Arctic Hydrographic Adequacy – an Update

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Introduction

The reduction in ice cover of the Arctic has increased ship traffic, yet in many areas of the Arctic the available survey data is old, incomplete, or non-existent. Similarly, while nautical charts are available across the Arctic, they are often at a scale suitable only for offshore voyage planning and potentially insufficient for current and anticipated navigational use. The area is vast, often difficult to access, and, even with diminished ice cover, often logistically challenging to deploy survey teams. The nations with charting responsibility for the Arctic jointly recognized the need for a method to prioritize survey and charting efforts and developed a risk-based method in 2015 [1]. We extend that methodology and incorporate updated information on survey confidence and vessel traffic. The inclusion of Russian waters is a significant improvement to the analysis.

Our basic approach closely follows the methods outlined in [1], and we again limited the scope of the study to the Exclusive Economic Zones (EEZ) of the members of the Arctic Regional Hydrographic Commission (Canada, Denmark, Norway, Russia, and the United States). We use a matrix of survey confidence and depth to develop gradated areas of potential navigational concern. We assign shallow areas with low confidence data as the highest concern, deep areas with high confidence data as the lowest concern, and assign graduations of concern to the intermediate combinations. We then intersect these areas of concern with the observed traffic to focus attention on those areas where there is current use. This analysis is available as an interactive web based map.

Since the 2015 study, other offices have completed risk-based studies that are more sophisticated than the model presented here (e.g. [2] [3]). These studies typically incorporate additional factors, such as environmental sensitivity, that we do not. These models also incorporate more sophisticated treatment of parameters that we do consider, such as seafloor complexity. Even where these models overlap with our study area, we believe there is utility in this simple, pan-Arctic model.

We find that of the over 11M km^2 study area, we have high confidence in the survey data of only 2% of the area. The overall situation is perhaps not as grim as this number might suggest. Based on the matrix of survey confidence and depth we find high potential concern for 38% of the area, medium concern for 45%, and low concern for 16%. We only observed traffic across 27% of the study area, with 11% of the study area experiencing traffic in areas of high potential concern. The traffic is also highly concentrated. If we threshold to areas that see over 12 transits per analysis cell, approximately 190,000 km^2, or 2% of the study area sees high traffic in areas of high potential concern.

Study Area

While the Artic is generally defined as north of the Arctic Circle, we expand the analysis here to encompass the expanded definition of the U.S. Arctic research and policy Act that includes the Bering Sea (Figure 1). We consider only the areas in the Arctic encompassed in the EEZ of the member states of the ARHC (Canada, Denmark, Norway, Russia, and the United States) for the analytic portion of this work. The accompanying web map extends the graphical analysis to 50° N latitude.

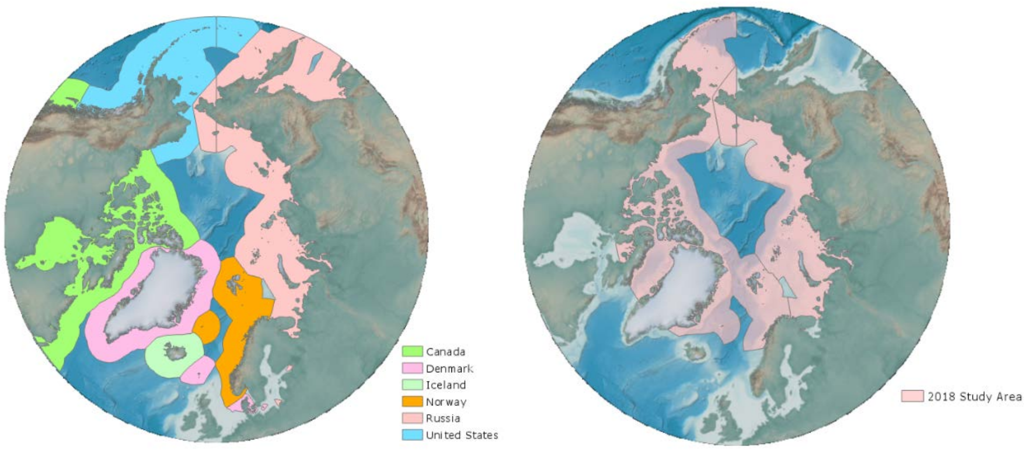

Figure 1: The study area (right) is the intersection of the combined EEZ of the ARHC member states (left) using the expanded definitions under the U.S. Arctic research and policy Act (i.e. Arctic Circle plus Bering Sea). Iceland has been included in the accompanying graphics, but not in the numerical analysis.

Methods

We used three inputs to this assessment: depth, survey confidence, and vessel traffic, and build a simple model to identify areas of particular interest to the hydrographic offices of the ARHC member states. Our analysis hinges on the assumption that the hydrographic offices are primarily interested in lowering the risk of surface navigation. We also assume that the hydrographic components of that risk are highest where the water is shallow, the existing data quality low, and the traffic high.

<u>Depth</u>

We divide the area into three depth bands, shallow, medium, and deep following the methods of [1]. We again use the idea that the idea of 'shallow' needs to accommodate some idea of geological nature of the area, recognizing that in an area with relatively flat and featureless seafloor, the risk of navigation near the seafloor is lower than in areas with rugged, high relief seabed. To capture this, we partitioned the areas into either simple or complex seafloor types. To the simple seafloor type, we assigned the northern part of the Bering Sea (north of 57°), the Chukchi Sea, the East Siberian Sea, and the Laptev Sea. We assigned the remainder to the complex seafloor type (Figure 2). For depths, we used the Global Multi-Resolution Topography GMRT Synthesis [4]. Table 1 shows the depth bands for both the simple and complex type areas.

Table 1: Depth bands for both simple (i.e. flat and featureless) and complex (i.e. rugged) seafloor types

	Simple	Complex
Shallow	0-20 m	0-100 m
Mid-Depth	20-50 m	100-200 m
Deep	50 m +	200 m +

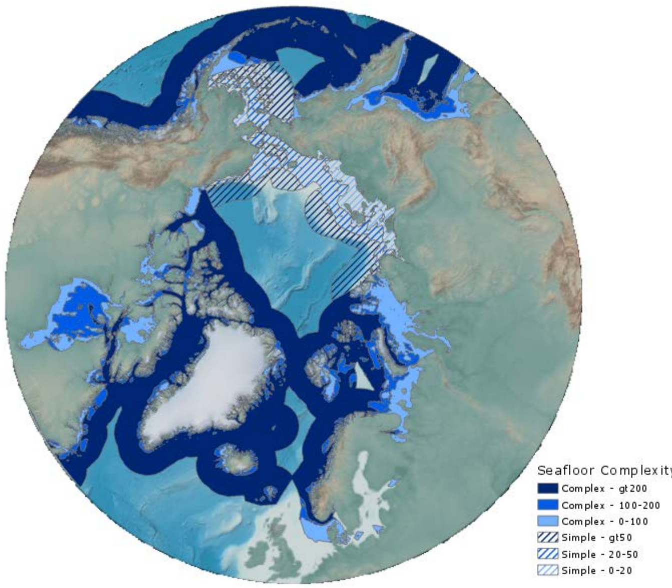

Figure 2: Depth bands for both simple (i.e. flat and featureless) and complex (i.e. rugged) seafloor types.

Survey Confidence

Electronic navigational Charts (ENC) encode survey confidence in the attribute CATZOC. Most of the ARHC members have assessed CATZOC in some fashion, but have not completed updating the official published electronic navigational charts with the CATZOC information. We used the assessed CATZOC rather than the published CATZOC where available (Table 2, Figure 3). For this study, we did not have CATZOC data available from Iceland, which we include in the graphics as unassessed. We have not included any data from Iceland in the analytics.

Table 2: Survey confidence source. We used updated assessments of survey confidence where information was available outside of the published ENC.

		Confidence Level			
Country	Basic Quality Metric	A	B	C	U
Russia	Published CATZOC	**Category A:** Controlled, systematic survey with high position and depth accuracy. Data acquired with a multibeam, channel or mechanical sweep system.	**Category B:** Controlled, systematic survey achieving similar depth accuracy to Category A surveys, but with less position accuracy. Data acquired using modern survey echosounder	**Category C:** Opportunistic survey achieving low depth and position accuracy. Equipment not specified.	Category D and Unassessed
United States	Assessed CATZOC	**Category A:** Controlled, systematic survey with high position and depth accuracy. Data acquired with a multibeam, channel or mechanical sweep system.	**Category B:** Controlled, systematic survey achieving similar depth accuracy to Category A surveys, but with less position accuracy. Data acquired using modern survey echosounder	**Category A:** Opportunistic survey achieving low depth and position accuracy. Equipment not specified.	Category D and Unassessed
Canada	Assessed CATZOC	**Category A:** Controlled, systematic survey with high position and depth accuracy. Data acquired with a multibeam, channel or mechanical sweep system.	**Category B:** Controlled, systematic survey achieving similar depth accuracy to Category A surveys, but with less position accuracy. Data acquired using modern survey echosounder	**Category A:** Opportunistic survey achieving low depth and position accuracy. Equipment not specified.	Category D and Unassessed
Denmark	Survey method	Multibeam echosounder	Post 1989 Single beam echosounder		Pre 1989 data and unassessed
Norway	Survey Method	multibeam	single beam	Pre-acoustic methods	unassessed

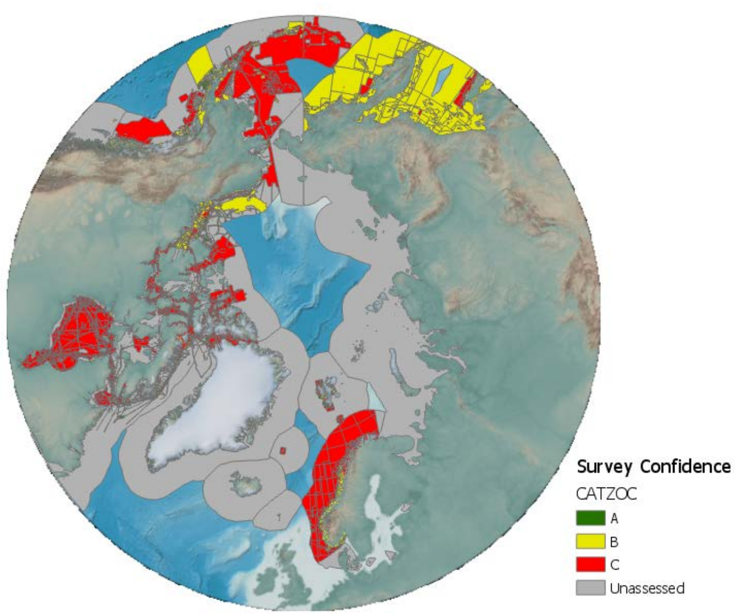

Figure 3: Survey Confidence based on either published CATZOC or assessed confidence based on data holdings.

Areas of Potential Concern

We characterized the potential concern for navigation as the matrix intersection of the survey confidence and depth. Where the survey confidence is high, equivalent to CATZOC A, we assigned low concern. Where the survey confidence is low, equivalent to a CATZOC C or lower, and the water shallow, we assigned high concern. Shows the assigned potential concern for navigation for other combinations of depth and survey confidence.

Table 3: Potential concern for navigation assigned based on depth and survey confidence.

Potential Concern for Navigation				
	Confidence Level			
	A	B	C	U
Depth Band				
Shallow	Low	Medium	High	High
Mid-depth	Low	Medium	High	High
Deep	Low	Low	Low	Medium

Figure 4 illustrates areas of potential navigational concern. Most of the study area is unassessed, driving the dominance of high to medium navigational concern across the study area (Table 4).

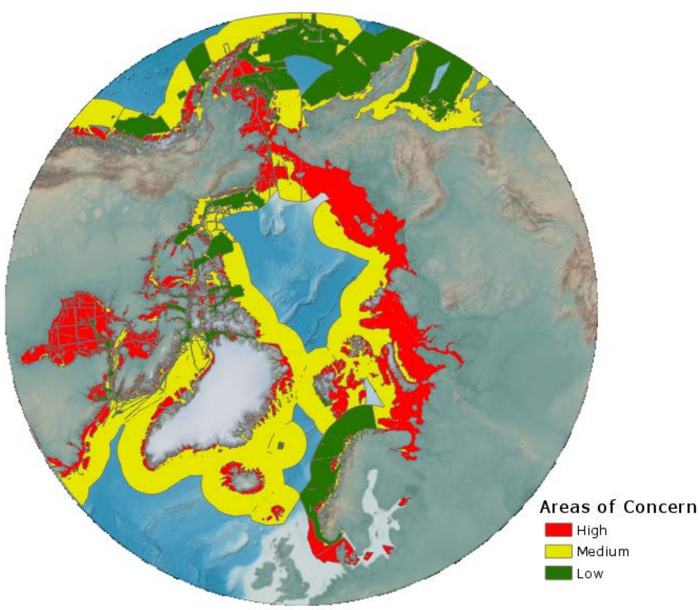

Figure 4: The areas of potential navigational concern. Areas of high concern are either shallow or mid depth and either poor quality data or unassessed.

Table 4: Area of potential concern for navigation.

Canada, Denmark, Norway, Russia, United States								
Areas of Potential Concern by Depth								
DEPTH BANDS	High Concern		Medium Concern		Low Concern		Total	
	M km^2	% of Study Area	M km^2	% of Study Area	M km^2	% of Study Area	M km^2	% of Study Area
Shallow	2.2	19%	0.2	1%	0.0	0%	2.4	21%
Mid-Depth	2.2	19%	0.1	1%	0.0	0%	2.3	20%
Deep	0.0	0%	4.9	43%	1.8	16%	6.7	59%
Total	4.4	38%	5.2	45%	1.8	16%	11.4	100%

Vessel Traffic

We used vessel Automatic Information System (AIS) broadcasts received by satellite for estimates of traffic. As was done in the previous study [1], we limited the vessel traffic to include only cargo, tanker, passenger, tug, fishing and towing vessels. The traffic data is for the full 2017 calendar year. We used 0.1° by 0.1° analysis cells and extracted the unique density (i.e. number of unique ships within the analysis cell) for the year (Figure 5). Basing the analysis cell on a geographic system is slightly problematic because the cell size changes with latitude. A 0.1° by 0.1° analysis cell is approximately ten times larger at the southern extent of the study area (the Aleutians) than at the northernmost extent of the study areas (north of Greenland). We would need to correct for this if we were concerned with the density itself. However, we are more concerned with the presence or absence of traffic. From this perspective, the resolution of our analysis changes with latitude, though there is a residual effect on the thresholding operation we later apply to the data.

Using unique density also has some additional, subtle effects. A vessel plying the same route on a regular schedule over a particular analysis cell (e.g. a ferry), counts as one vessel in this analysis. Similarly, we count a fishing vessel working within a particular analysis cell for many months as equivalent to a single vessel transiting once across the cell. This may tend to undercount the actual vessel traffic in a particular area. It may, however, more accurately reflect the number of individual customers of hydrographic products.

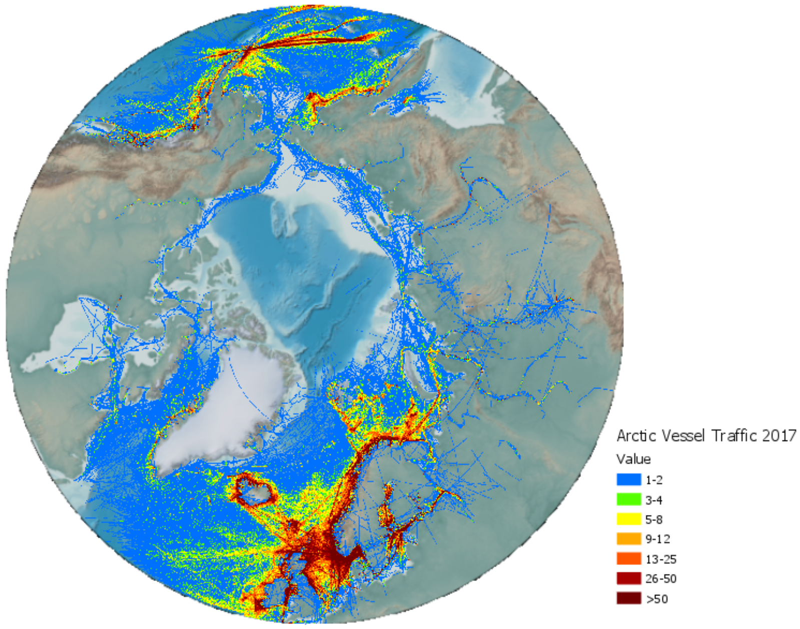

Figure 5: AIS based traffic density for traffic, limited to only cargo, tanker, passenger, tug, fishing and towing vessels. Density is unique vessels per analysis cell per year. Each analysis cell is 0.1° by 0.1°.

The intersection of the AIS data and the areas of potential navigational concern give us areas of actual concern, and thus priority, ranked by level of concern (Figure 6). Of all areas with at least some traffic, 44% is of high concern. Note that, because most of the traffic is concentrated into small areas, this does *not* mean that 44% of all traffic is transiting over areas of high concern. Looking at the entire study area, 9% has at least some traffic and is of high concern.

Table 6 shows the same analysis with a 12-vessel threshold to highlight areas with higher traffic density. Because of the variable size of the analysis cell, this threshold is not strictly consistent from the perspective of traffic density per unit area. Of all areas with at least twelve ships per analysis cell, 51% is of high concern. Looking at the entire study area, 1% has traffic density over 12 and is of high concern.

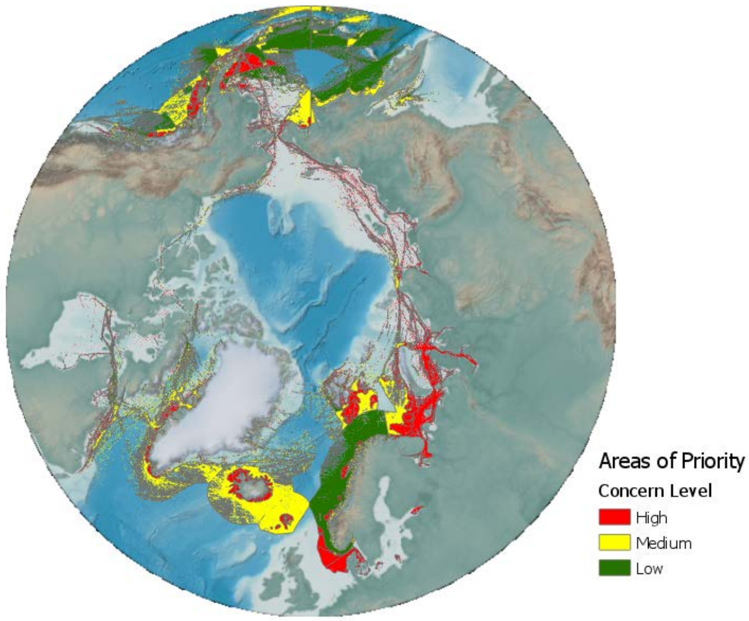

Figure 6: Areas of navigational concern, and thus priority, based on 2017 AIS traffic and areas of potential concern

Table 5: Summary of areas of concern based on 2017 AIS traffic and areas of potential concern.

Canada, Denmark, Norway, Russia, United States												
Areas of Potential Concern with Traffic (No threshold on number of ships)												
DEPTH BANDS	High			Medium			Low			All		
	M km^2	% of Study Area	% of Traffic Area	M km^2	% of Study Area	% of Traffic Area	M km^2	% of Study Area	% of Traffic Area	M km^2	% of Study Area	% of Traffic Area
Shallow	0.7	6%	21%	0.1	1%	2%	0.0	0%	0%	0.7	6%	24%
Mid-Depth	0.6	6%	21%	0.0	0%	1%	0.0	0%	0%	0.7	6%	23%
Deep	0.0	0%	0%	0.8	7%	26%	0.8	7%	28%	1.6	14%	53%
Total	1.3	11%	42%	0.9	8%	29%	0.9	8%	28%	3.0	27%	100%

Table 6: Summary of areas of concern based on 2017 AIS traffic over 12 vessels per analysis cell and areas of potential concern.

Canada, Denmark, Norway, Russia, United States												
Areas of Potential Concern with Traffic (Total Number of Ships = > 12)												
DEPTH BANDS	High			Medium			Low			All		
	M km^2	% of Study Area	% of Traffic Area	M km^2	% of Study Area	% of Traffic Area	M km^2	% of Study Area	% of Traffic Area	M km^2	% of Study Area	% of Traffic Area
Shallow	0.1	1%	19%	0.0	0%	5%	0.0	0%	1%	0.1	1%	24%
Mid-Depth	0.1	1%	19%	0.0	0%	4%	0.0	0%	1%	0.1	1%	24%
Deep	0.0	0%	0%	0.1	1%	15%	0.2	2%	37%	0.3	2%	52%
Total	0.2	2%	38%	0.1	1%	23%	0.2	2%	39%	0.5	4%	100%

Discussion and Conclusions

The assessment of navigational concern is rather stark. Nearly half (42%) of all areas transited by vessels in the Arctic is in areas we consider of high navigational concern. Indeed, we classified over a third (38%) of the entire area as high potential concern. A closer look at the drivers of this analysis suggests that the remedy may not be as intractable as these numbers suggest. A primary driver of the areas of navigational concern is that much of the area, which has at least some hydrographic data, is unassessed from a CATZOC perspective. A review and classification of existing holdings will certainly improve this analysis. Additionally, this traffic-based analysis suggests a clear mechanism for prioritizing new data acquisition where the need is the highest. The very high traffic densities in some areas, notably in the Norwegian, Barents, and Kara Seas suggest that crowd based approaches to acquire new hydrographic data may be attractive. In other areas dominated by corridor-like transits, such as the Northern Sea Route across the top of Siberia and the Northwest Passage across Canada, establishment and survey of traffic lanes might be a wise approach to efficiently improve the hydrographic data available to the most users.

References

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