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INDUSTRY PROBLEMS

Analysis of Transportation by Mixed-Type Ships along Siberian Rivers Using the Routes of the Northern Sea Route

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Abstract—The article examines transportation by mixed river–sea navigation ships connecting the Northern Sea Route (NSR) and the Siberian rivers—Ob, Yenisei, Khatanga, Anabar, Olenek, Lena, Yana, Indigirka and Kolyma for the period 2018–2021. The contribution of such transportation to the total cargo turnover of the Northern Sea Route has been studied. It has been shown that against the backdrop of overall growing shipping activity in the NSR waters, the volume of transported cargo and the share of river–sea cruises are systematically decreasing. An analysis of the main factors influencing the development of the identified negative trend was carried out. The age of the ships, their ice class, shipping activity on specific rivers, and the possibility of using rivers for the delivery of goods were studied.

Keywords: river cargo transportation, Siberian rivers, mixed river–sea navigation ships, Northern Sea Route

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Introduction. Siberian rivers are important shipping arteries connecting the Northern Sea Route (NSR) and ports within the continent. Despite the seasonality of shipping, today transport routes, including the use of river freight transport, are the main ones for delivering national economy cargo to the most inaccessible corners of the country. As part of the so-called "northern delivery," a variety of types of cargo are delivered along the rivers—food, building materials, fuel and energy products, bulk cargo and others [1, 2]. Rivers are also used for the delivery of project cargo and the export of finished products from enterprises operating in eastern and western Siberia.

In this regard, mixed river–sea navigation ships, capable of transporting cargo both along rivers and along the NSR, seem particularly promising. When using such ships, there is no need to transship cargo at estuary ports onto large sea ships, which saves time and resources for cargo delivery. At relatively short distances, mixed-type ships achieve better economic performance. Thus, according to [3], with the same operational indicators of use, the cost of transportation in mixed navigation ships is reduced by 90%.

The use of mixed river–sea navigation ships in a number of European countries has a long history. According to the thematic report on river–sea transport presented by the Central Commission for the Navigation of the Rhine [4], as of 2020, the total volume of river–sea transport in the EU is about 64 million t, the leader is the United Kingdom with 47.6 million t. The main users of transportation by mixed-type ships are the metallurgical and forestry industries, oil and gas and agricultural sectors.

At the same time, the Federal State Statistics Service of the Russian Federation (Rosstat) does not keep separate records of cargo turnover by mixed river–sea ships, and since 2015 it has excluded such transportation from the total cargo turnover of sea transport by type of navigation and takes them into account in cargo turnover inland water transport [5].

The paper [3] reports that in the Russian Federation, about 870 river–sea ships operate in the waters of various sea basins, calling annually at approximately 150 ports of 44 countries, as well as carrying out deliveries to the regions of the Far North. In the Russian Federation, the freight turnover of river–sea transportation is within 25 million t. According to data [6], the total freight traffic of the Ob–Irtysh and Yenisei basins in 2014 amounted to 15.6 million t, which is five to seven times less than the volume of transportation achieved in the 1980s. The article by Shcherbanin [7] provides a systematic analysis of cargo transportation along inland waterways, including Siberian rivers, and shows the prospect of their use for enterprises in the oil and gas sector. According to the author, in the 1980s, up to 40 million t of cargo were transported by river transport along the Ob alone per year in a northern direction, and in 2015, only 5.4 million t.

In the paper of Degteva [8], a comparative analysis of the volume of cargo transportation of river shipping companies operating on inland waterways at approaches to the NSR is performed, and also the

prospects for increasing the total volume of cargo transportation by river–sea ships is assessed. The author has identified a tendency to increase the use of inland water transport in the Northern Sea Route areas and established the existence of an existing potential reserve of possible cargo transportation using mixed-type ships. It was established that for the period 2013–2018, the number of river ships on the NSR increased by 70%.

The article by Gunnarsson [9], devoted to trends in the development of shipping along the NSR, notes its extremely high strategic and economic importance for the Arctic territories located along the inland waterways of Russia, which depend on river transport. The author believes that inland navigation along the NSR, taking into account the inclusion of the potential of rivers, can play a significant role in the future socio-economic development of remote regions of Russia. It is also noted [10] that under the conditions of sanctions, reducing operational risks in the extractive industries of Russia can be achieved through the development of transportation from large rivers to seaports.

In general, the scientific literature contains single studies devoted to the issues discussed in the article. This article makes an attempt to analyze and forecast the dynamics of cargo transportation by mixed river–sea navigation ships along the routes of Siberian rivers and the NSR.

Research methods. This paper examines cruises that were made in 2018–2021 in the waters of the Northern Sea Route and the Ob, Yenisei, Khatanga, Anabar, Olenek, Lena, Yana, Indigirka and Kolyma rivers, as part of the general NSR traffic (Fig. 1).

Statistical information for this study is taken from the following sources:

1) Database of shipping along the NSR of the Information Office of the Centre for High North Logistics (Murmansk).[1] The data contains information about the cruises of ships participating in navigation along the NSR. The information is based on real-time global position data for various types of ships, provided by Spire Maritime's proprietary satellite platform.[2]

2) Port State Control Information System: module "Registration of ship calls and departures in seaports of the Russian Federation,"[3] which contains the main characteristics of ships, such as a unique identification number, type of ship, flag, size data, information about the shipowner/operator.

3) Website of the NSR Administration[4] was used to determine the list of ships operating on the routes of interest. The information was taken from daily reports on the movement of ships on the approaches to the water area and in the NSR water area. The reports also provided information about the status of the ship's movement/operation as of the date of the report (for example, the ship is drifting, waiting for an icebreaker, moving towards some object in the water area, etc.). In addition, the NSR administration website was used to obtain information about the ice class, the permitted navigation route in accordance with the ship's ice class, its draft and navigation period, as well as information about the shipowner/operator, which is contained in the issued permits for navigation along the NSR.

4) Clarksons Research Digital Platform[5] and MarineTraffic system,[6] as well as the base of the Russian Maritime Register of Shipping[7] were used to obtain additional information on ship characteristics and shipping companies.

Cruises of ships that do not have an automatic identification system (AIS) were not taken into account in the statistical data and in the above analysis. The use of AIS equipment is regulated by the SOLAS Convention, according to which passenger ships must be equipped with an automatic identification system, regardless of size, ships with a gross tonnage of 300 register tons or more that carry out international cruises, ships with a gross tonnage of 500 register tons or more that do not carry out international cruises. In the case of non-self-propelled barges, the AIS signal is received from a tug that propels the barge, the registered tonnage of which remains unknown. Therefore, it seems impossible to estimate the amount of cargo transported by nonpropelled transport using AIS data.

In the study, one cruise is considered to be the movement of a ship between two ports of any water area, namely, leaving one port and calling at another port. The concept of "river–sea cruise" means: leaving a river port on one river, passing by sea and entering a port on another river; leaving one river port and entering a seaport; exit from a river port to another water area without entering the port (research ships and supply ships). At the same time, when analyzing the contribution of each cruise to the cargo turnover of a particular port, it was assumed that the ship operates in two ports in one cruise—a port of departure (loading) and a port of destination (unloading). If in the transportation under consideration the destination or departure point is a seaport, then from such a cruise only the operation of the river port is taken into account (Fig. 2).

Research results. Analysis of total cargo turnover in 2020–2021 on the Northern Sea Route showed that the share of river–sea transportation in it is extremely small (Table 1). Thus, in 2020, it amounted to only 1.03% of the total cargo turnover of the NSR, and in 2021, it decreased to 0.83%. The reduction was noted not only

[1] https://arctic-lio.com.
[2] https://insights.spire.com.
[3] https://portcall.marinet.ru.
[4] https://nsra.ru.
[5] https://clarksons.net.
[6] https://marinetraffic.com.
[7] https://rs-class.org.

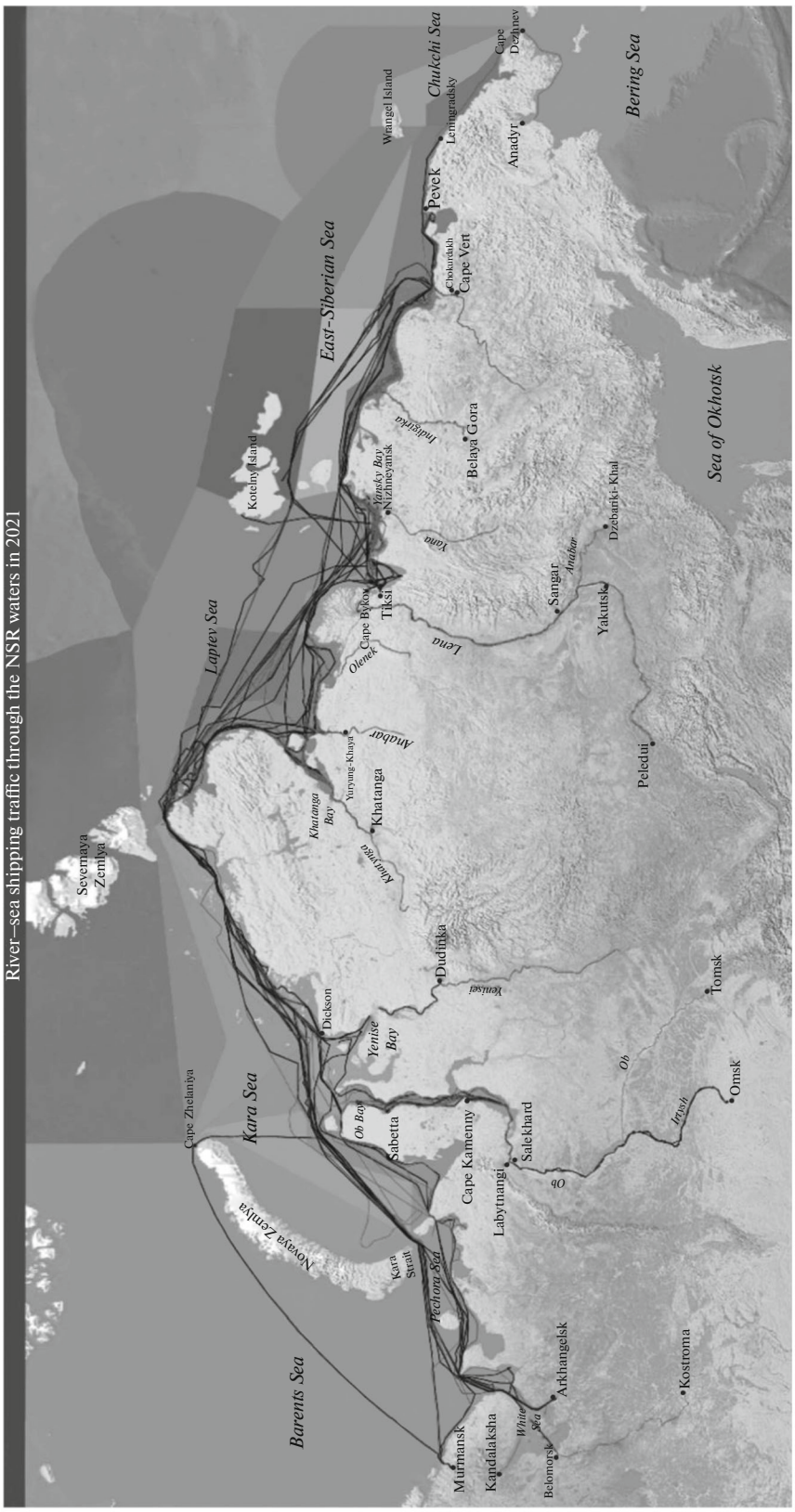

Fig. 1. Geography of cruises performed by mixed river–sea navigation ships for 2018–2021.

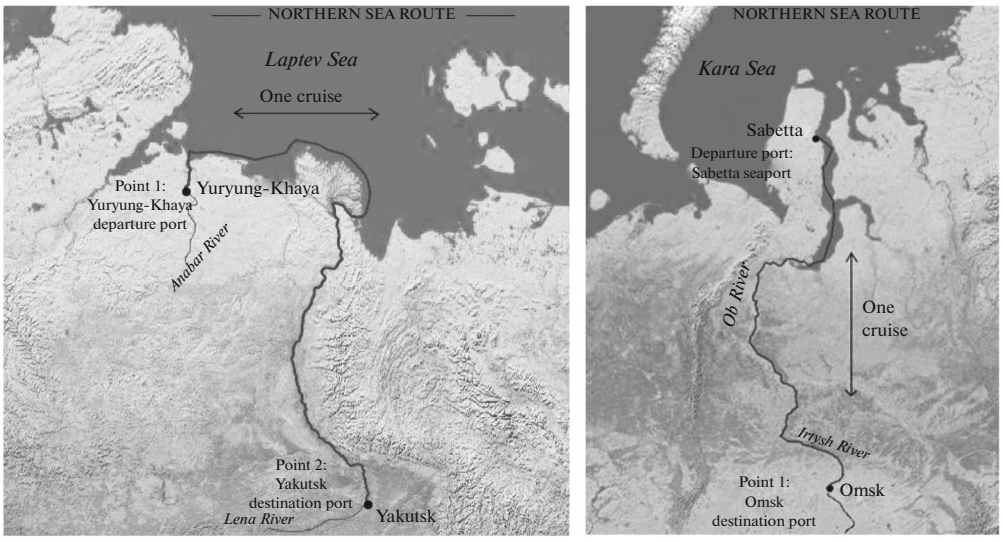

Fig. 2. Features of accounting for ship cruises and ports/port points for rivers (and entries into rivers).

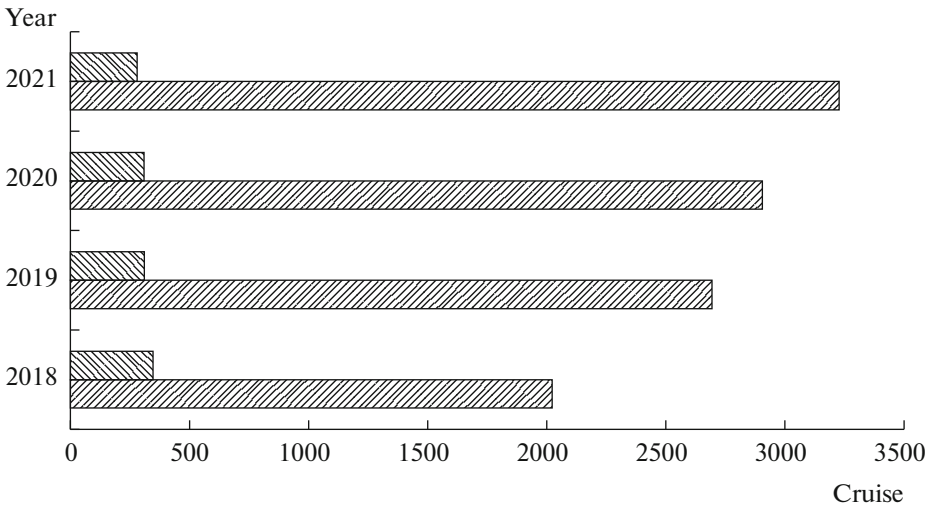

Fig. 3. Number of river–sea cruises in total shipping activity on the NSR in 2018–2021: ▧ number of cruises on the river–sea route; ▨ total number of cruises.

in relative but also in absolute terms: the number of cruises decreased from 309 in 2020 to 280 in 2021, the total gross register tonnage (GRT) of such cruises decreased from 1.041 million t in 2020 to 0.894 million t in 2021

During the period from 2018 to 2021 (Fig. 3), the total number of cruises on the NSR increased by 37% due to an increase in the number of transit transportation and associated icebreaker assistance, as well as the number of project cruises (Table 1). Against the backdrop of growing traffic in the NSR waters, activity on river–sea routes has been noticeably declining in recent years, the number of such cruises decreased by 19% (from 347 in 2018 to 280 in 2021), and their share in the total the number of cruises along the NSR decreased from 17.2 to 8.7%.

If we analyze the total gross tonnage of ships on the NSR in 2018–2021 (Fig. 4), it also shows an increase of 46.8% (from 57.373 million register tons in 2018 to 107.759 million register tons in 2021), which indirectly indicates an increase in the number of cruises of large-capacity ships. At the same time, the GRT of ships on the river–sea routes decreased from 1.119 million register tons in 2018 to 0.894 million register tons in 2021, which corresponds to a decrease in the proportion of river–sea ships in the total gross tonnage of ships on the NSR from 1.95% to 0.83%.

Thus, the decrease in the number of cruises by river–sea ships is accompanied by a decrease in the

Table 1. Freight turnover in 2020–2021 on the Northern Sea Route

Traffic category	2020			2021		
	number of cruises	GRT, t	share of total GRT of NSR, %	number of cruises	GRT, t	share of total GRT of NSR, %
Yamal LNG project: LNG export	510	64577066	63.65	524	68201755	63.29
Arctic Gate Terminal: oil export	435	18506270	18.24	399	18358187	17.04
Transportation of the Norilsk Nickel company in the port of Dudinka	201	3045649	3.00	250	3965751	3.68
Transit transportation	64	1461670	1.44	87	3771252	3.50
"Arctic LNG-2": transportation related to the development of the Salmanovskoye (Utrenneye) field	319	2679067	2.64	291	3870775	3.51
Operation of specialized fleet and support vessels	418	1603746	1.58	512	1937733	1.80
Icebreakers	220*	3748803	3.69	354*	6953033	6.45
Traffic connecting the NSR and the river navigation system	309	1051072	1.03	280	893902	0.83
Yamal LNG project: removal of gas condensate	49	1949418	1.92	41	1931114	1.79
Other**	380	2835784	2.80	356	3013300	2.80
Construction of the Bukhta Sever terminal and development of the Syradasai field	n/a	n/a	n/a	53	1048094	0.97
Development of the Kharasaveyskoye field	n/a	n/a	n/a	104	1456571	1.35
Total	2905	101458545	100.00	3227	107759440	100.00

* The number of cruises is conditional—movement from one water area to another.
** Other—cruises that cannot be attributed to a separate project or type of activity, such cruises have a different geography, cargo, destination or non-commercial purpose.

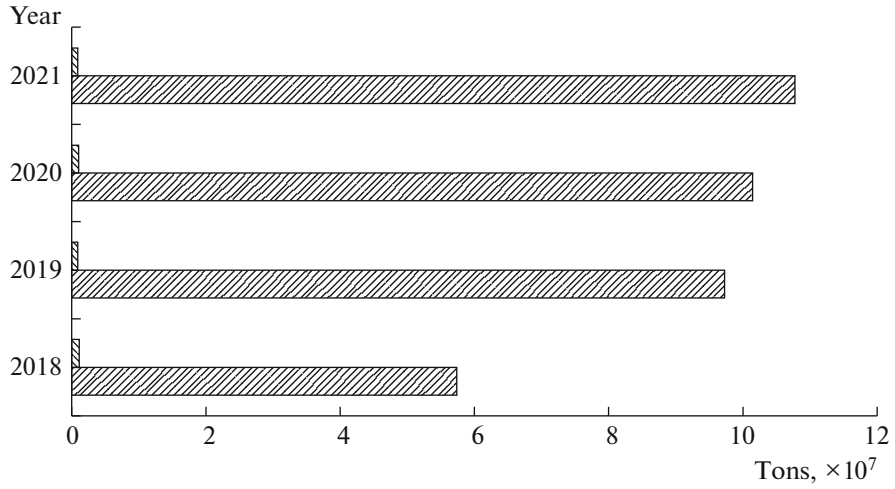

Fig. 4. Total gross tonnage (GRT) of ships on the river–sea routes in the total gross tonnage of ships on the NSR in 2018–2021: ▧ total gross tonnage of vessels on river–sea routes; ▨ total number of cruises on the NSR.

total gross tonnage of these ships over the period studied. The decrease in the proportion of the number of cruises is comparable to the decrease in the proportion of total gross tonnage, which indicates a general reduction in mixed-type shipping activity on Siberian rivers.

The main shipping activity of river–sea ships during the short summer navigation period is observed on the Kolyma, Lena, and Yana rivers (Table 2). Cruises along these rivers, as a rule, are associated with the implementation of the "northern delivery" program. It should be noted that due to the lack of AIS equipment on board, the study statistics did not include non-self-propelled towed barges, which can transport fairly large volumes of cargo.

To understand the observed trends, it is important to analyze the characteristics (ship type, age, ice class, shipowner) of the ships of the river–sea fleet.

The structure of the river–sea fleet is dominated by dry cargo ships (also known as general cargo ships) and tankers (Table 3). Since the delivery of project cargo on the river–sea lines is of a one-time nature and is not carried out annually, we can come to the conclusion that the bulk of general cargo and petroleum products are sent for the life support of remote regions, their state and municipal needs, personal and business purposes; all this constitutes the so-called "northern delivery."

The majority of ships operating on the river–sea routes belong to ship-owning companies based directly in river waters (Table 4). That is, it is these shipowners who provide the main traffic on Siberian rivers. Companies such as the Lena United River Shipping Company (LORP), the Khatanga Sea Trade Port (MTP), and the Northern River Shipping Com-

Table 2. Ship calls on river–sea routes to rivers and port points in 2020–2021

River and ports/port points in question in its waters 2020, 2021	2020		2021	
	number of calls	GRT, t	number of calls	GRT, t
Anabar River (Yuryung-Khaya)	12	32586	31	108256
Indigirka River (mouth, Chokurdakh, Belaya Gora)	28	60109	22	44598
Kolyma River (mouth, Cape Vert, Chokurdakh)	123	490734	110	422504
Lena River (Cape Bykov, Zhatai, Sangar, Yakutsk, Peleduy, Batamai, Zhigansk)	129	313691	96	226870
Ob River (Labytnangi, Salekhard) and Irtysh River (Omsk)	12	17353	10	9632
Olenek River (mouth)	6	31110	2	5722
Khatanga River (Khatanga)	30	72178	26	56847
Yana River (mouth, Nizhneyansk)	90	337481	104	335762
Yenisei River (Krasnoyarsk)	2	2994	n/a	n/a
General value	432	1251954	401	1153344

Table 3. Fleet structure on river–sea routes

Ship type	Number of ships per year			
	2018	2019	2020	2021
Tankers	25	20	24	20
Bry-cargo carrier	20	19	17	23
Tugs	1	3	4	6
Icebreakers	2	2	2	2
Supply ships	1	2	1	1
Other types (container ships, dredgers, research, fishing, diving)	4	1	1	–

Table 4. Distribution of the number of ships on the river–sea routes between shipowners

Shipowner	Number of ships per year*			
	2018	2019	2020	2021
Belfrakht	3	2	1	0
Valkur	3	1	3	1
Verkhnelensk River Shipping Company	1	1	0	1
Irtysh Shipping Company	3	3	1	2
LORP	20	23	19	21
Norilsk Nickel	1	1	1	1
Oil-Compact	4	1	3	3
Northern River Shipping Company	2	1	4	2
Khatanga MTP	9	9	11	11
Other	7	5	6	10

* Data on shipowners may change during the year, this is due to the chartering of ships for the working season, or for a cruise or a number of cruises.

pany carry out transportation with their fleet not only through the waters of the NSR, but also within rivers when ice conditions in the Arctic seas worsen. In addition, almost all of these ships remain for wintering and servicing in river ports. The activities of local companies in this region are obviously more economically feasible than attracting ships from the large seaports of Arkhangelsk, Murmansk and others.

Analysis of the ice class of ships on river–sea routes for the period from 2018 to 2021 (Fig. 5) showed that the vast majority of cruises are carried out by ships of the ice class Ice 1, a smaller number of cruises are carried out by ships that do not have an ice class and ships of the ice class Ice 2. The number of cruises by ships of high ice class (Arc 4–Arc 7) on the river–sea routes is low and demonstrates decreasing dynamics. Presumably, this may be due to periods of improved ice conditions, which allowed the use of ships of a lower ice class.

An analysis of the age of the fleet operated in 2018–2021 (Fig. 6) showed that most of it is represented by ships built in the Soviet period; there is a shortage of new generation ships.

The data we obtained on the age of ships operating in the Arctic are comparable with the results of a study on all river routes of the Russian Federation [11]. The authors made a forecast for a reduction in the fleet of mixed river–sea ships by 50–70% for the period from 2020 to 2025; the average age of scrapping a ship is 35.2 years.

The share of ships under 30 years old operating in the Arctic does not exceed 15%; the river–sea fleet is becoming outdated, with virtually no new units with a higher ice class and environmental characteristics that would expand logistics capabilities. According to the publication by *Morskie Vesti Rossii* [12], in 2020, Russian shipowners received 30 new sea and mixed river–sea ships with a total deadweight of 483.3 thousand t, which is not enough to replace retiring units.

An analysis of the ownership of the ships showed that all these ships belong to 30 shipowners, among which LORP, Northern River Shipping Company and Khatanga Seaport stand out with the largest number of ships.

Discussion and conclusions. An analysis of transportation by mixed river–sea ships connecting the NSR and the Siberian rivers Ob, Yenisei, Khatanga, Anabar, Olenek, Lena, Yana, Indigirka and Kolyma for the period 2018–2021 showed that the overall decrease in traffic on the river–sea routes during this period is

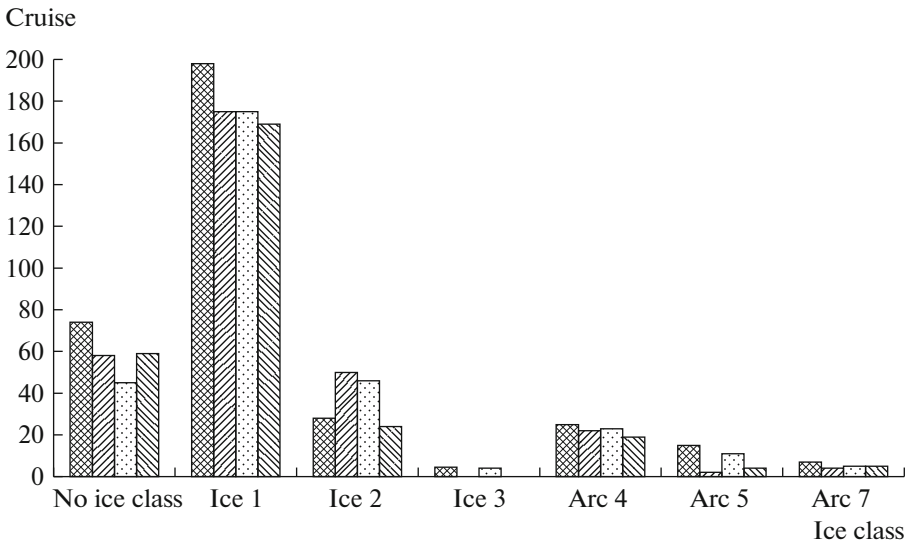

Fig. 5. Ice class of ships and the number of cruises they performed along the river–sea route with access to the NSR water area in 2018–2021: ▩ 2018; ▨ 2019; ⬚ 2020; ▧ 2021.

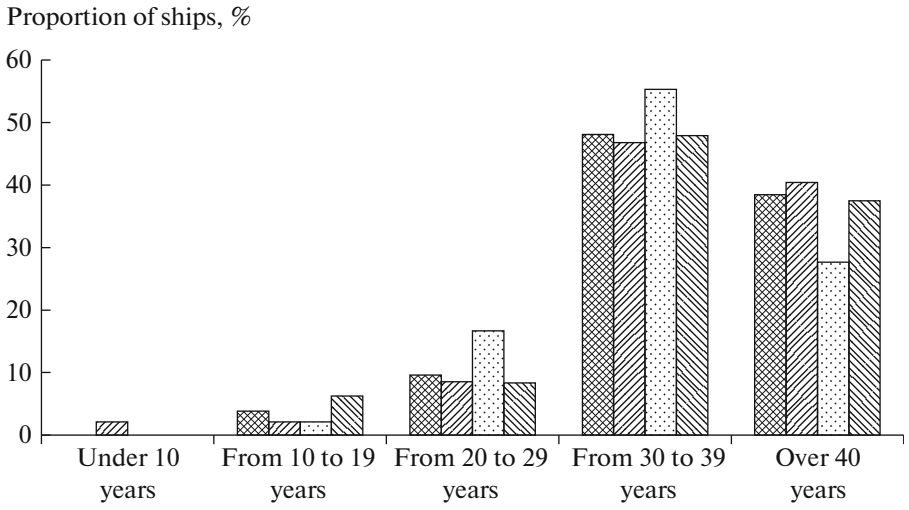

Fig. 6. Age characteristics of river–sea ships carrying out cruises along Siberian rivers with access to the Northern Sea Route, in the period 2018–2021: ▩ 2018; ▨ 2019; ⬚ 2020; ▧ 2021.

of a systematic nature. The greatest traffic during the period under review was observed in the Lena, Yana, Indigirka, Kolyma rivers, mainly due to the developed transshipment of cargo, in particular petroleum products, at the mouths of the designated rivers.

The structure of the river–sea fleet is represented mainly by dry cargo and tankers providing "northern delivery." The remaining types of ships make up no more than 15%. Ships of LORP and Irtysh Shipping Company participate in providing northern deliveries and make up the bulk of ships (from 42 to 56%) of all river–sea ships for 2018–2021.

The overwhelming majority of ships on the routes under consideration have weak ice reinforcement, mainly ice class Ice 1, Ice 2 or ships without ice class. These are river shipping ships that sail only during the summer navigation period.

Transportation volumes are a conditional indicator of the economic activity of the region. The number of ships and, as a consequence, the possibility of increasing transportation volumes indirectly lead to the development of economic activity in the region. However, against the backdrop of growing cargo turnover along the NSR with a decrease in the number of river–sea navigation cruises, the share of their contribution to the total cargo turnover will invariably decrease. The predicted negative trend is confirmed by such factors as the aging of the fleet and its insufficient replen-

ishment with modern ships with a high ice class. The commissioning of new ships does not meet the needs for these types of ships; fleet renewal is slower than its obsolescence. The interconnection of rivers with the NSR is carried out by mixed-type ships of Soviet construction (more than 75%).

The presented research results reveal a larger problem, which is that today dry cargo ships and container ships, including mixed-type ships, are not produced in the Russian Federation. There is no construction of domestic ships for new offshore projects. Most transportation is carried out by foreign-made ships, ships flying a foreign flag, the repair and maintenance of which becomes difficult against the backdrop of economic sanctions [13].

Another possible factor in reducing traffic on Siberian rivers is the deterioration of the technical condition of navigable hydraulic structures and the shallowing of rivers [14].

The reduction in activity on river–sea routes entails a slowdown in the development of ports serving such ships [15], and also negatively affects the economic involvement of the regions of western and eastern Siberia [16]. According to the analysis of the traffic of river–sea ships presented in the paper, it is clear that the ports of eastern Siberia, such as Khatanga, Tiksi, Pevek, are less developed than western Siberian ports, since they are not currently used for project purposes, and serve mainly to support the life of remote settlements in the interior of the continent [17].

It also seems relevant to expand the functionality of the ports of Sabetta (Ob River) [18] and Dudinka (Yenisei River) [19, 20], which are currently working for large projects for the needs of river navigation. Thus, the port of Sabetta is a large Arctic port, equipped with all the necessary infrastructure—deep-water berths, crane equipment, checkpoint, airport, container platform, icebreaking support and much more, but at the moment it only serves project goals. Opening the port's capacity to accumulate cargo transported along the Ob and its tributaries would help increase cargo turnover between river ports. Development of the potential of existing "project" ports at the mouths of rivers in eastern Siberia could not only increase the amount of cargo delivered as part of the northern delivery, but also contribute to the development of promising shelf projects [21]. The arrival of investments in the ports of the eastern coast of the NSR and an increase in cargo turnover may also become an impetus for updating the fleet operating on the river–sea routes.

* * *

Currently, the potential of Siberian rivers is used to an insignificant extent; cargo turnover along them has not reached the volumes carried out in the 1980s [7]. Modernization of the river–sea fleet should follow the path of producing new ships for Arctic conditions. Replenishing the fleet with new units with a higher ice class would make it possible to increase the navigation window and, as a result, increase the amount of cargo transported, as well as, if necessary, expand the geography of transportation; could entail the development of river ports and ports at river mouths, as well as the adjacent infrastructure (railway and road approaches), which will make it possible to more actively use the internal waters of Siberia for organizing both internal transport and transportation to the Asia-Pacific region.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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