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Navigability Indicators for the Northwest Passage and the Northern Sea Route

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Introduction

National Climate Assessment (NCA). The U.S. NCA [Melillo et al., 2014] acts as a national climate snapshot or status report. Climate "indicators" for the NCA are meant to provide a clear and concise way of quantifying the status and trends of various elements of the climate system and their biological significance.

Northwest Passage (NWP) *and* ***Northern Sea Route*** (NSR). The NWP and NSR are sea routes across portions of the Arctic Ocean that connect the Atlantic and Pacific Oceans. The NWP passes through the Canadian Arctic Archipelago, and the NSR passes north of Russia.

Navigability indicators. We are in the process of constructing navigability indicators for the NWP and NSR that indicate the percentage of the route's length that is free enough of sea ice to allow the passage of a ship. The navigability indicators change daily as sea-ice conditions change.

Arctic marine mammals. All seven of the marine mammal species that live in the Arctic year-round (beluga, narwhal, bowhead whale, ringed seal, bearded seal, walrus, and polar bear) occupy portions of both the NWP and the NSR. We are in the process of identifying and mapping key areas of their habitat that intersect the routes of the NWP and NSR, to see which species might be impacted by increased shipping and industrial development as Arctic sea ice continues to decline.

Methods

Sea-ice data. We use daily sea-ice concentration products derived from the Advanced Scanning Microwave Radiometer for the Earth Observing System (AMSR-E) on NASA's Aqua satellite, obtained from the Centre for Marine and Atmospheric Sciences (ZMAW) in Hamburg, Germany [Spreen et al., 2008]. Data are mapped to a polar stereographic grid with 6.25-km grid size, and are available from June 2002 to October 2011. AMSR-2 and other data will be used to extend results beyond 2011.

Navigability indicators. We outline the routes of the NWP and NSR on a base map using ArcGIS, extract the sea-ice data from within the route boundaries, and calculate the navigability indicators from the time series of sea-ice data within the routes.

Arctic marine mammals. Data on home ranges of Arctic marine mammals have been gleaned from more than 100 peer-reviewed journal articles. We focus on June-October, the most likely months for shipping activity through the NWP and NSR.

Results

Navigability indicators. We illustrate the method for one particular route of the NWP (**Fig. 1**) with sea ice shown for August 15, 2009. The sea-ice concentration as a function of distance along the route (**Fig. 2**) shows that the route is blocked in Viscount Melville Sound. The percentage of the route that is open from June-October, 2002-2011, is shown in **Fig. 3**.

Arctic marine mammals. Home ranges of bowhead whales, belugas, and narwhals in September are shown in **Figs. 4, 5, 6,** along with routes of the NWP. **Table 1** lists specific populations and abundance estimates.

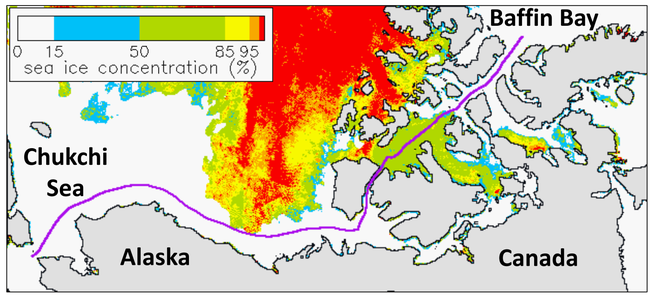

Fig. 1. One route of the NWP (purple curve) and sea-ice concentration on August 15, 2009.

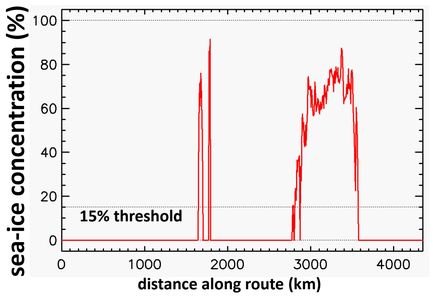

Fig. 2. Sea-ice concentration (%) vs. distance along route (km) for the route in Fig. 1 on August 15, 2009.

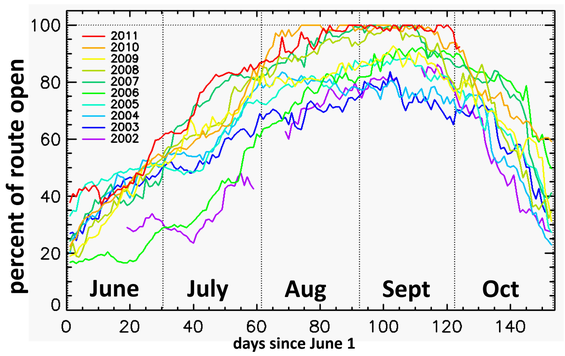

Fig. 3. Percent of route with < 15% sea-ice concentration vs. time, for 2002-2011.

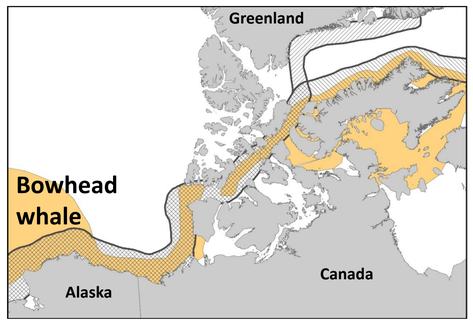

Fig. 4. Combined **bowhead whale** home ranges in September (beige) and one route of the NWP (cross-hatched).

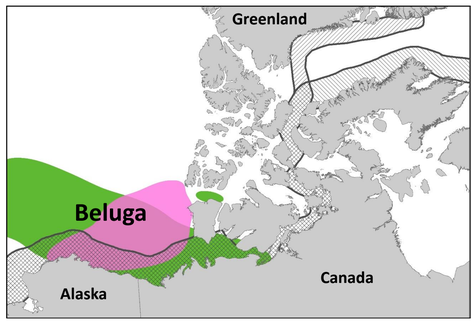

Fig. 5. Beluga home ranges in September for two distinct populations, and one route of the NWP (cross-hatched).

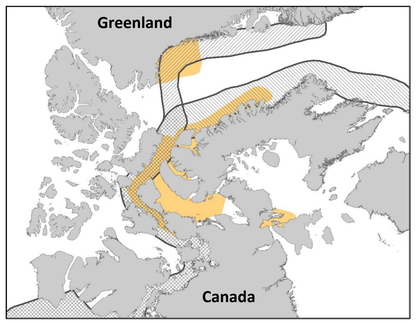

Fig. 6. Combined **narwhal** home ranges in September (beige) and one route of the NWP (cross-hatched).

Species	Population	July	Aug	Sept	Oct	Range confidence	Abundance (CI or CV) from Laidre 2015	CAFF Abundance	CAFF Status	CAFF Trend	Trend from Laidre 2015	Harvest
Bowhead	Bering -Chukchi-Beaufort seas	good	good	good	good		16892 (CI 15704-18928)	16,892 (95% CI 15,704– 18,928)	Reduced	Increasing	increasing	S
Bowhead	Eastern Canada-West Greenland	good	good	good	good		>6500	6,745 (CV 0.22)	Reduced	Increasing	increasing	S
bowhead	Svalbard-Barents Sea					incomplete	<100		Reduced	Unknown	unknown	none
bowhead	Okhotsk Sea					incomplete	<400	N/A - not included	N/A - not included	N/A - not included	unknown	none
beluga	Ungava					incomplete	32 (CI 0-94)	32 (95% CI 0 – 94)	Reduced	Unknown	unknown	S
beluga	Eastern Hudson Bay	good	good	good	good		3351 (CI 1552-7855)	3,351 (95% CI 1,552-7,855)	Reduced	Stable	stable	S
beluga	Western Hudson Bay	good	good	fair	incomplete		57300 (CI 37700-87100)	57,300 (95% CI 37,700-87,100)	Not Reduced	Unknown	unknown	S
beluga	James Bay	good	fair	fair	fair		14967 (CI 8316-26939)	14,967 (95% CI 8,316-26,939)	Not Reduced	Unknown	unknown	S
beluga	E high Arctic-Baffin Bay	good	good	good	good		21200 (CV 0.25)	21,200 (CV 0.25)	Reduced	Unknown	unknown	S
beluga	Cumberland Sound	fair	fair	fair	fair		1547 (CI 1187-1970)	1500	Reduced	Decreasing	unknown	S
beluga	Siberian and W Chukchi seas					incomplete	unknown	Unknown	Unknown	Unknown	unknown	S
beluga	Eastern Beaufort Sea	good	good	good	fair		39258 (CV 0.23)	41800	Not Reduced	Unknown	unknown	S
beluga	Eastern Chukchi Sea	good	good	good	good		3700	3700	Unknown	Unknown	unknown	S
beluga	Bristol Bay	good	good	fair	good		2877 (CV 0.23)	2877	Not Reduced	Increasing	increasing	S
beluga	Anadyr	fair	fair	fair	fair		15127 (CI 7447-30741)	15,127 (95% CI 7447 -30741)	Unknown	Unknown	unknown	S
beluga	White Sea					fair	6498 (CI 4664-8818)	6,498 (95% CI 4,664-8,818)	Unknown	Decreasing	declining	none
beluga	Kara & Laptev Seas					incomplete	unknown	Unknown	Unknown	Unknown	unknown	none
beluga	Eastern Bering Sea	fair	fair	fair	fair		18000	18000	Unknown	Unknown	unknown	S
beluga	Okhotsk Sea					incomplete	12226 (CV 6.8)	N/A - not included	N/A - not included	N/A - not included	unknown	none
beluga	Svalbard					fair	unknown	Unknown	Unknown	Unknown	unknown	none
beluga	Cook Inlet	good	good	good	good		315 (CV 0.13)	N/A - not included	N/A - not included	N/A - not included	declining	none
beluga	St. Lawrence Estuary					fair	979 (CV 0.14)	N/A - not included	N/A - not included	N/A - not included	declining	none
narwhal	Northern Hudson Bay	incomplete	good	fair	fair		12485 (CV 0.26)	12,485 (CV 0.26)	Not Reduced	Unknown	unknown	S
narwhal	Eclipse Sound	incomplete	good	good	good		20225 (CI 9471-37096)	10,489 (CV 0.24)	10,489 (CV 0.24)	Unknown	unknown	S
narwhal	Admiralty Inlet	incomplete	good	good	good		18048 (CI 11613-28053)	35,043 (CV 0.42)	Not Reduced	Stable	unknown	S
narwhal	Melville Bay	incomplete	good	fair	fair		6024 (CI 1403-25860)	3,091 (95% CI 1,228-7,783)	Reduced	Stable	unknown	S
narwhal	Inglefield Bredning					incomplete	8368 (CI 5209-13442)	8,368 (95% CI 5209-13,442)	Reduced	Stable	unknown	S
narwhal	Jones Sound/Smith Sound					incomplete	unknown	12,694 (CV 0.33)	Not Reduced	unknown	unknown	S
narwhal	Somerset Island	fair	good	good	good		27656 (9080-66061)	49,758 (CV 0.20)	Not Reduced	Stable	unknown	S
narwhal	East Greenland					incomplete	6444 (CI 2505-16575)	6,444 (95% CI 2505-16,575)	Unknown	Unknown	unknown	S
narwhal	Scoresby Sound	incomplete	fair	fair	fair		unknown					
narwhal	Svalbard					incomplete	unknown	Unknown	Unknown	Unknown	unknown	none
narwhal	Eastern Baffin Island					incomplete	10073 (CI 5333-17474)	17,555 (CV 0.35)	Not Reduced	Stable	unknown	S

Table 1. Bowhead, beluga, and narwhal populations in the Arctic. The columns July-Oct indicate our confidence level in the home range boundaries for that month, based on literature review. CAFF is Conservation of Arctic Flora and Fauna (www.caff.is). The last column indicates whether the population is subject to subsistence harvest (S) or not. Most population trends are unknown due to infrequent surveys.

2017 AMS Theme: Observations Lead the Way

At the request of AMS we include the following:

1. *Observations that are needed to benefit future research*
   High resolution daily sea-ice data with complete Arctic coverage; surveys and tracking of Arctic marine mammal populations; ship tracks.
2. *Instruments that are needed to make these observations*
   Satellite instruments like AMSR-2 or better; long-lasting telemetry devices for Arctic marine mammals; open database of ship tracks.
3. *The greatest observational needs for this discipline in general*
   Surveys and tracking of Arctic marine mammals.

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