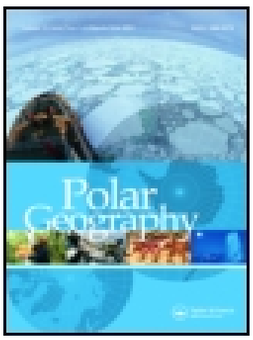

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'Road of life': changing navigation seasons and the adaptation of island communities in the Russian Arctic

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ABSTRACT

Adaptation of remote island communities in the Russian European Arctic to dramatic socioeconomic changes has been intensified by the impacts of climate changes in navigation seasons. Both the stability and duration of winter and summer navigation seasons and the start of the *rasputitsa* season, a shoulder period between the first two, are becoming more unpredictable and jeopardizing local mobility options. The ability to commute between neighboring settlements is an important aspect of island communities' viability. Local mobility depends on well-functioning ice roads during wintertime, tugboats during the *raputitsa* season and on passenger vessels or smaller boats during summer navigation. To examine whether and how the island population of the Arkhangelsk region adapts to changing conditions and what factors shape adaptation options, we apply a community-based adaptation approach. The results from qualitative interviews with 32 residents and relevant stakeholders indicate that further development of the island communities will rely on sufficient mobility options. Incorporation of climate prognoses and local knowledge can improve the planning of mobility measures. Current and future community adaptation is challenged by out-migration, unpredictability in the *rasputitsa* season and lack of investment in island development.

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Russian Arctic; local communities; navigation; climate change; adaptation; mobility

Introduction

The Arctic is warming two to three times faster than the rest of the globe (IPCC, 2018), resulting in significant changes to the cryosphere, such as sea ice reduction, thawing permafrost and the decreasing thickness and duration of ice roads on Arctic rivers (AMAP, 2017b; Meier et al., 2014; Prowse et al., 2017). The latter is particularly relevant for this study because it relates to the adaptation of remote island communities in the Russian Arctic whose mobility relies on the predictability of the navigation seasons and on the safety of ice roads.

Though changes in the cryosphere affect many Arctic communities (AMAP, 2011; Hovelsrud et al., 2011), this study aims to investigate the adaptation of remote communities without permanent, physical infrastructure connecting them to other settlements. Hence, we chose to bring our focus to the island communities in the Russian Arctic

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whose mobility is affected by the variation in navigations seasons. Due to the absence of permanent roads and railroad connections, these communities depend on seasonal winter and ice roads. Thus, we examine whether and how changes in river ice conditions affect local socioeconomic development.

For the past two decades, the impacts of climate change on the Arctic cryosphere have been documented by several Arctic assessment reports and have received much attention in the scientific literature (e.g. ACIA, 2005; AMAP, 2011, 2017a, 2017b; Hovelsrud et al., 2011; Meier et al., 2014; Suter et al., 2019). The experts from AMAP (2011, 2017b) document that the Arctic region experiences, among other stressors, warmer winter temperatures and reduction of ice duration and thickness. Prowse et al. (2017 in AMAP, 2017b) inform us that the duration of ice cover on lakes and rivers has declined by 4.3 days per decade (referring to Beltaos & Prowse, 2009; Benson et al., 2012) due to later freeze-up and earlier break-up of ice (see also Tsaturov & Klepikov, 2012). These changes in the cryosphere have extended the summer navigation season in Arctic freshwater channels, resulting in improved accessibility and, in some regions, increased ship traffic (Mokhov & Khon, 2015; Olsen & Nenasheva, 2018; Vorontsova, 2017). At the same time, these changes shorten the period of winter navigation and operation of ice roads, also known as *zimniki* or 'roads of life'. From a technical standpoint, *zimniki* on frozen river surfaces are complex, engineered constructions whose integrity depends on air temperature, river stream, water salinity, and ice thickness (Luzganov, 2011).

The population of the Russian European Arctic is distributed in numerous small communities connected by water routes and ice roads. The ice roads present a vital component of transportation infrastructure and local mobility during the winter season and are an important connection option for remote communities. For several regions, the interconnection of river and sea basins is crucial for the transportation of people and goods (Ministry of Transport of the Russian Federation, 2019). Some areas are characterized by a lack of roads and bridges between settlements, which is why ice roads play a significant role in island communities' viability (Luzganov, 2011) in that they enable daily mobility and keep local prices at a reasonable level (Tsaturov & Klepikov, 2012).

Changes in ice conditions lead to economic and social risks by threatening safe mobility and by negatively impacting the islands' industrial and socioeconomic development. Both challenging climatic conditions and weather changes can be barriers for the layout and maintenance of ice roads (Agafonova & Frolova, 2007), especially since the presence of ice and snow have become more unpredictable (Agafonova & Frolova, 2009). On some occasions, communities are cut off from the mainland during the period of the year when water channels are between ice-bound and ice-free, i.e. the *rasputitsa* season (Skorodumov & Emelianova, 2017). This unpredictability of the winter navigation season decreases the tourist appeal of the island territories, which have experienced socioeconomic restructuring since the collapse of the Soviet Union.

In recent years, Russia has been developing regional Arctic climate change adaptation strategies aimed at creating concrete tools for preventing and mitigating the possible negative consequences of climate change (AMAP, 2017a, p. 224). Despite increasing attention, however, there remains a gap in knowledge about whether and how local communities in the Russian Arctic are exposed to changing conditions and whether and how they deal with and adapt to those changes (e.g. Olsen & Nenasheva, 2018; Riabova & Klyuchnikova, 2018). Moreover, Riabova and Klyuchnikova (2018) argue that, though impacts of climate change in the Arctic increasingly receive attention among Russian scholars, there is still a

lack of adaptation studies using a local community or small town in the Russian Arctic as their unit of analysis. This is despite the fact that impacts of changing conditions are first and foremost felt at the local level, and that local residents can be the first actors to develop adaptive responses. For example, by examining the development of the Russian Arctic town of Vorkuta after the collapse of the Soviet Union, Shiklomanov et al. (2020) emphasize the role of regional local actors (e.g. the local administration and residents who own small businesses) in adaptating to new socioeconomic realities.

We address the knowledge gap described above by investigating the adaptation processes taking place at the local level. In doing so, we apply a community-based adaptation approach (Schipper et al., 2014) and integrate empirical data derived from 32 interviews with island residents and local stakeholders on how they perceive and adapt to changing conditions in the context of navigational changes. We suggest that such locally-developed adaptation strategies support existing governance arrangements. Moreover, this study contributes to the literature on global environmental change by examining the under-studied Russian context and adaptation of local communities.

Theoretical approach

This study applies an analytical framework built on recent advances from studies on community-based adaptation (CBA), especially those from the Arctic region (AMAP, 2017a; Hovelsrud & Smit, 2010). CBA is 'an approach to adaptation that allows local people to determine the objectives and means of adaptation practices' (Forsyth, 2013). Adaptation is increasingly referred to as 'a process taking place in the context of multiple stressors and along multiple dimensions' (AMAP, 2017a; Leichenko & O'Brien, 2008, pp. 219–252). Cumulative and interacting changes that trigger adaptation are most often associated with socioeconomic, environmental and climatic changes that are perceived as near-term risks or opportunities. Given that changes in river ice conditions and navigation seasons affect local socioeconomic development, we adopt CBA to examine the impacts of and community response strategies to climate change in combination with other changing conditions.

As Cinner et al. (2018, p. 120) argue, 'People have little incentive to adapt unless they believe that their actions can produce desired outcomes or forestall undesired ones'. This study's main objective is to understand those outcomes and/or adaptation options. In order to achieve that understanding, this study includes an examination of barriers to, limits on and opportunities for adaptation. We also approach adaptation as a context-dependent process shaped by the structure of the community and policy frameworks in addition to exposure-sensitivity, cumulative change and the local capacity to adapt (e.g. Hovelsrud & Smit, 2010; Smit & Wandel, 2006). This entails that adaptation options in one case region can differ significantly from those in neighboring regions.

Given that there are major differences between sectors, within and between local communities and in how the consequences of change manifest in a local community, different measures of adaptation are necessary. It is therefore useful to define and understand the aspects of adaptation options when analysing the empirical data. A recent report on adaptation in the Arctic identifies four interrelated dimensions of adaptation options: current adaptation strategies, processes that activate adaptation, barriers and limits to adaptation, and adaptation governance (AMAP, 2017a, p. 219) (Table 1).

The first dimension of adaptation options is adaptation strategies, which may fall into the following broad categories: technical and infrastructural solutions, innovations and

Table 1. Dimensions of adaptation options (Source: AMAP, 2017a, 2017b, p. 242).

Dimensions of current adaptation strategies	Dimensions in activating adaptation processes	Barriers and limits to adaptation
• Engineering technical solutions and innovation; Infrastructural improvements • Regulatory mechanisms • Technological standards • Economic mechanisms • Innovation and entrepreneurship • Product development and marketing • New knowledge • Institutional structures • Production practices and routines • Cross-sectoral interactions	• Knowledge about the change and challenges/opportunity • Attention to the change • Observations of real events (local outmigration, unemployment, longer growing seasons) • Extreme weather events (floods, avalanches) • Engaged officials and residents • Direct contact and involvement with research • Enabling institutions (municipality or county for example) • Livelihood flexibility and diversification • Access to knowledge • Access to human and financial resources, • Capacity building • Long term or short-term perspective on adaptation	• Motivation and the perceived need to adapt • Trade-offs between adaptation concerns and mandatory and more pressing tasks • Available and relevant knowledge • Lack of resources • Transferability of national goals and guidelines to local concerns • Unclear responsibilities and insufficient frameworks • Ignoring local/ traditional knowledge

Governing tools
- Cooperation and coordination on international, national, regional and local levels
- Distribution of responsibility for adaptation – at different levels
- Legal, regulatory, strategic and policy frameworks at various levels
- Climate scenarios and projections
- Policy and planning tools regional and local level – risk and vulnerability assessment, spatial planning
- Handbooks and guidelines on climate change adaptation planning; spatial planning taking climate change into account
- Networks and meeting points for sharing experience and knowledge dissemination among public agencies, ex. conferences
- Webpages as information hubs
- Cost-benefit analyses of adaptation in order to assess different options

development, regulations and institutions, economy, production practices, new knowledge and cross-sectoral interactions. Empirical studies will reveal how these play out/manifest in different contexts. Adaptation strategies can be proactive and reactive in how they are implemented (Smithers & Smit, 2009). Reactive strategies are responses to changing conditions that have occurred, while proactive strategies refer to anticipated measures that address possible future changes. Even though these strategies are usually undertaken at the local level, they include a broad range of stakeholders across regional and national scales.

The second factor that shapes adaptation options refers to barriers and limits to adaptation, which can be subjective or objective (e.g. Bay-Larsen & Hovelsrud, 2017). Limits and barriers fall into five broad and interrelated categories: (1) motivation and the perceived need to adapt, which reflect both the agency and capacity of actors; (2) available and relevant knowledge about the change that requires adaptation; (3) lack of resources and trade-offs in municipalities; (4) unclear responsibilities and insufficient frameworks, which are related to the gap between the transferability of national policy goals and guidelines that do not meet local concerns (e.g. Westskog et al., 2017), and (5) inclusion of local and traditional knowledge, the absence of which is highly likely to create barriers and lose opportunities.

The third dimension pertains to activating adaptation processes. An extensive review of the case studies in AMAP (2017a) reveals a broad range of processes and stakeholders that activate adaptation, which is critical for understanding future options for adaptation. These processes include (1) access to and knowledge about change, (2) attention to such changes through, for example, observations of extreme events, (3) capacity building and enabling institutions, (4) engaged officials and local residents, and /or (5) involvement with researchers (see also Dannevig et al., 2013). Moreover, several studies indicate that

livelihood flexibility and diversification, as well as access to knowledge and resources, strengthen a community's adaptive capacity and activate adaptation options (e.g. Risvoll & Hovelsrud, 2016) but may also be a barrier to adaptation (e.g. Keskitalo et al., 2011). Hence, processes that activate adaptation might be distributed across local, regional and national levels.

The final dimension that plays a role in shaping and implementing adaptation options is adaptation governance, which encompasses the three dimensions above (AMAP, 2017a). Adaptation governance crosscuts multiple societal scales and employs several tools for that purpose. Key features include coordination, collaboration and networking on international, national, regional and local levels, all of which relate to the distribution of responsibility for adaptation. This distribution, in turn, requires the presence or development of frameworks (legal, regulatory, policy-related and strategic). Such frameworks need to be informed by climate scenarios and projections, risk and vulnerability assessments, and planning tools.

Methodology

Our work is guided by a case study research design (Yin, 2014) and a community-based research approach in order to explore communities' adaptation in depth (e.g. Hovelsrud & Smit, 2010). This methodological approach promotes closer cooperation with communities and thus enables a better understanding of local perceptions of changing conditions and the ways in which a given community is exposed and adapts to them (Smit et al., 2010).

The primary data in this empirical study derives from qualitative, unstructured interviews with island residents and relevant stakeholders ($n = 32$). The fieldwork took place in June 2019. During that time, we interviewed 26 residents, including both working and retired populations, and six stakeholders comprising representatives from shipping – related organizations and public bodies based in Arkhangelsk (Table 2). Some of the interviewees were contacted beforehand while others were suggested by pre-chosen interviewees and subsequently recruited via a snowball technique (Blaikie, 2010, p. 179).

Given the explorative nature of the research, we used an open-ended interview guide with pre-defined topics in order to examine aspects of local adaptation. During the interviews, we asked about the residents' backgrounds, mobility options and limitations, changes in the local environment and the effects of those changes on the navigation season, transport infrastructure, strategies to deal with the impacts of changes and thoughts on further community development.

Almost all interviews were recorded, but detailed notes were taken when the interviewees preferred not to be recorded. We transcribed the interviews in Russian, the language used in the interviews, and translated the cited sections in this article into English. A coding system was used in this study to ensure the anonymity of the interviewees (A1–A32).

Table 2. Overview of the interviewees.

Type of interview	Interviewees involved in the study
26 personal unstructured interviews with residents of the island villages	24 residents of the villages Two former residents who still have property in one of the villages and visit it during summer navigation season
Six personal unstructured interviews with relevant stakeholders, located in Arkhangelsk	One representative from public body working with island's socio-economic development Five representatives from private and state-owned businesses within shipping related industries

The transcribed interviews were analysed with the use of the coding software NVivo (Bazeley & Jackson, 2013). Both predetermined and emerging codes were applied to a body of the empirical data. The predetermined codes comprise the categories used in the interview guide, while emerging codes, such as the role of stakeholders, local knowledge and economic potential, were added during the analysis.

Prior to and during the fieldwork, the primary data were also supplemented with secondary material, such as background information on a community's development, navigation trends and historical data. The secondary data comprise analyses of relevant documents, statistical data, literature and media. Using the secondary data, we developed a research protocol, interview guide and a baseline of the case area.

Case study area

The unit of analysis for this study is the population of island communities located in the delta of the North Dvina river in the Arkhangelsk region of the Russian European Arctic. Though many Arctic communities face cryosphere changes, the island communities selected for this study are exposed to unique changes in their navigation seasons, as there are no roads or railroad connections to the mainland.

The island communities in our case area are divided between two municipalities, the municipality of Ostrovnoe, composed of 48 small villages, and the municipality of Oktyabr'sky with a major settlement, the village of Keg. Five villages with permanent residents of the municipality of Ostrovnoe and Keg (Kegostrov) were chosen for this study (Figure 1). The island of Kegostrov is one of the largest in the delta of the North Dvina River and is closest to Arkhangelsk (approximately 2 km away).

The collapse of the Soviet Union resulted in high outmigration from the rural territories (e.g. Zakharov, 2019), including the island villages. The population of the Ostrovnoe municipality is still declining. In 2019, the community had 1896 residents, which has decreased by 139 people since 2016 (Arkhangelskstat, 2019). The villages are visited during the summer navigation season by *dachniki*, people who own a recreational property on the island. In addition to property owners, the islands are widely used for recreational and tourist purposes. The territory offers tourist attractions such as rebuilt churches, museums, traditional architecture, hiking paths and unique Arctic nature.

Those who live on the islands commute to Arkhangelsk, a neighboring settlement and the administrative centre of the region. During summertime, the settlements are accessible only by water. The two main types of mobility options to the islands are passenger vessels and privately-owned, usually small boats (Figure 2). The small boats in this study are all vessels with the capacity for 12 or fewer passengers. However, the Russian authorities also acknowledge another group within this category – boats with engines of up to five horsepower that do not require drivers' licenses (GIMS, 2005).

Passenger vessels are traditional and the most commonly used type of water transport (Nenasheva & Olsen, 2018). River shipping lines are divided into three types: intercity, suburban and local. The main criteria for these divisions are the distance from Arkhangelsk and the routes' durations. Intercity lines are designed for passenger transportation between settlements within the city, such as the shipping line to Kegostrov. Shipping lines to the islands of the Ostrovnoye municipality are the suburban routes, while local lines comprise routes of 100 km or longer (Table 3). This study covers the intercity and suburban lines, as they connect the case area with Arkhangelsk.

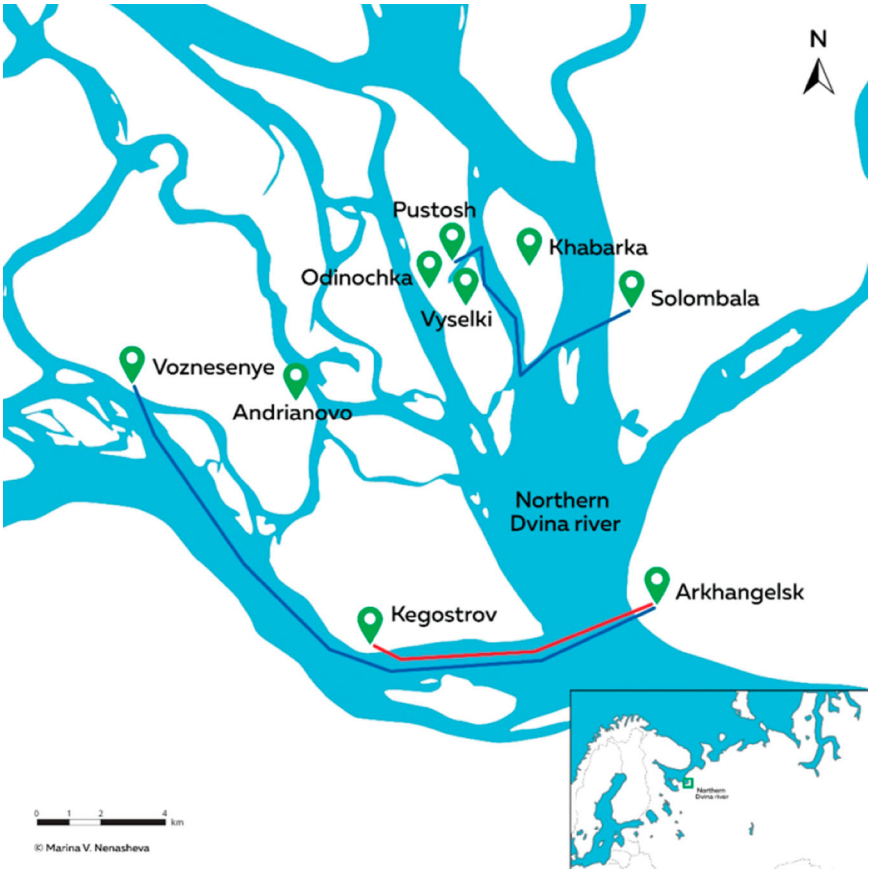

Figure 1. The case study area. Arkhangelsk - Kegostrov line illustrates an example of an intercity shipping line. Other two illustrate examples of suburban shipping lines.

Trips on intercity and suburban shipping lines usually take between 20 minutes (to the nearest settlement) and a couple of hours. While passenger vessels present a reliable form of local mobility, there are occasionally cancellations due to bad weather conditions (e.g. News29.ru, 2019). Moreover, due to the declining island population, the number of

Figure 2. Private boats (2a) and a passenger vessel (2b). Both photos are taken near the village of Voznesenie. Photographer: Julia Olsen.

Table 3. The number of river transport routes (Arkhangelsk River Port, 2019).

The number of river shipping lines	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019
Intercity	5	6	3	3	2	3	2	3	3	3	3
Suburban	4	5	6	6	3	5	6	5	5	5	5
Local	0	2	2	2	2	1	1	3	1	1	1
Total	**9**	**13**	**11**	**11**	**7**	**9**	**9**	**11**	**9**	**9**	**9**

regular river transport routes is declining (Table 3). During the winter period, ice roads are constructed in designated areas to connect island communities to each other and/or with Arkhangelsk.

From a historical perspective, the permanent population has been living in our case area since the 1400s (Bulatov, 1997). The islands' population also played a crucial role in regional shipping development after the establishment of Arkhangelsk in 1584, which became the first trade port that connected the Russian European Arctic and Europe. Since the establishment of the first association of Arkhangelsk pilots, many island residents worked on vessels as pilots and captains (Petukhov, 1864). The importance of the island territories endured during the Soviet time as they exported agricultural products to Arkhangelsk, had several regional medical centers and a scientific station, and were actively used as summer camps (Shorina, 2007). Before the collapse of the Soviet Union, Kegostrov had well-developed infrastructure.

Results

Below, we present the island residents' perceptions of changes in the navigation seasons that affect socioeconomic development. This section also describes whether and how residents deal with those changing conditions. We start with a description of three locally-identified navigation seasons – winter navigation, summer navigation and *rasputitsa* – and provide a presentation of available mobility and transportation options during each of them. These are also summarized in Table 4. Next, we present the changes in socioeconomic development that took place after the collapse of the Soviet Union, and which have been intensified by the unpredictability of navigation seasons. This part describes the interconnection of communities' viability and local economic development, as well as their dependence on sufficient mobility options.

Changes in navigation seasons and local mobility

Island residents define three main navigation seasons: winter navigation, when the North Dvina River is ice-bound and the ice roads are established; summer navigation, when the local population can use river transport; and the period of *rasputitsa*, a shoulder-season that can take place during and between the summer and winter seasons (Table 4). *Rasputitsa* is also known as a period of limited mobility, when the ice roads are closed and only tugboats can transport people and goods. According to one of the shipping stakeholders, the dates for opening the summer and winter navigation seasons are decided by the captain of the port of Arkhangelsk based on the river ice conditions (A1). However, residents of an island community can affect this decision: 'In our city, people can decide [navigation dates]. People are cut off from the mainland for a long time … If they appeal to the administration, the navigation dates can be extended' (A1). Another resident confirms that sometimes island residents have

Table 4. Description of transportation and mobility options during three navigation seasons.

Season	Transportation options	Mobility options	Advantages and disadvantages
Winter navigation	• Car • Walking to and from Arkhangelsk or between settlements	Ice roads[a]: Arkhangelsk with Kegostrov-Voznesenie-Konetsdvoria; Solombala (Arkhangelsk district) with Khabarka – Pustosh.	Advantages: • Ice Roads can be used almost all the time. • Sufficient for goods transportation and personal mobility. Disadvantages: • Ice roads can be crossed by caravans, a convoy of vessels navigating in ice-bound waters led by an icebreaker. Waiting time for re-freezing can be a couple of hours before car transportation is allowed in designated areas.
Summer navigation	• Passenger vessels • Private boats • Ferries	Passenger vessel lines[b]: Arkhangelsk-Rybolovo-Chubola; Arkhangelsk-Voznesenie-Toyvatovo; Arkhangelsk-Kegostrov; Solombala-Khabarka-Vyselki-Pustosh.	Advantages • Private boats are the most convenient mobility option between settlements • Passenger boats are a reliable link between settlements Disadvantages: • Expensive for private boats to dock in Arkhangelsk. • Passenger boats are an expensive option for goods transportation
Rasputitsa navigation	Tugboats	Tugboat lines: Arkhangelsk- Kegostrov	Advantages: • Tugboats are the only mobility option during the *rasputitsa* season • Operate for free Disadvantages: • Passengers have to stay outside

[a]The Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters in the Arkhangelsk region.
[b]Arkhangelsk River Port (http://arpnet.ru/).

to contact public bodies to adjust mobility options (A3) when ice situations change quickly (A4, A5) because these residents are usually the first to observe such changes.

The summer navigation usually lasts from May through November but, according to local observations, it is expanding (A7, A24, A29). This is also confirmed by interviewed stakeholders (A1, A21). During recent years, and especially during the last decade, river ice has formed later. An elder resident mentioned that only a decade ago, 'the river ice was forming in October, nowadays in December' (A26, also A18). Current winter navigation is more unpredictable and potentially disturbed by a *rasputitsa* period of melting of river ice that enables the tugboats and/or passenger vessels to start their operations in early winter (A1, A7). One resident remembers a winter when 'the ice finally formed in February and started melting in March' (A5).

During the winter navigation period, ice roads are constructed to connect the settlements. The roads can be used for walking and partly for transporting people, food and goods (A24), and thus play a significant role in local viability. One of the residents called one such road a 'road of life' (A16), while an interviewed stakeholder acknowledged the importance of ice roads for the transportation of building materials: 'The building materials are transported to the island only during wintertime by car. It is expensive during summertime and you cannot take a lot on a regular passenger vessel'. (A21). The ice roads are sometimes

Figure 3. A temporary bridge is used by island residents to cross a shipping corridor over the North Dvina River on their way to Arkhangelsk. Photographer: Rune Rafaelsen/Barentssekretariatet.

crossed by *caravans,* a convoy of vessels led by an icebreaker navigating ice-bound waters. In those situations, residents wait outside for the construction of a small bridge over the gap (a shipping corridor) in the ice while the river freezes up, allowing them to cross (A11). When a new convoy is expected, the bridges are removed by caretakers (Figure 3).

Water transport during summer navigation, such as private boats, small ferries and passenger vessels, covers several of the communities' needs. One stakeholder described the importance of this connection in the following way: ' … the delivery of people itself is an urgent [task]. Our authorities, those who are on the island territories, act promptly. Kegostrov, in general, cannot be ignored because thousands live there' (A1). One resident described river transportation as 'a means of life for the islands' (A18), while another underlined, 'If there were not sufficient transportation options, [the island settlements] would have died out a long time ago' (A14). Others emphasized the importance of shipping, arguing that it is the only available transport link during summertime for local mobility, community re-supply, and goods delivery, and that it is also crucial for local recreational and subsistence activities.

Passenger vessels are a reliable mobility option for island populations, visitors and tourists during summer navigation. Two operating vessels, 'Balhash' and 'Kommunar', have ice class and can operate a few weeks longer than standard passenger vessels, while tugboats start operating when the ice starts to form. Passenger vessels have several routes per day, but still do not cover all the settlements. The situation was different in Soviet time, when, according to local people, the passenger vessels operated more frequently and covered several settlements (A3, 27). Hence, there is a local wish to increase both the area and frequency of passenger vessel operation (A2, 26). Despite the stability of operations of passenger vessels, however, residents report cases of cancellations due to storms, ice conditions and

fog. The closing of navigation due to storms usually takes place during autumn but may also occur during summertime (A25).

During the summer navigation period, the local population uses small boats for local mobility. As one of the stakeholders mentioned, ' … private boats for the local population are like cars for the population in a city' (A1). Island residents use small vessels for recreation and subsistence activities such as fishing, hunting and camping, but also for travelling between settlements (A12, 26). According to one resident, 'Small vessels do not need moorage infrastructure. It is enough to leave the boat and that is all' (A12), but they do need this infrastructure when traveling to Arkhangelsk (A21). In addition to the passenger vessels and private boats, a small ferry navigates between Arkhangelsk and the island settlements delivering goods, supplies and mail (A6, A7, A28).

The third season of mobility, *rasputitsa*, is a period of uncertainty for the local population that was broadly discussed by our interviewees due to noticeable changes in ice conditions that take place during autumn, spring and occasionally wintertime (A25). During springtime, this period lasts from the day the ice roads are closed until summer navigation opens. However, *rasputitsa* occurrences during autumn and winter used to be more stable and predictable. A resident who has lived on one of the islands for decades described the changes in the following way:

> The warmer winters are a big disadvantage. *Rasputitsa* lasted previously for 2–3 weeks, and now it reaches 2 months. You are unable to use a boat and you won't go on foot … Can you imagine that it rains around the New Year time? The ice disappears and you can neither go nor drive. (A29)

During *rasputitsa,* the municipality provides a tugboat, which is a subsidized service. 'When river [ice] melts … a tugboat starts the navigation. Tugboats transport passengers for free, that is convenient. But this is expensive … for the city' (A2). However, not all residents are satisfied with this option as there are no cabins for the passengers and they must stay on the deck during the sail. Some refer to delays in operation: 'We did not have tugboats when the river opened' (A4). While another interviewee specified, 'We had to start work at 8 am, but tugboats started navigating after dinner. There was no need for them then' (A5).

The dependency on well-functioning mobility is noticeable during *rasputitsa*, when the change from one mobility option to another takes place during a short period of time. In addition to the *rasputitsa* season, the ice roads are dismantled each time a vessel – or an icebreaker followed by a convoy of several ships, i.e. caravans, – passes through. Though the restoration of ice roads does not take a lot of time (A11), it potentially affects peoples' mobility. The majority of the interviewees report that the local public bodies and stakeholders do their best to secure the mobility link between the city and island territories. The island residents are dependent on quick, official responses when seasonal changes are occurring that may limit mobility options. Residents value a direct and effective connection to public bodies and other stakeholders in the transport industry, both those located on the islands and in Arkhangelsk.

According to respondents, the local administrations try to immediately arrange transport connection with the mainland in periods of seasonal transition, e.g. *rasputitsa*. One resident mentioned that as soon as 'the river ice starts melting, everyone engages in establishing … tugboat [operations]' (A2). While another resident underlined that 'everything is solved by a call' (A3) meaning that the residents contact public bodies to report ice conditions and request a tugboat. When there are delays due to challenging river conditions, the local administration and the Arkhangelsk River Port may also issue special documents

explaining delays (to work) due to changing sailing conditions (A5). It was emphasized by one stakeholder that '[the residents] decide the opening and the closure of the navigation season. Several times, they were left with no connection with the mainland. Then they contacted the administration of the city or the region and the navigation was extended' (A1).

Socioeconomic development

The island population is, to varying degrees, dependent on well-functioning, year-round mobility options to commute to neighboring island settlements and to Arkhangelsk, where a large part of the working population is employed and where children go to school and kindergarten. Moreover, the entire population is dependent on occasional trips to Arkhangelsk as central organizations and key services are now located there, such as childcare facilities, hospitals, the airport, train station, entertainment organizations and major stores. Hence, the above described changes in navigation seasons have had a cascading impact on local socioeconomic development. The following section describes how local viability and enhancement of local economic potential are affected by unpredictability in navigation.

Community viability

The local population, especially those who were born and grew up on the islands, express a form of attachment to the island territories. They value the beauty of local nature, quietness, closeness to nature and safer daily life, when compared to city life. When we asked the elder population what factors attach them to the place, one interviewee expressed, 'I do not know, this modest beauty, maybe … we appreciate the generous manifestations of nature in a special way' (A19). We also observed this attachment to place among the interviewees who grew up on the islands but moved to the city and/or bought property or family houses on the islands, where they live during summertime.

At the same time, some interviewees who represent the working population with small children expressed their wish to move to the city. One interviewee told us: 'We have nothing here, nothing for children. If we start to bring our children to the city, we have [to cross] the river in the winter. You don't want to go back and forth all the time' (A4). Moreover, residents, especially those with small children, underline that distances between settlements represent another concern. One interviewee presents it in the following way: 'In the city, you commute without a bus, you can just walk, but not here' (A9).

In addition to high dependency on well-functioning mobility, quality of life is also challenged by a lack of local job opportunities, mostly due to the absence of industries. One interviewee suggests it might be a challenge for a working population to commute to Arkhangelsk: 'Poor young people. They have to work in the city. There is a lack of jobs here' (A6). As a result, the majority of the working population tries to find employment in Arkhangelsk or nearby. At the same time, several residents told us that the island villages were better developed during the Soviet time, when the majority of residents could work on the islands where there were industries, agriculture, social and childcare services (A18), a research station and an airport (A30). One interviewee pointed to an old industrial plant and said, 'I myself worked in the plant, you see the pipe stands there. We had two plants, woodworking and the collective farm, which was very rich. Everything has disappeared' (A3).

With the collapse of the Soviet Union, several industries were shut down while others experienced significant economic decline. This development directly affected the demographic composition of the island communities and reduced the frequency of passenger

vessel routes (A3). One interviewee was concerned about this decline and connected island development with industrial development: 'If there were any type of production [in the Soviet period] … there isn't production any longer' (A16).

During the Soviet period, the islands were used for agricultural purposes: 'Grasslands were allocated for local populations on the islands and we were driven to the hayfields' (A19). The agricultural industry was developed and well-organized (A14, A18). One stakeholder said that 'when potatoes were planted on the islands, a lot of people were there. Fewer now' (A13). Another remembered that the communities exported agricultural products to neighboring cities (A14). For most island residents, their own land offers a source of food and occupation during summertime: 'We are used to being here. We use our property for greenhouses, gardens and to plant potatoes' (A16).

Enhanced economic potential

Despite the dramatic changes after the 1990s, the interviewed local population and stakeholders see the potential in future economic development of the island territories. Much attention is given to tourism potential, while others suggest the possibilities of rebuilding the agricultural industry. However, both the residents and stakeholders emphasize that well-functioning mobility and transportation options are among the central enablers of those industries (A1, A6, A16, A18, A29).

Those who discussed the development of the tourism industry informed us that the villages of Kegostrov, Pustosh and Voznesenie could serve as tourist destinations. The latter two have museums – a space museum in Voznesenie and a Pilot museum in Pustosh (A16, A18, A30, A32). The number of visitors is still low, however – the Pilot museum, for example, is visited by about 1000 people per year (A18). Tourists visit the settlements mostly during the summer season (A6, A13), while few visit during the winter (A18). One interviewee pointed out that tourists come all the time, mostly from domestic locations, but also internationally. 'Life has become more eventful. The influx of tourists plays a big role for the village' (A30).

However, these local tourism attractions exist because of a few, engaged residents who secured funds and established local attractions. These engaged residents noted that 'it is impossible to establish a museum without additional [financial] support. We've managed it after receiving funding' (A18, A30, A31). Tourists also visit the rebuilt churches, while the local nature presents yet another attraction (most islands have areas of almost untouched nature). One resident remembers a trip to an island where they saw white swans (A19), a unique experience in those areas.

Agriculture presents another form of possible industry development and a job provision for island residents. One of the residents underlined that

> we have a lot of agricultural land. Our boats transported milk to Severodvinsk twice a day. Under the Soviet Union, everything was organized. We thought we were eternal … And then we decided that we should be reborn in our own gardens at least. We are not dead, we are alive. (A14)

With the collapse of the Soviet Union, all collective farms were shut down. Farmland became the property of private actors. 'In the 1990s, 22 farmers operated on the island, and now almost none are left' (A29). It is difficult and economically unprofitable to have a farm on the islands. Moreover, successful operation depends on safe mobility options that have been changing in past years. For example, one resident underlined that, during

the time of *rasputitsa*, some farm products cannot be delivered to the city (i.e. to market) and must be destroyed (A31).

Hence, similarly to tourism, agricultural development relies on well-functioning river transportation and mobility options (A29) in order to transport necessary materials and deliver products to market. For this industry, which requires greater ice thickness to accommodate heavy machinery, the period of *raputitsa* lasts longer than for residents.

Concluding discussion

Our empirical results describe the socioeconomic challenges that island communities in the Arkhangelsk region have undergone since the Soviet collapse. While dealing with the impacts of those challenges, they face emerging changes in the stability and duration of winter roads, the 'roads of life' that are important infrastructure during the winter season for people and goods transportation. The observed climate changes affect the length and stability of these ice roads and cause the unpredictable events of the *rasputitsa* season. Changing mobility patterns affect not only the viability of the island populations, but also local attractiveness for residents and entrepreneurs.

Based on the empirical results, we argue that local viability is affected by sufficient mobility and transportation options, while river transportation services (transportation options) are dependent on the number of passengers (number of residents using passenger vessels).

Table 5. Island residents' and stakeholders' perspectives on adaptation to changing navigation seasons and socio-economic development.

Adaptation options	Changes in mobility	Socio-economic changes
Adaptation strategies (residents)	• The ability to influence public bodies in order to improve mobility options and information • Use of private boats to help each other in goods delivery and mobility between islands. • Incorporation of local knowledge into decisions on opening/closing navigation	• Efforts to enhance island communities' attractiveness for tourism and agriculture
Processes that activate adaptation (residents)	• Residents' close connections to industrial and public stakeholders • Local government support/ transportation subsidies • Local engagement and networks • Local knowledge and place attachment	• Close connection to industrial and public stakeholders • Supporting funding options to establish local businesses • Local engagement in socio-economic development • Memories from the Soviet Period and a wish to rebuild the villages
Barriers to and limits on adaptation (residents and stakeholders)	• Unpredictable *rasputits*'-season • Regulations for use of smaller vessels • Lack of harbor infrastructure • Lack of resources to renew the fleet • Need to incorporate local knowledge in decision making on navigation	• Out-migration • Transportation frequency • Regulations for use of smaller vessels • Lack of investments in island development
Adaptation governance (indicated by stakeholders)	• Development of flexible transportation arrangements • Regulation adjustments for passenger vessels and small boats (e.g. use of small boats in the form of 'river taxis') • Engagement of local authorities • Increasing knowledge of changes in navigation	• Measures to improve island attractiveness and transportation • Enable funding opportunities to support local engaged residents in islands' promotion • Cooperation with local engaged residents

This means that a decreasing population may lead to decreases in transportation services that, in turn, will decrease the attractiveness of the region and lead to further outmigration. In this section, we examine these interconnections with the help of the adaptation options framework (AMAP, 2017a). Table 5 presents an evaluation of four dimensions of adaptation options to multiple changes. It illustrates how adaptation manifests at the local level in the context of two main, interrelated challenges: changes in local mobility and socioeconomic changes. We suggest that these aspects are pertinent for the adaptation processes.

The first row presents the interlinked adaptation strategies identified by island residents. There are on-going processes that enable the improvement of mobility options during winter and summer navigation, that contribute to the increasing socioeconomic attractiveness of the island, and that encourage the development of the tourism and agriculture industries. The listed strategies are proactive, but the direct connection with public bodies in situations of sudden change in navigation triggers reactive responses. This row also illustrates the importance of local knowledge and observation for making decisions on mobility options.

The described strategies, however, rely on several local factors that lead to their activation. The second row – resident-identified processes that activate adaptation – illustrates that the island residents' local knowledge and engagement are pre-conditions for adaptation strategies. This also corresponds to earlier studies that argue that local knowledge and local engagement activate adaptive capacity and result in adaptation strategies or responses (e.g. Hovelsrud et al., 2018). Moreover, adaptation will depend on the availability of economic resources and subsidies, as well as closer cooperation between industrial stakeholders and public bodies, including those located on the islands and in Arkhangelsk. We argue that the latter facilitates a common understanding of changing conditions and high dependency of the island communities on well-functioning mobility options.

The third row, barriers and limits to adaptation, indicates that such barriers manifest on both local and regional levels. These barriers are identified by both residents and stakeholders and include a knowledge of changes in navigation seasons and the unpredictability of the *rasputitsa* season, which correlates with earlier-identified skepticism toward the impacts of climate change in the Russian context (e.g. Graybill, 2013; Olsen & Nenasheva, 2018). Moreover, improvement of mobility options during the summer navigation season can be limited by insufficient infrastructure and an old fleet that requires investment for its renovation. Among other barriers, interviewees identified outmigration of the younger population and limitations on regulations for using small boats as river taxis.

The fourth row, adaptation governance, presents the governance mechanisms that facilitate community adaptation options while considering adaptation strategies, their enablers and their limitations (see also AMAP, 2017a, pp. 242–243). Here, much attention is given to (1) high dependency on socioeconomic development and economic investment in the island territories, (2) improvement of mobility options during all seasons, (3) regulations for use of small boats as river taxis, ((4) enhancing knowledge on changing conditions and (5) cooperation with engaged residents, industries and local public bodies. Hence, we argue that the islands have potential for socioeconomic development and enhancement of economic potential in the form of industrial development, as evidenced by industrial development during the Soviet era. However, we also indicate that the improvement of island communities' viability will continue to rely on well-functioning mobility options, especially during periods of transition between the three navigation seasons.

It is important to mention that the development of adaptation options may also create trade-offs (e.g. Reed et al., 2013) in investment allocations, as river transportation is

expensive and partly subsidized by the local municipality. In this context, it is acknowledged by several stakeholders that tourism presents a possibility for additional income generation at the local level and could lead to the further modernization of river transportation. In the same vein, passenger vessels are popular among domestic tourists during the summer season, and further marketing could benefit river transportation development. However, promoting the usage of passenger vessels for tourism also depends on the cooperation of several stakeholders, e.g. the shipping company and local and regional tourism enterprises.

Another trade-off derives from the diversity of transportation demands of island communities within the same region (i.e. the Arkhangelsk region). Transportation options vary throughout the year and affect the planning process for winter and summer navigation. More specifically, mobility and cargo options in the present case communities also differ from an island community in the same region, the community of Solovetsky, which was earlier studied by the authors of this paper (Olsen & Nenasheva, 2018). The main difference between these communities is rooted in the seasonality of operations for transporting goods and construction materials. While the island communities close to Arkhangelsk plan to transport most of such goods using ice roads, the community of Solovetsky plans transportation for the summer navigation season (ibid). It is important to note that the summer navigation season is increasing in length, while the winter season is shortening. This might present an additional challenge for planning activities in local and regional logistic organizations and local governments.

Conclusion

In this study, we have examined the elements that constitute local adaptation options in the context of changing navigation seasons on the North Dvina River, as well as the increasing unpredictability in ice road conditions and its cascading impacts on local viability and enhancement of economic potential.

Based on the discussion points, we would argue that the empirical material collected in Russian communities can contribute to better understandings of adaptation to changing ice conditions and other climate-induced changes. Three main conclusions emerge in our study. First, despite the observed changes in river ice conditions over the past two decades, the responses to these changes are still mostly *reactive* in nature. The mobility and transportation options correlate with day-to-day ice conditions. Sudden changes in ice conditions may result in the delay of passenger transportation. Since both shipping stakeholders and island residents emphasize that well-functioning transportation links are priorities, a more *proactive* planning process could increase the flexibility of mobility options.

This leads us to the second conclusion, which indicates that *local knowledge* about ice conditions is yet to be incorporated into local decision-making about the opening/closing of navigation seasons. Local populations, who observe local weather and ice roads firsthand, are sometimes better informed on transportation conditions than authorities in Arkhangelsk. The existing scientific literature acknowledges practices for the inclusion of local knowledge in monitoring and decision-making across the Arctic (e.g. Brady & Leichenko, 2020; Hovelsrud et al., 2018). One example is a local resident reporting system for weather conditions via a web page or phone application (e.g. Norwegian Barentswatch.no, regobs.no). Based on the results achieved in Norway, a neighboring Arctic country, we would argue that enabling such reporting can improve local mobility and decision-making for river navigation by limiting the uncertainties around local ice conditions.

Our third conclusion relates to the first two and suggests that a community-based adaptation approach is useful for studying the local impacts of climate-induced changes. This approach presents a set of tools to assess local perspectives on changing conditions and local adaptation strategies by actively engaging the local population and local stakeholders (e.g. Hovelsrud & Smit, 2010). Though a community-based adaptation approach is not broadly used to study Russian communities (e.g. Olsen & Nenasheva, 2018; Riabova & Klyuchnikova, 2018), we argue that its application allows for better understanding of local adaptation strategies, which are still understudied in the Russian Arctic. The results of this study indicate that locally-developed adaptation strategies can present supportive and supplemented responses to existing governance arrangements. However, the same approach faces challenges with upscaling (Forsyth, 2013). For example, as illustrated in the discussion section, two communities in the same region have developed different strategies for community supply due to differences in transportation options during the summer and winter navigation seasons.

Finally, since the role of small, private boats in community viability is highlighted in this paper, we wish to acknowledge that there is no standard definition for small vessels across the Arctic regions (e.g. Têtu et al., 2018). Since these vessels are used by the local population, their role in local adaptation processes presents a potential area for further research.

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