2015-12

Northern sea route: an overview of transportation risks, safety, and security

Hill, Emmaline; LaNore, Marc; Veronneau, Simon

Springer

Hill, Emmaline, Marc LaNore, and Simon Véronneau. "Northern sea route: an overview of transportation risks, safety, and security." Journal of transportation security 8.3-4 (2015): 69-78.
http://hdl.handle.net/10945/59412

J Transp Secur (2015) 8:69–78
DOI 10.1007/s12198-015-0158-6

Northern sea route: an overview of transportation risks, safety, and security

Emmaline Hill[1] · **Marc LaNore**[1] · **Simon Véronneau**[1]

Received: 9 March 2015 / Accepted: 1 May 2015 / Published online: 14 July 2015

Abstract As global warming takes its toll on Arctic sea ice, a new transportation superhighway emerges across the northern polar region. This new transportation route—the Northern Sea Route and Northwest Passage—brings many challenges and concerns. Significant obstacles preside along this route such as hazards to navigation, minimal or non-existent rescue and recovery services, inconsistent weather reporting, and reduced communication capability. In this paper, we review existing studies on the Northern Sea Route, discuss these risks and challenges, as well as present some of the advantages and opportunities associated with this emerging trade route. We conclude with a short discussion on safety and security implications.

Keywords Northern sea route · Northwest passage · Maritime safety · Maritime security · Polar routes

Introduction

As global warming reduces Arctic sea ice, a new transportation superhighway emerges across the northern polar region: the Northern Sea Route (NSR) and the Northwest Passage (NP). An important question is: What are the challenges and opportunities associated with these new transportation routes, and how will these factors affect trade transportation via these routes?

Revered expanses of seemingly unknown proportions reside north of the austere Siberian coastline. These vast expanses of difficult navigable, challenging waters and the polar ice have long daunted sailors and explorers, while at the same time these have

The views expressed in this document are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

✉ Simon Véronneau
sveronne@nps.edu

[1] Graduate School of Business and Public Policy, Naval Post Graduate School, 555 Dyer Road, Monterey, CA 93943, USA

drawn the most hardened and determined men. Traditional intercontinental maritime transportation and trade routes have taken sailors through the Suez Canal, the Panama Canal and around the horn of Africa or the tip of South America. For centuries, these routes prevailed as the *only* viable sea routes. Centuries of polar endeavors, however, have revealed and established an alternative route that connects the existing and well-established Northeast Passage (NEP) with the Bering Strait that separates Alaska and the eastern tip of Russia. This emerging route is known as the Northern Sea Route.

The challenges and opportunities associated with securing a reliable alternate sea route, while not inconsequential, are balanced by global interests in potential gains in economic efficiencies for cargo transport and access to and shipment of expansive natural resources. These interests bring security challenges as these areas of resources and opportunity are contested not only by polar countries but also non-polar countries wanting access to these new resources. While both the NSR and NP offer similar challenges in this paper, we focus specifically on the NSR issues and perspective. First we provide an overview of maritime transportation through the NSR, followed by a discussion of current challenges to its development as a global trade route and, finally, we conclude with future opportunities shaping this global transportation trend as well as safety and security considerations.

The northern sea route

From 1940 until 1991, a Soviet moratorium was informally enforced on foreign ships sailing the NSR. Soviet development and exploration continued during this period with the building of a fleet of icebreakers, further economic and infrastructure development of coastal ports and the advancement of hydrographic, ice and weather studies in the region (Johannessen et al. 2006). The Northern Sea Route, an emerging transportation option for linking Europe and Asia, is now open to passage by most vessels during the summer and autumn periods (American Bureau of Shipping [ABS] 2014).

The Russian Federation established the Administration of the Northern Sea Route in 2013 to "organize navigation in the water area of the NSR" and to update the permit-granting process under which ships of all flags can enter or transit the region (ABS 2014). The administration is actively working to strengthen the NSR as an appealing alternative for international shipping. The Russian Federation along with all Arctic nations—Canada, Kingdom of Denmark, United States of America, Iceland, Norway, Sweden and Finland—are members of the Arctic Council. This council is a high-level intergovernmental forum that is concerned primarily with environmental protection and sustainable development issues in the Arctic region (U.S. Department of State 2015). The Arctic Council's 2009 *Arctic Marine Shipping Assessment* highlighted the current, fragmented nature of governance in Arctic waters: global and national legal regimes that establish standards; a complex range of actors that affect shipping law, policy and practice; and the largest flag states and suppliers of marine labor do not border the Arctic Ocean. Furthermore, not all Arctic states are parties to important conventions nor are all relevant conventions in force (Arctic Council 2009).

The NSR facilitates global trade access to vast amounts of natural resources—namely oil and gas—contained in the Arctic. As economies look to diversify their reliance on energy sources, exploration and mining of these Arctic resources is on the

rise. As economies of scale can be realized, the growing rate of bulk cargo transportation is also assisting the NSR to become a more cost-effective alternative for other cargo types. The Arctic Council estimates maritime traffic to become about 40 million tons of oil and gas per year by the year 2020. This may in turn improve the economic effectiveness of cargo transportation through the NSR (Arctic Council 2009).

The NSR facilitates more than an international shipping and trade route connecting Europe and Asia: It also enables and sustains local Arctic economies by serving as a transit route for increasing demand for destination shipping. This shipping takes place specifically in the sectors of community re-supply, marine tourism and resource extraction. Mining oil and gas is a growing market in itself both along the NSR and the North America's Northwest Passage (NWP) (Kikkert 2012). Within the Russian Federation, the NSR joins the transport network that includes the largest rivers in Siberia (Mitenkov et al. 2003). Additionally, the NSR allows for intra-Arctic shipment between ports and harbors within the Russian Federation. This marine transport serves as the sole means of cargo shipping within the Arctic zone, supporting the export of mining, metallurgy and forest products and, also, the import of all supplies (Mitenkov et al. 2003).

The Russian Federation's fleet of powerful icebreaking ships, as well as ice-strengthened ships for moving most cargos, developed infrastructure along the NSR with well-honed ice navigation skills. This showed that navigation along the NSR is technically feasible and that there is a demand for import, export and, conceivably, transit (Arctic Council 2009). Demonstrating and building this transportation capability has proven its viability as a global option—albeit possibly a future option—to the Suez or Panama Canal.

Challenges

The Arctic is a vast and poorly charted expanse that is cloaked in danger. Relatively limited exposure to manned travel leaves much of the danger associated with this region misunderstood or discounted. The sheer remoteness of this region has hefty implications for rescue and recovery efforts, which we discuss later. Icing from sea spray, temperature, storms and icebergs are just a few of the myriad hazards to safe passage along this route.

Navigation technology and mapping

Navigational technology is greatly limited in the Arctic. The global positioning system (GPS) is limited by satellite coverage at these latitudes; magnetic compass loses north for obvious reasons; and, finally, gyrocompass struggles to stay true. Hence, safe navigation with these instruments is a serious challenge at best. Moreover, hydrographic information, specifically charts and soundings, lags behind much of the navigable waters of the world. This is due in part to the rapidly changing landscape of sea ice as well as the lack of proper detailed survey due to its prohibitive cost. Many charts of the Arctic in use today date back to the first explorer and the onboard surveyor drawing charts with the use of sextants and celestial navigation.

Draft restrictions and hydrographics

Open water depths along the NSR can range between 20 and 200 m. Ships transiting the NSR, however, must pass through various narrow and shallow straits in the Kara and Laptev Sea, depending on the specific route chosen. Table 1 lists the various straits along the NSR and their respective depths.

While most of these straits do not present much hazard to even the largest of cargo ships, depths as shallow as 8 m (or about 26') can be encountered in the Dmitriya Lapteva Strait, which would challenge most vessels' safe passage.

Weak satellites and poor maps are creating bottlenecks in what could be a massive Arctic transit route. Due to the remote nature of the NSR area, crews of passing ships map most of the latent sea ice. Due to weak satellite communications with the ships in this region, however, ship operators cannot transmit high-resolution images of the ever-changing route conditions. Moreover, bathymetric mapping is inadequate over much of the NSR. As a result, many ships are limited to fewer route options, which could create bottlenecks in these more charted and deeper shipping lanes. The Russian government has commissioned hydrographic surveys, which will help to shore up the shortcomings in adequate mapping. Furthermore, the International Maritime Organization (IMO) recently adopted a safety code for ships in Polar waters called the Polar Code, which includes agreements on mapping and charting issues as well as notices (Kendrick 2014).

Ports

Adequate port infrastructure is not solely an issue of draft/volume commensurate with ship size. For example, containerships require a deep draft port and port infrastructure requirements in the Arctic and those that are largely safety- and environment-related. Current port infrastructure in Alaska lacks 1) support to vessel traffic in the Arctic through the Bering Strait and 2) the fulfillment of search and rescue operations within the United States' area of responsibility. Alaskan Senator Begich stated "there are currently no adequate staging, support, and disaster response facilities in the area of Bering Strait," but current state partnership with private industry intends to develop Port Clarence "for infrastructure development that will positively benefit the shipping safety, search and rescue capability, security, and economic development in the region"

Table 1 Table of lowest drafts in Arctic straits (American Bureau of Shipping [ABS] 2014)

Strait	Depth
Kara Gate	50 m
Matisena and Lenina Straits	20–25 m
Vil'kitskogo Strait	50–50 m
Shokal'skogo Strait	200–250 m
Yugorskiy Shar Strait	13 m
Sannikova Strait	13–15 m
Dmitriya Lapteva Strait	8–9 m
Bering Strait	30–50 m

(Assessing U.S. preparedness in the Arctic 2013, p. 53). The Army Corps of Engineers and the Alaska Bureau of Land Management conducted a study of potential sites for an Alaskan deepwater port; however, the project is unlikely to move forward without the aid of private oil and gas industry support.

There are seven principal Arctic seaports along the NSR throughout the Russian Federation's waters: Amderma, Dikson, Dudinka, Khatanga, Tiksi, Pevek and Mys Shmidta. They are characterized by varying levels of infrastructure, capacity and navigable days and periods, which are mainly due to ice floes. This poses a challenge to the current nature of global supply chains dependent on schedule reliability. Commercially the most important of the Russian Federation's Arctic ports is Tiksi Port. It is located in the western part of the Tiksi Bay of the Laptev Sea and services ships sailing through the NSR; it receives cargo for enterprises in the Bulunkanskiy region; and it facilitates trans-shipment of export cargo from the Lena River with 19 portal cranes, four mobile cranes and one gantry crane (ABS 2014). The other ports all pose their own challenges and limitations, and they play diverse roles in their local economies and industrial complexes. In all cases, access is limited and most of them could use upgrading.

Communication

Radio communication between ships, icebreakers and the shore stations is carried out with the use of a combination of radio and satellite communication equipment. While moving in the ice convoy, radio communication between ships or between ship and icebreakers is carried out on the Very High Frequency (VHF) communication channel selected by the icebreaker master supervising the movement of the ice convoy (ABS 2014). Radio communications from ship-to-shore stations is more challenging due to line-of-sight and distance variables to operational shore stations' Medium Frequency (MF) and High Frequency (HF); thus, success is variable. Satellite communication equipment is key to consistent and quality ship-to-shore communications, and this can be achieved by using different systems including the Global Maritime Distress and Safety System (GMDSS), which uses Satellite and MF/HF radio to send text messages.

Rescue and recovery

With the emergence of a maritime trade route through this dangerous region of the world, the increase in requirement for and employment of search and rescue assets and salvage and recovery operations is paramount. As more and more merchant vessels, particularly those with limited polar environment experience or capability, turn to the NSR as a preferred trade route due to its transit efficiencies, the greater the need for public assets to be on patrol. Bordering countries to this region have long had military and coast guard presence on the Arctic waters; however, that presence may not be adequate to sustain the anticipated increase in traffic volume. As such, Russian Ministry of Transport's Marine Operations Headquarters organized search and rescue and environmental spill response along the NSR. They have established Marine Rescue Coordination Centers (MRCC) and Sub-Centers (MRSC) in Dikson, Tiksi and Pevek. The MRCCs and MRSCs have the necessary equipment designed to operate in harsh regions while, at the same time, they comply with 1) the International Convention on

Maritime Search and Rescue at Sea of 1979 and 2) the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual. The MRCC in Dikson will be operated year-round while MRSCs in Tiksi and Pevek will be seasonal in providing search and rescue coordination and oil spill response (Northern Sea Route Information Office [NSRIO] 2014).

The salvage and recovery infrastructure is largely under-developed. The lack of resources—no repair facilities or safe havens and limited salvage equipment along the NSR—may make a salvage operation complicated and very expensive—if even possible. Moreover, the logistics associated with obtaining resources and mobilizing to remote areas of the NSR to affect salvage operations is, at the least, daunting and perhaps financially prohibitive for many transportation companies.

Security

Ensuring maritime security is vital to a country's economy and is also of strategic importance (Leonard et al. 2015). Supply chains are also a vital and strategic asset economically, and can be a nation or organization's Achilles heel (Véronneau and Roy 2014). With this new global interest in these polar routes, as well as the resources available in the Arctic, security concerns are rising for all Arctic nations. Many Arctic countries lack the capacity to assert their sovereignty and to enforce security matters over the area. Non-Arctic countries are also disputing some of the current Arctic-nation's claim to land and border definition. Hence, right now there is somewhat of a security void in this part of the world, where a few nations have a handful of government/military ships with the capability to protect interests and enforce good order. Canada is currently building a fleet of Polar Patrol vessels to be manned and operated by the Canadian Navy. Despite this building strategy, Canada will only have a few ships and limited capability given the size of its territory comprised in the Arctic region. Of greater concern to the polar counties are the unclear aspirations of non-polar countries currently working on building ice-strengthened vessels and icebreakers. Perhaps they only want to be able to protect their interests in the Arctic or in Antarctica. It is hard to predict at this point. Given these safety and security concerns, the only way to enhance both is for Arctic countries to develop a better patrol strategy and to enhance their capabilities. For the past decades, the main focus of the military over the region has been to defend from air threat for such as the one posed by Russian bombers; this required that the air force have great capabilities for air patrol. Now, however, we are witnessing growing sea-based concerns and possible threats. This new reality requires land *and* sea enforcement and military capabilities.

Weather

Weather plays a significant role in any mode of transportation: Clear skies, dry roads and calm seas make for predictable and consistent transportation times and safe delivery statuses in any transport mode. Maritime transportation, however, is known for encountering perhaps the most challenging transportation environment. Most notorious among these challenging environments are such places as the horn of Africa, the Bering Sea and, chief among them, the Arctic. Next we discuss some of the weather characteristics of this region as they relate to maritime transport.

The NSR can be divided into three areas with regard to climate and weather phenomena. The Atlantic Area includes the Barents Sea, western part of the Kara Sea and part of the Arctic basin extending to the north. Frequent storms in winter and dull weather with frequent fogs and precipitation in summer are characteristic for this area. The Siberian Area includes the eastern part of the Kara Sea, Laptev Sea, and the western part of the East Siberian Sea. This area is influenced by the Siberian Low in winter. Air temperatures here tend to be lower than in surrounding areas in winter and higher in summer near the continental coast, although the northern parts of the area remain cool even during summer. The Pacific Area includes the eastern part of the East Siberian Sea and the Chukchi Sea. In winter it is strongly influenced by Pacific weather systems. Air temperature and wind strength is higher, and the amount of precipitation in this area is greater than in the surrounding areas. Summer can be stormy with wide fluctuations in temperatures and periods of dense fog (ABS 2014).

These three main areas are characterized by their own weather patterns, but the following conditions directly influence safe navigation of the NSR. The Polar Regions are notorious for dangerous and severe weather that is often inhospitable for humans, and it can wreak havoc on equipment. In addition to generally cold and windy conditions, these regions are susceptible to low atmospheric pressure areas, Polar Lows, which are severe, rapidly developing weather phenomena that bring strong winds, storm surges and/or heavy snow (KNMI 2015). These storms can come upon mariners and challenge safe travel, particularly in the narrow, shallow straits where visibility and precise course navigation are paramount. Wind is one of the most prevalent forces against precise navigation. With the added hazard of floating icebergs being pushed around by wind, safe ship navigation relies on managing the intense polar winds. Blizzard conditions exist approximately half of the month during June through October creating challenging transit conditions.

Fog and reduced visibility plague many areas of the NSR, particularly during the summer months as temperature differentials between the surface and the air manifest. Reduced visibility, like wind, can severely hamper precision navigation through narrow and shallow passages of the NSR.

Advantages and opportunities

As the marine navigation season/duration increases, the economy of ports along the NSR will in general increase due to economies of density and value-added transportation activities. A longer navigation season will spur more interest from shipping companies and will increase the traffic along the NSR. Khon et al. (2010) estimate that by the middle of the 20-first century NSR Arctic transportation may become competitive to the traditional Europe–Asia routes going through the Suez or Panama Canals.

As the density of ships along the NSR increases, some governments and researchers argue that expenses for icebreaker escort and ice reinforcement for cargo ships will decrease (Stephenson et al. 2013). As the reliability of infrastructure increases and the cost of transit traffic decreases, the commercial imperative of choosing Arctic transportation routes compared to the southern marine routes like the Suez or Panama Canals will become even more attractive (Stephenson et al. 2013). Instead of primarily

serving their local communities, established ports throughout the NSR will begin to benefit from new investments in opportunities from cargo transit differentiation throughout the region.

An emerging opportunity for NSR port and terminal development will require investment in infrastructure and utilization of the Arctic Ocean for trans-shipment. While investing in terminals and in fleets of year-round ice-classed Arctic ships operating across the Arctic Ocean is sizable, these Arctic and ice-worthy ships could be dedicated transportation assets to the NSR and possibly to the NWP as well (Arctic Council 2009). Some countries without any Arctic territories are making such investments. As Arctic waters become more navigable, public, private and academic entities are committing more resources, capital and time into assessing the NSR as a transportation solution and efficient alternative for global trade.

Trade efficiency

Sailing the Arctic to affect intercontinental trade and transport is markedly shorter than traditional routes. Significant cost savings can be realized through shorter transit distances: Either less transit time, slower transit speeds or a combination of both contribute to cost savings for shipping companies. Transport firms can save as much as 40 % in distance traveled by utilizing the NSR as opposed to traditional routing through the Suez Canal. This distance savings equates to time savings which can be reallocated or realized in a number of ways: faster delivery of critical goods; lower required inventory levels; more transport trips for the ship and shipper; and less labor and crew accommodation/feeding cost per trip.

As an alternative to shorter, faster shipping times, transportation companies can also utilize super-slow sailing: They can reduce their speed by the percentage of distance saved (e.g., 40 % less distance=40 % slower speed) and still arrive at the same time. This method of sailing greatly reduces a ship's energy use (fuel consumption is not linear with ship speed). Moreover, super-slow sailing, particularly along the NSR, greatly reduces the potential for disaster resulting from hazards to navigation germane to the Arctic (Humpert and Raspotnik 2012). Lastly, ships utilizing the NSR can avoid costly tolls required to transit the Suez Canal, which we can only expect to increase in the coming decades as both the Suez and Panama Canals reach capacity limits (See: Stephenson et al. 2013). Estimated economical profit of "Europe-Asia transit through the NSR relative to the Suez Canal is…up to 500,000 USD per passage" (Stephenson et al. 2013, p. 765).

Maritime trade opportunities are not solely a function of distance/time. Efficiencies can also be gained by avoiding those trade routes plagued by piracy. Martinez-Zarzosa's 2013 study explored the trade consequences with the adoption of alternative trade routes. They have particularly focused on the variation in maritime distance as a proxy for transport cost and the reduced risk of piracy that would result from adopting the Northern Sea Route instead of the Suez Canal. The conclusion was that the NSR could become a viable alternative once the non-iced season increases and the route is tradable all year long (Martinez-Zarzosa 2013).

An additional study to assess potential economic benefits by Stephenson et al. (2013) utilized a model to look at the relation between ice conditions and ship speed to simulate and analyze ice conditions affecting the ship performance through theses route. The authors' simulation concluded that by the end of the 20-first century it would

be possible to save 15 % in shipping cost by utilizing the NSR in lieu of the current Suez Canal route. This would be contingent on substantial investment in modernizing NSR infrastructure and containerships capable of traversing Arctic waters (Stephenson et al. 2013).

Conclusion

As an emerging transit route option for global maritime shipping, the NSR has long since proven its viability to sustain regional markets and add value to its port communities. While Arctic sea ice reduction is piquing international interest in the NSR regarding transportation and logistics, use of the NSR is not without weighty challenges. The most notable are the lack of comprehensive hydrographic information, narrow and shallow straits, inadequate search and rescue assets and formidable polar lows. Opportunities for maritime transportation include the creation of an Arctic trans-shipment market and efficiencies gained by shorter transit distances, energy reduction, piracy avoidance, etc. As current global trade routes through the Panama and Suez Canals reach capacity, we do not doubt that capital investment into the NSR will increase and it will become an attractive and efficient transportation option for international markets.

One major concern that remains at this time is the lack of capability for patrol as well as response to various incidents that could happen in the NSR or NWP. Most countries having claim to part of the Arctic do not possess the capability to properly respond even in the *best* part of the year. As traffic increases and more ships transit through the contentious space that is the Arctic, it will be essential for countries to not only be able to assert sovereignty but to also respond to incidents that come with shipping. These could include oil spills, medical evacuations and more tragic events such as sinking or fires onboard ships.

Of special concern is that certain countries without claim to territory in such waters are developing strong ice-strengthened military capabilities. One must question what the ambitions of these countries are and, as a result, this should serve as a wakeup call to the numerous Arctic nations delaying their Arctic-capability buildup. It is imperative for the commerce and prosperity of not only Arctic nations, but for other nations benefiting from these new routes, that the development of such routes is done in an orderly manner, as well as policed and monitored by these Arctic nations. For such remote areas, this has to take the form of ice-capable military ships, modern ports and naval bases to provide emergency response capabilities to both civilian and military emergencies. Lastly, while global warming is still being largely debated in the United States, the fact remains that whatever is the cause, the Arctic route is opening fast. It is no longer a hypothetical of *if* vessels could use these routes in masses, but a matter of *when*. Hence, it is imperative that the Arctic nations accelerate capability-buildup in order to not only maintain good order, but to maintain safety and security of this polar region.

References

American Bureau of Shipping (ABS) (2014) Navigating the Northern sea route: status and guidance. Retrieved from http://ww2.eagle.org/content/dam/eagle/publications/2014/NSR_Advisory.pdf

Arctic Council (2009) Arctic marine shipping assessment 2009 report. Retrieved from https://oaarchive.arctic-council.org/handle/11374/54

Assessing U.S. preparedness and response in the Arctic: The opportunities and challenges of increased marine activity: Field Hearing Before the Subcommittee on Oceans, Atmosphere, Fisheries and Coast Guard of the Committee on Commerce, Science and Transportation, United States Senate, 113 Cong. 1 (2013). Retrieved from http://www.gpo.gov/fdsys/pkg/CHRG-113shrg85764/html/CHRG-113shrg85764.htm

Humpert M, Raspotnik A (2012) The future of arctic shipping. port technology international (55th ed.). Retrieved February 15, 2015 from http://www.porttechnology.org/images/uploads/technical_papers/The_future_of_Arctic_shipping.pdf

Johannessen OM, Alexandrov V, Frolov IY, Sandven S, Pettersson LH, Bobylev LP, Kloster K, Smirnov VG, Mironov YU, Babich NG (2006) Remote sensing of sea ice in the Northern sea route: studies and applications (Geophysical sciences series). Springer Science+Business Media, New York

Kendrick L (2014) Map shortcomings could hinder Northern Sea Route growth*cps* Barents Observer. Retrieved from http://barentsobserver.com/en/Arctic/2014/06/map-shortcomings-could-hinder-northern-sea-route-growth-28-06

Khon VC, Mokhov II, Latif M, Semenov VA, Park W (2010) Perspectives of Northern sea route and Northwest passage in the twenty-first century. Clim Chang 100(3–4):757–768. doi:10.1007/s10584-009-9683-2

Kikkert P (2012) Promoting national interests and fostering cooperation: Canada and the development of a polar code. J Marit Law Commer 43(3):319–334

KNMI. Polar low – Meteorological physical background. Retrieved from http://rammb.cira.colostate.edu/wmovl/vrl/tutorials/satmanu-eumetsat/SatManu/CMs/PL/backgr.htm. Accessed 4 Feb 2015

Leonard TJ, Gallo P, Véronneau S (2015) Security challenges in United States sea ports: an overview. J Transp Secur 1–9

Martínez-Zarzoso I (2013) Alternative sea routes: what effects on maritime trade? SAIS Rev Int Aff 33(2):61–74

Mitenkov FM, Yakovlev OA, Polunichev VI, Panov YK, Ruksha VV, Golovinskii SA, Kashka MM (2003) Prospects for using nuclear power systems in commercial ships in northern Russia. At Energy 94(4):211–216. doi:10.1023/A:1024796501183

Northern Sea Route Information Office (NSRIO) (2014) Search and Rescue. Retrieved from http://www.Arctic-lio.com/nsr_searchandrescue

Stephenson SR, Smith LC, Brigham LW, Agnew JA (2013) Projected 21st-century changes to Arctic marine access. Clim Chang 118(3–4):885–899. doi:10.1007/s10584-012-0685-0

U.S. Department of State (2015) Arctic Council. Retrieved from http://www.state.gov/e/oes/ocns/opa/arc/ac/. Accessed on 16 Jan 2015

Véronneau S, Roy J (2014) Security at the source: securing today's critical supply chain networks. J Transp Secur 7(4):359–371