Marine Policy 51 (2015) 119–127

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Vessels, risks, and rules: Planning for safe shipping in Bering Strait

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ARTICLE INFO

Article history:
Received 14 April 2014
Received in revised form
29 July 2014
Accepted 30 July 2014

Keywords:
Bering Strait
Vessel traffic
Marine mammals
Seabirds
Subsistence
Mitigation

ABSTRACT

Commercial vessel traffic through the Bering Strait is increasing. This region has high biological and cultural significance, to which commercial shipping poses several risks. For this environment, these risks include ship strikes of whales, noise disturbance, chronic pollution, and oil spills. Indigenous Chukchi, Iñupiaq, St. Lawrence Island Yupik, Siberian Yupik, and Yup'ik peoples may be affected by proximity between small hunting boats and large commercial vessels leading to swamping or collisions, through displacement of animals or impacts to food security from contaminants, and through loss of cultural heritage if archeological sites and other important places are disturbed by wakes or an increase in people spending time on shore. Several measures are available to govern shipping through the region, including shipping lanes, Areas to Be Avoided (ATBAs), speed restrictions, communications measures, reporting systems, emissions controls, oil spill prevention and preparedness and salvage, rescue tug capability, voyage and contingency planning, and improved charting. These measures can be implemented in various ways, unilaterally by the U.S. or Russia, bilaterally, or internationally through the International Maritime Organization (IMO). Regulatory measures can be established as voluntary measures or as mandatory measures. No single measure will address all risks, but the framework presented herein may serve as a means of identifying what needs to be done and evaluating whether the goal of safe shipping has been achieved.

1. Introduction

The Bering Strait has been a nexus of trade for millennia [1]. People, materials, technology, and ideas flowed from Asia to North America and back, making the area a focal point for innovation and exchange. Commercial enterprises arrived more recently. In the 1840s, commercial whalers reached the Bering Strait, opening a new era of trade and exploitation [2]. The 20th century saw the rise of village, mine, or oilfield support vessels to destinations in northern Alaska and Russia, and more recently the proliferation of commercial ship traffic through and along the Northern Sea Route across Russia's Arctic coast [3]. Industrial development in the Arctic is driving an increase in destination shipping, and interest in the Bering Strait as a key passageway between the Pacific and the Arctic is gaining attention throughout the region and beyond [3].

The Bering Strait region (Fig. 1) is of great biological and cultural significance. Its highly productive waters [4,5] draw millions of seabirds to nest in the area [6], and millions more migrate through in spring and fall. The Bering Sea stock of bowhead whales (*Balaena mysticetus*), the Beaufort and East Chukchi Sea stocks of beluga whales (*Delphinapterus leucas*), and the majority of the world's Pacific walrus (*Odobenus rosmarus divergens*) migrate through the Bering Strait [7–9]. Gray whales (*Eschrichtius robustus*), humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*), bearded seals (*Erignathus barbatus*), ringed seals (*Phoca hispida*), spotted seals (*Phoca largha*), ribbon seals (*Phoca fasciata*), Steller sea lions (*Eumetopias jubatus*), and other marine mammals can be found

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http://dx.doi.org/10.1016/j.marpol.2014.07.027

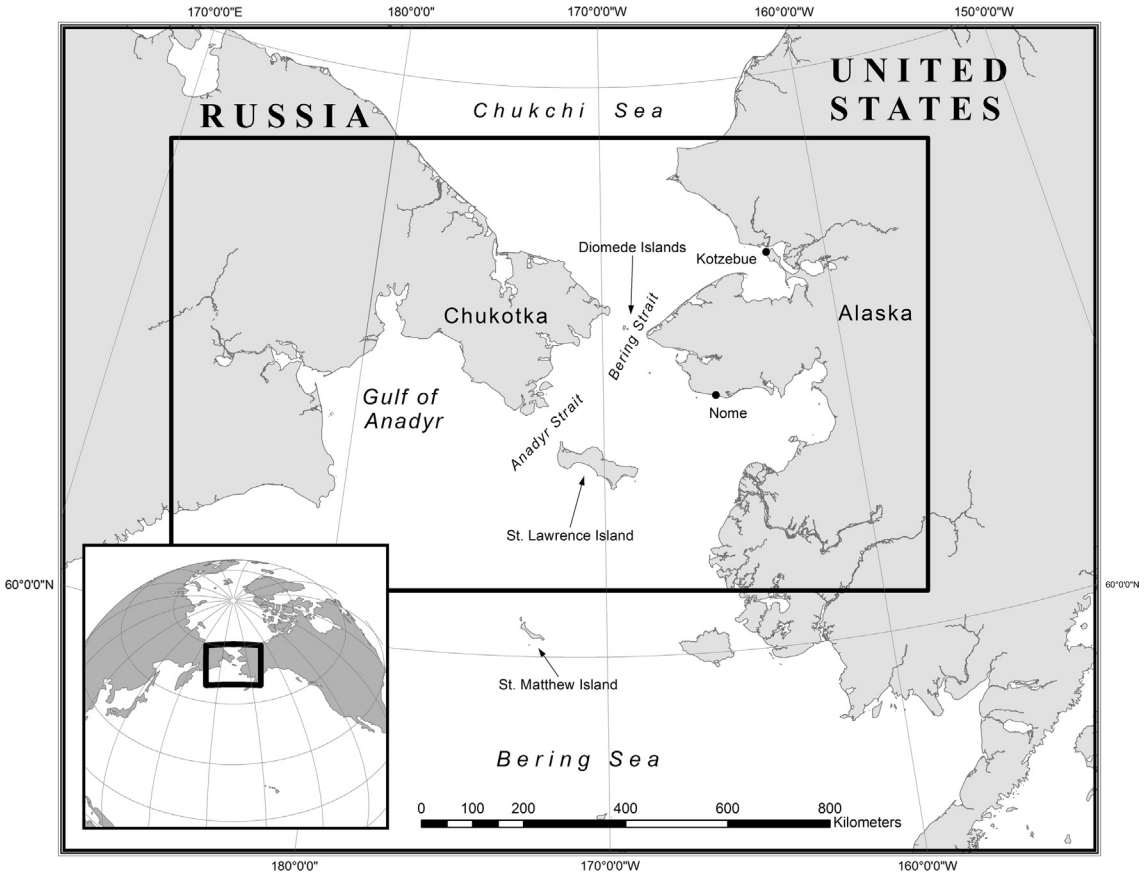

Fig. 1. Map of Bering Strait region.

here, year round or seasonally [8,10–12]. The region's communities include Chukchi, Iñupiaq, St. Lawrence Island Yupik, Siberian Yupik, and Yup'ik peoples, who continue to practice traditional ways of harvesting food and materials from the sea [13–16], and whose rights as indigenous peoples are recognized by national and international laws and practices (e.g., the United Nations Declaration on the Rights of Indigenous Peoples). In short, the stakes are high for ensuring sound management of shipping activities.

The management context, however, is not simple. A recognized "international strait" under the United Nations Convention on the Law of the Sea (UNCLOS), the Bering Strait is subject to special rules designed to ensure that vessels of all nations have relatively unimpaired access through the strait. The International Maritime Organization (IMO) is a specialized agency within the United Nations that, among other things, facilitates the adoption and implementation of regulatory measures in international straits where freedom of navigation jeopardizes vessels, people, or the environment, and when those measures are agreed upon by the states bordering the strait. Under this legal regime, coastal states adjacent to an international strait have limited ability to act unilaterally to impose mandatory regulations on international vessels passing through that strait, but voluntary measures can be recommended and domestic measures can be imposed on vessels subject to the jurisdiction of the country passing those regulatory measures [17].

There is no question that more vessels will transit the Bering Strait in the years to come. What must be determined is how that traffic can be managed in a way to minimize impacts to unique local environments and cultures encompassing some of the world's great concentrations of marine mammals and birds and thousands of coastal indigenous people, while realizing the economic benefits that trade and activity can bring, and whether new management regimes can be designed and implemented proactively rather than waiting for a disaster to happen first [18].

This paper examines vessel traffic that can be expected in the Bering Strait and nearby waters, the environmental and cultural risks associated with that traffic, and the regulatory and other measures that are available to address such risks. Developing a comprehensive suite of rules for Bering Strait vessel traffic will require action locally, nationally, and internationally. That said, many management actions can be taken one at a time or amended as time goes by, so that maritime safety and environmental protection can be improved in stages while respecting cultural values as traffic increases and experience is gained. At the same time, a framework such as this paper presents can put each individual management action in context, to measure progress and to make sure important steps are not overlooked.

2. Vessel traffic

The Arctic Marine Shipping Assessment [3] provided the first comprehensive review of Arctic shipping. Based on data collected from all Arctic states, AMSA determined that Arctic vessel traffic is diverse and includes bulk carriers, container ships, general cargo, government vessels, oil/gas service and supply vessels, passenger ships, pleasure crafts, tankers, tugs/barges, and fishing vessels. All of these vessel types can be found in the Bering Strait region (Fig. 2). In 2013, the U.S. Coast Guard counted 440 transits of the Bering Strait, as some vessels went through more than once (Rob Hynes, pers. comm.). Additional traffic crossed the waters between St. Lawrence Island and the Bering Strait, but did not travel north of Bering Strait itself.

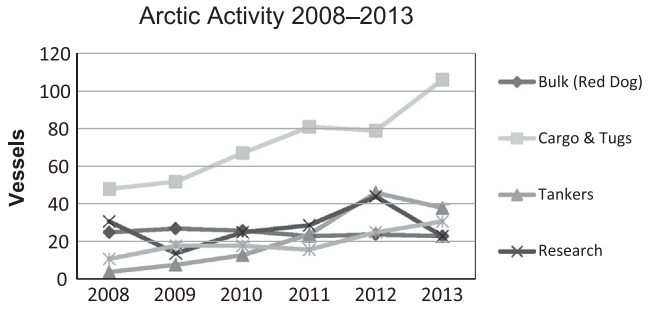

Fig. 2. Arctic activity 2008–2013. This figure reflects only selected categories of Arctic activity in USCG District Seventeen area of concern, which extends north of the Bering Strait, into Russia and Canada and up to the North Pole. Not included in this chart are government and unknown categories (relatively low numbers). "Bulk (Red Dog)" refers to bulk ore carriers going to and from the port of the Red Dog mine in northwestern Alaska, north of the Bering Strait. It is important to note that at least some of the decline in activity between 2012 and 2013 can be attributed to Royal Dutch Shell's pause in their Arctic activities. (Credit: USCG District Seventeen).

Traffic of nearly all types can be expected to increase, though patterns will vary. Destination shipping, for example, serves mines, oilfields, and other industries in Northern Alaska, Northwestern Canada, and Northeastern Russia. The volume of this traffic will depend on the level of industrial activity in these areas. The volume of shipping transiting the Arctic will depend on the viability of the Northern Sea Route in Russia, which is affected by ice conditions as well as economic and administrative considerations. Traffic through or along the NSR has increased exponentially, from just 2 vessels in 2009 to 71 vessels in 2013. Expert opinion suggests that cargo throughput is likely to increase from 1.36 million tons in 2013 to 4 million tons by 2015 and 65 million tons by 2020 (Rob Hynes, pers. comm.).

The bulk of vessel traffic will occur during the ice-free season, currently summer and fall. Changes in freeze-up and break-up may extend this season in both directions, particularly with ice-breaker escorts, but winter traffic will still require significant ice-breaking capacity. At present, this is limited primarily to research vessels, though ice-strengthened commercial transits may increase before long. Subsistence activity by boat, likewise, requires open water, and in recent years has been possible through much of the winter in open leads and polynyas, the areas of temporary or recurrent open water amid sea ice [19].

While the volume of traffic through the Bering Strait is modest compared with major ports or transit areas such as the Aleutian Islands, commercial vessels using the Strait operate in an ecologically rich area, among communities and animal populations with little experience with large-scale vessel traffic, far from assistance or support. Some of the risks described in the next two sections may be especially acute as people and animals habituate to the presence of commercial ships, even as other risks increase with the volume of traffic over time.

3. Environmental risks

The Bering Strait region is ecologically rich with high species diversity due in part to the overall productivity of the area, in part because it is a corridor between the Bering and Chukchi seas, and in part because it sits on the Arctic-subarctic ecotone (boundary between ecosystems) [4,6,20–23]. Vessels navigating the Bering Strait region pose numerous environmental threats including collisions with marine mammals (ship strikes), disturbance of seabirds and marine mammals, increased noise, and contamination of the marine environment (e.g., discharges, air pollution, waste, or ballast water that contains invasive species). Other threats include the potential for an accident such as grounding or sinking of a vessel, which would endanger the crew and rescue personnel in addition to threatening an environmental disaster. In light of the lack of capacity to respond due to remoteness and challenging conditions, most worrisome is the prospect of an oil spill, either from a tanker or of fuel oil from any vessel transiting the area.

3.1. Ship strikes

Direct collisions between vessels and marine mammals can result in mortality through massive trauma. Worldwide records of ship strikes on whales show that all large whales are at risk [24,25], with bowhead whales most likely to be at risk in the Bering Strait region. Bowheads seasonally congregate in the Bering Sea and the entire population of the Bering/Chukchi stock transits the Bering Strait twice a year. The period of greatest concern is in the fall (October through November) as bowheads move south along the Chukotka coast into the Strait at a time when vessel traffic remains high [26]. During spring, whales, walrus, and seals migrate north when sea ice is still present, so the risk of ship strikes is reduced due to lower levels of vessel traffic. Icebreakers, however, have the potential to disturb animals and habitat during spring migration. Ice-dependent seals are potentially at risk of displacement during spring and early summer (April through June) when they use ice for pupping and for molting.

3.2. Noise

Sound is vital to survival of marine mammals as they use it to detect their environment and communicate with one another [27,28]. Persistent or increasing noise disturbance could alter health, behavioral and migratory patterns [29].

Responses to vessels (e.g., disturbance) have been documented in a wide variety of marine mammal species and primarily include avoidance behavior and increased stress. Harbor seals left an area after repeated exposure [30] likely due to disturbance. Bowhead whales respond to anthropogenic sound in their environment [31–33] and concern that bowheads will avoid areas with industrial noise has been the subject of ongoing regulatory discussions of oil and gas operations in the Arctic [34]. In Canada, researchers observed belugas avoiding ice-breaking vessels at great distances and altering their behavior for days following the event [35].

Potential effects of increased sound from shipping on fish and invertebrates are difficult to assess due to a lack of direct information [36]. In general, vessel noises are within the auditory range of fishes. Ships produce high levels of infrasonic noise, which may be responsible for avoidance reactions observed in fishes [37].

3.3. Discharges and contamination

Contamination may occur from marine discharges, air pollution, and light pollution. Each of these can have long-term and short-term effects. Discharges include oily water, wastewater, ballast water, garbage, and other debris. Pollution is of high concern for animal health and also for humans eating animals that may have been exposed to contamination [38]. Pollutants can accumulate in animals and concentrations can increase dramatically in higher levels of the food web [39]. Spectacled eiders (*Somateria spectabilis*) also congregate in winter in vast numbers in small polynyas (open areas within the sea ice) where they would be highly vulnerable to pollution or disturbance [22].

Light pollution is another concern. Birds are attracted to lights and bird strikes occur during darkness and heavy fog. High intensity searchlights used as navigation aids during the fall can

attract birds, often resulting in birds colliding with into ship structures [40]. Steller's eiders (*Polysticta stelleri*), an endangered species, are especially at risk as they fly fast and low in large flocks.

Garbage and materials from a lost container cargo can also cause a variety of problems for wildlife. Of particular concern are plastic particles from polystyrene foam and other materials that break down over time and may be ingested by seabirds and marine mammals. Marine debris can also cause a variety of entanglement and other types of fouling [41–43]. Incineration of waste can cause emissions of furans, dioxins, heavy metals, and other pollutants. These can enter the marine environment and also affect human health, especially when the pollutants are emitted in the vicinity of communities [44].

3.4. Oil spills

Oil spills can result from an accident involving tankers and barges that carry oil and fuel or any vessel that runs on petroleum-based fuels. Oil spills are a concern due to acute and chronic toxicity to marine organisms, fouling of fur and feathers, ingestion of oil directly or through predation on organisms that have taken up oil compounds, and inhalation of volatile fractions of the oil [38]. This risk is compounded by the lack of effective cleanup techniques, response equipment, and capability in the Bering Strait region [45]. In most large spills, even with massive response efforts, the large proportion of oil remains within the environment and frequently response activities themselves leave a legacy of destruction [46,47]. In the Arctic, this is particularly problematic as oil is expected to degrade much slower than in more temperate environments such as the Gulf of Mexico [48]. Evidence of persistent oil in the beaches of Prince William Sound over two decades since the Exxon Valdez Oil Spill is testament to such long-term recovery horizons [49] and the potential for long-term impacts to shoreline habitats [50].

4. Cultural risks

The Bering Strait region is home to Chukchi, Iñupiaq, St. Lawrence Island, Siberian Yupik, and Yup'ik communities. People have inhabited the area for millennia, and continue traditional cultural practices tied to the marine environment [14,51–53]. Local residents and their communities will be impacted both directly and indirectly by vessel traffic in the Bering Strait region [3]. While these impacts may be both positive (e.g., port calls/deliveries) and negative (e.g., risks of oil spills, disturbance to animals and hunting), this paper focuses on the threats warranting management action in the near future. Direct threats include risk to life and property from vessel collisions, swamping, or the aftermath of an oil spill. Indirect threats include impacts to humans via effects on marine mammal, seabird, and fish populations, as described in Section 3. In addition, there may be threats to cultural heritage, for example, through the degradation of archeological sites.

4.1. Direct threats

Hunters from Bering Strait communities travel by small, open boat as far as 100 miles (160 km) or more from land [54,55]. These boats could be struck by a large vessel or swamped by a large vessel's wake, as has happened in the Torres Strait, Australia [56]. Given the cold water and distance from land and assistance in the Bering Strait region, such incidents would likely be fatal to those on the small boat, if the large vessel were unaware of the accident. When on broken ice during hunting, processing catches, or while towing a whale to land, small boats and crews may be seriously constrained in their ability to respond to a large vessel's presence.

4.2. Indirect threats

Indigenous residents of the Bering Strait region obtain a large proportion of their food from the sea [14,57], along with other materials such as ivory for carving and skins for clothing and handicrafts. Successful hunting requires sufficient animals, access to those animals, and confidence that the meat and organs are safe to eat, all of which may be affected by increased vessel traffic and their emissions and discharges.

Changes in the distribution of animals may affect access. For example, noise or other forms of disturbance from vessel traffic may cause marine mammals to shift their migratory path, which could force hunters to travel farther. In addition, animals that have been disturbed may change their behavior, becoming more wary of human activity such as hunting from small boats [58,59].

If commercial vessel traffic results in the discharge or emission of pollutants, or if there is a perception that this is the case, local residents may be less confident in the overall health benefits of eating locally produced foods. In a region where food security is already a major concern [60] and where episodes of starvation are known from archeological and historical records [2], such a loss of confidence in traditional foods could have a large impact on nutrition and resulting health, as well as on cultural identity and continuity [38,52].

4.3. Cultural heritage

The Bering Strait area is rich in archeological heritage and in present-day camps and cabins. Commercial vessel traffic is likely to be most common offshore, so that wakes are unlikely to cause additional erosion of sensitive sites. The increased presence of mariners, however, may lead to more visitors to such sites. While most such encounters are likely to be benign, there is still a risk that archeological artifacts or personal property might be taken. Making public the locations of archeological sites may simply provide a map for treasure hunters, but a lack of documentation may hinder other efforts to protect what is there [61]. On the other hand, documentation of what exists and its condition may help with prosecutions if harm to a site can be proved.

5. Regulatory and other measures

The regulation and management of vessel traffic worldwide uses a relatively limited number of measures to control the location, speed, and behavior of ships in order to reduce risks to safety and the environment [62]. Of course, management of risk is not elimination of risk, and the degree to which risks are reduced depends on the exact nature of the measures adopted and the degree to which they are followed in practice. Nonetheless, the tools for managing vessel traffic in the Bering Strait are established maritime measures used elsewhere in the world. Other measures may also be considered to inform mariners and reduce risks of accidents.

5.1. Regulatory and management measures

This section reviews six types of regulatory or management measures, which are among the main measures in use worldwide and, together, address the environmental and cultural risks described in previous sections. The ways in which these measures can be implemented are addressed in Section 6 below.

Shipping lanes are designed to confine vessel traffic to specific areas. This helps create regular traffic patterns while avoiding potentially dangerous locations (such as shoals) or culturally or environmentally sensitive areas (such as intensive hunting areas

or large bird colonies) [63]. Shipping lanes also help prevent accidents, because vessels follow expected routes. This measure is commonly used in narrow straits and areas of vessel congestion such as harbor entrances. Ideally, shipping lanes are straight or have as few turns as possible. If there is ice in the Bering Strait, mariners will want some room to maneuver, which can be accommodated if the shipping lane is wide enough.

Shipping lanes tell vessels where to go; Areas to Be Avoided (ATBAs) tell mariners where they should not go for reasons of hazards, safety, or environmental or cultural risk. In a remote region such as the Bering Strait, ATBAs may be used to keep sufficient space between vessels and shorelines to help ensure that a disabled vessel does not drift ashore before help can arrive. Between shipping lanes and ATBAs is the category of precautionary areas. Mariners may enter such areas, but are advised to take special care in light of hazards or sensitivities that exist in those places.

For some hazards, including ship-to-ship collisions and ship strikes of whales, speed restrictions can greatly reduce impacts and risks [24]. Seasonal management areas were also found to be effective in reducing vessel strike of migratory North Atlantic right whales (*Eubalaena glacialis*) [64]. Reducing speed, however, may entail an economic cost, because voyages will take longer, although slower speeds are more fuel efficient. Ships also need to maintain sufficient speed to maneuver, so speed restrictions need also to consider the safety of mariners and their vessels. Speed restrictions may have the additional benefit of reducing noise levels, which could have their greatest impacts in constricted areas such as a strait or in areas with marine mammal aggregations.

Vessels over 300 gross tonnes and all passenger vessels are required to have automatic tracking systems on board (Automatic Identification System, or AIS), which allow their position, speed, cargo, destination and other information to be monitored. Although not required, many smaller vessels are voluntarily equipped with AIS transmitters and receivers. Reporting systems may include an additional requirement to announce when they enter and leave designated areas. Additional communication could be required, for example, between vessels, with an official monitoring intermediary such as the U.S. Coast Guard, and with communities or a local communication center. Communications might include calls to locally used radio channels to alert hunters out in boats, or checking in with a local communication center upon arriving within radio range of that locale. Local hunting boats can also be equipped with AIS capability, so their presence can be noted by larger vessels well before they are in sight [65]. Mandatory reporting systems designed to help protect the endangered North Atlantic right whale are already in place for certain areas of the east coast of the United States (33 C.F.R. §169.100), and a mandatory vessel monitoring system is also required in the Northwestern Hawaiian Islands Marine National Monument (50 C. F.R. § 404.5). An AIS-based monitoring system that actively tracks vessels and enables greater information exchange between the Coast Guard, transiting vessels and local communities, would enhance accident prevention, facilitate early identification of vessels in distress, and assist the Coast Guard in ensuring that vessels comply with regulatory requirements.

Discharges of all kinds can be regulated, for ships in general and in specific areas. Emission controls are likely to be addressed, at least in part, in the broader context of Arctic shipping, for example through the development of the Polar Code by the IMO (see Section 6 below). For the Bering Strait region, additional regulations may be appropriate, such as minimum distances from shore or communities before discharging or incinerating waste.

Voyage and contingency planning is another important measure to mitigate risk. Research shows that human error contributes to 80% of navigational accidents, which suggests that correctly assessing information, creating and implementing viable plans for voyages, and monitoring these plans will significantly reduce risk of accidents and other mishaps [66]. In 2007, the IMO adopted "Guidelines for Voyage Planning for Passenger Ships Operating in Remote Areas." Some of the considerations in the guideline include information on the scarcity and limitations of search and rescue resources, navigational aids and charts; existing knowledge on ice, ice formations, and environmental conditions (wind, fog, weather, etc.); and consideration of safe areas and hazardous, marine corridors, and contingency plans in remote areas with limited search and rescue capabilities [67]. Voyage planning can also help mariner avoid sensitive areas and plan for additional time required by speed restrictions. These specific guidelines will likely be included in the Polar Code by the IMO (see Section 6 below).

Salvage, marine firefighting, and spill prevention and preparedness are essential services for reducing the risk of an incident and appropriately responding after an incident to prevent further damage or remove oil spilled in the marine environment. The U.S. Coast Guard recently implemented two new rules addressing these services, neither of which can be successfully met by existing resource providers in Alaska. The salvage and marine firefighting regulation includes required response timeframes only within 50 miles of the nearest Captain of the Port zone city – Anchorage for western Alaska – thereby exempting vessels traveling the Bering Strait from the timing requirement (Title 33, Code of Federal Regulations, Part 155, Subpart I). The domestic non-tank Vessel Response Plan rule requires vessels over 400 gross tons to contract with a resource provider, such as an Oil Spill Removal Organization (OSRO), that can respond to an oil spill with the required amount of equipment within a specified timeframe; 24 h is the amount of time that would apply to most Alaskan waters (Title 33, Code of Federal Regulations, Part 155, Subpart J). At present, there is only one Alaska-based U.S. Coast Guard classified OSRO for the Bering Sea, and it does not meet the current timeframe or equipment requirements, leaving a significant gap in emergency preparedness. Although not currently required, spill response capacity could also include local, trained personnel and equipment adequate to protect sensitive shorelines and provide advice about important marine ecosystems and wildlife.

An important accident prevention measure is the use of rescue-tugs to assist ships with mechanical problems, offer assistance to disabled ships and barges under tow when necessary, and prevent these ships from grounding and causing serious environmental damage. Though there is little precedent for mandating tug capabilities in the Arctic, since 1999 the Washington State maritime industry has permanently stationed an emergency response towing vessel at Neah Bay, Washington, near the mouth of the Strait of Juan de Fuca [68]. In 2009, the Washington State legislature passed an act that requires tank, cargo, and passenger vessels traveling to or from a Washington port through the Strait of Juan de Fuca to establish and fund an emergency response system that would provide an emergency response towing vessel, also to be stationed at Neah Bay (CWR §88.46.130). The loss of control and subsequent grounding of the Kulluk drill rig off Kodiak, Alaska, in 2012 is an example of the need for expanded rescue and tug capabilities in Arctic waters, which are much farther removed than Kodiak from available response capacity.

5.2. Other measures

Providing information and other support to mariners can also enhance safety and reduce risk. Weather and ice forecasting fall into this category, as does the Coast Pilot, a mariner's resource describing potential hazards and providing contact information

published in the U.S. by the National Oceanic and Atmospheric Administration.

Modern nautical charts are also important tools in providing safe and secure maritime transportation throughout Arctic waters. Nautical charts supply mariners with the latest information on accurate shorelines, topographic features, water depths, hazards, aids to navigation, and recommended routes. They also provide base geospatial data used for fishery stock assessments, coastal zone management, energy exploration, and other uses. Given that most of the region has been historically inaccessible due to the presence of thick, multi-year sea ice, much of the Arctic region has inadequate or outdated charting data. Moreover, existing charts date back to the 1800s, and the majority of Alaska's vast northern and western coastline has not been charted since the 1960s. As the U.S. Coast Pilot states, the Bering Sea is only "partially surveyed, and the charts must not be relied on too closely…" [69]. In 2013, NOAA identified the need for 14 new charts in the Arctic and is in the process of updating these charts. Charts have been released in the Bering Strait region that include the Bering Strait North (Chart 16190) and from St. Lawrence Island to the Bering Strait (Chart 16220) [70].

6. Regulatory implementation

Regulations can be implemented through voluntary measures, domestic regulations, and international regulations. These various measures would apply in different ways, depending on the nature of the vessel and the voyage. In practice, a regulatory regime could begin with voluntary measures and, depending on the success of those measures and a need for more formal actions, evolve towards mandatory standards of care established by the U.S. or Russia, in the case of domestic regulations, and the IMO, for international regulations. The measures themselves may be similar in nature and intent, with the main difference being the way they are implemented and enforced.

Voluntary safety and environmental protection measures may be recommended by regulators, including government agencies as well as the IMO. These measures can include all of the regulatory measures, such as voluntary vessel speed limits, reporting recommendations, routing recommendations, or other actions. Although commercial shippers do not have to adhere to voluntary measures, compliance with some voluntary measures can be high [71], though variable [72] and may be low or negligible for some measures, as was found for speed restrictions off the coast of California [73]. Compliance is likely due to a desire to operate responsibly to reduce risk, or requirements by insurers that vessels follow appropriate guidelines whether mandatory or not. If regulators recommend pragmatic voluntary measures to which commercial shippers are likely to adhere, regulators may be able to significantly increase on-the-water safety and environmental protections in a relatively short period of time. In addition to encouraging voluntary compliance in the short-term, these measures may facilitate adoption of binding measures in the long run.

Under UNCLOS, coastal states have authority to regulate vessels that fly the flag of the coastal state (Part VII, Articles 92 and 94) or that are going to or from a port of that state, and can enact a broad range of safety and protective measures. They can also regulate foreign-flagged vessels that in transit passage so long as such regulation does not discriminate among foreign ships or impair the right of transit passage (Part III, Article 42). Accordingly, domestic regulation by the United States or Russia could have a significant impact on safety and environmental protection in the region and could set the stage for international regulation. Such actions could be, but do need to be, done cooperatively by the two countries—although full coverage of the transboundary Bering Strait region would clearly require bilateral cooperation. These domestic regulations can cover the types of measures described in Section 5.

International regulation of vessel traffic is done through the IMO, which has established a variety of instruments designed to promote safety and prevent marine pollution by vessels. These include the two major Conventions, the International Convention for the Prevention of Pollution from Ships (MARPOL, adopted in 1973), the International Convention for the Safety of Life at Sea (SOLAS, adopted in 1974), as well as a resolution providing for the designation of Particularly Sensitive Sea Areas [74]. The IMO is currently negotiating a Polar Code that would apply to vessels in the Arctic and the Antarctic [75]. IMO regulations are likely to be developed from domestic regulations and at the request of the coastal states in question, rather than to be imposed upon existing local practices. IMO regulations may be preceded or accompanied by voluntary recommendations.

7. Discussion

Vessel traffic in the Bering Strait region is expected to continue to increase and to involve a vastly greater suite of nationalities and interests, bringing potential local economic benefits as well as a greater risk of harm to the environment and to local cultures and communities. Many actions can be taken, however, to manage risk so that economic benefits need not come at the expense of negative impacts to the environment or the people who live as part of the Bering Strait region's ecosystem. Table 1 shows which regulatory and other measures can help reduce the risks identified in this paper. No single measure addresses all the risks, but, taken

Table 1
Comparison of environmental and cultural risks (columns) and regulatory measures (rows). The first four risks are environmental ones and also cultural risks for those who depend on the environment for food and well-being. Note that most or all regulatory measures can be implemented by voluntary, domestic, or international action. Which vessels would be covered by each type of action, and how much of the risk would be reduced, depends on the details of the shipping activities in question.

Risk/Regulatory measure	Ship strikes	Noise	Discharges and contamination	Accidental oil spills	Vessel collisions	Disturbance to hunting	Damage to cultural heritage
Shipping lanes	X	X		X	X	X	
Areas-to-be-avoided	X	X		X	X	X	X
Speed limits	X			X	X	X	
Communications	X				X	X	X
Reporting systems					X	X	
Emission controls		X	X			X	
Salvage and oil spill prevention and preparedness			X	X			
Rescue tug capability			X	X			
Voyage and contingency planning	X			X	X	X	X
Charting				X			X

Table 2
Categories of regulatory implementation. Although mandatory measures are not necessarily dependent on having voluntary measures in place (and domestic measures are not required prior to international measures), in practice the development of regulations typically starts with voluntary and domestic measures and moves on from there.

Category of implementation	*To whom the measures apply*	*Effectiveness at reducing risk*
Voluntary	All vessels, but with no enforcement power	Depends on compliance, but there is likely to be pressure to comply Can be enhanced if insurers and others regard such measures as appropriate standards of care Can be enhanced by monitoring and communication
Mandatory (domestic)	Vessels addressed by the regulations that are either (a) registered in the country issuing the regulations, or (b) traveling to or from a port in that country	Depends on the proportion of vessels in the area that are subject to the regulations Other vessels may comply voluntarily or be required to do so by insurers Can be enhanced by monitoring and enforcement
Mandatory (international)	All vessels addressed by the regulations	Compliance can be enhanced by monitoring and enforcement

together, the measures described here can help reduce all of the risks described herein. In addition, each measure addresses at least two of the risks and may help indirectly with other risks as well, producing multiple gains for each action taken. We note that many of these ideas have been recommended by local residents as well, indicating a high degree of local support for adopting appropriate measures to govern shipping [76].

For example, the risk of a collision between a large vessel and a small hunting boat can be reduced in several ways. First, communication and reporting systems can help large ships and small boats be aware that both types of vessels may be operating in the same waters. Second, AIS can display the presence of vessels equipped with transmitters, which by law include large vessels and can also include hunters' boats. Third, vessels entering the area can announce their presence, course, and speed via radio. Fourth, designated shipping lanes can confine the presence of many ships to specific areas, making their presence and location more predictable, although some vessels such as tugs and barges traveling to villages will be outside the lanes designed for transiting vessels. Fifth, voyage planning can make mariners aware of sensitive areas in advance, so they take appropriate precautions. All five methods will contribute to greater awareness of the type and amount of marine traffic in the area at different seasons, and such awareness itself will likely assist in reducing the risk of collisions because mariners will not be taken by surprise.

These same steps can also help reduce disturbance to hunting. If hunters know where vessels are likely to be, they pursue hunting opportunities elsewhere. If designed with marine mammal concentration areas in mind, shipping lanes can help reduce ship strikes as well, as can speed restrictions and communication, including voyage planning based on recent sightings of marine mammals. The impacts of normal operations cannot be eliminated, but they can be managed in space and time to minimize effects on culture and environment.

Accidents, however, have the potential to cause the most widespread impacts of any of the threats posed by shipping. The record from the nearby Aleutian Islands [77] suggests that over time one or more spills may be close to inevitable. Increasing tug, salvage and spill response capabilities in the Bering Strait and Northwest Arctic should be considered, especially during peak vessel traffic periods. Such capacity could also aid in search and rescue if needed. Local training in emergency response could also enhance the region's ability to respond promptly while other assets are en route.

Identifying risks and associated regulatory measures is a first step, but taking action will depend also on effective governance of vessel traffic at local, national, and international levels. Bering Strait region communities will need to develop the technical and human capacity to work effectively with mariners and regulators, to identify community needs and priorities and to implement measures such as local use of AIS and communication systems. National governments will need to continue to develop appropriate regulatory frameworks, including local outreach and involvement as well as standards that are consistent with other such efforts in Arctic waters. Internationally, cooperation between the U.S. and Russia would be a big step forward and would pave the way for recognition of appropriate measures by the IMO. In this light, Table 2 outlines the progression from voluntary recommendations to domestic and international regulations. While voluntary recommendations may not be enforceable, they can also be made more quickly than formal regulations, compliance may be high, and they are a significant step towards formal regulations. Formal regulations are likely to take longer to develop and implement, but carry extra weight. Both approaches have a role in a system of effective governance for vessel traffic.

In summary, vessel traffic in the Bering Strait region is an economic opportunity, and also an opportunity for sound management of environmental and cultural risks. This paper presents a framework for various actions that can be taken locally, nationally, and internationally to reduce risks from vessel traffic, consistent with the principle of freedom of the seas as well as with responsible standards of care for vessel operations in areas. Acknowledging the risks and taking appropriate action proactively can help vessel traffic proceed without hindrance, while also protecting an important ecosystem and the cultures that depend on it, while both remain vibrant and healthy.

Acknowledgments

We thank the Bering Strait communities, with whom it has been our pleasure to work, for teaching us about what matters in the region. The Arctic Marine Mammal Coalition has been similarly helpful in articulating the concerns of Alaska Native hunters concerning shipping in the Bering Strait region. We thank the Oak Foundation for supporting efforts to address Arctic marine shipping. We are grateful to Ed Page, Roger Rufe, and Robert Hynes for sharing their knowledge and data with us. Britta Schroeder (Wildlife Conservation Society) produced Fig. 1 and Patricia Chambers (Pew Charitable Trusts) produced Fig. 2, for which we are grateful. We also acknowledge with appreciation the efforts of the U.S. Coast Guard to promote safe shipping and to include Bering Strait communities in doing so. Two reviewers provided constructive comments, as did David Laist from the Marine Mammal Commission, all of which improved the final paper.

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