Proceedings of the 26th International Conference on
Port and Ocean Engineering under Arctic Conditions
June 14-18, 2021, Moscow, Russia

Investigation of large-tonnage vessels routes in water area of the Northern Sea Route

Kristina Isaulova[1]

[1]Admiral Makarov State University of Maritime and Inland Shipping, Saint-Petersburg, Russia

ABSTRACT

The research is devoted to the description of shipping routes in the eastern sector of the Northern Sea Route, which includes the waters of the Laptev Sea and the East Siberian Sea. In contrast to the Kara Sea, where there are stable routes along which sea cargo transportation is carried out in the mode of year-round navigation, navigation in the eastern sector is mainly carried out in the summer and autumn navigation period. The main reasons for limiting the time of the navigation period are severe ice conditions and an abundance of shallow water areas. In the Laptev Sea water area, more than 70% of the area is occupied by areas with depths less than 30 m, and in the East Siberian Sea the share of such areas exceeds 85%. In the conditions of vast shallow water and difficult ice conditions, the use of large-tonnage vessels with a high class of ice reinforcement, as well as powerful icebreakers, to ensure coastal navigation is difficult. Prospects for year-round navigation in the eastern sector are associated with high-latitude and polar routes passing through areas with relatively great depths. The implementation of these projects involves the construction of super-powerful icebreakers capable of breaking 4-meter ice, as well as conducting an area survey of the bottom topography in order to determine safe promising routes for transport vessels of the YamalMax and AfraMax class. The estimation of the time for performing areal surveys of high-latitude routes, which meets the requirements of the S-44 standard of the International Hydrographic Organization, for the survey of the bottom relief in areas, navigation of vessels with the minimum allowable water supply under the keel, is carried out. Recommendations for optimizing the survey plan for promising routes are formulated.

KEY WORDS: Northern Sea Route; Hydrographic knowledge; Route deviation; Lateral deviation; Geoinformation modeling.

INTRODUCTION

The development of the Northern Sea Route (NSR) as a new Arctic transport route is a promising project. The NSR is the shortest route for the delivery of goods from Europe to the countries of the Arctic Pacific region. There are a number of advantages over the southern route through the Suez Canal, including: shorter distance; lack of queues and payment for the passage; remoteness from areas characterized by the presence of sea piracy. Since 2009, the NSR has been actively developing. Currently, the cargo turnover in the water area of the NSR is increasing annually. According to data from Grigoryev, M., (2020) the number of transit passages is increasing. So, in the period from 2009 to 2020. freight turnover increased from 20 thousand tons to 31.5 million tons (official data from the NSR Administration, 2021). Figure 1 shows the data of cargo transportation along the NSR in the period from 2009 to

2020.

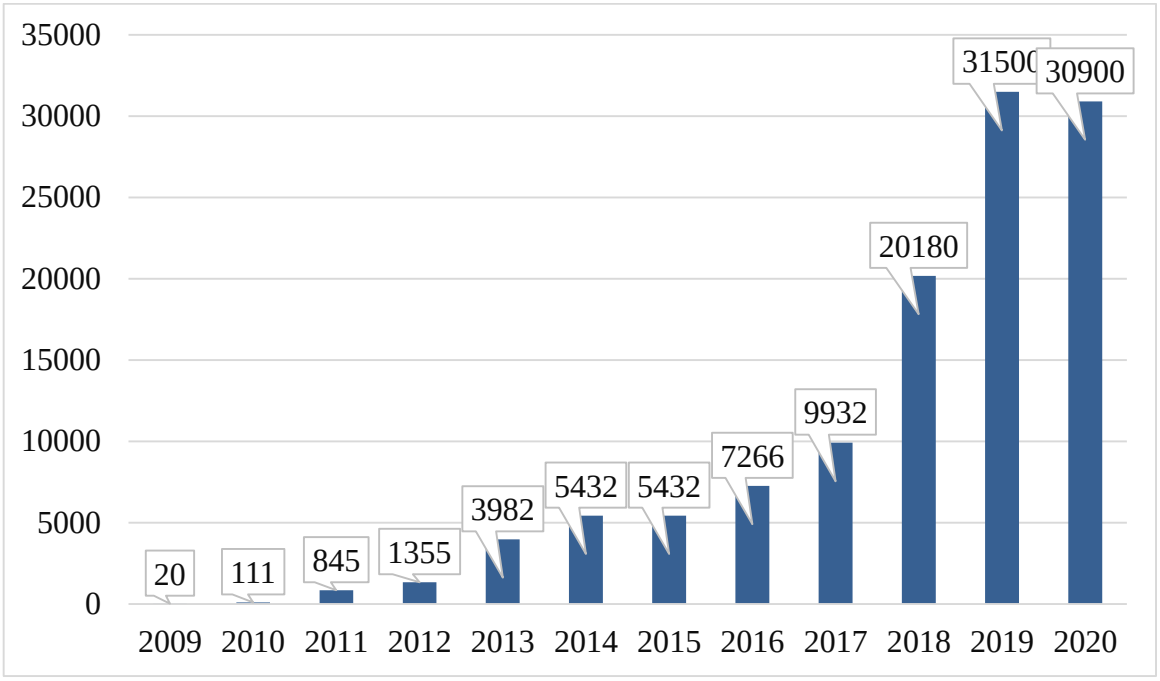

Figure 1. The volume of cargo transportation in the water area of the NSR over the last 10 years (in thousands of tons)

In the southwestern part of the Kara Sea, there has been year-round navigation for more than 10 years, these are the regions of the Ob Bay and the Yenisei river. Navigation conditions in the eastern sector of the NSR are less favorable than in the western sector. The water area of the NSR in the eastern sector is characterized by difficult hydrometeorological (Sharonov, 2018) conditions and an abundance of shallow water areas, as well as areas with insufficient knowledge of the seabed topography (Afonin, 2017). But despite the listed features, the prospects for the development of shipping in the seas of the eastern sector began to appear clearly. The prerequisite was the reconstruction of the Pevek port, which became the first deep-water port in the eastern sector, capable of receiving ships with a draft of up to 13 meters (official data from the PMA Administration, 2021). According to the plan for the development of the infrastructure of the Northern Sea Route, the modernization of existing and construction of new hydrographic vessels of the ice class Ice3 and Arc7 will be carried out. It is also planned annually to ensure the operation of navigation equipment, the development of the infrastructure of the GLONASS/GPS control segment and the survey of the bottom relief. One of the decisive factors in the development of the NSR is the presence of specialized self-propelled vessels designed to overcome ice. This applies to the eastern sector of the NSR, since it is in this area that severe ice conditions are noted. The icebreakers available today are capable of breaking through ice no more than three meters thick. As a rule, only nuclear-powered icebreakers are suitable for transit flights. In 2020, 21 icebreakers, of which 4 nuclear-powered ones received work permits from the Northern Sea Route Administration (official data from the NSR Administration, 2021). In the near future the icebreakers Yamal, Taimyr, Vaigach will run out of service, but they will be replaced by new icebreakers Arktika, Siberia, and Ural. The bulk of all cargo in the NSR is transported by heavy-tonnage vessels (Dobrodeev, 2020). These are gas carriers of the YamalMax project, container ships of the Norilsk Nickel project, tankers of the 42K Artic Shuttle Tanker project. The draft of the vessels is within the range of 9.5–11.8 m. The construction of new large-tonnage vessels and new nuclear-powered icebreakers with a large draft has led to the need to

carry out hydrographic work throughout the entire water area of the NSR. The current level of hydrographic knowledge of the water area of the eastern sector of the NSR does not meet the requirements of the standards of the International Hydrographic Organization (IHO S-57, 2000). The standards are adopted for surveying the seabed relief in the navigation areas of ships with an extremely small safe water supply under the keel (Zhao, 2016). To eliminate this discrepancy, all areas along which the routes of large-tonnage vessels pass must be surveyed with high accuracy and detail. This will ensure that underwater obstacles of up to 1 meter are detected and plotted on nautical charts.

METHODS AND MATERIALS

The area of the seas within the borders of the NSR is more than 3 million 500 thousand square kilometers. To ensure hydrographic survey with an inter-haul distance of no more than 250 m, it is necessary to carry out 12 million kilometers of linear measurement. It is also necessary to conduct an areal survey of the bottom relief. Then, the total volume will be more than a million linear kilometers, which matches with data from Peresypkin, V. (2007). Taking into account the hydrometeorological features of the navigation areas and an insignificant navigation period, one hydrographic vessel can survey no more than 15–20 thousand linear kilometers per period. This performance requires the use of more than 10 survey vessels. The vessels will be surveying the seabed relief for several decades. These measures will allow to find areas, the characteristics of which will allow them to equip new deep-water routes for shipping. This will increase the hydrographic knowledge of the NSR water area to the current level, which will meet international standards. The network of navigable routes located in the water area of the NSR is capable of providing safe navigation for ships whose draft does not exceed 6 m. The use of icebreakers for year-round navigation in such waters is difficult. Before starting the design of shipping routes, it is necessary to analyze both the water area itself and the fleet. There are a number of factors that influence the design of shipping lanes:

- The study of the bottom relief, as well as its provision with cartographic materials;
- Value of limiting depths in ports and on approaches to them;
- Characteristics of the tightness of the water area;
- Control of the reliability and reliability of determining the position of the vessel;
- Ice conditions, taking into account both climatic and seasonal changes;
- Distance to the Marine Rescue Coordination Center.

In the water area of the NSR, the bottom topography survey is carried out in several stages. At the first stage, routes are surveyed in a strip with a width of 2 km. At the second stage, the width of the survey swath will be increased to 10 km. Subsequently, the survey area will be further increased. The exit of the vessel outside the surveyed strip is associated with its possible landing on an unknown aground (Korolev, 2017). The data on the distribution of depths obtained by Tezikov A. (2020) indicate that the area of the Laptev Sea and the East Siberian Sea with depths less than 20 m exceeds 50%. The area of such sites in the Kara Sea is less than 9%, and in the Chukchi Sea - 1%. Thus, the risk of accidents associated with ships touching the ground and grounding in the Laptev and East Siberian seas is higher than in the Kara and Chukov seas. The choice of the design width of the survey strip, equal to 2 or 10 km, is due to the simplicity of planning hydrographic works and the need to quickly obtain information about depths along all recommended routes. However, the design survey lane width does not take into account the actual vessel traffic lane width. In this work, we used data on the movement of ships, which were obtained using geoinformation technologies (Ol'khovik, 2018). The technology makes it possible to determine the location of the vessel with a given discreteness, to assess the change in the total number of vessels in any part of

the NSR water area at a selected time. Also, geoinformation modeling technologies allow you to fix the deviation of the position of the vessels relative to the recommended routes.

RESULTS

The recommended routes in the water area of the NSR mainly pass through shallow areas of the Arctic seas, surrounded by areas, the bottom topography of which is not well studied hydrographically. The routes pass through the open part of the Kara Sea, the Laptev Sea, the East Siberian and Chukchi Sea, as well as through the straits connecting them. Separate routes run north of the island. Novaya Zemlya, Severnaya Zemlya archipelago and the Novosibirsk Islands archipelago. The location of the recommended routes is influenced by the season, the hydrographic features of each area, as well as the type of vessel carrying a particular cargo. But the main factor for choosing a sailing route in a certain area or in the entire water area of the NSR is the peculiarities of the distribution and state of ice fields. For navigation in the water area of the NSR, three routes are used: coastal, traditional and high-latitude. (Peresypkin, 2007). The coastal route runs along the mainland coast of the Arctic seas at a line-of-sight distance, which provides vessels with relatively shallow draft with the ability to determine their position using coastal beacons. The high-latitude alignment includes two main routes: a primary and an alternative high-latitude alignment. The alternate alignment runs north of the main high-latitude alignment. The undoubted advantage is that it passes through areas with great depths. But the route is blocked by long-term ice massifs, which limits the possibilities of its use for navigation. Recommended routes in the central and northern part of the Laptev Sea pass through the areas where the survey was carried out in detail 8000 m. In the East Siberian Sea, the recommended routes pass in the area where the bottom topography was surveyed with an inter-haul distance of 1000 m. The scheme of recommended routes in the eastern part of the NSR is shown in Figure 2. The recommended routes on the scheme are highlighted in green. The solid lines mark the sections of the recommended routes surveyed, the dashed lines mark the promising routes on which the areal survey is planned to be carried out. Curved lines mark the trajectories of large-tonnage vessels, built according to the data received from the automatic identification system (AIS).

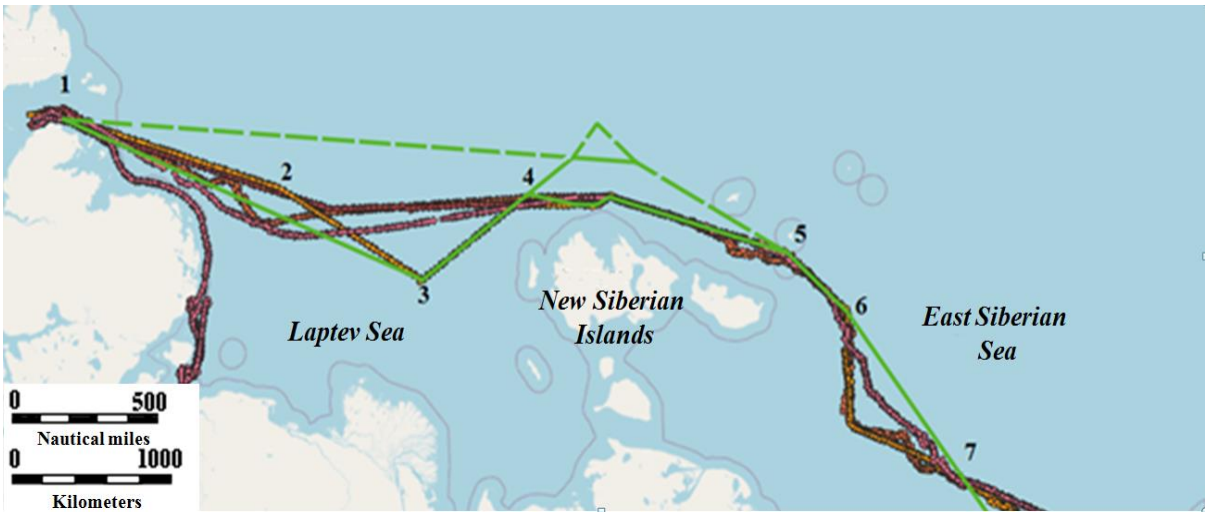

Figure 2. The scheme of recommended routes (green dashed line) for large-capacity vessels, divided into research sections (numbers)

The distribution of the total number of ships operating in the western and eastern sectors is different. In the winter navigation of 2020, an average of 35 vessels were operating in the

western sector every month, while in the eastern sector there was no navigation. During summer navigation, there is a significant increase in the number of ships due to the attraction of ships without Arctic reinforcements. In the western sector, on average, 145 vessels were operating, in the eastern sector - 45 vessels. The change in the number of ships in the eastern sector is characterized by a pronounced seasonal character. The density of the fleet flows depends on the daily number of vessels present in the water area of the NSR. The maximum density of the fleet in the eastern sector is observed from mid-July to early November. In the rest of the year, the rate decreases. In the Eastern Sector, the average daily number of ships in 2020 reaches its maximum value in September - 59 vessels. In the winter-spring period, there is no shipping, which corresponds to a zero flow density. The lowest flux density is noted in the Chukchi Sea, due to the absence of river and sea ports. In the period from August to September 2020, more than 50 motor ships operate daily in the waters of the Laptev and East Siberian Seas. In August and October, the flux density in the Laptev Sea exceeded the flux density in the East Siberian Sea, in which in November, on average, 7 vessels were operating, and in the other seas the fleet was practically absent. The use of geoinformation technologies makes it possible to obtain not only generalized characteristics of sea traffic flows, but also to determine the amount of lateral deviations of vessels from the recommended routes. The procedure for determining the lateral deviations of the trajectory of large-tonnage vessels from the recommended routes includes the following steps:

- Vessel identification;
- Identification of the navigation area of vessels;
- Selection of the time interval for registering information about the position of vessels;
- Creation of recommended routes on the marine electronic map;
- Building the trajectory of the movement of vessels;
- Measurement of deviations of trajectories of vessels from the recommended routes;
- Analysis of the received data;
- Development of recommendations on the use of recommended routes for navigation of large-tonnage vessels.

The results of measuring the lateral deviations of the trajectory of large-tonnage vessels from the recommended routes in the eastern sector of the NSR are shown in Table 1. The results are systematized by months, indicating the mean values of lateral deviations in nautical miles.

Table 1. Lateral deviations of the trajectory of large-tonnage vessels from the recommended ships routes

Month	Laptev sea		East-Siberian Sea		Chukchi Sea (Long Strait)
	Western part, section 1–2, miles	Eastern part, section 2-4, miles	Western part, section 6-7, miles	Eastern, section 7-8, miles	Section 8-9, miles
July	8	50	21.5	27.5	10.5
August	24	75	15	23.5	13.5
September	14	65	15	50	14.5
October	12	67.5	38	52.5	10.5
November	6	75	42	70	16

The leg numbers in Table 1 correspond to the point numbers shown in Figure 2. For leg 1-2 in

July 2019, the mean lateral deviation was 8 miles. In August, the value of lateral deviations increased and then amounted to: in August up to 24 miles, in September up to 14 miles, in October up to 12 miles. In November, lateral deviations were reduced to 6 miles. In section 2–4, most large-tonnage vessels run between the main and alternative high-latitude routes, and only a small part along the main route. In this section, the magnitude of lateral deviations is practically constant throughout the summer navigation and is within 67 miles. Routes in the East Siberian Sea in sections 6-7 and 7-8 also deviate significantly from the recommended routes. In section 6–7, the trajectories of some of the vessels pass along the main high-latitude route, the trajectories of the other part of the vessels follow an alternative route. From August to September 2019, the movement of vessels was carried out both along the main and along the alternative route. From October to November, vessels in section 6–7 cruised only along the main route, during this period the lateral deviations averaged 40 miles. Lateral deviations from the recommended route are 25 miles for Segment 7-8 from July to August, while the average is 58 miles from September to October. In the Chukchi Sea, in section 8–9, the deviations range from 10.5 to 16 miles. In some areas, vessels deviate from the recommended routes for a considerable distance. At the same time, during the winter navigation period, the line of the ships' movement coincides with the northern boundary of the fast ice edge. It is known that during the cold period of the year, from October to May, fast ice is established and preserved along the Arctic coast in the main navigable straits, with the exception of the Kara Vorota, Long and Beringov straits. Along its edge, solder openings are formed. The ice-free track during this period is usually used for the passage of ships. The use of high-latitude routes is difficult, since the northern part of the high-latitude routes is covered with thick ice, while the southern part runs at shallow depths, and cannot be used because of landfast ice. For this reason, the navigation of large-tonnage vessels at the beginning of the winter navigation period is carried out along the central route passing through the Sannikov Strait with a limiting depth of 12.8 m. The data obtained in the analysis of the lateral deviations of vessels, allow us to judge the width of the traffic lane of vessels. In the western part of the Laptev Sea, the minimum traffic lane width is 14 miles, in the eastern part - 15 miles. In the western part of the East Siberian Sea, the minimum width of the traffic lane is 35 miles, in the eastern part - 15 miles, in the Chukchi Sea (Long Strait) - 7 miles. The maximum lane width for vessels in the Laptev Sea reaches 34 miles in November, in the East Siberian Sea - 105 miles in August, in the Chukchi Sea - 25 miles in October. The actual trajectories of the movement of large-tonnage vessels in the summer-autumn navigation period of 2019 in some areas do not coincide with the recommended routes on which the areal survey was carried out. This is especially evident in the Laptev Sea in the area between points 2 and 4, as well as in the East Siberian Sea between points 7 and 8, where the deviation of the trajectory of large-tonnage vessels from the recommended routes reaches several tens of miles. It can be assumed that the position of the recommended routes on nautical navigational charts requires significant adjustments. It is also necessary to adjust the plan for conducting an areal survey of the water area, which is advisable to bring it in line with the actual routes of movement of vessels and the actual width of the strip of their movement. The width of the ship traffic lane in the entire water area of the eastern sector of the NSR is much more than 2 km and is of a variable nature.

CONCLUSIONS

Currently, in the eastern sector of the NSR, during the winter navigation, ships are sailing in an experimental mode under favorable ice conditions. The shipping routes of the Eastern Sector are used mainly in the summer-autumn period, from July to November. Changes in the speed regimes of ships in ice conditions have been sufficiently studied for the water area of

the Kara Sea (Ol'khovik, 2019), but such data are still insufficient for the eastern sector. Nevertheless, it can be assumed that the routes of movement of vessels when navigating in ice during the winter navigation period will differ significantly from the trajectory of movement of transport vessels during the summer navigation, therefore, this circumstance should be taken into account when planning future sea operations. The plan for carrying out hydrographic works in the Eastern sector of the NSR water area needs to be adjusted based on the accumulated experience of operating large-tonnage vessels. Areas where additional areal surveys are required include water areas with depths of less than 20-30 m, as well as areas in which information about the surrounding depths was obtained from the results of route or systematic measurements performed with a detail of 2000 m in shallow water areas.

ACKNOWLEDGEMENTS

The author expresses his gratitude to his scientific advisor, Professor Alexander Tezikov, for valuable advice in planning and carrying out research and for recommendations on the design of the article.

REFERENCES

Afonin, A., Tezikov, A., Ol'khovik, E., 2017. Methods development for assessing sea depth on the Northern Sea Route depending on the recording of hydrographical relief details. *In Proceedings of the International Conference on Port and Ocean Engineering Under Arctic Conditions*, p.050.

Grigoryev, M.N., 2020. Development of Transit Potential of the Northern Sea Route. *Outlines of global transformations: politics, economics, law*, 12(5), pp.109–129.

Dobrodeev, A.A., Sazonov, K.E., 2020. Motion of heavy-tonnage vessels in the ice drift conditions. *Arctic: Ecology and Economy*, (2(38)), pp.68–76.

Dobrodeev, A.A., Sazonov, K.E. 2019, Ice resistance calculation method for a ship sailing via brash ice channel, *Proceedings of the International Conference on Port and Ocean Engineering under Arctic Conditions*, p.014.

International Hydrographic Bureau 2000, IHO Transfer Standard for Digital Hydrographic Data (Special Publication No. S-57), Edition 3.1, International Hydrographic Bureau, Monaco.

Korolev, I.J., 2017. Verification of methods for assessment of the permissible vessel variation from the high-latitude Northern Sea Route. *Vestnik Gosudarstvennogo universiteta morskogo i rechnogo flota imeni admirala S. O. Makarova*, 9(1), pp.88–94.

Northern Sea Route Administration (NSRA), [Online], (Updated March 12, 2021), 2021. Available at: www.nsra.ru/en/ [Accessed 12 March 2021].

Ol'khovik, E., 2018. Geoinformation system use for transportations planning in water area of Northern Sea Route. *IOP Conference Series: Earth and Environmental Science*, 194, p.072010.

Ol'khovik, E., 2019. Study of changes of vessel's speed in ice conditions on the Northern Sea Route. *IOP Conference Series: Earth and Environmental Science*, 378, p.012096.

Peresypkin, V.I., 2007. The future of the Northern Sea Route. *Transport of the Russian Federation*, 11, pp. 12-17.

Primorsky Territory and Eastern Arctic Marine Port Administration (PMA), (Updated March 17, 2021), 2021. Available at: http://pma.ru/#firstPage [Accessed 17 March 2021].

Sharonov, A.Y. et al., 2018. The problem of hydrometeorological maintenance of year-round navigation in the East Siberian sea. *Vestnik Gosudarstvennogo universiteta morskogo i rechnogo flota imeni admirala S. O. Makarova*, 10(1), pp.170–182.

Tezikov A.L. et al., 2018. Studying the factors affecting the duration of navigation in the Northern Sea Route water area. *Vestnik Gosudarstvennogo universiteta morskogo i rechnogo flota imeni admirala S. O. Makarova*, 12(4), pp.734–744.

Zhao, H.Hu, 2016. Study on Economic Evaluation of the Northern Sea Route: Taking the Voyage of Yong Sheng as an Example. *Transportation Research Record: Journal of the Transportation Research Board*, 2549, pp.78-85.