A Ten-Year Projection of Maritime Activity in the U.S. Arctic Region, 2020-2030

U.S. COMMITTEE ON THE MARINE TRANSPORTATION SYSTEM

SEPTEMBER 2019

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This report was developed by the U.S. Committee on the Marine Transportation System's Arctic Marine Transportation Integrated Action Team, which includes representatives from:

- Bureau of Ocean Energy Management
- Bureau of Safety and Environmental Enforcement
- Environmental Protection Agency
- National Geospatial-Intelligence Agency
- National Maritime Intelligence-Integration Office
- National Oceanic and Atmospheric Administration
- Maritime Administration
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U.S. Committee on the Marine Transportation System
1200 New Jersey Avenue, SE
Washington, DC 20590
202-366-3612
www.CMTS.gov

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Preface

This document is the near final version of the U.S. Committee on the Marine Transportation System (CMTS) report, "A Ten-Year Projection of Vessel Activity in the U.S. Arctic Region", developed by the Arctic Marine Transportation Integrated Action Team. An initial draft of this document was released for public and interagency review on July 3, 2019, with comments accepted through July 31, 2019 to ArcticMTS@cmts.gov. A summary of the responses received is included in Appendix C. This report was presented and approved by the CMTS Coordinating Board for publication on September 24, 2019.

Acknowledgements

The authors of this report would like to thank the many organizations and individuals who have provided support to this project. Sincere thanks go to the U.S. Arctic Research Commission (USARC), which provided funding both for this report and for the 2018 CMTS & USARC Technical Workshop on Arctic Vessel Activities. Additional thanks go to the co-leads and members of the CMTS Arctic Marine Transportation System Integrated Action Team, the participants of the 2018 CMTS & USARC Technical Workshop, and the Woodrow Wilson International Center for Scholars' Polar Institute for their expertise and documentation to assist this work. The authors would also like to extend their thanks to the members of the interagency and public who provided valuable feedback during the public comment period. Special thanks for to the following individuals for their expertise, guidance, and assistance throughout this project: Sarah Harrison, Alyson Azzara, PhD, Alison Agather, PhD, Professor Lawson Brigham, PhD, Helen Brohl, John Farrell, PhD, Marin Kress, PhD, Tricia Hooper, Mike Sfraga, PhD, and Kyle Titlow.

Executive Summary

The Arctic is undergoing unprecedented change on multiple fronts, including the region's growing maritime traffic. In the last decade, the number of vessels operating in waters north of the Bering Strait around the Chukchi and Beaufort Seas has increased by 128% and is now 2.3 times larger than the number of ships passing through the region in 2008. These vessels have been engaged in a variety of activities, including natural resource exploration and extraction, commercial shipping, oceanographic research, and tourism in waters which previously were plied only by ships resupplying remote communities along the sparsely populated coastlines of western and northern Alaska.

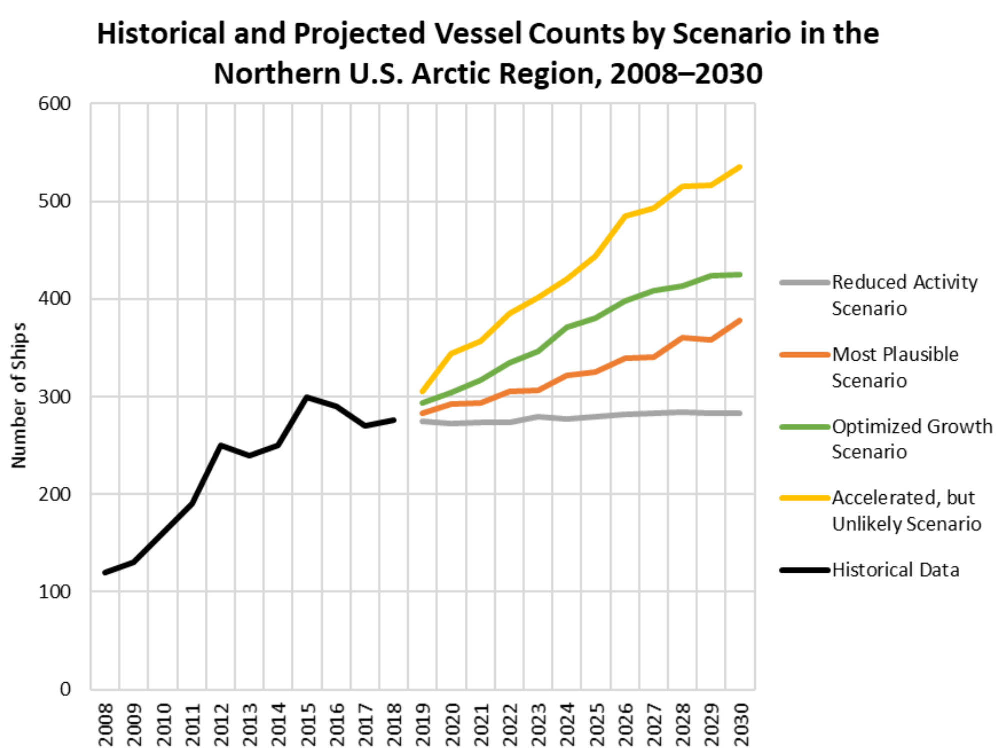
This report by the U.S. Committee on the Marine Transportation System (CMTS) U.S. Arctic Marine Transportation Integrated Action Team (Arctic IAT) is an update to the 2015 CMTS report, "A 10-Year Projection of Maritime Activity in the U.S. Arctic". It provides a detailed account of past and present vessel activity patterns in the northern U.S. Arctic and surrounding waters around the Bering Strait. The report also projects how many additional vessels might be expected in the region over the next decade, out to 2030 through four scenarios.

Efforts to update the 2015 CMTS report began in November 2018 with a 2-day technical workshop hosted by the CMTS, together with the U.S. Arctic Research Commission (USARC), focused on drivers of vessel activity in the Arctic, included in Section II of this report. Workshop participants included experts from government, the shipping industry, academia, and the Arctic region and provided the report with a rich data set of quantitative sources of vessel growth, as well as new perspectives about how non-quantifiable factors may affect vessel activity in the region. The workshop informed the guiding assumption of the projections featured in the report: a predictable operating environment is required to support long term growth of vessel activity in Arctic region, and while unpredictable conditions may also have growth, it is more likely to be sporadic and limited to specific sectors, and/or regions of the Arctic.

Section III of this report provides an overview of recent vessel activity trends in the U.S. Arctic region. Automatic identification system (AIS) data revealed that 255 ± 26 unique vessels transited through the U.S. Arctic and surrounding region from 2015–2017. By vessel type, over 50% of these vessels are tug, towing, and cargo vessels; other vessels included fishing vessels (10%), tourism (9%), tankers (7%), government/law enforcement/search and rescue (6%), research (5%) and other vessels (5%). By flag, U.S. flag vessels are the largest fleet in the U.S. Arctic region, by a considerable margin, but the number of flag states transiting through the region has climbed from 25 flag states in 2015 to 32 in 2017. This shift reflects that the region is undergoing a transition from primarily regional operations to an increasingly diverse and international set of users.

Furthermore, vessel traffic in the region has grown steadily over the last decade. According to U.S. Coast Guard data, after Royal Dutch Shell PLC (Shell) withdrew from offshore exploration in 2015, growth in the region slowed, but did not stall. Despite limited growth in the total number of ships using these waters during the 2015–2017 period, the length of the navigation season has been growing by as much as 7–10 days each year. Extrapolated out over the next decade, the navigation season in and around the Bering Strait may extend 2.5 months longer than present, potentially upending the region's highly seasonal navigation.

Section IV provides a detailed overview of the method used for this report, which brings together both qualitative and quantitative data about the region for four projection scenarios of vessel activity. This method estimates the number of ships expected in the region over the next decade, was developed specifically for this study, and utilizes publicly available data from 36 different sources of additional vessels. These sources of growth include new ice class vessels, rerouted shipping through the Arctic, planned infrastructure projects, and natural resource activities.



The four scenarios included in this study are the Reduced Activity Scenario, Most Plausible Scenario, Optimized Growth Scenario, and Accelerated, but Unlikely Scenario. Each provides a different possibility for vessel activity in the northern U.S. Arctic and surrounding waters over the next decade, ranging from annual growth rates of 0.3% to 4.9% and total annual vessel counts of 284 ships to 535 vessels. Of the four scenarios generated, the Most Plausible Scenario best agrees with mathematical projections from available historic data for the region. The Most Plausible Scenario, based on conservative assumptions, indicates that the number of vessels operating in the U.S. Arctic in 2030 is likely to be more than triple the number of vessels in 2008, while the highest estimates included in the Accelerated, but Unlikely Scenario reflect growth more than four times the 2008 numbers and twice the number we see today. The total transits and movements into, out of, and within the U.S. Arctic will likely more than double the vessel numbers, underscoring the urgency to take on planning and evaluation exercises to be prepared for a changing Arctic maritime environment.

Over the next decade, it is anticipated that natural resource activities in the Arctic, particularly the growth of liquefied natural gas (LNG) shipments from Russia and vessels needed to resupply mining operations in northern Canada, will play a large role in the volume of traffic transiting through the Bering Strait. Ice-strengthened ships and vessels engaged in trans-Arctic shipments are expected to steadily increase the volume of vessel traffic in the region over the next decade and infrastructure development, repair, modification, and relocation activities will also contribute to vessel activity in the region. This growth, however, will be better measured by the large numbers of transits or longer operating hours instead of by additional ships, due to the unique logistical challenges of transporting materials to the region. Additionally, because of rapidly changing environmental conditions which threaten the viability of infrastructure in the region, this source of growth may rapidly change over the next decade, leading to uncertainty in the projections included here.

Finally, while this report has aimed to be as comprehensive as possible, its reliance on AIS data means that this report does not account for or project smaller crafts, such as those used in small commercial fishing operations or subsistence hunting activities, and may undercount smaller recreational or tourist vessels like sailboats and yachts. Excluding subsistence hunting, for example, may underrepresent actual vessels in the U.S. Arctic region by 40% or more, according to estimates featured in Section III. Understanding both the magnitude and diversity of vessel activities in the region is critical to deconflicting the current uses, planning for future changes, and improving maritime domain awareness of the U.S. Arctic region.

List of Abbreviations

ACP	Autoridad del Canal de Panamá; Panama Canal Authority
AIS	Automatic Identification System
AISAP	Automatic Identification System Analysis Package
AML	Alaska Marine Lines
ANWR	Arctic National Wildlife Refuge
AOI	Area of Interest
Arctic IAT	Arctic Marine Transportation Integrated Action Team
ARPA	Arctic Research and Policy Act of 1984
ASTD	Arctic Ship Traffic Database
ASV	Autonomous Surface Vehicle
ATBA	Areas to be Avoided
AVEC	Alaska Village Electric Corporation
BBL	Barrel (42 U.S. gallons or 160 liters)
BEN	Bathymetric Explorer and Navigator
BOEM	Bureau of Ocean Energy Management
BUILD	Better Utilizing Investments to Leverage Development Transportation Discretionary Grant Program
CMTS	U.S. Committee on the Marine Transportation System
CNPC	China National Petroleum Corporation
EIA	Energy Information Administration
ERDC	U.S. Army Engineer Research and Development Center
FCC	Federal Communications Commission
G&G	Geological and Geophysical
IMO	International Maritime Organization
LE	Law Enforcement
LNG	liquefied natural gas
MLLW	mean low level water

MMSI	Maritime Mobile Service Identity
MTS	Marine Transportation System
MXAK	Marine Exchange of Alaska
NAIS	Nationwide Automatic Identification System
NAVCEN	U.S. Coast Guard Navigation Center
NOAA	National Oceanic and Atmospheric Administration
NPR-A	National Petroleum Reserve in Alaska
NSAR	National Strategy for the Arctic Region
NSRA	Northern Sea Route Administration
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
PAME	Protection of the Arctic Marine Environment
PEL	Planning and Environmental Linkages
Polar Code	International Code for Ships Operating in Polar Waters
SAIS	Satellite Automatic Identification System
SAR	Search and Rescue
Shell	Royal Dutch Shell, PLC
STIP	Statewide Transportation Improvement Program
UNCTAD	United Nations Conference on Trade and Development
USACE	U.S. Army Corps of Engineers
USARC	U.S. Arctic Research Commission
USCG	U.S. Coast Guard
VHF	Very High Frequency

About the U.S. Committee on the Marine Transportation System

The U.S. Committee on the Marine Transportation System (CMTS) is a Federal Cabinet-level, inter-departmental committee chaired by the U.S. Secretary of Transportation. The purpose of the CMTS is to create a partnership of Federal departments and agencies with responsibility for the Marine Transportation System (MTS). In 2010, the CMTS was directed by statute to coordinate transportation policy in the U.S. Arctic for safety and security[1], and established the CMTS Arctic Marine Transportation Integrated Action Team (Arctic IAT) to address infrastructure requirements supporting the U.S. Arctic Marine Transportation System, among other activities.

The National Strategy for the Arctic Region (NSAR) Implementation Plan directed the U.S. Department of Transportation to execute the tasks under the objective Prepare for Increased Activity in the Maritime Domain. The Office of the Secretary delegated these tasks to the CMTS in 2014. Subsequently, the CMTS delivered the following reports:

- "A 10-Year Projection of Maritime Activity in the U.S. Arctic"[2,] in January 2015
- "A Ten-Year Prioritization of Infrastructure Needs in the U.S. Arctic"[3] in April 2016
- "Recommendations and Criteria for Using Federal Public-Private Partnerships to Support Critical U.S. Arctic Maritime Infrastructure"[4] in January 2017.

Taken together, these three reports provide a framework to support a growing Arctic MTS with an understanding of future vessel activity, infrastructure required to support future vessel activity, and mechanisms to support the development of such critical infrastructure.

This document is an update of the 2015 report, "A 10-Year Projection of Maritime Activity in the U.S. Arctic". This report was developed by the CMTS Arctic IAT, with financial support from the U.S. Arctic Research Commission.

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[1] U.S. Coast Guard Authorization Act of 2010 (Public Law 111-281 § 307(c); 14 U.S.C. §90)
[2] Azzara, A. J., Wang, H., Rutherford, D., Hurley, B., and Stephenson, S. (2014). *A 10-Year Projection of Maritime Activity in the U.S. Arctic*. A Report to the President. U.S. Committee on the Marine Transportation System, Integrated Action Team on the Arctic Available at https://www.cmts.gov/downloads/CMTS_10-Year_Arctic_Vessel_Projection_Report_1.1.15.pdf
[3] U.S. Committee on the Marine Transportation System (2016). *A Ten-Year Prioritization of Infrastructure Needs in the U.S. Arctic*. A Report to the President. Available at https://www.cmts.gov/downloads/NSAR_1.1.2_10-Year_MTS_Investment_Framework_Final_5_4_16.pdf
[4] U.S. Committee on the Marine Transportation System (2017). *Recommendations and Criteria for Using Federal Public-Private Partnerships to Support Critical U.S. Arctic Maritime Infrastructure*. A Report to the President. Available at https://www.cmts.gov/downloads/NSAR_1.1.3_Recommendations_and_Criteria_2017_FINAL.pdf

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Section I: Introduction

PROJECT RATIONALE

This report is an update to the 2015 report, "A Ten-Year Projection Study of Maritime Activity in the U.S. Arctic", which projected the volume of vessel activity in the U.S. Arctic out to 2025 as part of the U.S. National Strategy for the Arctic Region. This report projects the potential growth of maritime activity in the northern U.S. Arctic and neighboring waters out to 2030, using in-depth analysis of historical vessel activity and an exploration of current and future drivers through four scenarios.

In the four years since the publication of the 2015 CMTS report, "A Ten-Year Projection Study of Maritime Activity in the U.S. Arctic", much has changed in the region. This update aims to provide decision makers and regional stakeholders with a wide-ranging portrait of potential changes in vessel activity in the region over the next decade.

BACKGROUND

The United States is an Arctic Nation, with over 46,600 miles (75,000 km) of shoreline in Alaska, including the Aleutian Islands.[5] Three Arctic seas bound the State of Alaska: the Bering, the Chukchi, and the Beaufort. Historically, these seas are frozen for more than half the year, typically limiting the Arctic maritime season from June through October, with unescorted and non-ice class navigation within a more limited time frame. However, this pattern appears to be rapidly changing as ice-diminished conditions become more extensive during the summer season. On September 16, 2012, Arctic sea ice reached its lowest coverage extent ever recorded, opening the way for the longest Arctic navigation season on record.[6,7] Additionally, the four lowest winter maximum ice extents in the satellite record (1979–2018)

[5] National Oceanic and Atmospheric Administration, Office of Response and Restoration. (2018) *Alaska ShoreZone: Mapping over 46,000 Miles of Coastal Habitat*. Accessed from https://response.restoration.noaa.gov/about/media/alaska-shorezone-mapping-over-46000-miles-coastal-habitat.html

[6] Jeffries, M. O., J. A. Richter-Menge and J. E. Overland, Eds., 2012: Arctic Report Card 2012. Available at: ftp://ftp.oar.noaa.gov/arctic/documents/ArcticReportCard_full_report2012.pdf

[7] McGrath, M. 2012. Gas tanker Ob River attempts first winter Arctic crossing, BBC News. Available at: http://www.bbc.co.uk/news/science-environment-20454757

have occurred in the past four years (2015–2018), with multi-year ice comprising less than half of what was measured in the mid-1980s.[8,9] In the U.S. Arctic, seasonal sea ice loss has been especially notable in the northern Bering Sea. Historically, sea ice extended from the Bering Strait southward to the Aleutian Islands, covering much of the Eastern Bering Sea shelf. Sea ice coverage for the Eastern Bering Sea for 2018 and 2019 was the two lowest years on record, amounting to 50% and 65% sea ice coverage, respectively, and resulting in ice-free waters in March as far north as Norton Sound.[10,11] (Figure 1)

While the loss of sea ice may increase the possibilities for both marine transportation and natural resource extraction in the Arctic, accessing and operating within the region remains challenging. Both annually and spatially variable sea ice can pose serious hazards to vessels transiting Arctic waters, and thus, most vessel activity is concentrated in a narrow seasonal operating window, extending from the summer to early fall. Although transiting Arctic waters has been eased by ice retreat, there are still unpredictable ice floes and inclement weather (e.g., extreme cold, heavy fog, severe storms). Further, some models suggest that wind speeds and wave height in the Arctic will increase in the absence of sea ice, posing further hazards to vessels operating in the region.[12] Environmental challenges aside, there are many critical infrastructure gaps in the region that make maritime operations challenging, such as a lack of a deep-draft port, designated harbors of refuge, reliable communications systems, and complete charting of the region to modern hydrographic standards.[13]

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[8] Richter-Menge, J., Overland, J.E., Mathis, J.T., and E. Osborne, Eds. 2017: Arctic Report Card, 2017. Available at ftp://ftp.oar.noaa.gov/arctic/documents/ArcticReportCard_full_report2017.pdf

[9] Osborne, E., Richter-Menge, J., and M. Jeffries, Eds. 2018: Arctic Report Card, 2018. Available at ftp://ftp.oar.noaa.gov/arctic/documents/ArcticReportCard_full_report2018.pdf

[10] Cornwall, W. "Vanishing Bering Sea ice threatens one of the richest U.S. seafood sources". May 15, 2019. *Science Magazine.* Accessed from https://www.sciencemag.org/news/2019/05/vanishing-bering-sea-ice-threatens-one-richest-us-seafood-sources

[11] International Arctic Research Center. (2019). "Bering Sea Ice Conditions: Winter 2019". University of Alaska Fairbanks. Accessed from: https://uaf-iarc.org/2019/04/11/bering-strait-sea-ice-conditions-winter-2019/

[12] Aksenov, Y.; Popova, E.E.; Yool, A.; Nurser, A.J.G., Williams, T.; Bertino, L.; and Berg, J. "On the future navigability of Arctic sea routes: High-resolution projections of the Arctic Ocean and sea-ice". 2016. *Marine Policy*.

[13] U.S. Committee on the Marine Transportation System. (2018). "Revisiting Near-Term Recommendations to Prioritize Infrastructure Needs in the U.S. Arctic". Washington, D.C. Accessed from: https://www.cmts.gov/downloads/NearTermRecommendationsArctic2018.pdf

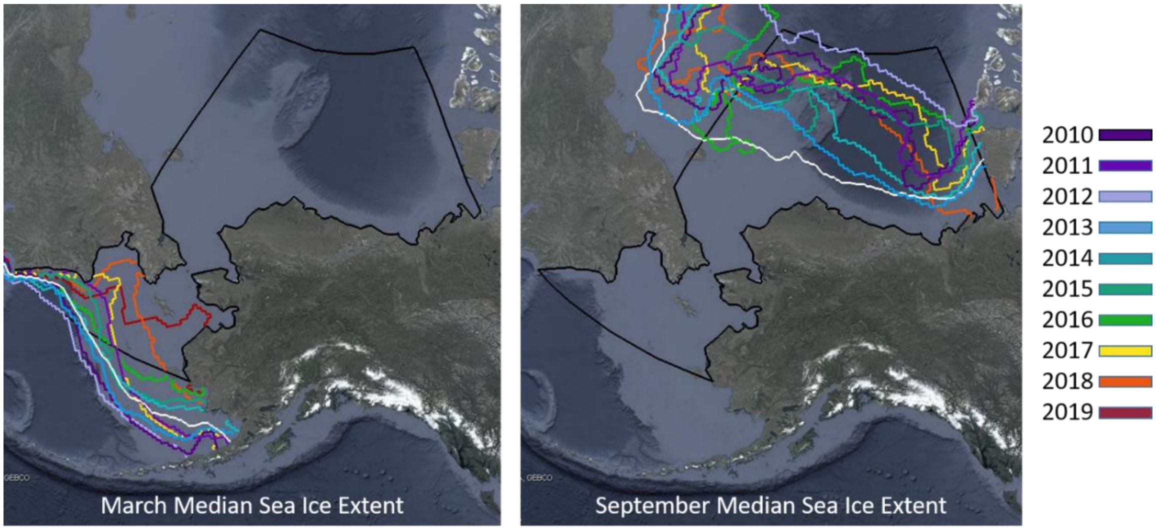

Figure 1: Median sea ice extent for March (left) and September (right). Study area of interest outlined in black; median sea ice extent for 1981-2010 is presented in white, while years 2010 and onward are color coded according to legend on right. Sea ice index data sourced from the National Snow and Ice Data Center.[14] Map plotted with Google Earth Pro.

STUDY AREA OF INTEREST

The Arctic is defined in many ways for different domestic and international purposes. Common definitions include: 1) the areas above the Arctic Circle (66° 32'N); 2) areas delineated by the 10-degree isotherm; 3) the newly developed definition under the IMO's International Code for Ships Operating in Polar Waters (Polar Code) and 4) the definition used by the Arctic Monitoring and Assessment Program Working Group of the Arctic Council. In accordance with the Arctic Research and Policy Act (ARPA) of 1984, the U.S. legally defines the Arctic as:

> "… all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers [in Alaska]; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain".[15]

[14] Fetterer, F., K. Knowles, W. N. Meier, M. Savoie, and A. K. Windnagel. 2017, updated daily. Sea Ice Index, Version 3. March and September Mean Monthly Extent, 2010-2019. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5K072F8.

[15] Arctic Research and Policy Act of 1984 (Public Law 98-373, §112; 15 U.S.C. §4111)

This definition includes parts of Alaska well below the Arctic Circle, including the Aleutian Islands, which is part of an important Great Circle shipping route between east Asia and the Pacific Northwest of the United States.

The 2015 CMTS vessel projection report, this report's predecessor, focused on vessels north of St. Lawrence Island in the Bering Sea, through the Bering Strait, as far west as Wrangel Island in the Chukchi Sea, across the North Slope of Alaska as far east as Banks Island in the Beaufort Sea and Amundsen Gulf. This current study extends the study area of interest southward to 60°N, in alignment with the International Maritime Organization's Polar Code definition of the Arctic in the Bering Sea region and to capture vessel activity at Nome, a regional hub (Figure 2). This report specifically focuses on only on a portion of the U.S. legal definition of the Arctic to concentrate on the waters with lower volumes of traffic passing through the high Arctic, rather than the large volume of Great Circle traffic passing through the Aleutian Islands and the large volume of fishing vessel traffic in the southern Bering Sea. Additionally, the study area of interest also encompasses non-U.S. waters to develop a more holistic understanding of the region.

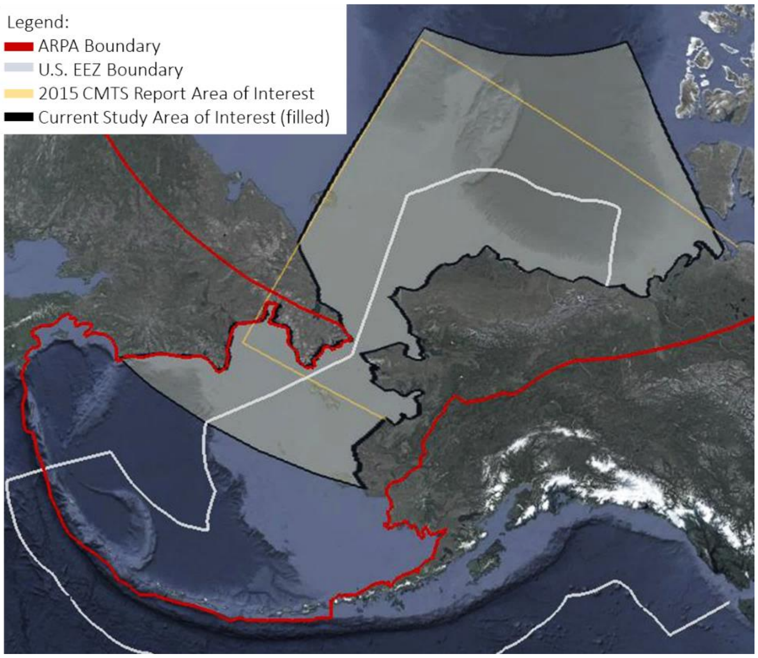

Figure 2: Map of the study area of interest and 2015 CMTS report study area of interests. The present study's area of interest is shaded and outlined in black, the study's predecessor area of interest is outlined in yellow, the U.S. EEZ is outlined in white, and the U.S. legal definition of the Arctic according to the Arctic Research Policy Act of 1984 is outlined in red. Note that neither the study area of interest for this report nor the 2015 CMTS report encompass the entire U.S. definition of the Arctic. Map plotted with Google Earth Pro.

STUDY COMPONENTS

This study consists of an overview of potential drivers of vessel activity in the Arctic (Section II) and an analysis of past and present vessel activities in the Arctic (Section III). Analyses of both potential drivers and recent vessel activity were used to develop and inform the study's four projection scenarios of anticipated vessel counts for the study's area of interest out to the year 2030 (Section IV). A summary and conclusion of the report's findings is highlighted in the concluding chapter (Section V), and supporting materials for the report are included as Appendices.

Section II: Drivers of Vessel Activity in the Arctic

Change in the Arctic is both multifaceted and multivariable. No single driver can predict overall vessel activity in any region, but especially not in the Arctic. To better understand the variety of motivations for transiting to and through the Arctic, the CMTS with support from the U.S. Arctic Research Commission and the Woodrow Wilson Polar Institute hosted a 2-day workshop November 14–15, 2018 on drivers of vessel activity, hereafter referred to as the 2018 CMTS & USARC Technical Workshop. This event brought together 41 experts from industry, academia, government, and the Arctic region. Participants identified and ranked over 70 different drivers of vessel activity, across nine different categories, including:

- Natural Resources
- The Global Economy
- Changing Geopolitics
- Regulatory Changes
- Infrastructure
- Improved Technology and Operations
- Environmental Change
- The Human Element
- Changing Fuel Landscape

While the workshop did not seek consensus between participants, information provided by participants served as the foundation for crafting the projections featured later in this report (Section IV).

One important take away from the workshop was that there are many reasons why vessels transit through the Arctic. Therefore, scaling all growth up or down according to a single indicator would oversimplify the complex dynamics of the region. Accurately projecting how these vessels are expected to change over the next decade requires delving into the granular details of what is most likely to contribute to (or detract from) growth. Participants provided specific examples throughout the workshop, including examples of (1) natural resource exploration and development projects, (2) infrastructure development projects, (3) details about ship orders and those expected to join the 'Arctic fleet', and (4) the feasibility of seasonally rerouting ships through the Arctic. These examples provided critical input for calculating the projections featured in this study.

There are also a multitude of factors which may affect vessel activity, but which could not easily be translated into quantifiable metrics for this study's projections. Workshop participants noted the global economy, geostrategic location and growing importance of the Arctic, regulatory environment, and the 'social license' to operate in the region all as elements which certainly have and will continue to impact how vessels in the region operate. One common theme surrounding these issues is the role that each can play in creating risk and uncertainty for operators sailing through the Arctic. For example, any operator engaged in natural resource exploration and development requires a degree of certainty on multiple fronts, such as the market's projected demand for the resource, the nature of regulatory requirements, and whether the resource can be extracted and brought to market in a timely, profitable, and environmentally sound fashion. Operators in the Arctic, however, must also deal with the unique challenges of the region which include: the extreme and rapidly changing nature of the physical environment; high cost of mobilization; lack of extensive existing infrastructure; and careful consideration of indigenous cultures, subsistence practices, and fragility of the Arctic environment. Taken together, these factors create a high cost of entry to operate in the region. These challenges are not unique to the natural resource industry; shipping, tourism, and investors looking to finance large-scale infrastructure projects in the region also face a high cost of entry to operate in the region.

Mitigating the risks and uncertainties for Arctic navigation is key to creating a predictable operating environment, which in turn can maintain and even enable the growth of vessel operations in the region. Some of this risk mitigation includes expanded informational infrastructure to support the marine transportation system, such as accurate nautical charts for the Arctic region, comprehensive and timely weather forecasts featuring fog and sea ice forecasts, and other relevant real-time environmental data. Other elements include expanded and reliable communications networks[16] and designated harbors of refuge for vessels to seek out during inclement weather and to support safe operations for all operators, including subsistence hunters. The marine insurance industry can also play a vital role to offset the risks incurred with vessel operation, which can include coverage for lost cargo, environmental damages, rescue, and salvage operations. Workshop participants noted that the development of a standardized system of marine insurance catered toward vessel operators in the Arctic could mitigate the risk of operating in the Arctic and eventually incentivize participation in the Arctic marine transportation system. Regulatory action can also play a role to mitigate risk, such as the International Maritime Organization's International Code for Ships Operating in Polar Waters (Polar Code). The Polar Code entered into force in 2018 and builds upon other existing treaties to address safe and environmentally-

[16] Personal communication, Mr. Arnold Brower, Jr., Executive Director, Alaska Eskimo Whaling Commission, July 2019.

sound operating requirements for vessels transiting through waters in high latitudes; the geographic boundaries of where the Polar Code applies in Arctic waters is included in Figure 3. The Polar Code is broad in scope, addressing elements of ship design, construction, required equipment, training and operational concerns, search and rescue, voyage planning, and protection of the Arctic ecosystem.

Figure 3: Boundaries of the IMO's Polar Code in the Arctic. The black line denotes the maximum extent of Arctic waters for which the Polar Code applies. Image adapted from Figure 2 within MEPC 68/21/Add.1, Annex 10.[17]

Guided by this reasoning, the scenarios included this report each assume different degrees of certainty for operators and planners in the region. The scenarios included in the report and the vessel projections generated from these scenarios are built on the underlying hypothesis that the more risk that can be mitigated and the more certainty operators have about the region, the greater the growth potential for vessel activity in the Arctic. Further discussion of this is included in Section IV of the report and in Appendix A.

[17] International Code for Ships Operating in Polar Waters. (2018). Text as adopted accessed from http://www.imo.org/en/MediaCentre/HotTopics/polar/Documents/POLAR%20CODE%20TEXT%20AS%20ADOPTED.pdf

Section III: Overview of Past and Present Vessel Activities in the Arctic

The volume of vessel activity in the study's area of interest was examined using historical automatic identification system (AIS) data, in conjunction with the annual traffic summaries by vessel type for Arctic waters north of the Bering Strait provided by the U.S. Coast Guard, historical traffic from the Northern Sea Route and the Northwest Passage, and the recently established Arctic Ship Traffic Data (ASTD)[18] project. Understanding historical and current trends of vessel activity is integral to understanding and projecting the future composition of vessel traffic.

METHODS

AIS utilizes the marine very high frequency (VHF) radio band to transmit information about a vessel's position, course, vessel speed, and other data automatically several times a minute.[19] Other data encoded in AIS data transmissions include the vessel's maritime mobile service identity (MMSI) number, which can be used to identify the vessel name, flag, and type of ship.

AIS data from satellite automatic identification system (SAIS) and the Nationwide Automatic Identification System (NAIS) was obtained from the U.S. Coast Guard Navigation Center (NAVCEN) from January 1, 2015 – December 31, 2017 for an area over much of Alaska and surrounding waters.[20] The SAIS and NAIS data were merged, removing duplicate data points with matching time, latitude, longitude, and MMSI number. The data was then passed through a spatial filter to limit the data to AIS pings from within the study area of interest (Figure 4). This was done step-wise, first by excising all points with latitudes less than 60°N and then points which fell outside of hydrographic waterbody polygons from the U.S.

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[18] The Arctic Ship Traffic Data Project is a Project of the Protection of the Arctic Marine Environment Working Group of the Arctic Council, which brings together ship traffic data across the whole, Polar Code definition of the Arctic. Please see p.18 of this report for more information.

[19] U.S. Coast Guard. (2014). Automatic identification system overview. Accessed from https://www.navcen.uscg.gov/?pageName=AISmain

[20] 52° N to 75°N and from 134 °W to 179°W

Geological Survey to remove points either (a) within the Cook Inlet south of Anchorage[21] or (b) falsely reported as being over land.[22]

The data was again filtered to remove MMSI numbers (and corresponding data) which had only 1 data point (of either SAIS or NAIS) and those numbers which were only detected by one type of AIS receiver. These steps reduced the size of the data considerably, and by limiting the data only to those vessels which were detected by both satellite and terrestrially-based AIS receivers that are part of the NAIS, these filtration steps narrowed the analysis to ocean-going vessels and vessels transiting through the Bering Strait. The MMSI numbers were then passed through one final filter, to limit the range of MMSIs from 201000000 to 775999999, corresponding to those MMSIs broadcast by ships.[23]

[21]U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service. (2013). Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (4 ed.): Techniques and Methods 11–A3, 63 p., https://pubs.usgs.gov/tm/11/a3/. Data accessed from https://www.usgs.gov/core-science-systems/ngp/national-hydrography/watershed-boundary-dataset?qt-science_support_page_related_con=4#qt-science_support_page_related_con

[22]U.S. Geological Survey. (2018). NHDPlus High Resolution. Accessed from https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution

[23] U.S. Coast Guard Navigation Center. (2019). Maritime Mobile Service Identity Overview. Accessed from https://www.navcen.uscg.gov/?pageName=mtmmsi

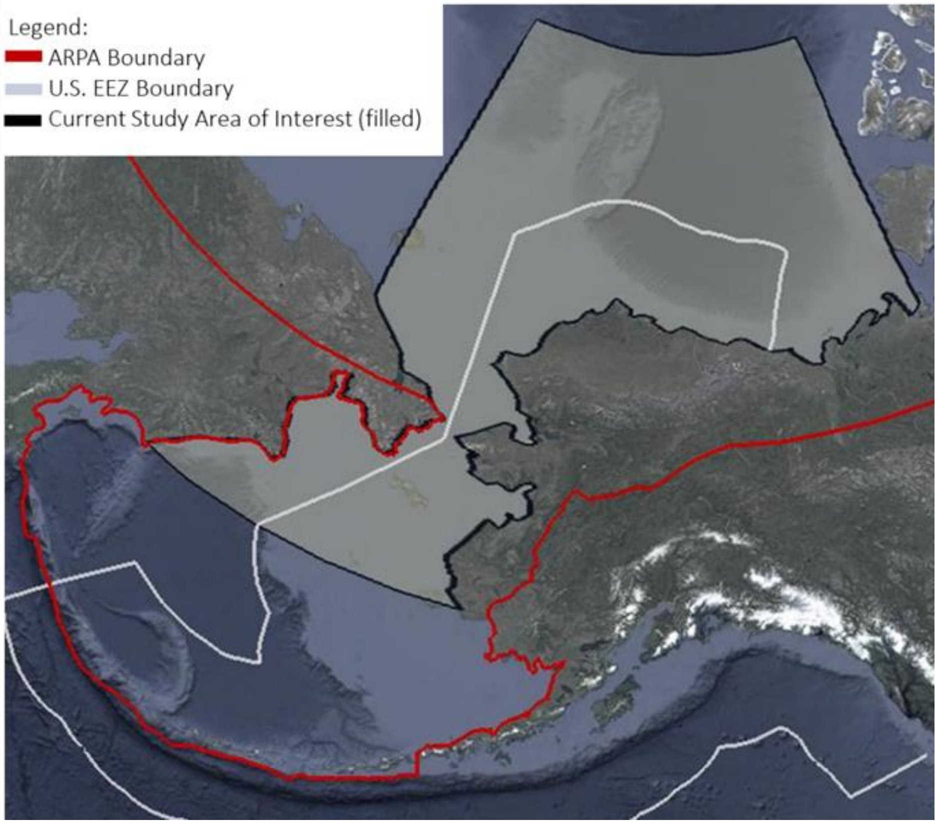

Figure 4: Map of the study area of interest. The present study's area of interest is shaded and outlined in black, the U.S. EEZ is outlined in white, and the U.S. legal definition according to the Arctic Research Policy Act of 1984 is outlined in red. Note that the study area of interest does not encompass the entire U.S. definition of the Arctic. Map plotted with Google Earth Pro.

MMSIs obtained from these filtration steps were annotated with vessel name and vessel type through cross referencing the MMSI against publicly available sources of data, including MarineTraffic.com, VesselFinder.com, and Federal Communications Commission (FCC) Ship License Search. Vessel flag data was obtained by cross referencing the first three digits of the MMSI, also known as the maritime identification digits, with the International Telecommunications Union's Table of Maritime Identification Digits.[24] After classification, all recorded ship positions were plotted in a series of individual maps created with ArcGIS Pro.

[24] International Telecommunications Union. (2017). Table of Maritime Identification Digits. Accessed from https://www.itu.int/en/ITU-R/terrestrial/fmd/Pages/mid.aspx

To better understand vessel activity (as opposed to raw numbers of ships), density plots were constructed using data from 2017. Track lines from the filtered AIS data were constructed using the BOEM and NOAA Office for Coastal Management's "Marine Cadastre Track Builder" tool for ArcGIS Pro.[25] This tool allowed for the creation of line features recreating the tracks taken by those vessels whose AIS points were observed in the area of interest in the year 2017. The tracks connect AIS points for individual ships in chronological order, breaking only when the time and distance between consecutive points exceed 6 hours and/or 75 miles. These values were determined using the mean speed of vessels within the dataset. Concurrently, a grid of 5 square kilometer cells was constructed which covered all oceanic water bodies within the area of interest (rivers in the AOI were excluded). An overlay tool in ArcGIS Pro tabulated the distance, in kilometers, that vessels traveled within each cell (kilometers travelled per 5 square kilometer cell). These density values for 2017 were depicted in a map created with ArcGIS Pro. Due to the parametric distribution of the data, geometric intervals were chosen to bin the resulting density values.[26]

To further understand the intra-annual variation of vessel activity, NAIS data from January 1, 2016– December 31, 2018 was analyzed for the study area using the Automatic Identification System Analysis Package (AISAP), developed by the U.S. Army Corps of Engineers. AISAP is a web-based tool for acquiring, analyzing, and visualizing near-real-time and archival data from the U.S. Coast Guard, and was developed with input from the U.S. Army Engineer Research and Development Center (ERDC) and the U.S. Coast Guard. This data allowed for further exploration of granular information about the duration of the navigation season in the study area of interest. The total number of unique MMSIs operating in the region (as a proxy for ships), broken out on a daily basis, were examined to further understand the seasonal navigation patterns and variability of the study region. This analysis was supplemented by seasonal density plots (built with method described above and included in Appendix E).

[25] Bureau of Ocean Energy Management and NOAA Office of Coastal Management. (n.d.) "Marine Cadastre Track Builder". Accessed from https://coast.noaa.gov/digitalcoast/tools/track-builder.html

[26] ArcGIS Desktop 9.3. (2008). "Geometrical interval". Accessed from: http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Geometrical_interval

RESULTS

Number of Vessels by Type and Year

After geographically restricting the combined SAIS and NAIS data, a total of 1,944 unique MMSIs within the study area of interest were detected between January 2015 to December 2017. Filtering the data by the standards for ship MMSI resulted in 1,870 unique MMSIs corresponding to ships. Of those, 876 unique MMSIs had 2 or more detected pings within the study area of interest, and 582 unique MMSIs were detected on both NAIS and SAIS. Of these 582 total MMSIs, there was an average of 255 ± 26 (mean ± standard deviation) unique MMSIs detected each year, 2015–2017, within the study area of interest.

An average of 255 unique vessels were found to have operated each year within the study area of interest from 2015–2017, with 245 vessels detected in 2015, 284 in 2016, and 235 in 2017. The three most numerous types of vessels were dry cargo ships, tugs, and towing vessels, comprising just over 50% of the vessels operating in the region on average across 2015–2017. The remaining 50% was spread across fishing vessels (11%), passenger and adventure vessels (9%), tankers (7%), research ships (5%), offshore supply vessels (4%), and a variety of specialized vessels (categorized as 'Other', 5%). The complete breakdown of vessels by type is detailed in Table 1.

Within the 'Other' category, individual ships operating in the region can be attributed to specific surges of activity in the region. For example, the drill ship, anchor handling vessels, and anti-pollution ships in the study area in 2015 are directly attributed to Shell's exploration of the Burger Prospect in the Chukchi Sea, which was discontinued prior to the start of the 2016 shipping season. Cable-laying vessels in 2016 and 2017 are likely related to Phase 1 of Quintillion's Subsea Cable System, which includes a subsea fiber optic network stretching from Nome to Prudhoe Bay.[27]

It is difficult to interpret any temporal trends from this limited data set. However, it is likely that the total peak of unique vessels in 2016 is related to higher numbers of heavy load carriers and unspecified cargo ships operating within the area of interest, which may be related to a combination of expansion of infrastructure along Russia's Northern Sea Route and Shell's demobilization efforts. This interpretation reflects the importance both natural resource exploration and infrastructure development can have on marine traffic in the region. Additionally, vessels related to fishing and adventure activities

[27] Quintillion. (2018). "System: Phase 1—Alaska". Accessed from: http://qexpressnet.com/system/

increased each year, while the total number of offshore supply vessels fell each year across the three years studied.

Number of Vessels by Flag State

A total of 38 unique flag states sailed vessels through the area of interest from 2015–2017. The breakdown of vessels in the study area of interest by flag state is detailed in Table 2. By flag, the U.S. has the largest number of unique ships operating within the confines of the study's area of interest, with tugs and towing vessels comprising the largest type of U.S. vessels. Second behind the U.S. is Russia, which has a number of small cargo ships and tankers operating within the region to service Russian communities facing the same constraints of resupply and limited infrastructure as communities in western and northern Alaska. All other flag states comprised, on average, less than 5% each of the total number of ships in the region. While the total number of vessels oscillated between the three years examined, the number of flag states has increased over the three years included in this baseline analysis, from 25 states in 2015 to 32 in 2017. This increase in the diversity of the flag states is a strong indication that there is a shift away from regionally focused players operating for local economic and community purposes toward global interest and a diversification of the market connected by Arctic shipping. These changes speak to the perspective that opportunities in the region are changing—and the composition of Arctic traffic is evolving: the Arctic waters around the Bering Strait are transitioning from having a mix of regional operators to an increasingly diverse and international set of operators and waterway users.

Table 1: Summary of vessels within the study area of interest by vessel type, 2015 – 2017

Vessel Types	2015	2016	2017	Mean ± SD	Percentage
Cargo	**61**	**97**	**79**	**79 ± 18**	**31.0%**
Bulk Carrier	23	24	27	25 ± 2	9.7%
Container Ship	0	0	1	0 ± 0.6	0.1%
Deck Cargo Ship	0	1	1	1 ± 0.6	0.3%
General Cargo	16	20	16	17 ± 2	6.8%
Heavy Load Carrier	2	9	2	4 ± 4	1.7%
Landing Craft	6	6	3	5 ± 2	2.0%
Pallet Carrier	1	1	1	1 ± 0	0.4%
Reefer	1	0	2	1 ± 1	0.4%
Ro-Ro	1	0	0	0 ± 0.6	0.1%
Unspecified Cargo	11	36	26	24 ± 13	9.6%
Towing/Tug	**64**	**59**	**36**	**53 ± 15**	**20.8%**
Towing	32	42	26	33 ± 8	13.1%
Tug	32	17	10	20 ± 11	7.7%
Fishing	**18**	**31**	**34**	**28 ± 9**	**10.9%**
Tanker	**19**	**16**	**18**	**18 ± 2**	**6.9%**
Hazard A (Major)	0	0	1	0 ± 0.6	0.1%
Hazard B	1	1	2	1 ± 0.6	0.5%
LNG Tanker	0	0	1	0 ± 0.6	0.1%
Oil Tanker	18	13	14	15 ± 3	5.9%
Shuttle Tanker	0	2	0	1 ± 1	0.3%
Gov't/LE/SAR	**16**	**13**	**17**	**15 ±2**	**6.0%**
Adventure	**12**	**15**	**16**	**14 ± 2**	**5.6%**
Pleasure Craft	5	4	5	5 ± 1	1.8%
Sailing	5	11	11	9 ± 3	3.5%
Yacht	2	0	0	1 ± 0.6	0.3%
Research	**15**	**8**	**14**	**12 ± 4**	**4.8%**
Small Craft from R/Vs	1	0	5	2 ± 3	0.8%
Research Vessels	14	8	9	10 ± 3	4.1%
Offshore Supply Ship	**14**	**12**	**3**	**10 ± 6**	**3.8%**
Passenger	**9**	**10**	**8**	**9 ± 1**	**3.5%**
Other	**13**	**19**	**8**	**13 ± 6**	**5.2%**
Anchor Handling Vessel	4	2	0	2 ± 2	0.8%
Anti-Pollution Equipment	2	0	1	1 ± 1	0.4%
Cable Layer	0	2	1	1 ± 1	0.4%
Drill Ship	1	0	0	0 ± 0.6	0.1%
Drilling Unit	1	0	0	0 ± 0.6	0.1%
Factory Trawler	1	10	1	4 ± 5	1.6%
Fishery Patrol Vessel	1	0	0	0 ± 0.6	0.1%
Icebreaker	3	2	2	2 ± 0.6	0.9%
Port Tender	0	1	0	0 ± 0.6	0.1%
Salvage	0	1	0	0 ± 0.6	0.1%
Special Craft	0	1	1	1 ± 0.6	0.3%
Supply Vessel	0	0	1	0 ± 0.6	0.1%
Utility Vessel	0	0	1	0 ± 0.6	0.1%
Unknown	**4**	**4**	**3**	**4 ± 1**	**1.4%**
Grand Total	**245**	**284**	**235**	**255 ± 26**	**100.0%**

Table 2: Summary of vessels in the study area of interest by flag state, 2015 – 2017

Flag State	2015	2016	2017	Mean	Percentage
United States	133	97	82	104	40.8%
Russian Federation	41	82	58	60	23.7%
Panama	8	19	18	15	5.9%
Netherlands	6	17	4	9	3.5%
Canada	6	6	9	7	2.7%
Marshall Islands	9	3	5	6	2.2%
Singapore	8	5	2	5	2.0%
Liberia	5	6	3	5	1.8%
Antigua and Barbuda	2	3	6	4	1.4%
Cyprus	4	2	4	3	1.3%
United Kingdom	1	5	4	3	1.3%
Bahamas	3	3	3	3	1.2%
France	0	5	4	3	1.2%
Germany	0	4	4	3	1.0%
Hong Kong	1	3	4	3	1.0%
Curacao	1	3	2	2	0.8%
Wallis and Futuna	3	2	1	2	0.8%
China	0	2	3	2	0.7%
Japan	1	1	3	2	0.7%
Malta	1	1	2	1	0.5%
Norway	1	1	2	1	0.5%
South Korea	0	2	2	1	0.5%
St. Kitts and Nevis	1	1	2	1	0.5%
Cayman Islands	3	0	0	1	0.4%
Finland	2	0	1	1	0.4%
Portugal	0	2	1	1	0.4%
Sierra Leone	0	1	2	1	0.4%
Greece	2	0	0	1	0.3%
Netherlands Antilles	0	2	0	1	0.3%
Bermuda	1	0	0	0	0.1%
Cook Islands	0	0	1	0	0.1%
Croatia	1	0	0	0	0.1%
Latvia	0	1	0	0	0.1%
New Zealand	0	0	1	0	0.1%
Sweden	1	0	0	0	0.1%
Switzerland	0	1	0	0	0.1%
Virgin Islands	0	1	0	0	0.1%
Unknown	0	3	2	2	0.7%
Grand Total	**245**	**284**	**235**	**255**	**100.0%**

TRACKLINE DENSITY FOR STUDY AREA OF INTEREST

Analysis of trackline density within the area of interest provides information about where vessels are transiting within the study area of interest and is presented in Figure 5. In this map, the 5 km square grid cells within the area of interest are colored according to the number of kilometers traveled through each cell in 2017. Cells with darker colors have less distance traveled through them, while lighter colors have increasing distances traveled through each cell, and therefore are inferred to have higher levels of vessel activity. Activity, in this case, includes vessels transmitting AIS signals, which incorporates both vessels underway and those engaged in other activities, such as lightering fuel offshore.[28] Other items of note on this map include the Exclusive Economic Zone boundaries marked as dashed lines and the locations of Areas to be Avoided are also plotted in hashed boxes on the map; these areas are around Nunivak Island, St. Lawrence Island and King Island and were adopted in May 2018 and implemented in December 2018 as part of voluntary routing measures through the Bering Sea.[29]

Overall, much of the vessel traffic in 2017 is concentrated along the coastlines within the study area of interest (Figure 5), while regions more than 75 miles (120 km) offshore in the Chukchi Sea, Beaufort Sea, and in the Bering Sea south of St. Lawrence Island were all less transited.

Regions within U.S. waters with the highest amount of activity include Prudhoe Bay, Utqiagvik, Point Hope, Red Dog Mine (to the south of Kivalina), Kotzebue, Wales, Port Clarence, Nome, the Yukon River delta, Hooper Bay, and in the Etolin Strait to the east of Nunivak Island. The largest and most heavily traveled of these regions is around Nome, AK, a critical hub for resupplying smaller communities in the region. Many of these locations also coincide with common lightering locations, regions where tankers transfer fuel to barges to delivery to smaller communities.[30] Another source of these elevated levels of vessel activity in these regions may be related to hydrographic surveys, which require multiple transits of a single area to develop an accurate map of the seafloor. For example, in 2017, Port Clarence, a body of naturally occurring deep water located northwest of Nome on the Seward Peninsula, was surveyed by

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[28] These vessels are often anchored offshore, and the only distance traveled is the small distance as the vessel moves within its fixed radius of anchoring.

[29] Maritime Executive. (2018). IMO Authorizes New Being Sea Routing. Accessed from https://www.maritime-executive.com/article/imo-authorizes-new-bering-sea-routing

[30] Fletcher, Sierra, and Robertson, Tim. (2019). "Overview of Tanker Lightering in Arctic Alaska". Accessed from https://oceanconservancy.org/wp-content/uploads/2019/03/190306-OC-Lightering-Report-vFINAL.pdf

NOAA's Office of Coastal Survey.[31] Port Clarence's naturally deep water also provides some limited natural protection for ships in inclement weather, so this increased activity may also stem from vessels seeking refuge in this area.[32]

Within Russian waters, the Gulf of Anadyr is more heavily traveled than waters north of the Bering Strait. These coastal waters in the Chukchi Sea are likely related to transits of the Northern Sea Route, which extends along Russia's northern coast as far east as Cape Dezhnev in the Bering Strait.

This traffic density analysis included here is not directly comparable to the density calculations provided in the 2015 CMTS report[33], but some of the findings from that analysis agree with the findings from the 2017 AIS data. Namely, the coastal waters in the Bering Strait were and remain some of the most heavily transited in the region, along with the waters around Red Dog Mine and Prudhoe Bay. Again, it should be emphasized that the track density included in Figure 5 is only for the year 2017, and further analysis of multiple consecutive years with the same methodology is required to differentiate between regions with sustained higher levels activity, such as the waters around Nome, Prudhoe Bay, and Red Dog Mine, and those with transient bursts of activity, such as Port Clarence in 2017 or the Burger Prospect in the Chukchi Sea.

[31] National Oceanic and Atmospheric Administration Office of Coast Survey. (2017). "Planned NOAA Hydrographic Survey Projects—2017: Port Clarence, AK" Storymap accessed from: https://arcg.is/04vOWe

[32] U.S. Army Corps of Engineers—Alaska District and Pacific Ocean Division. (2015). "Draft Integrated Feasibility Report, Draft Environmental Assessment, and Draft Finding of No Significant Impact: Alaska Deep-Draft Arctic Port System Study". Accessed from https://www.poa.usace.army.mil/Portals/34/docs/civilworks/arcticdeepdraft/ADDMainReportwithoutappendixes.pdf

[33] The two are not directly comparable for three key reasons: 1) The 2015 report utilized a kernel density analysis of interpolated track data, which smooths the data to highlight relative areas of high and low activity density. 2) The AIS data included here contains all AIS data for the region for a complete calendar year, while the 2015 report utilized all available data, which was only a few select months. 3) The areas of interest are slightly different between the two reports, see Figure 2.

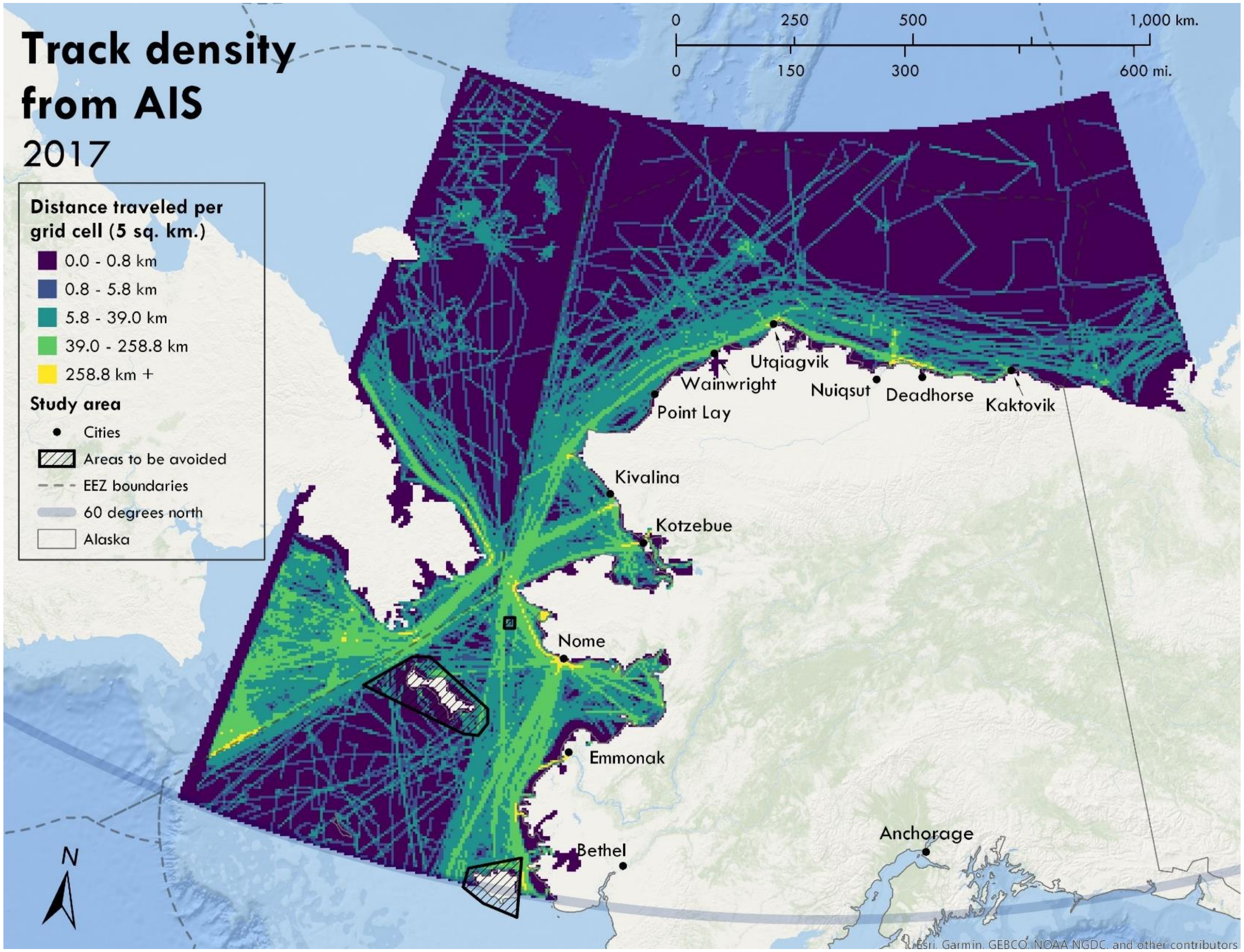

Figure 5: Track Density from 2017 AIS data. Each 5 km x 5 km cell colored according to the total distance traveled during 2017. Data intervals spaced geometrically for all 2017 AIS data to better highlight distribution of distances traveled across the region.

Ship Position by Vessel Type

The location of vessels within the study area of interest were also examined to understand the spatial distribution of ships and where specific ship types are operating within the region. In the following maps (Figures 6–13), the vessel positions broadcast by AIS were plotted and color-coded according to vessel type annotations. Additionally, the locations of Areas to be Avoided are also plotted in hashed boxes on all figures; these areas are around Nunivak Island, St. Lawrence Island and King Island and were adopted in May 2018 and implemented in December 2018 as part of voluntary routing measures through the Bering Sea.[34] These maps can be used to develop a qualitative understanding of where specific users are operating in and around the Bering Strait, but do not reflect or relay any quantitative information in either the color intensity or size of points mapped.

Although the vessel type does not always correspond to the function of the ship, there are some distinct patterns that emerge across the study area of interest by the location of specific vessel types (Figures 6–13).

Among cargo vessels, most of the bulk cargo ships operate to and from the Red Dog Mine in the Northwest Arctic Borough, south of Kivalina (Figure 6). Additionally, the distinct patterns of cargo vessels around Nome underscore the importance of Nome as a regional hub to service remote communities in the region (Figure 6).

Most of the tug and towing vessels in the region operate within U.S. waters among communities all along the western and northern coasts of Alaska (Figure 7). Additionally, AIS signals from towing vessels were detected along both the Yukon and Kuskokwim Rivers, where these vessels are likely providing resupply to inland communities across the state.

Most fishing-related vessels broadcasting AIS and operating within the area of interest did so south of the Bering Strait with much of the traffic concentrated in Russian waters, along the coastline within Norton Sound, and to the south and southeast of St. Matthew's Island near the southern edge of the study's area of interest (Figure 8). There were at least two fishing vessels north of the Bering Strait

[34] Maritime Executive. (2018). IMO Authorizes New Being Sea Routing. Accessed from https://www.maritime-executive.com/article/imo-authorizes-new-bering-sea-routing

during this study, but it is likely that these ships were used as vessels of opportunity for research, rather than for fishing operations, given their vessel track patterns.

Tankers serve a vital role to resupply fuel to communities, yet because of limited onshore infrastructure and shallow near-shore waters, much of the fuel is lightered to smaller vessels offshore. As a result, tankers rarely come as close to the shoreline as small cargo, tug, or towing vessels (Figure 9). One notable exception are communities near Prudhoe Bay, which is powered by natural gas generated from oil activities in the region. Still, some tankers did sail east from Utqiagvik to deliver fuel to communities and/or mining operations in Canada.

Tourism related vessels include passenger ships (e.g. cruise ships) and adventure crafts (e.g. sailboats, yachts, and small pleasure crafts); these vessels ventured towards Wrangle, St. Lawrence, and St. Michael's Island, likely to see Arctic wildlife, and for the most part avoided the Norton Sound entirely. Notably, many of the adventure vessels sailed through the study area of interest as part of a transit of the Northwest Passage (Figure 11).

Vessel patterns associated with research activities are distinct from most other vessel types in the study area of interest (Figure 12). These patterns include straight transects (such as those in the Chukchi Sea), grid-like surveys (such as those in the Bering Sea), and nonlinear vessel tracks likely reflecting interaction with and/or avoidance of sea ice (such as those in the northern Beaufort Sea). Additionally, other types of vessels exhibiting these patterns may have been vessels conducting research. For example, the U.S. Coast Guard Cutter Healy, a multi-mission medium icebreaker with extensive research capabilities, was classified as a government vessel in this study, but conducted oceanographic research as part of its mission in the area of interest in 2015, 2016, and 2017 (Figure 10).

Finally, offshore supply vessel activity was primarily concentrated in the Chukchi Sea, near the Burger Prospect, and in the Beaufort Sea, around and within existing offshore oil facilities on artificial barrier islands near Prudhoe Bay (Figure 13). Following the decision of Shell to withdraw its leases from the Chukchi and Beaufort Seas prior to the 2016 navigation season, the only offshore supply vessels in the study area of interest were operating around the existing offshore oil facilities on artificial barrier islands near Prudhoe Bay.

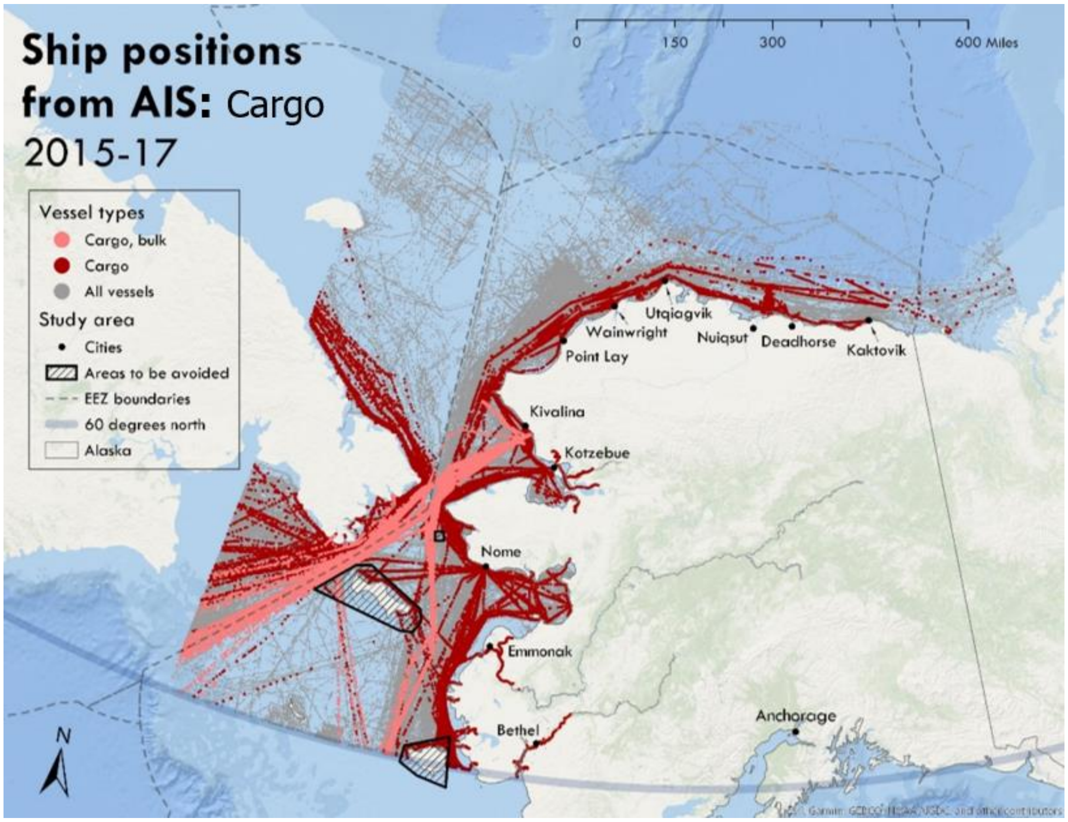

Figure 6: Ship positions from AIS, 2015–2017, Cargo Vessels. Locations for bulk cargo vessels in pink, all other types of cargo vessels in red. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

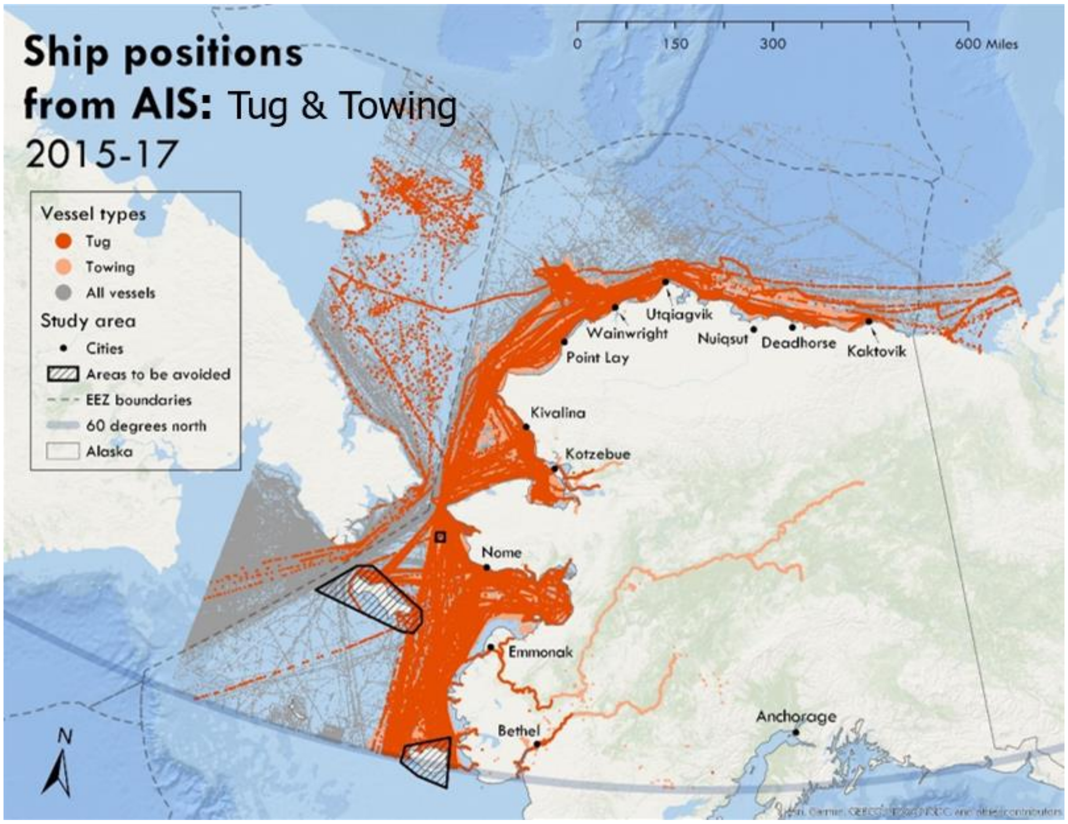

Figure 7: Ship positions from AIS, 2015–2017, Tug and Towing Vessels. Locations for tug vessels in dark orange, towing vessels in light orange. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

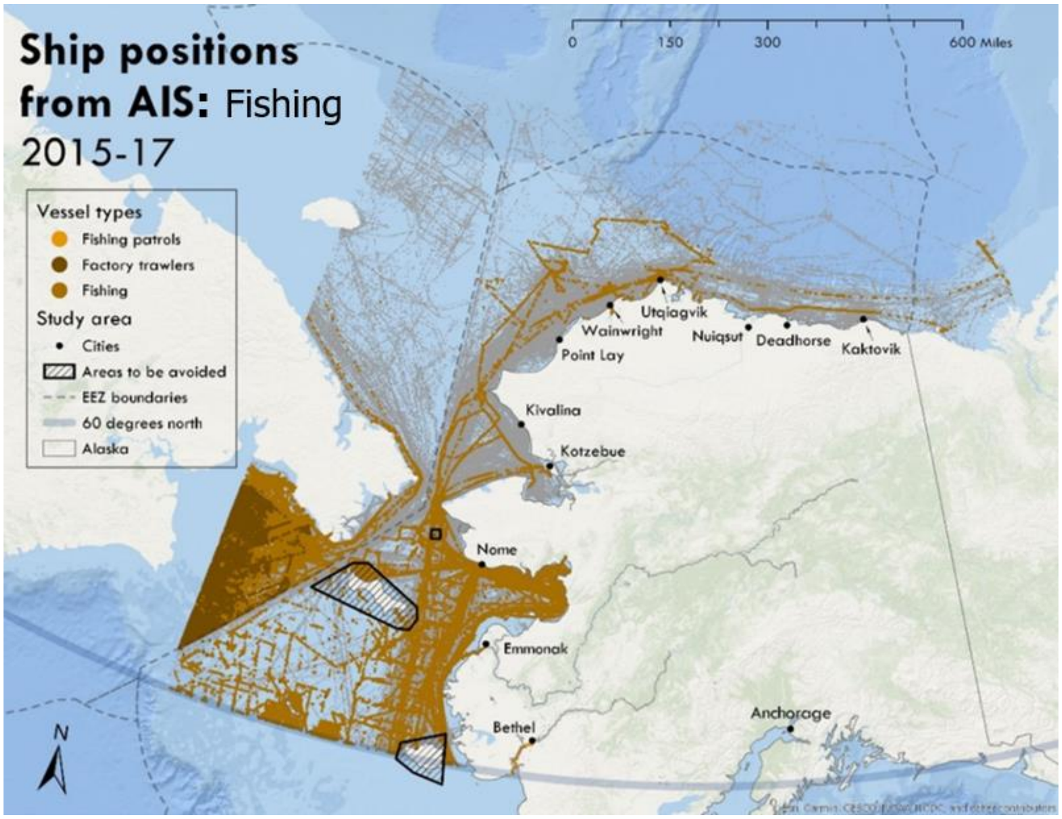

Figure 8: Ship positions from AIS, 2015–2017, Fishing Vessels. Locations for fishing vessels in light brown, factory trawlers in dark brown, fishing patrols in gold. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

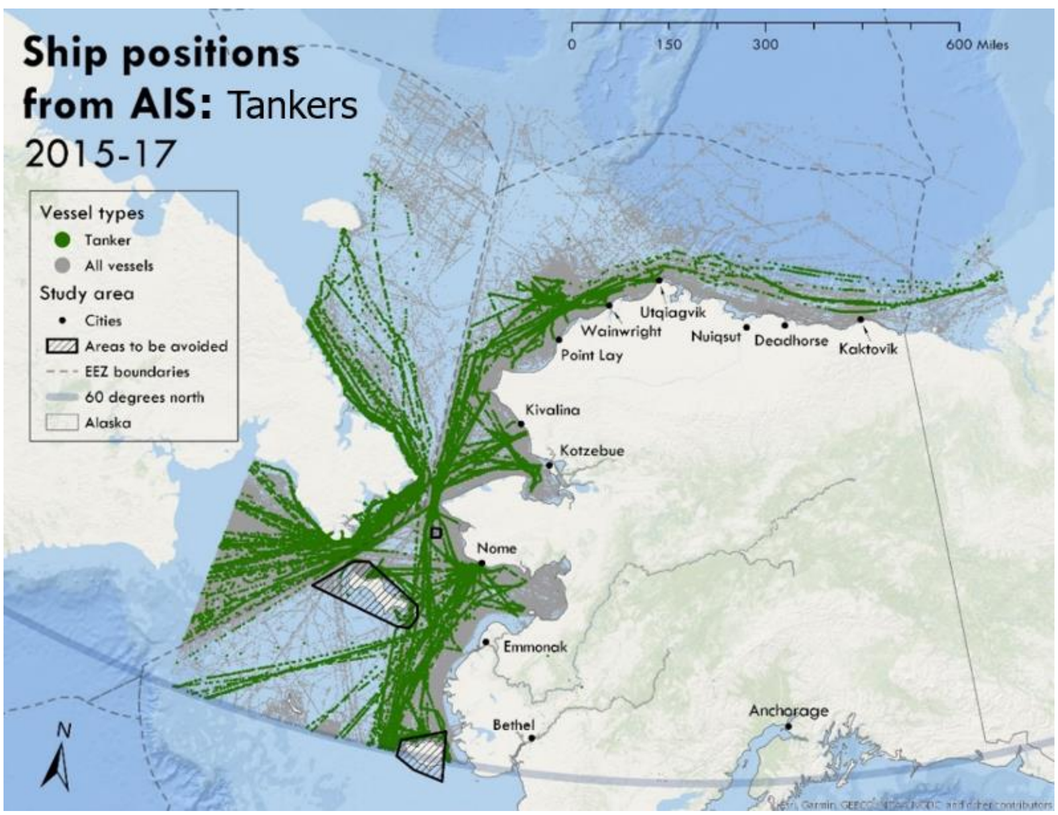

Figure 9: Ship positions from AIS, 2015–2017, Tankers. Locations for tankers in green. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

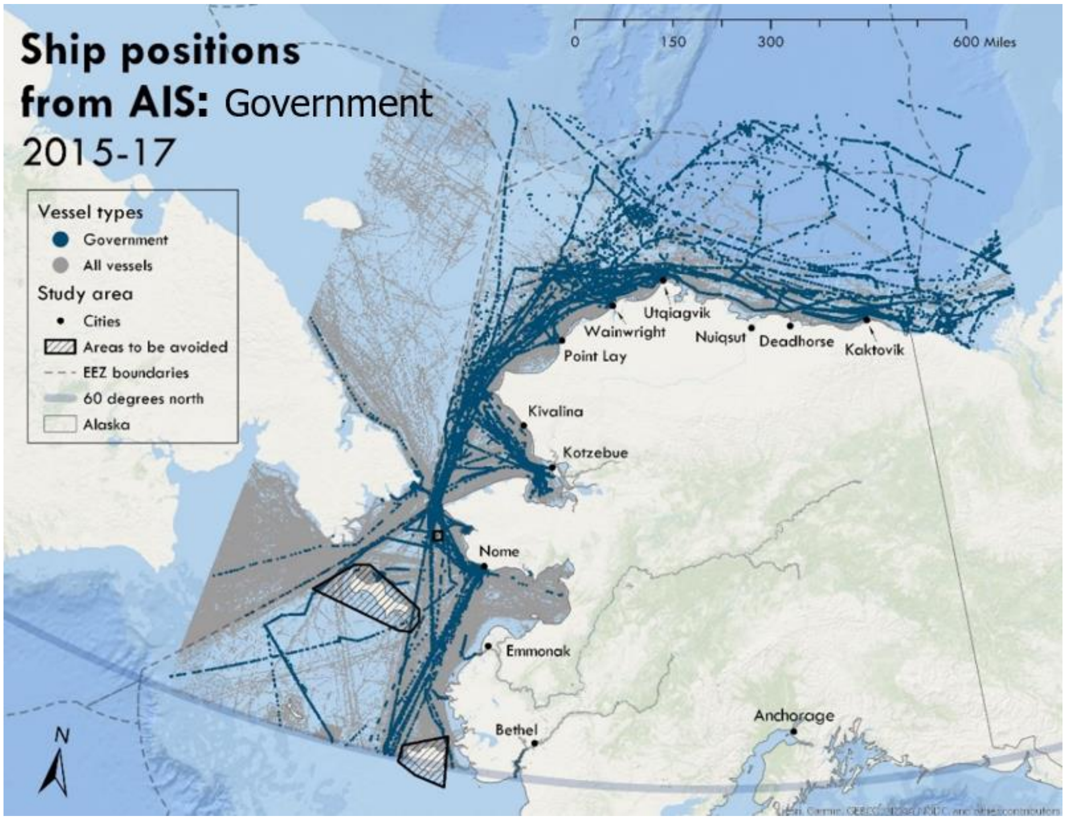

Figure 10: Ship positions from AIS, 2015–2017, Government, Law Enforcement, and SAR Vessels. Locations for government related vessels in blue. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

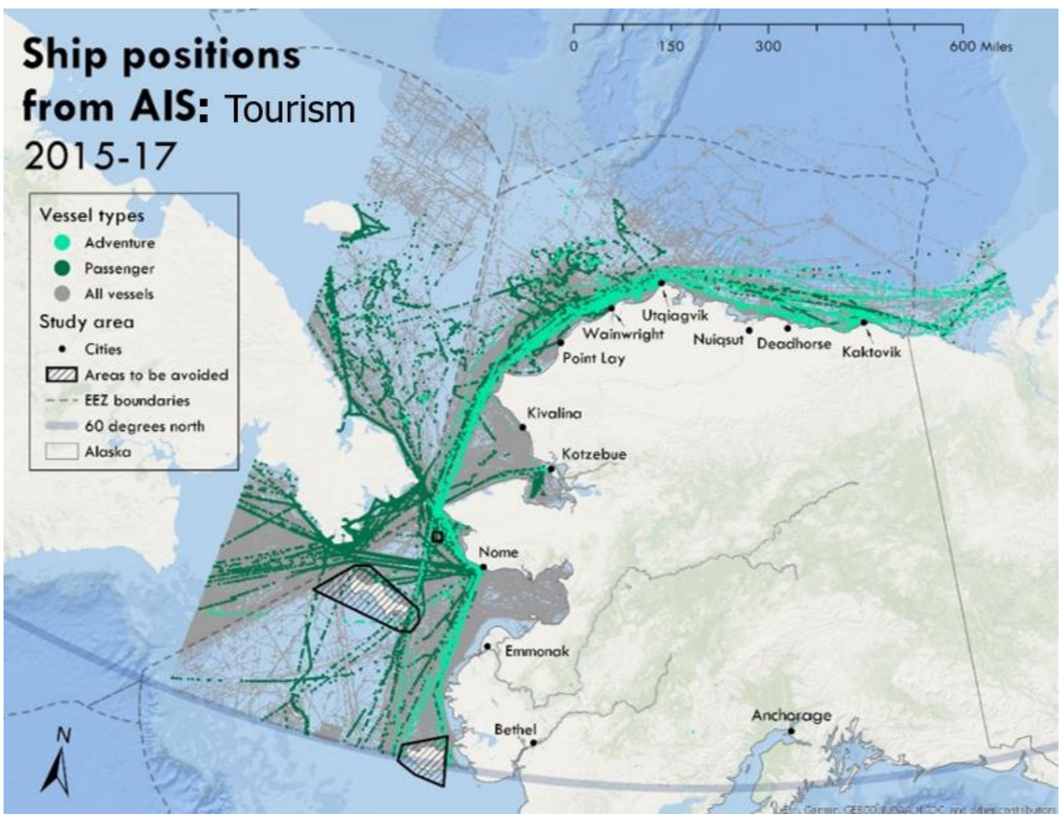

Figure 11: Ship positions from AIS, 2015–2017, Tourism-related Vessels. Locations for passenger vessels in dark green, all other adventure vessels, including sailboats, yachts, and pleasure crafts in light green. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

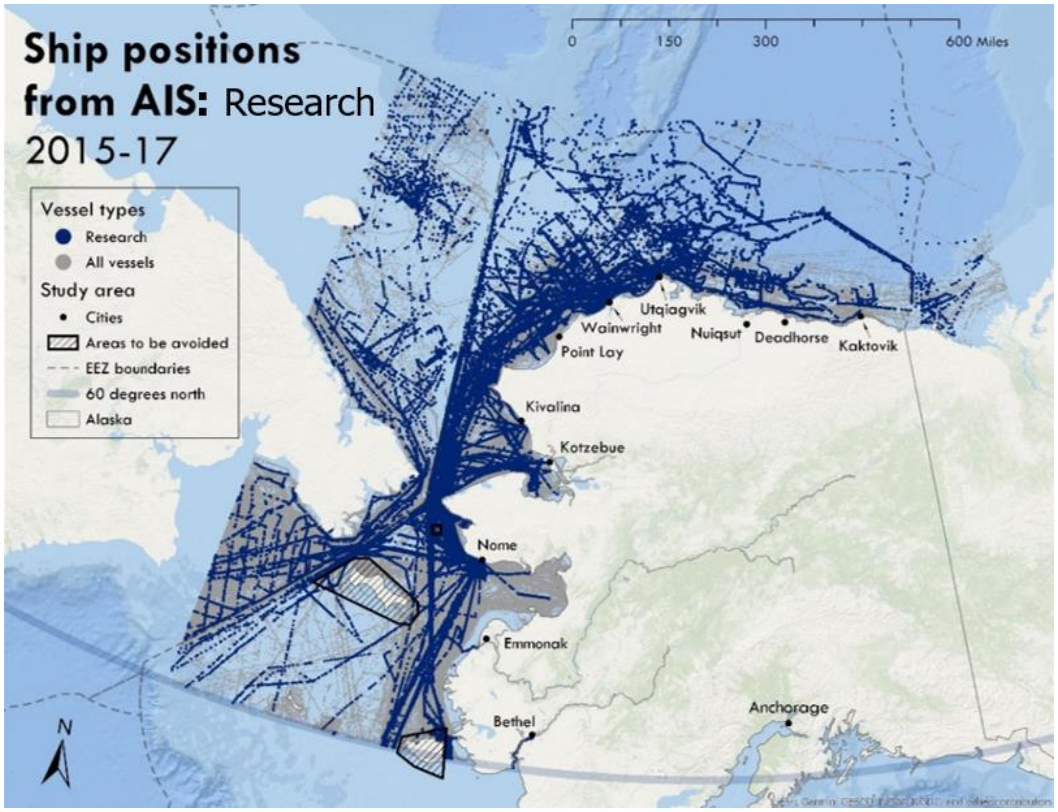

Figure 12: Ship positions from AIS, 2015–2017, Research Vessels. Locations for research vessels in dark blue. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

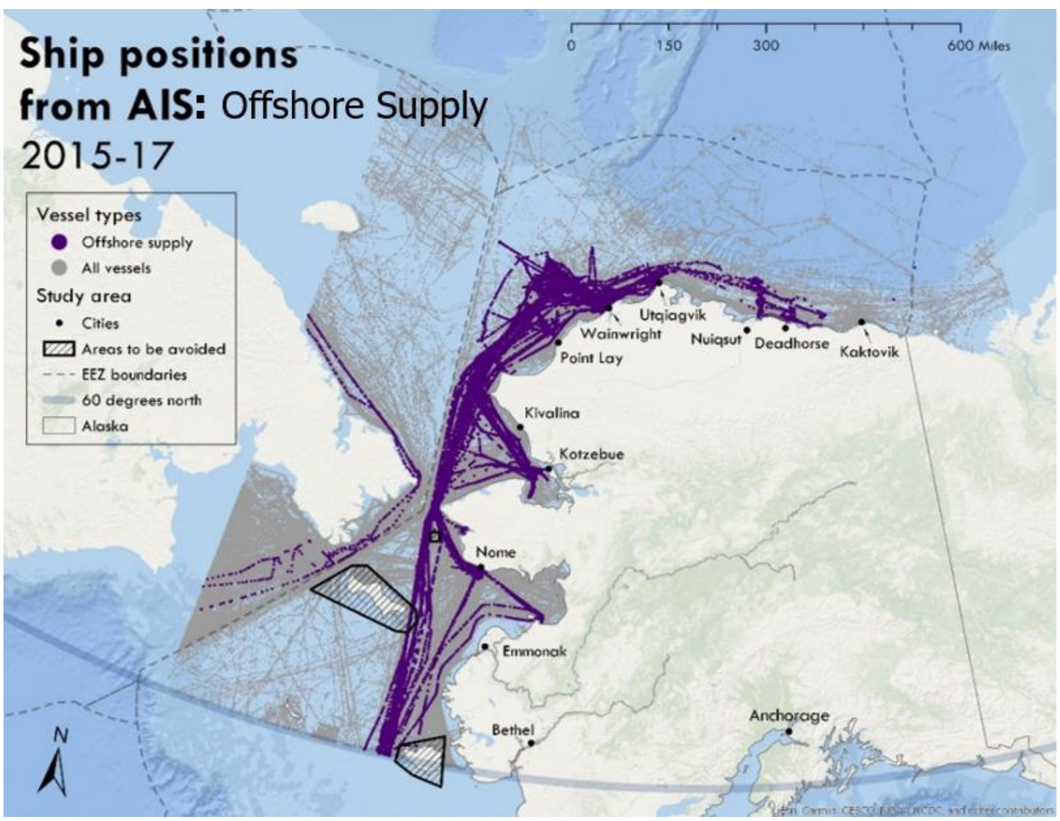

Figure 13: Ship positions from AIS, 2015–2017, Offshore Supply Vessels. Locations for offshore supply vessels in purple. All other vessels broadcasting AIS plotted as grey dots. Dot size or color intensity does not indicate any quantifiable metric.

DYNAMICS OF THE NAVIGATION SEASON

Analysis of AIS signals within the area of interest through time reveals a seasonally dynamic navigation season. The number of unique MMSIs broadcast via AIS each day was used as a proxy for the number of ships operating in the study area of interest. The number of vessels broadcasting AIS each day rapidly increased in mid-May, peaking in August each year (Figure 14, top). For the three years analyzed (2016, 2017, and 2018), there was an average of 2 vessels/day operating in December–May, while June–November had an average of 65 vessels/day. There is no official start of the navigation season in this region, like there is for the St. Lawrence Seaway.[35] For this study, then, the navigation season is defined as the period when there are more than 10 vessels on the water broadcasting AIS. Using this definition of the navigation season for the study's area of interest, the start of the navigation season appears to be starting earlier each year (Figure 14, lower left). Similarly, the end of the navigation season also appears to be happening later each year (Figure 14, lower right). The navigation season grew from 159 days in 2016, to 171 in 2017, and 180 in 2018 or an average of 10 days each year.

This observation is further supported by data collected by the Marine Exchange of Alaska (MXAK), a non-profit organization which owns and operates 130 terrestrial AIS stations and 40 real-time weather sensors across the state of Alaska that provide information and services in support of a safe maritime operating environment across Alaska.[36] The MXAK has also monitored the length of the navigation season in the Bering Strait region since 2010, by recording the first and last dates that vessels cross the Bering Strait (in either direction). According to MXAK's historical data, the navigation season in the Bering Strait ranged from 142 to 206 days over the last decade. Analysis of the MXAK data also reveals that the navigation season increased an average of 7 days each year, from 144 days in 2010 to 200 days in 2018 (Figure 15). [37]

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[35] The St. Lawrence Seaway's navigation season extends from late March to late December each year and is overseen by the Great Lakes-St. Lawrence Seaway System, which issues seaway notices informing mariners of scheduled lock and canal opening dates and times, allowable drafts, and other pertinent navigation information. For more, please see http://www.greatlakes-seaway.com

[36] Marine Exchange of Alaska. (2019). Core Services. Accessed from: https://www.mxak.org/services/

[37] Marine Exchange of Alaska. (2019). "2018: Bering Strait and Arctic Transits Report".

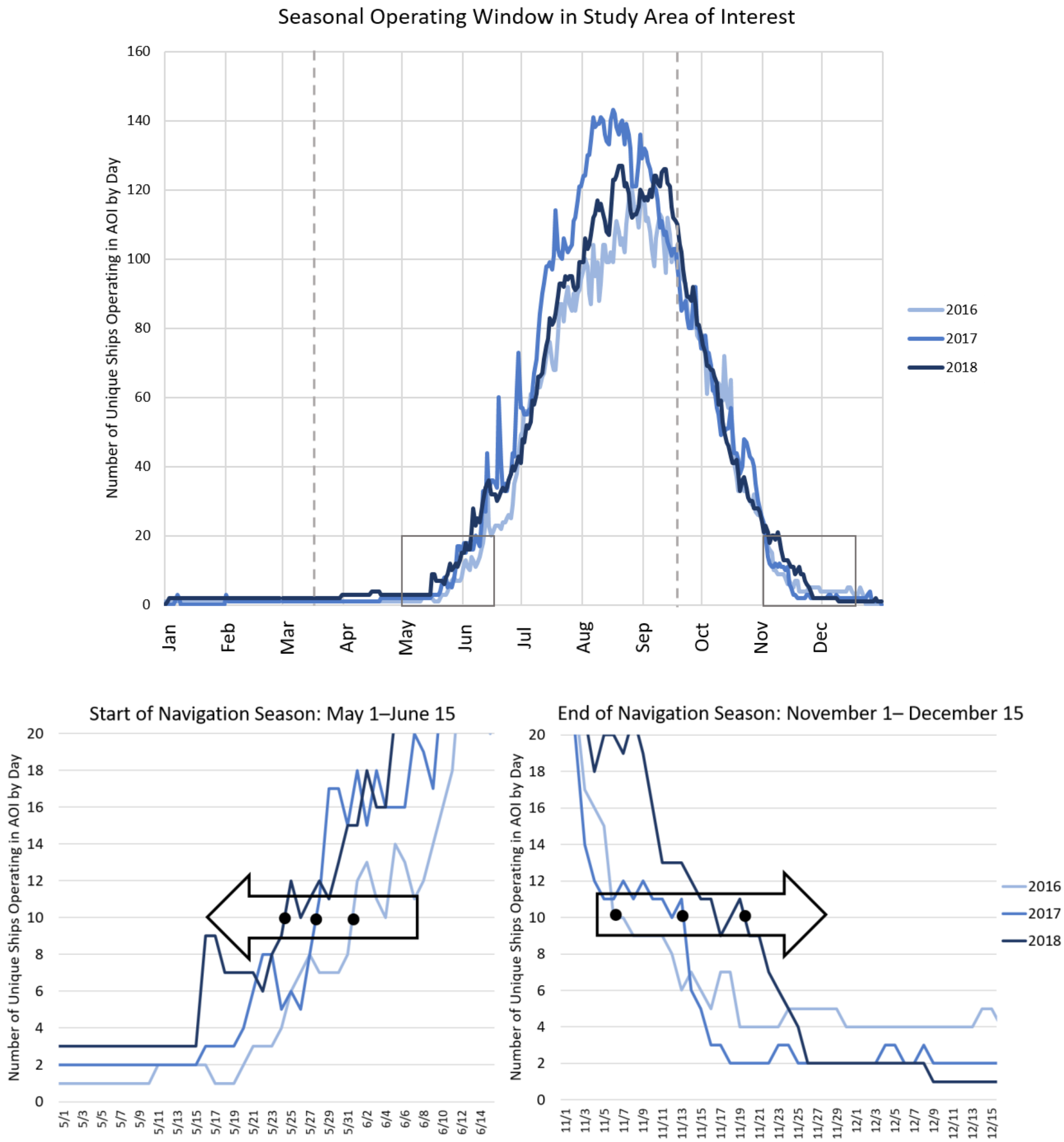

Figure 14: Plot of the number of unique vessels operating in the area of interest via NAIS by calendar day, 2016--2018. Data plotted for 2016–2018 for the entire year (top), May 1–June 15 (lower left), and November 1–December 15 (lower right). These insets show the increasing number of vessels operating earlier in the spring and later in the fall over the 3 years analyzed. AIS data only contains NAIS data and was obtained through USACE's AISAP for the study area of interest. Dashed vertical grey lines on top figure correspond to the annual ice extent maximum (mid-March) and minimum (mid-September) for the Bering Sea.

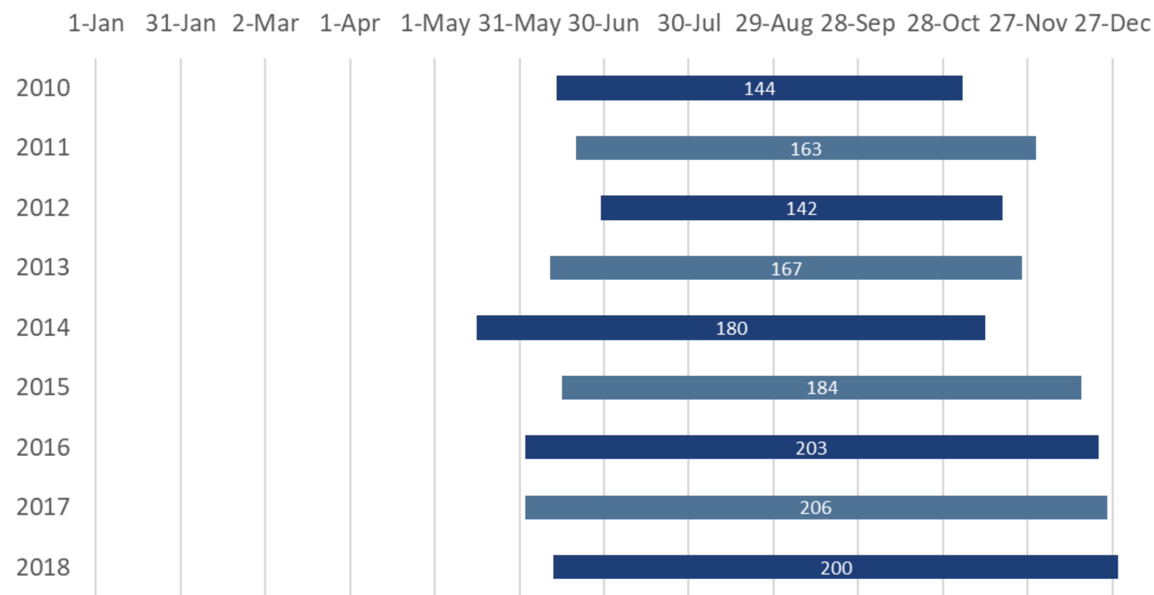

Figure 15: Arctic navigation season length for 2010—2018 from MXAK. Figure provided by the Marine Exchange of Alaska, "2018: Bering Strait and Arctic Transits Report".

Taken together, these data provide substantial evidence that the length of the navigation season is growing each year in the study area of interest. Not only does this growth appear to be uncoupled from sea ice extent, it is growing much faster than anticipated by studies using sea ice models to predict navigability. One such study projected that the coastal ice-free season may lengthen by 1.3–1.7 days each year in the central region (60°–65°N) and 1–1.5 days each year in the northern region (>65°N).[38] However, the growth in the length of the navigation season as observed via AIS in this study and by MXAK's historical data set show that the navigation season is growing anywhere from 4—10 times faster than those modeled rates.

This finding provides vital insight into the changing operational dynamics of the region and of the evolving situational requirements of vessels in the study area of interest. Despite modest differences in vessel numbers between the selected years studied, the time of year in which these vessels are operating is shifting. Earlier operations in the spring may have profound impacts on spring subsistence hunting

[38] Melvin, April et al. (2016). Climate change damages to Alaska public infrastructure and the economics of proactive adaptation. *Proceedings of the National Academy of Sciences*. 114 (2) E122-E131. Accessed from https://doi.org/10.1073/pnas.1611056113

activities on the water and ice. Later operations in the fall also mean that operators are using the waterways under fewer hours of daylight each day. For example, there are less than 8 hours of daylight in Nome, AK by early November and less than 5 hours by December; while ice coverage may diminish further, daylight, or lack thereof, will remain the same. Other vital infrastructure components of the marine transportation system will also have to extend their operating windows to support this growing season, including search and rescue (SAR), marine weather forecasting, port facilities and support vessel operation and availability.

Finally, it should be noted that the differences between these two methods to measure the length of the navigation season also raise some interesting questions, specifically about the start and end of the seasons, when more than 10 vessels are operating in the area of interest versus when the first vessels pass through the Bering Strait are interesting. These differences may simply indicate vessels are operating in the Bering Sea south of the Bering Strait; however, they may also indicate vessels operating north of the Bering Strait, such as icebreakers in Russian waters or vessels operating with icebreaker escort. This possibility means that vessels could be operating in the Russian Arctic before U.S. assets can be positioned above the Bering Strait because ice conditions prevent non-icebreaking ships from accessing the region. These data gaps are a prime example of information that is not readily collected, a further demonstration of the rapid pace of change in the region, and the urgent need to focus on understanding those changes.

DISCUSSION

COMPARING BASELINE DATA WITH OTHER RELEVANT DATASETS

To understand the baseline maritime vessel data within a wider regional context, 2015–2017 AIS data for the study area of interest was compared with historical vessel data activity for other regions of the Arctic during overlapping time periods. These regions include: waters north of and around the Bering Strait, the Northern Sea Route, the Northwest Passage, and the wider Arctic region.

WATERS NORTH OF AND AROUND THE BERING STRAIT

The U.S. Coast Guard District 17 (USCG D17) compiles annual data on the number of unique vessels by type within an area of interest extending from the Bering Strait, north to the North Pole, east to Banks Island and west to New Siberian Islands (Figure 16). USCG D17 has collected and compiled these data annually since 2008, providing one of the longest ongoing data sets for vessel activity for much of this study's area of interest (Figure 17).

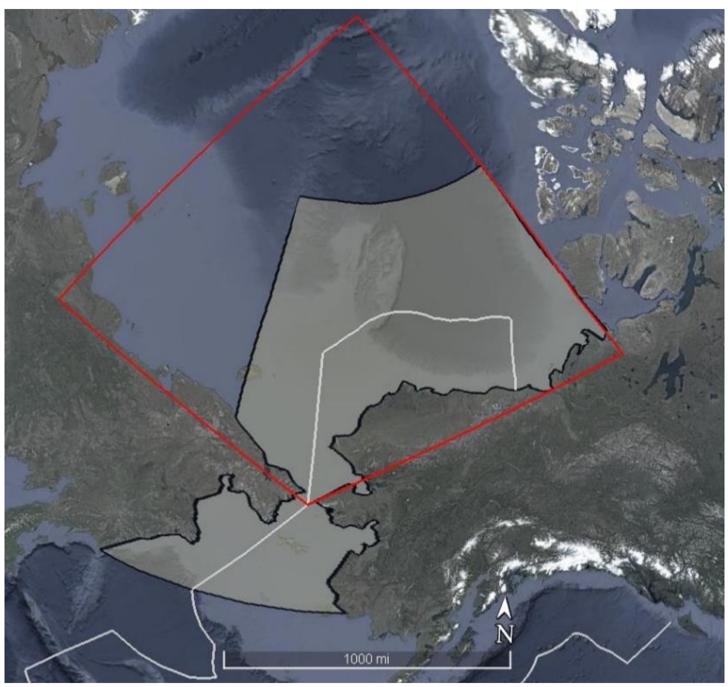

Figure 16: Map of overlapping areas of interest for this study and USCG historical dataset. The study area of interest for this report is outlined in black and shaded in gray; the area of interest north of the Bering Strait is outlined in red; the U.S. EEZ is outlined in white. Map plotted with Google Earth.

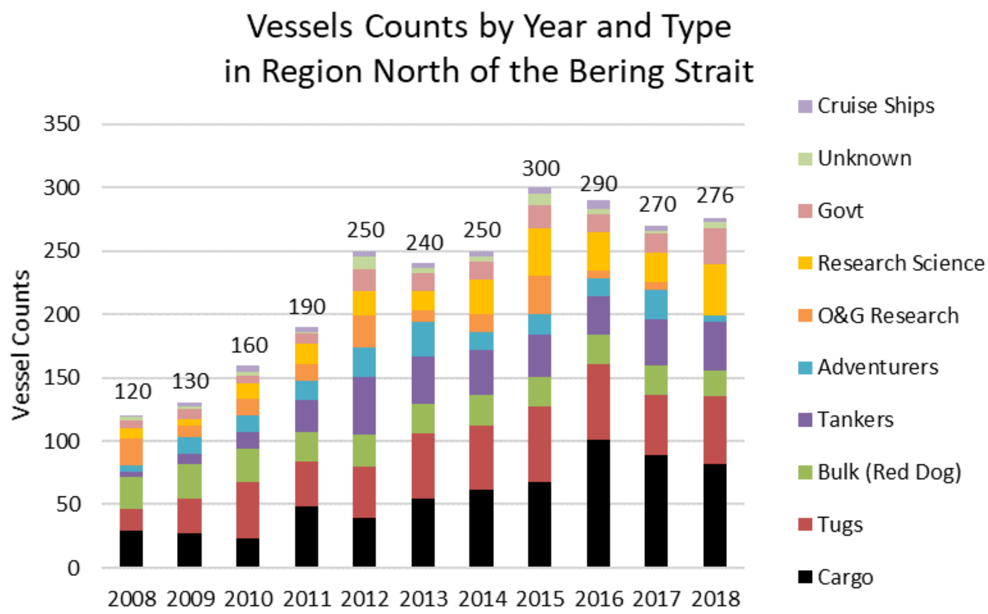

Figure 17: Vessel counts by year and type in the area of interest north of the Bering Strait. Data provided by U.S. Coast Guard District 17.

The number of unique vessels for this area of interest steadily increased since data collection began in 2008 and peaked in 2015 at 300 vessels. This coincided with Shell's exploratory drilling efforts at the Burger Prospect in the Chukchi Sea. In early 2016, Shell announced its intent to not pursue further exploration and withdrew from its leases in the Beaufort and Chukchi Seas. In the years since Shell's withdrawal, the total number of unique vessels transiting this area of interest has decreased slightly, but not substantially so, from the peaks observed in 2015 to an average of 279 ± 10 unique vessels for 2016–2018. As vessels related to oil and gas research have decreased, vessels attributed to other research and government activities (e.g. law enforcement and search and rescue) have increased. One notable difference between the USCG dataset and the data gathered for this study area of interest is the lack of fishing vessels, which as discussed previously, is because fishing vessels and related activities are concentrated in waters south of the Bering Strait (see Figure 8).

The overall number and distribution of ships within the USCG data set is in close agreement with the distribution of vessels found in this study's area of interest and is a valuable corollary data set for this report's area of interest.

NORTHERN SEA ROUTE

The Northern Sea Route Administration (NSRA) is the government agency for the Russian Federation that oversees passage through the Northern Sea Route, which includes Russian waters extending from the Kara Sea to the Bering Strait.[39] Historical data for complete transits of the Northern Sea Route by vessel name, flag, and vessel type were compiled from 2014–2018 from data made available by the Northern Sea Route Information Office (Figure 18 and Figure 19).[40] The data presented here underestimates the volume of traffic along the Northern Sea Route, as it only includes complete transits, rather than all vessels operating along the route, including ice-breaking LNG tankers transporting LNG from the Yamal peninsula to Europe and Asia and vessels suppling smaller communities along the Russian coastline. The choice to focus on these vessels within the larger NSRA dataset is to better understand the ships that also transit through the Bering Strait and therefore, through this study's area of interest.

Russian flagged ships make up the largest share of vessels transiting the Northern Sea Route, counted as both the total number of complete transits and unique vessels completing transits. However, in 2018, voyages completed by cargo vessels owned by COSCO (all of which were general cargo ships flagged to China and/or Hong Kong) were equal to the number of transits completed by Russian flagged ships (Figure 18). This transition in flag state dynamics is echoed in a transition of vessel types; in 2014, more than half of the transits were completed by tankers, while in 2017 and 2018, most vessels were completed by general cargo ships (Figure 19). These changes indicate that, like the waters in this study's area of interest, the Northern Sea Route is also undergoing a transition from primarily regional operations to an increasingly diverse and international set of users.

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[39] Northern Sea Route Administration. 2019. "Object of activity and functions of NSRA". Accessed from: http://www.nsra.ru/en/glavnaya/celi_funktsii.html

[40] Northern Sea Route Administration (2014–2018). Annual Transit Statistics. Obtained via the Center for High North Logistics. Accessed from http://arctic-lio.com/?cat=27

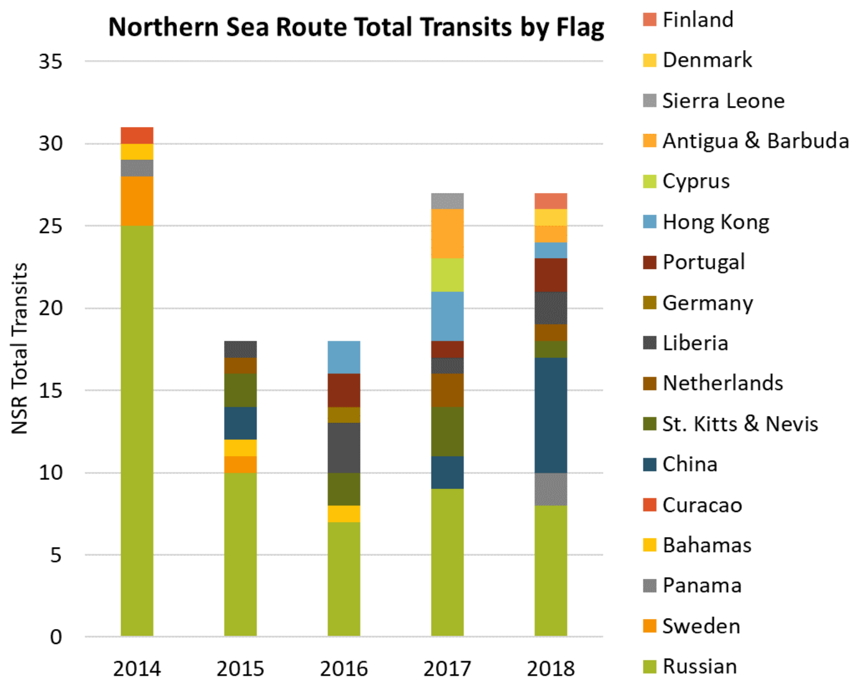

Figure 18: Tally of complete transits of the Northern Sea Route by year and flag. Data obtained from the Northern Sea Route Administration via the Center for High North Logistics.

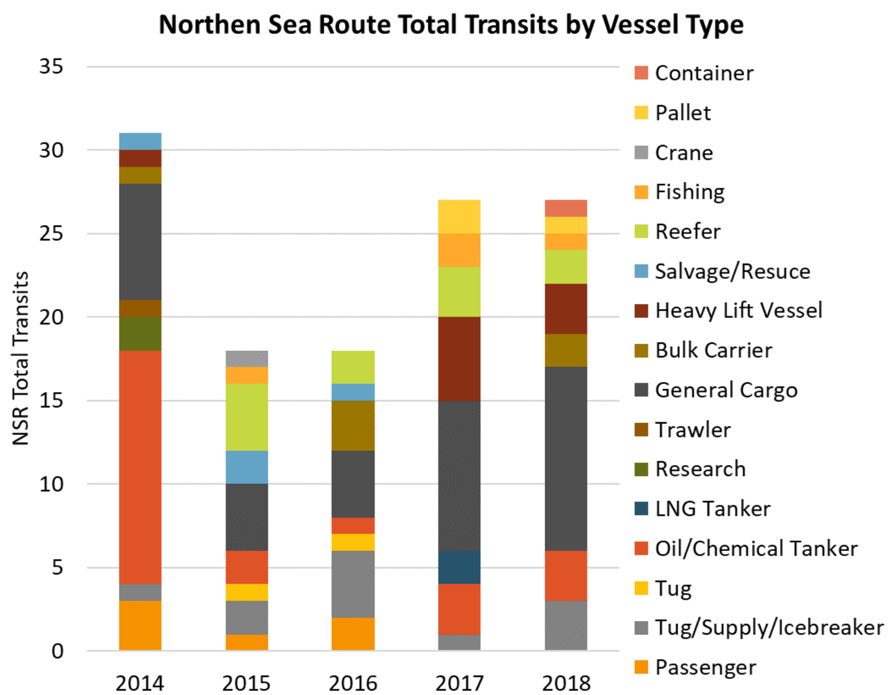

Figure 19: Tally of complete transits of the Northern Sea Route by year and vessel type. Data obtained from the Northern Sea Route Administration via the Center for High North Logistics.

There is a subset of these transits of particular interest for the projections featured later in the report: vessels which could be considered to be transiting *through* the Arctic, as opposed to destinational shipping to or from the Arctic. These vessels are assumed to be non-Russian flagged vessels with origins and destinations outside of Russia. From 2015–2018, the number of these transits increased from 6 to 16 unique vessels. Though these values are small and the dataset is sparse, this pattern suggests that the Northern Sea Route may be used as an alternative to other trans-oceanic shipping routes. These data also provide valuable baseline information for the level of seasonally rerouted shipping through the Arctic, a factor which will be considered in Section IV of this report.

NORTHWEST PASSAGE

Historical traffic for the Northwest Passage was obtained from Headland *et al*., which includes an extensive record going back to Amundsen's historic expedition in 1906. The focus for this comparison is on the vessel traffic of the last decade, which coincides with the first year (2008) that the annual number of vessels completing transits of the Northwest Passage surpassed historical averages (Figure 20).[41]

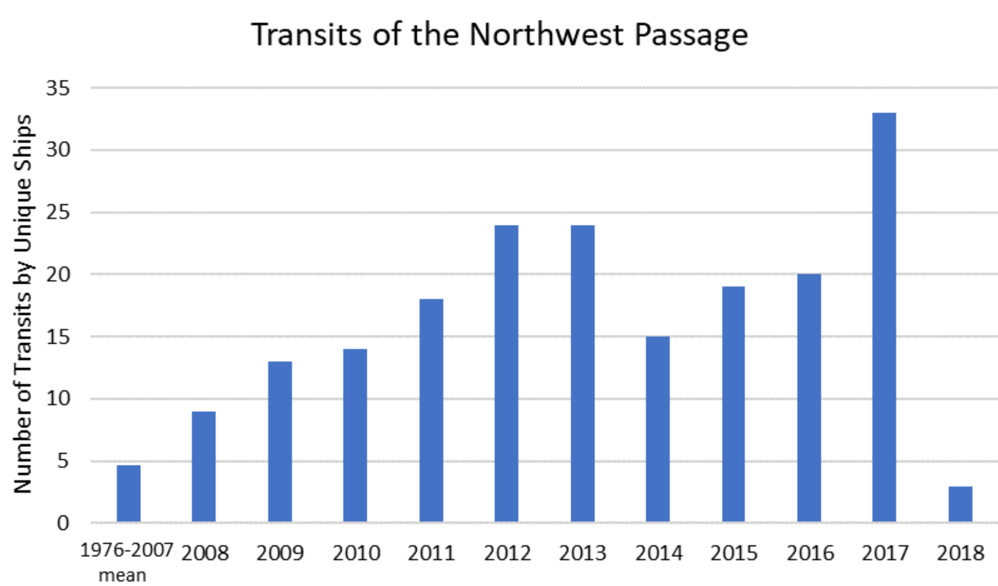

Figure 20: Tally of unique ships completing transits of the Northwest Passage by year, 2008–2018. Data obtained from Headland et al. (2018).

[41] Headland, R.K. et al. (2018). Transits of the Northwest Passage to End of the 2018 Navigation Season: Atlantic Ocean ↔ Arctic Ocean↔ Pacific Ocean. Scott Polar Research Institute. Accessed from https://www.spri.cam.ac.uk/resources/infosheets/northwestpassage.pdf

The few vessels transiting the Northwest Passage have predominantly been small, adventure-type craft or small, ice-strengthened cruise ships. Prior to 2008, the average number of ships completing transits was less than 5 unique ships each year; in the last decade, an average of 17 ships have completed transits each year. Only eight of the total 222 completed Northwest Passage transits have been to transport commercial cargo, indicating that the region has not historically been a major commercial throughway. More recently, much of the activity has been tourism-related activities, as evidenced that all but nine of the total transits of the Northwest Passage from 2015–2017 were completed by cruise ships or adventure vessels.[42] Notably, there was a sharp drop in vessel activity in 2018, due to extensive icing of the Northwest Passage, making the route inaccessible for all but three vessels.

As with the data compiled for the Northern Sea Route, this volume of vessel activity likely underestimates the total vessel activity as this only reflects completed transits, but does serve as a valuable reference point for the vessels within the study area of interest. There were 19 unique ships which transited the Northwest Passage in 2015, 20 in 2016, and 33 in 2017, representing an average of 10% of the total number of unique vessels in this study's area of interest in 2015–2017.

ARCTIC SHIP TRAFFIC DATA PROJECT

The Arctic Ship Traffic Data (ASTD) Project, launched in early 2019 by the Protection of the Arctic Marine Environment (PAME) Working Group of the Arctic Council, brings together ship traffic data across the whole Polar Code definition of the Arctic. Analysis of ASTD traffic data found that a total of 2,043 unique vessels transmitted AIS in the Polar Code region of Arctic in 2017, with 1,584 of those vessels registered to Arctic States (77.5%).[43]

The area of interest for this study is only a portion of the whole Arctic region where the Polar Code applies (Figure 21) and is generally, a much less transited part of the Arctic, as evidenced by the fact that only 11.5% of the total number of unique ships operating in the Polar Code definition of the Arctic region transited through this study's area of interest. [44]

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[42] Ibid.

[43] These data and analyses were provided during the 2018 CMTS & USARC Technical Workshop on Arctic Vessel Activity, held in Washington, D.C., 14–15 November 2018.

[44] Ibid

With time, it is likely that the ASTD project will become a valuable tool to understanding not just vessel patterns and trends within this study's area of interest, but also throughout the pan-Arctic region. For the purposes of this study, the data comparison between the study area of interest and the full Polar Code Arctic provides valuable perspective on the importance of the region and acknowledgement that there are activities in the pan-Arctic region that could and will impact activity in and around the U.S. Arctic region. Some of these possibilities are further discussed in the Section IV of this report.

Figure 21: Study area of interest in relation to the extent of the Polar Code in the Arctic. The study area of interest is outlined and shaded in black; the extent of the Polar Code in the Arctic is outlined in blue; and the U.S. EEZ is outline in white.

LIMITATIONS OF AIS DATA AND OVERLOOKED VESSEL ACTIVITIES

The analysis presented here includes only those vessels broadcasting AIS information. In 2002, the International Maritime Organization (IMO) made it mandatory for AIS to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages and all passenger ships irrespective of size.[45] Additionally, in 2016, the U.S. Coast Guard expanded the carriage requirements for vessels

[45] International Maritime Organization. (2018). AIS transponders. Accessed from http://www.imo.org/en/OurWork/safety/navigation/pages/ais.aspx

operating in U.S. waters to encompass all vessels engaged in commercial service, including fishing vessels over 65', as well as towing vessels of 26' or more in length and more than 600 horsepower, all self-propelled vessels certified to carry more than 150 passengers, and self-propelled vessels engaged in dredging operating in or near a commercial channel or shipping fairway in a manner likely to restrict or affect navigation of other vessels.[46] These AIS carriage requirements do not apply to foreign vessels not destined for, or departing from, a port or place subject to the jurisdiction of the U.S.; and/or are on innocent passage through a territorial sea of the U.S., or transit through navigable waters of the U.S. which form a part of an International strait, including the Bering Strait. Although the analysis of AIS data can provide insights into the kinds of activities in the region, it does not capture all activities, including vessels on innocent passage below the IMO's size requirement and vessels smaller than the AIS carriage requirement, such as subsistence hunting crafts, small crafts launched from research and passenger ships, some sailboats and small yachts.

In this study's methodology, the decision to exclude MMSIs greater than 775999999 was an attempt to exclude vessels improperly broadcasting AIS and other entities which broadcast AIS, such as fixed Aids to Navigation. However, this additional step removed several small crafts launched from other ships from this analysis, including four small passenger vessels related to two cruise ships and two support crafts related to cable laying vessels. These non-U.S. flagged vessels all followed the MMSI format of "98" followed by the beginning of the MMSI of the parent ship from which they were launched.[47] However, several small crafts launched from U.S. flagged vessels were included in the data set, despite such filtering. This is because there is no provision in the U.S. to assign MMSIs that correspond to the parent vessel; instead these vessels receive their own unique MMSI from the FCC. It was only through other methods that it was determined that these vessels were small skiffs used by research vessels *Fairweather* in 2015 and 2017 and *Sikuliaq* in 2017. These inclusions accurately portrayed the volume of vessels attributed to research activities, but also underrepresented the true footprint of vessels which launch smaller vessels into their vicinity, including cruise ships and vessels laying undersea cables. Understanding the number of these small support crafts associated with research, tourism, and other

[46] Title 33, Code of Federal Regulations, § 164.46; For more information, please see https://www.navcen.uscg.gov/?pageName=AISRequirementsRev

[47] According to USCG's Navigation Center, stations used on craft associated with a parent ship, such as launches, tenders, towed vessels, etc. may use the format 9182M3I4D5X6X7X8X9 where the digits 3, 4 and 5 represent the MID and X is any figure from 0 to 9. However, no provision currently exists for assigning these identities in the United States. For more, please see https://www.navcen.uscg.gov/?pageName=mtmmsi

activities is required to more accurately constrain the total number of vessels in the region and their impact.

One other activity excluded by using AIS data exclusively is the vessel activity related to subsistence hunting, the longest ongoing type of vessel activity in the Arctic. While some subsistence hunting does not require the use of vessels, the harvest of marine mammals and some fishing activities do require watercraft, the most familiar of which is the *umiak* or *umiaq*, an open skin boat used in traditional subsistence whaling, in addition to other vessels, many of which are small motorized vessels. Whaling activities vary by community and by season, following the migration patterns of the whales through the region. The bowhead whale, an important subsistence and cultural resource for many subsistence communities in the region, has a spring migratory corridor between the Bering Strait and Cape Bathurst, a fall migratory corridor between Hershel Island and Utqiagvik, and a winter migratory corridor extending into the northern Bering Sea (Figure 22).[48]

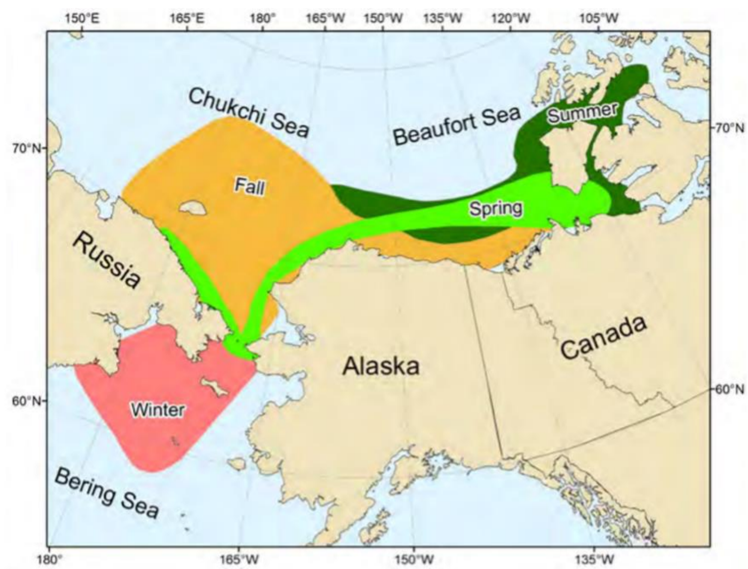

Figure 22: Seasonal areas of use by bowhead whales as determined from satellite telemetry, 2006–2012. Figure from Quakenbush *et al*. 2013.

There is little data available on the volume of vessel activity associated with subsistence hunting, but what data is available suggests that this baseline analysis (which is reliant on AIS exclusively) missed a

[48] Quakenbush, L.T., Small, R.J, and Citta, J.J. (2013). "Satellite Tracking of Bowhead Whales: Movements and Analysis from 2006–2012". OCS Study BOEM 2013-01110. Accessed from: https://www.adfg.alaska.gov/static/research/programs/marinemammals/pdfs/bowhead_2013_boem_final_report.pdf

considerable portion of the total number of vessels in the Arctic by excluding subsistence vessels. For example, among the 11 whaling communities in the northern Bering Sea and Alaskan Arctic, there are 165 registered whaling captains.[49] Assuming each captain and whaling crew uses a single unique vessel, the total number of vessels based on AIS alone within the study area of interest may underrepresent actual vessels by 40%. This estimation is likely very conservative, as a 2013 report from BOEM about subsistence whaling activities from a single community on the North Slope noted that whaling crews preferred having 5–7 small boats to scout for whales and recorded as many as 13 unique boats engaged in whaling activities on a day when a whale was landed.[50] Given the importance and the widespread practice of subsistence hunting to communities along the Bering Strait and the North Slope, it is imperative to close this data gap in order to develop a complete understanding of vessel activities in the region. Closing this gap is critical to deconflicting the current uses of these waterways and planning for future changes in the region.

Potential Changes in the Composition of Vessel Activity

The region of interest for this study has undergone unprecedented changes over the past decade, and the analysis of vessels over the last few years presented in this chapter suggest more changes are still to come in the composition of marine traffic in and around the waters of the Bering Strait.

Within the 2018 AIS data obtained via the U.S. Army Corps of Engineer's AISAP, there were two notable vessels which may indicate that the composition of vessels moving through the region may change considerably. First, one MMSI in 2018 was found to correspond to the Bathymetric Explorer and Navigator (BEN), an unmanned surface vehicle used for the first time to assist in collecting data for hydrographic surveys vessels for NOAA.[51] While there may not be autonomously piloted ships through this part of the Arctic in the next decade, it is highly likely that there will be more autonomous vehicles

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[49] Alaska Eskimo Whaling Commission. (n.d.) Our Whaling Villages. Accessed from: http://www.aewc-alaska.com/whaling-villages.html

[50] Bureau of Ocean Energy Management. (2013). "Monitoring Cross Island Whaling Activities, Beaufort Sea, Alaska: 2008–2012 Final Report, Incorporating ANIMIDA and cANIMIDA (2001–2007). Accessed from: https://www.boem.gov/uploadedFiles/BOEM/BOEM_Newsroom/Library/Publications/BOEM_2013-218.pdf

[51] Downs, Rob. (2018). "NOAA researches autonomous survey system in the Arctic". NOAA Office of Coast Survey Blog. Accessed from: https://noaacoastsurvey.wordpress.com/category/unmanned-systems/

used for research activities, especially as the demand for real-time environmental data in the region increases.

Secondly, in September 2018, Maersk's *Venta Maersk* made a complete transit of the Northern Sea Route, crossing through the study area of interest.[52] Smaller container ships have sailed along the Northern Sea Route before, but this shipment was the first trans-Arctic shipment of containerized cargo. At the time, Maersk itself did not see "the Northern Sea Route as a commercial alternative to [their] existing network, which is defined by …customers' demand, trading patterns, and population centers".[53] However, ongoing discussions since Maersk's successful maiden voyage raise the prospect of whether containerized cargo might one day regularly transit through the Arctic.[54] The United Nations Conference on Trade and Development (UNCTAD) estimates that container ships are among the fastest growing types of ships engaged in international waterborne commerce and are expected to grow 6% annually from 2018–2023.[55] Such a development would likely dramatically alter the spread of vessel types transiting through the Bering Strait and the study area of interest.

Additionally, within both AIS data sets for the area of interest, fishing vessels were a considerably larger portion of vessels than anticipated. Some of these fishing vessels are simply vessels of opportunity used for research activities in the region, owing to the shapes of their track lines (e.g. Figure 8). Commercial fishing in the study area of interest is only currently allowed in U.S. waters south of the Bering Strait and non-U.S. waters, yet these waters are adjacent to the Bering Sea, one of the largest and most productive commercial fishing grounds in the U.S. This region is undergoing unprecedented environmental change, and as the water temperatures in the region increase, commercial fisheries, and by extension, fishing vessels may move farther north, expanding further into waters included in this study

[52] Reuters. (2018). "Maersk sends first container ship through Arctic route". Accessed from: https://www.reuters.com/article/us-arctic-shipping-maersk/maersk-sends-first-container-ship-through-arctic-route-idUSKCN1L91BR

[53] BBC News. (2018). "Container ship to break the ice on Russian Arctic route". Accessed from: https://www.bbc.com/news/business-45271766

[54] Reuters. (2019). "Maersk explores Arctic shipping route with Russia". Accessed from: https://www.reuters.com/article/us-arctic-shipping-maersk/maersk-explores-arctic-shipping-route-with-russia-idUSKCN1TF0WW

[55] Compare this rate with the 3.8% annual growth rate projected for all waterborne commerce; United Nations Conference on Trade and Development. (2018). Review of the Marine Transport 2018 (Rep.). Accessed from: https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

area of interest. Within the three years sampled here for the baseline analysis, the number of unique ships categorized as fishing vessels climbed from 18 in 2015 to 34 in 2017. These data alone cannot confirm that fishing activity is increasing in the area, because, as noted previously, AIS carriage requirements for fishing vessels depend on the size of the vessel and the region of operation. Additionally, there are regulatory restrictions which will likely limit uninterrupted growth of commercial fishing activities in part of the study area of interest and the wider Arctic region. In 2009 the North Pacific Fishery Management Council approved and NOAA's National Marine Fisheries Service then implemented the Fishery Management Plan for Fish Resources of the Arctic Management Area.[56] This policy closed commercial fishing of any kind in Federal waters north of the Bering Strait.[57] Furthermore, in 2018, the U.S. signed onto the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean with nine other signatories, including all of the other Arctic States.[58] This international moratorium will remain in effect for sixteen years once entered into force, which is not expected until 2020.

SUMMARY

This section provides an overview of recent vessel activity in and around the study area of interest. An average of 255 unique vessels broadcasting AIS transited through the area of interest annually between 2015 and 2017. On average 31% of these vessels were cargo vessels, 21% tug and/or towing vessels, 11% fishing vessels, 9% tourism related vessels (passenger and adventure ships) 7% tankers, and the remainder split between government (LE and SAR), research, and a variety of other activities. By flag state, U.S. flag vessels make up 41% of the vessels in the study area of interest, Russian flag vessels make up 24% of the vessels, and the remaining 35% of vessels are from 35 other flag states, each with a considerably smaller percentage than Russia or the U.S.

Both the operators and operating conditions for vessels traveling through and around the Bering Strait are undergoing changes. The composition of operators appears to be changing, as the total number

[56] North Pacific Fishery Management Council. (2019). "Arctic Fishery Management". Accessed from: https://www.npfmc.org/arctic-fishery-management/

[57] North Pacific Fishery Management Council. (2009). "Fishery Management Plan for Fish Resources of the Arctic Management Area". Accessed from: https://www.npfmc.org/wp-content/PDFdocuments/fmp/Arctic/ArcticFMP.pdf

[58] NOAA National Marine Fisheries Service. (2018). "U.S. Signs Agreement to Prevent Unregulated Commercial Fishing on the High Seas of the Central Arctic Ocean". Accessed from: https://www.fisheries.noaa.gov/feature-story/us-signs-agreement-prevent-unregulated-commercial-fishing-high-seas-central-arctic

of flag states operating in the region is increasing, both in this study's area of interest and along the Northern Sea Route. Historical data provided by the U.S. Coast Guard for waters north of the Bering Strait indicate that the number of unique vessels has increased by 128% over 2008 levels. In that time, there is also evidence that vessels have been operating in the region for longer periods of time each year. The number of vessels broadcasting AIS increases sharply in mid-May/early-June, peaks in mid-August, and then decreases through the fall, with the season ending in mid-November. Over the 3-years analyzed for the report, the length of this navigation season is getting longer, growing by 7–10 days each year, even as the total number of vessels in the area has not changed substantially.

Finally, using AIS to understand how many and what kinds of ships operating in the region overlooks other users that must be accounted for: vessels used for subsistence hunting and other vessels below the AIS carriage requirements. Closing these gaps is an important step to developing a comprehensive understanding of civilian uses of the waterways in the U.S. Arctic and surrounding maritime areas.

Section IV: Projections of Vessel Activity in the Northern U.S. Arctic Region, 2020 – 2030

Given the myriad of drivers behind vessel activity and the observed types of vessel activity in the northern U.S. Arctic and immediate surrounding areas, projecting the volume of vessel activity is challenging. Previous studies have developed estimates by extrapolating historical vessel activity and global shipping or economic indicators into the future, linked with supporting data to constrain the final numbers. This report's methodology expands on the methodology used to build the 2015 CMTS report, "A 10-Year Projection of Maritime Activity in the U.S. Arctic". This updated projection combines four major, quantifiable sources of growth to manually estimate the number of ships operating in the region over the next decade. This method can be readily modified to incorporate more data or to update the projections, and may also be easily adapted for other areas of interest in the Arctic.

This section includes a discussion on the methodology, followed by detailed discussion of the quantifiable sources of growth which were used to calculate and project the number of vessels expected to transit through the study area of interest. The section ends with a discussion of the four projections included in the report.

METHODS

The analysis is based on four projection scenarios. The scenarios are each based on the combination of four different categories of growth. To create the final numbers for each scenario, the vessel numbers from each source of growth were stacked together, resulting in the total growth for each projection. Figure 23 illustrates this process.

The four scenarios developed for this report are: Reduced Activity Scenario, Most Plausible Scenario, Optimized Growth Scenario, and Accelerated, but Unlikely Scenario. This final scenario, Accelerated, but Unlikely, was developed to understand what the maximum growth of vessel activity could be for the region given the sources of growth considered.

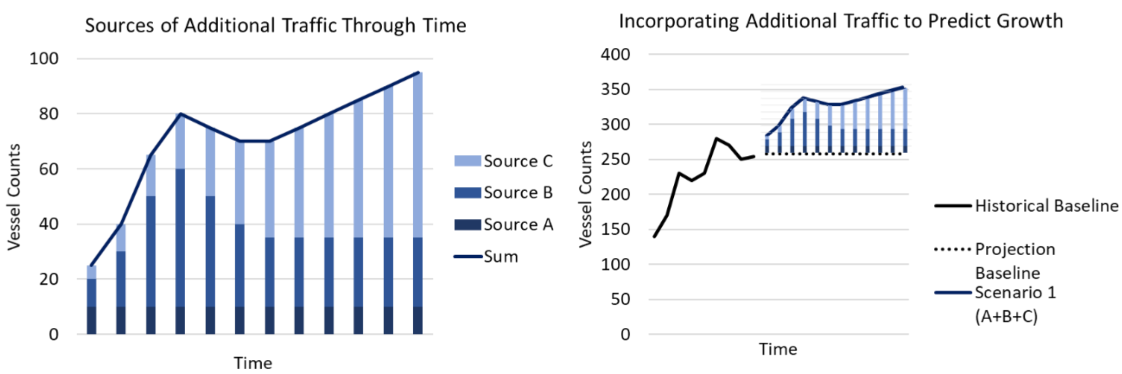

Figure 23: Schematic of methodology to manually forecast projections. Individual sources of additional vessels are combined for each point in time (left) and added to a baseline of established activity (right) to determine the final projected number of ships for each point in time of the study.

BASELINE

For the projections included in this study, it is assumed that vessel traffic would build upon the baseline of established vessel activity in the region. The annual baseline used for the projections included in this report is 255 ± 26 unique vessels, which is the average number of vessels plus/minus the standard deviation of unique vessels operating in the study area of interest in 2015–2017 detected on both SAIS and NAIS. Further discussion of how this was calculated is included in Section III of this report.

SOURCE OF GROWTH

A number of factors that could contribute to growth (or decline) of vessel activity were considered as part of the 2018 CMTS & USARC Technical Workshop on Arctic Vessel Activity. Over 70 individual drivers of vessel activity were identified by workshop participants and considered for incorporation; however, only quantifiable drivers that could be readily translated into vessel activity were considered sources of growth in the projections. These sources of growth fall into four key categories: (1) natural resource exploration and development; (2) infrastructure development; (3) expansion of the Arctic fleet[59]; and (4) expansion of seasonally rerouted shipping through the Arctic.

[59] For the purposes of this study, the term "Arctic fleet" refers to vessels designed specifically to operate in the Arctic environment, such as ice-hardened research and tourism vessels and escort icebreakers; icebreaking LNG tankers are considered in the projection as part of natural resource-related activities.

To determine the volume of vessel activity related to natural resource and infrastructure projects, proposed and planned projects were examined and analyzed in-depth, applying publicly available data such as those found in environmental impact statements and permit applications, and assigning a range of values for the associated vessel activity for each activity across the four scenarios. Sources of growth related to the expansion of the Arctic fleet were obtained from news articles and vessel order books, and assigned ranges which were then assigned to one of the four scenarios in the same manner as the previous two types of growth. For the growth of seasonally rerouted shipping through the Arctic, data from Autoridad del Canal de Panamá (ACP; Panama Canal Authority), the United Nations Conference on Trade and Development (UNCTAD), and the Northern Sea Route Administration (NSRA) were used to formulate ranges of ships utilizing the Arctic in place of trans-oceanic routes, including those involving transits of the Suez or Panama Canals.

SCENARIOS

This study features four scenarios which explore how all these sources of growth may converge over the next decade to shape the volume and type of vessel activity within the northern U.S. Arctic and immediate surrounding region. Each of the four scenarios assumes different capabilities for projects to overcome the many technical, financial, logistical, social, environmental, and regulatory hurdles in the path of more vessel activity in the region encompassed in the study area of interest.

- The Reduced Activity Scenario assumes that the high risks of operating in the region are not mitigated over the next decade. In turn, this uncertainty limits the volume of growth in the region. To reflect this, this scenario incorporates the lowest amount of traffic for each source of growth and assumes that planned projects will not proceed at the rates anticipated or estimated in the available literature.
- The Most Plausible Scenario assumes that some of the risks for operating in the region will be mitigated. This scenario incorporates the most reasonable estimates of traffic growth and vessel counts into a single scenario.
- The Optimized Growth Scenario assumes that much of the risk for operating in the region will be mitigated over the next decade. This scenario incorporates higher rates of growth, with the intent to capture vessel counts and growth rates in the realms of what is possible, but not necessarily most probable.

- The Accelerated, but Unlikely Scenario assumes that the risks of operating in the region are completely mitigated and incorporates all sources of growth for the region, including components which may be unlikely according to best available data. This scenario is meant to act as a ceiling for the projections in this study; while theoretically possible, this combined scenario is unlikely.

Assumptions

This methodology rests on three key assumptions. First, it assumes that the number of unique vessels included in the baseline of recent vessel activity (255 ± 26) will continue to transit through the study area of interest every year for the next decade. These vessels include ships related to community resupply (tugs, towing vessels, tankers, and a portion of the total cargo vessels), research and hydrographic survey vessels, and cruise and adventure tourism—all of which are expected to maintain their existing presence in the region, with some year to year variability and with the assumption that retired vessels will be replaced. For example, the bulk cargo carriers related to the Red Dog Mine, which have ranged from 23–27 vessels annually over the last decade, are also expected to remain consistent throughout the mine's lifetime and the duration of this study's projection period. While there may be some fluctuations in the total number of vessels (such as the number of offshore supply vessels), it is likely that these fluctuations will be within the observed standard deviation between 2015–2017, 26 vessels or about 10% of the mean.

Secondly, the sources of growth considered are all assumed to be independent from one another and no feedback loops between individual sources of growth were factored into the calculations. For example, a large infrastructure development, such as a deep-draft port in the region may attract additional vessels to the region after completion, thereby feeding a loop of infrastructure begetting vessels and increased vessel activity, which in turn, could trigger more infrastructure development. However, due to the immense uncertainty of such feedbacks, these additional vessels have not been included.

Thirdly, the results of this method assume that all sources of growth have been reasonably accounted for and included in the projections. As part of the 2018 CMTS & USARC Technical Workshop on Arctic Vessel Activity, participants identified over 70 drivers of vessel activity, including projects which ranged widely with respect to being 'shovel-ready'. Additionally, feedback from the public comment and interagency review period provided vital details on six additional factors not considered in the draft version of this report.[60] Despite best attempts to be as inclusive as possible, there may be projects which have not yet been proposed and which could contribute to vessel activities in the study area of interest, especially towards the latter half of the decade. However, this method's granular nature means that the projections may be easily updated to reflect new potential sources of growth as information becomes available.[61]

SOURCES OF GROWTH

This section will detail the categories of growth incorporated into projections. The four types of growth included in this study are: (1) natural resource exploration and development, (2) domestic infrastructure development (3) expansion of the Arctic fleet, and (4) seasonally rerouted shipping through the Arctic. Within each type of growth are multiple line items which were incorporated into the projections. A summary of the all sources of growth considered for the projections is included in Table 3.

[60] For further information, please see Appendix C.

[61] To support future updates and/or adaptations, all data used for the projections is contained in Appendix B of this report.

Table 3: Overview of sources of growth considered for vessel projections

Type of Growth	Sources of Growth
Natural Resource Development	Offshore Geological and Geophysical Research (US)
	Liberty Hilcorp Development Project (US)
	Eni's Beaufort Sea Exploration from Spy Island Drillsite (US)
	Oil and Gas Activities in the Willow Prospect within the National Petroleum Reserve (US)
	Oil and Gas Activities in the Arctic National Wildlife Refuge (US)
	LNG Production on the North Slope (US)
	Yamal LNG Project (Russia)
	Arctic LNG 2 Project (Russia)
	Ob LNG Project (Russia)
	Transshipment Facilities at Kamchatka and Murmansk (Russia)
	China's Icebreaking LNG Tankers
	Expansion of the Red Dog Mine (US)
	Graphite One Project in Nome (US)
	Hope Bay Gold Mine (Canada)
	Back River Gold Mine (Canada)
	Mary River Mine (Canada)
	Offshore Geological and Geophysical Research for Offshore Wind Development (US)
Infrastructure Development	Relocation of Kivalina, AK
	Relocation/Protection-in-Place of Shishmaref, AK
	Relocation of Newtok, AK
	Modification of the Port of Nome
	Lower Yukon River Regional Port and Road Project in Emmonak, AK
	Construction of the Kotzebue to Cape Blossom Road
	Road Improvements in Utqiagvik, AK
	Road Improvements in Nome, AK
	Road Improvements in Selawik, AK
	Airport Repair in Alaska
	Onshore Renewable Wind Development Projects
	Expanded Services for Community Resupply and Waste Backhaul
Expansion of the Arctic Fleet	USCG Polar Security Cutters
	Russian Icebreakers
	Canadian Icebreakers
	Chinese Icebreakers
	Other Icebreakers
	Expansion of Polar Class Cruise and Adventure Ships
Seasonally Rerouted Shipping	A Panamax-sized Fleet of Select Vessel Types

Natural Resource Activities

The Arctic holds vast natural resources. Exploration and development of the American Arctic has been closely associated with Arctic natural resources since the Gold Rush era. These resources, and those from neighboring Arctic States, are likely to continue to play a key role in the fate of the Arctic, as new resources are made accessible by changing environmental conditions and changing demands. A summary of how these natural resource activities are anticipated to add to vessel traffic in the study area of interest is summarized in Figure 24.

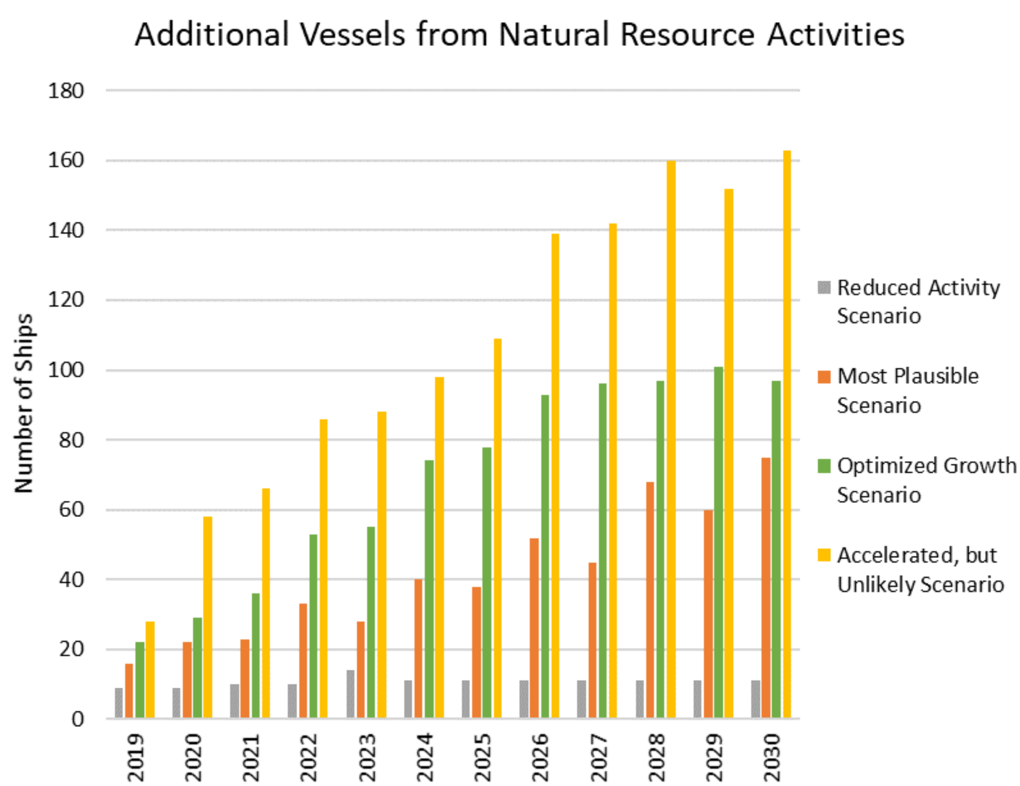

Figure 24: Combined sums of vessel traffic related to natural resource activities in the Arctic by scenario.

OIL AND GAS EXPLORATION AND DEVELOPMENT

Exploration and development of oil and gas resources in the Arctic have the potential to greatly transform the amount of vessel activity in this study's area of interest. Within the U.S., exploration and development of these resources will likely depend on oil and gas prices (as driven by global supply and demand patterns), the availability of leases in Federal waters, and many other factors, the prospect of which remains uncertain. Oil and gas developers require a considerable degree of certainty for market demand and profitability, particularly for remote locations with minimal infrastructure. When Shell began its exploration of the Burger Prospect in the Chukchi Sea, oil prices were at record high levels, averaging close to $95/barrel (bbl) from 2011–2014, before dropping to less than $50/bbl in 2015.[62] In 2018, spot prices reached $65, and are projected to range from $57–$59.50/bbl through the end of 2020.[63]

In terms of leasing, in 2017 the Bureau of Ocean Energy Management (BOEM) developed the 2019–2024 National Outer Continental Shelf Oil and Gas Leasing Program, which includes plans for oil and gas lease sales in the Beaufort Sea in 2019, 2021, and 2023 and Chukchi Sea in 2020, 2022, and 2024.[64] However, prior to leaving office in 2016, President Obama removed all submerged Federal lands of the Chukchi Sea and a majority of the Beaufort Sea from future leasing activities under the Outer Continental Shelf Lands Act (OCSLA).[65] Efforts to overturn this action via Executive Order were not upheld in a recent court decision, making future exploration and development of oil and gas in parts of the Chukchi and Beaufort Seas uncertain.[66] Taken together, this market and regulatory uncertainty suggests that there is a moderate chance for offshore oil and gas development within this study's timeframe.

One notable exception, however, is the potential for development of LNG, which, as discussed later, is likely to transform dynamics of Arctic marine transportation considerably over the next decade. It is already doing so in the Yamal Peninsula of Russia, which is sending an increasing number of LNG tankers to market via the Bering Strait.

[62] Energy Information Administration. (2019). West Texas Intermediate Crude Oil Spot Prices. Accessed from: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=A

[63] Energy Information Administration. (August 2019). Short Term Energy Outlook: Prices. Accessed from: https://www.eia.gov/outlooks/steo/report/prices.php

[64] Bureau of Ocean Energy Management: Alaska OCS Region. (2019). 2019 Beaufort Sea OCS Oil and Gas Lease Sale. Accessed from https://www.boem.gov/beaufort-call/

[65] The White House, Office of the Press Secretary. (2016). "United States- Canada Joint Arctic Leaders' Statement" [Press Release]. Accessed from: https://obamawhitehouse.archives.gov/the-press-office/2016/12/20/united-states-canada-joint-arctic-leaders-statement

[66] Thuanawala, Sudhin. (2019). "Judge restores Obama-era drilling ban in Arctic". AP News. Accessed from: https://www.apnews.com/6631cf4aed3348a7b767c0c2b7445ca4

Oil and Gas Exploration and Activities within the U.S.

Offshore Geophysical and Geological Surveys

Offshore geophysical and geological (G&G) surveys are used to locate offshore marine mineral resources and are among the first requirements prior to oil and gas exploration and production or offshore infrastructure siting. Based off recent applications for the Arctic Alaska Outer Continental Shelf, each G&G survey would require a fleet of approximately 9 vessels, including vessels to house the crew due to the limited onshore infrastructure available on the North Slope. Such large-scale operations may also require additional fuel sources, and likely, an additional tanker would be required to supply the fleet with fuel via lightering, raising the total count of vessels for each operation to 10 vessels per G&G permit.

In April 2018, the TGS-NOPEC Geophysical Company applied for a permit to conduct geophysical exploration for mineral resources in waters of the Beaufort Sea outer continental shelf (OCS) Area. The proposed program was to start July 15 and be completed by October 31, 2019, and be repeated in 2020 in the same region. As outlined in TGS-NOPEC's Plan of Operations, the G&G survey would utilize 9 vessels each year, including two multipurpose landing crafts for the two seismic sources, one large vessel for crew housing and mitigation, and six smaller vessels for transport and deployment of crew and equipment.[67] In late May 2019, TGS-NOPEC withdrew its application from BOEM, indicating that G&G survey activities would not contribute to vessel growth in the region for 2019 and 2020. As of June 2019, there are no pending G&G permits for the Alaskan Arctic or remaining permits to be fulfilled.

Using the recent developments of G&G survey permits and the greater uncertainty surrounding offshore oil and gas development, it is assumed that no G&G surveys will be conducted in the Reduced Activity Scenario over the next decade. In the Most Plausible Scenario, it is assumed that one survey with 10 ships will be conducted in the Beaufort Sea every even year over the next decade within the region where leasing has historically been beginning in 2022, per the draft proposed lease schedule for the 2019–2024 National Outer Continental Shelf Oil and Gas Leasing Program[68]. In this scenario, it is assumed that no surveys will be conducted in the Chukchi Sea, conferring the scenario's projection with year-to-year fluctuations throughout the next decade. The Optimized Growth Scenario is expected to follow the same pattern as the Most Plausible Scenario, but assumes that there will be surveys in the Chukchi Sea,

[67] TGS-NOPEC Geophysical Company. (2018). "Barrow Arch 3D 2019: Plan of Operations—Public Copy". Accessed from: https://www.boem.gov/Plan-of-Operation/

[68] Bureau of Ocean Energy Management. (2017). "Draft Proposed Program Areas, Sale Years, and Potential Exclusion Areas: Alaska". Accessed from: https://www.boem.gov/NP-DPP-Map-Alaska/

too, contributing 10 ships to the annual count. The Accelerated, but Unlikely Scenario assumes that there will be surveys in both the Chukchi and Beaufort Seas, with 1 survey of 10 ships in the Chukchi Sea every even year, and 2 surveys of 10 ships in the Beaufort Sea every odd year. A summary of anticipated G&G surveys by region is included in Table 4.

Table 4: Summary of projected G&G surveys by scenario

	Annual Number of G&G Surveys Anticipated in the Beaufort Sea	Annual Number of G&G Surveys Anticipated in the Chukchi Sea	Additional Ships Projected from G&G Surveys by Scenario in 2030
Reduced Activity Scenario	0 surveys	0 surveys	0 ships
Most Plausible Scenario	1 survey every other year, beginning 2022	0 surveys	10 ships
Optimized Growth Scenario	1 survey every other year, beginning 2022	1 survey every other year, beginning 2023	10 ships
Accelerated, but Unlikely Scenario	2 surveys every other year, beginning 2022	1 survey every other year, beginning 2023	20 ships

Liberty Hilcorp Development Project

Hilcorp Alaska LCC proposed to construct an artificial gravel island and 5.6 miles of connecting subsea pipeline in the shallow waters of the North Slope to the west of Prudhoe Bay. Construction of the project would require 1–2 seagoing barges, ocean class tugs, coastal barges, assist tugs, and crew boats, as well as a bathymetric vessel for surveying and a hovercraft for crew transport.[69] During construction of the artificial island, connecting pipeline, and other facilities, there would be 7–12 vessels per annum operating in the immediate region. The requirement for vessels would drop off following the completion of construction in Year 4 of the project, and oscillate from 5–7 vessels each year for both the drilling and production operations phases of the project (Figure 25).

[69] Bureau of Ocean Energy Management: Alaska OCS Region. (2018). "Liberty Development and Production Plan: Final Environmental Impact Statement (Vol 1)". BOEM 2018-050. Accessed from: https://www.boem.gov/Vol-1-Liberty-FEIS/

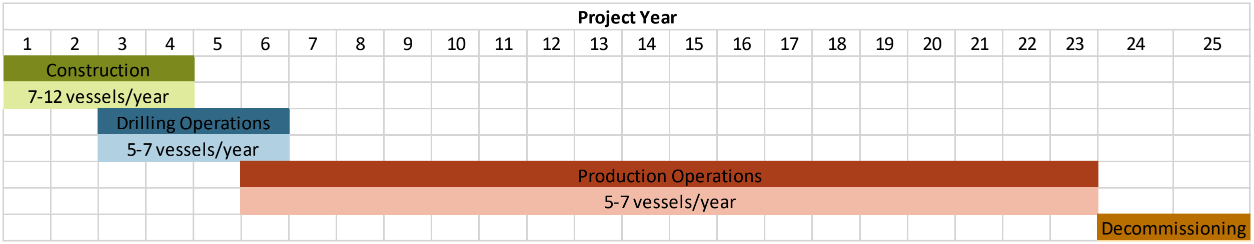

Figure 25: Schematic of Vessel Requirements for the Liberty Hilcorp Project. Adapted from Table 2-3 of the Liberty Development and Production Plan Final Environmental Impact Statement.[70]

In 2018, the Department of Interior approved the oil and gas development and production plan for the project,[71] but before construction could begin, the project encountered two major obstacles. In November 2018, construction was stalled due to a lack of shore fast sea ice, which the project planned to leverage for the initial construction of the artificial gravel island.[72] In December 2018, the Federal government's decision to approve Hilcorp's Liberty project was challenged in a Federal lawsuit, which remains ongoing.

Given the legal and logistic challenges with this project, the start date of the Hilcorp Liberty Project is explored in each of the four scenarios, detailed in Table 5. In the Reduced Activity Scenario, it is assumed that the project will not begin construction until after the end of the study period, while construction begins in 2028, 2024, and 2020 for the Most Plausible Scenario, Optimized Growth Scenario, and Accelerated, but Unlikely Scenarios, respectively.

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[70] Bureau of Ocean Energy Management: Alaska OCS Region. (2018). "Liberty Development and Production Plan: Final Environmental Impact Statement (Vol 1)". BOEM 2018-050. Accessed from: https://www.boem.gov/Vol-1-Liberty-FEIS/

[71] Department of Interior. (2018). "Interior Approves Long-Awaited First Oil Production Facility in Federal Waters Offshore Alaska" [Press Release]. Accessed from https://www.doi.gov/pressreleases/interior-approves-long-awaited-first-oil-production-facility-federal-waters-offshore

[72] Milman, Oliver. (2018). "U.S. oil firm's bid to drill for oil in Arctic hits snag: a lack of sea ice". *The Guardian*. Accessed from: https://www.theguardian.com/environment/2018/nov/15/arctic-oil-drilling-texas-hilcorp-beaufort-sea

Table 5: Summary of additional vessels related to the Liberty Hilcorp project by scenario

	Year											*After Study Projection Window*				
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	*2031*	*2032*	*2033*	*2034*	*2035*
Reduced Activity Scenario												*Construction*				
												7-12 vessels/year				
Most Plausible Scenario									Construction				*Drilling Operations*			
									7-12 vessels/year				*5-7 vessels/yr*			
Optimized Growth Scenario					Construction				Drilling Operations				*Production Operations*			
					7-12 vessels/year				*5-7 vessels/yr*				5-7 vessels/yr			
Accelerated, but Unlikely Scenario	Construction				Drilling Operations				Production Operations							
	7-12 vessels/year				*5-7 vessels/yr*				5-7 vessels/yr							

Eni's Beaufort Sea Exploration from Spy Islands Drillsite

Eni US Operating Co. Inc. is the only entity on the Arctic Alaska Outer Continental Shelf with active, ongoing exploration plans. Eni has proposed and received approval to conduct exploratory sideways drilling of Eni's Nikaitchuq North Project in Federal waters in the Beaufort Sea[73] from Eni's Spy Island Drillsite, an artificial island within state waters located offshore of Oliktok Point. As part of the Exploration Plan filed in 2017, Eni's operation would require only three ships to transport goods and crew to the Spy Island Drillsite in the open water season.[74] These three ships, along with other vessels used for resupply, were accounted for as part of the baseline, and therefore are not included as a potential source of growth in any of the projection scenarios.

Oil and Gas Activities in the Willow Prospect within the National Petroleum Reserve

In 2018, ConocoPhillips moved forward with their proposal to develop oil and gas reserves within the northeast area of the National Petroleum Reserve in Alaska (NPR-A), within the North Slope Borough.[75] In August 2019, the Bureau of Land Management issued a draft environmental impact

[73] Note, these are leases OCS-Y-1753, OCS-Y-1754, and OCS-Y-1757

[74] Eni US Operating Co. Inc. (2017). "Section L1 and 2: Support Vessels and Aircraft Information" from the Initial Exploration Plan of Nikaitchuq North, Alaska. Accessed from: https://www.boem.gov/Page-L1-Corrected/ and https://www.boem.gov/Page-L2-Corrected/

[75] DeMarban, Alex. (2018). "ConocoPhillips' Willow prospect advances with review effort by Federal government". Anchorage Daily News. Accessed from: https://www.adn.com/business-economy/energy/2018/08/07/conocophillips-large-willow-prospect-advances-with-review-effort-by-federal-government/

statement for the project.[76] The scope of the proposal includes up to five drill sites, a central processing facility, an operations center pad, gravel roads, ice roads, ice pads, 1–2 airstrips, a module transfer island, pipelines, and a gravel mine site, and is expected to have a peak production of 130,000 barrels of oil per day of its 30–32 year life. ConocoPhillips has proposed that construction for the project would take 7–9 year, beginning in 2021, and that the Willow Processing Facility would be operational in 2024 or 2026. While the prospect is located onshore, it is expected that a total of 6 sealift barges will be required to deliver prefabricated modules to the site on the North Slope. The current plan anticipates that modules for the initial drillsites would be delivered by sealift barge during the summer of 2023; a second sealift barge operation would deliver modules for the additional drillsites in approximately 2028.

For the projection scenarios, it is also assumed that 1 tanker will be required to supply construction activities with the necessary fuel for every year of construction, and that the sealift requirements will total six ships, in two separate sealifts spread 5 years apart. A summary of this is detailed in Table 6.

Table 6: Summary of vessel requirements for the Willow Prospect Project

	Construction Time Period	First Sealift	Second Sealift
	1 tanker/year	*3 ships*	*3 ships*
Reduced Activity Scenario	Project is assumed not to advance within the projection timeframe		
Most Plausible Scenario	2023–2031	2025	2030
Optimized Growth Scenario	2022–2030	2024	2029
Accelerated, but Unlikely Scenario	2021–2029	2023	2028

76 U.S. Department of the Interior Bureau of Land Management. (2019). "Draft: Willow Master Development Plan Environmental Impact Statement: Volume 1". Accessed from https://eplanning.blm.gov/epl-front-office/projects/nepa/109410/20002247/250002672/Willow_MDP_DEIS_Vol_1_508-2019-08-23.pdf

Oil and Gas Activities in the Arctic National Wildlife Refuge (ANWR)

There has been interest in recent years to develop oil and gas resources within the Arctic National Wildlife Refuge (ANWR), specifically in the 1.5 million acre coastal plain. The U.S. Energy Information Administration (EIA) estimated that a total of approximately 3.4 billion barrels of crude oil could be produced from the coastal plain over a 20-year production life.[77] There is also estimated to be 7.04 trillion cubic feet of technically recoverably natural gas in the same region.[78]

In 2017, the Secretary of the Interior signed a secretarial order to update resource assessments for the ANWR coastal plain.[79] While there has been controversy about developing oil and gas resources in this part of the U.S. Arctic, the Department of Interior's Bureau of Land Management is in the final stages of developing a leasing program for federal lands within the Coastal Plain of the ANWR located in the northeast Alaskan Arctic. If leasing, exploration, and development occurs within this large expanse of Federal lands, it can be expected that it will also result in additional vessel activity in the study area of interest related to the construction and fuel resupply. However, scenarios produced by EIA projected that production in ANWR would depend on a multitude of factors and likely would not happen until 2031 at the earliest.

For the scenarios included in this report, it is assumed that developments within the ANWR will have the same requirements as the Willow Prospect in the NPR-A. Furthermore, owing to the paucity of details available about future developments and EIA's assumptions about production beginning in 2031, it is assumed that further developments within the timeframe of this projection would only happen in the Accelerated, but Unlikely Scenario. In this scenario, it assumed that construction of a project would require 1 tanker/year from 2028—2030 and that 3 barges would be required in 2030 to deliver pre-fabricated modules to the site to reach the production phase by 2031. A summary is included in Table 7.

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[77] Van Wagener, Dana. (2018). "EIA Annual Energy Outlook: Issues in Focus-- Analysis of Projected Crude Oil Production in the Arctic National Wildlife Refuge". Energy Information Administration. Accessed from: https://www.eia.gov/outlooks/aeo/anwr.php

[78] Attanasi, E.D. (2005). "Undiscovered oil resources in the Federal portion of the 1002 Area of the Arctic National Wildlife Refuge: an economic update". U.S. Geological Survey Open-File Report 2005-1217. Accessed from: https://www.arlis.org/docs/vol1/61483852.pdf

[79] U.S. Department of Interior Office of the Secretary. (2017). Secretarial Order No. 3352: National Petroleum Reserve-Alaska. Accessed from: https://www.doi.gov/sites/doi.gov/files/uploads/so-3352.pdf . Additional information available from: https://www.doi.gov/pressreleases/secretary-zinke-signs-order-jump-start-alaskan-energy

Table 7: Summary of vessel requirements for development of oil and gas in ANWR

	Construction Time Period	First Sealift	Second Sealift
	1 tanker/year	*3 ships*	*3 ships*
Reduced Activity Scenario	Project is assumed not to advance within the projection timeframe		
Most Plausible Scenario	Project is assumed not to advance within the projection timeframe		
Optimized Growth Scenario	Project is assumed not to advance within the projection timeframe		
Accelerated, but Unlikely Scenario	2028–2035	2030	After 2030

LNG Production on the North Slope

There are believed to be 3.3 trillion cubic feet of natural gas in Alaska. Currently natural gas production volumes from the North Slope far exceed local demand, with much of the extracted gas reinjected to maintain crude oil production rates from facilities on the North Slope.[80] According to 2016 estimates by BOEM, there may be a further 105 trillion cubic feet in Federal waters of the Chukchi and Beaufort Seas.[81] Taken together, that could equal 2.5 times as much natural gas off the north coast of Alaska as there is estimated to be in reserve for the Yamal LNG Project on the Sabetta Peninsula in the Kara Sea.[82] There has been some discussion about how to move this gas off the North Slope, and whether it makes sense to transport it via ship or pipeline. [83] The option to construct a pipeline to connect to existing liquefaction facilities near Cook Inlet would not likely contribute any vessel activity through the study area of interest. Shipping LNG, however, would impact the area of interest's vessel activity substantially. If such a project were able to use existing North Slope oil and gas infrastructure, it might be

[80] Energy Information Administration. (2018). "Alaska: State Profile and Energy Estimates". Accessed from https://www.eia.gov/state/analysis.php?sid=AK

[81] Bureau of Ocean Energy Management: Alaska OCS Region (2017). "2016a Assessment of Oil and Gas Resources: Alaska Outer Continental Shelf Region." BOEM 2017-064. Accessed from: https://www.boem.gov/BOEM-2016A-Assessment-of-Oil-and-Gas-Resources-OCS/

[82] Hydrocarbons Technology. (2019). "Yamal LNG Project, Sabetta". Accessed from: https://www.hydrocarbons-technology.com/projects/yamal-lng-project-russia/

[83] DeMarban, Alex. (2018). "Alaska gas line backers reject idea of North Slope LNG exports by tanker". *Anchorage Daily News*. Accessed from: https://www.adn.com/business-economy/energy/2018/01/17/alaska-pipeline-backers-reject-idea-of-north-slope-lng-exports-by-boat/

possible for an LNG export operation to be established within the next decade. Such an operation, modeled off the Yamal LNG Project in Russia, could require 15 icebreaking LNG tankers, making 2–3 roundtrips each per season, crossing the Bering Strait upwards of 75–90 times in a season to deliver fuel to Asia, or many smaller trips to deliver LNG fuel to harbors and ports within Alaska, including regional hubs like Dutch Harbor or Nome.[84]

Given the number of hurdles that would have to be cleared to initiate LNG export off the North Slope, this source of growth is only considered in the Accelerated, But Unlikely Scenario. It is estimated that construction of an offshore, deep-water LNG terminal, pipelines, and onshore liquefaction facility would require 2 ships each year beginning in 2022, with other supplies hauled to the site via the Dalton Highway; this estimate is based off previous sealift requirements for another major construction project on the North Slope and surrounding waters.[85] It also assumes that five LNG icebreaking tankers could be built and be made available for exporting LNG by 2025, adding an additional icebreaking LNG tanker each year for the remainder of the decade for a total of 10 vessels servicing the facility by 2030.

Oil and Gas Exploration and Activities Outside the U.S.

Over the last decade, Russia has made extensive progress developing natural gas resources and supporting infrastructure on its northern coast. This progress has had immediate impact on the Arctic marine transportation system, as much of the gas is expected to be shipped to markets in Asia and Europe in built-for-purpose icebreaking LNG tankers. Further growth of the LNG sector in Russia is expected to directly impact the amount of vessel activity in this study's region of interest, as vessels exporting LNG to Asia from the Yamal Peninsula must pass through the Bering Strait (and therefore through this study's area of interest) to reach Eastern markets.

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[84] For further information, please see the calculations included in Appendix D, Table D-1.

[85] As part of the construction of the Eni Nikaitchuq Arctic Production Facility, located offshore of the North Slope, 2 process and utilities modules weighing 4,000 tons each had to be barged to the site from Louisiana, where they were built, while the remaining modules were built in Alaska. For more, please see the press release from ENI: https://www.eni.com/en_IT/media/2011/02/eni-starts-production-from-the-nikaitchuq-field-in-alaska

Yamal LNG Project

Construction on the Yamal LNG project, jointly developed by Novatek, Total, the China National Petroleum Corporation (CNPC), and Silk Road Fund, began in 2013. The Yamal LNG plant is expected to produce 16.5 million tons of LNG and 1.2 million tons of gas condensate each year.[86] To support export of LNG from the Yamal LNG facility, 15 icebreaking LNG tankers were ordered from South Korea's Daewoo Shipbuilding & Marine Engineering Co. and will be engaged in year-round navigation along the Northern Sea Route.[87] The first shipment of LNG from the facility was completed in December 2017 on the icebreaking LNG tanker, the *Christophe de Margerie*.[88] As of 2018, eight of these ships were in operation, two were conducting sea trials, four are expected to be delivered from late 2019 to early 2020, and the final ship remains under construction. It is anticipated that by 2021 all 15 ships will be in operation, though it is unclear whether all would be directed to Asia through our study area of interest.

It is estimated that that 15 icebreaking LNG tankers could make a total of 30–32 roundtrips to Asia, crossing the Bering Strait 60–64 times annually during a short operational window.[89] This assumes each ship has the capacity to carry 73,000 tons of LNG and that the operational window for shipping LNG to the east via the Northern Sea Route is only for July, August, and September of each year (92 days annually). Such values represent an equivalent of 10% of the ships and 12% of the transits through the Bering Strait in 2018 according to data provided by the U.S. Coast Guard.

For the four scenarios included in this study, it is assumed that icebreaking LNG tankers originating from the Yamal Peninsula will continue to add to vessel traffic in the study area of interest. The Reduced Activity Scenario assumes that most of the vessels servicing the Yamal LNG project will be diverted westward to Europe. Both the Most Plausible Scenario and Optimized Growth Scenarios assume that more vessels will be diverted east throughout the 2020s, growing at rates of 1 vessel every 2 years and 1 vessel every year, respectively. The Accelerated, but Unlikely Scenario assumes that all vessels will be diverted east as soon as the navigation season after they are delivered. A summary of the annual

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[86] JSC Yamal LNG. (2015). "About the Project". Accessed from: http://yamallng.ru/en/project/about/

[87] JSC Yamal LNG. (2015). "About the Project: LNG Shipping". Accessed from: http://yamallng.ru/en/project/tankers/

[88] Farchy, Jack and Mazneva, Elena. (2017). "Russia Commissions $27 Billion Yamal LNG Project in Russian Arctic". Bloomberg. Accessed via GCaptain from https://gcaptain.com/russia-commissions-27-billion-yamal-lng-project-russian-arctic/

[89] For further information, please see the calculations included in Appendix D, Table D-1.

number of vessels originating from the Yamal LNG facility passing through the study area of growth is detailed in Table 8.

Table 8: Additional vessels per year from the Yamal LNG Project expected to pass through the study area of interest

<table>
<tr><th></th><th></th><th colspan="12">Total number of icebreaking LNG tankers per year</th></tr>
<tr><th></th><th>Scenario Assumption</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th></tr>
<tr><td>Reduced Activity Scenario</td><td>1 vessel added every 2 years until 6 vessels/year</td><td colspan="2">4</td><td colspan="2">5</td><td colspan="8">6</td></tr>
<tr><td>Most Plausible Scenario</td><td>1 vessel added every 2 years until 9 vessels/year</td><td colspan="2">4</td><td colspan="2">5</td><td colspan="2">6</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">9</td></tr>
<tr><td>Optimized Growth Scenario</td><td>1 vessel added every year until 14 vessels/year</td><td colspan="2">4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td>Accelerated, but Unlikely Scenario</td><td>vessels added to AOI as soon as they are delivered</td><td colspan="2">10</td><td>14</td><td colspan="9">15</td></tr>
</table>

Arctic LNG 2 Project

Expansion of natural gas development with the Arctic LNG 2 project on the Gydan Peninsula will also impact the number of vessels transiting through the study's area of interest over the next decade. The Arctic LNG 2 project is expected to start production in 2023 and to produce 19.8 million tons of LNG per year once at full capacity, which is anticipated in 2025.[90] The project, which includes the development of natural gas and liquefaction facilities, is jointly funded by Novatek, Total, China National Petroleum Corporation, China National Offshore Oil Corporation, and Japan Arctic LNG B.V.[91] To overcome the potential shortage of ice-capable ships to transport the product, Novatek has ordered 5 additional Arc7 icebreakers, the first of which is expected to be delivered in 2023 and the four remaining delivered by 2025, coinciding with key milestones of the Arctic LNG 2 project.[92] Russia has allocated $800 million to

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[90] Humpert, Malte. (2019). "Novatek signs contract for construction of Arctic LNG 2, Orders New Arctic LNG Carriers". High North News. Accessed from: https://www.highnorthnews.com/en/novatek-signs-contract-construction-arctic-lng-2-orders-new-lng-carriers

[91] Mitsui & Co. (2019). "Signing of Share Purchase Agreement for Equity Participation into Arctic LNG 2 Project in Russia". [Press release]. (Translated from Japanese). Accessed from: https://www.mitsui.com/jp/en/release/2019/1228966_11219.html

[92] Humpert, Malte. (2019). "Novatek signs contract for construction of Arctic LNG 2, Orders New Arctic LNG Carriers". High North News. Accessed from: https://www.highnorthnews.com/en/novatek-signs-contract-construction-arctic-lng-2-orders-new-lng-carriers

construct additional icebreaking LNG tankers to support shipments of LNG from the Arctic LNG 2 project, but it is unclear how this allocation would affect existing orders.[93]

A summary of additional ships transiting the study area of interest related to the Arctic LNG 2 project is outlined in Table 9. In the Reduced Activity Scenario, it is assumed that zero additional ships pass through the study area of interest. The three remaining scenarios all include a two-year long construction period (during which 2–3 vessels related to construction pass through the study area of interest), followed by a progression of accelerated growth as additional icebreakers are added to support LNG export.

Table 9: Additional vessels from the Arctic LNG2 Project expected to pass through the study area of interest

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		Construction			Arctic LNG Tankers Passing Through Study Area of Interest Annually							
Reduced Activity Scenario	*Assumed that No Vessels to Pass through Study Area of Interest*											
Most Plausible Scenario		*2 vessels/yr*			*1 vessel/yr*		*5 vessels/yr*					
Optimized Growth Scenario		*2 vessels/yr*			*1 vessel/yr*	*2 vessels/yr*	*5 vessels/yr*		*6 vessels/yr*		*7 vessels/yr*	
Accelerated, but Unlikely		*3 vessels/yr*			*1 vessel/yr*	*3 vessels/yr*	*5 vessels/yr*	*6 vessels/yr*	*7 vessels/yr*	*8 vessels/yr*	*9 vessels/yr*	*10 vessels/yr*

Ob LNG Project

There is additional interest in a third LNG project in Russia's Yamal-Nenets Autonomous District: the Ob LNG Project. In May 2019, Novatek, one of the principal funders of the Yamal LNG and Arctic LNG 2 projects, announced the construction of a new LNG site on the Yamal Peninsula. While funding for the Ob LNG Project is likely to be announced in late 2019, the project could be expected to produce as much as 4.8 million tons of LNG annually and begin production as early as 2023 using Russian investments and technologies exclusively.[94]

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[93] Hellenic Shipping News. (2019). "Russia Plans to Allocate $800 Million for LNG Tankers". Source: Caspian News. Accessed from: https://www.hellenicshippingnews.com/russia-plans-to-allocate-800-million-for-lng-tankers/

[94] Staalesen, Atle. (2019). "Novatek announces 3rd LNG project in the Arctic". The Barents Observer. Accessed from: https://thebarentsobserver.com/en/industry-and-energy/2019/05/novatek-announces-3rd-lng-project-arctic

Given the uncertainty around funding of this project, the Ob LNG Project is only considered in the two highest growth scenarios, the Optimized Growth and Accelerated, but Unlikely Scenarios. This study assumes that the maximum number of icebreaking LNG takers needed to service the facility will be 5 unique vessels, based on the relative projected output from this third facility. A summary of additional vessels anticipated from the Ob LNG Project is include in Table 10.

Table 10: Additional vessels from the Ob LNG Project expected to pass through the study area of interest

<table>
<tr><td></td><td>2019</td><td>2020</td><td>2021</td><td>2022</td><td>2023</td><td>2024</td><td>2025</td><td>2026</td><td>2027</td><td>2028</td><td>2029</td><td>2030</td></tr>
<tr><td></td><td></td><td colspan="2">Construction</td><td></td><td colspan="8">Ob LNG Tankers Passing Through Study Area of Interest Annually</td></tr>
<tr><td>Reduced Activity Scenario</td><td colspan="12">Assumed that No Vessels to Pass through Study Area of Interest</td></tr>
<tr><td>Most Plausible Scenario</td><td colspan="12">Assumed that No Vessels to Pass through Study Area of Interest</td></tr>
<tr><td>Optimized Growth Scenario</td><td></td><td colspan="2">1 vessel/yr</td><td></td><td colspan="3">1 vessel/yr</td><td colspan="3">2 vessels/yr</td><td colspan="2">3 vessels/yr</td></tr>
<tr><td>Accelerated, but Unlikely</td><td></td><td colspan="2">1 vessel/yr</td><td></td><td>1 vessel/yr</td><td>2 vessels/yr</td><td>3 vessels/yr</td><td>4 vessels/yr</td><td colspan="4">5 vessels/yr</td></tr>
</table>

Transshipment Facilities at Kamchatka and Murmansk

Beyond production facilities, there has also been considerable discussion about building transshipment facilities either end of the Northern Sea Route to optimize the logistics of LNG shipments from the Arctic. These proposed facilities would reduce the sailing distance for the built-for-purpose icebreaking LNG tankers, and therefore increase the number of trips taken by each vessel to transport LNG from the Russian Arctic.

In the east, Novatek has proposed building an LNG terminal on the Kamchatka Peninsula, which was approved by the Russian Government in March 2019.[95] This proposed terminal is anticipated to have an annual capacity of 20 million tons, sufficient to support the combined east-bound shipments of the Yamal LNG and Arctic LNG 2 projects.[96] According to Russian Prime Minister Dmitry Medvedev, the

[95] Sea News. (2019). "RF Government Approves Kamchatka LNG Project". Accessed from: http://seanews.ru/en/2019/03/20/en-rf-government-approves-kamchatka-lng-project/

[96] Maritime Executive. (2017). "Novatek Signs Chinese Deals for Arctic LNG 2". Accessed from: https://www.maritime-executive.com/article/novatek-signs-chinese-deals-for-arctic-lng-2

Kamchatka Facility is expected to be completed in 2022.[97] Construction of this facility is not expected to contribute to vessel activity factored in this projection study, because the proposed facility is south of the study area of interest. Upon its completion, however, this facility may stimulate further activity in the region, as ships moving LNG from the Yamal and Gydan peninsulas would have shorter transits to deliver their cargo. If completed as planned in 2022, the transshipment hub could allow Yamal's 15 LNG icebreaking tankers to make 38–45 complete trips to the facility, transiting the Bering Strait 76–90 times in a single season.[98]

On the other side of the Northern Sea Route, Novatek has also proposed building another LNG transshipment terminal near Murmansk on the Kola Peninsula.[99] Like the other proposed terminal on the Kamchatka Peninsula, the facility near Murmansk would have an annual capacity of approximately 20 million tons per year. In July 2019, the Russian Federation approved Novatek's proposal and expects the project to be completed by 2023.[100] It is not anticipated that construction of this project will require any additional vessels to transit through the study area of interest.

China's Icebreaking LNG Tankers

China's demand for LNG is also expected to play a role in the coming decade. In early June 2019, COSCO Shipping Holdings Co. and PAO Sovcomflot announced a joint venture to move LNG from the Arctic to China, adding as many as 21 new icebreaking LNG tankers to the region, with 12 from Sovcomflot and COSCO and an additional 9 from China Shipping LNG Investment Co.[101] Sovcomflot has already secured financing for 3 LNG-fueled tankers, which will be delivered in 2022–2023 and operate

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[97] Staalesen, Atle. (2018). "Next door to Murmansk submarine base could come Arctic LNG terminal". The Barents Observer. Accessed from: https://thebarentsobserver.com/en/industry-and-energy/2018/08/next-door-murmansk-submarine-base-could-come-arctic-lng-terminal

[98] For further information, please see the calculations included in Appendix D, Table D-1.

[99] Staalesen, Atle. (2018). "Next door to Murmansk submarine base could come Arctic LNG terminal". The Barents Observer. Accessed from: https://thebarentsobserver.com/en/industry-and-energy/2018/08/next-door-murmansk-submarine-base-could-come-arctic-lng-terminal

[100] Tass. (2019). "Russian government approves construction of Novatek's LNG terminal in Murmansk". Accessed from: https://tass.com/economy/1069304

[101] Costas, Paris. (2019). "China, Russia Carriers to Ship Gas on Arctic Route". *The Wall Street Journal*. Accessed from: https://www.wsj.com/articles/china-russia-carriers-to-ship-gas-on-arctic-route-11560284812

under a 20-year charter with Novatek, the operator of the Yamal LNG facility.[102] It is estimated that delivery of the remaining 19 ships from Sovcomflot, COSCO, and China Shipping LNG Investment Co. could range from 1–3 ships/year. For the projections featured in this report, it is assumed that all delivered ships would pass through the study area of interest annually. Both different initial delivery dates and growth rates are explored in the four scenarios and detailed in Table 11.

Table 11: Summary of Chinese icebreaking LNG tankers anticipated to pass through study area of interest

	First Delivery	Additional Icebreaking LNG Tankers Expected Each Year after First Delivery	Total Number of Chinese Icebreaking LNG Tankers in 2030
Reduced Activity Scenario	3 ships in 2023	0 ships	3 ships
Most Plausible Scenario	3 ships in 2023	1 ship/year	10 ships
Optimized Growth Scenario	3 ships in 2022	1 -2 ships/year	15 ships
Accelerated, but Unlikely Scenario	3 ships in 2022	2 -3 ships/year	21 ships

MINERAL RESOURCES

The Arctic is home to considerable mineral resources besides petroleum, and marine transportation is a primary way to export these resources and to support the extraction efforts to obtain these resources. In the following section, mineral resources projects which may contribute to vessel activity in the region over the next decade are discussed.

Mineral Resources within the U.S.

Expansion of the Red Dog Mine

The Red Dog Mine, located in the Northwest Arctic Borough near Kivalina and operated through an agreement between Teck American, Inc. and the NANA Regional Corporation, is one of the largest zinc

[102] Maritime Executive. (2019). "Russia and China Sign Arctic Deal". Accessed from: https://www.maritime-executive.com/article/russia-and-china-sign-arctic-deal

and lead mines in the world. In 2018, Red Dog Mine produced 545,000 metric tons of zinc and 97,000 tons of lead in 2018, accounting for 97% of zinc and 66% of lead production for the state of Alaska.[103] Shipment of ore from the mine has consistently contributed 23–27 bulk carriers to the annual inventory of vessels transiting through this study's area of interest. This volume of activity is expected to remain consistent through 2031, the expected lifetime of the mine without expansion.[104] In 2018, Teck American Inc. submitted a draft environmental evaluation document to the U.S. Army Corps of Engineers[105] and a permit with Alaska Department of Natural Resources[106] for its proposed exploration of the Anarraaq and Aktigiruq prospect, located 8 miles north of the existing Red Dog Mine. The volume of vessel activity associated with such an expansion remains unclear, but a feasibility study for the Lik Mine, a deposit located 17 miles from the Red Dog Mine, found that that reserve could produce 350,000 short wet metric tons annually over a nine-year production life, translating to 6 additional bulk carriers transiting through the study area of interest, annually.[107] A summary of the annual vessel requirements for the Lik deposit are included in Table 12.

Table 12: Summary of annual vessel requirements for the Lik Deposit.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduced Activity Scenario	Project Does Not Advance											
	0 vessels/year											
Most Plausible Scenario	Project Does Not Advance											
	0 vessels/year											
Optimized Growth Scenario	Project Advances in 2021; Completed in 2029											
	0	*0*	*6*	*8*	*6*	*6*	*6*	*6*	*6*	*6*	*5*	*0*
Accelerated, but Unlikely Scenario	Project Advances in 2020; Completed in 2028											
	0	*6*	*8*	*6*	*6*	*6*	*6*	*6*	*6*	*5*	*0*	*0*

[103] Werdon, M.B. (2019). "Alaska's Mineral industry in 2018: Mines, Development, and Exploration" [Presentation]. Alaska Division of Geological & Geophysical Surveys. Slides accessed from: http://dggs.alaska.gov/pubs/id/30164

[104] Teck Resources Limited. (2019). "About Red Dog" and "Operating Results". Accessed from: https://www.teck.com/operations/united-states/operations/red-dog/

[105] Teck American Incorporated. (2018). "Draft Environmental Evaluation Document: Anarraaq and Aktigiruq Exploration Program." Accessed from: https://www.poa.usace.army.mil/LinkClick.aspx?fileticket=PPtCaICjFfY%3D&portalid=34

[106] Alaska Department of Natural Resources: Division of Mining, Land, and Water. (2018). Anarraaq-Aktigiruq Project Page. Accessed from: http://dnr.alaska.gov/mlw/mining/largemine/anarraaq-aktigiruq/

[107] HDR Engineering, Inc. (2014). "Feasibility Study: Lik Deposit Transportation System, prepared for the Alaska Industrial Development and Export Authority". Accessed from: http://www.aidea.org/Portals/0/PDF%20Files/20141231FINALLikFeasibilityStudyv2.pdf

This theorized expansion is explored in the Optimized Growth and Accelerated, but Unlikely Scenarios, using estimates from the Lik Mine. In the Optimized Growth Scenario, it is assumed that the expansion begins in 2021 and is completed by 2029, adding 6 vessels for each year within that period and 8 vessels in Year 2 (2022). The Accelerated, but Unlikely Scenario assumes that the expansion begins in 2020 and is concluded by 2028, also adding 6 vessels for each year within that period, and 8 vessels in Year 2 (2021).

Graphite One Project in Nome

The Arctic's rare-earth elements, platinum-group elements, and graphite deposits are also key natural resources for Arctic planners to consider. There is a growing demand for these mineral resources, which can be used in rechargeable batteries, radar systems, avionics, and satellites[108], but there is only one rare-earth mine in operation within the U.S. [109] Graphite One Resources, Inc., has proposed extracting graphite on the Seward Peninsula from Graphite Creek, the largest large-flake graphite deposit in the U.S. The site is located about 37 miles north of the City of Nome.[110] According to the company's preliminary economic analysis report, the Graphite One Project would mine 60,000 metric tons per year of graphite concentrate, which would be loaded into containers and transported by truck to the Port of Nome for loading onto barges during the navigation season.[111] Assuming 18 tons of concentrate is loaded into each container, and each large barge can accommodate 200 containers, the Graphite One Project would ship 16–17 barges each year to its product manufacturing plant in the State of Washington. Such a value would double to current number of large barges calling on Nome. A construction decision is slated for 2020; if advanced, construction of the mine would be expected to take six years before shipping out

[108] Szumigala, David and Werdon, Melanie. "Rare-earth elements: A brief overview including uses, worldwide resources, and known occurrences in Alaska" State of Alaska Department of Natural Resources, Information Circular 61. Accessed from http://dggs.alaska.gov/webpubs/dggs/ic/text/ic061.pdf

[109] Norman, Ann; Zou, Xinyuan; and Barnett, Joe. September 2014. "Critical Minerals: Rare Earths and the U.S. Economy". National Center for Policy Analysis. Accessed from http://www.ncpathinktank.org/pdfs/bg175.pdf

[110] Werdon, M.B. (2019). "Alaska's Mineral industry in 2018: Mines, Development, and Exploration" [Presentation]. Alaska Division of Geological & Geophysical Surveys. Slides accessed from: http://dggs.alaska.gov/pubs/id/30164

[111] As cited in U.S. Army Corps of Engineers: Alaska District. (2019). "Port of Nome Modification Feasibility Study: Draft Integrated Feasibility Report and Environmental Assessment." Accessed from: https://www.poa.usace.army.mil/Portals/34/docs/civilworks/publicreview/portofnome/IFREADraft6May2019MasterDraftFinal.pdf?ver=2019-05-07-193529-953

its first product. Construction of the mine would likely require an annual sealift of 4 ships to supply the mine construction with requisite fuel, equipment, and consumables.

In all vessel growth scenarios except the Reduced Activity Scenario, it is assumed that the Graphite One Project will advance and that construction will begin in 2020, adding 4 additional ships each year for fuel, equipment, and consumables for six years. In 2026, it is assumed that the mine will begin production, and in the Most Plausible Scenario, the Graphite One Project will ship 5 barges each year, while the Optimized Growth Scenario will ship 10 barges each year. In the Accelerated, but Unlikely Scenario, it is assumed that the mine will open in 2026 and begin shipping concentrate at its maximum rate the same year (17 barges/year) and maintain that rate through 2030. Additionally, it is assumed across all scenarios that the mine will require 4 ships annually to resupply the mine with fuel, consumables, and equipment once in the production phase. A summary of this is included in Table 13.

Table 13: Summary of vessels associated with the Graphite One Project anticipated to pass through study area of interest by scenario

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduced Activity Scenario	Project Does Not Advance *0 vessels/year*										
Most Plausible Scenario	Construction *4 vessels/year*						Production *5 barges/year + 4 vessels for resupply/year*				
Optimized Growth Scenario	Construction *4 vessels/year*						Production *10 barges/year + 4 vessels for resupply/year*				
Accelerated, but Unlikely Scenario	Construction *4 vessels/year*						Production *17 barges/year + 4 vessels for resupply/year*				

Mineral Resources Outside the U.S.

The development of mineral resources in western and northern Canada may also impact vessel activity in this area of interest, primarily through annual sealift to resupply the mines with fuel and equipment.

Hope Bay Gold Mine

The sealift associated with the Hope Bay Gold Mine in Nunavut, Canada is likely to add to vessel activity within the study area of interest over the next decade. TMAC Resources Inc. first produced gold from the region in 2017 and estimates that there are a total of 4.9 million ounces of gold in the mine.[112] While much of the gold will likely be flown out of the site, the fuel, equipment, and consumables for the mine are expected to be moved via ship to the mine during a narrow 10-week navigational window.[113] According to experts gathered at the 2018 CMTS & USARC Technical Workshop, the mine is currently serviced by 4–6 freight barges and 1–2 cargo ships each year. As of 2019, only one of the three deposits at the site is operational, but expansion to the other two deposits on the site is expected in 2020 and 2022, likely increasing the sealift with mine expansion.

In the Reduced Activity Scenario, it is assumed that the sealift to supply the Hope Bay Gold Mine will remain steady at 5 vessels annually, while the Most Plausible Scenario assumes that the sealift will increase to 7 ships total over the next decade. The two highest growth scenarios assume that the sealift to support the Hope Bay Gold Mine will reach 9 ships annually (Optimized Growth Scenario) and 11 ships annually (Accelerated, but Unlikely). A summary of additional vessels anticipated to pass through the study's area of interest by scenario is included in Table 14.

[112] Mining Technology. (2019). "Hope Bay Gold Mine, Nunavut." Accessed from https://www.mining-technology.com/projects/hope-bay-gold-mine-nunavut/

[113] TMAC Resources. (n.d.) "Putting 'HOPE' Back into Hope Bay". [Presentation] Accessed from: http://s1.q4cdn.com/893791552/files/doc_presentations/2018/2018-01-16-TD.pdf

Table 14: Summary of vessels associated with the Hope Bay Gold Mine anticipated to pass through study area of interest by scenario

<table>
<tr><th></th><th></th><th colspan="12">Total number of vessels servicing Hope Bay Gold Mine via study AOI per year</th></tr>
<tr><th></th><th>Scenario Assumption</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th></tr>
<tr><td>Reduced Activity Scenario</td><td>Stays steady at 5 vessels/ year</td><td colspan="12">5</td></tr>
<tr><td>Most Plausible Scenario</td><td>Adds 1 vessel every 4 years until 7 vessels/year</td><td colspan="4">5</td><td colspan="4">6</td><td colspan="4">7</td></tr>
<tr><td>Optimized Growth Scenario</td><td>Adds 1 vessel every 3 years until 9 vessels/year</td><td colspan="3">6</td><td colspan="3">7</td><td colspan="3">8</td><td colspan="3">9</td></tr>
<tr><td>Accelerated, but Unlikely Scenario</td><td>Adds 1 vessel every 2 years until 11 vessels/year</td><td colspan="2">6</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">10</td><td colspan="2">11</td></tr>
</table>

Back River Gold Mine

Sabina Gold and Silver Corporation's Back River Gold Mine Project, located in Bathurst Inlet in Nunavut, Canada, is also likely to contribute to increased vessel activity over the 2020s. The project is expected to transition from advanced exploration and permitting to early development in 2019.[114] Pending further discovery of minerals in the region, the project is estimated to have a 10-year operating life, followed by 11 years of reclamation, closure, and post-closure activities.[115] As part of the project's final Environmental Impact Statement, operators estimated that mine resupply would require 3–5 vessels annually, originating at either Bécancour, Quebec in the east or Vancouver, British Columbia in the west.[116]

The operation would also likely use lightering barges to transfer cargo and fuel from larger ships to the site's marine laydown area during the open-water season. In 2018, Sabina Gold and Silver Corporation expanded its Marine Laydown Area and completed its first sealift, comprised of three cargo barges, one fuel barge, and one other vessel loaded with equipment and consumables for a total of 5

[114] Sabina Gold & Silver Corp. (n.d.) "Back River Project: About the Project". Accessed from: https://backriverproject.com/about/

[115] Sabina Gold & Silver Corp. (n.d.) "Back River Project: Project Timeline". Accessed from: https://backriverproject.com/about/timeline/

[116] Sabina Gold & Silver Corp. (2015). "The Back River Project: Final Environmental Impact Statement, Volume 1: Main Volume." Accessed from: http://backriverproject.s3-us-west-2.amazonaws.com/wp-content/uploads/2015/12/07202330/Volume-1-Main-Volume.pdf

vessels.[117] Development of nearby reserves or infrastructure required to explore nearby reserves may ultimately increase the annual sealift to a total 6–10 vessels annually over the next decade, according to experts who attended the 2018 CMTS & USARC 2018 Technical Workshop. However, an east-bound option from the mine is available, so it is unlikely that all vessels would transit through the study area of interest.

Various diversion rates were explored across the four scenarios. The Reduced Activity Scenario assumes that the all resupply will come from the east, adding 0 ships to the projected vessel count for the study area of interest. The Most Plausible Scenario assumes that 3 vessels will transit to the site from the west, crossing through the study area of interest, while the Optimized Growth Scenario assumes 5 vessels annually for resupply from the west. The Accelerated, but Unlikely Scenario assumes that the annual sealift for this project will add 5 vessels to the area of interest from 2019–2022, and then will increase to 10 vessels annually by 2024. A summary of this is included in Table 15.

Table 15: Summary of vessels associated with the Back River Project anticipated to pass through study area of interest by scenario

	Scenario Assumption	**2019**	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduced Activity Scenario	All vessels approach site from the east	*0 vessels/yr*											
Most Plausible Scenario	Some vessels approach site through AOI	*3 vessels/yr*											
Optimized Growth Scenario	More vessels approach site through AOI	*5 vessels/yr*											
Accelerated, but Unlikely Scenario	Adds 1 vessel every 2 years until 10 vessels/year	*5 vessels/yr*		*6 vessels/yr*		*7 vessels/yr*		*8 vessels/yr*		*9 vessels/yr*		*10 vessels/yr*	

Mary River Mine

The Mary River Mine, owned and operated by Baffinland Iron Mines Corporation, is an open pit iron ore mine on Baffin Island in Nunavut, Canada. The mine began shipping iron ore from its location in northern Canada in 2015, increasing its output from 0.917 million tons in 2015 to 5.1 million tons in 2018. Vessels used to ship the ore have likewise increased, from 13 Panamax-sized vessels in 2015 to 71 in

[117] Sabina Gold & Silver Corp. (2018). "Sabina Gold & Silver Reports Marine Laydown Area (MLA) Earthworks Completed in Line with 2015 Feasibility Costs and Ahead of Schedule and First Sealift at Back River Received" [Press Release]. Accessed from: http://www.sabinagoldsilver.com/news/sabina-gold-and-silver-reports-marine-laydown-area-mla-earthworks-completed-in-line-with-2015-feasibility-costs-and-ahead-of-schedule-and-first-sealift-at-back-river-received

2018. All shipments to date have moved eastward from Baffin Island to Europe, except for , two shipments in 2018 that were were delivered to Taiwan and Japan via the Northern Sea Route. In Phase 2 of Baffinland Iron Mines Corporation's plans for the Mary River Mine, the mine will expand its output to 12 million tons annually by 2025, raising the annual number of ore carrier voyages to 176, resupply transits to 48, and tug transits to 20.[118]

Most of this traffic is not expected to contribute to vessel activity in the study area of interest or pass through the Bering Strait. However, as the mine's output and the ice-free season expands over the next decade, it is possible that several ore carriers will pass through the Northwest Passage, transiting through this study's area of interest on route to Asia. Reflecting this potential, vessels associated with the Mary River Mine have been incorporated to all scenarios, except for the Reduced Activity Scenario. In the Most Plausible Scenario, it is assumed that 1–2 bulk carriers will pass through the study's area of interest each year. In the Optimized Growth Scenario, two additional ships are expected to utilize the route, growing by two additional ships every three years, reaching 8 additional ships by the end of the decade. In the Accelerated, but Unlikely Scenario, this rate is expedited, totaling 12 ships by 2030. A summary of this is included in Table 16.

Table 16: Summary of vessels associated with the Mary River Mine anticipated to pass through study area of interest by scenario

<table>
<tr><th></th><th></th><th colspan="12">Total number of vessels servicing the Mary River Mine via study AOI per year</th></tr>
<tr><th></th><th>Scenario Assumption</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th></tr>
<tr><td>Reduced Activity Scenario</td><td>All vessels approach site from the east</td><td colspan="12">0</td></tr>
<tr><td>Most Plausible Scenario</td><td>Gradually increase from 1 to 2 vessels/year</td><td colspan="3">1</td><td colspan="4">1--2</td><td colspan="5">2</td></tr>
<tr><td>Optimized Growth Scenario</td><td>Adds 2 vessels every 3 years until 8 vessels/year</td><td colspan="3">2</td><td colspan="3">4</td><td colspan="3">6</td><td colspan="3">8</td></tr>
<tr><td>Accelerated, but Unlikely Scenario</td><td>Adds 2 vessel every 2 years until 12 vessels/year</td><td colspan="2">2</td><td colspan="2">4</td><td colspan="2">6</td><td colspan="2">8</td><td colspan="2">10</td><td colspan="2">12</td></tr>
</table>

[118] Fisheries and Oceans Canada: Canadian Science Advisory Secretariat. (2019). "Science Review of the Phase 2 Addendum to the Final Environmental Impact Statement for the Baffinland Mary River Project." Science Response 2019/015. Accessed from: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2019/2019_015-eng.pdf

OTHER NATURAL RESOURCES

Other mineral resources in the region include a large deposit of high quality coal in northwest Alaska, however development of this resource is unlikely given the decline in coal consumption in the U.S. and continuing decline in coal shipments from the U.S.[119, 120]

Beyond mineral and petroleum resources, other natural resources and related activities may also contribute to vessel activity in northern U.S. Arctic waters, provided they are found to be economically viable, which is unlikely to be determined within the next decade. Some of these activities include expanded aquaculture and mariculture, seafloor mining, pharmaceutical bioprospecting from the Arctic marine environment, and offshore wind development in the Bering Sea.

Of these activities, offshore wind development may be among the most plausible. Offshore Alaska has a net wind potential 68% higher than all other U.S. states combined, and development of this resource could close key energy gaps for communities and energy-intense industries in western and northern Alaska.[121] To reflect this resource potential, the Accelerated, but Unlikely Scenario includes G&G surveys related to offshore wind development, with 10 vessels conducting G&G surveys in 2025 followed by 2–4 ships each year for the remainder of the projection period.

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[119] Energy Information Administration. 2018. "U.S. coal consumption in 2018 expected to be the lowest in 39 years". *Today in Energy*: December 4, 2018. Accessed from https://www.eia.gov/todayinenergy/detail.php?id=37692

[120] Energy Information Administration. 2018. "U.S. coal shipments reach their lowest levels in years". *Today in Energy:* August 3, 2019. Accessed from https://www.eia.gov/todayinenergy/detail.php?id=36812

[121] Doubrawa, Paula, et al. (2017). "Offshore Wind Energy Resource Assessment for Alaska". National Renewable Energy Laboratory. Technical Report NREL/TP-5000-70553. Accessed from: https://www.nrel.gov/docs/fy18osti/70553.pdf

INFRASTRUCTURE DEVELOPMENT

Infrastructure development in the U.S. Arctic is another critical source of growth for vessel activity in region. Building, repairing, and replacing infrastructure in the high U.S. Arctic may require sealift to supply construction efforts. Once built, some of this infrastructure may beget further vessel activities in the region, in positive feedback loops. However, as outlined in the assumptions of this study, this additional traffic is not considered in this projection effort, owing to the vast uncertainty associated with developing such feedback loops. A summary of the projected growth of overall vessel traffic related to infrastructure development is detailed in Figure 26.

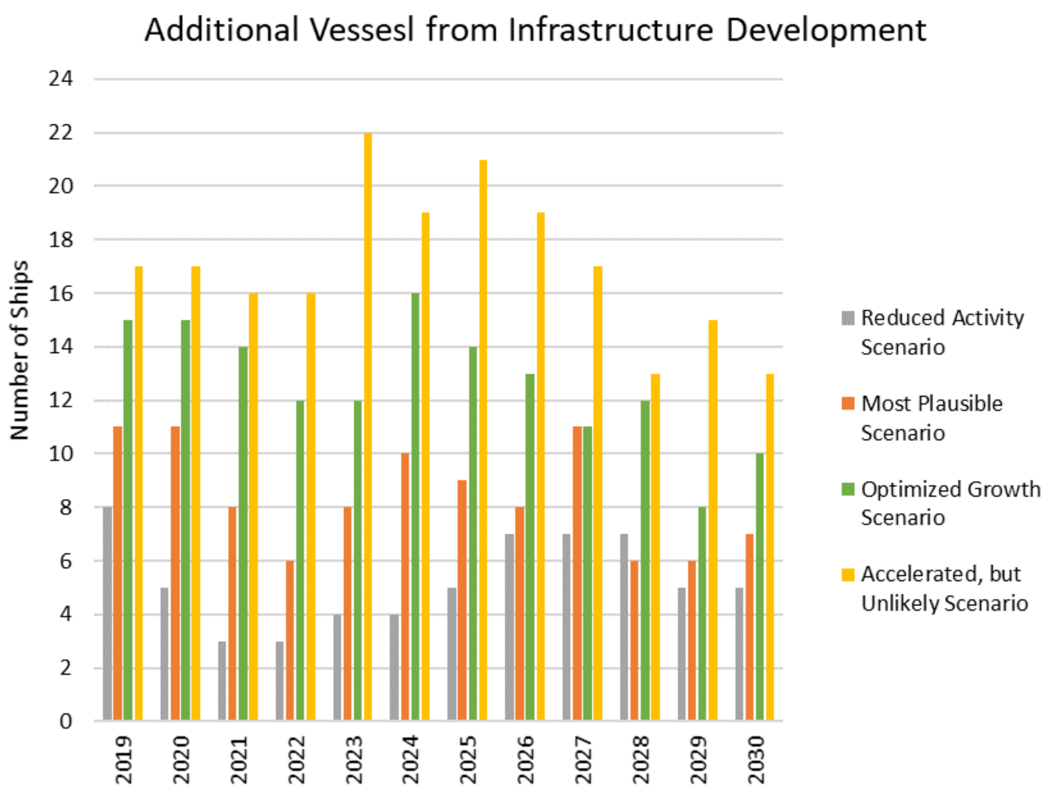

Figure 26: Combined sums of vessel counts related to infrastructure development in the study area of interest by scenario.

To estimate the volume of vessels anticipated due to infrastructure development, anticipated port, road, airport, and other types of infrastructure development, including or repair, replacement, modification, and relocation projects from state and Federal databases were considered and evaluated. Infrastructure planning data sources include the U.S. Army Corps of Engineers, the Alaska's Statewide

Transportation Improvement Plan (STIP), the Northwest Arctic Regional Transportation Plan, and the Yukon-Kuskokwim Regional Transportation Plan.

This section is divided into three parts: (1) infrastructure development and modification projects in reaction to the rapidly changing Arctic climate; (2) planned infrastructure directly related to marine transportation; (3) planned infrastructure development that is reliant on the marine transportation system for completion.

INFRASTRUCTURE DEVELOPMENT IN REACTION TO A RAPIDLY CHANGING CLIMATE

Although there is not as much infrastructure in place in the high U.S. Arctic, what does exist is under threat due to a rapidly changing climate. The 4th National Climate Assessment noted that the changing environment, including loss of shore-fast ice combined with stronger weather events, has contributed to widespread erosion along the coastlines and rivers of Alaska, with rates of up to 59 feet per year along Alaska's northern shoreline.[122] Beyond changes at the coast, nearly 70% of the current infrastructure in the pan-Arctic's permafrost domain is at risk due to the high thaw potential which could impact near-surface infrastructure, such as the Dalton Highway, the Trans-Alaska Pipeline, and Distant Early Warning Line Sites.[123] Thirty-one Alaska Native Villages have been identified as facing imminent flooding and erosion threats by federal and state officials; 15 of these villages are located along the coastline in this study's area of interest (Figure 27, top).[124] Of the 15 communities within the study area of interest facing imminent flooding, the U.S. Army Corps of Engineers has completed five erosion and flood damage reduction projects, which the Corps continues to monitor (Figure 27, bottom). [125] These projects were completed in Kivalina, Shishmaref, Deering, Unalakleet, and Emmonak. Total cumulative damages to

[122] U.S. Global Change Research Program. 2018. *The Fourth National Climate Assessment: Chapter 26, Alaska*. Accessed from https://nca2018.globalchange.gov/chapter/26/

[123] Hjort, Jan et al. December 11, 2018. "Degrading permafrost puts Arctic infrastructure at risk by mid-century". *Nature Communications* 9, Article number: 5147. Accessed from https://www.nature.com/articles/s41467-018-07557-4#Abs1

[124] U. S. Government Accountability Office. (2009). ALASKA NATIVE VILLAGES Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion. (Rep.). Accessed from: https://www.gao.gov/new.items/d09551.pdf

[125] U.S. Army Corps of Engineers- Alaska District. (n.d.) Erosion and Flood Damage Reduction Projects. Accessed from: https://www.poa.usace.army.mil/About/Offices/Construction-Operations/Erosion-and-Flood-Mitigation/

infrastructure statewide in the next century could amount to $5.5 billion, with most damages to roads, buildings, and airport runways.[126] The complete sealift requirements to respond to these threats in the U.S. Arctic remains unclear. This projection incorporates several planned projects into its scenarios to underscore the region's expected reliance on the marine transportation system to respond to the impacts of a changing Arctic climate.

[126] Melvin, A. et al. (2017). Climate change damages to Alaska public infrastructure and the economics of proactive adaptation. *Proceedings of the National Academy of Sciences, 114*(2), E122-E131. Accessed from: https://www.pnas.org/content/early/2016/12/20/1611056113

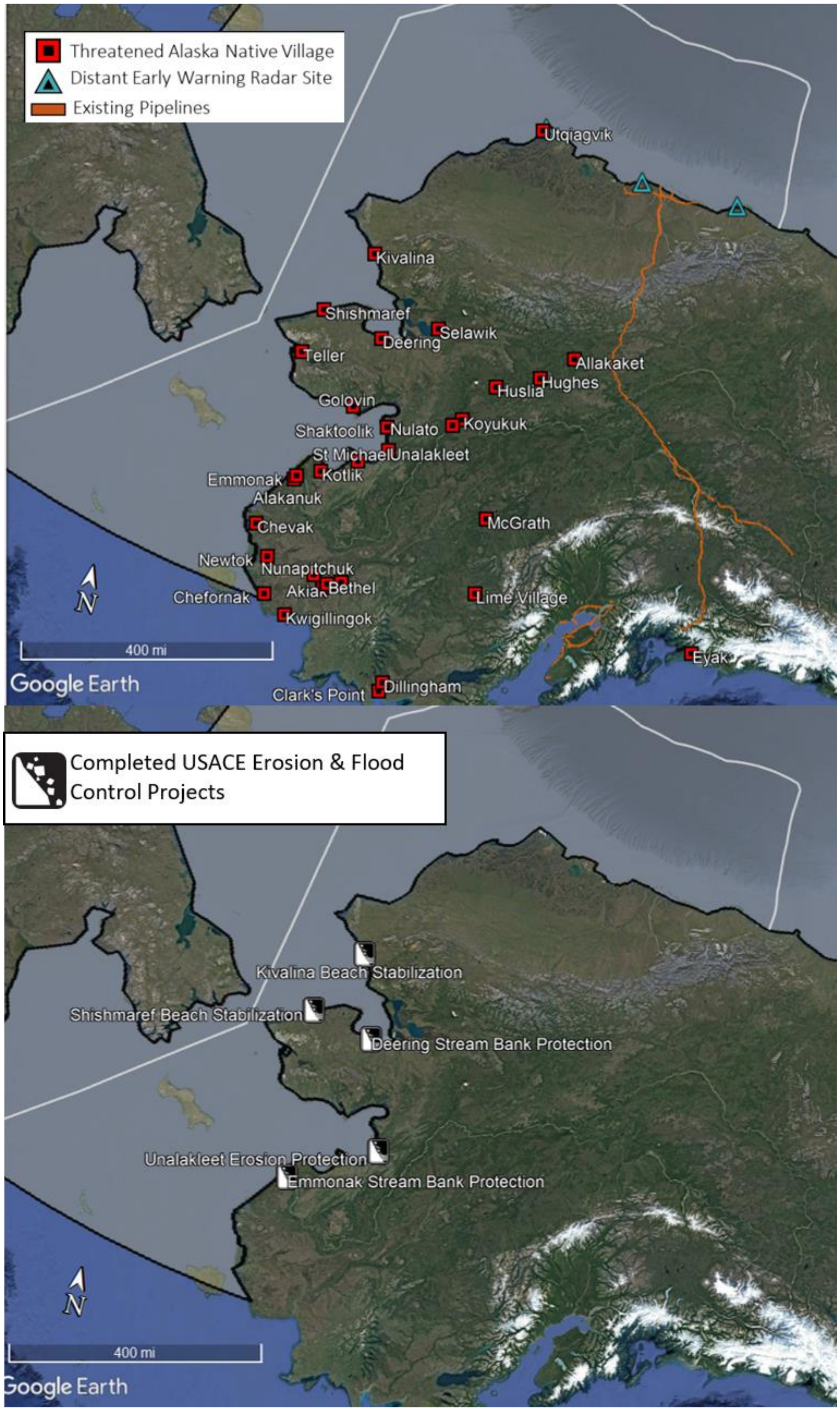

Figure 27: Map of communities and select infrastructure threatened by climate change in relationship to the study area of interest (top); map of completed flood and erosion control projects by U.S. Army Corps of Engineers within coastal communities along study area of interest (bottom).

Relocation of Kivalina, AK: Construction of Evacuation and School Site Access Road

Kivalina is a small village which has been listed as imminently threatened by flooding and erosion and is one of 12 such villages exploring relocation options.[127] The village is located on the southern tip of a 7.5-mile-long barrier island between the Chukchi Sea and a lagoon at the mouth of the Kivalina River, about 80 miles (130 km) northwest of Kotzebue in the Northwest Arctic Borough. Efforts to fortify the village against erosion include the installation of a rock revetment in 2010 by the U.S. Army Corps of Engineers, which reduced the size of the village but provided the community with time to decide and secure funding for relocation.[128] In 2018, Kivalina secured funding to construct a school at Kisimigiiqtuq Hill, a site situated 7 miles inland which would provide the start of the communities relocation inland, as well as funding for an access route to the site, which doubles as an evacuation route from severe storms.[129] Construction for the access route is slated to begin in 2019. This construction project will include a 7.7 mile, two-lane gravel road and a 3,200-foot lagoon crossing. Much of the material for the gravel road can be sourced locally, utilizing the abundance of alluvial fill available in the region, but this project will still require some sealift support. The proposed project is estimated to require 2–3 barges of material for the project, including steel for the 188-foot single span steel girder bridge, geotechnical fabric, and materials for the gravel road construction, and is expected to cost $30.25 million. Construction plans for the proposed school at Kisimigiiqtuq could not be located, but it is assumed that an additional 1–2 ships would be required to complete the construction of the school, and that such construction would only commence after the gravel road is completed.

Over the next decade, the relocation of Kivalina could contribute substantially to the vessel traffic patterns of this study's area of interest, however, it will depend on how well the effort is funded. The evacuation route construction project will cost $30 million, while the total cost to relocate Kivalina is

[127] United States Government Accountability Office. (2009). ALASKA NATIVE VILLAGES Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion. (Rep.). Accessed from: https://www.gao.gov/new.items/d09551.pdf

[128] U.S. Climate Resilience Toolkit. (2017). Relocating Kivalina. Accessed from: https://toolkit.climate.gov/case-studies/relocating-kivalina

[129] Oliver, S. G. (2018). Funding secured for Kivalina school, access road. Accessed from: https://www.adn.com/arctic/2018/08/11/funding-secured-for-kivalina-school-access-road/

estimated to cost $100–$400 million.[130] In the Reduced Activity Scenario, it is assumed that funding is not secured beyond the 2019 season, limiting the community's ability to relocate inland. In the Most Plausible Scenario, it is assumed that relocation efforts will happen incrementally, with surges of 2–3 ships every three years as funding is delivered. In the Optimized Growth Scenario, it is assumed that this effort adds 1–2 barges annually. In the Accelerated, but Unlikely Scenario, it is assumed that all necessary funding is secured without delay, and that the relocation of Kivalina contributes 2–3 barges every year over the next decade to provide materials and equipment needed to relocate the village 7 miles inland. A summary of this is included in Table 17.

Table 17: Expected sealift requirements for the relocation of Kivalina

<table>
<tr><th></th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th></tr>
<tr><td></td><td colspan="3">Construction</td><td colspan="9">Other Sealift Requirements</td></tr>
<tr><td rowspan="2">Reduced Activity Scenario</td><td rowspan="2">2 vessels</td><td colspan="2" rowspan="2">0 vessels/yr</td><td colspan="9">Additional Funding is Not Secured</td></tr>
<tr><td colspan="9">0 vessels/yr</td></tr>
<tr><td>Most Plausible Scenario</td><td colspan="3">1-2 vessels/yr</td><td colspan="2"></td><td>Surge
3 vessels</td><td colspan="2"></td><td>Surge
2 vessels</td><td colspan="2"></td><td>Surge
3 vessels</td></tr>
<tr><td>Optimized Growth Scenario</td><td colspan="3">2-3 vessels/yr</td><td colspan="9">1-2 vessels/yr</td></tr>
<tr><td>Accelerated, but Unlikely Scenario</td><td colspan="3">2-3 vessels/yr</td><td colspan="9">2-3 vessels/yr</td></tr>
</table>

Relocation and Protect-In-Place of Shishmaref, AK

The community of Shishmaref is also actively exploring relocation options, which could impact the level of vessel activity over the next decade. Shishmaref is located on a barrier island in the Chukchi Sea just north of the Bering Strait, and is under severe threat due to rapid rates of coastal erosion. Over the last 15 years, the Bureau of Indian Affairs, the City of Shishmaref, and the U.S. Army Corps of Engineers have invested in shoreline protection for the community, including 1,380 feet of shoreline protection installed from 2004 to 2007.[131] In 2009 and 2010, a rock-wall barrier was constructed for protection along significant portions of the coast fronting the community. Nevertheless, an estimated

[130] U.S. Climate Resilience Toolkit. (2017). Relocating Kivalina. Accessed from: https://toolkit.climate.gov/case-studies/relocating-kivalina

[131] Gregg, R.M. (2018). "Relocating the Native Village of Shishmaref, Alaska Due to Coastal Erosion". Climate Adaptation Knowledge Exchange: Case Study. Accessed from: https://www.cakex.org/case-studies/relocating-native-village-shishmaref-alaska-due-coastal-erosion

one-third of the community, including the airport, residential structures and community infrastructure, remain exposed. Further protection projects are anticipated later this summer, as the Alaska Department of Transportation & Public Facilities included rebuilding, resurfacing, and armoring portions of the Shishmaref Landfill Road to address damage sustained from a storm in 2013 as part of the 2019 Northern Region Construction Season.[132]

Considering the continued damages to existing infrastructure, the community has actively been exploring relocation options. A U.S. Army Corps of Engineers study from 2004 estimated that relocating Shishmaref to the Alaska mainland would cost $180 million.[133] In 2016, the city of Shishmaref completed a feasibility study of potential relocation sites, which include the Old Pond site and the West Tin Creek Hill, both located several miles inland.[134] The Alaska Department of Transportation and Public Facilities also started a planning and environmental linkages (PEL) study to "identify obstacles impeding sustainable community infrastructure", including locally sourced material required for protecting existing infrastructure and for building new infrastructure for relocation.[135]

There is substantial uncertainty about how much vessel traffic relocating or protecting-in-place Shishmaref may require. The only planned vessel activity includes bathymetric surveys in 2019 of the immediate region surrounding Shishmaref as part of the PEL study, and it is anticipated that construction on the Shishmaref Landfill Road will warrant 1 barge of supplies and equipment.

The additional vessel requirements for relocating Shishmaref remain unclear, and this uncertainty is reflected in the projection scenarios. In the Reduced Activity Scenario and the Most Plausible Scenario, it is assumed that funding and planning for this relocation will not be secured within the next decade, and therefore no additional vessels will be added to the projection. In the two other scenarios, it is assumed that further developments will happen in the latter half of the 2020s. In the Optimized Growth Scenario,

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[132] Alaska Department of Transportation and Public Facilities. (2019). 2019 Construction Season Info. Accessed from: http://www.dot.alaska.gov/nreg/construction/

[133] Gregg, R.M. (2018). "Relocating the Native Village of Shishmaref, Alaska Due to Coastal Erosion". Climate Adaptation Knowledge Exchange: Case Study. Accessed from: https://www.cakex.org/case-studies/relocating-native-village-shishmaref-alaska-due-coastal-erosion

[134] AECOM Technical Services. (2016). *Shishmaref Relocation Site Selection Feasibility Study* (Rep.). Accessed from: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Site_Selection_Feasibility_Study_FINAL_022316.pdf

[135] Alaska Department of Transportation and Public Facilities. (2017). Shishmaref Relocation Road Planning and Environmental Linkages (PEL) Study - NFHWY00352. Accessed from: http://dot.alaska.gov/nreg/shishmaref/

it is assumed that funding is secured by 2027, with 1–2 barges utilized each year after through 2030. In the Accelerated, but Unlikely Scenario, it is assumed that plans are designed and funding for relocation and/or protection-in-place infrastructure are secured by 2025, and 2–3 barges are utilized each year thereafter for this purpose. A summary of this is included in Table 18.

Table 18: Summary of anticipated vessels associated with the relocation of Shishmaref

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduced Activity Scenario	Construction	Additional Funding is Not Secured										
	2 vessels/yr	*0 vessels/yr*										
Most Plausible Scenario	Construction	Additional Funding is Not Secured										
	2 vessels/yr	*0 vessels/yr*										
Optimized Growth Scenario	Construction								Relocation/Protect-in-Place Activities			
	2 vessels/yr								*1-2 vessels/yr*			
Accelerated, but Unlikely Scenario	Construction						Relocation/Protect-in-Place Activities					
	2 vessels/yr						*2-3 vessels/yr*					

Relocation of Newtok, AK

Newtok, AK is a small community threatened by erosion from the Ningliq River and is among the villages identified by the 2009 GAO report as imminently threatened. Newtok has been actively pursuing relocation since the early 2000s and plans to complete its relocate to a new village site on Nelson Island to the south, called Mertarvik, by 2027. Construction at the new site began in 2007, with the drilling of the first water well and the construction of three new homes at the site by Newtok residents. Other major construction milestones have included a barge landing facility, an access road, a quarry, an airport layout, and additional homes. In 2019, the planned construction included 13 more homes, a modular power plant, modular water plant, a landfill, an equipment shop, and the completion of the Mertarvick Evacuation Center.[136] By 2023, it is expected that 380 people will have relocated to Mertarvik and that there will be 65 occupied homes, a school, a clinic, and a DOT airport in place; by 2027, the relocation is expected to be complete with a 15–35 additional homes and full running water and sewer throughout the community. The timely and complete relocation of Newtok is heavily depended on available funding and resources.[137]

[136] Cadiente, Romy and Dixon, Gavin. (2018). "Newtok Planning Group October Update". Slide presentation accessed from: https://s3-us-west-2.amazonaws.com/ktoo/2018/12/ANTHC-NVC_NPG_Presentation_10-17-2018.pdf

[137] Ibid

For the scenarios featured in this study, it is assumed that the sealift required for the ongoing construction of Mertarvik was captured in the baseline analysis, and therefore only future surges of traffic associated with the relocation of Newtok are expected in the next decade. In the Reduced Activity Scenario, no additional vessels are projected throughout the 2020s. In the Most Plausible Scenario, one additional vessel is expected in 2023 and 2027, coinciding with planned project milestones. In the Optimized Growth Scenario, it is assumed that one additional vessel will be added to the study area of interest each year through 2027, and in the Accelerated, but Unlikely, it is assumed that 2 additional vessels will be added to the study area of interest through 2027.

PLANNED MARINE TRANSPORTATION SYSTEM INFRASTRUCTURE PROJECTS

Modification of the Port of Nome

Since 2008, state and Federal officials have investigated where in the northern U.S. Arctic would be most conducive for another deep-draft port, as the only deep-draft port near the region is located at Dutch Harbor in the Aleutian Islands. The 2013 Alaska Deep Draft Arctic Port System Study shortlisted Nome, Port Clarence (Teller), and Cape Darby as all-purpose candidate sites for a deep-draft port.[138] The draft integrated feasibility report, environmental assessment, and finding of no significant impact for the Alaska Deep Draft Arctic Port System provided detailed analyses on the three listed sites and proposed a tentatively selected plan to expand the Port of Nome.[139] This project was paused in late September 2015, after Shell announced plans to cease exploratory drilling in the Chukchi Sea.[140] In 2018, the U.S. Army Corps of Engineers- Alaska District entered into an agreement with the City of Nome to examine the

[138] U.S. Army Corps of Engineers and State of Alaska Department of Transportation and Public Facilities. (2013). "Alaska Deep-Draft Arctic Port System Study" Accessed from: https://www.poa.usace.army.mil/Portals/34/docs/AKports/1ADDAPSReportweb.pdf

[139] U.S. Army Corps of Engineers—Alaska District and Pacific Ocean Division. (2015). "Draft Integrated Feasibility Report, Draft Environmental Assessment, and Draft Finding of No Significant Impact: Alaska Deep-Draft Arctic Port System Study". Accessed from https://www.poa.usace.army.mil/Portals/34/docs/civilworks/arcticdeepdraft/ADDMainReportwithoutappendixes.pdf

[140] U.S. Army Corps of Engineers—Alaska District, Office of Public Affairs. (2015). "Corps, partners temporarily suspend study for Alaska Deep-Draft Arctic Port System" [Press Release] Release No. 15-018. Accessed from http://dot.alaska.gov/stwdmno/ports/assets/pdf/arctic_study_pause.pdf

feasibility of constructing navigation improvements for the Port of Nome.[141] A draft of the Port of Nome Modification Feasibility Study was released in May 2019, outlining the tentatively selected plan for the project.[142] Proposed modifications in this plan include extending the existing west causeway by 3,484 feet; removing the existing east breakwater and replacing it with a new 3,900-foot causeway; deepening the existing Outer Basin from 22.5 to 28 feet below mean lower low water (MLLW); creating a Deep Water Basin to 30 or 40 feet below MLLW; and constructing 5 new docks.[143] This effort is estimated to cost between $419–$451 million, split between the Federal government and the project's non-Federal sponsor.

Additionally, to meet the demands of the expanded port, this study's projections also estimate that after the modification of the port is completed, the port will also need to construct an adequate port reception facility. Port reception facilities are facilities to which ship operators may send contaminants that cannot be discharged at sea, such as residues, oily-water mixtures, garbage (including plastics), sewage, and effluent from scrubber systems. These reception facilities also may receive abandoned and/or lost fishing gear and similar items that may be retrieved in the broader effort to reduce marine plastic litter. Currently, there are no ports operating along the Bering Strait with formal waste reception facilities.[144] A Preliminary Engineering Report for a Port Waste Reception Facility in Nome recommended construction take place over three phases, with Phase 3 requiring the construction of a lift or pump station at the proposed deep water dock with a force main pipe to connect to the city's sewage lagoon.[145]

For this study's projections, it is assumed that the modification of the Port of Nome will require 1 vessel for 1 year of pre-construction research and that construction would last 4 years, utilizing 1 vessel in the first year and 4 vessels (assuming 1 dredger, 1 barge for lightering dredged material, 1 equipment

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[141] U.S. Army Corps of Engineers—Alaska District. (2018). "Corps begins new feasibility study for Port of Nome". [News Release]. Accessed from https://www.poa.usace.army.mil/Media/News-Releases/Article/1431934/corps-begins-new-feasibility-study-for-port-of-nome/

[142] U.S. Army Corps of Engineers—Alaska District. (2019). "Draft Integrated Feasibility Report and Environmental Assessment and Draft Finding of No Significant Impact: Port of Nome Modification Feasibility Study" Accessed from https://www.poa.usace.army.mil/Portals/34/docs/civilworks/publicreview/portofnome/IFREADraft6May2019MasterDraftFinal.pdf?ver=2019-05-07-193529-953

[143] Ibid

[144] Bristol Engineering Services Corporation. (2018). "City of Nome, Port of Nome Waste Reception Facility: Preliminary Engineering Report". Prepared for the City of Nome. Accessed from: https://www.nomealaska.org/egov/documents/1528232879_41128.pdf

[145] Ibid

barge, and 1 additional tanker for fuel) in each subsequent year of construction until completion. Across the scenarios, it was also assumed that the project would have different construction start dates. The Reduced Activity Scenario assumes the modification would begin construction in 2025 and be completed in 2028; the Most Plausible Scenario assumes that construction would begin in 2024 and be completed in 2027; the Optimized Growth Scenario assumes that construction would begin in 2023 and be completed in 2026; and finally, the Accelerated, but Unlikely Scenario assumes construction would begin in 2022 and be completed in 2025. The current study also estimates that an additional two ships each year for two years following completion of the port modifications would be required for construction of a port reception facility to support the expanded traffic at Nome. A summary of the projected vessel requirements by scenario is include in Table 19.

Table 19: Summary of anticipated vessels associated with the Port of Nome modification

<table>
<tr><th></th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th></tr>
<tr><td rowspan="2">Reduced Activity Scenario</td><td></td><td>Pre-Construction Research</td><td></td><td></td><td></td><td></td><td colspan="4">Construction for Port Modificiation</td><td colspan="2">Port Waste Reception Facility</td></tr>
<tr><td></td><td>1 vessel</td><td></td><td></td><td></td><td></td><td>1 vessel</td><td colspan="3">4 vessels/yr</td><td colspan="2">2 vessels/yr</td></tr>
<tr><td rowspan="2">Most Plausible Scenario</td><td></td><td>Pre-Construction Research</td><td></td><td></td><td></td><td colspan="4">Construction for Port Modificiation</td><td colspan="2">Port Waste Reception Facility</td><td></td></tr>
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<tr><td rowspan="2">Optimized Growth Scenario</td><td></td><td>Pre-Construction Research</td><td></td><td></td><td colspan="4">Construction for Port Modificiation</td><td colspan="2">Port Waste Reception Facility</td><td></td><td></td></tr>
<tr><td></td><td>1 vessel</td><td></td><td></td><td>1 vessel</td><td colspan="3">4 vessels/yr</td><td colspan="2">2 vessels/yr</td><td></td><td></td></tr>
<tr><td rowspan="2">Accelerated, but Unlikely Scenario</td><td></td><td>Pre-Construction Research</td><td></td><td colspan="4">Construction for Port Modificiation</td><td colspan="2">Port Waste Reception Facility</td><td></td><td></td><td></td></tr>
<tr><td></td><td>1 vessel</td><td></td><td>1 vessel</td><td colspan="3">4 vessels/yr</td><td colspan="2">2 vessels/yr</td><td></td><td></td><td></td></tr>
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Lower Yukon River Regional Port and Road Project in Emmonak

In 2018, the Lower Yukon River Regional Port and Road Renovation Project in Emmonak, Alaska was awarded $23 million as part of the Better Utilizing Investments to Leverage Development (BUILD) Transportation Discretionary Grants.[146] This grant is expected to be centered on improving infrastructure in Emmonak, a small city within the Kusilvak Census Area,[147] which, because of its location on the delta of the Yukon River, serves as a redistribution hub for barges moving cargo to communities along the Yukon

[146] The BUILD Program was previously known as TIGER (Transportation Investment Generating Economic Recovery).

[147] The Kusilvak Census Area was formerly known as the Wade Hampton Census Area.

River.[148] The funding will be used to repair and upgrade approximately 3.5 miles of high-use service roads as well as construct a permanent barge and landing craft ramp and dock/wharf with up to two berths capable of handling 500-ton barges. This project was previously identified by the 2018 Yukon Kuskokwim Delta Transportation Plan.[149] Further details about the sealift required for this project are not available as of June 2019, but per the requirements of the BUILD award, the funding must be obligated by September 2020 and will expire in September 2025, it is anticipated that construction will be complete by 2025.

For the scenarios, it is estimated that this project will likely begin construction in 2023, utilizing 1 vessel for hydrographic surveys of the channels used to approach Emmonak, and 1–2 barges of materials and equipment for two years of construction to be completed by 2025. In the two high growth scenarios (Optimized Growth Scenario and Accelerated, but Unlikely), it is anticipated to add 2 barges per year, while the two lower growth scenarios (Reduced Activity Scenario and Most Plausible Scenario) will utilize 1 barge per year for equipment. Additionally, because this effort is intended to improve existing infrastructure, it is not anticipated that this project will trigger immediate growth in the use of Emmonak as a regional hub for communities along the Yukon River. A summary of the projected vessels related to this infrastructure project are included in Table 20.

Table 20: Summary of anticipated vessels associated with Lower Yukon River Regional Port and Road Project in Emmonak, AK

	Construction Year 1 (2023)	Construction Year 2 (2024)	Construction Year 3 (2025)
Reduced Activity Scenario	1 vessel	1 vessel	1 vessel
Most Plausible Scenario	1 vessel	1 vessel	1 vessel
Optimized Growth Scenario	1 vessel	2 vessels	2 vessels
Accelerated, but Unlikely Scenario	1 vessel	2 vessels	2 vessels

[148] Alaska Department of Commerce, Community and Economic Development, Division of Economic Development. (2014). "Lower Yukon River Regional Port Project: Situational Analysis and Potential Impacts". Accessed from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.645.9761&rep=rep1&type=pdf

[149] Alaska Department of Transportation and Public Facilities. (2018). Yukon Kuskokwim Delta Transportation Plan: Executive Summary. Accessed from: http://dot.alaska.gov/stwdplng/areaplans/area_regional/assets/ykd/2_YK_Executive-Summary.pdf

OTHER PLANNED INFRASTRUCTURE DEVELOPMENT PROJECTS

According to existing state and regional transportation plans, there are several planned infrastructure construction projects which will require sealift, including road construction and modification, airport improvements, and renewable energy projects.

Construction of the Kotzebue to Cape Blossom Road

The construction of an 11-mile gravel road to connect Kotzebue to Cape Blossom on the Baldwin Peninsula in the Northwest Arctic Borough is expected to add to the vessel activity in the study area of interest.[150] The project will connect the city to the Kotzebue Electric Association Wind Farm and to Cape Blossom, where deeper water may allow access for larger ships servicing the community. Construction for the project began in 2017, with the barging and staging of construction materials. The next phase of construction is slated to begin during the winter season of 2020–2021, continue during winter 2021–2022, with final construction completed in summer 2024. The entire project is estimated to require 799,500 tons (533,000 CY) of material, some of which must be transported to the peninsula via ship. According to project plans, 94% of the material may be sourced locally, but the 49,500 tons (33,000 CY) required for Phase 3 would require 248 trips using a single barge loaded to 200 tons, which is the typical size used for deliveries to Kotzebue. The shallow waters surrounding the peninsula limit the size of barges able to bring material to the construction site, as the primary approach to Kotzebue is a narrow channel, with 5–7 feet depth and constantly changing sandbars at the mouth of the Noatak River.[151] If all the materials for the project had to be barged, it would take an estimated 8–16 navigation seasons just to stage the material necessary to build the road.[152] Such an operation would likely utilize 1–2 barges, but require hundreds of transits to and from the source in the Noatak River.

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[150] Alaska Department of Transportation and Public Facilities: Northern Region. (n.d.). "Kotzebue to Cape Blossom Road" Project 76844/NCPD-0002(204). Accessed from: http://dot.alaska.gov/nreg/capeblossomroad/

[151] National Oceanic and Atmospheric Administration, Office of Coast Survey. (2012). "Kotzebue Harbor and Approaches". Chart 16161, 1:50,000. Accessed from https://charts.noaa.gov/PDFs/16161.pdf

[152] 799,500 tons* 1 trip/200 tons *1 day/2 trip= 2000 days to move * 120 days/season= 17 seasons; if 100,000 tons/season can be moved, this changes to 799,500 tons* 1 season/100,000 tons = 7.95 seasons to complete with one barge.

In the proposed scenarios, it is assumed that only the fuel to support the construction and the non-locally sourced material (49,500 tons) would need to be shipped to the site. In the Reduced Activity Scenario, it is assumed that all materials, fuel, and equipment are in place and no additional sealift will be required for construction. In the Most Plausible Scenario, it is estimated that 1 additional ship would be needed from 2020 to 2023 to supply the construction with sufficient fuel and equipment; in both the Optimized Growth and Accelerated, but Unlikely Scenario this is extended to 2 ships annually. A summary is included in Table 21.

Table 21: Summary of additional vessels associated with construction of Kotzebue to Cape Blossom Road

	Construction Year 1 (2020)	Construction Year 2 (2021)	Construction Year 3 (2022)	Construction Year 4 (2023)
Reduced Activity Scenario	0 vessels	0 vessels	0 vessels	0 vessels
Most Plausible Scenario	1 vessel	1 vessel	1 vessel	1 vessel
Optimized Growth Scenario	2 vessels	2 vessels	2 vessels	2 vessels
Accelerated, but Unlikely Scenario	2 vessels	2 vessels	2 vessels	2 vessels

Road Improvements in Utqiagvik, AK

In 2020, Utqiagvik is expected to begin construction on road improvements to rehabilitate and pave 0.625 miles of Ahkovak Street, including drainage improvements, according to the State of Alaska's 2018–2021 Statewide Transportation Improvement Program (STIP).[153] This project is estimated to cost $7.15 million, with a further $6.5 million required after 2021. It is anticipated that this project will likely require sealift, as the materials required for paving roads are unlikely to be sourced locally. It is anticipated that this project will require 1 ship in 2020 for all scenarios, and an additional ship in 2022 and 2024 for both the Optimized Growth Scenario and the Accelerated, but Unlikely Scenario.

[153] State of Alaska Department of Transportation & Public Facilities. (June 2019). "Statewide Transportation Improvement Program: Amendment 3". Accessed from: http://dot.alaska.gov/stwdplng/cip/stip/assets/STIP.pdf

Road Improvements in Nome, AK

According to the Statewide Transportation Improvement Program database, the City of Nome is expected to have $50.8 million in road improvement projects, beginning in 2019 and continuing past 2021.[154] These projects include the rehabilitation, repair, and construction of pedestrian paths and drainage improvements along Seppala Drive ($21.7 million), Bering Street ($4 million), the Port Road ($12.6 million), and the Center Creek Road ($12.6 million).

This construction, like many road improvement projects in the region, will likely require sealift to supply the necessary materials for this project. The Reduced Activity Scenario assumes all material will be sourced locally or will be small enough so as not to require an entire ship of materials, therefore these projects will not add any additional vessels to the region. In the Most Plausible Scenario, there will be 2 additional vessels each year from 2019–2021, with one additional vessel annually until 2025. In the Optimized Growth Scenario, it is assumed that there will be 2 vessels each year from 2019–2021, with an additional vessel each year through 2030 to support other repairs. In the Accelerated, but Unlikely Scenario, it is assumed that the road improvement projects at Nome will contribute an additional 2 vessels each year, beginning in 2019, and that funding will continue through the rest of the decade to support other road improvements in the city. A summary is provided in Table 22.

Table 22: Summary of additional vessels associated with road improvements in Nome

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduced Activity Scenario	All Materials Sourced Locally											
	0 vessels/yr											
Most Plausible Scenario	Construction											
	2 vessels/yr			*1 vessel/yr*								
Optimized Growth Scenario	Construction											
	2 vessels/yr			*1 vessel/yr*								
Accelerated, but Unlikely Scenario	Construction											
	2 vessels/yr											

Road, Boardwalk, and Footbridge Improvements in Selawik, AK

The Statewide Transportation Improvement Plan includes funding for improvements in the small village of Selawik in the Northwest Arctic Borough beginning in 2019. One element is the rehabilitation of two footbridges, which is anticipated to be completed in 2019 and is unlikely to require any additional

[154] State of Alaska Department of Transportation & Public Facilities. (June 2019). "Statewide Transportation Improvement Program: Amendment 3". Accessed from: http://dot.alaska.gov/stwdplng/cip/stip/assets/STIP.pdf

sealift support. The second element is the rehabilitation of the existing barge landing access road and the construction of a new gravel barge staging pad. This second project is expected to cost $5.1 million dollars and expected to be completed by 2021. It is anticipated that this second component may require additional vessel support; accordingly, 1 additional ship in 2019–2021 included in the two highest growth scenarios to reflect this construction project. A summary is included in Table 23.

Table 23: Summary of additional vessels associated with road improvements in Selawik

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduced Activity Scenario	No Additional Sealift Required											
	0 vessels/yr											
Most Plausible Scenario	No Additional Sealift Required											
	0 vessels/yr											
Optimized Growth Scenario	Construction											
	1 vessel/yr											
Accelerated, but Unlikely Scenario	Construction											
	1 vessel/yr											

Airport Improvements

Aviation is the other vital mode of transportation for the Northwest region of Alaska, providing linkages to remote communities without road access. Within this study's area of interest, it is anticipated that construction related to airport improvements will impact the volume of vessel activity through 2030. Within this study's area of interest, there are a total of 49 airports near the coast which could have sealift demands impacting the volume of vessel activity in the region.[155] The 2004 Northwest Alaska Transportation Plan reviewed which airports in the northwest region of the study area of interest would require upgrades or expansion through 2025, and the recently published Yukon Kuskokwim Delta Transportation Plan identified three airports in need of improvements in southwest region. Additionally, the Statewide Transportation Improvement Plan identified six airport construction projects within the study area of interest slated for construction in 2019.[156] These projects include:

- Installation of beach erosion control at the Kivalina Airport

[155] Alaska Department of Transportation and Public Facilities, Division of Information System & Services Transportation Geographic Information Section. (2018). Public Airports in Alaska. (Map). *U.S. Department o Transportation Federal Highway Administration and Federal Aviation Administration*. Accessed from: http://dot.alaska.gov/stwdplng/mapping/dataproducts/Public_Airports.pdf

[156] Alaska Department of Transportation and Public Facilities. (2019). *2018-2021 Statewide Transportation Improvement Program (STIP)*. Accessed from: http://dot.alaska.gov/stwdplng/cip/stip/assets/STIP.pdf

- Skewing and extending the runways as part of reconstructing the Kiana Airport
- Repaving the runway, taxiway, and taxi lane and construction of a Maintenance and Operations facility at the Utqiagvik Airport
- Repairing settlement areas, installing a perimeter fence, and access road at the Nome Airport
- Rehabilitating the White Mountain and Holy Cross Airports with surfacing, dust palliative, lighting system, and aviation aids to navigation

Additionally, it is anticipated that more airport repairs will be conducted in the near-future, including at the Deering Airport[157] and Kotlik Airport[158] in 2020 and at the Kotzebue Airport in 2021.

Furthermore, runways must meet strict construction standards, meaning much of the material must be barged in specifically for the project. For example, details about the plans for the Kotzebue Airport project in 2021 were provided by the Alaska Department of Transportation and Public Facilities. For that future project, an estimated 35,500 cubic yards of material needs to be barged to the site to repave the main apron, taxi lanes, and taxiways. Moving this quantity of material may require multiple trips back and forth from the source of the material; smaller barges must be used in many of these remote communities due to the shallow waters nearshore and the lack of current bathymetric data for much of the region.[159] For example, during a recent renovation of the Kotzebue Airport, 100 loads of 1000 tons of rocks were sailed and staged during a 75-day operating window.[160]

Taking these data together, this study estimates that airport construction projects are likely going to continue throughout the next decade. Inundation of runways by erosion or precipitation or subsidence resulting from permafrost thaw may accelerate the rate at which runways need to be repaired, thereby also accelerating the volume of vessel traffic associated with airport maintenance. In this projection study, it is estimated that the number of airport repair projects that require ocean-going sealift in the

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[157] Alaska Department of Transportation and Public Facilities. (2017). Notice. *RFP No. 25-17-1-070 Deering Airport and Access Road Improvements & Deering Airport Snow Fence - Alaska Online Public Notices*. Accessed from: https://aws.state.ak.us/OnlinePublicNotices/Notices/View.aspx?id=187664

[158] Alaska Department of Transportation and Public Facilities. (2019). Notice. *ITB NFAPT00251 Kotlik Airport Rehabilitation - Alaska Online Public Notices*. Accessed from: https://aws.state.ak.us/OnlinePublicNotices/Notices/View.aspx?id=194467

[159] For more about bathymetric data gaps in the Arctic, please see: NOAA Office of Coast Survey. (2018). "NOAA surveys the unsurveyed, leading the way in the U.S. Arctic". Accessed from: https://www.nauticalcharts.noaa.gov/updates/?p=171043

[160] U.S. Army Corps of Engineers Alaska District. (2019). Kotzebue Harbor Feasibility Study. Economics Appendix. Accessed from: https://www.poa.usace.army.mil/Portals/34/docs/civilworks/publicreview/kotzebueharbor/KotzebueAppDEconomics.pdf?ver=2019-01-09-152556-093

study's area of interest will range from 3–6 projects annually and that each project will require 1 barge for paving materials. In the Reduced Activity Scenario, it is assumed that 3 vessels will be added to the study area of interest; in the Most Plausible Scenario, it is assumed that 4 vessels will be added; in the Optimized Growth Scenario, it is estimated that 5 vessels will be added; and in the Accelerated, but Unlikely it is estimated that 6 vessels will be added. A summary of the projected sealift demands associated with airport repairs within the area of interest is included in Table 24.

Table 24: Summary of additional vessels associated with airport improvements across AOI

	Size of Annual Sealift to Support Airport Repairs
Reduced Activity Scenario	3 vessels/year
Most Plausible Scenario	4 vessels/ year
Optimized Growth Scenario	5 vessels/year
Accelerated, but Unlikely Scenario	6 vessels/year

Extrapolating to transits, it is anticipated that these ships may make hundreds of transits in a single season, depending on the bathymetry around the construction sites. This could greatly expand the amount of activity in the region when examined by transit as opposed to vessel count alone.

Onshore Renewable Wind Projects

Most the energy used by communities and industries in western and northern Alaska is diesel fuel delivered during the short summer navigation season via tankers and lightered onto smaller barges. Efforts to expand the diversity of energy sources, particularly of renewable energies, may require vessels to bring in equipment and large pieces of infrastructure in the coming years. In 2016, the Department of Energy awarded nearly $1 million for the installation of renewable energy sources in Kotzebue, Buckland, and Deering, Alaska.[161] Several wind turbine projects for communities in western Alaska have been

[161] Department of Energy. (2016). "Energy Department Announces Over $9 Million in Funding for 16 Indian and Alaska Native Community Clean Energy and Energy Efficiency Projects." *Energy.gov*. Accessed from: https://www.energy.gov/articles/energy-department-announces-over-9-million-funding-16-indian-and-alaska-native-community

funded by the Department of Energy, in partnership with the Alaska Village Electric Cooperative (AVEC), including Stebbins and St. Michael, Pitka's Point and St. Mary's, and Unalakleet, with one of these projects still under construction. This effort is expected to add 1 cargo ships in 2019 to deliver the main body of the turbine in Stebbins and St. Michael in 2019. These renewable energy projects are not expected to replace the need for tankers and lightering barges to supply fuel to the region, as these energy projects are likely to augment, rather than replace, the existing energy infrastructure. In the Accelerated, but Unlikely Scenario, it is assumed that other renewable energy projects will be funded in the region over the next decade, adding 2 ships every three years to supply materials for renewable energy installations. In all other scenarios, it is assumed that no additional vessels will be required after 2019.

Expanded Services for Community Resupply & Waste Removal

Community resupply is a large component of current regional maritime traffic, and for these scenarios, it is assumed that the sealift associated with this effort will remain steady throughout the next decade. It should be noted, however, that while the number of ships may remain constant, their time operating on the water may increase. Alaska Marine Lines (AML) will expand its service to the Arctic region in 2019 through a new partnership with Bowhead Transport to provide the destination services at the North Slope villages of Point Hope, Point Lay, Wainwright, Utqiagvik, and Kaktovik.[162] AML will also service Deadhorse with 2 annual sealifts, along with Naknek, Dillingham, Nome, Bethel, Kotzebue, and more than 65 villages along the western coast of Alaska.[163] This expansion will likely not add more vessels to the fleet servicing communities in the region, but will increase the number of transits made by the existing fleet throughout the narrow shipping season. Other vessels servicing communities include Crowley's Western Alaska Fleet of tug and barges.[164]

In addition to community resupply, the marine transportation system plays a vital role in removing waste from rural Alaskan communities. The State of Alaska Division of Environmental Health's

[162] Bowhead Transport Company. (2017). Background & History. Accessed from: https://bowheadtransport.com/about/background-history/

[163] Hellenic Shipping News Worldwide. (2018). Alaska Marine Lines expands Western Alaska service to Arctic ports. Accessed from: https://www.hellenicshippingnews.com/alaska-marine-lines-expands-western-alaska-service-to-arctic-ports /

[164] Crowley Maritime Corporation. (2019). Western Alaska Marine Delivery. Accessed from: http://www.crowley.com/what-we-do/alaska-fuel-sales-and-distribution/western-alaska-marine-delivery/

Solid Waste Program regulates health and environmental compliance at solid waste facilities throughout the state, including in rural communities within this study area of interest. While some materials may be safely disposed of in local landfills, it remains challenging to dispose of both recyclable materials and household hazardous waste, such as used electronics, light bulbs, lead-acid batteries, anti-freeze, paint, and unused prescription medications. Coordinating and optimizing backhaul requires the same level of logistics of community resupply, and is largely coordinated with network of support of non-governmental organizations, private partners, village, regional, state, and Federal partners. [165] In some communities within the study area of interest, this hazardous waste is backhauled through a hub and spoke structure, where villages stage, package, and prepare materials locally, and then ship the materials by barge or small boat to the hub for consolidation before shipment to the final destination capable processing or recycling the materials, usually in Seattle.[166] Other communities are not well suited for participation in the hub and spoke model, and instead ship directly from the villages to the final destination, usually Anchorage or Seattle.

For the purposes of this study, it is not anticipated that waste removal will contribute additional vessels within the study area of interest. The consideration of waste, however, does add an additional layer of complexity to the Arctic marine transportation system: many re-supply vessels leaving the region are hauling waste, which in some cases, may be hazardous to the marine environment if released.

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[165] Zender Environmental Health and Research Group. (2015). "Regional Waste Backhaul in Rural Alaska: YR 2015 Baseline Assessment Draft Report". Accessed from: http://www.zendergroup.org/docs/backhaul_assessment.pdf

[166] Zender Environmental Health and Research Group. (2015). "Regional Waste Backhaul in Rural Alaska: YR 2015 Baseline Assessment Draft Report". Accessed from: http://www.zendergroup.org/docs/backhaul_assessment.pdf

Expansion of the Arctic Fleet

Another source of growth for the volume of vessel activity in the Arctic are the vessels expected to join the global fleet with capability to sail and/or transit Arctic waters. These vessels include new Polar Security Cutters, icebreaking research vessels, and an assortment of other vessels with ice capability.[167] A summary of the total number of vessels expected to be added to the area of interest by this source of growth is depicted in Figure 28.

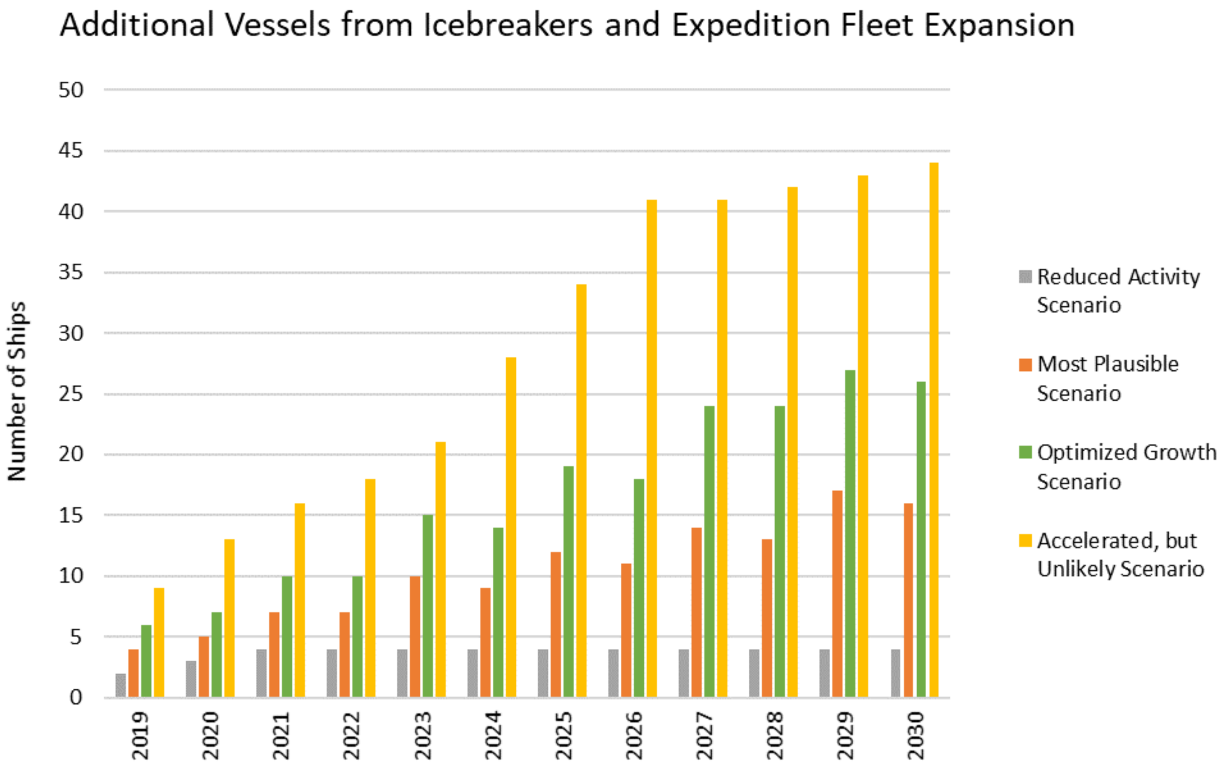

Figure 28: Combined sums of vessel counts related to fleet expansion in the study area of interest by scenario.

EXPANSION OF ICEBREAKERS

USCG Polar Security Cutters

In recent years, U.S. Coast Guard (USCG), together with the U.S. Navy, has been working to jointly fund the building of new Polar Security Cutters to recapitalize the nation's capability to access both polar

[167] Note: Icebreaking LNG tankers were previously considered under the Natural Resources section of the projections; see pages 49-63 of this report.

regions year round. The 2019 U.S. Federal Budget included $655 million to start the construction of the first Polar Security Cutter, along with an additional $20 million to purchase long lead-time materials for the construction of a second.[168] The USCG mission analyses for the polar regions calls for six icebreakers, at least three of which must be heavy icebreakers, to meet national security responsibilities. The current plan is to have three heavy polar icebreaking ships in operation by 2026,[169] with the first of these heavy polar icebreakers intended to meet national mission demands in Antarctic to replace the aging *USCGC Polar Star*.

For the four growth scenarios, it is assumed that the first new addition to the fleet will operate exclusively in Antarctica, and therefore will not affect vessel activity in the study area of interest. The Reduced Activity Scenario assumes that funding for the additional vessels will not be secured until after 2030. The remaining two icebreakers are assumed to be delivered in 2025 and 2029 in the Most Plausible Scenario, while the Optimized Growth Scenario assumes delivery in 2025 and 2027. The Accelerated, but Unlikely Scenario assumes the two vessels will be delivered and operational in 2024 and 2026, which assumes there will be no issues securing funding for the effort and an on-time delivery for both vessels.

Russia's Icebreakers

Russia is also slated to expand its icebreaking fleet, with the launch of three new nuclear-powered icebreakers over the early 2020s as part of Project 22220. [170] The first of the new ships, *Arktika* is slated to be commissioned in the 2019, season, with sister ships *Sibur* and *Ural* expected to follow in 2020 and 2021, respectively.[171] Two other ships from Project 22220 are expected to be delivered in 2024 and 2026.[172] This effort moves Russia closer to its stated goal of having at least 13 heavy duty icebreakers,

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[168] Werner, Ben. February 15, 2019. "Coast Guard secures $655 million for Polar Security Cutters in new budget deal". *USNI News*. Accessed from https://news.usni.org/2019/02/15/polar_security_cutter_coast_guard.

[169] Heavy Polar Icebreaker (HPIB) Detail Design and Construction Solicitation. Accessed from https://www.fbo.gov/index.php?s=opportunity&mode=form&id=8bfe58952dcb8836951b3b4d604520fc&tab=core&tabmode=list&=

[170] The Maritime Executive. (2019). Russia Launches Nuclear Ice-Breaker Ural. Accessed from: https://www.maritime-executive.com/article/russia-launches-nuclear-ice-breaker-ural

[171] Reuters. (2019). Russia launches new nuclear-powered icebreaker in bid to open up Arctic. Accessed from: https://www.theguardian.com/world/2019/may/26/russia-launches-new-nuclear-powered-icebreaker-in-bid-to-open-up-arctic

[172] U.S. Coast Guard Office of Waterways and Ocean Policy. (2019). Major Icebreakers of the World 2019.

including 9 nuclear-powered icebreakers, by 2035. This translates to the launch of approximately one new icebreaker each year until 2035, though it is unlikely that all vessels will be used in the study's area of interest.

Given how close Russia is to launching the first three ships, all scenarios assume that there will be 3 Russian icebreakers operating in this study's area of interest by 2021. The Reduced Activity Scenario assumes that no additional icebreakers will operate in the study area of interest, while the remaining scenarios each assume additional vessels will be added beyond 2021. In the Most Plausible Scenario, it is assumed that 5 icebreakers will transit the area of interest by 2030, while the Optimize Growth Scenario assumes 6 icebreakers, and the Accelerated, but Unlikely assumes 7 icebreakers.

Canadian Icebreakers

In August 2018, Canada purchased and awarded a contract to convert 3 medium icebreakers to assist in icebreaking missions in Atlantic Canada, the St. Lawrence and Great Lakes, and Arctic regions.[173] The three vessels, from the Offshore Supply Vessel operator Viking Supply Ships, will be converted by Chantier Davie Shipbuilding and enter into service shortly thereafter. The first, *CCGS Captain Molly Kool*, entered into service in December 2018, servicing Canada's Atlantic region, with the other two vessels expected to be delivered in 2019.[174]

It is unlikely that these new icebreakers will become annual components of vessel traffic in this study's area of interest, given the large icebreaking mission of the Canadian Coast Guard. In the Reduced Activity Scenario, it is assumed that none of these new icebreakers transit through the region, while the Most Plausible Scenario estimates that one icebreaker will transit through every other year. The Optimized Growth and Accelerated, but Unlikely Scenario posits that this rate will be slightly higher, adding, at most, three additional vessels to the total count every other year.

[173] Canadian Coast Guard. (2019). Canadian Coast Guard's latest icebreakers. Accessed from: http://www.ccg-gcc.gc.ca/Icebreaking/Fleet

[174] The Maritime Executive. (2018). Canada Buys Commercial Icebreakers for its Coast Guard. Accessed from: https://www.maritime-executive.com/article/canada-buys-commercial-icebreakers-for-its-coast-guard

Chinese Icebreakers

Besides China's planned addition of 21 icebreaking LNG-tankers discussed previously in this study, there may be other Chinese ice-capable ships transiting the Arctic over the next decade. In late 2018, China launched its first locally-built icebreaker, *Xue Long 2*, expanding the nation's icebreaking research vessels to two.[175] The Polar Class 3, diesel powered vessel is expected to be commissioned in 2019, likely joining the *Xue Long* in both Arctic and Antarctic research missions annually. This assumption informed the estimation for the scenarios, which all assume that the *Xue Long 2* will become a yearly visitor to the region across all four scenarios.

China's dedicated icebreaking fleet is also expected to grow beyond its two research vessels. In July 2018, the China National Nuclear Corporation solicited bids for construction of the nation's first nuclear-powered icebreaker.[176] According to details provided in March 2019 to the press by the China General Nuclear Power Group, a state-owned nuclear power company, the nuclear icebreaker will be comparable to the *Arktika*-class icebreakers.[177] Little information is available about the delivery of this first icebreaker or about whether additional vessels will follow, but given Chinese investments along the Northern Sea Route, the demonstrated ability to build icebreaking vessels domestically, and the planned expansion of icebreaking LNG tankers, it is possible that more Chinese-built icebreakers will operate in the study area of interest over the next decade, in addition to the planned 21 icebreaking LNG tankers discussed previously.

For the purposes of developing projections, various growth rates of are explored in the four scenarios. The Reduced Activity Scenario posits that only 1 vessel, *Xue Long 2*, will be launched in the next decade. The Most Plausible Scenario assumes that the second Chinese-built icebreaker will be launched in 2023, coinciding with the delivery date of China's icebreaking LNG tankers. The final two scenarios assume that additional icebreakers will be constructed and launched before 2030. The Optimized Growth Scenario assumes a third icebreaker will be delivered before the end of the decade, while the

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[175] The Maritime Executive. (2018). China Launches Icebreaker *Xuelong 2*. Accessed from: https://www.maritime-executive.com/article/china-launches-icebreaker-xuelong-2

[176] Eiterjord, Trym Aleksander. (2018). "China's Planned Nuclear Icebreaker". The Diplomat. Accessed from: https://thediplomat.com/2018/07/chinas-planned-nuclear-icebreaker/

[177] Nilsen, Thomas. (2019). "Details of China's nuclear-powered icebreaker revealed". The Barents Observer. Accessed from: https://thebarentsobserver.com/en/arctic/2019/03/details-chinas-nuclear-powered-icebreaker-revealed

Accelerated, but Unlikely Scenarios assumes a fourth icebreaker will be built and launched before the end of the decade. A summary of projected Chinese icebreakers is included in Table 25.

Table 25: Summary of additional Chinese icebreakers expected in study area of interest by 2030

	Additional Anticipated Icebreakers in Study Area of Interest by 2030			Total Number of New Chinese Icebreakers in Study Area of Interest by 2030
	Icebreaking LNG Tankers*	Research Icebreakers	Other Icebreakers	
Reduced Activity Scenario	3 vessels	1 vessel	0 vessels	4 vessels
Most Plausible Scenario	10 vessels	1 vessel	1 vessel	12 vessels
Optimized Growth Scenario	15 vessels	1 vessel	2 vessels	17 vessels
Accelerated, but Unlikely Scenario	21 vessels	1 vessel	3 vessels	25 vessels
	*Considered under Natural Resources section of report			

Other Icebreakers

Several other icebreakers are expected to be launched in the near future and have the potential to sail through the study area of interest in the next decade, many of which are specifically designed for Arctic and Antarctic research. The RRS *Sir David Attenborough*, owned by the United Kingdom's Natural Environment Research Center, was launched in 2018 and is scheduled to enter into service in August 2019 as a research vessel working in both the Arctic and Antarctic.[178] The German research vessel, *Polarstern 2*, is expected to be launched by 2022.[179] South Korea is also expected to launch its second research vessel for polar research in 2023.[180] Both Australia and Chile are also expected to launch icebreakers in the early 2020s, but it is likely that those vessels will primarily transit Antarctic waters.

For the scenarios featured in this report, it is assumed that some of these new vessels will transit through the study area of interest. By 2030, it is projected that 0, 1, 2, and 3 additional ships will pass

[178] British Antarctic Survey. (2018). "RRS *Sir David Attenborough*". Accessed from https://www.bas.ac.uk/polar-operations/sites-and-facilities/facility/rrs-sir-david-attenborough/

[179] Maritime Journal: Insight for the European Commercial Marine Business. (2018). "German Research Ships Get a Going-Over". Accessed from: https://www.maritimejournal.com/news101/vessel-build-and-maintenance/vessel-repair-and-maintenance/german-research-ships-get-a-going-over

[180] U.S. Coast Guard Office of Waterways and Ocean Policy. (2019). Major Icebreakers of the World 2019.

through the study area of interest in the Reduced Activity Scenario, Most Plausible Scenario, Optimized Growth Scenario, and Accelerated, but Unlikely Scenario, respectively.

EXPANSION OF POLAR CLASS CRUISE AND ADVENTURE SHIPS

Tourism in the Arctic has largely been centered in the European and Russian Arctic, but is expected to expand into the study area of interest in the years to come. In advance of the 2019 season, seven unique cruise ships planned to call on Nome.[181] By 2022, it is anticipated that 28 new, specially designed expedition ships will add to the world-wide fleet of 80 expedition ships.[182] These vessels are smaller than traditional cruise ships, accommodating around 200 guests each.[183] Of the 28 new expedition vessels, several will meet Polar Class (PC) requirements, including Ponant's LNG-powered *Le Commandant Charcot* (PC 2), Vantage Cruise Lines' *Ocean Explorer* and *Ocean Odyssey* (both PC6), and Hurtigruten's hybrid 530-passenger ship *Roald Amundsen*.[184]

It is anticipated that many of these vessels will service the European Arctic and Antarctic, but may expand to the U.S. and Canadian Arctic to accommodate passenger demands for unique destinations and experiences. In the Reduced Activity Scenario, it is assumed that ships from this expedition fleet will not transit through the study area of interest, working under the auspices that tours will be confined to Svalbard, Iceland, and the east coast of Greenland and that the adventure ships currently servicing the region will continue to do so. In the Most Plausible Scenario, it is anticipated that this expanded fleet will begin to become a growing component of traffic in the region, adding 1 vessel every 2 years, until 7 vessels pass through the study area annually in 2030. The Optimized Growth Scenario anticipates that 2 vessels will be added every 2 years, until half of the planned fleet becomes regular fixtures of the area of interest's vessel count. The Accelerated, but Unlikely Scenario estimates that all 28 will pass through the area of interest annually by 2026. A summary of this projected activity is included in Table 26.

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[181] Information provided during the 2019 Arctic Waterways Safety Committee Meeting: March 18, Anchorage AK. Meeting materials may be accessed from: http://www.arcticwaterways.org/

[182] Nilsen, Thomas. (2018). Arctic cruise ship boom. *The Barents Observer.* Accessed from: https://thebarentsobserver.com/en/travel/2018/05/arctic-cruise-ship-boom

[183] Cruise industry News. (2018). 2018 Expedition Market Report Preview. Accessed from https://www.cruiseindustrynews.com/store/product/digital-reports/2018-expedition-report/

[184] Ibid.

Table 26: Summary of additional vessels anticipated from expanded adventure fleet

		Total number of additional adventure ships per year in study AOI											
	Scenario Assumption	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Reduced Activity Scenario	0 additional vessels added each year	*0*											
Most Plausible Scenario	1 vessel added every 2 years until 7 vessels in AOI	*2*		*3*		*4*		*5*		*6*		*7*	
Optimized Growth Scenario	2 vessels added every 2 years until 14 vessels in AOI	*4*		*6*		*8*		*10*		*12*		*14*	
Accelerated, but Unlikely Scenario	All of planned ships sail within study AOI as soon as they are delivered	*7*	*10*	*12*	*14*		*20*	*25*	*28*				

Seasonally Rerouted Shipping Through the Arctic

The fourth and final quantifiable source of growth incorporated into the projections is the volume of traffic transiting through Arctic waters as an alternative route to established trans-oceanic routes. One of the major appeals of utilizing the Northern Sea Route and Northwest Passage for shipping is the promise that these routes would trim costly distance from transoceanic shipping routes. For example, the Northern Sea Route saves 35–60% of the distance compared to other, more traditional routes, such as the Suez Canal for carriers shipping between northern Europe and the far East,.[185] However, the advantage to using these routes assumes that sea ice is minimal, environmental conditions are favorable, and insurance and other costs are comparable to other transoceanic routes.

In the 2015 CMTS Arctic vessel projection report, this growth was referred to as diverted global traffic, and it was assumed that the shorter distances and reduced piracy risks of the northern routes would outweigh the environmental and logistical challenges to operate in the Arctic. The 2015 CMTS report assumed this diversion would apply to approximately 5% of the July–November transoceanic traffic,[186] in line with other published estimates at the time.[187] Additionally, the report was limited to only include the current ship profiles traveling across the region (tankers, containers, general cargo and bulk carriers).

Our previous approach, however, did not take into consideration the unique demands of operating in the region. In addition to meeting build and operating requirements of the newly established Polar Code, vessels must also adhere to the draft limitations for transiting through the shallow region. The Northern Sea Route extends about 4740 nautical miles with a controlling draft of 41 feet (12.5 m), while the Northwest Passage runs 5225 nautical miles and a controlling draft of 33 feet (10 m).[188] This

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[185] Arctic Marine Shipping Assessment (2009). Protection of the Arctic Marine Environment Working Group, Arctic Council. Accessed from https://oaarchive.arctic-council.org/handle/11374/54

[186] Azzara, A. J., Wang, H., Rutherford, D., Hurley, B., and Stephenson, S. (2014). *A 10-Year Projection of Maritime Activity in the U.S. Arctic*. A Report to the President. U.S. Committee on the Marine Transportation System, Integrated Action Team on the Arctic Available at https://www.cmts.gov/downloads/CMTS_10-Year_Arctic_Vessel_Projection_Report_1.1.15.pdf

[187] Corbett, J.J., Lack, D.A., Winebrake, J.J., Harder, S., Silberman, J.A., and Gold, M. (2010). "Arctic shipping emissions inventories and future scenarios" *Atmospheric Chemistry and Physics*, 10, 9689-9704. https://doi.org/10.5194/acp-10-9689-2010

[188] Chief of Naval Operations. (2014). The United States Navy Arctic Roadmap for 2014 to 2030 (Rep.). Accessed from: https://www.navy.mil/docs/USN_arctic_roadmap.pdf

report assumes that the shallow waters of the region limit the kinds of vessels able to fully utilize the Northwest Passage and the Northern Sea Route to Seawaymax, Handysize, Handymax, Qatarmax, and Panamax sized vessels.[189,190,191]

To estimate the growth of vessels related to this type of activity, historical data from the Panama Canal and from the Northern Sea Route along with projected global growth rates were used to model how the region may be used by vessels as an alternative transoceanic route during a limited, seasonal operating window.

Per vessel traffic data from the Northern Sea Route from 2014–2018, the average number of vessels transiting through the Northern Sea Route considered to be shipping through the Arctic was 12 vessels in 2017 and 16 vessels in 2018.[192] Taking an average of the two, it is assumed that 14 vessels are the baseline of vessels being seasonally rerouted through the Arctic.

Transit data from the Panama Canal and projected growth rates of international seaborne trade for specific vessel classes for 2018–2023 developed by the United Nations Conference on Trade and Development (UNCTAD) were combined to estimate the pool of suitable candidates to be rerouted through the Arctic. Only vessels transiting the canal that met the right seasonal (July–November), size (Panamax), and type (bulk carriers, tankers, general cargo, refrigerated cargo[193] and container ships) were considered to meet the requirements for transiting through the Arctic.[194]

The baseline of total ships meeting the candidate requirements was generated from mean historical data from the Panama Canal from the 2017 and 2018. There was an average of 3,975 ± 128

[189] Various Bulk carrier sizes and employment guide. (2010). Accessed from: http://bulkcarrierguide.com/size-range.html

[190] Rodrigue, J. (2017). Tanker Sizes and Classes. Accessed from: https://transportgeography.org/?page_id=6877

[191] Kantharia, R. (2019). The Ultimate Guide to Ship Sizes. Accessed from: https://www.marineinsight.com/types-of-ships/the-ultimate-guide-to-ship-sizes/

[192] Per the discussion of the Northern Sea Route on page 32–34 of this report, vessels assumed to be seasonally rerouted through the Arctic (as opposed to engaged with destinational shipping) are vessels with origins and destinations outside of Russia which are not Russian flagged ships making complete transits of the Northern Sea Route.

[193] Though not included in the 2015 report, 11 reefers have transited the Northern Sea Route since 2015, with 2 meeting the non-Russian origin/destination requirement of this model, indicating that that some refrigerated cargo could feasibly be routed through the Arctic.

[194] United Nations Conference on Trade and Development. (2018). Review of the Marine Transport 2018 (Rep.). Accessed from: https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

total Panamax sized-ships that met the candidate requirements in 2017 and 2018. Applying the vessel-specific growth rates from UNCTAD, this volume of traffic is expected to grow 62% over baseline 2017–2018 values (Table 27).

For the scenarios included in this report, a selected percentage of these Panama Canal vessels were added to the baseline of vessels to explore different potential growth rates of the captured Arctic fleet. The established baseline of vessels using the Arctic for trans-oceanic shipment was 14 vessels, which represents 0.41% of the current pool of vessels that could possibly be rerouted. This percentage was used to inform the values selected for the four scenarios. The Reduced Activity Scenario assumes that vessels rerouted through the Arctic will maintain the current value of 0.41% of the seasonal Panamax traffic until 2030. The Most Plausible Scenario assumes this pool will grow to 0.75% of the candidate pool over the next decade, while the Optimized Growth Scenario assumes that 1.0% will be rerouted. Finally, the Accelerated, but Unlikely Scenario assumes that 1.5% of the applicable seasonal Panamax traffic may be rerouted through the area of interest by 2030.

Table 27: Projected growth of Panamax vessels transiting the Panama Canal, 2019–2030

Panamax Vessels Utilizing the Panama Canal*	FY 2017	FY 2018	Average (FY17–18)	Projected Growth*	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Container	1,539	1,395	1,467	6.00%	1,555	1,648	1,747	1,852	1,963	2,081	2,206	2,338	2,478	2,627	2,785	2,952
Dry bulk	2,790	2,476	2,633	4.90%	2,762	2,897	3,039	3,188	3,344	3,508	3,680	3,861	4,050	4,248	4,456	4,675
Chemical Tankers	1,955	2,035	1,995	2.60%	2,047	2,100	2,155	2,211	2,268	2,327	2,388	2,450	2,513	2,579	2,646	2,715
Liquefied Petroleum Gas	337	407	372	2.60%	382	392	402	412	423	434	445	457	469	481	493	506
LNG	4	-	2	2.60%	2	2	2	2	2	2	2	2	3	3	3	3
Crude Tankers	607	583	595	1.70%	605	615	626	637	647	658	670	681	692	704	716	728
General Cargo	724	658	691	3.80%	717	745	773	802	833	864	897	931	967	1,003	1,041	1,081
Refrigerated	868	779	824	3.80%	855	887	921	956	992	1,030	1,069	1,110	1,152	1,196	1,241	1,288
Passengers†	239	236	238	n/a												
Roll-on/Roll-off†	779	793	786	n/a												
Other†	322	348	335	n/a												
Total Panamax	10,164	9,710	9,937													
Candidates for the Arctic, by Type	8,824	8,333	8,579		8,925	9,287	9,665	10,060	10,473	10,905	11,357	11,830	12,324	12,841	13,382	13,948
Candidates for the Arctic, by Type & Season‡	**4,066**	**3,884**	**3,975**		**3,570**	**3,715**	**3,866**	**4,024**	**4,189**	**4,362**	**4,543**	**4,732**	**4,930**	**5,136**	**5,353**	**5,579**
Candidates for the Arctic, by Type & Season‡, without containers	**3,530**	**3,333**	**3,431**		**2,948**	**3,055**	**3,167**	**3,283**	**3,404**	**3,530**	**3,661**	**3,797**	**3,938**	**4,086**	**4,239**	**4,398**

* Panama Canal data obtained from the Panama Canal Authority[195]; Annual Projected Growth values obtained from the UNCTAD Review of Maritime Transport, 2018[196]
† These types of vessels were assumed not to be diverted or captured through the Arctic and therefore, are excluded from projection calculations
‡ 40% of the traffic, on average for FY 2017–2018, moved through the Panama between July – November

[195] Statistics and Models Administration Unit (MEMM). (2018). Traffic Through the Panama Canal by Lock Type and Market Segment Fiscal Years 2018-2017 (Rep. No. 11). Accessed from: https://www.pancanal.com/eng/op/transit-stats/2018/Table-11.pdf

[196] United Nations Conference on Trade and Development. (2018). Review of the Marine Transport 2018 (Rep.). Accessed from: https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

Using these assumptions, the number of additional vessels rerouted to Arctic transits is expected to grow across all four scenarios. In the Reduced Activity Scenario, the number of additional ships expected is 9 vessels by 2030. The Most Plausible Scenario projects that an additional 28 vessels will pass through the area of interest by 2030. The Optimized Growth Scenario projects that an additional 42 vessels will transit the area of interest by 2030. Finally, the Accelerated, but Unlikely Scenario estimates that 70 vessels will cross through the area of interest by 2030. While the scenarios presented here all include containerized cargo ships, this volume is expected to be a very small slice of the total rerouted shipping activity, contributing only 2–11 container ships by 2030. A summary of these findings is included in Table 28 and presented in Figure 29.

Table 28: Summary of additional vessels anticipated in study area of interest resulting from rerouted shipping through the Arctic

	Number of Additional Ships Rerouted Each Year	Projected Number of Additional Ships Rerouted in 2030	Projected Total Number of Ships Rerouted through the Arctic 2030
Reduced Activity Scenario	0 – 1 vessels	9 vessels	23 vessels
Most Plausible Scenario	2 – 3 vessels	28 vessels	42 vessels
Optimized Growth Scenario	3 – 4 vessels	42 vessels	56 vessels
Accelerated, but Unlikely Scenario	6 – 7 vessels	70 vessels	84 vessels

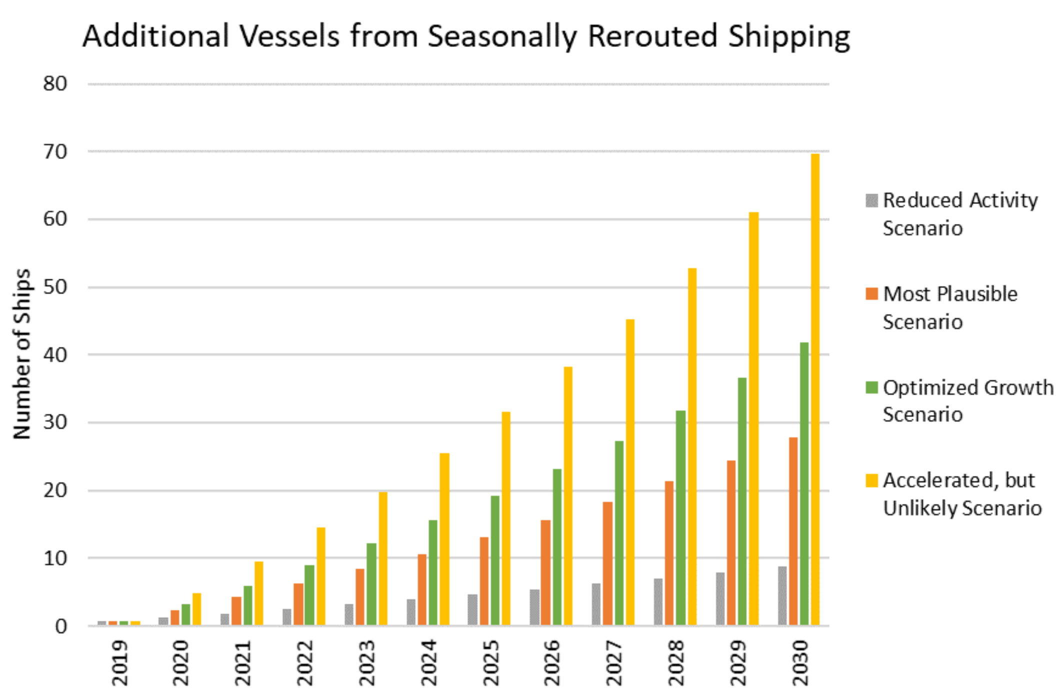

Figure 29: Summary of additional vessels related to the seasonally rerouted ships through the Arctic.

PROJECTION RESULTS & DISCUSSION

In the final steps of the projection process, the estimated vessel counts associated with each discrete source of growth were totaled together to calculate the additional vessels expected annually through 2030. This sum was then added to the assumed baseline of vessel activity to generate a total value of projected vessels by year for each scenario. As previously discussed, this assumed baseline of vessel activity is 255 vessels. A summary of the scenario results is presented in Table 29, Figure 30, and Figure 31.

There are multiple ways to examine the results of these projections, and the following pages will discuss the results by sources of growth, by scenario, and finally, in relation to relevant and available historical data.

Table 29: Summary of additional vessels by source and scenario in 2030

	Natural Resource Development & Activities	Infrastructure Development	Fleet Expansion	Seasonally Rerouted Shipping	Total Additional Vessels by 2030
Reduced Activity Scenario	11 vessels	5 vessels	4 vessels	9 vessels	**29 vessels**
Most Plausible Scenario	72 vessels	7 vessels	17 vessels	28 vessels	**124 vessels**
Optimized Growth Scenario	92 vessels	10 vessels	27 vessels	42 vessels	**171 vessels**
Accelerated, but Unlikely Scenario	153 vessels	13 vessels	45 vessels	70 vessels	**281 vessels**

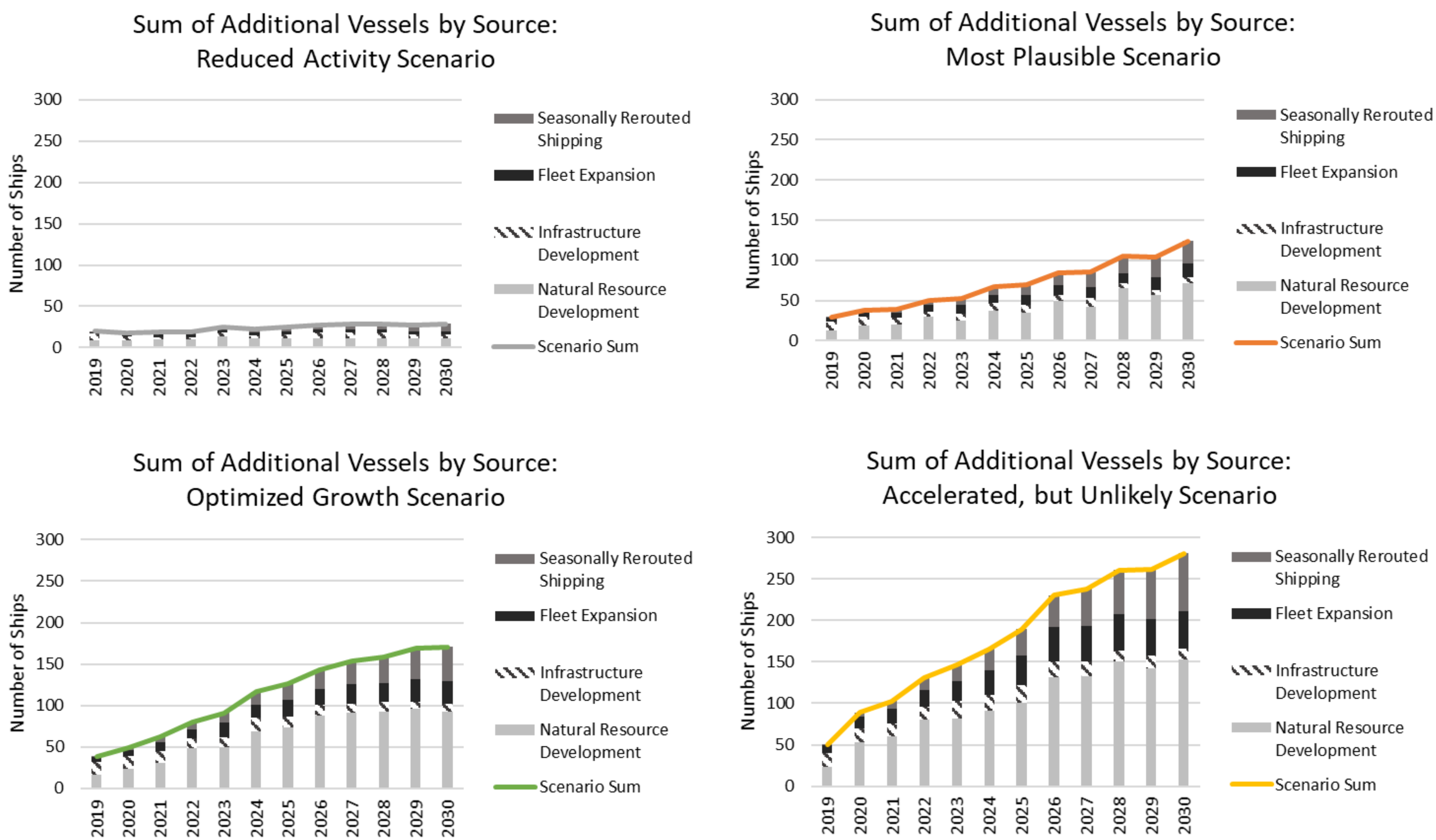

Figure 30: Additional vessels by type of source of growth for the four scenarios. The colored line on each graph is the trace of the total annual growth in additional vessels for each scenario.

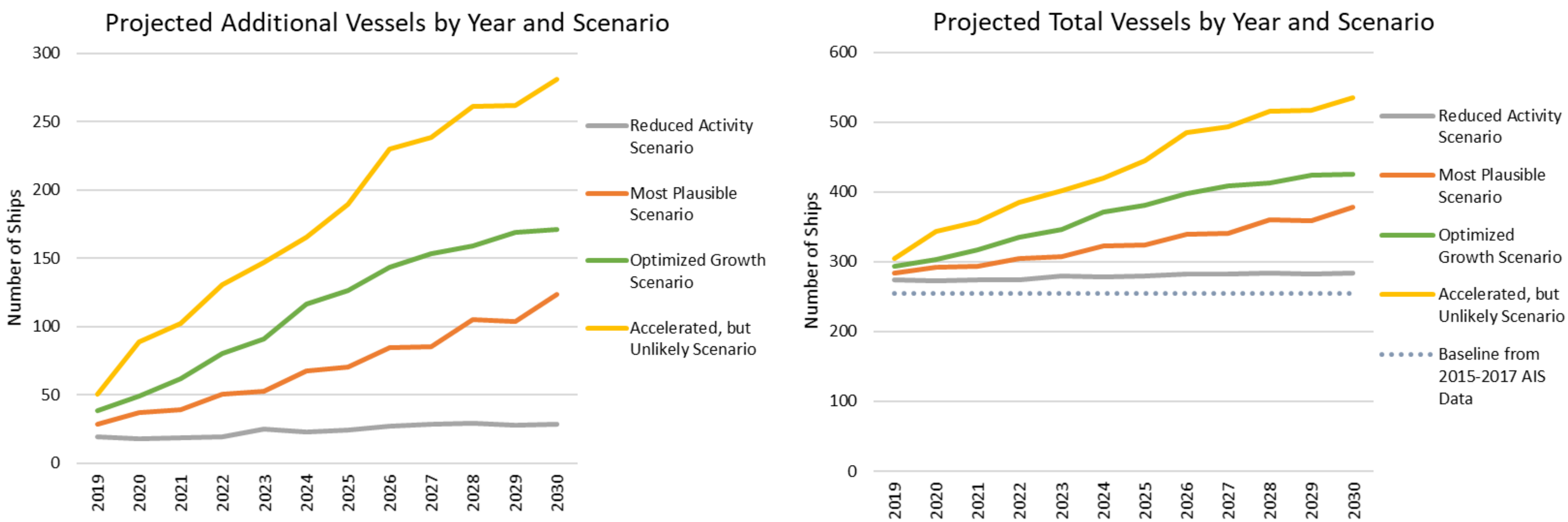

Figure 31: Projected additional ships by scenario (left) and total number of ships by scenario (right). Total number of additional vessels (left) is the sum of all sources of growth by year for each scenario. These additional values were added to the assumed baseline level of vessel activity to generate the total number of unique vessel projected to pass through the study area of interest through the next decade (right).

Comparing the Sources of Growth

The four types of growth considered for this projection were selected after careful consideration of the possible quantifiable drivers of vessel activity through the study area of interest. Of the total 36 sources of growth considered for these projections, almost half of the factors considered were related to natural resource activities in the Arctic.

NATURAL RESOURCE ACTIVITIES

Consistently, across all scenarios, natural resource exploration and development related traffic was the largest contributor to projected traffic growth among the four types of sources of growth assessed. By 2030, natural resource exploration and development is expected to contribute 11 vessels in the Reduced Activity Scenario, 72 vessels in the Most Plausible Scenario, 92 vessels in the Optimized Growth Scenario and 153 vessels in the Accelerated, but Unlikely Scenario. More than 50% of this natural resource-related growth in all four scenarios is anticipated to be growth from the development of non-U.S. natural resources. This result suggests that the Bering Strait is expected to become a major gateway for export of the Arctic's natural resources over the next decade, particularly for Russian exports of LNG and in support of mineral resource extraction in Canada.

SEASONALLY REROUTED SHIPPING THROUGH THE ARCTIC

Second behind natural resource development is the growth of vessels rerouted through the Arctic, which this study has modeled to grow linearly with time. By 2030, this study estimates that transshipment through the Arctic will contribute 9 vessels in the Reduced Activity Scenario, 28 vessels under the Most Plausible Scenario, 42 vessels in the optimized growth scenario, and 70 vessels in the Accelerated, but Unlikely Scenario. Additionally, the scenarios presented here all include containerized cargo ships, but this volume is expected to be a very small slice of the total rerouted shipping activity, contributing 2–11 container ships by 2030.

These rerouting estimates also do not account for any vessels attempting to cross the Arctic via the Transpolar Sea Route[197], which even under high climate forcing models, is not expected to be accessible to ships less than Polar Class 6 vessels before the mid-century, let alone within the timeframe of this projection.[198] It is expected that the use of this route will increase, however, once the Arctic Ocean is seasonally ice free, and when it is accessible, growth from this source of vessel activity in the study area of interest will likely grow faster than the rates estimated here, because the Transpolar Sea Route does not have the same draft restrictions as other trans-Arctic passages.

EXPANSION OF THE ARCTIC FLEET

The expansion of the Arctic fleet, which includes icebreakers and ice-hardened cruise ships, is the third largest source of growth among the elements considered. By 2030, it is anticipated that there will be an additional 4 vessels added to the fleet in the Reduced Activity Scenario, 17 vessels in the Most Plausible Scenario, 27 vessels in the Optimized Growth Scenario, and up to 45 vessels in the Accelerated, but Unlikely Scenario. While there is a high probability that these vessels will be launched and transit polar waters, it remains to be seen how many and how often these vessels ply waters around the Bering Strait.

Icebreaking vessels launched by Russia and Canada are likely to provide services along the Northern Sea Route and Northwest Passage, respectively, and therefore are expected to spend the least amount of time in the study area of interest. However, other icebreakers that will transit through the Bering Strait, including the USCG Polar Security Cutters and icebreaking research vessels, are likely to spend considerable time in the region, and so measuring future vessel activity by unique ships may significantly underestimate the volume of activity attributable to these vessels.

Ice-hardened cruise and adventure ships have the potential to be the largest source of unique vessels added to the Arctic fleet over the next decade. Although the 28 new adventure cruise ships expected to be launched by 2024 may be used for cruises to the Antarctic, European Arctic, or Central

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[197] The Transpolar Sea Route refers to the future sea route 'across the top' of the Arctic, connecting the Atlantic and Pacific Oceans through the central Arctic Ocean.
[198] Melia, N., Haines, K., and Hawkins, E. (2016). Sea ice decline and 21st century trans-Arctic shipping routes. *Geophysical Research Letters*. 43, 9720-9728. Accessed from https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2016GL069315

Arctic oceans, the demand for extreme and exotic destinations continues to grow and shape the cruise industry.[199] The long-term viability of this growth, however, depends on multiple factors, such as the growth of marine transportation system infrastructure to support tourists, the health of both local and global economies to support the tourism industry, and the social license to operate in the region.

INFRASTRUCTURE DEVELOPMENT

As measured by additional unique vessels, the smallest source of growth considered in this study is related to infrastructure development. While all other types of growth were found to have a close linear relationship with time, infrastructure development sources of growth did not appear to have any correlation with time. This source of vessel activity was very challenging to predict, given the complexities of financing, staging, and construction in the region. Additionally, this projection primarily accounted for the projects with a sealift requirement planned for the first half of the 2020s. Vessel activity related to infrastructure development, particularly efforts to replace, repair, and/or armor existing infrastructure, may increase dramatically over the next decade as environmental changes along the coastline and onshore shorten the lifespan and/or threaten the existing infrastructure in the region.

By transits, however, this source of vessel activity may grow to become one of the largest over the next decade. The current vessels that supply coastal communities along western and northern Alaska are largely small tug/towing vessels with shallow drafts, including landing crafts, designed to be beached onshore to offload goods (see Table 1). In Kotzebue, one of the larger communities in the study area of interest, it takes 3 different lightering vessels to get commodities to the community. The first includes transferring to smaller vessels in Nome, sailing to Kotzebue, and then lightering again onto smaller, 200 dwt landing craft vessels capable of reaching shore. One example included in the USACE Kotzebue Harbor Feasibility Study noted the final stage of transfer can be as much as 10–15 lightering trips per sailing to fully unload.[200] Given all this, this source of vessel activity remains the most difficult to constrain among the ones considered in this study.

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[199] Cruise industry News. (2018). 2018 Expedition Market Report Preview. Accessed from https://www.cruiseindustrynews.com/store/product/digital-reports/2018-expedition-report/

[200] U.S. Army Corps of Engineers, Alaska District. 2019. "Kotzebue Harbor Feasibility Study: Navigation Improvements at Cape Blossom". Accessed from https://www.poa.usace.army.mil/Portals/34/docs/civilworks/publicreview/kotzebueharbor/KotzebueAppDEconomics.pdf?ver=2019-01-09-152556-093

COMPARING THE PROPOSED SCENARIOS

The four scenarios featured in this study each assumed different outlooks about how the risk associated with operating in the region may be mitigated, resulting in four different trajectories about how vessel activity in the northern U.S. Arctic region and the study area of interest might develop over the next decade.

- The Reduced Activity Scenario assumes that the high risks of operating in the region are not mitigated over the next decade and to reflect this, the lowest amount of traffic for each source of growth were assumed. The Reduced Activity Scenario totaled 284 vessels in 2030, a value just slightly higher than the margin of error assumed for the scenario's baseline, 255 ± 26. The scenario had an average annual growth rate of 0.30%, which is slightly less than the average annual growth rate for the State of Alaska from 2010–2017 (0.59%)[201], a period of rapid growth followed by a state-wide recession triggered by the crash in the price of oil and large state deficits.[202] The largest source of growth included in this scenario comes from non-U.S. flagged vessels, most notably, foreign flagged icebreakers, icebreaking LNG tankers delivering Russian LNG to Asia, as well as vessels required to resupply Canadian mining operations.

- The Most Plausible Scenario incorporates the most reasonable estimates of traffic growth and vessel counts into a single scenario, assuming operators will have enough certainty to advance growth in the region, but at a more conservative pace. By 2030, under this scenario, it is expected that the region will have 379 vessels transiting through the area of interest, a value that represents a 48% increase over the projection baseline (2015–2017) and just about three times larger than 2008's vessel numbers. The average annual growth for vessels in the region from 2019–2030 under this scenario is expected to be 2.58%. This rate is in line with cargo trends at the Port of Nome from 2010–2018 (2.35%)[203] and with the U.S. economy over the same period (2.32%).[204] In this scenario, it is assumed that development moves forward for several U.S.

[201] Bureau of Economic Analysis. (2018). Gross Domestic product by state: Alaska. SAGDP2N. Data accessed from: https://www.bea.gov/data/gdp/gdp-state

[202] Brehmer, E. (2019). Economists say Alaska recession likely to end in 2019. Accessed from: https://www.adn.com/business-economy/2019/01/27/economists-say-alaska-recession-likely-to-end-in-2019/

[203] Personal communication, Joy Baker, Port Director, City of Nome, February, 2019.

[204] International Monetary Fund. 2019. World Economic Outlook: IMF Data Mapper. Data obtained from https://www.imf.org/external/datamapper/ on April 5, 2019.

natural resource projects in addition to many more non-U.S. natural resource projects. Vessels associated with infrastructure development, particularly related to infrastructure repair, replacement, and armament, are assumed to be few in number and sporadic in deployment. Additionally, it is anticipated that tourism-related traffic is expected to grow modestly and that planned infrastructure projects will progress as or near scheduled.

- The Optimized Growth Scenario assumes that much of the risk for operating in the region will be mitigated and incorporates the higher rates of growth from the available data. This scenario captures vessel counts and growth rates in the realms of what has been proposed, but these quantities may not necessarily be the most probable. From the elements of growth incorporated in this study, it is assumed that the total number of vessels transiting through the study area of interest will be 425 vessels by 2030, a value which is nearly 70% higher than the projection's baseline (255 vessels) and nearly 3.5 times higher than the number of ships transiting through the region in 2008. The projected average annual growth rate required to reach this level is 3.31%, which is consistent with pre-recession rates of cargo through the Port of Nome (3.58% from 2010–2015),[205] indicating that this region has sustained this rate of growth before and may be able to do so in the future. This scenario builds on the Most Plausible Scenario, adding more vessels for each element of growth at faster rates. Notably, this scenario includes vessels related to ambitious projects which have been proposed but still have a large degree of uncertainty about their feasibility. These projects include the Arctic LNG 2 facility and offshore exploration of the Chukchi Sea for oil and gas.

- The Accelerated, but Unlikely Scenario incorporates all sources of growth for the region, including components which may be unlikely according to the best available data. This scenario is meant to act as a ceiling for the projections; while theoretically possible, this combined scenario is highly unlikely. Under this scenario, the number of ships transiting the study area of interest in 2030 is 535 vessels, which is over twice the average number of ships in the area in 2015–2017 and 4.4 times higher than 2008 numbers of vessels. To reach this total, this scenario grows on average of 4.93% each year, a rapid rate which outpaces the projected rate of the Global GDP from 2019–

[205] Personal communication, Joy Baker, Port Director, City of Nome, February, 2019

2023 (4.06%).[206] Additional differences between this scenario and the Optimized Growth Scenario arise from the inclusion of both onshore and offshore renewable wind projects, transits from other icebreakers assets from neighboring Arctic states and non-Arctic states, shipment from LNG from the North Slope, and robust efforts to address infrastructure needs stemming from the rapidly changing environment. For this scenario to come to fruition, significant advances in the predictability and structure for Arctic operations would need to occur. This includes consistent implementation and enforcement of international regulatory standards, like the Polar Code, as well as standards for classification of ships and insurance requirements. This scenario also assumes that the regulatory and permitting environment for offshore activities remains stable and that global commodity prices provide sufficient demand for long-term investment and operation.

Comparing the Results with Historical Trends in the Region

Although there is little historical data for the study's complete area of interest, there is considerable overlap between this study's area of interest and the historical data for a similar region collected by the U.S. Coast Guard.[207] This area extends from the Bering Strait, north to the North Pole, east to Banks Island and west to New Siberian Islands, and since 2008, USCG District 17 has compiled vessel counts for this region (see Figure 17).

Comparing the projected data with the historical data from this area reveals that three highest growth scenarios are in close agreement with mathematical regressions of the available historical data, indicating that the projected growth aligns with trends in the region over the last decade (Figure 32). The Accelerated, but Unlikely Scenario vessel projection values are in very close agreement with the linear regression from the USCG data set. The Most Plausible Scenario vessel projection values are in close agreement with the natural logarithmic regression of the same historical data set. The Optimized Growth Scenario lays approximately between the two fitted curves. The historical data has a slightly better fit to the natural logarithmic regression ($R^2 = 0.89$) compared to the linear regression ($R^2 = 0.83$), indicating that the Most Plausible Scenario has the best agreement with the historical data available among the four

[206] International Monetary Fund. 2019. World Economic Outlook: IMF Data Mapper. Data obtained from https://www.imf.org/external/datamapper/ on April 5, 2019.

[207] For more, please see previous discussion on pages 30–31 of this report.

scenarios proposed. If the number of vessels in the study area of interest over the next decade aligns with the mathematical predictions based on historic data, it would suggest that the region may enter a period of slower, but consistent growth over the next decade than what was observed in the last decade. In other words, the Most Plausible Scenario best agrees with historic data trends and predicts a slow, but steady growth of vessels in the region, driven by a balanced mix of the four factors used to build the projections.

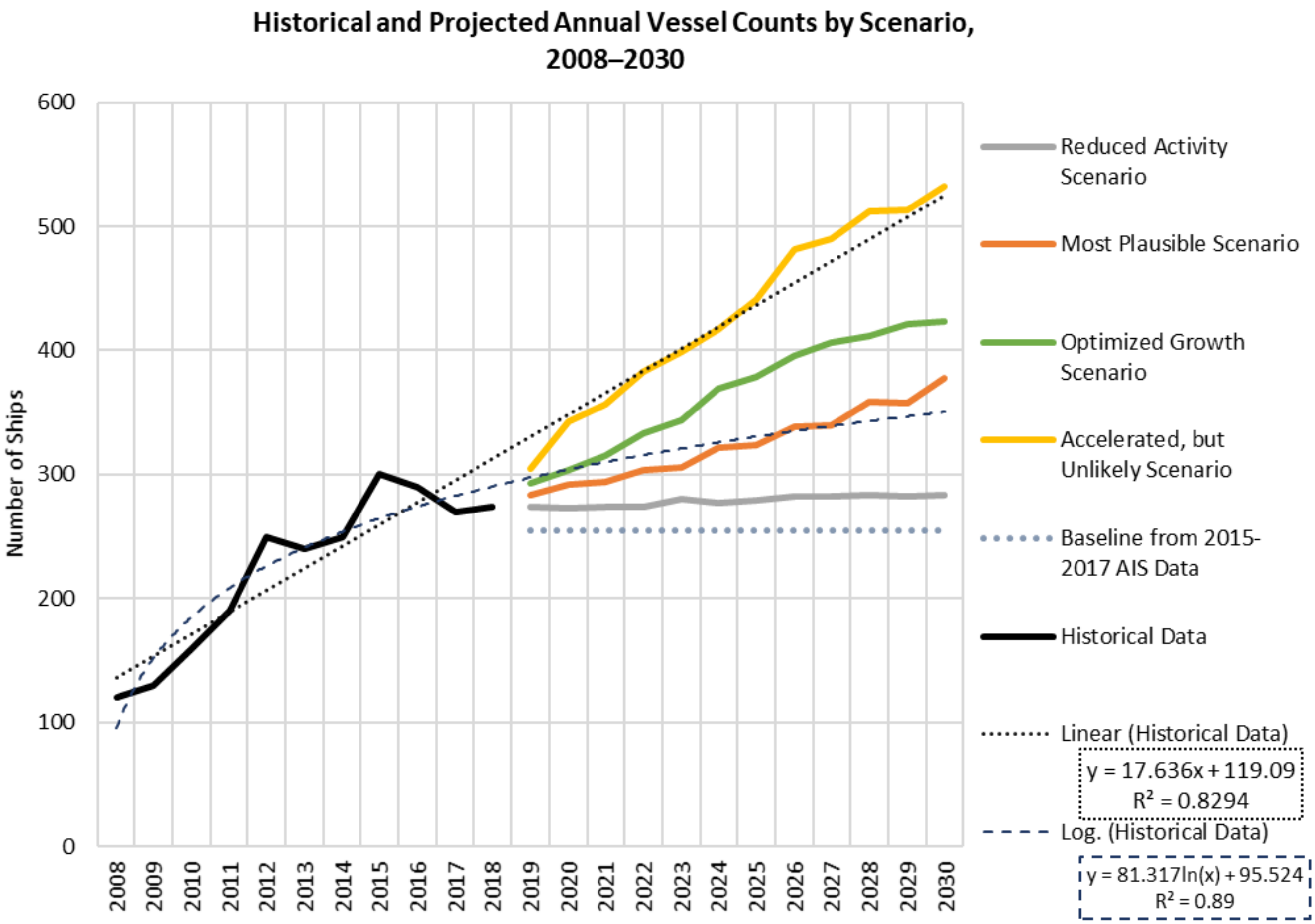

Figure 32: Historical and projected number of annual vessels by scenario, 2008–2030. Historical data for waters north of Bering Strait provided by USCG (black line), along with the projected values of unique vessel counts in area of interest from 2019–2030, with and without container ships for the Accelerated, but Unlikely, Optimized Growth Scenario, Most Plausible Scenario, and the Reduced Activity Scenario. The dotted line is the assumed baseline of vessel activity, measured from the 2015–2017 mean number of ships in the study area of interest. Linear and natural logarithmic regressions are fitted to the historical USCG data sets; formulae for best fit lines and R^2 values are listed below in legend.

Furthermore, the alignment with the logarithmic growth curve implies something else about the region by its shape, which flattens out over time maturing from relatively fast-paced growth and approaching little to no growth toward the end of the curve. This approach toward equilibrium implies that the system has reached a carrying capacity [208], or the point at which the environment, market, or system is unable to continue to grow because of one or more limiting factors. The alignment of the Most Plausible Scenario with a logarithmic curve for the U.S. Artic means that the rapid expansion witnessed over the past decade is slowly reaching the point where a critical factor supporting that past growth will essentially become an inhibiting factor for future growth. There are many possible factors that meet this description: infrastructure, investment, and regulatory and operational certainty among them.

Future growth matching the Optimized Growth and Accelerated, but Unlikely scenarios will require the U.S. Arctic marine transportation system to overcome these limiting factors. As an example, rapid expansions in infrastructure, particularly marine transportation system-related infrastructure, may support surges of growth in vessel numbers. This was observed in the region recently during the lead up to exploratory drilling in the Chukchi Sea in the early 2010s; when Shell pulled out of the region, some of the infrastructure built to support the effort, including communications infrastructure, went with them. Sustained regional growth in the northern U.S. Arctic should not be expected without substantial leaps forward with infrastructure in the region to support new vessels from fleet expansion, resource development, and seasonally rerouted shipping. Infrastructure in this context includes many things, such as accurate and available nautical charts, a robust communications system, port reception facilities, trained and certified mariners, aids to navigation, and harbors of safe refuge, and many other factors needed to support an emergent Arctic marine transportation system. [209]

[208] In biology, the carrying capacity is the maximum number of a population that a given environment may support indefinitely.

[209] U.S. Committee on the Marine Transportation System. (2018). "Revisiting Near-Term Recommendations to Prioritize Infrastructure Needs in the U.S. Arctic". Washington, D.C. Accessed from: https://www.cmts.gov/downloads/NearTermRecommendationsArctic2018.pdf

Section V: Summary and Conclusions

This report provides further information about how vessel activity in the northern U.S. Arctic has and may continue to change over the next decade. It builds upon the foundations established in the 2015 CMTS report, "A 10-Year Projection of Vessel Activity in the U.S. Arctic". This report explores the drivers of vessel activity in the Arctic and their implications on future vessel activity, and the details of recent vessel activity using AIS data for the study area of interest. These components underscore the complex dynamics at work in the northern U.S. Arctic region and surrounding waters. Quantitative and qualitative elements from these efforts were used to construct and calculate four potential growth scenarios for the number of vessels anticipated in the region through 2030. A summary of these results is presented in Table 30.

Table 30: Summary of the scenario projection results for the study area of interest

Scenario	Additional Vessels in 2030	Total Vessels in 2030	Projected Average Annual Growth Rate	Change from 2008 Baseline Level	Change from Current (2015–2017) Baseline
Reduced Activity Scenario	29	284	0.30%	136%	11%
Most Plausible Scenario	124	379	2.58%	215%	48%
Optimized Growth Scenario	171	425	3.31%	255%	67%
Accelerated, but Unlikely Scenario	281	535	4.93%	346%	110%

The results of these scenarios suggest that there will be 29–281 additional vessels transiting in and around the Bering Strait by 2030, increasing the number of ships in northern U.S. Arctic waters and the surrounding region by 136–346% over 2008 levels. It is notable that even the Reduced Activity Scenario shows additional vessel growth in the region over the next decade. Of the four scenarios generated, the Most Plausible Scenario best agrees with mathematical projections from available historic data for the region. The Most Plausible Scenario, based on conservative assumptions, indicates that the number of vessels operating in the U.S. Arctic in 2030 is likely to be more than triple the activity in 2008, while the highest estimates included in the Accelerated, but Unlikely Scenario reflect growth more than four times the 2008 numbers and twice the number we see today.

However, the projected number of unique vessels does not capture the complete extent of the anticipated activity in the region, because this method did not estimate the total number of trips or transits that can be expected with these vessels. This is a critical differentiation and possibly the more important aspect for understanding the implications of growing activity in the region. As mentioned within various scenarios, while only one barge or one tanker may be required for a given project, that vessel may account for many of the actual transits in the region.

As with any projection effort, the values projected can be refined as more data becomes available and is incorporated into the model. For this study, further information about any of the thirty-six quantified elements of growth incorporated in the projection will improve the values assigned across the scenarios and in turn the accuracy of these projections. Additionally, this study recognizes that while AIS is a tremendously powerful tool for analyzing vessel activity, it is not without limitations. AIS data was used to establish a baseline for these vessel projections, providing rich details with respect to flag and vessel type. However, it does not account for any vessels not using AIS, which includes commercial fishing vessels smaller than the AIS carriage requirements, subsistence related vessels, and small pleasure crafts transiting the area. The exclusion of subsistence vessels, alone, may mean that the baseline for this study is off by 40%, and possibly much more.

This report does not make policy recommendations, but its findings highlight some of the implications of increasing use of the region without continued and corresponding development of the groundwork to support evolving vessel activity. These include, but are not limited to, more ships operating in the region, longer navigational seasons, and more people, both mariners and passengers, at risk in the event of a maritime incident. Each transit represents its own unique risks and potential for emergency response, environmental incident, collision, allision or grounding, depending on the area of operation. The total transits and movements into, out of, and within the U.S. Arctic will likely be more than double the vessel numbers, underscoring the urgency to take on planning and evaluation exercises to be prepared for a changing Arctic maritime environment.

The implications for these increases in vessel activity, vessel transits, and the increasing participation in Arctic shipping from Arctic and non-Arctic states impacts potential mission areas for many U.S. departments and agencies. It also raises the level of engagement beyond what is needed for successful community and industry resupply to requirements for successful development and safe and sustainable maritime operations in an increasingly accessible, global waterway. Further information about these activities is critical to improving maritime domain awareness in the Arctic and the safety of all mariners in the region.

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Appendices

A. SUMMARY OF THE 2018 CMTS & USARC TECHNICAL WORKSHOP ON ARCTIC VESSEL ACTIVITY

On November 14-15, 2018, the U.S. Committee on the Marine Transportation System (CMTS) and the U.S. Arctic Research Commission (USARC), with support from the Wilson Center's Polar Institute, hosted the technical workshop, "Arctic Shipping: Boom, Bust, or Baseline?". Over the course of this two-day workshop, 41 participants from the Federal departments and agencies, academia, industry, other Arctic Nations, and regional Alaska representatives discussed the future of vessel activity in U.S. Arctic waters (Figure A-1). This workshop and the information collected are critical components of the Arctic Marine Transportation IAT's efforts to update the projections for vessel activity in U.S. Arctic waters published in the 2015 report, *A 10-Year Projection of Maritime Activity in The U.S. Arctic Region*. The updated projection report is expected to be completed by mid-2019.

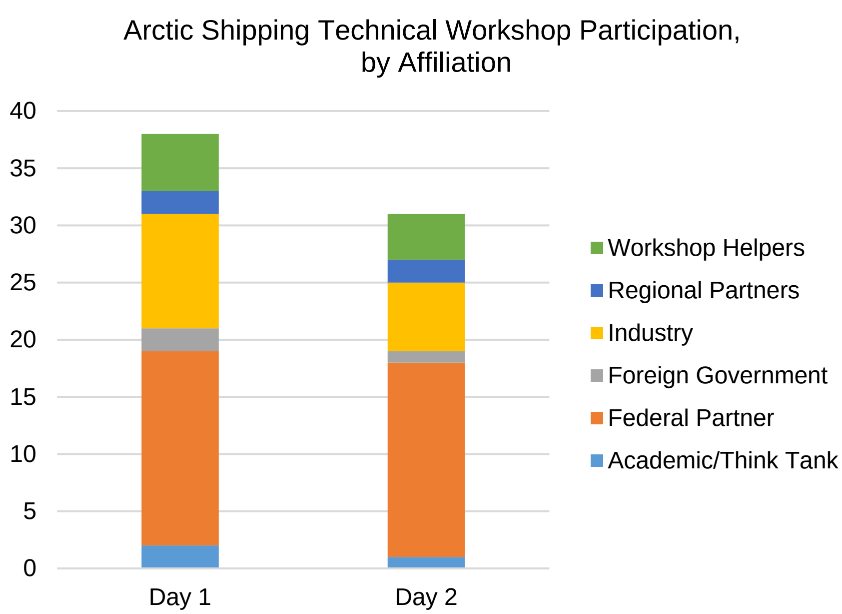

Figure A-1: Breakdown of workshop participation by affiliation

The technical workshop was intended to provide input for three overarching questions for integration into the updated report: (1) What drives (and will drive) vessel activity in the U.S. Arctic? (2) Which driving factors are the most important to consider? and (3) How can the driving factors be quantified? These three questions originated from a review of the first report and a reassessment of the assumptions used to generate the projection scenarios.

Summary of Workshop

Past efforts to understand vessel activity in the Arctic were re-visited during the first portion of the workshop through presentations by Alyson Azzara, Ph.D., International Trade Specialist within the U.S. Department of Transportation's Maritime Administration and Lawson Brigham, Ph.D., Distinguished Professor of Geography and Arctic Policy at the University of Alaska Fairbanks, who provided an overview of the Arctic Council's 2009 Arctic Marine Shipping Assessment and the 2015 CMTS report to provide background on past efforts and outline the challenges and uncertainties that needed to be incorporated into the future report.

Following a review of past efforts to project vessel activity in the Arctic, an expert panel provided a snapshot of what vessel activity in the U.S. Arctic looks like today, so as to better understand what the traffic might look like in the future. The panel featured speakers from the Alaska Marine Pollution Response Network, U.S. Coast Guard, and Bureau of Ocean Energy Management.

Workshop participants spent the first portion of the afternoon on the first day participating in a cascade brainstorm focused on answering the two questions:

- What are the major drivers of maritime traffic in the Arctic? and;
- What are the major sectors involved in maritime activity in the Arctic?

This discussion touched on drivers ranging from the development of non-traditional natural resources to global commodity prices, tourism, research and others across nine different categories identifying 60+ drivers. Although the focus of the report will be on the U.S. Arctic, no limitations were placed on sectors or areas where maritime activity would occur on the understanding that shipping and maritime activity can affect or influence the U.S. Arctic even if the activity does not originate or terminate in U.S. waters or ports.

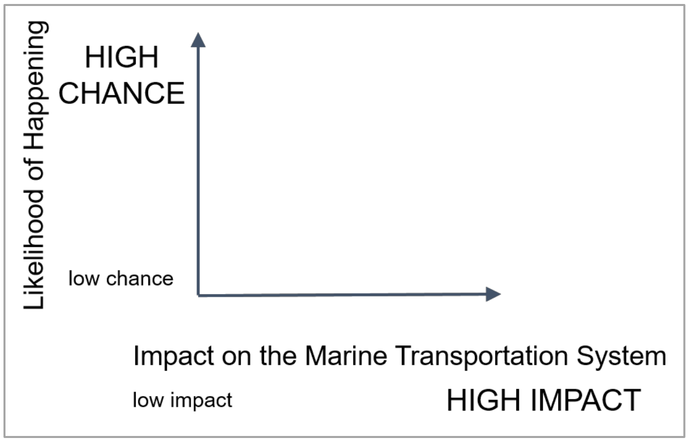

Figure A-2 Schematic used to rank driver importance

Following the large group discussion, participants continued their work in small break-out groups. The goal of this exercise was to facilitate further refinement of the drivers and to rank them as a function of the probability of occurring and the potential impact on maritime activity in Arctic waters. To do this, participants placed the drivers on an XY- scale (Figure A-2) according to where they thought it would fall on the probability-impact continuum. Each placement was discussed among the full group and the rationale for placement recorded by the notetakers. These placements and justifications will be used to help develop projection scenarios and identity which drivers belong in different scenarios based on underlying assumptions of activity and impact in different sectors.

The qualitative discussions of the first day gave way to thorough quantitative discussions on the second day as participants shared resources and metrics to incorporate into the next iteration of projecting vessel activity in the U.S. Arctic. To support this portion of the agenda, participants were asked: Of the drivers identified, how would you quantify their impact on Arctic vessel activity?. Stated another way, what metrics could be used to track a given driver's impact on Arctic vessel activity? Participants were asked to consider metrics that are currently used, metrics that are being developed or newly reported, and links to reports that contain metrics of this sort. Participants were also asked to consider whether there are other sources of information that could be used as a proxy or indicator for changes in maritime activity in the region. These could be anything from market trends to new policies, regulations, or initiatives likely to influence sectors active in the region. Participants provided workshop organizers with a broad sweep of information, all of which will be incorporated into the updated projections report.

An Abridged List of Drivers Discussed at the 2018 CMTS & USARC Technical Workshop:

- Natural Resources
    - Offshore Oil & Gas Operations
    - LNG Projects
    - Mineral Resources
    - Non-traditional Natural Resources Sourced from the Arctic
- The Global Economy
    - Global Commodity Prices
    - Economic Future of Key Arctic and non-Arctic States
    - Insuring Vessels in the Arctic
- Changing Geopolitical Importance of the Arctic
- Regulatory Changes
    - International regulations in the Arctic and wider maritime community
    - U.S. Regulations
    - State and local laws and regulations
- Infrastructure
    - Physical Infrastructure to support the MTS
    - Physical Infrastructure with Sealift Requirements
    - Projects to Combat Coastal Erosion, Thawing Permafrost, and Sea Level Rise
    - Informational Infrastructure
    - MTS Response Services
- Improved Technology and Operations
    - Coastal Community Resupply and Development
    - Rerouted Global Shipping Traffic
    - Novel Mechanisms to Operate an Arctic MTS
    - Autonomous technologies in the maritime sector
- The Human Element
    - Growing Global Interest in and Awareness of the Arctic
    - The 'Social License to Operate' in the Arctic
    - Tourism
- Environmental Changes
    - Sea Ice Retreat
    - Coastal Erosion
    - Changes to the Marine Food Web and Species Distribution
    - Thawing Permafrost
- Changing Fuel Landscape
    - Use of renewable fuels in the Arctic
    - Use of renewable and alternative fuels (e.g. LNG) in the maritime sector

B. DATA TABLES OF PROJECTED VESSEL COUNTS BY SOURCE AND SCENARIO

The following data tables include the assumed numbers of vessels by source and scenario for each of the 36 sources of growth used to project vessel activity in the study area of interest.

Scenario Abbreviations	
RAS	Reduced Activity Scenario
MPS	Most Plausible Scenario
OGS	Optimized Growth Scenario
ABU	Accelerated, but Unlikely Scenario

		Number of Additional Vessels to Transit Study Area of Interest by Year											
Natural Resource Activities	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Offshore G&G Research for O&G	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Offshore G&G Research for O&G	*MPS*	*0*	*0*	*0*	*10*	*0*	*10*	*0*	*10*	*0*	*10*	*0*	*10*
Offshore G&G Research for O&G	*OGS*	*0*	*0*	*0*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Offshore G&G Research for O&G	*ABU*	*0*	*0*	*0*	*20*	*10*	*20*	*10*	*20*	*10*	*20*	*10*	*20*
Liberty Hilcorp	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Liberty Hilcorp	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*12*	*11*	*12*
Liberty Hilcorp	*OGS*	*0*	*0*	*0*	*0*	*0*	*12*	*11*	*12*	*12*	*7*	*5*	*6*
Liberty Hilcorp	*ABU*	*0*	12	11	12	12	7	5	6	5	6	7	5
Eni Beaufort Sea Exploration	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Eni Beaufort Sea Exploration	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Eni Beaufort Sea Exploration	*OGS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Eni Beaufort Sea Exploration	*ABU*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Willow Prospect in NPR-A	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Willow Prospect in NPR-A	*MPS*	*0*	*0*	*0*	*0*	*1*	*1*	*4*	*1*	*1*	*1*	*1*	*4*
Willow Prospect in NPR-A	*OGS*	*0*	*0*	*0*	*1*	*1*	*4*	*1*	*1*	*1*	*1*	*4*	*1*

Natural Resource Activities (cont'd)	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Willow Prospect in NPR-A	*ABU*	*0*	*0*	*1*	*1*	*4*	*1*	*1*	*1*	*1*	*4*	*1*	*0*
Development of ANWR	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Development of ANWR	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Development of ANWR	*OGS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Development of ANWR	*ABU*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*	*4*
US LNG Production on North Slope	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
US LNG Production on North Slope	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
US LNG Production on North Slope	*OGS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
US LNG Production on North Slope	*ABU*	*0*	*0*	*0*	*2*	*2*	*2*	*5*	*10*	*15*	*15*	*15*	*15*
Yamal LNG	*RAS*	*4*	*4*	*5*	*5*	*6*	*6*	*6*	*6*	*6*	*6*	*6*	*6*
Yamal LNG	*MPS*	*4*	*4*	*5*	*5*	*6*	*6*	*7*	*7*	*8*	*8*	*10*	*10*
Yamal LNG	*OGS*	*4*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
Yamal LNG	*ABU*	*10*	*14*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*
Arctic LNG 2	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Arctic LNG 2	*MPS*	*0*	*2*	*2*	*0*	*1*	*1*	*5*	*5*	*5*	*5*	*5*	*5*
Arctic LNG 2	*OGS*	*0*	*2*	*2*	*0*	*1*	*2*	*5*	*5*	*6*	*6*	*7*	*7*
Arctic LNG 2	*ABU*	*0*	*3*	*3*	*0*	*1*	*3*	*5*	*6*	*7*	*8*	*9*	*10*
Ob LNG Project	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Ob LNG Project	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Ob LNG Project	*OGS*	*0*	*1*	*1*	*0*	*1*	*1*	*1*	*2*	*2*	*2*	*3*	*3*
Ob LNG Project	*ABU*	*0*	*1*	*1*	*0*	*1*	*2*	*3*	*4*	*5*	*5*	*5*	*5*
Transshipment Facilities at Kamchatka and Murmansk	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Transshipment Facilities at Kamchatka and Murmansk	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Transshipment Facilities at Kamchatka and Murmansk	*OGS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Transshipment Facilities at Kamchatka and Murmansk	*ABU*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
China's Icebreaking LNG Tankers	*RAS*	*0*	*0*	*0*	*0*	*3*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Natural Resource Activities (cont'd)	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
China's Icebreaking LNG Tankers	*MPS*	*0*	*0*	*0*	*0*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
China's Icebreaking LNG Tankers	*OGS*	*0*	*0*	*0*	*3*	*4*	*6*	*7*	*9*	*10*	*12*	*13*	*15*
China's Icebreaking LNG Tankers	*ABU*	*0*	*0*	*0*	*3*	*5*	*10*	*12*	*15*	*17*	*20*	*21*	*21*
Expansion of Red Dog	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Expansion of Red Dog	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Expansion of Red Dog	*OGS*	*0*	*0*	*6*	*8*	*6*	*6*	*6*	*6*	*6*	*6*	*5*	*0*
Expansion of Red Dog	*ABU*	*0*	*6*	*8*	*6*	*6*	*6*	*6*	*6*	*6*	*5*	*0*	*0*
Graphite from Nome	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Graphite from Nome	*MPS*	*0*	*4*	*4*	*4*	*4*	*4*	*4*	*9*	*9*	*9*	*9*	*9*
Graphite from Nome	*OGS*	*0*	*4*	*4*	*4*	*4*	*4*	*4*	*14*	*14*	*14*	*14*	*14*
Graphite from Nome	*ABU*	*0*	*4*	*4*	*4*	*4*	*4*	*4*	*21*	*21*	*21*	*21*	*21*
Hope Bay	*RAS*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*
Hope Bay	*MPS*	*5*	*5*	*5*	*6*	*6*	*6*	*6*	*6*	*7*	*7*	*7*	*7*
Hope Bay	*OGS*	*6*	*6*	*6*	*7*	*7*	*7*	*8*	*8*	*8*	*9*	*9*	*9*
Hope Bay	*ABU*	*6*	*6*	*7*	*7*	*8*	*8*	*9*	*9*	*10*	*10*	*11*	*11*
Back River Gold Mine	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Back River Gold Mine	*MPS*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*
Back River Gold Mine	*OGS*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*
Back River Gold Mine	*ABU*	*5*	*5*	*6*	*6*	*7*	*7*	*8*	*8*	*9*	*9*	*10*	*10*
Baffinland's Mary River Mine	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Baffinland's Mary River Mine	*MPS*	*1*	*1*	*1*	*2*	*1*	*2*	*1*	*2*	*2*	*2*	*2*	*2*
Baffinland's Mary River Mine	*OGS*	*2*	*2*	*2*	*4*	*4*	*4*	*6*	*6*	*6*	*8*	*8*	*8*
Baffinland's Mary River Mine	*ABU*	*2*	*2*	*4*	*4*	*6*	*6*	*8*	*8*	*10*	*10*	*12*	*12*
G&G Research for Wind Energy	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
G&G Research for Wind Energy	*MPS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
G&G Research for Wind Energy	*OGS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
G&G Research for Wind Energy	*ABU*	*0*	*0*	*0*	*0*	*0*	*0*	*10*	*2*	*2*	*2*	*4*	*4*

		Number of Additional Vessels to Transit Study Area of Interest by Year											
Infrastructure Development Activities	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Relocation of Kivalina	*RAS*	2	0	0	0	0	0	0	0	0	0	0	0
Relocation of Kivalina	*MPS*	2	2	1	0	0	3	0	0	2	0	0	3
Relocation of Kivalina	*OGS*	3	2	3	2	1	2	1	2	1	2	1	2
Relocation of Kivalina	*ABU*	3	2	3	2	3	2	3	2	3	2	3	2
Relocation/Protect-in-Place Shishmaref	*RAS*	2	0	0	0	0	0	0	0	0	0	0	0
Relocation/Protect-in-Place Shishmaref	*MPS*	2	0	0	0	0	0	0	0	0	0	0	0
Relocation/Protect-in-Place Shishmaref	*OGS*	2	0	0	0	0	0	0	0	1	2	1	2
Relocation/Protect-in-Place Shishmaref	*ABU*	2	0	0	0	0	0	2	3	2	3	2	3
Relocation of Newtok, AK	*RAS*	0	0	0	0	0	0	0	0	0	0	0	0
Relocation of Newtok, AK	*MPS*	0	0	0	0	1	0	0	0	1	0	0	0
Relocation of Newtok, AK	*OGS*	1	1	1	1	1	1	1	1	1	0	0	0
Relocation of Newtok, AK	*ABU*	2	2	2	2	2	2	2	2	2	0	0	0
Port of Nome	*RAS*	*0*	*1*	*0*	*0*	*0*	*0*	*1*	*4*	*4*	*4*	*2*	*2*
Port of Nome	*MPS*	*0*	*1*	*0*	*0*	*0*	*1*	*4*	*4*	*4*	*2*	*2*	*0*
Port of Nome	*OGS*	*0*	*1*	*0*	*0*	*1*	*4*	*4*	*4*	*2*	*2*	*0*	*0*
Port of Nome	*ABU*	*0*	*1*	*0*	*1*	*4*	*4*	*4*	*2*	*2*	*0*	*0*	*0*
Lower Yukon River Regional Port and Road: Emmonak	*RAS*	*0*	*0*	*0*	*0*	*1*	*1*	*1*	*0*	*0*	*0*	*0*	*0*
Lower Yukon River Regional Port and Road: Emmonak	*MPS*	*0*	*0*	*0*	*0*	*1*	*1*	*1*	*0*	*0*	*0*	*0*	*0*
Lower Yukon River Regional Port and Road: Emmonak	*OGS*	*0*	*0*	*0*	*0*	*1*	*2*	*2*	*0*	*0*	*0*	*0*	*0*
Lower Yukon River Regional Port and Road: Emmonak	*ABU*	*0*	*0*	*0*	*0*	*1*	*2*	*2*	*0*	*0*	*0*	*0*	*0*
Kotzebue to Cape Blossom Road	*RAS*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Kotzebue to Cape Blossom Road	*MPS*	*0*	*1*	*1*	*1*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Kotzebue to Cape Blossom Road	*OGS*	*0*	*2*	*2*	*2*	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Infrastructure Development Activities (cont'd)	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kotzebue to Cape Blossom Road	*ABU*	*0*	*2*	*2*	*2*	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Utqiagvik	*RAS*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Utqiagvik	*MPS*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Utqiagvik	*OGS*	*0*	*1*	*0*	*1*	*0*	1	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Utqiagvik	*ABU*	*0*	*1*	*0*	*1*	*0*	1	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Nome	*RAS*	0	*0*	0	*0*	0	*0*	0	*0*	*0*	*0*	*0*	*0*
Road Improvements Nome	*MPS*	2	*2*	2	1	1	1	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Nome	*OGS*	2	*2*	2	1	1	1	1	1	1	1	1	1
Road Improvements Nome	*ABU*	2	2	2	2	2	2	2	2	2	2	2	2
Road Improvements Selawik	*RAS*	0	*0*	*0*	*0*	*0*	*0*	0	*0*	*0*	*0*	*0*	*0*
Road Improvements Selawik	*MPS*	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Selawik	*OGS*	1	1	1	0	0	0	*0*	*0*	*0*	*0*	*0*	*0*
Road Improvements Selawik	*ABU*	1	1	1	0	0	0	*0*	*0*	*0*	*0*	*0*	*0*
Airport Repair	*RAS*	3	3	3	3	3	3	3	3	3	3	3	3
Airport Repair	*MPS*	4	4	4	4	4	4	4	4	4	4	4	4
Airport Repair	*OGS*	5	5	5	5	5	5	5	5	5	5	5	5
Airport Repair	*ABU*	6	6	6	6	6	6	6	6	6	6	6	6
Renewable Wind Development	*RAS*	1	0	0	0	0	0	0	0	0	0	0	0
Renewable Wind Development	*MPS*	1	0	0	0	0	0	0	0	0	0	0	0
Renewable Wind Development	*OGS*	1	0	0	0	0	0	0	0	0	0	0	0
Renewable Wind Development	*ABU*	1	0	0	0	2	0	0	2	0	0	2	0
Expanded Services for Community Resupply and Waste Removal	*RAS*	0	0	0	0	0	0	0	0	0	0	0	0
Expanded Services for Community Resupply and Waste Removal	*MPS*	0	0	0	0	0	0	0	0	0	0	0	0
Expanded Services for Community Resupply and Waste Removal	*OGS*	0	0	0	0	0	0	0	0	0	0	0	0
Expanded Services for Community Resupply and Waste Removal	*ABU*	0	0	0	0	0	0	0	0	0	0	0	0

		Number of Additional Vessels to Transit Study Area of Interest by Year											
Arctic Fleet Expansion	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
USCG Polar Security Cutters	*RAS*	0	0	0	0	0	0	0	0	0	0	0	0
USCG Polar Security Cutters	*MPS*	0	0	0	0	0	0	1	1	1	1	2	2
USCG Polar Security Cutters	*OGS*	0	0	0	0	0	0	1	1	2	2	2	2
USCG Polar Security Cutters	*ABU*	0	0	0	0	0	1	1	2	2	2	2	2
Russian Icebreakers	*RAS*	1	2	3	3	3	3	3	3	3	3	3	3
Russian Icebreakers	*MPS*	1	2	3	3	3	3	3	3	3	3	3	5
Russian Icebreakers	*OGS*	1	2	3	3	3	3	3	3	3	3	5	5
Russian Icebreakers	*ABU*	1	2	3	3	3	3	3	3	5	5	5	5
Canadian Icebreakers	*RAS*	0	0	0	0	0	0	0	0	0	0	0	0
Canadian Icebreakers	*MPS*	0	0	0	0	1	0	1	0	1	0	1	0
Canadian Icebreakers	*OGS*	0	0	0	0	2	1	2	1	2	1	2	1
Canadian Icebreakers	*ABU*	0	0	0	0	2	1	2	3	2	3	2	3
Chinese Icebreakers	*RAS*	1	1	1	1	1	1	1	1	1	1	1	1
Chinese Icebreakers	*MPS*	1	1	1	1	2	2	2	2	2	2	2	2
Chinese Icebreakers	*OGS*	1	1	1	1	2	2	2	2	3	3	3	3
Chinese Icebreakers	*ABU*	1	1	1	1	2	2	2	3	3	3	4	4
Other Icebreakers	*RAS*	0	0	0	0	0	0	0	0	0	0	0	0
Other Icebreakers	*MPS*	0	0	0	1	1	1	1	1	1	1	1	1
Other Icebreakers	*OGS*	0	0	1	1	2	2	2	2	2	2	2	2
Other Icebreakers	*ABU*	1	1	1	2	3	3	3	3	3	3	3	3
Expedition Fleet Expansion	*RAS*	0	0	0	0	0	0	0	0	0	0	0	0
Expedition Fleet Expansion	*MPS*	2	2	3	3	4	4	5	5	6	6	7	7
Expedition Fleet Expansion	*OGS*	4	4	6	6	8	8	10	10	12	12	14	14
Expedition Fleet Expansion	*ABU*	7	10	12	14	14	20	25	28	28	28	28	28

		Number of Additional Vessels to Transit Study Area of Interest by Year											
Seasonally Rerouted Shipping	Scenario	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Seasonally Rerouted Shipping	*RAS*	1	1	2	2	3	4	5	5	6	7	8	9
Seasonally Rerouted Shipping	*MPS*	1	2	4	6	8	11	13	16	18	21	24	28
Seasonally Rerouted Shipping	*OGS*	1	3	6	9	12	16	19	23	27	32	37	42
Seasonally Rerouted Shipping	*ABU*	1	5	10	14	20	25	32	38	45	53	61	70

Unique Vessel Counts by Vessel Type in Area of Interest North of Bering Strait

Data collected and compiled by U.S. Coast Guard, District 17

Type of Ship	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cargo	29	27	23	48	39	55	62	68	101	89	82
Tugs	17	28	45	36	41	51	50	59	60	47	53
Bulk (Red Dog)	26	27	26	23	25	23	24	24	23	24	21
Tankers	4	8	13	25	46	38	36	33	30	36	38
Adventurers	5	13	13	15	23	27	14	16	14	23	5
O&G Research	21	9	13	14	25	9	14	30	6	6	0
Research Science	8	5	12	16	19	15	27	38	31	24	40
Govt	6	8	7	8	17	14	14	18	14	15	29
Unknown	3	2	3	1	11	4	5	9	4	2	5
Cruise Ships	1	3	5	4	4	4	4	5	7	4	3
Total	**120**	**130**	**160**	**190**	**250**	**240**	**250**	**300**	**290**	**270**	**276**

C. SUMMARY OF RESPONSES RECEIVED DURING PUBLIC COMMENT AND INTERAGENCY REVIEW

The CMTS posted a draft of the "Ten-Year Projection of Maritime Activity in the U.S. Arctic Region, 2020- 2030" on July 3 to www.cmts.gov and requested comments on the draft report from both the public and interagency on or before July 31, 2019 to ArcticMTS@cmts.gov.

To support soliciting feedback, the report was presented to ~ 200 people during the month of July, through multiple lines of outreach, including virtual briefings and presentations to Federal partners and the public. At the close of the comment period, a total of 20 written comments were received, with 14 comments received from Federal partners across 11 agencies and 6 comments from the public.

Overall, the comments received found that the projections featured in the study were reasonable and justifiable. While some reviewers noted that the sectors discussed were balanced, one reviewer noted that it was heavy on natural resource activities and wondered if it was because of the extensive details currently available about those planned activities.

The comments received provided valuable, citable information about other factors to be considered in the projections, including:

- Potential oil and gas activities in the National Petroleum Reserve and the Arctic Wildlife National Refuge
- Recent funding developments along the NSR affecting the values used in the Arctic LNG 2 project and the Ob LNG project (which previously had not been considered)
- The relocation of Newtok, AK
- Other planned icebreakers not originally considered
- The role of backhaul and/or solid waste removal in the Arctic MTS

The comments also provided important ways in which the report could be improved, including:

- Clarifying the areas of interest discussed in the report and clarifying that this report only focuses on a part of the U.S. Arctic and what the U.S. law defines the Arctic as
- Clarifying terms used in the report and consistency using those terms throughout the document
- Including tables throughout the projections section
- Incorporating other supporting data sets provided by commenters
- Emphasizing the importance of infrastructure to support communications in the region
- Spelling, grammar, and minor sentence structure improvements
- Detailed appendix with all the data in tables
- Providing a list of references and agencies who provided/published data that was cited.

D. CALCULATIONS FOR TRANSITS THROUGH THE BERING STRAIT TO/FROM LNG PROJECTS ON THE NORTHERN SEA ROUTE

To estimate the number of transits through the Bering Strait related to LNG activities along the Yamal Peninsula, several key assumptions were made about the operating conditions of the Northern Sea Route, including:

- LNG from Russia is shipped to the East from July to September (92-day season) and is shipped from Yamal to either Busan, South Korea or to the proposed transshipment facility on Kamchatka (Figure D-1)
- LNG from Russia is shipped to the West from October to June (273-day season) and is shipped from Yamal to either Rotterdam, the Netherlands or to the proposed transshipment facility near Murmansk (Figure D-1)
- Ship speeds along the NSR could range from 12 kts (low) to 15 kts (high)
- Bunkering and debunking operations each take 2 days and may only happen 1 ship at a time (i.e. multiple ships could not be loaded from the same facility on the same day.
- Each vessel is capable of hauling 73,000 tonnes of LNG each trip.

The resulting number of transits and volume of LNG transported are included in Table D-1.

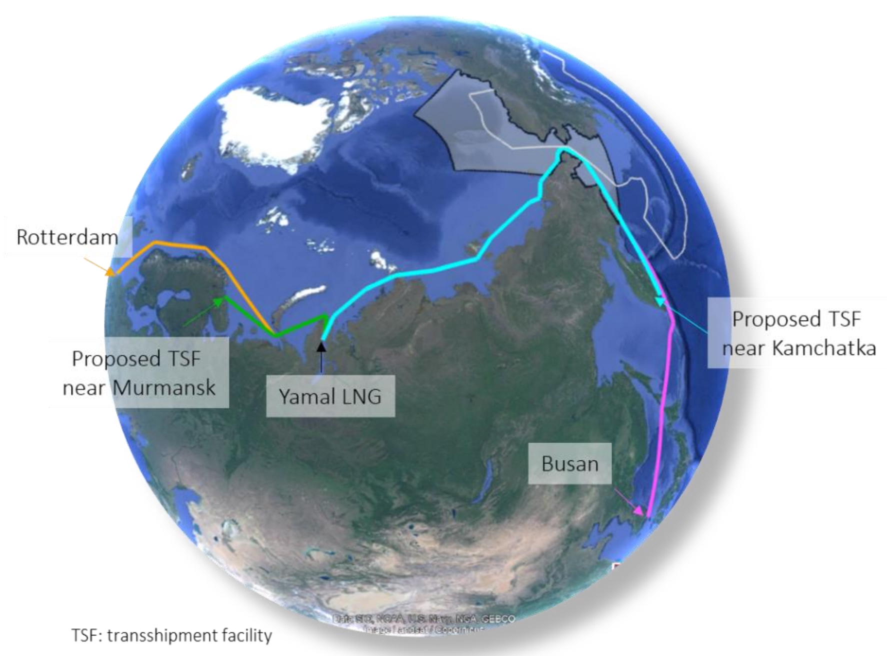

Figure D-1: Schematic of assumed origins and destinations for transits along NSR related to LNG developments

Table D-1: Summary of projected transits through the Bering Strait resulting from LNG activities along the Northern Sea Route and Prudhoe Bay

Season	Selected Route	Route Distance		Assumed Vessel Speed		One-way Sail Duration	Roundtrip Duration	Assumed number of ships in fleet	Average No. of Trips per Ship	Number of roundtrips each Season	LNG transported each Season	Bering Strait Crossings each Season
		miles	*nautical miles*	*mph*	*kts*	*days*	*days*				*tonnes*	
July-September	Yamal to Busan	6115	7037	10.4	12	24.4	52	15	2.0	30	2,190,000	60
				13.0	15	19.5	43	15	2.1	32	2,336,000	64
July-September	Yamal to Kamchatka Transshipment Hub	4157	4784	10.4	12	16.6	38	15	2.5	38	2,774,000	76
				13.0	15	13.3	31	15	3.0	45	3,285,000	90
October-June	Yamal to Rotterdam	2920	3360	10.4	12	11.7	28	15	9.7	146	10,658,000	n/a
				13.0	15	9.3	23	11	9.5	142	10,366,000	
October-June	Yamal to Murmansk Transshipment Hub	1100	1266	10.4	12	4.4	12	6	9.1	137	10,001,000	n/a
				13.0	15	3.5	11	6	9.9	148	10,804,000	
July-September	Prudhoe Bay to Busan	4191	4784	10.4	12	16.6	38	15	2.5	38	2,774,000	76
				13.0	15	13.3	31	15	3.0	45	3,285,000	90

E. TRACKLINE DENSITY BY SEASON, 2017

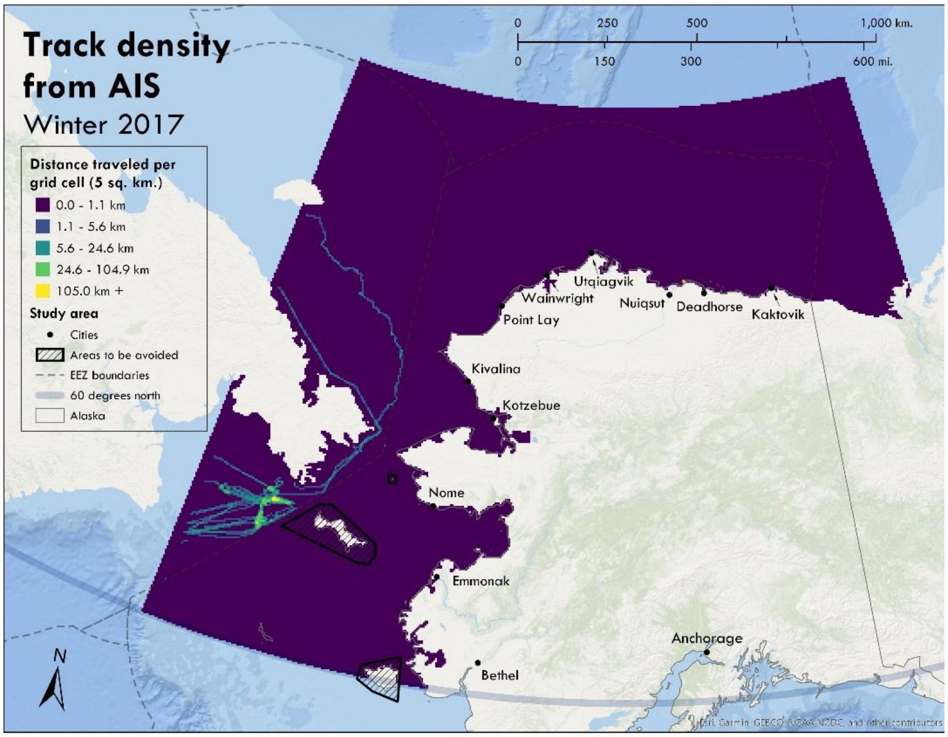

Figure E-1: Trackline Density from 2017 AIS data for Winter 2017. Each 5 km x 5 km cell within the water colored according to the total distance traveled from January 1- March 21, 2017 and December 22-31, 2017. Data intervals spaced with geometric intervals; note the scale is different from Figure 5 on p. 19.

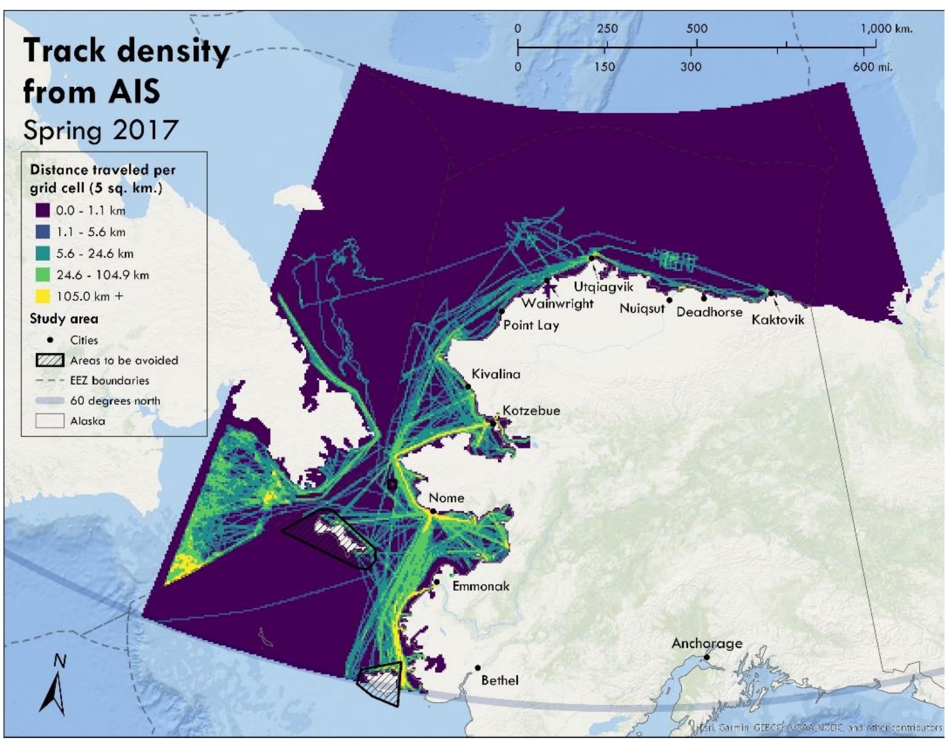

Figure E-2: Trackline Density from 2017 AIS data for Spring 2017. Each 5 km x 5 km cell within the water colored according to the total distance traveled from March 22 to June 21, 2017. Data intervals spaced with geometric intervals; note the scale is different from Figure 5 on p. 19.

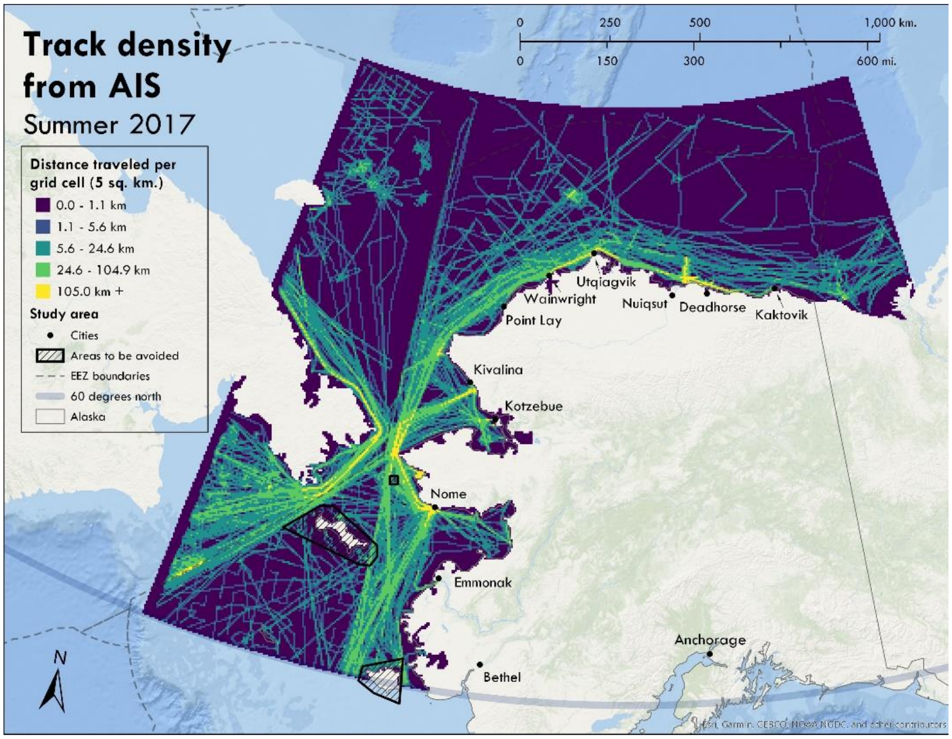

Figure E-3: Trackline Density from 2017 AIS data for Summer 2017. Each 5 km x 5 km cell within the water colored according to the total distance traveled from June 22 to September 21, 2017. Data intervals spaced with geometric intervals; note the scale is different from Figure 5 on p. 19.

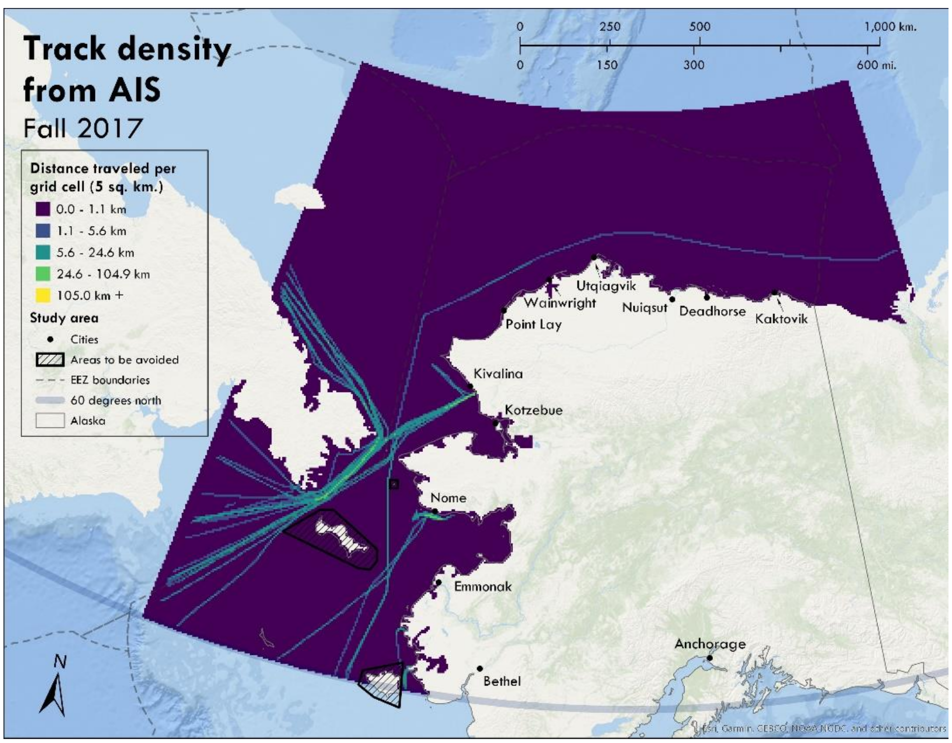

Figure E-4: Trackline Density from 2017 AIS data for Fall 2017. Each 5 km x 5 km cell within the water colored according to the total distance traveled from September 22 to December 21, 2017. Data intervals spaced with geometric intervals; note the scale is different from Figure 5 on p. 19.