Restrictions on sewage and graywater discharges, however, are more lenient and are the focus of this section (see Table 6 for definitions of sewage and graywater).

Vessels that produce sewage and graywater discharge those wastes — treated or untreated — into the sea or retain them and dispose of them onshore. Under MARPOL Annex IV, ships are allowed to discharge untreated sewage in areas at least 12nm offshore [78]. Discharge of untreated graywater is permitted anywhere, unless national rules apply.

*Table 6 - Definitions of sewage and graywater.*

| Discharge Type | Definition |
|---|---|
| **Sewage** | "Drainage and other wastes from any form of toilets, urinals, and WC scuppers; drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises; drainage from spaces containing living animals; or other waste waters when mixed with the drainages … above" [102]. |
| **Graywater** | "Drainage from dishwater, shower, laundry, bath and washbasin drains. It does not include drainage from toilets, urinals, hospitals, and animal spaces … and it does not include drainage from cargo spaces" [157]. |

The lack of graywater regulation is of concern given that graywater can be just as detrimental to the marine environment as raw sewage. Graywater may contain bacteria, metals, chemicals, pathogens, food waste and high concentrations of nutrients such as nitrogen and phosphorus. Fecal coliform concentrations in untreated vessel graywater have been found to be higher than untreated domestic wastewater [158].

Discharges of sewage and graywater can lead to oxygen depletion, spread pathogenic bacteria and viruses, and increase nutrient levels in the surrounding ecosystem, possibly leading to toxic algal blooms and eutrophication that can cause harmful disturbances throughout food chains [158, 159]. The increase of nutrients is of particular concern in cold Arctic marine ecosystems where cold water inhibits decomposition of nutrients [160]. People consuming marine resources can contract a range of illnesses from contaminated waters, which is of particular concern considering the number of indigenous peoples whose diet heavily relies on marine resources [161].

Passenger vessels in particular discharge significant volumes of sewage and graywater. The 2008 U.S. EPA Cruise Ship Discharge Assessment Report found average reported sewage discharge rates to be 8.4 gallons/day/person, while graywater discharges total anywhere from 45 gallons per day per person to 65 gallons per day per person [162]. At present, there are relatively few passenger vessels operating in the Polar Code region, although some areas like Svalbard see a heavier concentration of tourist vessels. But Arctic marine tourism is projected to grow significantly, and discharge from these types of vessels is likely to become more of an issue [7]. Local communities are particularly concerned about discharge from cruise ships and similar passenger vessels [163].

### 5.3.2 Regulatory and mitigation measures

To discharge sewage within 3nm of land, MARPOL requires vessels over 400 GT and passenger vessels certified to carry more than 15 people use an IMO-approved sewage treatment plant that meets thermotolerant coliform, total suspended solids (TSS), biochemical oxygen demand (BOD) and pH standards [157]. Ships discharging sewage from 3nm to12nm miles from land must either meet the standards used within 3nm or at least comminute and disinfect their sewage. To discharge untreated sewage, vessels must be at least 12nm from shore, and must be moving at a speed of no less than 4 knots [78]. The Polar Code applies the MARPOL distance requirements to the ice shelf, fast ice or areas of ice concentration exceeding 1/10. For example, to discharge untreated sewage, vessels not only must be at least 12nm from shore, they also must be at least 12nm away from the ice shelf, fast ice or areas of ice concentration exceeding 1/10 [105].

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In addition to general treatment and discharge standards, MARPOL Annex IV requires ports and terminals to have sewage reception facilities and establishes standards for those port reception facilities [78]. However, the cost of building compliant facilities and limitations on the ability to process wastes makes compliance with this standard difficult in remote areas of the Arctic [103].

MARPOL sewage requirements have received criticism for not specifying limits on chemical, metal and other pollutants — even though such limits are commonly required for many land-based sources of sewage. Critics also contend that treatment standards are antiquated and do not reflect the capabilities of more modern sewage treatment technologies [164]. In addition, sampling, monitoring and recordkeeping practices are also not required, leaving a major loophole in the Annex.

In addition to the standard Annex IV requirements, MARPOL provides for designation of "special areas" where more stringent discharge protections are warranted [79]. At present, IMO has approved just one Annex IV special area, located in the Baltic Sea. The special area will take effect between 2019 and 2023, depending on ship age and route travelled [165]. It will require vessels to either dispose of their sewage at a port reception facility or treat sewage to meet certain standards for phosphorus and nitrogen before it is discharged.

Some nations have established sewage standards that are more stringent than the IMO standards, and/or established graywater treatment standards. In the United States, states can petition to have no sewage discharge zones within state (3nm) waters [166]. In the state of Alaska, large cruise ships must use an advanced wastewater treatment system to treat both graywater and sewage before discharging in state waters [167].

Compliance with discharge limitations is a significant concern. A 2008 EPA study concluded that the vast majority of U.S.-approved Type II sewage treatment plants on passenger vessels did not meet sewage treatment standards [168]. Similarly, a 2012 paper submitted to the IMO reported that the vast majority of vessel sewage treatment plants did not meet IMO standards. Reasons for noncompliance vary from improper maintenance to operational error [157]. Intentional noncompliance is also a problem. Recently, the Caribbean Princess cruise ship was fined for illegally dumping contaminated waste and oil from its ship into the Caribbean Sea for eight years, demonstrating the importance of effective enforcement [169].

## State Regulations Governing Discharge of Graywater and Sewage off the Coast of Alaska

### Cruise Ships

Alaska law prohibits the discharge of any treated sewage, graywater or other wastewater from a passenger vessel capable of carrying 250 passengers or more into Alaskan marine waters unless the vessel operates under a permit from the state [167]. To comply with the permit, large commercial passenger vessels must use advanced wastewater treatment systems that treat both sewage and graywater. Advanced wastewater treatment systems "provide improved screening, biological treatment, solids separation (using filtration or flotation), and disinfection (using ultraviolet light)" as compared to traditional marine sanitation devices (MSDs) designed to meet less stringent national standards [168]. The permit requires cruise ships to maintain discharge logs and submit them monthly. Vessels are also required to host an "ocean ranger" who monitors and records "information related to the engineering, sanitation, and health related operations of the vessel" [167]. As of 2014, nearly half of the roughly 30 large commercial passenger vessels operating in Alaskan waters obtained a general permit to discharge into state waters [167].

### 5.3.3 Recommendations to mitigate risks of vessel discharges

- Use future revisions to the Polar Code or other regulatory mechanisms to require the same treatment standards for graywater as those that exist for sewage in the Polar Code region, at a minimum.
- Determine the costs, benefits and means of implementing more stringent requirements for sewage (and graywater) treatment in Arctic waters (e.g., like those seen in Alaska) for passenger vessels traveling in the Polar Code Arctic.
- Pursue creation of sewage and/or graywater no-discharge zones in relevant Arctic waters.
- Support the build-out of proper port reception facilities for wastewater in Arctic ports located in areas where waste management is feasible.
- Modify MARPOL Annex IV or explore another mechanisms to require sampling, monitoring and record-keeping of sewage (and graywater) discharges in Arctic waters.

## 5.4 Invasive species

Invasive species are "animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species" [170]. Invasive species prey on and/or compete with native species, resulting in alterations of habitats, biodiversity, food webs and ecological stability [171].

Shipping is a significant vector in the spread of aquatic invasive species. Most aquatic invasive species are introduced as a result of shipping via ballast water and hull fouling [171]. Aquatic invasive species can result in serious ecological, economic and health-related effects. They have led to incidents as diverse as the collapse of commercially important fisheries to cholera outbreaks affecting human populations [171–173].

Some areas of the marine Arctic — particularly areas in the North Atlantic not within the Polar Code region — have already experienced notable non-native species invasions. Most parts of the Arctic, however, remain relatively undisturbed [174]. But increasing surface water temperature and changing salinity levels will reduce the environmental barriers currently limiting the establishment of more temperate species [3, 175]. These factors, in combination with the potential increase of ballast water discharges and transport of organisms via hull fouling as shipping increases in the region, will increase the risk of nonindigenous invasive species introductions. As a result, in the future, invasive species could threaten the ecological and economic viability of the region [1, 176].

One study determined that by 2050, "the Arctic is expected to have the largest species turnover with regard to invading and locally extinct species, with a modeled invasion intensity of five times the global average" [177]. Another study, focused on Svalbard, concluded that while the current risk of invasion in Svalbard is low, by the second half of twenty-first century, the island will be more vulnerable to invasion as a result of climate change and increased vessel traffic [176].

Invasion threats will be greatest where Arctic shipping routes join regions of similar temperature aquatic environments [175]. The Northern Sea Route connecting the north Pacific with the North Atlantic is a prime example. Many Arctic communities fear invasive species may impact access to subsistence resources [174]. Prevention of invasion is the most effective and most cost-effective strategy; eradication and control measures are more costly and less effective [178].

The Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) working group, in cooperation with the Protection of the Arctic Marine Environment (PAME) working group, recently began to address the risk of invasive species in the Arctic region. The working groups are creating an action plan to develop and implement "common measures for early detection and reporting, identifying and blocking pathways of introduction, and sharing best practices and techniques of monitoring, eradication and control [179]." This initiative addresses all Arctic invasive pathways, not just vessel traffic vectors.

As noted above, the two key vectors for introduction of invasive species are ballast water and hull fouling. The following subsections explain these mechanisms in more detail, and describe current regulatory prevention measures to prevent non-native species invasion, as well as regulatory gaps and limitations.

### 5.4.1 Ballast water overview

Large vessels lacking a full load of cargo take in ballast water to maintain displacement and stability, and subsequently discharge that ballast water in a different location when adding cargo. Ballast water and sediment discharge is one of the most prevalent sources of nonindigenous species and can harbor harmful pathogens [173]. Species taken into ballast tanks and later discharged in other locations have the possibility of establishing invasive populations in non-native bodies of water and causing significant economic and ecological damage [180].

### 5.4.2 Ballast water regulatory and mitigation measures

In 2004, the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Management Convention). The Ballast Water Management Convention strives "to prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources which arise from the transfer of harmful aquatic organisms and pathogens via ships' ballast waters and related sediments" [181]. The Ballast Water Management Convention, which will enter into force September 8, 2017, requires that ships implement a ballast water and sediments management plan, carry a ballast water record book and an international ballast water management certificate, and carry out ballast water management to an agreed ship-specific standard [181].

The Ballast Water Management Convention also requires most vessels to install an IMO-approved ballast water management system that treats ballast water to meet concentration-based viable organism limits and human pathogen limits. The IMO has a proposed timeline (awaiting approval at the MEPC meeting in July of 2017) by which vessels must install a compliant system and meet treatment standards. In the meantime, the Ballast Water Management Convention requires ships exchange their ballast. Once the Ballast Water Management Convention is in effect, flag states will enforce installation of type-approved systems, while port states can monitor, inspect and enforce performance. This will require port states to enact relevant regulations and develop monitoring and enforcement programs [181].

The Ballast Water Management Convention's ballast water treatment standards have come into question as they do not necessarily reduce levels of viruses, bacteria and small protists to safe concentrations [182]. Moreover, not all ballast water treatment systems are equally effective, and vessel owners may elect to install cheaper, lower-performing systems upon ratification of the Ballast Water Management Convention [182]. There has also been concern that not all approved ballast treatment systems will function properly in Arctic environments, i.e., in cold temperatures [182]. The Polar Code suggests that type-approval certification take into account the effectiveness of water treatment systems in colder waters, and the 2016 revised IMO ballast water management system testing guidelines suggest this will be the case [183].

Certain regions of the Arctic may be able to adopt more stringent ballast water standards for ships subject to their jurisdiction. For example, in the United States, the state of California established (and is soon to implement) limits on total bacteria and virus concentrations that do not exist in U.S. or IMO standards [182].

### 5.4.3 Recommendations to mitigate risks of ballast water

- Enhance national and collaborative scientific monitoring and assessments of ballast-related invasion risks.

- Develop an Arctic-specific regional plan to assess and address the risk of ballast water as a vector for species invasion (either through current Arctic Council work or other means) and considers the possible need for more stringent treatment and/or enforcement standards.

### 5.4.4 Hull fouling overview

Hull fouling, also known as biofouling, occurs when organisms adhere to ships' hulls, or hull appendages. These organisms can be transported to non-native regions and pose a risk of invasion [184]. Recent studies reveal biofouling may be an even more significant invasive species vector than ballast water [185]. While ballast water can be treated to reduce risk of a species invasion, it is difficult to completely prevent organisms from attaching to the hull, and once attached, it is extremely difficult to remove or kill the organisms in a pragmatic fashion [182].

The greatest risk of introduced species via biofouling is generally considered to come from vessels that are heavily fouled. A variety of factors govern the extent of hull fouling on a ship, including: effectiveness of the ship's antifouling coating, age of the coating, location of hull fouling, ship speed, length of time since the hull's last cleaning and amount of time spent at source ports. Slow-moving vessels that have long stopovers in port likely pose the highest risks [186]. In Arctic waters, the scouring effect of vessels transiting ice-covered waters may hasten removal of antifouling coating, fouling mechanisms and organisms themselves [182].

The best way to manage hull fouling is to prevent it from happening in the first place with an effective antifouling coating [182]. Antifouling coatings impede organism attachment to the hulls of vessels, decreasing invasion risk and reducing drag that compromises energy efficiency. Biocidal tributyltin (TBT) based antifouling paints proved an effective antifouling agent, but their use was banned in 2008 after studies showed TBT and other organotins easily leach from hulls, are extremely toxic to a range of marine organisms and accumulate in the food chain. There are doubts as to whether alternative antifouling agents are as effective as TBT [182].

If antifouling coatings do not prevent all organisms from adhering to a ship's hull, those organisms must be physically removed. However, in-water removal may result in bio-invasion. Dry-dock removal is preferred from an ecological standpoint, but is much more costly [182].

### 5.4.5 Hull fouling regulatory and mitigation measures

To address the threat of invasion from hull fouling, in 2011 the IMO approved the guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines). These voluntary guidelines recommend installation and maintenance of an antifouling coating and development of a plan to manage hull fouling; they also provide suggestions with respect to inspection, cleaning and record keeping [187]. While IMO regulations are voluntary, some nations have created mandatory antifouling regulation in their own waters. For example, beginning May 15, 2018, all vessels that will anchor, berth or be brought ashore in New Zealand after a voyage outside of New Zealand waters must comply with specific "clean hull" regulations [188].

In Arctic waters, ships will need antifouling coatings that can withstand abrasion from ice and remain effective in cold water. The Polar Code recommends ships follow the IMO's Biofouling Guidelines, and specifically recommends consideration of measures "to minimize the risk of more rapid degradation of antifouling coatings associated with polar ice conditions" [105]. An assessment of the effectiveness of the most appropriate antifouling coatings for Arctic operations would be timely as the Polar Code begins to take effect.

### 5.4.6 Recommendations to mitigate risks of hull fouling organisms

- Develop an Arctic-specific regional plan to assess and address hull fouling risk and mitigation measures (either through current Arctic Council work or other means) with consideration of possible mandatory regulations for Arctic ports, or more stringent hull-cleaning requirements.
- Conduct a scientific review of available antifouling agents and rate their effectiveness in an Arctic context.
- Enhance national and collaborative scientific monitoring and assessments of hull fouling invasion risks.

## 5.5 Noise and ship strikes, with focus on marine mammals

### 5.5.1 Overview

Some species of the Arctic marine ecosystem, particularly marine mammals, can be adversely impacted by vessel traffic-related ship strikes and noise. In most marine areas, low frequency noise from propellers and engines of commercial vessels is the dominant source of anthropogenic noise [189]. Until recently, the underwater environment of the Arctic remained relatively free of anthropogenic noise. However, underwater noise caused by vessel traffic, military use of sonar, seismic exploration and resource extraction is becoming more prevalent in the region [190]. Icebreakers in particular produce louder and more variable sounds than other vessels [7].

Since cetaceans and pinnipeds use sound for communication, echolocation, and predator avoidance, anthropogenic noise can disturb marine mammals in a variety of ways, including: "(a) disruption of behavior (e.g., feeding, breeding, resting, migration), (b) masking of important sounds, (c) temporary or permanent hearing loss, (d) physiological stress or physical injury, and (e) changes to the ecosystems that result in a reduction of prey availability" [190]. Noise increases can lead to habitat displacement, behavioral changes and alterations in the intensity, frequency and intervals of calls. A 2012 study indicated exposure to low-frequency noise may be associated with chronic stress in whales [189]. However, whether these responses result in significant consequences for individuals or populations is not well understood [189].

Noise masking may hinder marine mammals' ability to detect approaching vessels, possibly increasing the risk of ship strikes. Vessel strikes can cause serious injury or death to marine mammals involved in such incidents [191]. Records show all large whales are vulnerable to ship strikes, and Arctic species like bowhead and Pacific right whales are potentially most vulnerable to ship strikes [192, 7].

In the Arctic, marine mammals and ships often must share the same water. Many portions of the Northern Sea Route and Northwest Passage include narrow passages. In periods of ice cover, both mammals and ships use the same leads and polynyas as preferred routes [69]. Similarly, marine mammals traveling through the relatively narrow 53 mile-wide Bering Strait may be particularly vulnerable to increasing vessel traffic, because fall migration of key whale species overlaps with periods of higher vessel traffic in a topographic bottleneck [8].

Many Arctic indigenous peoples hunt marine mammals (e.g., bowhead whales, seals and walruses). Hunting is both an important source of food for the community and an important component of their culture. Indigenous hunters have expressed concern about the possible impacts of increasing vessel traffic on subsistence hunting practices. While marine mammal mortality from ship strikes is a concern, so too is the possibility of a small, open hunting skiff being struck by a transiting vessel [193]. In addition, subsistence hunters worry that sound from transiting vessels may displace the marine mammals they depend on [8, 194]. For example, researchers in Canada observed belugas that avoided ice-breaking vessels and altered their behavior for several days [195].

### 5.5.2 Ship strike regulatory and mitigation measures

At this time, the only effective ways to reduce ship strikes on marine mammals are to avoid areas with known concentrations, or to reduce speed if transit must occur in these areas. Identification of areas of high risk requires a detailed understanding of both marine mammal and vessel distribution. Once high-risk areas are identified, routing measures or speed restrictions may be effective mitigation measures [196].

Routing measures, such as permanent or seasonal traffic separation schemes or ATBAs have proven somewhat effective in mitigating vessel strikes. These measures can be adopted by the IMO, or by national regulation if within a territorial sea. For example, in 2007, the IMO adopted a voluntary seasonal ATBA (effective from 1 June through 31 December) in the Roseway Basin region on the Scotian Shelf of the Northwest Atlantic to protect endangered North Atlantic right whales from ship strikes. A 2009 study showed high rates of vessel compliance with the closure and concluded that implementation of the ATBA lead to an "82% reduction in the risk of lethal vessel strikes to right whales due to vessel-operator compliance" [197]. The study also concluded that high compliance was achieved because the ATBA was adopted by the IMO.

Dynamic Management Areas (DMAs) may be enacted in regions where collision risk is high. DMAs are used to protect North Atlantic right whale populations off the eastern coast of the United States. A mandatory ship reporting system, operated by the USCG and the National Oceanic and Atmospheric Administration (NOAA) Fisheries, requires ships greater than 300 GT that enter right whale habitats to report to a shore-based station. In return, the ships are sent a message that includes information on right whales, their vulnerability to ship strikes, precautionary measures to avoid hitting a whale and the latest data on the location of right whales [198]. When whale aggregations are sighted in known high-risk areas, mariners are requested to either avoid that particular region or slow down [199]. DMAs require close to real-time reporting systems, which may make a similar measure in the Arctic difficult to implement at this time. However, with further development of real-time monitoring and communications networks in the region, this may be a more widely accepted mitigation measure in the future.

Vessel speed limits are also used to decrease incidents of ship strike related mortality. Speed plays an important role in whether a marine mammal will survive an encounter with a vessel. A 2007 study demonstrated that marine mammal mortality increased from 21% when vessels traveled at 8.6 knots to 79% when vessels traveled at 15 knots. The probability of mortality decreased to below 50% when vessels traveling at higher rates of speed slowed down to 11.8 knots [200].

In November 2008, NOAA adopted a regulation requiring all vessels 65 feet (19.8 m) and greater in length to travel at 10 knots or less in endangered right whale-designated critical habitat areas in U.S. waters on a seasonal basis. Despite extensive outreach efforts to inform mariners of the speed restrictions, a five-year study found first-year compliance with 10-knot speed restrictions in these seasonal management areas was low: less than 5% of vessel trips consistently remained below 10 knots. Compliance rose to nearly 25% over the five-year study, with those not in full compliance at least maintaining speeds of 10 knots or less for longer periods of time within the area. Citations and fines proved to be the most effective mechanism to improve compliance [201].

# The Polar Code on Mitigation of Vessel-related Marine Mammal Impacts

The Polar Code states vessels must "[t]ake into account the potential hazards of the intended voyage" including "current information and measures to be taken when marine mammals are encountered relating to known areas with densities of marine mammals, including seasonal migration areas; current information on relevant ships' routing systems, speed recommendations and vessel traffic services relating to known areas with densities of marine mammals, including seasonal migration areas." The Code also specifies that, "in the event that marine mammals are encountered, any existing best practices should be considered to minimize unnecessary disturbance" [105]. It is not yet clear how mariners traveling in the Arctic will access data or necessary resources to comply with these requirements.

### 5.5.3 Noise regulatory and mitigation measures

A variety of ship design, ship maintenance, policy solutions and economic incentives can decrease underwater noise and its adverse impacts. For example, vessels can maintain polished, clean hulls and propellers, insulate engines and use resilient mountings on machinery, modify propellers to reduce cavitation, or simply slow down to operate below cavitation inception speed to reduce noise [202]. Using these techniques to quiet a vessel can be extremely effective at reducing underwater vessel noise. A 2014 study found that quieting the loudest 10% of ships would decrease a large proportion of noise admitted by all ships [203]. Although quieting existing vessels can be expensive, economies of scale may ultimately bring the costs down. Building new vessels with quieter propeller and hull shapes is much less expensive than retrofitting existing ships [204].

It is also possible to incentivize the use of quieting technologies. As of 2017, the port of Vancouver awards vessels that reduce underwater noise with up to a 47% discount to the harbor rates. This is the first real economic driver to reduce underwater noise from vessels [205].

Routing measures and closures may also be helpful in the context of noise disturbance. Incorporating noise impacts into spatial planning may improve ecological integrity and species resilience in certain regions [206]. Theories vary on how best to apply routing measures to decrease impacts. While many risk management plans identify sites where marine mammal habitat is affected by anthropogenic noise and should therefore be mitigated, some researchers have proposed that designation and spatial protection of key marine mammal habitats that are currently quiet may prove more effective than attempting to quiet noisy habitats [206].

A voluntary IMO policy has been created to address the threats noise poses to marine mammals. In 2014, the IMO adopted the voluntary Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life. The guidelines "recognize that shipping noise can have short-term and long-term impacts on marine life; call for measurement of shipping noise according to objective ISO standards; identify computational models for determining effective quieting measures; provide guidance for designing quieter ships and for reducing noise from existing ships … and advise owners and operators on how to minimize noise through ship operations and maintenance …" [207].

Several countries also have noise impact-related national regulations and strategies. The Marine Strategy Framework Directive is a European initiative that considers a multitude of anthropogenic "stressors" and their potential cumulative effects. It specifies that levels of underwater noise must not adversely affect the marine environment [208]. In the United States, a number of laws protect marine mammals, including the Endangered Species Act, the National Marine Sanctuaries Act and the Marine Mammal Protection Act, which specifically protects marine mammals from anthropogenic noise. Entities wishing to conduct a noise- producing activity, such as oil and gas or research studies, must meet requirements designed to prevent undue impacts on the species [204]. More recently, NOAA developed an Ocean Noise Strategy Roadmap that identified strategies for addressing and mitigating the impacts of underwater noise [209].

### 5.5.4 Recommendations to mitigate risks of ships strikes and noise on marine mammals

- Work with indigenous communities and the scientific community to identify and map key habitat areas — including migratory areas, calving areas and regions of high marine mammal concentrations — that could be particularly affected by marine noise or transiting vessels. Ensure the information generated by this effort is readily available to ship owners and operators for marine mammal avoidance purposes.
- Ensure noise assessments address not only vessel traffic noise, but the cumulative effect of all noise impacts, including seismic surveys and other relevant noise sources.
- Encourage the Arctic Council (e.g., through the proposed Best Practices Forum) or other entities to develop a mechanism for compiling and distributing information to mariners regarding high concentrations of marine mammals to assist in compliance of Polar Code marine mammal regulations. This information should include both historic data and — whenever possible — real-time data.
- Implement speed limits and/or routing measures — such as traffic lanes or ATBAs — to decrease the probability of vessel strikes and to reduce noise in high-risk areas. These measures might be seasonal in nature depending on the habits of marine mammals. Compliance must be monitored and enforced.
- Ensure subsistence hunters and local communities have the ability to communicate with vessels in the region.
- Investigate the possibility of requiring vessels that intend to operate in polar waters — particularly new builds — to meet stringent ship-quieting standards.
- Determine how economic incentives — such as port fees and other measures — might be used to promote ship-quieting technologies in Arctic waters.



# 6 Recommendations

*As the Arctic experiences profound environmental changes, including a rapid decline in sea ice extent, thickness and duration, the region will also see an increase of vessel traffic and industrial activity. Vessel traffic in remote and challenging Arctic waters poses substantial safety and environmental risks, including possible impacts on the cultural practices and food security of Arctic indigenous peoples.*

*The maritime community has already made significant strides toward addressing some of these challenges. For example, the IMO's Polar Code — which entered into effect in January 2017 — establishes a suite of new standards and practices designed to increase safety and environmental protection in high-latitude seas, including the Arctic Ocean. However, substantial gaps remain. This section summarizes recommendations from previous portions of the report and suggests overarching measures that could provide additional risk mitigation and environmental protection to address potential adverse impacts of vessel traffic in Arctic waters.*

## 6.1 Pursue recommendations to mitigate the specific environmental risks posed by Arctic vessel traffic

Not all threats to the Arctic marine environment posed by vessel traffic are addressed by existing regulatory and non-regulatory governance mechanisms. Implementing the following recommendations (identified throughout section 5 and summarized in Table 7) will better protect the integrity of the Arctic marine ecosystem, including those who rely on it for subsistence needs.

As shown in Table 7, some mitigation measures can address multiple threats. For example, switching from HFO use to distillates or LNG will reduce both the adverse effects of oil spills and harmful sulfur and black carbon emissions. Spatial protection measures like ATBAs can protect key areas from oil spills and other discharges, protect marine mammals from ship strikes and enhance mariner safety.

Some Arctic waters may merit application of multiple types of specific protective measures. In such circumstances, PSSA designation may be warranted. Routing measures and associated vessel traffic monitoring requirements, as well as fuel use and carriage restrictions and emissions controls, can be integrated as associated protective measures in a PSSA. A 2013 analysis of possible Arctic PSSA designation concluded a core sea ice area in the central Arctic Ocean, with ATBAs to prevent vessels transiting this core, would likely be an effective and feasible measure for protecting the central Arctic Ocean ecosystem [71]. Because there is relatively little vessel traffic in the central Arctic Ocean at present, designation of a PSSA in that region would be a proactive measure. Further research into the viability of one or more Arctic PSSAs to address multiple stressors should be conducted as stakeholders address the specific environmental threats listed in Table 7.

*Table 7 - Summary of recommendations presented in section 5 to reduce specific environmental threats posed by Arctic vessel traffic.*

<table>
<tr><th>Environmental Threat</th><th>Recommendations</th></tr>
<tr><td rowspan="5">Oil spills</td><td>Establish routing measures to decrease the likelihood of ship groundings and other incidents and protect ecologically valuable or sensitive areas from oil spills.</td></tr>
<tr><td>Amend MARPOL Annex 1 to phase out the use of HFO in the Arctic.</td></tr>
<tr><td>Conduct a study on carriage of HFO and crude oil in the Arctic region to determine the amount of heavy and medium fuels carried as cargo in the region and explore possible mitigation measures.</td></tr>
<tr><td>Determine the possible long-term environmental, economic and pragmatic aspects of constructing and operating LNG-operated vessels, bearing in mind both environmental benefits and drawbacks.</td></tr>
<tr><td>Develop a long-term shipping fuel/propulsion option for vessels operating in the Arctic that mitigates the risk of spills and reduces reliance on fossil fuels.</td></tr>
<tr><td rowspan="4">Emissions</td><td>Pursue establishment of an Arctic ECA to address the magnified warming impacts of black carbon in Arctic regions.</td></tr>
<tr><td>Encourage the IMO to commit the shipping sector to expedited greenhouse gas reductions that align with the goals of the Paris Agreement.</td></tr>
<tr><td>Amend MARPOL Annex 1 to phase out the use of HFO in the Arctic to mitigate its emissions impacts.</td></tr>
<tr><td>Establish a long-term vision for fuels used by vessels operating in the Arctic, and the usage of technical and operational measures that reduce harmful emissions.</td></tr>
<tr><td rowspan="5">Discharges</td><td>Use future revisions to the Polar Code or other regulatory mechanisms to require the same treatment standards for graywater as those that exist for sewage in the Polar Code region, at a minimum.</td></tr>
<tr><td>Determine the costs, benefits and means of implementing more stringent requirements for sewage (and graywater) treatment in Arctic waters (e.g., like those seen in Alaska) for passenger vessels traveling in the Polar Code Arctic.</td></tr>
<tr><td>Pursue creation of sewage and/or graywater no-discharge zones in relevant Arctic waters.</td></tr>
<tr><td>Support the build-out of proper port reception facilities for wastewater in Arctic ports located in areas where waste management is feasible.</td></tr>
<tr><td>Modify MARPOL Annex IV or explore another mechanisms to require sampling, monitoring and record-keeping of sewage (and graywater) discharges in Arctic waters.</td></tr>
</table>

| Environmental Threat | Recommendations |
| --- | --- |
| **Invasive Species** | Enhance national and collaborative **scientific monitoring and assessments of ballast water and hull fouling invasion risks.**<br><br>Develop an **Arctic-specific regional plan to address and assess the risk of ballast water as a vector for species invasion** (either through current Arctic Council work or other means) and considers the possible need for more stringent treatment and/or enforcement standards.<br><br>Develop an **Arctic-specific regional plan to assess and address hull fouling risk and mitigation measures** (either through current Arctic Council work or other means) with consideration of possible mandatory regulations for Arctic ports, or more stringent hull-cleaning requirements.<br><br>Conduct a **scientific review of available antifouling agents** and rate their effectiveness in an Arctic context. |
| **Ship Strikes and Noise** | Work with indigenous communities and the scientific community to **identify and map key habitat areas** — including migratory areas, calving areas and regions of high marine mammal concentrations — that could be **particularly affected by marine noise or transiting vessels**. Ensure the information generated by this effort is readily available to ship owners and operators.<br><br>Ensure **noise assessments address not only vessel traffic noise, but the cumulative effect of all noise impacts**, including seismic surveys and other relevant noise sources.<br><br>Encourage the Arctic Council (e.g., through the proposed Best Practices Forum) or other entities to develop a **mechanism for compiling and distributing information to mariners regarding high concentrations of marine mammals** to assist in compliance of Polar Code marine mammal regulations. This information should include both historic data and — whenever possible — real-time data.<br><br>Implement **speed limits and/or routing measures** — such as traffic lanes or ATBAs — to decrease the probability of vessel strikes and to reduce noise in high-risk areas. These measures might be seasonal in nature depending on the habits of marine mammals. Compliance must be monitored and enforced.<br><br>Ensure subsistence hunters and **local communities have the ability to communicate with vessels** in the region.<br><br>Investigate the possibility of requiring vessels that intend to operate in polar waters — particularly new builds — to meet **stringent ship-quieting standards**.<br><br>Determine how **economic incentives** — such as port fees and other measures — might be used **to promote ship-quieting technologies** in Arctic waters. |

## 6.2 Leverage broader governance mechanisms to reduce risk and strengthen environmental protections

The Polar Code is unquestionably a major step in the attempt to strengthen governance of Arctic vessel traffic. However, it is not a silver bullet: it does not and cannot directly target all the safety and environmental challenges related to Arctic vessel traffic, does not apply to all vessels that operate in the Arctic (e.g., its safety provisions do not apply to non-SOLAS vessels) and does not fully address broader concerns about lack of infrastructure and information in the region. There are also challenges with respect to the interpretation and enforcement of the Polar Code.

There are many opportunities to fill gaps and strengthen measures designed to minimize the impacts of vessel traffic in the Arctic. For example, IMO processes could be used to develop Polar Code provisions tailored to non-SOLAS vessels. Continued international collaboration at both the IMO and Arctic Council provides opportunities to create or inform a variety of policy solutions that are international in scope. And the maritime industry itself can work collaboratively with other stakeholders to develop and implement additional safety and environmental protection measures. The cruise industry, for example, could build on existing efforts to establish best practices for tour vessels sailing in the Arctic. All these avenues — and more — offer opportunities to address possible safety and/or environmental concerns and enhance and harmonize governance of Arctic vessel traffic.

## 6.3 Include Arctic communities in decision-making processes

It is critical to include Arctic communities — particularly indigenous communities — as full participants in decision-making processes. Local and traditional knowledge provides vital information. Community input can help ensure that subsistence practices and other aspects of indigenous cultures are not exposed to undue risk from increasing vessel traffic, or from ill-informed attempts to regulate that traffic. Although indigenous representatives have an established role at the Arctic Council, there is currently no Arctic indigenous representation at the IMO. Seeking input from indigenous communities with respect to better understanding and protecting marine mammals — whether via ATBAs, traffic lanes, speed limits, communications systems or other measures — can help protect the marine environment and food security, as well as reduce the risk of conflicts between subsistence hunters and other mariners.

## 6.4 Enhance Arctic maritime infrastructure

Enhancement of Arctic maritime infrastructure can improve safety, reduce user conflicts, prevent incidents and aid in more effective accident response. Key concerns include the lack of up-to-date charting and other information that aids safe navigation and lack of physical and incident response infrastructure.

Expansion of physical and response infrastructure — such as new ports, SAR assets, icebreakers and tools to enhance incident prevention and response — is critical. Ensuring local communities have access to adequate prevention and response assets is particularly important. Development of better communication infrastructure and use of emerging technologies have the potential to greatly improve navigational safety, vessel monitoring systems and environmental protection in the Arctic. At the same time, it is necessary to consider limitations imposed by the Arctic environment. If a port community has no practical waste disposal options, development of vessel waste reception facilities may be impossible.

National development of Arctic maritime infrastructure is expensive and time-consuming, and will be weighed against competing national priorities. Future Arctic infrastructure projects will require close cooperation amongst Arctic countries and/or investment of government and private sector funds. In the meantime, industrial actors in the Arctic (e.g., tourism, oil and gas, or mining businesses) should supply the infrastructure necessary to support their operations.

As Arctic maritime infrastructure is developed and/or enhanced in the future, considerations of local indigenous communities and the environment must be addressed to ensure growth occurs in a safe and sustainable manner.

## 6.5 Continue to conduct vessel traffic studies of the region

Continuing study of Arctic vessel traffic will help illuminate trends as the environment and global economy change. Currently, most vessel traffic data is proprietary and expensive to obtain. Development of vessel traffic data-sharing initiatives like the Arctic Ship Traffic Data project — which aims to share vessel traffic activity data among all Arctic Council nations — should be encouraged. This project will give Arctic Council nations easier access to previously costly data, which will benefit not only these nations but all interested stakeholders.

At the same time, vessels should be encouraged to provide more accurate and refined AIS data. As shown by the analysis in Section 2, many vessels report out incomplete or incorrect data about their vessels. Relevant national government agencies should work with vessel operators to ensure vessels provide correct and complete data to facilitate a better understanding of vessel activity.

## 6.6 Support scientific study, observation and monitoring

In addition to further compiling, sharing and applying data that directly informs shipping, continued investment in scientific observation and monitoring must occur to better understand possible risks of shipping in a changing Arctic (e.g., invasive species pathways). This includes data that integrate indigenous knowledge and monitor variables relevant to subsistence uses. Expanded investment in science observations and monitoring helps address key questions related to the concerns of local communities, climate change and environmental impacts. It is also necessary to provide foundational data for planning and adaptive management, especially in this rapidly changing part of the world.

## 6.7 Address Arctic vessel traffic in the broader context

The commercial and industrial activities that drive growth in Arctic shipping will not occur in isolation from one another. Instead, they will often overlap in time and/or space, possibly resulting in cumulative effects generated from overlapping impacts. Resource extraction will create new infrastructure and may promote other types of industrial development. For example, a new oil and gas operation or mine may generate a new port facility, which would promote community growth and trigger the need for additional vessel support. In addition, local impacts from commercial and industrial operations may co-occur with impacts from global climate change — including warming temperatures, diminishing sea ice and increasing ocean acidification. Understanding and minimizing adverse cumulative effects to Arctic communities and the Arctic ecosystem should be prioritized. Doing so will require coordinated and integrated planning and management.

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