Mapping Weather, Water, Ice and Climate Knowledge & Information Needs for Maritime Activities in the Arctic

Survey report

Jelmer Jeuring
Maaike Knol

Acknowledgements

We express our sincere gratitude to all participants of the survey who dedicated their time and were willing to share their experiences.

Authors

Jelmer Jeuring, Geography Department, Umeå University, Umeå, Sweden.

Maaike Knol-Kauffman, Norwegian College of Fishery Science, University of Tromsø - the Arctic University of Norway, Tromsø, Norway.

For questions about this report, contact Jelmer Jeuring: jelmer.jeuring@umu.se

For questions about the SALIENSEAS project, contact Machiel Lamers: machiel.lamers@wur.nl

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EXECUTIVE SUMMARY

Introduction

Recently, there has been wide agreement that WWIC information services for polar areas require further development in line with end-users needs (Dawson et al., 2017; Lamers, Duske, et al., 2018). Earlier studies found that forecasters and service developers have little insight into how their services are actually used, where, and in what contexts (Jeuring, Knol, & Sivle, forthcoming). To tailor to specific user needs for Weather, Water, Ice and Climate (WWIC) information services in the maritime Arctic, a more detailed understanding is needed about the situated context of maritime activities, where they are undertaken, and which types of WWIC information are used, throughout planning and operational phases and among various types of end-users. In order to elicit such insights, from January 2019 until May 2019, the SALIENSEAS project launched an online participatory mapping survey, targeted at maritime users around Greenland and Svalbard.

Using participatory mapping made it possible to embed the survey questions in an intuitive, activity-oriented perspective, and to put the user experience at the center of the study. Hereby, the survey has delivered situated spatial information about the use of WWIC information for maritime planning and operations, and it provided in-depth insights in the impact of WWIC conditions on maritime activities.

The report provides an overview of key characteristics of respondents (n = 22) and their maritime activities in Arctic waters (Section 3.1). Key topics enquired via the mapping interface included 1. Voyage planning; 2. Tasks and activities sensitive to adverse WWIC conditions; and 3. Information (in)accuracy. Additionally, several activity-based narratives (Section 3.2), based on the drawings and responses from survey participants from different maritime sectors, provide a deeper insight into the connections between planning and execution of specific maritime activities, the impact of WWIC conditions and the use of WWIC information.

Methodology

The online interface used for this survey was based on the Maptionnaire[1] functionality. Maptionnaire is a map-based crowdsourcing platform, developed in the context of urban planning. The respondents of this study were invited to use the purpose-built survey to draw and comment upon their experiences of using WWIC information in relation to specific activities and locations of maritime activities. For each of the areas and locations drawn, respondents were asked a range of open-ended and/or multiple-choice questions.

Findings

Most of the respondents currently have professionnal occupations on vessels that sail in Arctic waters. A small number has a job on shore, assisting vessels or working on planning and logistics. The majority represents the cruise tourism sector, while fisheries, cargo/supply, passenger transport and maritime research are represented too. Key findings include:

1. Voyage planning
   - Voyage planning is interpreted as a multidimensional practice, of which the significance and content changes across temporal levels and differs between maritime sectors;
   - Uncertainty about and adaptation to WWIC conditions are strongly embedded in any type of maritime activity, and the liberty to stray from specific parts of voyage plans is necessary in order to successfully carry out an overall voyage or operation.

[1] www.maptionnaire.com

2. Tasks and activities sensitive to adverse WWIC conditions
   - WWIC conditions have a nuanced, yet significant, impact on different maritime activities, at different locations;
   - Tasks and activities which are particularly sensitive to adverse WWIC conditions are port calls, the navigation of certain (often narrow) areas, and cruise tourism activities such as landings and excursions;
   - Activities appeared to be most sensitive to sea ice related factors. Almost 90 percent of drawn activities were stated to be very or extremely sensitive to adverse impacts of variability in sea ice concentration. Other important factors that stood out were wind (both speed and direction), followed by horizontal visibility and wave conditions;
   - The impact of adverse WWIC conditions varies, from increased uncertainty in route planning and choice of equipment, to difficulties to execute planned activities, decreased passenger comfort, or the need to build in spatial or temporal flexibility in voyage planning and execution.

3. Information (in)accuracy and (in)sufficiency
   - While respondents have indicated that there are many instances where they do not have enough information (information insufficiency), they seem generally satisfied with the accuracy of the WWIC information that is available;
   - Respondents often experience information insufficiency regarding sea ice and wind (sea ice concentration, sea ice thickness, sea ice extent, wind speed and wind direction). Importantly, planning and operations are considered most sensitive to the variability of these same conditions;
   - WWIC information services are experienced to have a limited and unequally distributed geographical coverage. Whereas some areas are well covered, like South Greenland, or Isfjorden and the area around Longyearbyen in Svalbard, the available information for geographical regions outside these “centers” is experienced as insufficient to a greater degree;
   - Limited download capacity constrains access to information sources is an important challenge for maritime activities in the high north;
   - Sharing of experiences with (in)accurate WWIC information with NMHSs occurs on a limited basis.

Discussion and recommendations

There is a strong need to further uncover how the multidimensionality of voyage planning is put in practice, especially because voyage planning is increasingly embedded in regulations, such as SOLAS and the Polar Code.

Access to sufficient and accurate information about sea ice and wind conditions is most vital to many operators in the Arctic, and should be the focus of the further development of Arctic forecasting.

Additional suggestions for improvement of services pertain to local wind and wave information (both direction and height). Importantly, there appears to be a desire for products that can convey *dynamics* of WWIC conditions, for example through interfaces depicting sea-ice drift. Aligning with findings elsewhere (see also Dawson et al., 2017), there is a need to increase the frequency of sea-ice charts and to bridge the gap toward communicating real-time sea ice information as much as possible.

There is a need to deal with existing technological limitations and find solutions at the local level that can provide some legroom for at least some maritime stakeholders. For example, testing out new interfaces or products (low-bandwidth WWIC information distributed via email) before rolling it out to larger groups of users. Other options include investing in WWIC services for local communities along the Greenland coast; making available paid services to vulnerable stakeholders with limited funds (e.g., small scale fisheries); or target development of high resolution products at especially challenging areas for navigation (e.g., Prince Christian Sound, ports or cruise landing sites).

Despite a number of methodological limitations, online participatory mapping provides concrete entrances for in-depth interactions between providers and users of WWIC information, especially when integrated in a stepwise data collection and subsequent co-production practices. Overall, this report calls for continuous efforts to obtain insights in needs for WWIC information services of maritime stakeholders by considering the spatially and temporally salient practices of planning and executing maritime Arctic activities on a detailed level as possible.

1. INTRODUCTION

Mapping knowledge & information needs for WWIC Services in the maritime Arctic

While large public and private sector investments are currently made in the development of observations, modelling, forecasting and integrating Weather, Water, Ice and Climate (WWIC) (Dawson et al., 2017) information in, and for, the Arctic regions, the potential of these efforts for enhancing WWIC services for Arctic marine end-users is currently not yet fully realized.

Importantly, to tailor to specific user needs for WWIC information services in the maritime Arctic, a more detailed understanding is needed about the situated context of maritime activities, where they are undertaken, and which types of WWIC information are used, throughout planning and operational phases and among various types of end-users.

In order to elicit such insights, from January 2019 until May 2019, the SALIENSEAS project launched an online participatory mapping survey, targeted at maritime users around Greenland and Svalbard. This document reports on the key findings from the survey campaign.

Aims and approach of the SALIENSEAS project

The SALIENSEAS project brings together a team of social and natural scientists, personnel of National Meteorological and Hydrological Services (NMHSs), and end-users. SALIENSEAS is organized in three work packages. The study reported in this document is developed under Work package 1.

- Work package 1 aims to better understand the mobility patterns, constraints, challenges, decision making contexts and information needs of end-users in different European Arctic marine sectors;
- Work package 2 formulates design principles, simulates the use of tailor-made services and develops a support-tool for co-producing and testing salient weather, sea ice services climate services with Arctic marine end-users;
- Work package 3 aims to co-develop user-relevant and sector specific weather and sea ice services and dissemination systems dedicated to Arctic marine end-users tailored to key social, environmental and economic needs.

The Norwegian and Danish Meteorological Institutes are both represented as partners in the SALIENSEAS project. Each hold national and international responsibilities for large parts of the Arctic to provide WWIC services on time scales from days to seasons. The findings presented in this report directly feed into the knowledge base of these two NMHSs and provide a basis to improve their services.

Report outline

The remainder of this report is structured as follows. Chapter 2 includes background information about participatory mapping as methodology and about the online interface used in this study, Maptionnaire. The chapter also provides details about survey development and participant selection. Chapter 3 covers the findings of the survey campaign. A discussion in Chapter 4 embeds the findings in the existing body of research on WWIC user needs in the maritime Arctic. Along a number of implications and recommendations, the report connects the results with the practical context of providing and using WWIC information services for Arctic maritime activities.

2. METHODOLOGY

2.1 A participatory mapping approach

To get insight into the locations and contexts of maritime activities, we used a softGIS approach and designed this survey around a web-based geographic mapping interface. The term 'softGIS' refers to the collection of attitudinal or experienced values about existing places or development practices (Babelon, Ståhle, & Balfors, 2017). A variety of crowdsourced softGIS platforms is currently available, that facilitates the sharing of knowledge by tagging places on a map and providing comments (Lamoureux & Fast, 2019). The online interface used for this survey was based on the Maptionnaire[2] functionality. Maptionnaire is a map-based crowdsourcing platform, developed in the context of urban planning. The online software enables researchers and policymakers to design and implement a digital mapping survey, by making use of a set of preconstructed building blocks and tools (Brown & Fagerholm, 2015). SoftGIS is a relatively new form of *participatory mapping*, an umbrella term for a variety of spatial technologies which aim to 'engage and empower marginalized groups in society' (Brown & Kyttä, 2018, p. 1), such as Public Publication GIS (PPGIS), Participatory GIS (PGIS) and Volunteered Geographic Information systems (VGI). Next to its ability to give a 'voice' to difficult to societal stakeholders that are difficult to reach, the methodological power of participatory mapping lies also in the intuitive way of eliciting local, spatially salient knowledge.

The respondents of this study were invited to use the purpose-built Maptionnaire survey to draw and comment upon their experiences of using WWIC information in relation to specific activities and locations of maritime activities. For each of the areas and locations drawn, respondents were asked a range of open-ended and/or multiple-choice questions. The results were not publicly accessible and Maptionnaire does not allow respondents to view other respondents' survey responses. Anonymity of participants was therefore guaranteed.

2.2 Participants

Selection of participants was primarily based on existing cooperation through the SALIENSEAS project. An announcement of the survey was sent out to stakeholders already involved in the project. In addition, announcements were published on the SALIENSEAS website and on social media.

By giving several language options (English, Danish, Norwegian) the intention was to reach a broad group of European Arctic stakeholders. To reach specific sectors, mails were sent out to industry associations such as the Association of Arctic Expedition Cruise Operators (AECO – also connected to SALIENSEAS), Fiskebåt (the interest- and employers association of the Norwegian ocean-going fishing fleet), the Association of Fishermen and Hunters in Greenland (also connected to SALIENSEAS), and to a list of approximately fifteen individual fishers/fishing companies that we know operate in Arctic waters.

2.3 Survey design

The content of the survey was developed though a stepwise iterative process. The topics were chosen based on literature and, importantly, on the insights derived from the SALIENSEAS co-scoping workshop, held in Tromsø in January 2018 (Lamers, Knol, et al., 2018). The format of the questions was topic of iterative discussions between the authors of this report, and various suggestions were provided by project partners of the SALIENSEAS project. Furthermore, beta-versions of the survey

[2] www.maptionnaire.com

were pilot-tested within the Norwegian Meteorological Institute and the Danish Meteorological Institute, which resulted in several adaptations to, for example, question format and the order of questions. Beta-versions of the survey were also pilot-tested by some members of the SALIENSEAS Advisory Group. The survey was purposefully not pilot-tested in the target population, since we acknowledged that the target population is limited in size and difficult to reach out to. Therefore, we decided to only share the final version of the survey within the target population, in order to increase the chances of response.

Participants were landing on a welcome page (Figure 1), where language selection was provided (English, Danish, Norwegian). After an explanation of the goal and structure of the survey, participants were offered several drawing practices, in order to get familiar with the mapping tools. Drawings could be lines (e.g., voyage tracks), polygons (e.g., areas where activities take place, where WWIC information is needed), or points (e.g., activity locations). The actual mapping survey consisted of five pages (see Figure 2 for an example).

Several non-spatial open questions about maritime planning and operations followed the mapping exercises. In addition, several personal/organizational background questions were asked (years of experience, months of operations). The final page of the survey allowed participants to leave their contact details, and to give any feedback they wished to communicate.

Figure 1. Survey landing page.

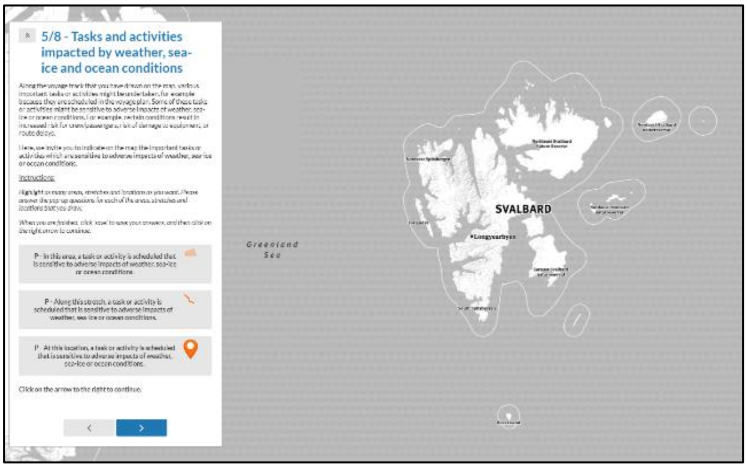

Figure 2. Mapping page example.

3. FINDINGS

This chapter is outlined along two sections. Section 3.1 provides an aggregate impression of the survey responses. It gives an overview of key characteristics of respondents and their maritime activities in Arctic waters. Then, three subsections each address one key topic enquired via the mapping interface. These key topics are 1. Voyage planning; 2. Tasks and activities sensitive to adverse WWIC conditions; and 3. Information (in)accuracy. The aggregate overview of Section 3.1 is complemented by a narrative approach in Section 3.2., which provides a deeper insight into the connections between the different drawings referring to planning and execution of maritime activities, and the role of WWIC information in these activities. The subsection consists of several activity-based narratives, based on typical responses from survey participants from different maritime sectors.

3.1 Respondents and their maritime activities

The first question was a general question to get insight into the general purpose of using WWIC information during planning and operational decisions. Participants were asked for what purpose, within their current main job, they use WWIC information most often (appraisal/planning, executing/operational, or both).

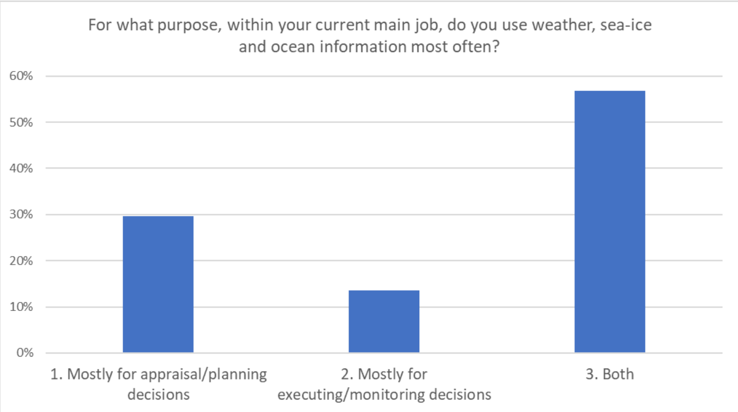

Figure 3. Purpose of using WWIC information

This question was answered by a total of 74 respondents (Figure 3). Most of them (57 %) uses WWIC information both for planning and operational decisions. A large part of these respondents filled out no or few other parts of the remainder of the survey. Therefore, the reported data in this section is based on answers from a smaller sample of respondents (n = 22). These respondents provided answers to most of the survey items and used the mapping interface for one or several drawings.

Table 1. Average experience of respondents in Arctic waters

Average planning experience
16.0 years (SD=14.4)
Average operational experience
17.2 years (SD=13.9)

Most of the respondents currently have professionnal occupations on vessels that sail in Arctic waters. A small number has a job on shore, assisting vessels or working on planning and logistics. The majority represents the cruise tourism sector, while fisheries, cargo/supply, passenger transport and maritime research are represented too.

Respondents generally have plenty years of experience with both operational and planning activities in Arctic waters (Table 1). However, with a standard deviation of about 14 years, there seems to be a lot of variation too. When asked about their skills of knowing the risks posed by WWIC conditions in the Arctic, respondents show a great level of confidence: over 90 percent assess their own skills as (very) good or excellent (Figure 4). A summation of reported vessel activity per month (Figure 5), shows that summer months tend to be busier than winter months, according to respondents' answers. Here, it is important to keep in mind that the majority of respondents represent the cruise tourism sector.

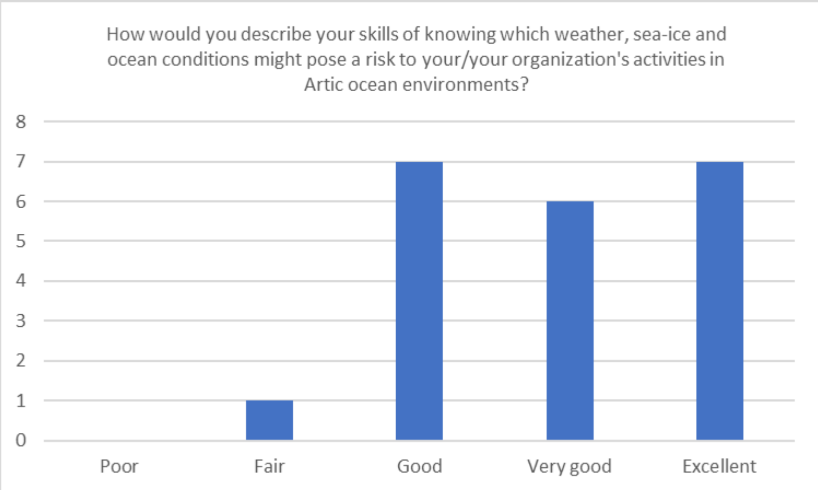

Figure 4. Self-assessed skills level of risk assessment.

Figure 5. Percetage of respondents engaging in operational activities per month.

3.1.1 Voyage Plans

The mapping part of the survey started with the request to draw a typical track of a voyage plan for one of the participants' vessels. Several questions then followed about drawn tracks, for example regarding the duration of the trip, the lead-time of the planning phase and the confidence of being able to execute the voyage without disruptions. A total of 43 voyages were drawn. For 31 voyage tracks, detailed answers were provided, by 25 respondents (Figure 6). A summary of answers is provided here in order to get a general overview. For more details see Section 3.2, where a number of drawn voyage tracks are linked with the subsequent topics addressed in the survey (tasks and activities sensitive to adverse WWIC conditions, and information (in)accuracy).

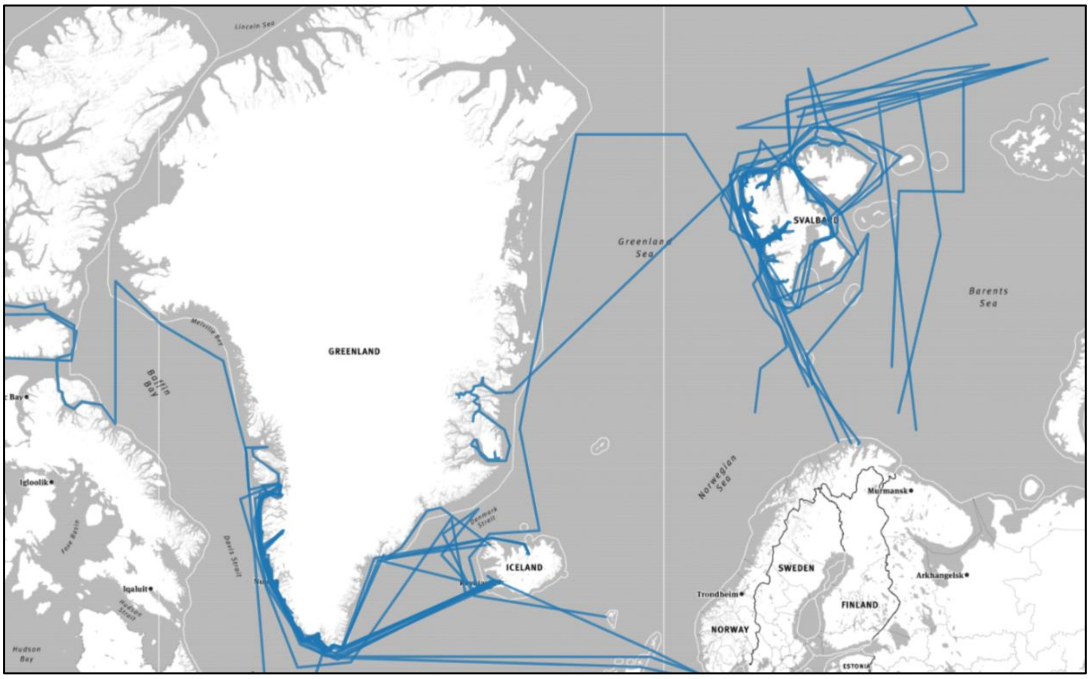

Figure 6. Voyage tracks drawn by participants.

Most voyages were categorized under cruise tourism (Figure 7). Most voyage plans (or parts thereof) appear to be created only several days in advance (Figure 8). The relatively short 'lead-time' of voyage planning is interesting, as it can have a strong influence on what type of WWIC information is needed/available in the planning phase. Moreover, it appears that also several cruise tourism voyage plans (or at least parts thereof) are created only several days in advance. This is somewhat at odds with findings elsewhere, stating that cruise tourism voyages are planned months or even years in advance (Arctic Council, 2009; Bystrowska, 2019; Lamers, Duske, & van Bets, 2018). See also Chapter 4 for a more in-depth discussion on this topic.

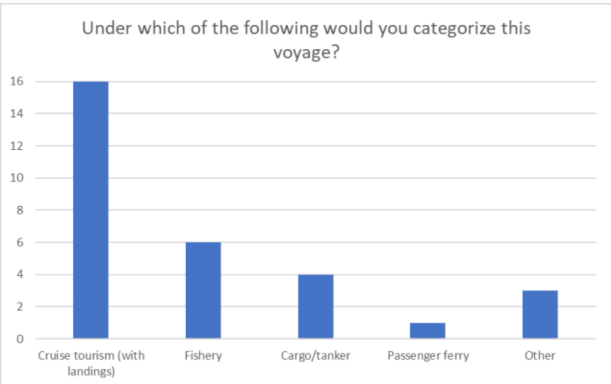

Figure 7. Voyage plan type.

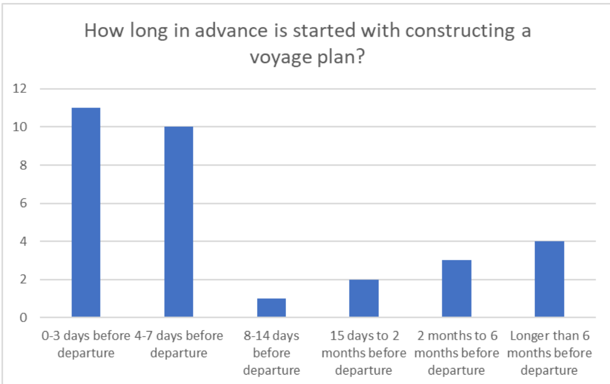

Figure 8. Lead-time for voyage plan construction.

For over half of the drawn voyage plans, participants had (very) high confidence that no major deviations would occur (Figure 9). On the other hand, confidence was (very) low for about a quarter of the voyage plans. Participants were also invited to answer several open questions in relation to the voyage planning. The first question was 'which scheduling/route planning decisions are of primary importance to you?' Answers were categorized based on a grounded approach (Glaser, Strauss, &

Strutzel, 1968)[3] in: 1. Regulation/Security, 2. WWIC Conditions, 3. Timing/Locations and 4. Other (Table 2). Decisions related to WWIC conditions were mentioned most often as important, seconded by spatio-temporal decisions. Complying with (safety) regulations was also mentioned as an important aspect in voyage planning decisions.

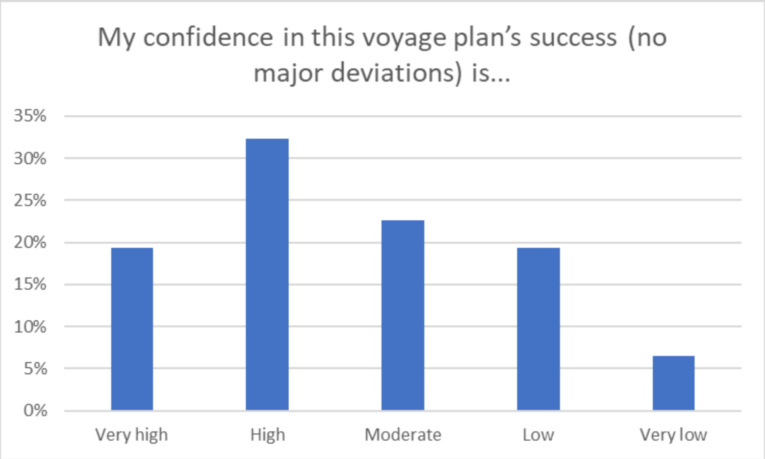

Figure 9. Level of confidence in voyage plan success.

Table 2. Scheduling/route planning decisions of primary importance

WWIC Conditions	Timing/Locations	Regulations/Security	Other
Weather x 4	*Port call timing x 4*	*Security*	*Optimal tourist experience*
Ice conditions x 4	*Voyage plan x 3*	*Safe route*	
Wind x 3	*Activities x 2*	*Marpol route*	
Swell direction x 2	*Timing in relation to ice*	*Ice class of the ship*	
Visibility	*Short route*	*Crew's experience*	
Temperature			

The second open question was 'what type of events or resources create costs (financial, human, technology costs) and therefore impact your scheduling decisions?' Again, weather conditions were mentioned most often. In addition, digital infrastructure was mentioned as an important cost, for example investments made for high latitude internet access (Table 3).

Table 3. Costs-creating events and resources

WWIC Conditions	Timing/Locations	Digital infrastructure	Other
Weather x 6	*Delay on departure*	*Iridium internet x 2*	*Tours*
Sea ice x 2		*WWIC information x 2*	*Disposal of vessels*
Env. circumstances		*Big data*	

Third, participants were asked to respond to the question 'what are the most important resources (information, tools, approaches, skills) you rely on in planning decisions that decrease chances of disruptions?' Again, responses are categorized (Table 4). Virtually all responses pertained to WWIC information, which often include external sources such as weather forecasts. Personal experience and skills were mentioned several times too, next to forms of direct observations.

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[3] Categorizations found in other Tables were derived in a similar way.

Table 4. Important resources for planning

External sources	Personal	Direct observations	Other
Weather information x 10 *Ice information x 5* *Satellite images x 3 (Coastal)* *Wind x 2* *Nautical Publication* *DMI (< 36 hours)* *UKMO (Long term)*	*(Previous) experience x 4* *Skills*	*Talking to other ships* *Look at nature, clouds, temperature (esp. in spring)*	*Backup plan* *Cruise director* *Plan well in advance*

Finally, participants were asked to share their thoughts on product improvement, which could reduce planning uncertainty (Table 5). Various detailed answers were provided, which include suggestions on animated products, higher frequency of product updates, more real-time products, forecast improvements and improvements in digital infrastructure. The latter aspect seems to be directly challenging any product improvement, since for example resolution tends to positively correlate with bandwidth size.

Table 5. Suggestions for improving WWIC services.

Where do you see room for improvement in weather, ocean and sea ice forecasts to reduce the uncertainties you are faced with in your planning decisions?
Dynamics
• Drift ice forecasts for Cape Farewell • Animated weather forecast like windytv.com • Animated weather forecasts standardized
Frequency
• More frequently updated ice-charts for W-Greenland, especially for break-up/freeze-up periods • Higher frequency of ocean and sea ice forecasts • Daily ice-charts • Ice-charts in the weekend • Weather forecast 2-3 times a day in combination with egg code format • Twice daily updates
Real-time
• Quick looks for W-Greenland • Real-time sea ice information • Restoration of Ice Patrols' helicopter reconnaissance
Infrastructure/access
• High speed internet in the Polar Regions • Delivery of observations and forecasts through ships' e-mail system instead of via websites • Free access to all weather and ice information • Improved internet access • Low-bandwidth products, to be used for selecting specific high-res products for download
Forecasts
• Sea ice forecasts • Standardized presentation formats • Sea ice forecasts with 2-3 weeks lead-time • Local high-resolution metocean forecasts • Short and long-term sea ice forecasts • Break-up and freeze-up forecast • Local high-resolution ice forecasts
Other
• More wave information

3.1.2 Tasks and activities sensitive to adverse WWIC conditions

On a subsequent mapping page, participants were asked to give content to their voyage plan by illustrating where activities are planned that are sensitive to adverse impacts of WWIC conditions. Again, a range of questions followed each drawn activity (e.g., about activity duration, spatio-temporal flexibility of the activity, specific WWIC conditions potentially impacting the activity). A total of 46 drawings were made. However, for 38 drawings detailed answers were provided (Figure 10). By far most of the drawings were polygons (i.e., areas), complemented by some lines and points.

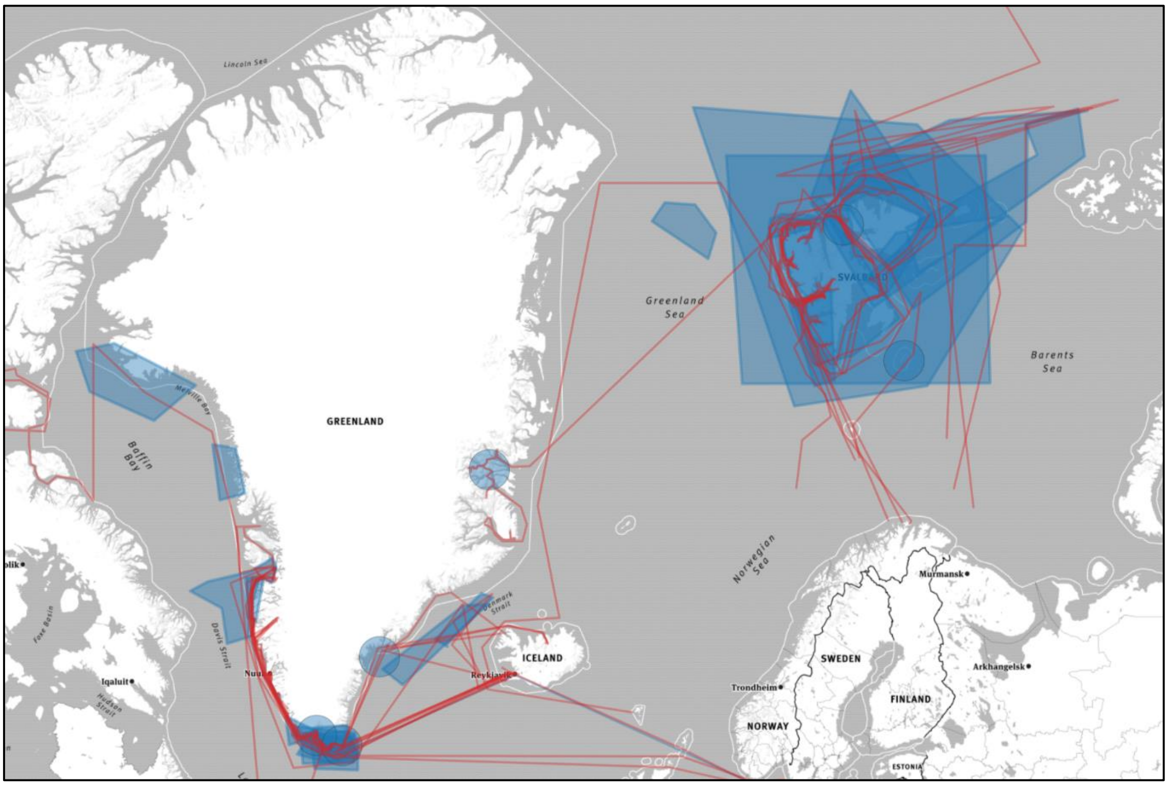

Figure 10. Drawings of locations for activities sensitive to adverse WWIC conditions (blue) and voyage plans (red).

Over half of the activities typically take 24 hours or less. Almost a third of the activities take six hours or less, while about a quarter of the activities take more than two days (Figure 11).

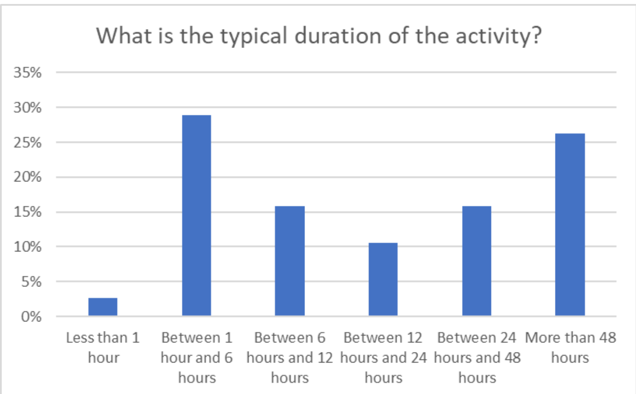

Figure 11. Activity duration.

The drawings pertained to a variety of activities, ranging from port calls to navigation and specific tourism or fishing activities (Table 6). Specific areas that were mentioned were mainly ports in Greenland and Prince Christian Sound in southern Greenland. Some participants referred to WWIC conditions (e.g., sea ice) instead of specific activities. It is not known why this was done, but it might be that these conditions are causing adversities for these participants in the drawn areas.

Table 6. Overview of activities which are sensitive to adverse WWIC conditions.

Purpose/goal of this task or activity
Port calls
• Call at Ilulissat
• Supply to Hopen
• Call at Qaqortoq
• Calling Tasiiliaq
Navigation
• Sailing through Prince Christian Sound x 3
• Coastal route
• Ice sailing
Tourism
• Scenic cruising/sight-seeing x 7
• Landing/excursions x 4
Fishing
• Fisheries x 4
Other
• Research
• Ship rescue

Another aspect of interest was spatio-temporal flexibility of the activities. Timing of activities appeared to be most often slightly to moderately flexible (Figure 12). Timing of only a few activities was stated to be not flexible at all. However, the level of spatial flexibility appeared to be much lower for many activities, with 50 percent being not flexible at all, Figure 13).

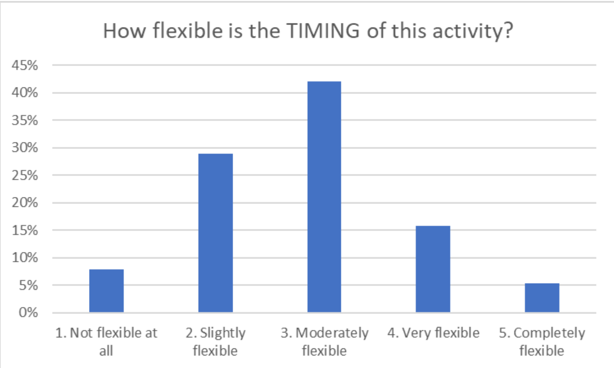

Figure 12. Temporal flexibility.

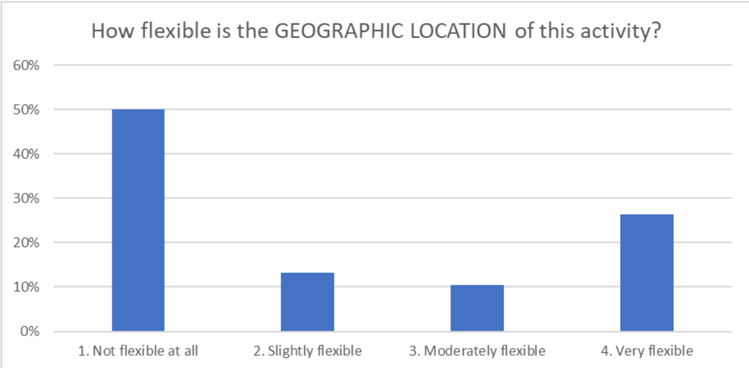

Figure 13. Spatial flexibility.

Participants were asked when the activities they indicated on the map typically become part of a voyage plan. It appeared that a large part of these activities become explicitly embedded in a voyage plan only a few days before execution. At the same time Figure 14 shows that over 50 percent of drawn activities are included at least two weeks in advance, and almost 50 percent of those are planned more than six months in advance.

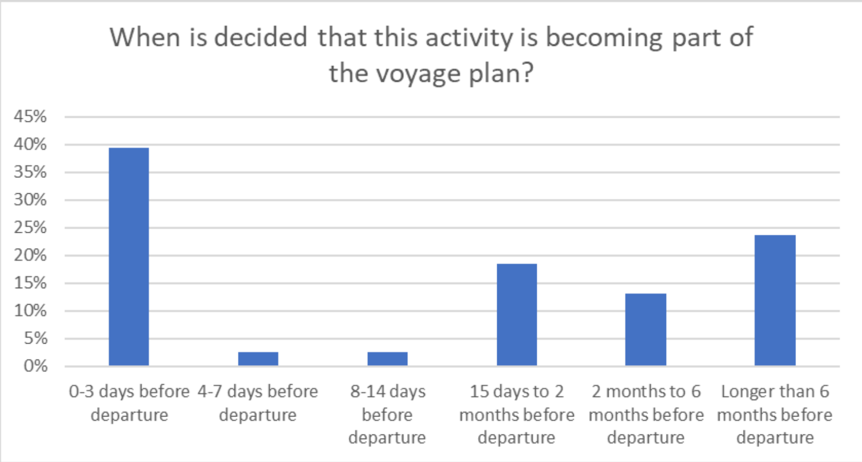

Figure 14. Lead-time for activities becoming part of voyage plans.

Previously reported findings (subsection 3.1.1 and 3.1.2) already made clear that WWIC conditions play an important role in voyage planning and execution of activities (see also Dawson et al., 2017; Lamers, Knol, & Ljubicic, 2017). The detailed insights in what the conditions will be, and if they are favorable enough often only can be known hours or days in advance. It is no surprise then that 'go/no-go' decisions for marine activities are reported to be made within twelve hours in advance for almost half of the illustrated activities, and within 48 hours for about 85 percent of the activities that were drawn by the participants (Figure 15).

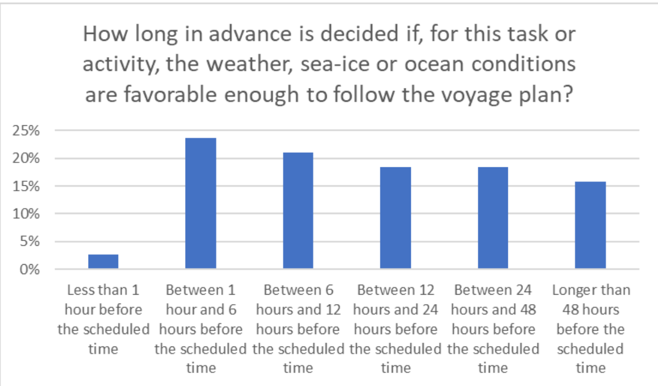

Figure 15. Lead-time for go/no-go decisions for planned activities.

A more detailed insight into specific WWIC factors that are perceived to have adverse impact on maritime activities is gained from Figure 16. For each drawn activity, participants could tick from a list of WWIC factors. Activities appeared to be most sensitive to sea ice related factors. For example, almost 90 percent of drawn activities were stated to be very or extremely sensitive to adverse impacts of sea ice concentration variability. Another important factor that stood out was wind (both speed and direction), followed by horizontal visibility and wave conditions.

Subsequently, participants were asked how often they typically perceived to have insufficient information about WWIC conditions in order to make planning or executive decisions for drawn activities (Figure 17). Sea ice related information was most often perceived to be insufficient. In addition, visibility, wind and wave information scored high on perceived insufficiency. Interestingly, it is exactly those factors, which respondents argue to have the highest potential for adverse impact on maritime activities.

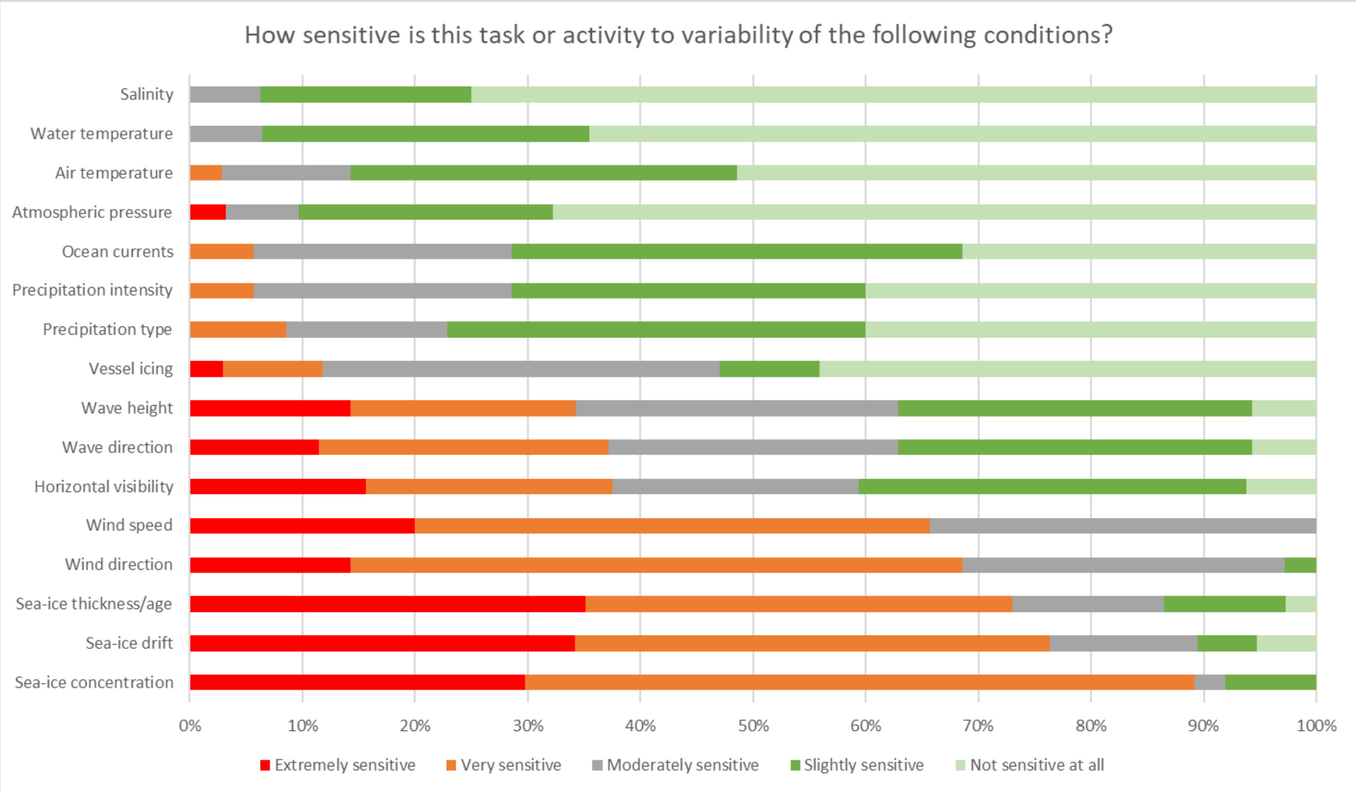

Figure 16. Sensitivity of activities to variability of specific WWIC conditions.

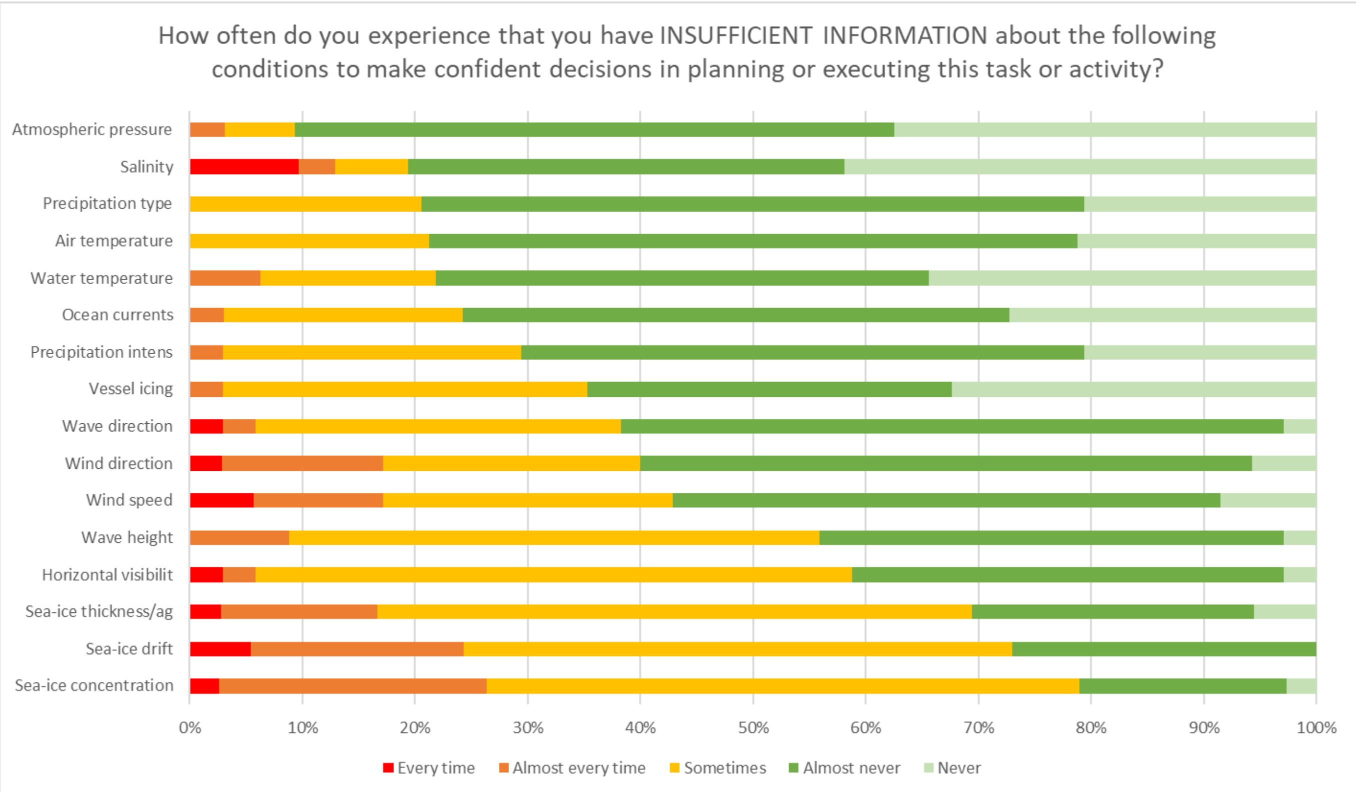

Figure 17. Frequency of perceived information sufficiency per WWIC factor.

Table 7. Factors resulting in increased decision uncertainty.

If you perceive that information about any of the above factors is insufficient, could you please explain which specific characteristics result in increased uncertainty?
Frequency of ice-charts updates
• It is especially the ice conditions that can tease in the area. The intervals between the ice charts are relatively long and the ice conditions can change much between two charts. The satellite images on ocean.dmi.dk help a lot if visibility is good. Web camera at Hotel Arctic is widely used (is out of service at present); • Long intervals between the ice charts in the period when it closes in Dec/Jan and when it opens in April/May. Thereby there is great uncertainty about what ice you encounter on the route especially between Sisimiut and Aasiaat; • If ice charts and ice reports are 1 to 2 days old and based on "old" data when they were made, then there is a lot of uncertainty. If you encounter large unexpected concentrations of *storis* it may be necessary to turn around; • Ice charts are not always available up to date. Decisions about how long I try to get through drift ice and at what point I need to abandon the plan is difficult. Ice charts I use are from MET Norway; • It's rare that we cannot get sufficient information to make a decision on the visit to the pack ice, but it would be great to have more frequent updates without being reliant on ship to ship communication for this. With limited communication in the Arctic on small ships, the source and format of the information we receive can often be unreliable; • Main issue is accurate and up-to-date ice information.
Local observations
• Konstable Point is characterized by local conditions that change rapidly; • The shutdown of the Ice Patrol Narsarsuaq has strongly affected the information. The near-real-time ice information provided by the Ice Patrols' helicopter reconnaissance was very useful; • Local weather conditions are not always available, such as ice flights.
Digital infrastructure
• Internet coverage; • Lack of Vsat coverage so that we must use iridium can be a problem. The bandwidth may be problematic for downloading good enough maps.
General WWIC factors
• Visibility is an important factor, if there is *storis*, uncertainty increases; • These are the same factors that increase the uncertainty of all calls or crossings in Greenland; wind and ice; • Would like more information about ice thickness and waves (height, direction); • Info about ice type is missing. No Ice forecast with confident available.

A follow-up question attempted to flesh out the potential consequences of information insufficiency, by asking participants what characteristics result in increasing levels of decision uncertainty. The response is categorized and depicted in Table 7. Low frequency of ice-chart updates was mentioned several times, next to a lack of local, high-resolution observations.

A subsequent question was posed about how insufficient WWIC information impacts the planning and execution of activities (Table 8). Increased uncertainty is related to unexpected outcomes of decisions and surprises about environmental conditions. Various constraints are mentioned, which are materializing as trip cancellations or route adaptations. Behavioral adaptation (e.g., broadening information seeking) was also mentioned.

Table 8. Uncertainty impacting on maritime activities.

If you perceive that information about any of the above factors is insufficient, could you please explain how this affects the planning or execution of the task or activity?
Unexpected outcomes
• If you do not have updated information about the ice, then you may experience rather big surprises as you approach the area;
• Sometimes we are sailing at greater speed than necessary, thus using more fuel, to later find out the weather is better than expected;
• Whether the information is complete or not, it is the conditions when approaching land that determine if the task/activity can be executed;
• Insufficient information leads to uncertainty about whether cruising schedule can be followed;
• Little information on the ice patterns means the expedition leader has less time to plan the route;
• Since there is sometimes up to a week between the charts, the conditions can be quite different than on the ice chart. If there are too many uncertainties, the trip must be canceled.
Cancellations
• Cancellation of calls x 4;
• Cancellation of operations.
General activity constraints
• The lack of up-to-date ice-charts during the weekend affects planning and executing of the voyage;
• Our vessels have various properties to operate in ice. For this reason, it is a great advantage for us to have a good prediction of the ice conditions, so that we can carry out the assignments with suitable resources;
• Difficult to determine which vessel to use for the operation;
• The ship must be ready to stop the operation at short notice and ready for maneuvering throughout the operation;
• Then you sail south of Cape Farewell;
• Timing is an essential part. Being able to time the timetable for calling will be able to reduce the time required for the assignment. It often happens that vessels remain waiting for conditions to carry out the operation versus being able to do so immediately as a result of good forecasts.
• We stay flexible and always have a plan B and/or C.
Cautiousness
• In case some data is insufficient we will sail with caution and try to get required information as soon as possible;
• Sail with caution and try to get information from different sources.
Broaden information seeking
• If there is insufficient info, I contact a local friend at the destination;
• In case some data is insufficient we will sail with caution and try to get required information as soon as possible;
• We will try to get this data as soon as possible;
• Then you have to try other sources and if they cannot contribute a result, then the sailing schedule must be changed. For example, missing ice charts for the entrance to the Prince Christian Sound from the east can result in you having to round the Cape Farewell instead, but if you now know a ship that is coming, you can always ask them.

Participants were also asked which threshold values for WWIC parameters are important for making a 'go/no-go' decision for drawn activities. The open questions allowed participants to associate freely, which resulted in a range of answers that put specific thresholds in situated contexts (Table 9). Specific thresholds pertained mostly to sea ice concentration and wind speed. An important finding was also that various participants framed thresholds as only relevant when assessed in an integrated form, or contingent on a combination of WWIC conditions, equipment and activity purpose.

Table 9. Thresholds and contexts for WWIC conditions affecting go/no-go decisions.

Which threshold values for weather, sea ice or ocean parameters are important for making a 'go/no-go' decision for this task or activity?
Specific thresholds
• Ice condition more than 7/10 concentration; • More than 1-2/10 sea ice; • *Storis* less than 1-2/10; • No more than 1/10 *storis* when approaching and in the fjord; • Wind > 25/30 knots; • Wind less than 12 m/s; • Wind less than 12-15 m/s; • Wind speed more than 12-15m/s; • Visibility less than 1-2sm; • Wave height > 4.5/5 m; • Preferably no temperatures below zero;
WWIC factors
• Ice water coverage; • Wave height and direction; • When you are going to beach a light boat and have it out again, waves will be the most important parameter, but ice and visibility are important as well; • Wind, concentration and drift of sea ice; • At excessive ice concentrations one may have to cancel calls at the Disko Bay. The plan is tight and there is not much time to mess in the ice. Not some definite limit values, but ice thicknesses above 40 cm and concentrations above 7/10 should alert people; • Sea ice concentration, drift, location, thickness et cetera are the most influential factors in deciding this part of the itinerary. Should conditions not be favorable, we will not attempt this part of the trip and will stay closer to the archipelago. Severe weather or low visibility also have an impact here as travelers want to be able to see the ice/bears when they get there. Knowing the position of the ice/details of the ice is key to this.
Integrated assessment
• Not some definite threshold values, as one takes an integrated assessment. It is especially during the *storis* season that the conditions are challenging; • Combination of all. An assessment is being made if the planned activity can be executed; • It is an overall assessment of all parameters that determine whether the passage can be implemented.
Contingent
• Depending on the scenario; • Depends on the voyage; • Depends on ship type; • In general, it is not possible to say which parameters we use, it is entirely up to the ship in question that assesses whether we can sail with tender boats and whether we should sail inland, of course listening according to our (pilot's) advice and guidance.
Other
• We always go, if extreme weather we might delay departure some hours; • None, is determined when approaching land.

Finally, participants were asked what typical alternative actions (‘plan B’) are in case WWIC conditions make it impossible to execute activities as scheduled in voyage plans (Table 10). Responses were categorized as spatial adaptations (e.g., route change), temporal adaptations (e.g., postponement or cancellation) or activity adaptation (e.g., another excursion).

Table 10. Alternative actions in case of adverse WWIC conditions.

In the case that the task or activity can not be carried out due to adverse weather, sea ice or ocean conditions, what is the most likely alternative action/'Plan B'?
Spatial adaptation • Alternative route; • We just find another nice spot to land or take another route; • Aborting the call in question and re-route the vessel for the next safe port of call; • New route; • South of Cape Farewell; • New route - alternative location. For example, Skolingen; • If approaching land cannot be done, an alternative route can be selected; • On the west coast there is mostly an alternative sailing but not calling. On the east coast it is not an option; • Alternative routing / cancelling port / change port order; • Cancel ports of call / re-route / change port order; • Redirectioning.
Temporal adaptation • Then passengers must be put ashore in Aasiaat. The ship does not have time to wait and must try again a week later; • Then the ship sails north again and tries again a week later; • Plan B is trying again in a week; • Wait until better weather, if ice maybe wait or cancel; • Mostly rescheduling activities; • There is no plan B; call canceled; • Rescheduling, cancelling; • Plan B is moving it in time until the conditions fit - which means that the assignment takes up a larger part of the patrol; • New time for the operation; • Wait.
Activity change • If we are not able to visit the ice, then we would proceed to visit other landing sites around the archipelago; • Another landing site or activity; • Do other activity until the weather or the ice has improved.
Multiple • Consider alternative route or cancelling the port; • Choose another fixing area, or wait for weather improvement; • Depends on itinerary: alternative route or cancelling of the port will be considered.

3.1.3 Information (in)accuracy

In the third mapping exercise, participants were asked to reflect on (recent) situations, in which WWIC information (e.g., seasonal outlooks, forecasts, ice charts) had a significant impact on executing the activities, because the information turned out to be particularly 'accurate/right', or 'inaccurate/wrong'. In line with the previous mapping pages, several questions were asked about the drawn areas, for example about the type/source of information, and how the (in)accurate information impacted the activities undertaken or planned.

A total of seventeen drawings were made. For thirteen of these (Figure 18), additional information was provided by the respondents. A small majority of the drawings pertained to inaccurate information. Note that the small number of responses limits the potential of making generalized inferences, and that the findings reported below provide only anecdotical insights.

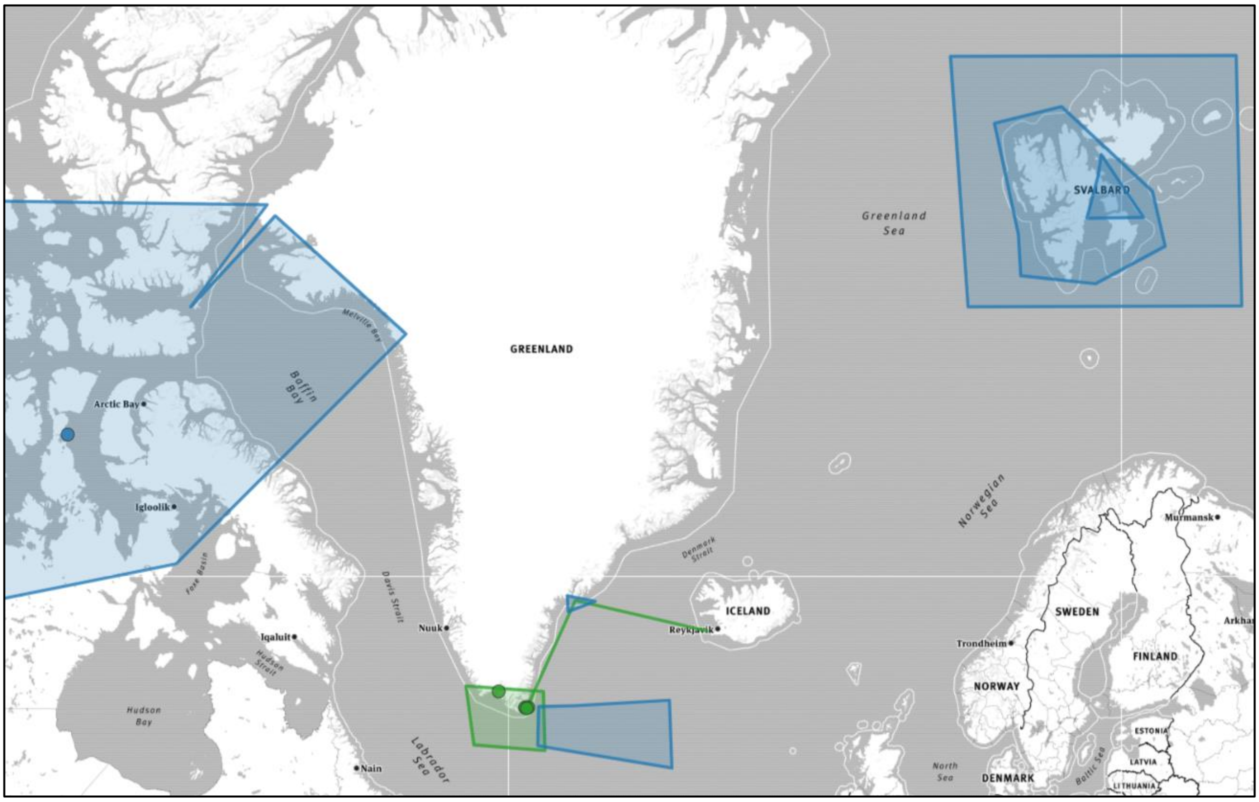

Figure 18. Drawings of areas where experiences of accurate (green) and inaccurate (blue) WWIC information occurred.

Having drawn a geographical area where (in)accurate WWIC information impacted decision making, participants were invited to provide more details about these experiences. At several occasions, the impact of inaccurate information appeared to be significant, ranging from cancellations and alternation of entire itineraries, to logistical issues in terms of vessel choice (Table 11). Experiences of accurate WWIC information (Table 12) mostly related to being able to execute a specific activity (route or port call). Overall, it seems that inaccurate information results in experienced impacts on the overall voyage, while accurate information seems to be experienced in a context of activities on a more detailed level. This observation however is based on a small number of (anecdotal) accounts and should be verified in future research.

Table 11. Experiences of inaccurate WWIC information

Which specific parameters or format of WWIC information was inaccurate?	How did this information impact the decisions that had to be made?	Most important goal at stake	Date	Sources involved
Incorrect information about the thickness of the ice meant circumnavigation wasn't possible.	It impacted the entire itinerary. The ship was forced back along the route already sailed to return to Longyearbyen as the ice was too thick to push through.	n.a.	June 2017	n.a.
The weather in this area was much better than predicted one week earlier.	We left a fishing vessel behind in the port.	Safety for the crew, ship and cargo.	Christmas 2018	Other (www.en.vedur.is, www.fcoo.dk, www.windy.com)
Usually, direction of wind and swell	Cancel operations or re-position to other more protected areas	Wind	June to September	Polarview
Heavier winds and much more ice than expected ended with a cancellation of the call to Tasiilaq.	Nothing, it is the season where everything can occur, one year is ice-free, the next year 20 cm compact *storis*.	No calls to the city as planned.	End of June	DMI, Other (Weather service in Søndre Strømfjord)
Hard to get exactly enough weather and ice data.	Cancellation of the cruise trip	Cancellation of trip.	September	DMI, Other (Canadian weather and ice warning)
Historically wave height values were too low, vessels hired could not be used.	Great impact, had to return next season to finish.	HSE risk, Economic consequence.	July 2016	n.a.

Participants were also asked to provide in more detail which environmental factors did impact the events that were recalled (Figure 19). Impact of sea ice related factors (especially sea ice drift and sea ice concentration) was (very or extremely) high for the major part of the responses. Wind and visibility were also often mentioned as having a high impact. These findings align with those reported in previous sections of the report.

Providing feedback to NMHSs is an important aspect of increasing value of WWIC information services. Therefore, participants were asked whether they shared their experiences of (in)accurate WWIC information with Nordic NMHSs (Figure 20). While most of the experiences being shared pertained to inaccurate WWIC information, findings give the impression that a majority of significant events (either with accurate or inaccurate WWIC information) is not given feedback about to NMHSs.

Table 12. Experiences of accurate WWIC information

Which specific parameters or format of WWIC information was accurate?	How did this information impact the decisions that had to be made?	Most important goal at stake	Date	Sources involved
When calling Narsaq on January 7th in the evening, the wind lied very precisely according to DMI City weather.	It was possible to call Narsaq. Half an hour earlier, a call would not be possible.	Safe harbor maneuver.	7 January 2019	DMI
Ice charts and weather forecast were correct for passing Prince Christian Sound.	Decision was made to execute voyage passing PCS.	Passengers were able to see PCS as planned in the catalog.	July 2018	YR, DMI, Radio VHF/MF, GMDSS.org
Ice charts was correct	Decision was made to enter PCS.	Passengers were able to see PCS as advertised.	July 2018	YR, DMI, Radio VHF/MF, NAVTEX, GMDSS.org, Other (SPOS)
Concentration and position	Was used in connection with risk assessment and final decision to sail into the area.	Ice concentration	July, August, September	DMI, Other (Arcticweb)
Ice concentration, ice drift, wind, visibility	All of these factors determine if an entrance can be made in PCS	Safe entry into the sound	September	DMI, Other (GPS)

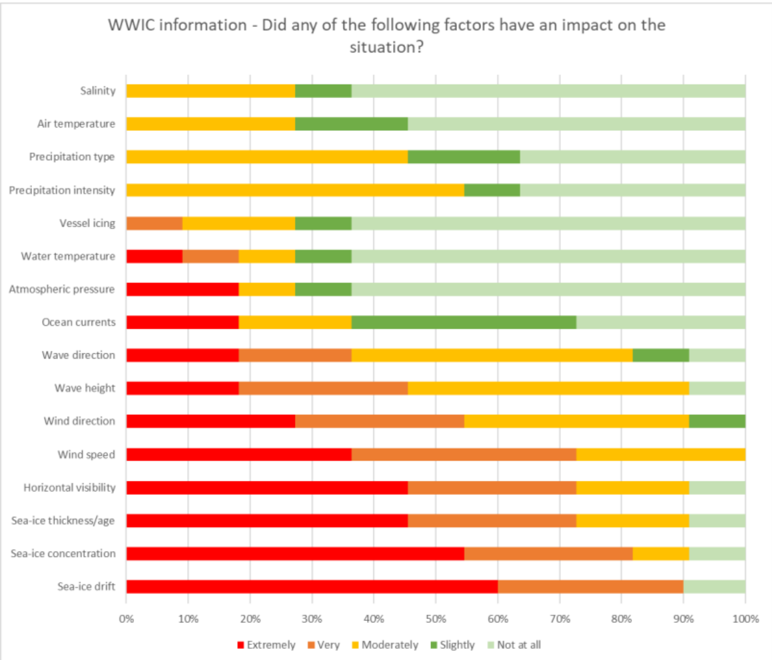

Figure 19. WWIC factors related to events, which were impacted by (in)accurate WWIC information.

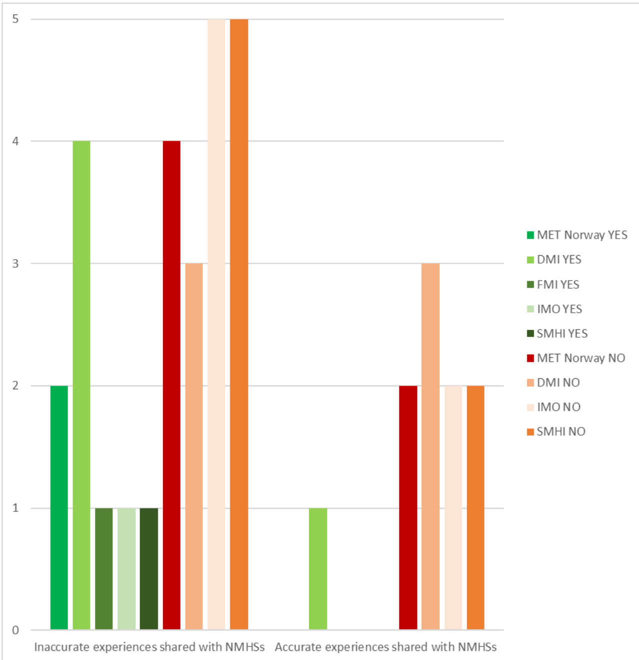

Figure 20. Number of experiences of (in)accurate WWIC information shared with Nordic NMHSs.

3.2 Spatial narratives about the use of WWIC information

Section 3.1 provided an overview of the responses of participants who participated in the mapping survey. Complementing the semi-quantitative approach of that section, this section employs a narrative approach, in order to get a deeper insight into the connections between the different drawings of planning and operational maritime activities, and the role of WWIC information. A selection of individual responses is reported which exemplify the situated context of the use of WWIC information in planning and executing maritime operations in the Arctic. Spatial information provided by several participants illustrate these narratives. Subsections 3.2.1-3 include perspectives from three maritime sectors, hereby providing a more detailed view on experiences for these sectors.

The legend for the drawings is as follows:

- Red = Voyage tracks
- Blue = Sensitive activities
- Orange = Inaccurate WWIC information
- Green = Accurate WWIC information

3.2.1 Cruise tourism

Along the Greenland coast (#356)

This section describes a voyage consisting of a cruise with landings along the Greenland coast. The duration of the voyage is ten days, and the voyage typically takes place between July and October. Typically, all cities along west Greenland are called. The number of persons on board is estimated around 1000. The confidence is very high about being able to carry out the voyage plan without major deviations.

A location is identified where a task or activity is scheduled that is sensitive to adverse impacts of WWIC conditions (blue spot, Figure 21). The location refers to a port call in Tassiilaq, along the east Greenland coast. The duration of the activity is between one and six hours. Both the temporal and the geographic flexibility is not flexible at all. The activity is becoming part of the voyage plan at least 6 months in advance.

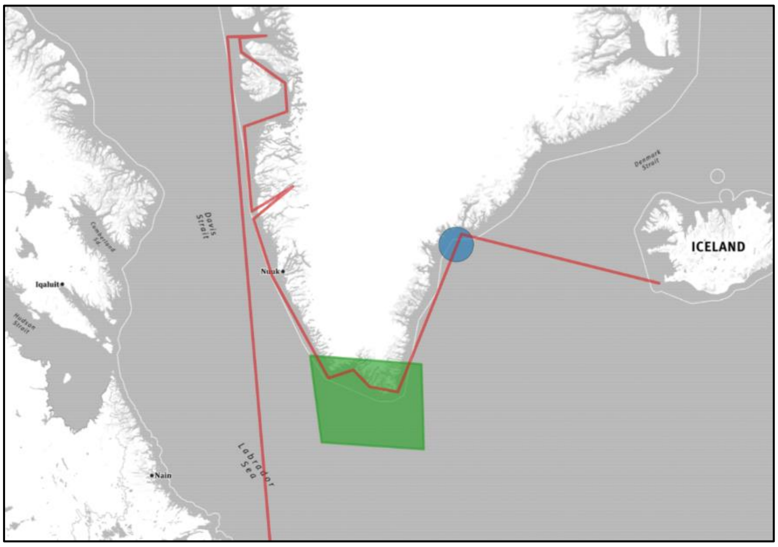

Figure 21. Cruise tourism voyage.

Between 12 and 24 hours before scheduled operations, it is decided if WWIC conditions are favorable enough to call into the port. The port call is typically sensitivity to WWIC conditions as follows:

- Very: wind speed, wind direction, sea ice concentration, sea ice drift, sea ice thickness, vessel icing, wave height, wave direction;
- Moderately: horizontal visibility;
- Slightly: precipitation intensity;
- Not at all: air temperature, precipitation type, atmospheric pressure, ocean currents, water temperature, salinity.

Specific threshold values of WWIC conditions for making a go/no-go decision for the port call depend on the ship-type being used for the cruise.

It almost never occurs that there is insufficient information about WWIC conditions in order to make decisions about whether a port call is possible or not. However, in case the port call is not possible due to adverse WWIC conditions, the call is cancelled, and an alternative route is decided upon, possibly including another port call.

Furthermore, an area was identified where accurate WWIC information had a significant impact on planned activities. The area was south Greenland (see Figure 21). The WWIC information that was accurate pertained to sea ice position and sea ice concentration. The information was used in connection with a risk assessment and resulted in a final decision to sail into the area. The situation occurred over summer, but it is unclear if it refers to a specific event or to a general observation. The accurate information was attributed to the Danish Meteorological Institute, and also to ArcticWeb. The experience was shared with DMI, but not with other Nordic NMHSs.

WWIC factors that had an impact on the described activity context:

- Very: sea ice concentration, sea ice drift, sea ice thickness;
- Moderately: wind speed, wind direction, wave height, wave direction, horizontal visibility;
- Slightly: precipitation intensity, precipitation type, ocean currents;
- Not at all: air temperature, vessel icing, atmospheric pressure, water temperature, salinity.

Despite information being accurate in this specific context, an important concern is that currently not all information is available for free. Open access to WWIC information and increased cooperation between the Arctic countries' NMHSs and standardization of presentation formats could help voyage planning and operations for cruise tourism.

Through the Northwest Passage (#526)

This is an expedition cruise, with about 400 passengers onboard. The voyage is typically undertaken in the summer season between May and October, with high confidence that it can be carried out as planned without major deviations from the voyage plan. The vessel has Ice Class PC 6 and an ICE B+C CE certificate. Planning of the voyage starts more than 6 months before departure. No specific internet data package for digital communication during the voyage is purchased.

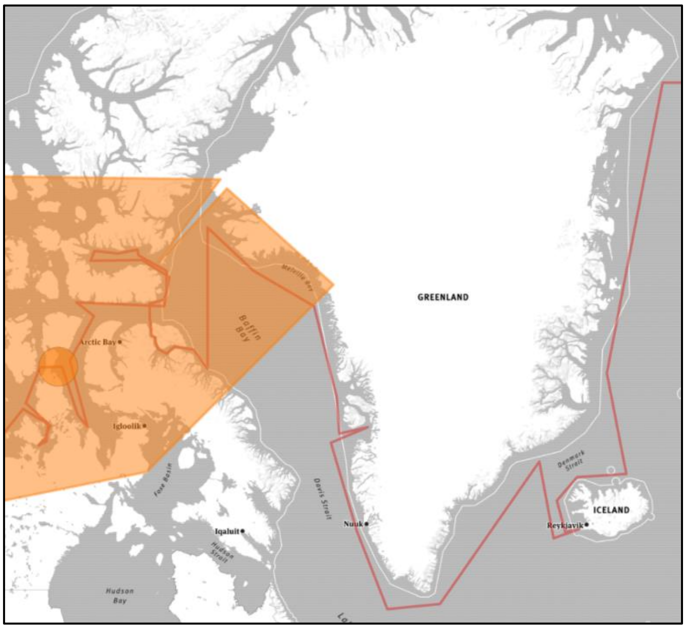

Figure 22. Cruise tourism voyage.

In the orange area indicated in Figure 22, inaccurate WWIC information had a significant impact on planned activities. This area comprises basically a part of the Northwest Passage route, while the specific activity context pertains to a difficult to navigate straight (Figure 23). The particular situation described pertains to late summer (September). While sailing the route, it was difficult to make a plan several days in advance. WWIC factors that had extreme impact on the situation: wind speed, wind direction, sea ice concentration, sea ice drift, sea ice thickness/age, ocean currents, atmospheric pressure, horizontal visibility. Specific uncertainty resulted from inaccurate information related to sea ice conditions. A comparison is made between different ice-chart providers: the Canadian ice chart with egg code was appreciated, above the charts that are used in Norway/Svalbard. These experiences have been shared with the Danish Meteorological Institute, but not with other Nordic NMHSs.

Figure 23. Location where inaccurate WWIC information impacted expedition cruise.

Within the area discussed just above, a more detailed location where inaccurate WWIC information impacted activities during this voyage is depicted in Figure 23. Here, it was difficult to get precisely enough weather and ice data. WWIC information sources involved were DMI and the Canadian NMHS. Factors with an extreme impact in this situation were: sea ice concentration, sea ice drift, sea ice thickness, ocean currents, atmospheric pressure, horizontal visibility, water temperature. Because of insufficient information, it was decided to cancel a part of the voyage. An important lesson described by de respondent is that it is impossible to get accurate enough forecasts for more than 5 days ahead. Experiences were shared with DMI.

3.2.2 Fisheries

East Greenland and northeast Svalbard (#562)

A small number of responses provided experiences from the fishing sector. This narrative is based on some of those responses. The voyages and activities depicted in Figure 24 and Figure 25 typically take place between January-April and October-December. The vessel has an Ice class and a CE certificate (Ices 1A). It typically has about seventeen people on board.

Timing and geographic location of the fishing operations are very flexible. WWIC information is used both for planning purposes and during operational activities. Voyage planning appears to be done along a (spatial) scope that changes over time: voyages into the fishing grounds (blue area Figure 24) are planned between 15 days and 2 months in advance in the Greenland context, and 8-14 days in advance in the Svalbard context (blue area Figure 25). However, the actual voyage track to reach the fishing grounds is planned maximum one week before departure. Also, it is decided between 24 and 48 hours in advance if WWIC conditions are favorable enough to follow the voyage plan.

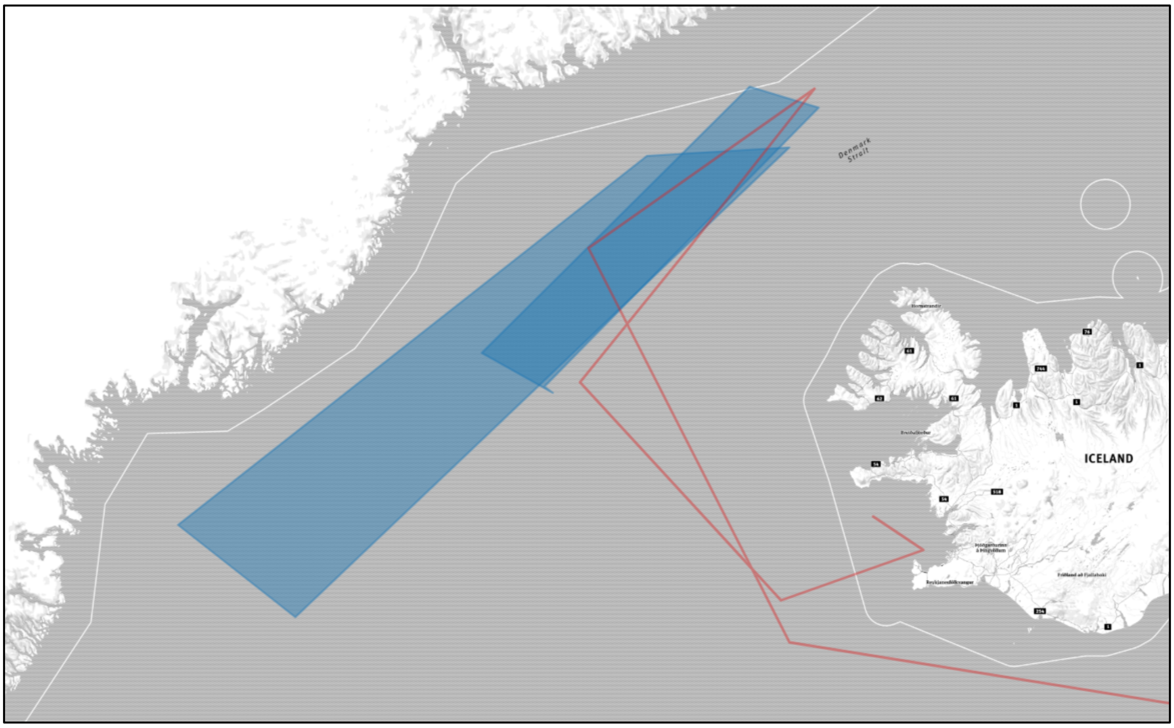

Figure 24. Fishery voyage track and fishing areas.

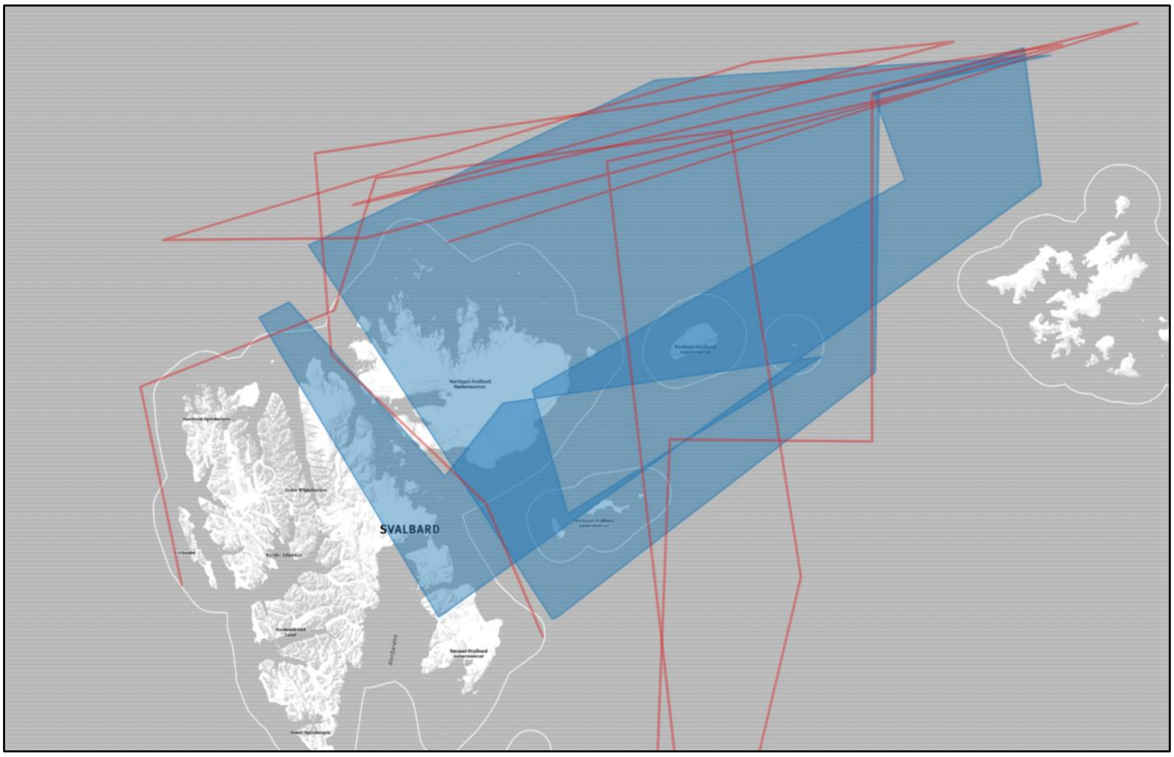

Figure 25. Fishery voyage track and fishing areas.

In the assessment of operational sensitivity to WWIC conditions, variability of the following factors is considered. The fishing operations are particularly sensitive to wind (speed, direction) and sea ice conditions:

- *Extremely/very sensitive:* Wind speed, wind direction, sea ice concentration, sea ice drift, sea ice thickness/age;
- *Moderately/slightly sensitive*: Vessel icing, wave height, wave direction, water temperature, ocean currents, air temperature;
- *Not sensitive*: Atmospheric pressure, horizontal visibility, salinity, precipitation intensity, precipitation type.

Information insufficiency is experienced in a varying degree for the following WWIC conditions:

- *(Almost) every time/sometimes*: Wind speed, wind direction, sea ice concentration, Sea ice drift, sea ice thickness/age, vessel icing, wave height;
- *(Almost) never*: Air temperature, wave direction, ocean currents, horizontal visibility; Precipitation intensity, precipitation type, atmospheric pressure, water temperature, salinity.

It is important to notice that the conditions for which insufficient information is available to make confident decisions in planning or executing this task or activity, are also the factors to which the fishing operations are very/extremely sensitive. Specific improvements mentioned in the fishing context pertain to more frequent updates. In various planning and operational decision-making tasks, individual skills play an important role as an information resource to rely upon.

3.2.3 Cargo and passengers

Greenland west coast (#195)

This narrative in the context of passenger shipping is located mainly along the (west)coast of Greenland (Figure 26). The duration of the voyage undertaken was one week. The voyage, with about 100 passengers and crew on board, typically can be undertaken all year, except January and February. An internet package (V-SAT 512/256) is purchased for the trip in order to stay connected. A casco and liability insurance is purchased for the trip. The confidence of being able to execute the voyage as planned without major disruptions is high.

Activities which are sensitive to adverse WWIC conditions include sailing particular stretches along the west coast of Greenland (large blue areas on Figure 26). The timing of this activity is slightly flexible, however the geographic locations are not flexible at all.

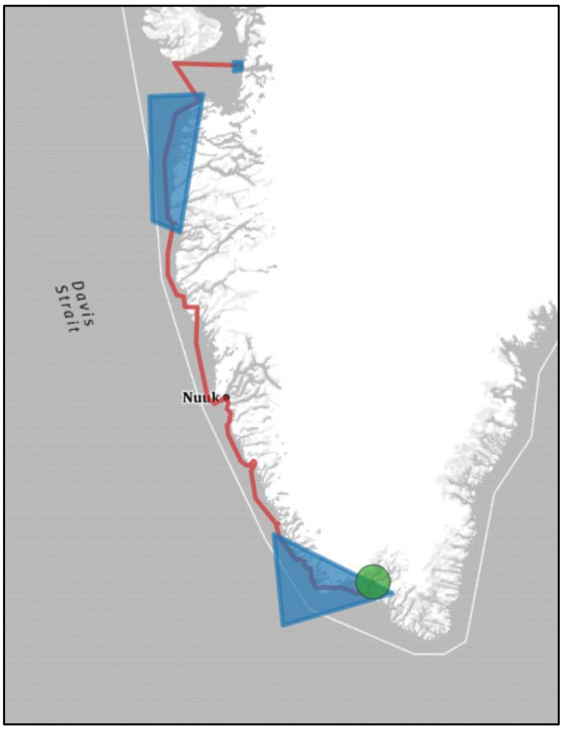

Figure 26. Passenger transport along Greenland west coast.

Sailing along these stretches usually takes between 24 and 48 hours, and it is decided maximum three days in advance if these areas will be entered. For the northernmost stretch, it is decided between 12-24 hours if WWIC conditions are favorable enough. For the southern stretch there is some more lead-time, as a decision is made between 24-48 hours in advance. Another sensitive activity is calling the port of Ilulissat, an activity which takes only between one and six hours. The port call is decided to be viable on short notice, with a decision about favorable enough WWIC conditions being made maximum six hours in advance.

The port call and the sailing of these stretches is very sensitive to variabilities in sea ice concentration, sea ice drift and sea ice thickness, and moderately sensitive to wind speed and wind direction. Coastal sailing is also moderately sensitive to vessel icing, wave height and wave direction. Sensitivity to other factors is only slight at most. *Storis* is of particular concern, and not always enough information is available about prevailing sea ice conditions. Thresholds which should alert people include ice thicknesses above 40 cm and ice concentrations above 7/10. Experiences of information insufficiency pertains to sea ice concentration, sea ice drift and sea ice thickness, especially for the stretch north of

Nuuk. This is of particular concern between December and May, when the sea ice tends to grow too thick for most vessels and intervals between updates of sea ice charts tend to be longer than preferred. For both areas, weekly updates are experienced as too few, as conditions can change significantly in these periods. For the port call in Illulissat, information about drift ice tends to be insufficient. Lack of up-to-date information about these conditions results in high uncertainties and big surprises, which in turn can affect scheduled voyages to be cancelled, or voyages to be postponed until more recent sea ice information becomes available. If a port call cannot be made, passengers will have to be put ashore in another port and picked up at another occasion.

Greenland south coast (#318)

Another narrative located along the Greenland coast comprises cargo shipping (Figure 27). The narrative is based on several drawings. The voyages take between one to three weeks in total. While a voyage is scheduled at least six months in advance, actual voyage plans are constructed between four and seven days in advance. Typically, the vessel has a total of about fifteen people onboard.

The voyage can be undertaken throughout the year, including the winter and spring seasons. Both an internet data package and an insurance are purchased for this voyage. The confidence that the voyage plan can be executed without major deviations is low to moderate. This low confidence can be related to the whole voyage being indicated as sensitive to adverse WWIC conditions (blue line, Figure, 27). Even though the timing of the voyage is slightly flexible, there is no geographic flexibility, meaning that the route is determined, but that delays are anticipated.

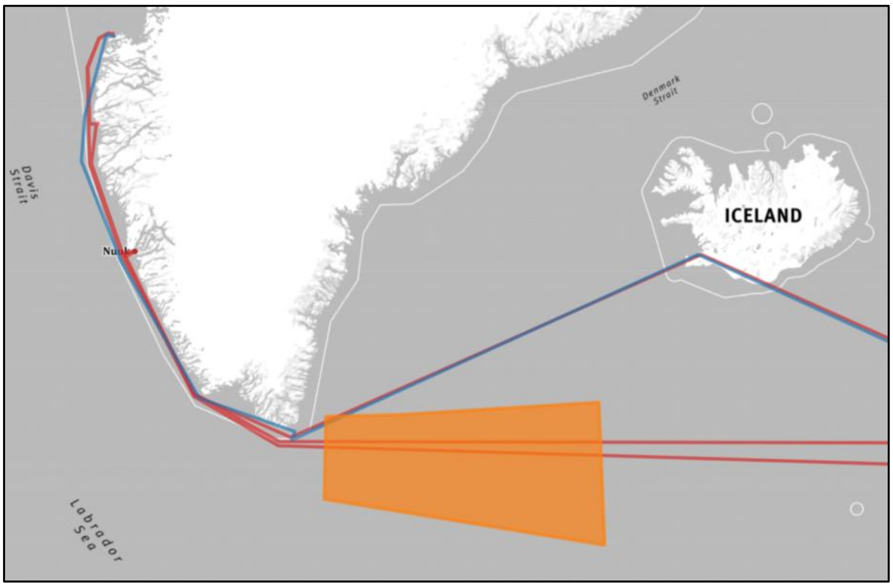

Figure 27. Cargo shipping voyage

The variability of the following factors is potentially impacting the voyage:

- *Very sensitive:* Wind speed, wind direction, wave height, wave direction;
- *Moderately sensitive*: Sea ice concentration, sea ice drift, vessel icing, ocean currents, horizontal visibility;
- *Slightly sensitive*: Sea ice thickness/age, air temperature;
- *Not sensitive at all*: Precipitation type, precipitation intensity, atmospheric pressure, salinity.

An assessment of WWIC conditions to be favorable enough to execute the voyage is taken at least 48 hours in advance. It is also explicitly stated that voyages are always undertaken, and if conditions are adverse, delays are accepted and even cancellations of (part of) the voyage is an option.

Insufficient information about WWIC conditions is sometimes experienced, when it comes to sea ice (concentration, drift and thickness), precipitation type and vessel icing, horizontal visibility and water temperature. When uncertainty arises about WWIC conditions, this can result in attempting to sail faster than planned, in order to avoid delays. However, this can sometimes lead to vessels arriving at their destination earlier than planned, when conditions were better than assessed, based on available WWIC information. Such a situation of inaccurate WWIC information occurred during a voyage, when the south coast of Greenland was approached (orange area, Figure 27). Based on forecasts that included wind (speed, direction) and wave (height, direction), a cargo load was left in port. From this it can be inferred that probably a windstorm was forecast. However, it turned out that WWIC conditions were favorable enough to have taken the load and transport it to Greenland. The experience of inaccurate information sources that were used in this particular situation (www.en.vedur.is, www.fcoo.dk, www.windy.com), was not shared with any of the Nordic NMHSs.

4. DISCUSSION AND RECOMMENDATIONS

Recently, there has been wide agreement that WWIC information services for polar areas require further development in line with end-users needs (Dawson et al., 2017; Lamers, Duske, et al., 2018). Earlier studies found that forecasters and service developers (e.g. researchers in NMHSs) have little insight into how their services are actually used, where, and in what contexts (Jeuring, Knol, & Sivle, forthcoming). This survey has been an attempt to partially fill this gap by collecting contextualized information about experiences with WWIC services in the Arctic through a participatory mapping approach. Using participatory mapping made it possible to embed the survey questions in an intuitive, activity-oriented perspective, and to put the user experience at the center of the study. Hereby, the survey has delivered situated spatial information about the use of WWIC information for maritime planning and operations, and it provided in-depth insights in the impact of WWIC conditions on maritime activities. Importantly, the survey gained an understanding of the degree to which used WWIC services deliver sufficient and accurate information for maritime operations, and it provided insights into users' preferences with respect to the types and formats of information that would be valuable to improve or develop. While this survey confirms conclusions drawn from other workshops and surveys, such as the need for (near) real-time information on sea ice qualities and conditions (Hislop & Hamon, 2019), it also conveys several relevant new insights.

4.1 Voyage planning as a multidimensional concept

It appeared that voyage planning is interpreted as a multidimensional practice, of which the significance and content changes across temporal levels and differs between maritime sectors. Different interpretations of voyage planning were visible in participants' answers through typical planning lead-times for the drawn voyage tracks. For example, several voyage tracks for cruise tourism were stated to be 'planned' only several days in advance, while it is known that cruises and port calls are scheduled up to years prior to departure (Lamers, Duske, et al., 2018). The Arctic Marine Shipping Assessment states that while such tours are booked well in advance, many of the itineraries are somewhat "opportunistic" (Arctic Council, 2009, p. 79), thus incorporating a lot of flexibility. In our study, differences were thus visible in planning lead-times between overall voyages and specific activities. These discrepancies can be somewhat confusing and should be investigated further.

A potential explanation of the difference of interpretation of the concept of voyage planning could lie in the respondents' primary tasks and responsibilities, as they might have to deal more with operational, *en-route* decision making. Further inquiry in the practical use of the 'voyage planning' concept, its multidimensional character, and the level of flexibility within the execution of planned voyages, could provide a more detailed insight about the extent to which these findings align or contradict. There are currently only few studies about voyage planning practices (see, for example: Jeong, Kang, Kim, Kim, & Roh, 2018; Pastusiak, 2016; Skóra & Wolski, 2016), which often take on a technical approach. This leaves a strong need to uncover how the multidimensionality of voyage planning is put in practice, especially because voyage planning is increasingly embedded in regulations, such as SOLAS and the Polar Code (Kirchner, 2017).

4.2 Subtle but significant impact of WWIC conditions on maritime operations

The findings of the survey show that different WWIC factors have a nuanced, yet significant, impact on different maritime activities, at different locations. Tasks and activities which are particularly sensitive to adverse WWIC conditions are port calls, the navigation of certain (often narrow) areas, and cruise tourism activities such as landings and excursions. The impact varies, from increased uncertainty in route planning and choice of equipment, to difficulties to execute planned activities, decreased passenger comfort, or the need to build in spatial or temporal flexibility in voyage planning and execution. These findings somewhat contradict with findings from Bystrowska (2019) who states that WWIC conditions only have a limited influence on maritime activities. It might be that WWIC conditions are becoming salient only relatively late in the decision-making process, or because most of currently available WWIC information in the Arctic only offer enough certainty up to several days. It might however also depend on the level of detail at which enquiries are made.

This study's findings point out that uncertainty and adaptation are strongly embedded in any type of maritime activity, and the liberty to stray from specific parts of voyage plans is necessary in order to successfully carry out an overall voyage or operation. For example, several participants note that their maritime operations are put in practice as planned, until conditions become too adverse. This implies that these operations attempt to stick to voyage plans as long as possible. While such an approach might be suitable for some maritime sectors (e.g., cargo or passenger ferries), cruise tourism operations might turn more quickly to a 'plan B' and have alternative activities or routes. It is thus likely that the same WWIC information will be interpreted differently and have a different impact across user contexts.

4.3 Information insufficiency is a challenge

While respondents have indicated that there are many instances where they do not have enough information (information insufficiency), the impression of this survey is that they are generally satisfied with the accuracy of the information that is available.

In terms of experienced information insufficiency, there are some WWIC conditions about which respondents experience a lack of sufficient information, regardless of the activity they are undertaking, and regardless of the geographic location where they operate. In general, respondents often experience information insufficiency regarding sea ice and wind (sea ice concentration, sea ice thickness, sea ice extent, wind speed and wind direction). The results also show that operations are considered most sensitive to the variability of these same conditions (Figure 16 &17). We could infer from this that access to sufficient and accurate information about sea ice and wind conditions is most vital to these operators in the Arctic, and should be the focus of the further development of Arctic forecasting. Additional suggestions for improvement of services pertain to wave information (both direction and height). Importantly, findings suggest that there is a desire for products that can convey *dynamics* of WWIC conditions, for example through interfaces depicting sea-ice drift. Dynamic interfaces can help assess the pace and direction of changing conditions and thus be a useful tool in operational/tactical decision making (e.g., routing). Finally, and aligning with findings elsewhere (see also Dawson et al., 2017), there is a need to increase the frequency of sea-ice charts and to bridge the gap toward communicating real-time sea ice information as much as possible.

Although somewhat unsurprising, it is relevant to note that, when respondents were asked about their own threshold values for making a go/no go decision for certain tasks or activities, answers frequently included concrete wind and ice parameters, which also gives the impression that they desire rather detailed information about local conditions. In the Greenlandic context, *storis* turned out to be a much-used concept (used for the thick ice that drift out Fram Strait and along the East Greenland current towards the Cape Farewell area). *Storis* information is characterized by large uncertainty, though vital in planning and operational decisions. Additionally, WWIC conditions were also considered on a higher, more integrated level. This implies a level of situated knowledge to be present among participants that allows for what Daipha (2015b) calls a practice of *collage*, that is to 'distill the complexity of the atmosphere into a provisionally coherent account through a process of assembling, appropriating, superimposing, juxtaposing, and blurring disparate pieces of information' (Daipha, 2015a, p. 800) in order to come to an integrated assessment of current or forecast environmental conditions. Incompleteness or inaccuracy of information from one source, or related to one WWIC factor can be compensated by, or embedded in alternative information, and together result in a sufficiently complete assessment of the situation.

The findings also show that WWIC information services are experienced to have a limited and unequally distributed geographical coverage. For example, whereas some areas are well covered, like South Greenland, or Isfjorden and the area around Longyearbyen in Svalbard, the available information for geographical regions outside these "centers" is experienced as insufficient to a greater degree. Another, well-known, issue pertains to bandwidth limitations in the Arctic (Knol et al., 2018), especially north of 78 degrees. Limited download capacity that constrains access to information sources was mentioned several times as an important challenge for maritime activities in the high north. While the technical side of digital infrastructures will gradually improve for the Arctic on a higher level, there is at the same time a need to deal with the existing limitations and find solutions at the local level that can provide some legroom for at least some maritime stakeholders. For example, testing out new interfaces or products (e.g., low-bandwidth WWIC information distributed via email) can be done on a small scale before rolling it out to larger groups of users. Similarly, options to consider include investing in WWIC services for local communities along the Greenland coast; making available paid services to vulnerable stakeholders with limited funds (e.g., small scale fisheries); or target development of high resolution products at especially challenging areas for navigation (e.g., Prince Christian Sound, ports or cruise landing sites).

4.4 Limitations and next steps

The use of a map-based survey platform in this study has facilitated the collection, management and visualization of citizen generated data (Lamoureux & Fast, 2019). To our knowledge, this approach has not been used before with the aim to elicit user experiences and preferences in relation to WWIC information services. SoftGIS has been developed, and is currently still mainly used, within the field of urban planning in order to elicit local knowledge. The approach often has a quantitative point of departure to acquiring qualitative knowledge, in that it aims to collect insights from large samples. Hereby it capitalizes on the opportunities of the internet to reach large groups of people. We employed a softGIS approach in a sparsely populated area, aiming at the maritime sector in the high north. Thus, rather than aiming for a large sample size in order to make generalized statements, we made exploratory use of softGIS in the maritime Arctic context in order to collect contextualized spatial knowledge.

There is a sensible sweet spot of data richness, to be reached in qualitative research. For example, it is recommended to not ask too many questions in a softGIS survey (Babelon et al., 2017). This survey however was relatively extensive and data collection therefore probably suffered from user fatigue. While we were aware of this risk beforehand, we chose to include a relatively large number of questions. We anticipated on the small target population to provide a limited number of participants and reasoned that participants who were willing to share their experiences, would be willing to do so extensively, as they have a vested interest in NMHSs to provide them with the WWIC information they need. We thus anticipated to gather in-depth insights in the use of WWIC information from a small but dedicated number of participants. We expected that the use of softGIS (as opposed to alternative forms of participatory mapping) would enhance possibilities for participation of remote stakeholders, provided that they have an internet connection. While the study succeeded to reach out to a diverse group of maritime operators, it still appeared difficult to involve participants. An explanation can be that the digital interface creates a mental distance toward the study and probably limits motivation to fill in the survey. This is also argued in a study comparing several map-based crowdsourcing platforms; while these platforms are viable options for the collection, management and visualization of citizen generated data, they do not offer much public engagement beyond the crowdsourcing of data (Lamoureux & Fast, 2019). An additional complicating factor is that the maritime sector is almost per definition difficult to reach, given that their activities bring them to remote areas, often for extensive periods. These factors at least partly explain the relatively low response to the mapping survey.

Representativeness of participatory mapping/softGIS responses is a general issue of concern (Babelon et al., 2017; Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012). In this particular study, representativeness of different sectors operating in the maritime Arctic turned out to be challenging. While fishing vessels, supply, research and survey vessels, as well as cargo vessels and tankers make up a clear majority in terms of number of vessels involved in maritime operations in the Arctic (Arctic Council, 2009; Eguíluz, Fernández-Gracia, Irigoien, & Duarte, 2016), most of the respondents of this survey represent the cruise tourism sector. The key conclusions and recommendations in this report could have been somewhat different if we had acquired a more diverse representation of sectors, also taking in mind that fisheries/hunting are year-round activities. Because of this, generalizations based on the findings in this report are difficult to make. The results should be interpreted with these limitations in mind. Yet, the report provides many valuable in-depth insights in the use of WWIC information and the related challenges perceived by various maritime stakeholders.

Moreover, in-depth results of a softGIS interface become more informative when integrated in a more conventional participatory approach and when softGIS becomes part of a tool box (Babelon et al., 2017). For example, softGIS can be part of a stepwise data collection, where participants first provide experiences through Maptionnaire, which subsequently are used for follow-up interviews or group discussions, or are embedded in demonstration services, where end-users can test out and give feedback on new products and interfaces (see, for an excellent example: Walker et al., 2016). This allows participants to further illustrate answers and permits the researcher to ask additional questions when clarification is needed. Overall, the situated response provides concrete entrances for in-depth interactions between providers and users. In case of this study, the findings reported here indeed do feed into subsequent practices of co-production. For example, a next step in the SALIENSEAS project is a Serious Gaming exercise, for which the format is partly informed by the results of this mapping study. Furthermore, the findings presented in this report directly contribute to the knowledge base of user needs in MET Norway and DMI. Hereby it can provide a tangible basis for engaging in interactions with specific end-users (Jeuring et al., forthcoming), with the goal to collaboratively improve WWIC services.

Based on our experiences with softGIS in the particular setting of Arctic maritime operations, future studies are encouraged to further explore the advantages of this type of participatory mapping. However, an important lesson from this study is that it is imperative to embed softGIS in an approach that allows to bridge the distance between researcher and participants as much as possible. Increased participation rates and enhanced value of insights into user needs could be reached by tighter collaborations with organizations or individual maritime stakeholders, and by investing time in face-to-face meetings to explain the purpose of the survey.

Finally, an important challenge we experienced pertained to language. The survey was available in English, Norwegian and Danish. However, it was not offered in Greenlandic, which potentially strongly limited the uptake of the survey in the Greenlandic communities. Future (participatory based) research in Greenland contexts should consider the need to tailor any instruments to the language requirements of its residents. Particularly since Greenlandic communities are important users of WWIC information and are strongly dependent on sea ice conditions for maintaining their everyday livelihoods.

4.5 Conclusion

This report provides insight into the ways WWIC information is embedded in planning and operational processes of various types of maritime voyages and activities in the Arctic. The study adds to the body of knowledge on user needs in this context, and is innovative in that it took on a genuine user perspective. This is where this study differs from most research on user requirements for WWIC information, which often puts the perspective of the provider first. For example, conventional user needs surveys often ask about requirements and product use, without any reference to specific tasks, activities or contexts. This study takes those tasks, activities and user contexts as point of departure. Hereby it provides a more detailed and realistic insight into the use of WWIC information, the challenges herein as perceived by maritime stakeholders, and the spatiotemporal contexts in which they arise. This report calls for continuous efforts to obtain insights in needs for WWIC information services of maritime stakeholders by considering the spatially and temporally salient practices of planning and executing maritime Arctic activities on a detailed level as possible.

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