Examining the Maritime Activities and Environmental Effects of The Ice Class Ships

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The Russian Federation has a great advantage in the Arctic Ocean because of its long coastline which also has less sea ice concentration in summer to allow vessels to pass with ease. Due to newly opening polar routes in the Arctic, maritime logistics, port and maritime affairs have become more sensitized for Arctic Council countries. But this increase is coming with various anthropogenic effects on Arctic Environment. Polar Code aims to control, force and advice for ships with many environmental applications to ensure safety. Arctic Council's Arctic Marine Shipping Assessment (AMSA) report emphasizes the increase in vessel traffic in the Arctic due to climate change and eight recommendations were made to take steps for Arctic Environment. Also, the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) working on the same issue. Nevertheless, the Arctic Environment is still vulnerable to increased maritime activity and many more steps including increasing scientific research will be on the agenda.

As a result of this, this study aims to provide the latest overview of the situation to the regional and international lawmakers for the sustainability of Arctic maritime activities and its environmental effects by the ice-class ships within the scope of the polar code with a statistical approach, using the database of the Russian Northern Sea Route Administration (NSRA). However, the uncertain results of the war between Russia and Ukraine could change the Arctic's future different from the results of these study.

Introduction

Global changes in the climate have started to show evident impacts on daily life and the environment. Within this scope, especially in the oceans, there are many critical changes such as reduction of sea ice extents, melting of glaciers, sea-level rise, ocean acidification, carbon capture and storage, migration of animals, increase in ocean temperature and ecosystem change (Capurro et al., 2021). All those changes at sea are also affecting maritime transportation, especially in the Arctic Ocean.

The Arctic Ocean covers many seas and has borders with five different countries namely Canada, Kingdom of Denmark, Norway, the Russian Federation, and the United States of America. The longest coastline of the Arctic Ocean belongs to the Russian Federation. When the size of the

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territory of the Russian Federation was examined, it was seen that 18% of its area is located in the Arctic Region (Yatsenko et. al., 2022). Since the underground and surface resources of this region constitute the largest export goods of the Russian economy, logistics has the most important place in the development of the Russian Arctic (Shestak et. al., 2020). When considering maritime logistics, ports and maritime affairs on the Arctic Ocean have strategic importance (Pahl & Kaiser, 2018). Sea ice loss in the polar regions due to global climate change is mostly experienced in the Arctic Ocean when compared with the Antarctic (Southern) Ocean (Steiner et. al., 2021). The Northern Sea Route (NSR) lies between the Bering Strait and North Cape and it is one of the most important routes in the Arctic Ocean. The NSR has been used with the help of icebreakers since the 1980s, on the Arctic coast of Russia from east to west. Although the NSR and NWP are suitable for maritime transport due to the thinning of the sea ice in summer, fast ice formation is observed which can block the passage of ships, especially in the northern route following the Russian coast (Pastusiak, 2016). According to the modelling studies and international reports mentioned in the IPCC, experts predict that the Arctic Ocean will be an ice-free zone during the summer by the middle of the 21st century due to increasing temperatures (IPCC, 2021).

The first review of Arctic shipping was provided by the "Arctic Council's Arctic Marine Shipping Assessment" (AMSA) using vessel traffic data of the Arctic countries for 2004 (AMSA, 2009). This assessment aimed to identify the vessel traffic in the Arctic and to determine the potential environmental impacts of maritime activities in the region (Gunnarson, 2021). With the establishment of the Russian Northern Sea Route Administration (NSRA) in 2013, studies on maritime traffic along the Russian Arctic coast have increased. Russia determined the definitions of the NSR and its sea borders in national legislation with the NSRA and supported the preparation of the Polar Code (Todorov, 2021). Figure 1 shows the available routes of the NSR, Russian exclusive economic zone limit, Russian territorial waters and other marine boundaries (Brubaker & Ragner, 2010).

Figure 1: Northern Sea Route (Brubaker & Ragner, 2010).

Studies in the literature examining the ship traffic in the Arctic are based on Automatic Identification System (AIS) data. Eguiluz et al. (2016) analysed maritime activities in the Arctic between 2010 and 2014. Eriksen and Olsen (2018) evaluated the cruises that took place in the same years. Similarly, Silber and Adams (2019) studied maritime activities in the Arctic between 2015 and 2017. By analysing the ship traffic data provided by the NSRA, Humpert (2014) evaluated the Arctic shipping for the NSR transit for a season in 2013. Lasserre and Alexeeva (2015) evaluated the transit ship voyages on the NSR by year. Zhang and Meng (2016) examined the maritime activities of ships using NSR between 2009 and 2014. Li and Otsuka (2019) assessed maritime activities between 2013 and 2017. Lasserre et al. (2019) compared the voyages made over the NWP and the NSR. Marchenko (2014) examined the safety of navigation in Arctic waters, sea ice statistics, economic and political predictions within the scope of NSR, as well as evaluating the shipping activity. Moe (2014) discussed the use of NSR in terms of maritime law and made elaborations regarding Russian national legislation. Zhang et al. (2016) examined Arctic sea routes in terms of the economical appropriateness of using NSR for shipping companies. Zhang et al. (2019) stated that the inadequacy of available ship data poses a challenge in conducting risk analyses for NSR transit. Gunnarson (2021) provided an empirical update on studies of ship traffic analysis on the NSR. All of the studies on the ship traffic of the Russian Arctic Region in the literature were based on international transit voyages. Studies carried out based on domestic voyages in Russia are very limited.

Considering the AMSA 2009 report, the increase in ship traffic in the Arctic region due to climate change has revealed the necessity of discussing its effects on the environment. Eight recommendations were made to legislators in the Arctic environment section of the report, and six of these recommendations were revised in 2021, thanks to concrete steps taken by the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) over the past 12 years. However, despite the steps taken such as the 2020 sulphur restriction and ballast treatment, the Arctic Ocean environment is still vulnerable to increased maritime activity due to climate change. Because of that, this study aims to provide suggestions to policymakers for the sustainability of the Arctic maritime region by examining the maritime activities and environmental effects of the ice class ships within the scope of the polar code with statistical methods, using the database of the NSRA.

Sea ice conditions

Winds from North America, Asia and Europe trap sea ice in the Arctic Ocean between 60° and 90° north latitude. There are connections to other seas from only two main parts of the Arctic Ocean. One of them is the Bering Strait and the Pacific Ocean, while the other is the connection between Greenland and the European Continent to the Atlantic Ocean. Since the water temperature in these regions is warmer than that of the Arctic Ocean, when the sea ice drifts to these parts, it melts and forms the ice limits. Sea ice is the main object in the Polar Oceans but it's very dynamic and attracts many scientific research questions such as the different patterns of sea ice in two Polar Regions, the role of the feedback of ice and climate, etc. To find answers to these questions many studies on in-situ, remote sensing and modelling continue (Holland & Kimura, 2016).

Satellites constantly monitor the area covered by the Arctic sea ice and many institutions share various data on an up-to-date basis. However, in these data, the thickness values are not as up-to-date as the extent values. The National Snow and Ice Data Centre (NSIDC) shares daily Arctic Ocean Sea Ice coverage data, both graphically and visually (NSIDC, 2022). Within the scope of the current data, the data of the maximum (NASA, 2021a) sea ice on 21st March and the minimum

(NASA, 2021b) sea ice on 16th September in the Arctic and the extent values according to the months of 2021 is shown in Figure 2.

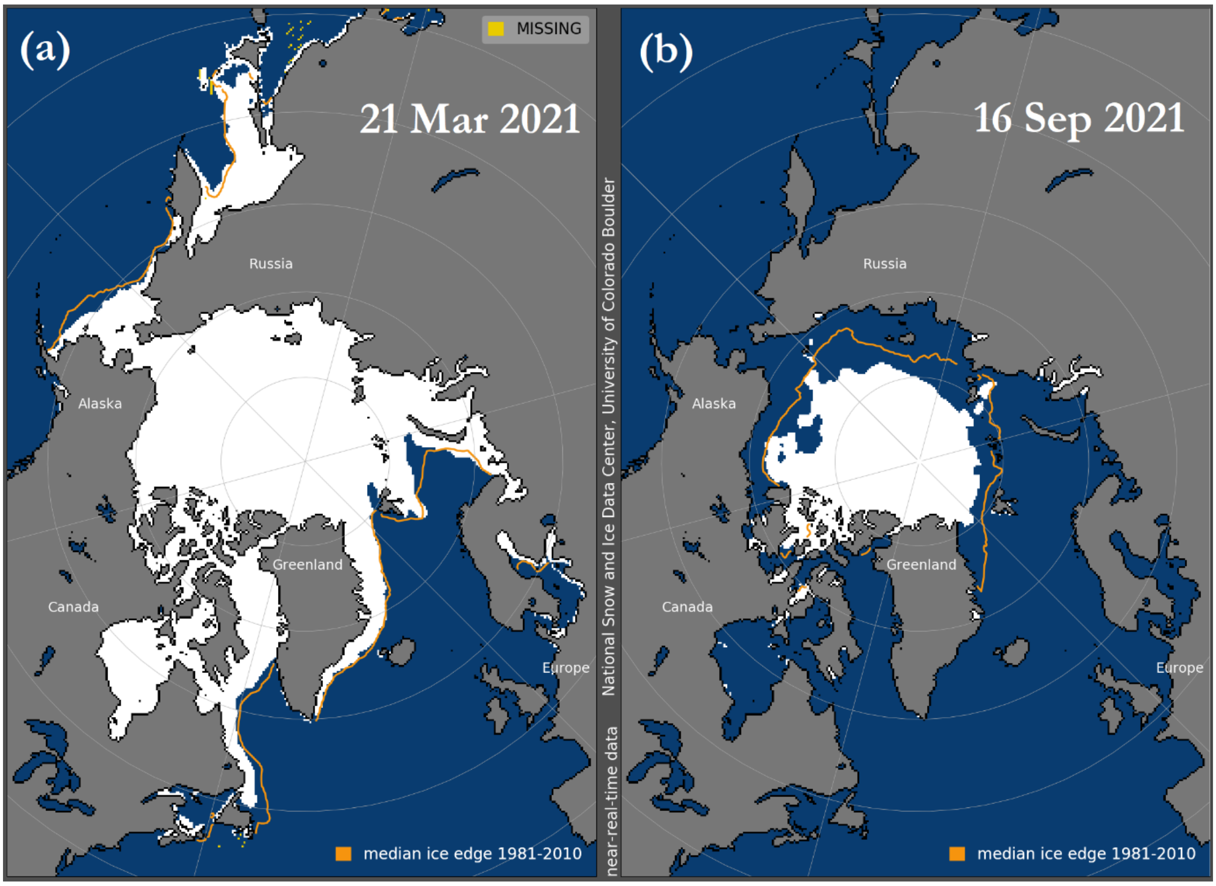

Figure 2: Sea Ice Extents in 2021 (NSIDC, 2022).

When Figure 2 is examined, it is seen that the Arctic sea ice reached its widest extent on March 21, but this level was the lowest winter extent examined since 1981. This scenario shows that sea ice is not freezing enough, and signals that more open seas will be seen as the summer melts increase (NSIDC, 2022). In addition, as seen in the figure, the melting of sea ice in the summer months is quite remarkable.

In the special report (page 7) published by the Intergovernmental Panel on Climate Change (IPCC) for policymakers in 2021, it was emphasized that between 1979-1988 and 2010-2019 Arctic sea ice was melting by 40% in September (maximum melting period / minimum extent) and 10% in March (maximum freezing period / maximum extent), mostly due to the anthropogenic effect. In the same report page 10, the annual average of Arctic Sea Ice between 2011 and 2020 was observed at its lowest level since at least 1850. It is also stated that the extent of sea ice formed in the Arctic in late summer has been the smallest in the last 1000 years. According to the IPCC, many changes in the global climate system are directly related to the increasing global temperatures and show that there will be more frequent droughts, increased precipitation amounts, decreasing snow levels, and increased melting of Arctic sea ice and permafrost in the coming periods. Also, the report expresses that this melting trend provides the basis for the predictions that the Arctic Ocean will have no sea ice in summer in 2050 (IPCC, 2021: 21) which will create many sea ice free conditions for ships in the Arctic.

Sea ice in the Northern Hemisphere, which broke a record with a volume of 0.05 million km^3, is almost twice the volume of ice formed in the Southern Ocean. The average thickness of sea ice in the Arctic Ocean is around 3 meters, while in Antarctica this ratio is between 1 and 1.5 meters (Sandven & Johannessen, 2006). While there is little data on Antarctica on these measurements, sea ice volume measurements in the Arctic Ocean have been made in research with submarines since the 1960s. Nevertheless, these are also insufficient to see the whole picture (Rothrock et al., 1999). In addition to the area covered by the sea ice, its thickness is also important for the ships and ship classes that will interact with the sea ice.

Sea ice, which can spread over an area as large as the surface area of Russia on the Arctic Ocean during the winter months, has been followed almost daily by satellite data since 1978 (Rodrigues, 2008). Since satellites with passive microwave and radar sensors are less affected by conditions such as weather conditions and cloudiness, they enable us to record more data in larger time series than images taken from optical satellites (Parkinson, 2014). Volume information is derived by trying to understand the thickness of the sea ice from the height of the above-water parts of the sea ice, and ICESat (Ice, Cloud, and land Elevation Satellite) satellites were developed especially for this issue and sent to orbit (Zwally & Yi, 2004). Many different technological sensors are used in satellites today, and most of them can take images without being affected by atmospheric conditions. Synthetic Aperture Radar (SAR), an active microwave equipment for sea ice observation, is widely used in this context. In short, SAR images present images with reflections from the sea surface (Wager et al., 2020). However, first-year sea ice and old ice can present similar or dissimilar images in terms of their different physical properties. While the windless sea appears darker, rough sea and sea ice can resemble each other. When the backscatter values taken from the Earth Resources Satellite (ERS) SAR images are examined in the research conducted in the Barents Sea, the newly formed sea ice has almost the same backscatter coefficient as the open and windless sea; while the fresh ice, new ice with crystal flowers and hummock that has lost its smooth surface by deforming has same values equal to rough sea (Sandven et al., 1999). In the light of technological developments, it is important to have expertise in sea ice and to gain experience by confirming some images in terrestrial studies in order to analyse many different satellite data and images, which are created as a result of the use of new satellite sensors and equipment in the development of technology. In this way, sea ice forecast will be more accessible to ships at a more accurate rate. Accurate data is important for ships to save time, protect the environment and predict hazards, especially in the Arctic seas. Nowadays, the sea ice forecasts are reachable from different sources such as the long-term ice forecast published by the Northern Sea Route Administration with the data produced by the Arctic and Antarctic Research Institute of Russia (Moe & Brigham, 2017).

Maritime activity

The list of ships that were permitted to navigate through the NSR between 2016 and 2021 was retrieved from the NSRA database. Centre for High North Logistics (CHNL) information office's data analyses were also used in order to evaluate ice-class ship passages. The effects on the environment of voyages according to the types of ships were analysed using the statistical method (NSRA, 2022).

Datasets were collected to evaluate the annual changes in ice-class ships' voyages across the NSR over a five-year period. Ship data was digitised for annual changes in ship characteristics. Similarly, the number of voyages by years made it possible to assess the environmental impact of ships navigating in the region, especially ice-class ships. These data also enabled the differentiation of transit voyages according to the point of origin and destination.

Types of Ice Class Vessels

Ice class vessels can be divided into three groups: low class (no ice, ice1), medium class (ice2 – arc6) and high class (arc7 – arc9). Low-class vessels may navigate in ice-free waters where the ice concentration is lowest and can sail with an escort during the winter period. On the other hand, medium-class vessels navigate on the NSR at an optimum speed during the summer months and can perform the transit voyage in 15 days. As the higher-class ones are icebreakers, they complete their voyage on the NSR on the fastest route, providing the maximum economic speed both in the summer and winter seasons (Sibul et al., 2022).

Polar Code

Although positive effects have occurred on world maritime trade as a result of the melting sea ice in the Arctic, it should not be ignored that lack of sea ice could lead to various effects and environmental disaster in Arctic (Hungington et. al., 2022). Within the scope of maritime trade, new routes have been opened in the Arctic Region and it is obviously seen that Russia will gain in economic and commercial dimensions as more offshore regions are formed along the northern coasts of Russia. In addition, the largest icebreaker (nuclear powered and diesel-electric) fleet in the world belongs to Russia which will help contribute assistance through icy waters to the passage of commercial vessels (Moe & Brigham, 2017). Navigational safety and economic new trade routes in the Polar Regions are also on the agenda in the summer months when there is no sea ice. When the "Polar Code Regarding Ships Operating in Polar Waters" published by the International Maritime Organization (IMO) is examined, it is seen that rules are set for both polar regions; however, due to commercial reasons, while giving details about the Arctic region, various rules were introduced by ignoring the Southern Ocean conditions. As a result of the Arctic region's creation of a route that provides time and money in intercontinental trade, countries that direct maritime trade such as China have turned the route to the north and started to follow sea ice more closely. In fact, the Chinese call this route the new Polar Silk Road (China's Arctic Policy, 2018; Peng et al., 2022). Studies are also increasing within the scope of the presence of sea ice on these new routes and meteorological forecasts and notifications to sailors. In the study of Wagner et al. (2020), the delivery of sea ice forecasts to the stakeholders in the maritime industry, the shortcomings in the forecasts, satellite sensors and innovations, socio-economic impacts and the needs in the coming years were examined in detail.

On May 15, 2015, the IMO adopted amendments to the International Convention for The Prevention of Pollution from Ships 1973/1978 (MARPOL) annexes to prevent environmental pollution in polar waters (IMO, 2015). Polar Code consists of Part I on maritime safety and Part II, which regulates the protection of the marine environment. Part II prohibits the discharge of oil and harmful liquid substances and the discharge of animal carcasses, as in the MARPOL annexes. There are also restrictions on the discharge of sewage, garbage and food waste. While developing Polar Code, it received support from the Russian maritime industry and Russian scientists. However, since the Russian Arctic fleet is old and its capability to comply with new environmental regulations seems to take long period. As a result, the prohibition of the discharge of oily waste in the Arctic region was opposed for economic reasons. Despite the opposition of the Russian maritime industry, a ban on discharge was implemented and a transitional period was provided for vessels that are constantly in the Arctic (Todorov, 2021).

Environmental Effects & Challenges

Vessel traffic and increasing maritime activity are going to affect the Arctic environment in different ways. These environmental effects could include emissions, Black Carbon (BC) (Zhang, et al., 2019), ballast water (Rosenhaim et al., 2019), oil and gas explorations (Henderson et al., 2016), etc.

According to a study which used a fully coupled Earth-system model (CESM 1.2.2), increasing vessel passage in the Arctic Ocean will reduce the warming by approximately 1°C until 2099 while creating clouds by its sulphate-driven liquid water-cloud formation. (Stephenson et al., 2018). In addition, they stated gas and particulate emissions caused by ships would strongly affect the regions of the Arctic.

Ballast water

Most vessels visiting the Arctic region to load cargo contain ballast water from the last port, as they come from a temperate region. Therefore, although the ballast water contains non-indigenous species released by discharging ballast into Arctic waters, the survival of these species is expected to be low due to the climate of the Arctic Ocean. However, as the Arctic gets warmer, the survival potential of these species will increase (Goldsmit et al., 2018). Ballast Water Management Convention (BWMC) also cover in Arctic Ocean and ratified by all Arctic States. Also, Russia is one of the Lead State & Partner to BWMC and ballast water exchange requirements applying in all Russian Arctic Ports (AMSA, 2017).

Black carbon

Black carbon (BC) which is a result of ship emissions could lead to worse environmental effects such as faster melting sea ices in the Polar Regions. BC emission rates are lower in the Arctic rather than in other seas for now but increasing maritime activity in the vicinity is showing that it is going to grow (Corbett et al., 2010). Many other studies completed and still continue on the impact of BC emissions especially in Arctic due to shipping (Li et. al., 2020; Kong et al., 2021; Chen et. al., 2022).

Oil spill

Drilling operations and tanker voyages in the Arctic are the main causes of risk of oil spills. If the necessary precautions are taken and prepared for emergencies, the potential of the risk will decrease (Heininen et al., 2014). The International Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic, signed under the auspices of the Arctic Council in May 2015, is a useful step toward addressing environmental threats due to oil pollution. The Russian Federation incorporated this agreement into its national law with the Federal Law on the NSR (2012) and the Ministry of Transport Rules for Navigation over the NSR (2013). These laws explain the transit conditions on the Russian Arctic coast and determine who is responsible for environmental accidents that may occur. It also imposes insurance requirements on the owners of the polluting vessels. Costly tariffs were determined as a deterrent for aid and logistics that may be required in an emergency (Dushkova et. al., 2017).

Anthropogenic effect

Numerous marine and industrial pollutants are reported from the Arctic Ocean (Nuttall 2018; Fetisov et. al., 2020; Svavarsson et. al., 2021; Lian et. al., 2022). It is observed that these pollutants increase significantly due to the rise of fossil fuel consumption with the development of maritime activities in the region. Most of them are transported to the Arctic waters by oceanic currents or air currents, including pollutants that are highly harmful to the environment in the Arctic region, such as organochlorines, heavy metals and polycyclic aromatic hydrocarbons (AMAP, 2017). As a result of intensive industrial activities in the Russian Arctic region over the last 80 years, negative effects have occurred on the environment. The anthropogenic impact on the Arctic ecosystems covers 5-10% of the total area of the Russian Arctic. Although the population density is much lower than in many regions, anthropogenic pollution is much higher than in other Arctic areas (Dushkova et. al., 2017).

Sea ice changing; albedo effects

One of the three main factors affecting the energy flow in the climate system of the Earth is the albedo effect. Albedo is defined as the amount of radiation from the Sun reflected from the surface. The Arctic Circle is the region with the highest albedo on the earth's surface after Antarctica. Areas covered with snow or ice have maximum albedo because of their high reflectivity. For this reason, as the sea ice and glacial areas melt, the albedo of the oceans or the soil under this layer decreases day by day (Acker, et al. 2014). Changes in the rates of absorbed, emitted or reflected radiation affect the world's climate system, causing instabilities and disasters in weather events. Today, BC, which is produced as a result of fossil fuel use, can absorb light strongly (Lack et al., 2014). Due to this feature, it is classified as a pollutant that changes the temperature, precipitation frequency, surface albedo and snowfall rates and increases climate change (Pino-Cortés et al., 2021). Urban, industrial, and maritime activities in the Arctic also increase other greenhouse gas emissions, including BC.

Nuclear waste

Nuclear waste is another environmental challenge for the Russian Arctic. About half a century ago, facilities were built in the Russian Arctic region to carry out fuel operations and maintenance of nuclear submarines. Especially around the Kara Sea and the Barents Sea, where the Novaya Zemlya Archipelago is located, radioactive waste and ship parts were buried in the sea (Stepanets et. al., 2005). In addition, nuclear submarines that sank due to maritime accidents also caused serious environmental impacts in the Russian Arctic. Various radioactive wastes buried in the Kara Sea are known, but there are also many unfound objects. Moreover, extensive nuclear bomb tests in the Novaya Zemlya Archipelago, including Barents and the Kara Sea region, led to significant environmental pollution. Between 1955 and 1990, a total of 132 atmospheric, underwater and underground nuclear test explosions were held here (Yakovlev et al., 2021). Even after the cessation of nuclear tests in the archipelago, radiation levels are still above normal reference values. Seabed sediments along the archipelago's coastline revealed an increased content of caesium and plutonium, with high concentration throughout the Barents Sea (Nikitin & Shchukin, 2014).

Results and discussions

Ships navigating along the Russian coast in the NSR make more voyages, especially during the summer season between June and October. The NSRA gives voyage permission to vessels wishing to navigate through the NSR if they apply in advance. According to the duration of the permits, the permitted ship may navigate with more than one permit in the same year, or it may not navigate on the NSR with permission. Therefore, not only the number of ships and the number of permits but also the number of voyages that took place in the NSR were analysed and compared. Table 1 provides the number of ships, permits, voyages and transits that occurred between 2016 and 2021. It is obviously seen that the number of ships, voyages and transits increases each year and that causes increased maritime activity, which could lead to environmental problems for the vulnerable Arctic Ocean. The transit voyages in this table refer to ships coming from a port other than Russia and passing through the NSR to another port without stopping in Russia. The total number of voyages, on the other hand, indicates the ships coming from outside Russia and calling at the Russian port, departing from the Russian port and going to another port abroad or making voyages in the Russian cabotage. All of these ships definitely use the NSR for any part of their voyages.

Table 1: Total voyages of all ships through the NSR including transits.

Year	Ice Class Ships	All Ships	Permission Numbers by NSRA	Voyage	Transits
2016	330	622	718	1705	19
2017	319	591	662	1908	27
2018	268	584	792	2022	27
2019	301	625	799	2694	37
2020	361	716	1014	2905	64
2021	439	882	1229	3225	86

It was determined that emissions are reduced for vessels navigating over the NSR as the distances are much shorter compared to the classical Panama and Suez Canal routes. However, although there is a decrease in emissions, many companies have declared that they will not use the Arctic route due to the possibility of environmental disasters that may occur due to ship accidents, especially oil spills (Gunnarsson and Moe, 2021). But, when the data is examined, it is seen that the voyages increased and accordingly the number of permitted vessels increased proportionally.

Vessels opt for the routes according to the ice-class level and navigation depends on the seasons. Since the ice concentration decreases in the summer season, the shortest alternatives on the NSR are preferred. In the winter season, because the ice conditions are a direct factor in the rotation, the speed of the vessels decreases, and the voyage time and distances increase as well. While low ice-class vessels are directly dependent on ice conditions, high ice-class vessels operate on the NSR regardless of the season. Medium ice-class vessels have the opportunity to sail independently during periods when the ice concentration is relatively moderate, but the voyage may be longer as their speed may be slower depending on the ice. In addition, it may have to navigate a longer route to avoid thicker ice (Sibul et al., 2022). In that case, fuel consumption will also increase due to the rise in distances and the prolongation of the voyage times. Therefore, there will be a negative environmental impact due to emissions from ships in the winter season. Furthermore, air pollution will be observed in the summer season as the ice conditions soften and ship traffic increases. Since the boost in traffic will double the risks of accidents such as oil pollution in the region that will damage the Arctic ecosystem.

Contributing to scientists, international organizations highlight the importance of sea ice, support ongoing research and create budgets for new ones. One of them, the United Nations' Decade of Ocean Science for Sustainable Development, was created by the UN to cover the ten years between 2021 and 2030. In this context, the Arctic and Southern Oceans will also be scrutinized in the upcoming period, especially in the climate-environment-ecosystem as main headings (Ocean Decade, 2022).

While all those shipping and environmental challenges takes place on Arctic, surprisingly the war created a new era in Arctic shipping (Kirchner, 2022). Due to the situation, the logistic operation of maritime trade will change and many new consequences such as increasing Russia and China collaboration will be on the agenda (Vicik, 2022).

Conclusion

This study summarised the latest updates on environmental challenges including policies related to polar shipping, especially on the Russian Arctic coast. Due to decreasing sea ice extent, more ice-class ships will be operating in the near future. However, this will bring new consequences to anthropogenic effects on the Arctic environment. Like many other research projects related to Arctic shipping, there is a need for an integrated analysis of climate and maritime transportation to clarify the relationship between anthropogenic effects on the climate in the Arctic.

While the results of many scientific studies carried out in terrestrial and small areas emphasize that the climate is changing rapidly, the large-scale sea ice change scenarios mentioned in this section show that ship traffic will increase especially in the Arctic. Under the scope of the Ocean Decade studies carried out by the UN, the importance of the oceans in the polar regions will be revealed to a great extent, and it can be predicted that sea ice research will further increase. There is a need to carry out sea ice studies and to increase measurement stations such as buoys, especially in the Polar Regions where people cannot make in situ measurements in winter, with autonomous systems to improve maritime trade. To sum up, the Polar Regions will be more on the agenda in the future with their unique and pure environment.

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