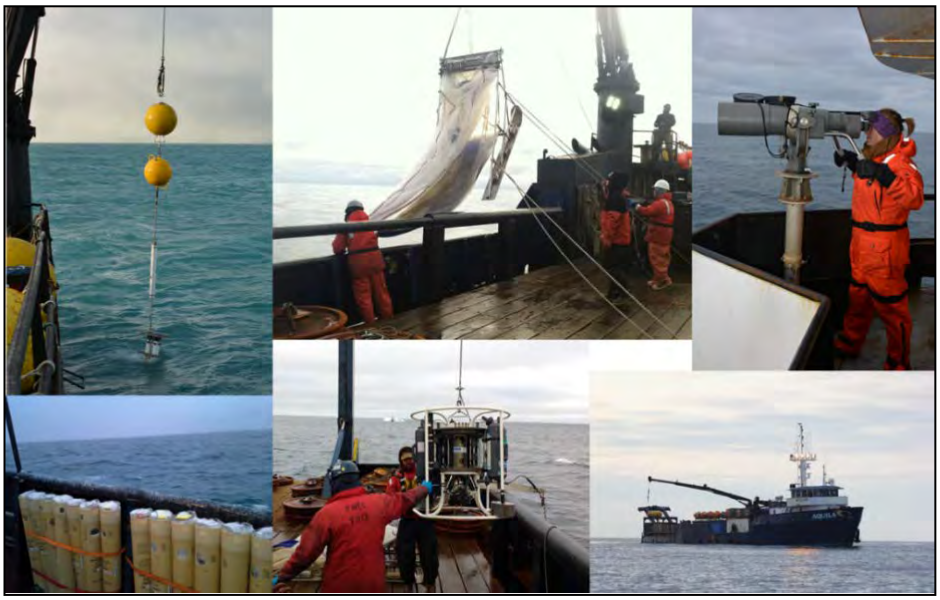
OCS Study
BOEM 2019-024

Chukchi Sea Acoustics, Oceanography, and Zooplankton Study: Hanna Shoal Extension (CHAOZ-X)

And

Arctic Whale Ecology Study (ARCWEST)

Supplemental Report



Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE, Seattle, WA 98115-6349

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Bureau of Ocean Energy Management
Alaska Outer Continental Shelf Region
U.S. Department of the Interior
3801 Centerpoint Drive, Suite 500
Anchorage, AK 99503-5823

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Alaska Outer Continental Shelf Region
Bureau of Ocean Energy Management
U.S. Department of Interior
3801 Centerpoint Drive, Suite 500
Anchorage Alaska 99503-5823

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Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
U.S. Department of Commerce
7600 Sand Point Way NE
Seattle, Washington 98115-6349

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Email of authors: Catherine.Berchok@noaa.gov, Jessica.Crance@noaa.gov, and Phyllis.Stabeno@noaa.gov

List of acronyms

A

ADCP: Acoustic Doppler Current Profiler · 71; Acoustic Doppler Current Profiler · 19
AFSC: Alaska Fisheries Science Center · 13
AMSR-E: Advanced Microwave Scanning Radiometer – Earth Observing System · 73
APL/UW: Applied Physics Laboratory/Univ. of Washington · 15
ARCWEST: ARCtic Whale Ecology Study · 13
AURAL: Autonomous Underwater Recorders for Acoustic Listening · 20

B

BOEM: Bureau of Ocean Energy Management · 13
BOWFEST: BOWhead Feeding Ecology STudy · 13

C

CHAOZ: CHukchi Acoustics Oceanography and Zooplankton study · 13
CHAOZ-X: CHAOZ-eXtension study · 13
CTD: Conductivity, Temperature, Depth · 16

D

DBO: Distributed Biological Observatory · 13
DiFAR: Directional Frequency Analysis and Recording · 21
DMSP: Defense Meteorological Satellite Program · 73
DPP: Draft Proposed Program · 13

E

EcoFOCI: Ecosystems & Fisheries-Oceanography Coordinated Investigations · 15
EP: Exploration Plan · 13
ESA: Endangered Species Act · 13

F

FOCI: Fisheries-Oceanography Coordinated Investigation · 73

G

GPS: Global Positioning System · 21

I

IERP: Integrated Ecosystem Research Program · 14
ISUS: *In Situ* Ultraviolet Spectroscopy · 71

M

MML: Marine Mammal Lab · 13
MMPA: Marine Mammal Protection Act · 13

N

NARR: North American Regional Reanalysis · 75
NCIS: Northern Chukchi Integrated Studies · 15
NEPA: National Environmental Policy Act · 13
NOAA: National Oceanic and Atmospheric Administration · 13
NSIDC: National Snow and Ice Data Center · 73

P

PAM: Passive Acoustic Monitoring · 13
PAR: Photosynthetically Active Radiation · 19
PMEL: Pacific Marine Environmental · 13
PRIEST: Pacific RIght whale Ecology STudy · 13

R

RACE: Resource Assessment and Conservation Engineering · 13
RCM: Rotary Current Meter · 19

S

S&T: Science and Technology · 13
SSMI/S: Special Sensor Microwave Imager/Sounder · 73
SUNA: Submersible Ultraviolet Nitrate Analyzer · 71

T

V

I. Contents

II. List of Figures

III. List of Tables

IV. Introduction

A. Background

The combination of climate change and increasing anthropogenic impacts, coupled with the steadily increasing abundance and related seasonal range expansion by several subarctic marine mammal species, mandates that more complete information on the year-round presence of Arctic marine mammals is needed in the Chukchi and Beaufort, as well as the Bering Seas. Long-term data on marine mammal spatio-temporal occurrence are critical for establishing baseline information that can be used to inform current and future National Environmental Policy Act (NEPA) analyses, Endangered Species Act (ESA) Section 7 consultations, Marine Mammal Protection Act (MMPA) documentation for Lease Sales, Exploration Plans (EP)s, and Draft Proposed Program (DPP)s, and to guide post-sale and post-exploration decision-making in Alaskan waters. In addition, marine mammals are excellent proxies for ecosystem change, since they respond to shifts in abundance and distribution of large zooplankton and small fish taxa. As conditions continue to rapidly change, information on these upper trophic level species will be critical to accurately model top-down control in Arctic ecosystems.

Passive acoustic monitoring (PAM) remains the best tool for large-scale, year-round assessment of marine mammal spatio-temporal occurrence, and ambient noise levels, especially in the harsh conditions of the enormous Alaska Region. The passive acoustics group at the Alaska Fisheries Science Center (AFSC) Marine Mammal Lab (MML) has maintained nearly a decade of long-term PAM in the Alaskan Arctic and Bering Sea. This record was begun in 2007 through the Bureau of Ocean Energy Management (BOEM)-funded Pacific RIght whale Ecology Study (PRIEST) and BOWhead Feeding Ecology Study (BOWFEST) projects in the Bering and Beaufort Seas, and continued in 2010 through the BOEM-funded CHukchi Acoustics Oceanography and Zooplankton (CHAOZ), CHAOZ-extension (CHAOZ-X), and ARCtic Whale Ecology Study (ARCWEST) projects in the Chukchi Sea, as well as through supplemental funding through the National Oceanic and Atmospheric Administration (NOAA) Office of Science and Technology (S&T). These moorings have been distributed throughout the main migratory pathways and in wintering and summering grounds of many Arctic and subarctic marine mammals. Many of these moorings have been co-located with long-term biophysical moorings maintained by the Pacific Marine Environmental Laboratory (PMEL)/ Resource Assessment and Conservation Engineering (RACE) divisions, providing concurrent sampling of lower and upper trophic level ecosystem components. These moorings have also occupied five of the Distributed Biological Observatory (DBO)[1] zones since 2009 (DBO 1 & 5), 2010 (DBO 4), and 2012 (DBO 2 & 3), providing long-term data on marine mammal presence concurrently with all biophysical occupations of the DBO sampling lines. Here we report on the field work completed, data obtained, and results produced from the no-cost extension of the CHAOZ-X study (22 September 2017 – 30 September 2018).

B. Objectives of supplemental study

- Deployment of two additional years (2017-18 and 2018-19) of passive acoustic moorings to extend the near-decade-long data series in the Alaskan Arctic.
- Continued analysis of mooring data to document the spatio-temporal presence of baleen and toothed whales, ice seals and walrus, vessel and airgun noise, and ice noise.
- Continued analysis of ambient noise levels.

[1] https://www.pmel.noaa.gov/dbo/

- Additional peer-reviewed publications on the results from the CHAOZ-X project.

C. Deliverables

- 2 additional years of long-term Alaskan Arctic passive acoustic data from 21 sites
- 2 additional years of long-term oceanographic data from 8 of these mooring sites
- At least 1 additional peer-reviewed publication
- Complete 1 year analysis from at least 6 additional recorders for the seasonal presence of baleen and toothed whales, ice seals and walrus, vessel and airgun noise, and ice noise.

D. Summary of research effort

This report includes the description of field work and analysis completed since the CHAOZ-X final report draft was submitted on 20 April, 2018 (Mocklin and Friday 2018). Because of the varying time frames involved with collection and analyses of the different data types, relative to the submission of the final report, this report includes data as follows. Field efforts from 2017 and 2018 will be described; these include retrieval of the 2016-17 and 2017-18 moorings and deployment of the 2017-18 and 2018-19 moorings, along with oceanographic sampling and underway passive acoustic monitoring (sonobuoys). Analyses included here will begin with the 2015-16 mooring data, since those were not included in the CHAOZ-X and ARCWEST final reports; shipboard data will just include those collected during the 2017 and 2018 seasons; raw CTD (Conductivity, Temperature, Depth) information collected during the 2016 season will be provided to BOEM, but are not discussed here.

Two Arctic cruises were successfully completed during this supplemental study; the first leg of the 2017 Arctic Integrated Ecosystem Research Program (IERP) and the 2018 Healy HLY18-01. On the 2017 IERP cruise (Figure 1), 11 of our PAM moorings and 14 oceanographic moorings were retrieved; a total of 11 PAM and 11 oceanographic were deployed at 12 sites. Three of these sites (C1, C4, and C11) had the additional deployment of acoustic fish echosounder moorings (AFSC/C. Wilson), and one (C12) included a zooplankton echosounder (Univ. New Hamp/J. Miksis-Olds); these instruments and data belong to other groups and will not be included here. The AL15_AU_CL1 mooring that was unrecoverable during the 2016 field season was spotted using side-scan sonar on the R/V Siquliaq, and recovered by the R/V Norseman II using dragging techniques.

Table 1. Cruise information for the 2017 and 2018 field surveys.

Year	Start Date	End date	Start port location	End port location	Vessel	Captain	Chief Scientist
2017	8/1/2017	8/24/2017	Dutch Harbor, AK	Nome, AK	R/V Ocean Starr	Pete Hall	Dr. Johanna Vollenweider
2018	8/4/2018	8/24/2018	Nome,AK	Nome,AK	USCGC Healy	Greg Tlapa	Drs. Robert Pickart & Jacqueline Grebmeier

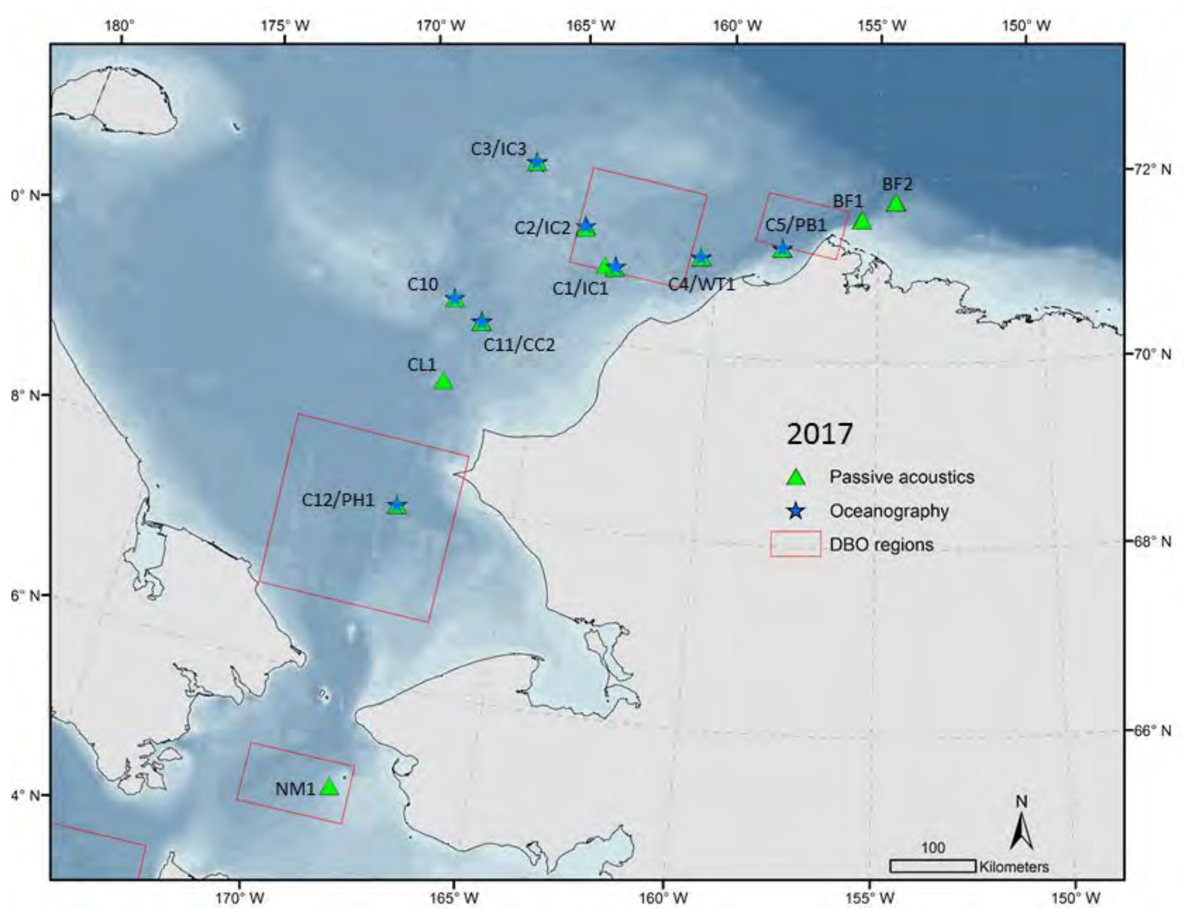

Figure 1. Moorings retrieved and/or deployed during the first leg of the 2017 IERP cruise. Passive acoustic moorings are shown with green triangles, while oceanographic moorings are blue stars. The passive acoustic recorders at CL1 and C10 were retrieval only; the recorder at C10 was deployed by Kate Stafford (APL/UW) and is not included in this report.

The Healy cruise was an integrated effort between EcoFOCI/MML and NOAA's Arctic program Distributed Biological Observatory/Northern Chukchi Integrated Studies (DBO/NCIS); we are only including the data collected as part of EcoFOCI/MML here. On this cruise (Figure 2), 10 of our PAM and 11 oceanographic moorings were retrieved; 10 PAM and 17 oceanographic moorings (including three pop-ups) were deployed at 15 sites. In addition, the 3 acoustic fish echosounder moorings were turned around, as was the zooplankton echosounder on the mooring at C12. Table 2 and Table 3 list all mooring recoveries and deployments in 2017 and 2018. The Bering Sea passive acoustic moorings (2017-18, and 2018-19) were retrieved and redeployed on the NOAA ship Dyson during its spring (DY17-01, DY18-01) and fall (DY17-03) cruises, and the R/V Aquila on the fall (AQ18-01) cruise. This information is presented in Appendix E, and data will be available as the analyses progress. .

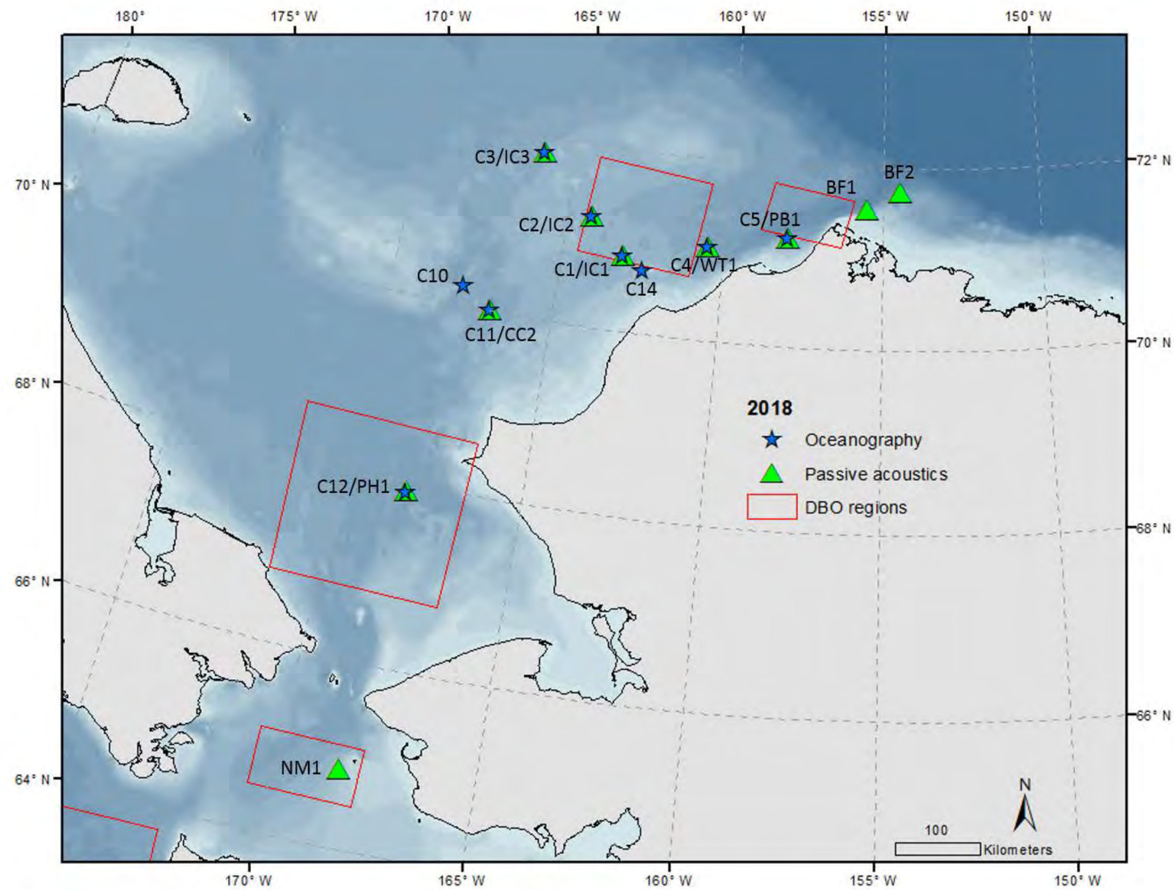

Figure 2. Moorings retrieved and deployed during the 2018 Healy cruise. Passive acoustic moorings are shown with green triangles, while oceanographic moorings are blue stars. The C14 and northern C12 oceanographic moorings were deployment only; the recorder at C10 was deployed by Kate Stafford (APL/UW) and is not included in this report.

Opportunistic passive acoustic monitoring and CTD sampling was conducted on both research cruises listed above. A total of 39 (out of 43) sonobuoys were successfully deployed in 2017 and 35 (out of 44) in 2018 (see Section V.B.2). CTD's were deployed 52 times in 2017 and 62 in 2018 (see Section VI.B.2). All CTD casts included sampling of nutrients and chlorophyll, but the chlorophylls were collected as part of the DBO/NCIS program and will not be included here. Finally, a total of 12 satellite tracked drifters were deployed – six in 2017 and six in 2018 (see Section VI.B.2).

E. Structure of report

The majority of this report focuses on the results from the long-term passive acoustic monitoring component of the original CHAOZ-X study (Section V.B.1). Although the summary tables and plots include data collected from the CHAOZ, CHAOZ-X, and ARCWEST studies, the discussion will focus on what differed (and what remained the same) between the data analyzed for this report and those collected previously. Again, it should be noted that the chlorophyll data obtained from the CTD casts were collected as part of the DBO/NCIS project and will not be included in this supplemental report. A summary of the oceanographic data collect can be found in Section III. For both sections, all methods described in the CHAOZ-X and ARCWEST final reports (Mocklin and Friday 2018; Vate Brattström et al. 2019) were also used for work included in this supplemental report. A brief summary for each component, however, is included below.

Table 2. All passive acoustic recorder mooring information, 2015-2018. * = mooring analyzed for this report (regular frequency band), ‡ = mooring analyzed for this report (high frequency band). Gray shading = moorings deployed/retrieved during the ARCWEST and CHAOZ-X studies, but analyzed for this supplemental report.

Mooring	Mooring Cluster	Latitude (°N)	Longitude (°W)	Water depth (m)	Recorder Start Date	Recorder End Date	Number of Days with Data	Sampling Rate (Hz)	Duty Cycle (min on/ min total)	Deployment Date	Retrieval Date
CX15_AU_IC3*	C3	71.829	166.077	43	9/18/2015	9/14/2016	362	16384	80/300	9/17/2015	9/13/2016
AW15_AU_BF2*‡	MC3	71.750	154.462	79	9/16/2015	9/8/2016	358	16384	80/300	9/14/2015	9/8/2016
AW15_AU_BF3	MC4	71.686	153.178	102	9/16/2015	9/8/2016	358	16384	80/300	9/14/2015	9/8/2016
AW15_AU_BF1	MC2	71.552	155.533	69	No	Data	-	16384	80/300	9/14/2015	9/8/2016
CX15_AU_IC2*	C2	71.229	164.226	41	9/14/2015	9/14/2016	366	16384	80/300	9/13/2015	9/14/2016
AW15_AU_PB1*	C5	71.206	158.015	46	9/15/2015	9/7/2016	358	16384	80/300	9/14/2015	9/7/2016
AW15_AU_WT1*‡	C4	71.047	160.503	49	9/14/2015	9/7/2016	359	16384	80/300	9/13/2015	9/7/2016
AW15_AU_IC1*‡	C1	70.836	163.109	42	9/19/2015	9/15/2016	362	16384	80/300	9/18/2015	9/15/2016
AW15_AU_CL1*‡	-	69.317	167.623	49	9/21/2015	4/2/2017	560	16384	80/300	9/19/2015	8/24/2017
AW15_AU_PH1*	C12	67.910	168.198	57	9/22/2015	2/10/2016	141	16384	80/300	9/20/2015	9/21/2016
AW15_AU_KZ1*‡	-	67.124	168.604	42	9/22/2015	9/21/2016	365	16384	80/300	9/21/2015	9/21/2016
AL16_AU_IC3*	C3	71.829	166.079	43	9/15/2016	8/20/2017	340	16384	80/300	9/14/2016	8/20/2017
AL16_AU_BF2*	MC3	71.754	154.456	98	9/9/2016	8/14/2017	340	16384	80/300	9/8/2016	8/14/2017
AL16_AU_BF1*	MC2	71.550	155.539	67	9/9/2016	8/13/2017	339	16384	80/300	9/8/2016	8/14/2017
AL16_AU_IC2*	C2	71.229	164.214	41	9/15/2016	10/6/2016	22	16384	80/300	9/14/2016	8/8/2017
AL16_AU_PB1*	C5	71.206	158.002	46	9/8/2016	8/12/2017	339	16384	80/300	9/7/2016	8/12/2017
AL16_AU_WT1*	C4	71.042	161.516	48	9/8/2016	8/11/2017	338	16384	80/300	9/7/2016	8/12/2017
AL16_AU_IC1*	C1	70.835	163.114	43	9/17/2016	8/9/2017	327	16384	80/300	9/15/2016	8/9/2017
AL16_AU_CC2*‡	C11	70.016	166.860	47	9/20/2016	8/7/2017	322	16384	80/300	9/19/2016	8/8/2017
AL16_AU_CL1*‡	-	69.319	167.608	49	9/21/2016	8/6/2017	320	16384	80/300	9/20/2016	8/7/2017
AL16_AU_PH1*	C12	67.907	167.200	57	9/22/2016	8/12/2017	325	16384	80/300	9/21/2016	8/6/2017
AL16_AU_NM1*‡	-	64.849	168.393	41	9/24/2016	8/5/2017	316	16384	80/300	9/23/2016	8/5/2017
AL17_AU_IC3*	C3	71.830	166.078	44	8/22/2017	8/12/2018	356	16384	80/300	8/20/2017	8/12/2018
AL17_AU_BF2	MC3	71.752	154.473	98	8/15/2017	8/18/2018	369	16384	80/300	8/14/2017	8/18/2018
AL17_AU_BF1	MC2	71.550	155.546	68	8/15/2017	8/17/2018	368	16384	80/300	8/18/2018	8/17/2018
AL17_AU_IC2	C2	71.229	164.213	43	8/10/2017	8/13/2018	369	16384	80/300	8/8/2017	8/13/2018
AL17_AU_PB1*	C5	71.205	158.019	47	8/14/2017	8/16/2018	368	16384	80/300	8/12/2017	8/16/2018
AL17_AU_WT1*	C4	71.041	160.515	48	8/13/2017	8/14/2018	367	16384	80/300	8/12/2017	8/15/2018
AL17_AU_IC1*	C1	70.838	163.108	45	8/10/2017	9/11/2017	33	16384	80/300	8/9/2017	8/14/2018
AL17_AU_CC2*	C11	70.016	166.860	47	8/9/2017	8/11/2018	368	16384	80/300	8/8/2017	8/11/2018
AL17_AU_PH1*	C12	67.907	168.202	58	8/24/2017	8/10/2018	352	16384	80/300	8/23/2017	8/10/2018
AL17_AU_NM1	-	64.849	168.392	44	8/7/2017	8/8/2018	367	16384	80/300	8/5/2017	8/8/2018
AL18_AU_IC3	C3	71.829	166.067	46	8/15/2018	DPLYD	-	16384	80/300	8/12/2018	DPLYD
AL18_AU_BF2	MC3	71.751	154.464	87.8	8/20/2018	DPLYD	-	16384	80/300	8/18/2018	DPLYD
AL18_AU_BF1	MC2	71.551	155.534	70.1	8/20/2018	DPLYD	-	16384	80/300	8/18/2018	DPLYD
AL18_AU_IC2	C2	71.215	164.260	45.3	8/16/2018	DPLYD	-	16384	80/300	8/13/2018	DPLYD
AL18_AU_PB1	C5	71.203	158.012	49	8/17/2018	DPLYD	-	16384	80/300	8/16/2018	DPLYD
AL18_AU_WT1	C4	71.043	160.497	52.4	8/17/2018	DPLYD	-	16384	80/300	8/15/2018	DPLYD
AL18_AU_IC1	C1	70.840	163.117	45	8/17/2018	DPLYD	-	16384	80/300	8/14/2018	DPLYD
AL18_AU_CC2	C11	70.016	166.865	48.6	8/13/2018	DPLYD	-	16384	80/300	8/11/2018	DPLYD
AL18_AU_PH1	C12	67.911	168.197	60.7	8/11/2018	DPLYD	-	16384	80/300	8/10/2018	DPLYD
AL18_AU_NM1	-	64.851	168.395	44.6	8/10/2018	DPLYD	-	16384	80/300	8/18/2018	DPLYD

Table 3. All oceanographic mooring information, 2015-2018. ADCP = Acoustic Doppler Current Profiler, SBE-16= SEACAT (T&S), SBE-37= Microcat (T&S), RCM9=Aanderaa current meter, RCMsg= Aanderaa SeaGuard, O2= oxygen sensor; PAR=light radiation sensor. *Data from instruments in italics are still being QA/QCed.

Year	Mooring Cluster	Mooring	Deployment Date	Retrieval Date	Latitude (°N)	Longitude (°W)	Water depth (m)	Instruments*
2015-16	C1	15CKP-1A	9/18/15	9/15/16	70.838	163.125	43	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		15CKIP-1A	9/18/15	9/15/16				SBE-37, RCM9, O2, Ice Profiler
	C2	15CKT-2A	9/19/15	9/14/16	71.231	164.223	41	SBE-37
		15CKP-2A	9/13/15	9/14/16				Fluorometer, ADCP, SBE-16, PAR, Nitrate
		15CKIP-2A	9/13/15	9/14/16				SBE-37, RCM9, O2, Ice Profiler
	C4	15CKIP-4A	9/13/15	9/7/16	71.038	160.514	47.5	SBE-37, RCM9, O2, Ice Profiler
		15CKP-4A	9/13/15	9/7/16				Fluorometer, ADCP, SBE-16, PAR
2016-17	C1	16CKP-1A	9/15/16	8/9/17	70.838	163.125	43	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		16CKIP-1A	9/15/16	8/9/17				SBE-37, RCMsg, O2, Ice Profiler
	C2	16CKP-2A	9/14/16	8/8/17	71.233	164.217	41	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		16CKIP-2A	9/14/16	8/8/17				SBE-37, RCM9, O2, Ice Profiler
	C3	16CKP-3A	9/14/16	8/20/17	71.828	166.070	43	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		16CKIP-3A	9/14/16	8/20/17				SBE-37, *RCM9, O2*, Ice Profiler
	C4	16CKP-4A	9/7/16	8/12/17	71.038	160.514	47.5	Fluorometer, ADCP, SBE-16, PAR, RCM9
	C5	16CKP-5A	9/7/16	8/12/17	71.203	158.011	46	Fluorometer, ADCP, SBE-16, PAR, SBE-37
	C10	16CKP-10A	9/19/16	8/7/17	70.211	167.787	47	SBE-16, Fluorometer, ADCP
	C11	16CKP-11A	9/19/16	8/8/17	70.013	166.855	46	SBE-16, Fluorometer, ADCP
	C12	16CKP-12A	9/21/16	8/6/17	67.911	168.195	58	SBE-16, Fluorometer, RCM9, O2, ADCP
2017-18	C1	17CKP-1A	8/9/17	8/14/18	70.838	163.125	43	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		17CKIP-1A	8/9/17	8/14/18				SBE-37, RC9, Ice Profiler
	C2	17CKP-2A	8/8/17	8/13/18	71.231	164.223	41	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		17CKIP-2A	8/8/17	8/13/18				SBE-37, RCM9, Ice Profiler, *O2*
	C3	17CKP-3A	8/20/17	8/12/18	71.828	166.070	43	Fluorometer, ADCP, SBE-16, PAR, Nitrate
		17CKIP-3A	8/20/17	8/12/18				SBE-37, RCM9, Ice Profiler
	C4	17CKP-4A	8/12/17	8/15/18	71.038	160.514	47.5	Fluorometer, ADCP, SBE-16, PAR, O2, RCM9
	C5	17CKP-5A	8/12/17	8/16/18	71.203	158.011	46	Fluorometer, ADCP, SBE-16, PAR, SBE-37
	C10	17CKP-10A	8/7/17	8/12/18	70.211	167.787	47	SBE-16, Fluorometer, ADCP
	C11	17CKP-11A	8/7/17	8/11/18	70.013	166.855	46	SBE-16, Fluorometer, ADCP
	C12	17CKP-12A	8/23/17	8/11/18	67.911	168.195	58	RCM9, O2, ADCP
2018-19	C1	18CKIP-1A	08/14/18	DPLYD	70.8390	163.1289	46	SBE-37, RCM9, Ice Profiler, O2
		18CKP-1A	8/14/18	DPLYD				Fluorometer, ADCP, SBE-16, PAR, Nitrate, MTR
	C2	18CKIP-2A	8/13/18	DPLYD	71.2138	164.2526	45	SBE-37, RCM9, Ice Profiler, O2, Turbidity
		18CKP-2A	8/13/18	DPLYD				Fluorometer, ADCP, SBE-16, PAR, Nitrate
	C3	18CKIP-3A	8/12/18	DPLYD	71.8286	166.0527	52	SBE-37, RCM9, Ice Profiler, O2
		18CKP-3A	8/12/18	DPLYD				Fluorometer, ADCP, SBE-16, PAR, Nitrate
	C4	18CKP-4A	8/15/18	DPLYD	71.0437	160.5083	52	Fluorometer, ADCP, SBE-16, PAR, O2, RCMsg
	C5	18CKP-5A	8/16/18	DPLYD	71.2078	158.0175	50	Fluorometer, ADCP, SBE-16, SBE-37, PAR
	C10	18CKP-10A	8/12/18	DPLYD	70.2193	167.7918	49	Fluorometer, ADCP, SBE-16
	C11	18CKP-11A	8/11/18	DPLYD	70.0170	166.8534	49	Fluorometer, ADCP, SBE-16
	C12	18CKP-12A	8/11/18	DPLYD	67.9097	168.1899	61	ADCP, RCM9, O2, Turbidity
	C14	18CK-14A	8/14/18	DPLYD	70.7076	162.4509	42	SBE-37, RCM9, O2

V. Passive acoustics

A. Methods

1. Moorings

Autonomous Underwater Recorders for Acoustic Listening (AURAL, Multi-Électronique, Rimouski, QC, Canada) were used on subsurface moorings comprised of an anchor, chain, acoustic release, passive acoustic recorder, and 30" steel subsurface float (total length of mooring ~8 m; hydrophone ~6 m off the seafloor). The AURALs recorded for an entire year at a sampling rate of 16 kHz, with 16-bit resolution and 16 dB gain, on a duty cycle of 85 min of recording every 5 hours (28%). With these settings the AURALs had a spectral noise floor of 52 dB re 1 μPa^2 /Hz (Kinda et al. 2013) and a maximum input pressure (a signal saturation level) of 154 dB re 1 µPa, for a dynamic range of 90 dB over the effective bandwidth of the system. In addition to the passive acoustic data, each AURAL was equipped with a built-in temperature (-10° C to 40° C, resolution 0.0625° C, accuracy ± 0.5° C) and pressure (0 to 1000 psi [0~682 m], resolution 1.3 cm, accuracy ± 0.25% max) sensors which each sampled once per recording period.

Raw data from the recorders were converted into 10 min sound files (.wav). Image files (.png) of spectrograms were then pre-generated from recordings (FFT 1024, 0.85 overlap, Hamming window). These image files displayed either 225 s of data from 0 to 800 Hz (mid-frequency signals) or 90 s of data from 0 to 8.192 kHz (high-frequency signals). These bin lengths were chosen to allow for the analyst to view the maximum amount of data for that frequency band in a single frame, without needing to continually expand the data using the zoom function. After the analyses were complete, the data results were re-compiled into ten-minute bins, which is the ***analysis interval length*** of the study. Given the staggered duty cycle of the recorders, the results were normalized by dividing the number of analysis intervals with calls detected for that day by the number of available intervals for that day. The results that follow are hence presented as ***calling activity****,* which is defined as the percentage of time intervals with calls for each day. It is important to note that calling activity does not indicate the number of call detections or number of animals vocalizing.

An in-house, MATLAB-based program (SoundChecker) was used. It operates on the pre-generated image files (described above), which reduces the computational time needed to generate spectrograms during analysis. The image files are indexed to allow for zoom and playback functioning during analysis. For each image file, the analyst selects one of four options: yes, no, maybe, and no-with-noise to indicate whether a species was detected in that file. The no-with-noise option is selected when the presence of high levels of noise mask potential calls from that species or sound source. The analysts were highly conservative when assigning yes designations; if there was any doubt as to the source of the calls within an image file, it was marked as maybe. The results below use only those image files marked as yes. Future studies using these data will be expedited as only the image files marked with yeses and maybes will need to be included and the full data set will not need to be re-analyzed. All acoustic data were analyzed for the presence of the following: bowhead (*Balaena mysticetus*), right *(Eubalaena japonica)*, humpback *(Megaptera novaeangliae)*, gray *(Eschrichtius robustus)*, and minke whales *(Balaenoptera acutorostrata)*, walrus *(Odobenus rosmarus)*, unidentified pinnipeds, as well as vessel noise and seismic airguns in the mid-frequency band; and beluga *(Delphinapterus leucas)*, killer whale (Orcinus orca), minke whale (boing call), bearded (*Erignathus barbatus*) and ribbon seals (*Histriophoca* *fasciata*), and environmental noise (ice) in the high frequency band. Information on species/source differentiation can be found in Mocklin and Friday (2018).

2. Shipboard

During all field survey cruises, sonobuoys were deployed opportunistically to monitor for the presence of vocalizing marine mammals. A sonobuoy is a free-floating, expendable, short-term passive acoustic listening device that transmits signals in real time via VHF radio waves to a receiver on the vessel (Rone et al. 2012). The hydrophone is suspended down from the surface float at a programmable depth. Here, the sonobuoys were shortened to place the sensor at ~22m depth. On all cruises, 53F sonobuoys were used (manufactured by either Sparton or Undersea Sensor Systems Inc.), and deployed in Directional Frequency Analysis and Recording (DiFAR) mode; the frequency response was flat (±3 dB) from 0.6 to ~2 kHz.

A single mast holding both an omnidirectional and Yagi antenna was attached to the highest possible location on the vessels with the directional antenna facing astern. The Yagi was used primarily during transit when the sonobuoy was guaranteed to be behind the vessel, the omnidirectional when other scientific operations caused the sonobuoy to not be directly behind the vessel. The signals received by the shipboard antennas were pre-amplified and input to a WinRadio sonobuoy receiver (WiNRADiO Communications, Oakleigh, Australia) then into an external soundcard. The soundcard digitized the signal at a sampling rate of 48 kHz, and was connected to a laptop computer where the recordings were monitored in real-time using ISHMAEL (Mellinger 2001) software. Source levels of received signals were not calculated, as the recording system was not calibrated. Directional bearing information of the calls was obtained using DiFAR demultiplexing software and a custom MATLAB interface. A GPS feed into the computer provided the ship's position, updated every minute, as well as the sonobuoy deployment location and time. A custom tracking and plotting program implemented in MATLAB (CLB) allowed for real-time plotting of the vessel and sonobuoy locations, as well as the bearing of calling marine mammals. Directional bearing information was calibrated using the ship as a sound source. All data were simultaneously recorded to an external hard drive.

B. Results

1. Moorings

A total of 8403 hours of passive acoustic recordings were analyzed for this supplemental report, including those from the 2015-16 deployment year that were retrieved, but not analyzed, prior to submission of the CHAOZ-X final report[2]. Figure 3 provides a summary of the locations of all moorings analyzed for this supplemental report. Table 2 includes details on which recorders were analyzed and which frequency bands were completed. Species included in the regular frequency band (*) were bowhead, gray, humpback, minke, and right whales, walrus, as well as noise from vessels and seismic airguns. Species include in the high frequency band (‡) were beluga, killer, and sperm whales, minke

[2] These results include data through December 31, 2015. Previous reports ended in September 2015, and so numbers and results presented here may vary.

whale boings, bearded and ribbon seals, and ice noise. Fin whales were not analyzed at these moorings for this report[3].

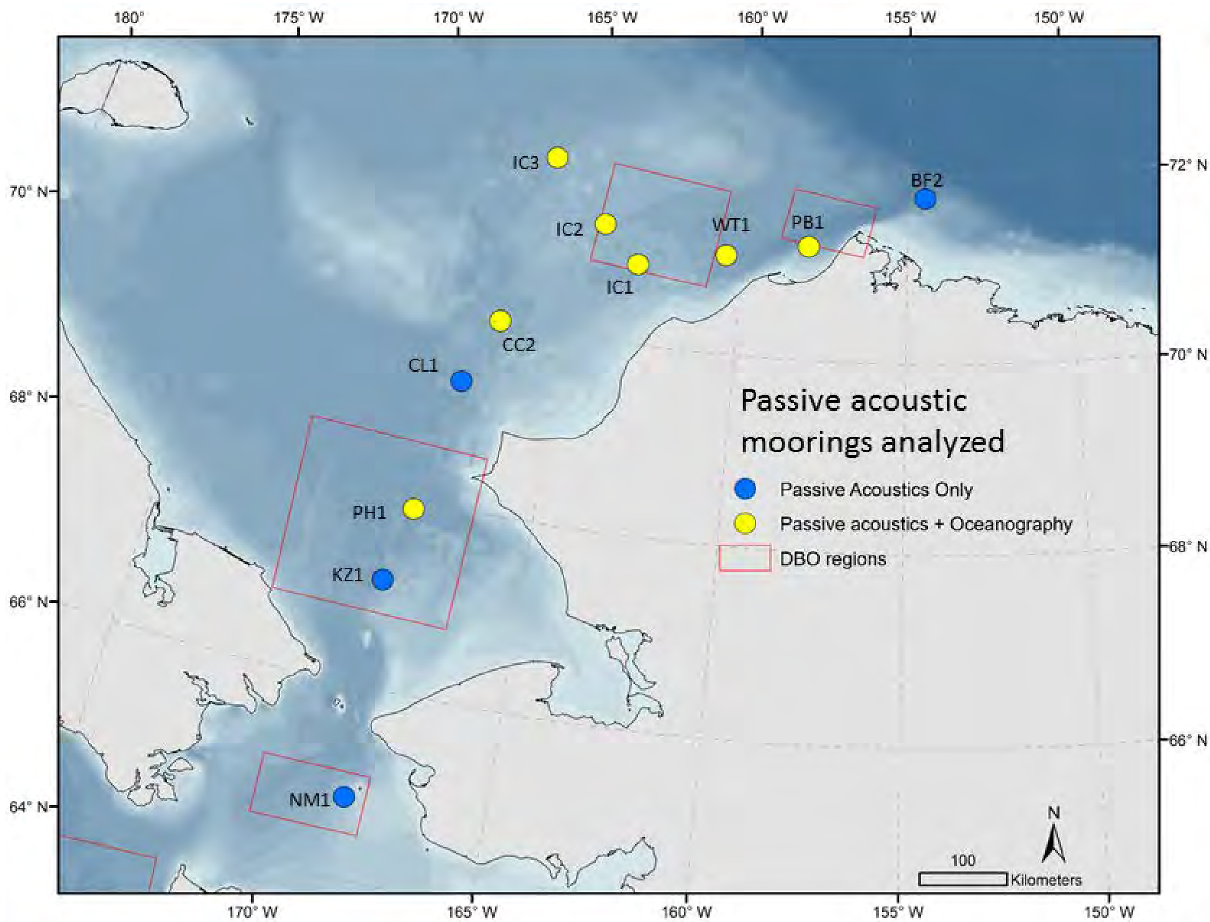

Figure 3. Location of all passive acoustic moorings with analysis results in this report. Circle color indicates whether mooring was located alone or in a cluster of oceanographic moorings.

Because of the staggered duty cycle used for the recordings, there was differing sampling effort among days. This was normalized by dividing the number of ten-minute sound files with calls[4] detected for that day by the number of available ten-minute sound files for that day. The results that follow are presented as the percentage of ten-minute time intervals with calls for each day (Figure 4). This will be referred to as ***calling activity*** for the remainder of this report. It is important to note that calling activity indicates the duration of sustained calling for that day, not the number of call detections or number of animals vocalizing. For example, if a day shows 100% beluga calling activity that means that 100% of the ten-minute time bins in that day contained at least one beluga call. Any day that has detections in 50% or

[3] The work begun with Cornell University for the fin whale autodetectors did not progress once the ARCWEST/ CHAOZ-X projects ended. We currently have a dedicated team member working on autodetectors in the Bering Sea for right whales who will attempt fin whales in the near future (May 2019).
[4] In the context of this report we define calls and calling activity to include any and all sounds produced by an animal.

more of its ten-minute time bins is considered a day with peak calling. Anomalies in monthly calling (days in month with calling (*dc*)/days in month with effort (*de*)) were computed (Equation 1) for each year (*y*) by subtracting the mean monthly calling from 2010-2018 for each month (*m*) from the monthly calling for that month. These will be called monthly calling anomalies (MCA).

$$MCA_{y,m} = \left(\frac{dc}{de}\right)_{y,m} - \frac{\sum_{i=2010}^{2018} \left(\frac{dc}{de}\right)_{i,m}}{9}$$

Equation 1. Equation used to calculate monthly calling anomalies. See text for details.

For the sake of brevity, the tables on key timing events (e.g., migration dates), when not directly relevant to the results, will also not be included with the main text; they are provided instead in APPENDIX B. Additionally, the monthly calling distribution plot figures that were presented as maps in the ARCWEST and CHAOZ-X final reports, will be included in APPENDIX C.

The results for the species/signals analyzed were divided into Arctic and subarctic species. The Arctic species included bowhead, gray, and beluga whales, bearded seals, and walrus. These species are good proxies for Arctic ecosystem change because they represent a variety of differing habitat and dietary niches. As such, this results section will focus on these five species. The subarctic species detected, humpback whales, killer whales, and ribbon seals, had minimal amounts of calling activity; their results will be presented following those for the Arctic species. In both cases, the results from this supplemental analysis (i.e., 2016-18) will be presented along with those from the CHAOZ, CHAOZ-X, and ARCWEST studies (i.e., 2010-15) to allow discussion of longer-term trends. For simplicity these comparisons will reference the year-range and not list all project names or citations to those studies.

Arctic species

Bowhead whales

As with the 2010-15 results, bowhead whale calling activity during 2016-18 was detected on all passive acoustic moorings analyzed for this report (Table 2, Table 4). The BF2 (Barrow Canyon) site continued to have the greatest percentage of days with calls, while the IC2 and IC3 sites (offshore Icy Cape) ranked lowest (Table 4). Table 4 also shows that although the percentage of days with calls detected did not vary much between the time periods analyzed, the data analyzed for this report (2016-18) had a much higher percent of days with peak calling than those for the earlier reports (2010-15). The only sites where this was not the case were the IC2 and IC3 sites off Icy Cape.

Table 4. Total bowhead whale calling activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	908	491	48	26	54
PB1	850	376	154	44	18	41
WT1	1219	535	251	44	21	47
IC3	1752	464	251	26	14	54
IC2	1745	516	253	30	14	49
IC1	1869	704	333	38	18	47
CC2	-	-	-	-	-	-
CL1	1225	416	242	34	20	58
PH1	1226	430	288	35	23	67
KZ1	1227	523	367	43	30	70
NM1	1209	459	336	38	28	73

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	591	300	200	51	34	67
PB1	957	379	256	40	27	68
WT1	905	388	262	43	29	68
IC3	953	257	140	27	15	54
IC2	279	61	22	22	8	36
IC1	619	237	163	38	26	69
CC2	690	262	205	38	30	78
CL1	583	135	96	23	16	71
PH1	712	316	278	44	39	88
KZ1	265	72	51	27	19	71
NM1	583	227	186	39	32	82

The CHAOZ-X and ARCWEST final reports described both spring and fall bowhead migrations occurring from 2010 through 2015, with bowhead presence occurring mostly during the open water season at the northeastern-most mooring sites (IC1-BF2), and during the ice season at the southern-most sites (CL1-NM1). The spring migration was shown to occur mostly inshore, while the fall migration fanned out over the Chukchi shelf – out to the offshore Icy Cape site (IC3). These general patterns were also seen from 2016 through 2018 with a few notable exceptions. First, during the ice season, there was sustained bowhead whale calling presence in 2017-18 off Point Hope (PH1) for the first time in six years (Figure 4). There was also sustained overwinter presence at the newly occupied site CC2 in the Central Channel during this same time period. Furthermore, the northeastern-most moorings (BF2, PB1, WT1) all showed increased bowhead whale presence overwinter. This can be seen in the higher percent of days with calling activity in January (compared to the results from 2010-2015). For example, the moorings from Icy Cape to Barrow range from 34-54% (Table 5); no values topped 5% from 2010-2015.

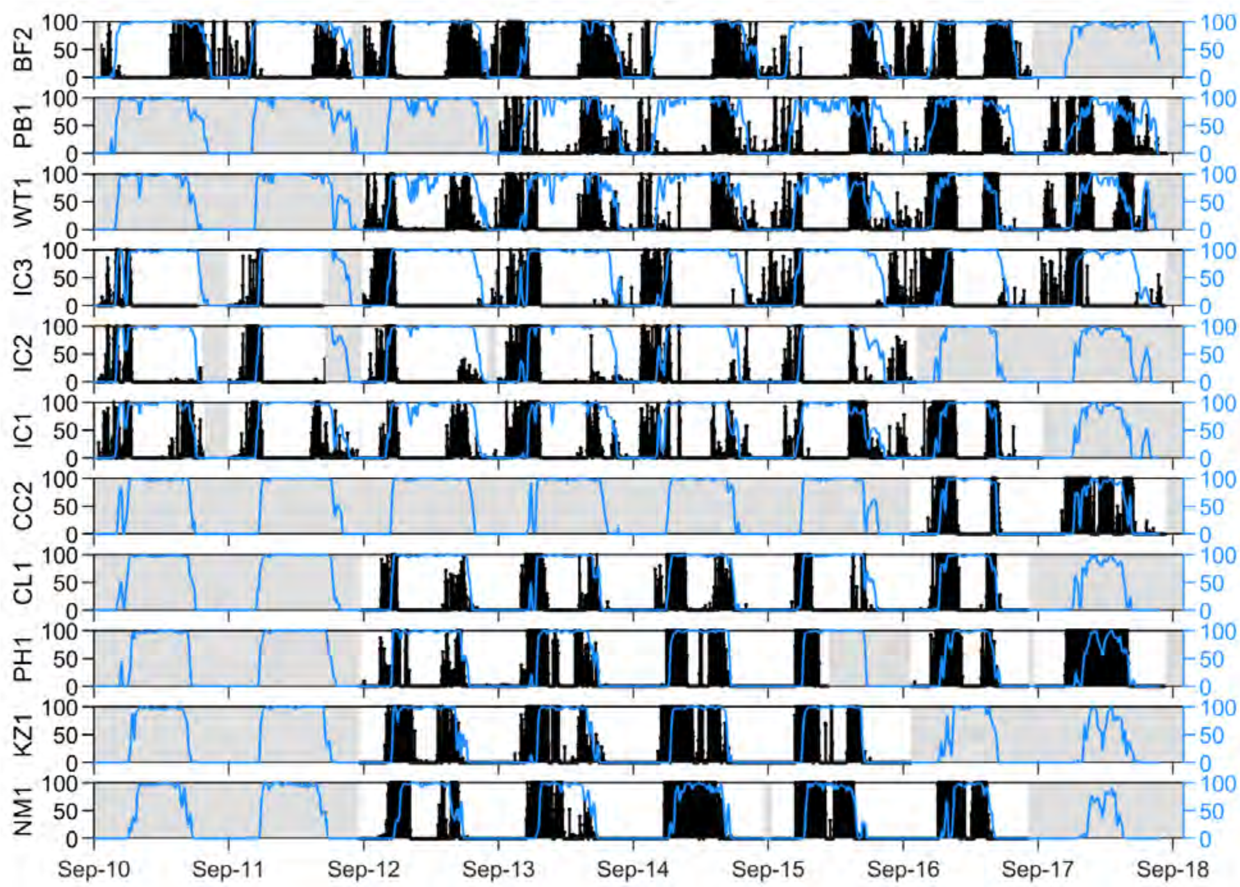

Figure 4. Bowhead whale calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

The 2016 open water period showed bowhead whales persisted off Barrow (BF2) similar to what was seen in 2011 and 2012 (Figure 4). A sustained presence of bowheads was also found during the 2016 open water season at the offshore Icy Cape (IC3) site.

The changes between the 2010-15 period and the 2016-18 period are best visualized by plotting the monthly calling anomaly. As seen in Figure 5, there is a positive anomaly of 50% from 2016 to 2018 in January for all mooring sites shown except for NM1. This high positive anomaly continues through March for the PH1 mooring site, and began at the Barrow Canyon sites (BF2, WT1, IC1) in December starting in 2015. Positive anomalies of varying degree are seen for the mooring sites near Barrow Canyon (BF2, IC1, WT1) in August of 2016.

Table 5. Monthly bowhead whale calling activity, 2016-2018 for all moorings shown in Figure 3. # = # days with calling activity; Eff = # days with recordings; % = % days with calling activity/ days with recordings.

	NM1			KZ1			PH1			CL1			CC2			IC3			IC2			IC1			WT1			PB1			BF2		
Month	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	62	62	**100**	16	31	**52**	78	93	**84**	28	62	**45**	53	62	**86**	16	93	**17**	0	31	**0**	23	62	**37**	50	93	**54**	47	93	**50**	20	62	**33**
Feb	24	57	**42**	8	29	**28**	34	66	**40**	0	57	**0**	18	56	**32**	0	85	**0**	0	29	**0**	0	57	**0**	0	85	**0**	1	85	**1**	0	57	**0**
Mar	57	62	**92**	0	31	**0**	32	62	**52**	1	62	**2**	27	62	**44**	0	93	**0**	0	31	**0**	0	62	**0**	4	93	**4**	6	93	**6**	1	62	**2**
Apr	46	60	**77**	30	30	**100**	58	60	**97**	26	59	**44**	23	60	**38**	0	90	**0**	16	30	**53**	41	60	**69**	79	90	**88**	75	90	**83**	40	60	**67**
May	10	62	**16**	17	31	**55**	16	62	**26**	29	62	**47**	38	62	**61**	8	93	**8**	5	31	**16**	55	62	**89**	77	93	**83**	81	93	**87**	62	62	**100**
Jun	0	60	**0**	1	30	**3**	0	60	**0**	4	60	**7**	4	60	**7**	7	90	**8**	2	30	**7**	18	60	**30**	22	84	**27**	33	90	**37**	52	60	**87**
Jul	0	62	**0**	0	31	**0**	0	62	**0**	0	62	**0**	2	62	**3**	25	93	**27**	7	31	**23**	8	62	**13**	7	62	**12**	8	93	**9**	19	62	**31**
Aug	0	36	**0**	0	31	**0**	0	24	**0**	0	37	**0**	0	41	**0**	28	73	**30**	20	31	**65**	19	62	**31**	10	61	**16**	0	77	**0**	26	45	**50**
Sep	0	30	**0**	0	21	**0**	0	39	**0**	0	30	**0**	0	41	**0**	26	59	**44**	11	29	**38**	12	40	**21**	23	60	**39**	11	59	**19**	24	29	**83**
Oct	0	31	**0**	0	0	-	1	62	**2**	1	31	**3**	1	62	**2**	37	62	**60**	0	6	**0**	6	31	**19**	19	62	**31**	25	62	**41**	25	31	**81**
Nov	0	30	**0**	0	0	-	35	60	**59**	15	30	**50**	34	60	**57**	50	60	**83**	0	0	-	24	30	**80**	39	60	**65**	39	60	**65**	6	30	**20**
Dec	28	31	**90**	0	0	-	62	62	**100**	31	31	**100**	62	62	**100**	60	62	**97**	0	0	-	31	31	**100**	58	62	**94**	53	62	**86**	25	31	**81**

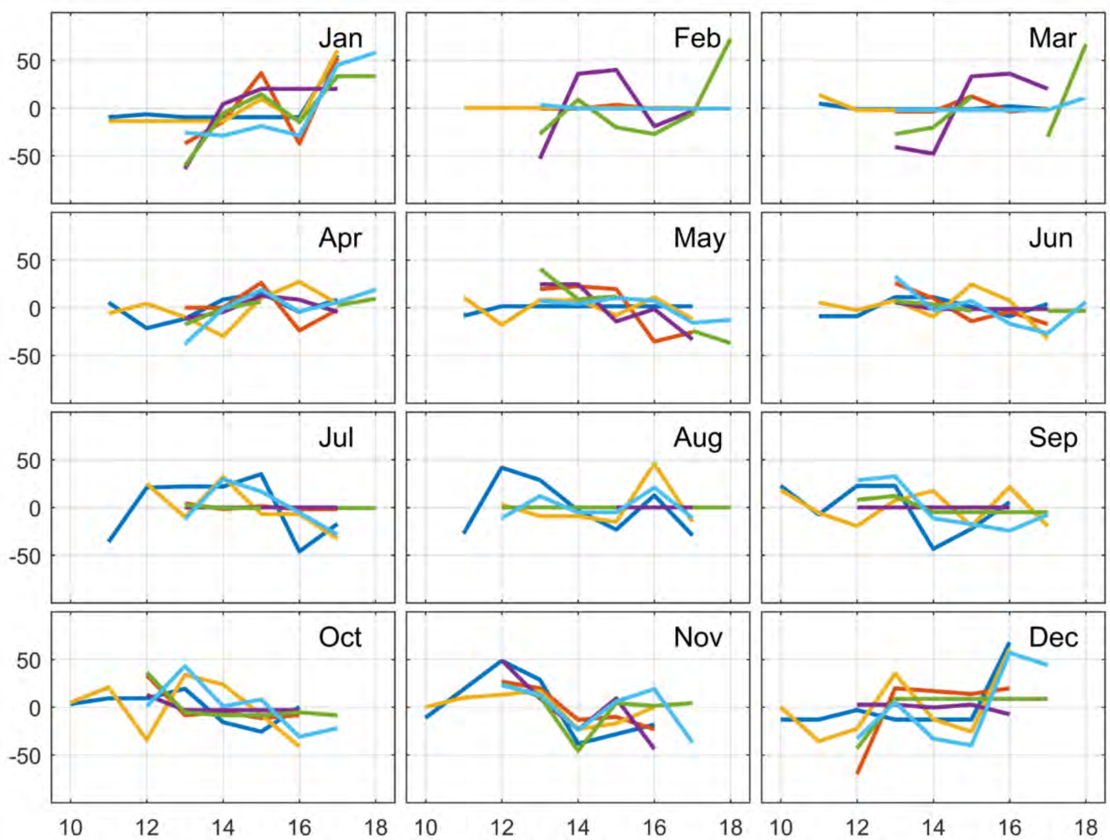

Figure 5. Monthly bowhead calling activity anomaly from 2010 to 2018 (See Equation 1). Colors indicate mooring site; yellow=IC1, dark blue = BF2, light blue = WT1, green = PH1, orange = CL1, and purple = NM1. X-axis is two-digit year.

Dates for the beginning and end of the spring migration were consistent with those found for 2010-2015. The spring migration started roughly late February to early March just south of Bering Strait, mid-March to mid-April at the southern Chukchi sites, and at the beginning of April at the northernmost sites (Table 6). There was a wide range of end dates for the spring migration at the northernmost sites (e.g., May through August), but it consistently ended in May for the southern Chukchi sites, and late April-early May south of Bering Strait (NM1). It is difficult to determine exactly when the beginning of the fall migration passed by the northern mooring sites, given the amount of calling activity present at those sites throughout the open water period. The dates varied among years and mooring locations, starting sometime between September and December at the northern sites, mid-November at the southern Chukchi sites, and mid-November through early December south of the Bering Strait. The end to the migration occurred a little later each year at all mooring sites (Table 6). There were a couple of more southern mooring sites that had continuous bowhead presence during the ice period, which made it difficult or impossible to determine an exact migration end date.

The difference between bowhead calling activity during the earlier studies and this study can be seen in Figure 6. The darker green segments show time periods where bowhead whale calling was present at high levels in almost all years; dark blue shows similarly high ice concentrations in most years. The later years have more concentrated periods of high calling activity for the spring migration at all sites, the open water season at the northern sites, and during the ice period at the southern sites.

The strong correlation between gunshot calling at the central Chukchi sites (IC1-3 and CL1) described in Vate Brattström et al. (2019) did not continue for the years of this study (Figure 7). In fact, the lower levels of gunshot calling found at the southern and northern sites for the earlier study was seen at all mooring sites after 2015. The only site where gunshot calling increased was PB1, where a correlation was found during the spring migration from 2015 on.

Table 6. Key timing events for bowhead whale calling activity. Ice start and end dates were obtained from satellite-derived ice concentration data. *These dates were obtained by estimating the dates for the main pulses in Figure 4.

Year	Mooring	Calling		Peak Calling		Spring Pulse* Dates		Fall Pulse* Dates		Ice End Date	Ice Start Date
		Start	End	Start	End	Start	End	Start	End		
2015	BF2	2-Apr	28-Nov	11-Apr	28-Nov	2-Apr	2-Aug	6-Oct	28-Oct	5-Aug	11-Oct
	PB1	9-Mar	1-Dec	2-Apr	28-Nov	2-Apr	19-Jun	16-Sep	1-Dec	7-Jul	28-Oct
	WT1	2-Jan	1-Dec	3-Jan	30-Nov	1-Apr	10-Jun	12-Sep	1-Dec	30-Jun	9-Nov
	IC1	1-Jan	19-Dec	2-Jan	2-Dec	1-Apr	6-Jul	12-Oct	4-Dec	15-Jun	13-Nov
	CL1	1-Jan	29-Dec	1-Jan	27-Dec	27-Mar	30-May	13-Nov	29-Dec	13-Jun	20-Nov
	PH1	1-Jan	31-Dec	1-Jan	31-Dec	24-Mar	21-May	13-Nov	17-Jan	1-Jun	3-Dec
	KZ1	1-Jan	30-Dec	1-Jan	30-Dec	19-Mar	24-May	12-Nov	18-Jan	24-May	1-Dec
	NM1	1-Jan	31-Dec	1-Jan	31-Dec	cont.	5-May	14-Nov	4-Feb	21-May	9-Dec
2016	BF2	27-Mar	28-Dec	17-Apr	27-Dec	11-Apr	28-Jun	21-Nov	20-Jan	24-Jul	7-Nov
	PB1	9-Jan	31-Dec	13-Apr	29-Dec	10-Apr	4-Jul	28-Oct	23-Jan	11-Sep	7-Nov
	WT1	8-Apr	31-Dec	9-Apr	31-Dec	8-Apr	3-Jun	1-Nov	24-Jan	8-Sep	7-Nov
	IC1	7-Apr	31-Dec	8-Apr	31-Dec	7-Apr	2-Jun	6-Nov	23-Jan	11-Jul	24-Nov
	CC2	23-Oct	31-Dec	19-Nov	31-Dec	-	-	7-Nov	27-Jan	25-Jun	6-Dec
	CL1	14-Apr	31-Dec	14-Apr	31-Dec	14-Apr	24-May	13-Nov	30-Jan	20-Jun	25-Nov
	PH1	1-Jan	31-Dec	1-Jan	31-Dec	no data	no data	14-Nov	8-Feb	24-May	9-Dec
	KZ1	3-Jan	3-Jun	4-Jan	10-May	1-Apr	21-May	-	-	19-May	3-Dec
	NM1	1-Jan	31-Dec	1-Jan	31-Dec	25-Feb	22-Apr	3-Dec	15-Feb	23-May	13-Dec
2017	BF2	1-Jan	13-Aug	1-Jan	14-Jul	10-Apr	16-Jul	-	-	5-Jul	1-Dec
	PB1	1-Jan	31-Dec	4-Jan	31-Dec	4-Apr	13-Jun	18-Nov	30-Jan	29-Jun	1-Dec
	WT1	1-Jan	31-Dec	1-Jan	31-Dec	5-Apr	23-May	20-Dec	29-Jan	21-Jun	13-Oct
	IC1	1-Jan	29-Jun	1-Jan	26-Jun	15-Apr	23-May	-	-	22-May	2-Dec
	CC2	1-Jan	31-Dec	1-Jan	31-Dec	27-Apr	23-May	4-Nov	23-Jan	13-May	6-Dec
	CL1	1-Jan	22-May	1-Jan	10-May	14-Apr	22-May	-	-	12-May	1-Dec
	PH1	1-Jan	31-Dec	1-Jan	31-Dec	31-Mar	13-May	13-Nov	-	20-May	10-Dec
	NM1	1-Jan	28-Apr	1-Jan	15-Apr	4-Mar	21-Apr	-	-	7-May	16-Dec
2018	PB1	1-Jan	22-Jul	1-Jan	23-Jun	26-Mar	27-Jun	-	-	20-Jul	-
	WT1	1-Jan	22-Jun	1-Jan	21-Jun	26-Mar	21-May	18-Nov	29-Jan	16-Jul	-
	CC2	1-Jan	11-Jul	1-Jan	17-May	19-Apr	22-May	-	-	15-May	-
	PH1	1-Jan	9-May	1-Jan	3-May	cont.	9-May	-	-	20-May	-

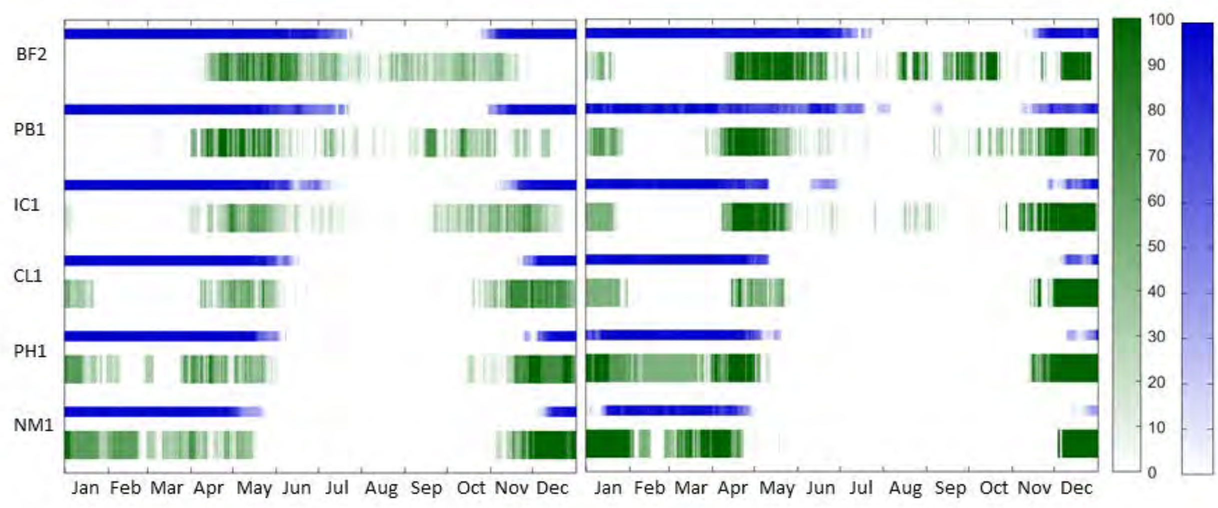

Figure 6. Percent daily average bowhead presence (green) and percent daily average ice concentration (blue) for six mooring locations along the bowhead whale migration corridor, 2010-2015 (left) and 2016-2018 (right). Number scale is valid for both color bars.

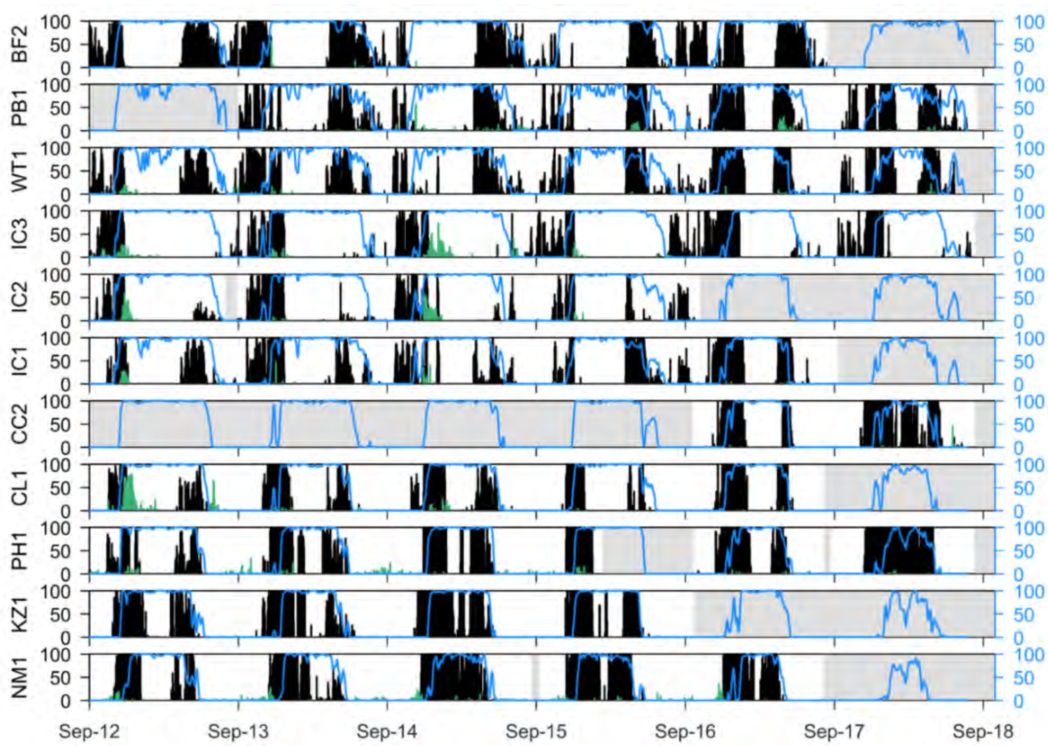

Figure 7. Gunshot call activity (green) overlaid on bowhead whale calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Beluga Whales

Although the beluga whale analysis is not as complete as that for bowhead whales, the results for the finished moorings do not show anything unexpected as compared with the results from 2010-15. Beluga whale calling activity was detected on all the moorings analyzed for this report (Table 2, Table 7). The recorder with the highest proportion of beluga whale calling activity was the one closest to Barrow (BF2, Table 7). Peak calling levels were low for most sites. However, although the percentage of days with calling has remained fairly consistent (or decreased) between 2010-15 and 2016-18 (Table 7), the number of those days with peak levels of calling activity increased more than double at the mooring sites near Barrow Canyon (BF2) and in the southern Chukchi (KZ1).

As with the earlier data from 2010-2015, both the spring and the fall beluga migrations were seen in the 2016-2018 study period, the spring being the larger of the two at all sites (Figure 8, Table 8). Similar to bowhead whales, beluga whales were detected during their spring migration well before ice break up in the Chukchi. Dates for the start of the spring migration were mid- to late-March for the southern moorings and early April for the northern ones (Table 9), similar to what was seen in 2010-15. Also similar was the end of the spring migration, April/May for the southern moorings and May/June for the northern ones. Although there was another pulse of calling that overlapped with fall ice formation at the BF2 site, it is not possible to determine whether this was a fall migration pulse or just presence on a feeding ground, since it lasted the entire open water season on all three years of this study. For the other moorings, it seems that the end of the fall migration occurred somewhere in October/November in the northern sites and December at the southern sites (Table 9), again matching the timing seen in the 2010-15 period.

Because of the number of moorings that still need to be analyzed for beluga whales, there was not much of an actual difference between the 2010-15 and 2016-18 data sets in the daily average plots. All data from 2010 through 2018 is therefore plotted in Figure 9. Here the spring and fall migrations are shown for all moorings, as is the open water season presence at BF2 (and somewhat at PB1). For this reason, the monthly calling activity anomaly plot (e.g., Figure 5) will also be omitted.

Table 7. Preliminary beluga whale calling activity, 2010-2015 (left) versus 2016-2018 (right, preliminary). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	799	156	42	8	20
PB1	742	180	9	24	1	5
WT1	1212	280	32	23	3	11
IC3	1647	227	7	14	<1	3
IC2	1636	256	7	16	<1	3
IC1	1869	445	72	24	4	16
CC2	0	0	0	-	-	-
CL1	1225	150	25	12	2	17
PH1	1124	354	67	31	6	19
KZ1	1227	235	17	19	1	7
NM1	842	142	4	17	<1	3

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	252	118	54	47	21	46
PB1	-	-	-	-	-	-
WT1	291	49	6	17	2	12
IC3	-	-	-	-	-	-
IC2	-	-	-	-	-	-
IC1	284	66	5	23	2	8
CC2	690	122	25	18	4	20
CL1	583	113	19	19	3	17
PH1	-	-	-	-	-	-
KZ1	265	37	12	14	5	32
NM1	583	58	5	10	1	9

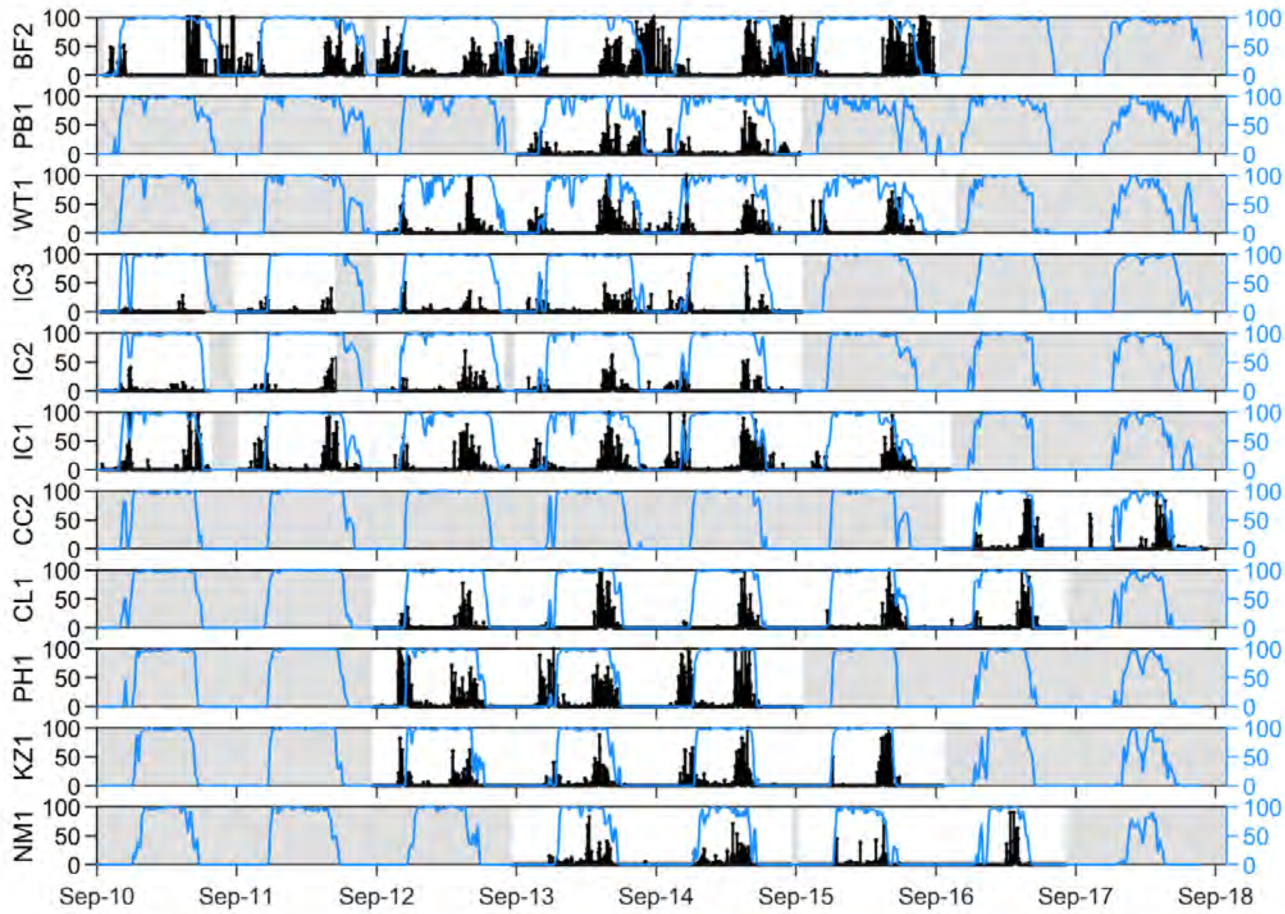

Figure 8. Preliminary beluga whale calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 8. Preliminary monthly beluga whale calling activity, 2016-2018. Analyses are still ongoing for NM1, IC1, WT1, and BF2 (Figure 3). KZ1 and CL1 were not deployed for 2017-18. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

	NM1			KZ1			CL1			CC2			IC1			WT1			BF2		
Month	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	6	62	**10**	1	31	**3**	1	62	**2**	2	62	**3**	0	31	**0**	0	31	**0**	0	31	**0**
Feb	4	57	**7**	0	29	**0**	3	57	**6**	7	56	**13**	0	29	**0**	0	29	**0**	0	29	**0**
Mar	29	62	**47**	1	31	**3**	9	62	**15**	6	62	**10**	0	31	**0**	0	31	**0**	1	31	**3**
Apr	17	60	**29**	24	30	**80**	36	59	**62**	44	60	**74**	17	30	**57**	10	30	**33**	12	30	**40**
May	2	62	**3**	11	31	**35**	46	62	**74**	37	62	**60**	29	31	**94**	28	31	**90**	27	31	**87**
Jun	0	60	**0**	0	30	**0**	5	60	**9**	6	60	**10**	19	30	**63**	9	30	**30**	25	30	**83**
Jul	0	62	**0**	0	31	**0**	0	62	**0**	1	62	**2**	1	31	**3**	2	31	**6**	31	31	**100**
Aug	0	36	**0**	0	31	**0**	1	37	**2**	0	41	**0**	0	31	**0**	0	31	**0**	22	31	**71**
Sep	0	30	**0**	0	21	**0**	0	30	**0**	0	41	**0**	0	29	**0**	0	27	**0**	0	8	**0**
Oct	0	31	**0**	0	0	**-**	1	31	**3**	5	62	**8**	0	11	**0**	0	20	**0**	0	0	**-**
Nov	0	30	**0**	0	0	**-**	5	30	**17**	0	60	**0**	0	0	**-**	0	0	**-**	0	0	**-**
Dec	0	31	**0**	0	0	**-**	6	31	**19**	14	62	**23**	0	0	**-**	0	0	**-**	0	0	**-**

Table 9. Preliminary key timing events for beluga whale calling activity. Ice start and end dates were obtained from satellite-derived ice concentration data. *These dates were obtained by estimating the dates for the main pulses in Figure 8.

Year	Mooring	Calling		Peak Calling		Spring Pulse* Dates		Fall Pulse* Dates		Ice End Date	Ice Start Date
		Start	End	Start	End	Start	End	Start	End		
2015	BF2	6-Apr	19-Nov	23-Apr	17-Oct	6-Apr	1-Jun	24-Jun	3-Nov	5-Aug	11-Oct
	PB1	3-Jan	12-Sep	21-Apr	17-May	2-Apr	29-May	-	-	7-Jul	28-Oct
	WT1	2-Apr	26-Nov	26-Apr	4-Nov	14-Apr	21-May	4-Nov	26-Nov	30-Jun	9-Nov
	IC3	4-Jan	20-Jul	25-Apr	27-Apr	24-Apr	1-May	-	-	30-Jun	11-Nov
	IC2	12-Apr	26-Jul	16-Apr	28-Apr	12-Apr	1-May	-	-	15-Jun	21-Nov
	IC1	15-Jan	23-Nov	11-Apr	3-Jun	9-Apr	18-Jun	14-Oct	23-Nov	15-Jun	13-Nov
	CL1	10-Feb	29-Dec	12-Apr	5-May	30-Mar	25-May	22-Nov	3-Dec	13-Jun	20-Nov
	PH1	7-Jan	27-May	26-Mar	3-May	24-Mar	15-May	-	-	1-Jun	3-Dec
	KZ1	1-Jan	6-Dec	30-Mar	6-Dec	24-Mar	10-May	5-Dec	6-Dec	24-May	1-Dec
	NM1	2-Jan	17-Dec	20-Mar	31-Mar	14-Mar	6-May	10-Dec	17-Dec	21-May	9-Dec
2016	BF2	6-Mar	27-Aug	15-Apr	25-Aug	14-Apr	13-Jun	17-Jun	27-Aug	24-Jul	7-Nov
	WT1	14-Apr	4-Jul	30-Apr	28-May	14-Apr	7-Jun	-	-	8-Sep	7-Nov
	IC1	13-Apr	3-Jul	20-Apr	20-May	13-Apr	26-Jun	-	-	11-Jul	24-Nov
	CC2	12-Dec	27-Dec	-	-	-	-	12-Dec	27-Dec	25-Jun	6-Dec
	CL1	13-Jan	26-Dec	27-Apr	15-May	13-Apr	15-Jun	21-Nov	26-Dec	20-Jun	25-Nov
	KZ1	1-Jan	28-May	10-Apr	5-May	31-Mar	10-May	-	-	19-May	3-Dec
	NM1	11-Jan	27-May	17-Apr	17-Apr	28-Mar	24-Apr	none	none	23-May	13-Dec
2017	CC2	27-Jan	8-Dec	19-Apr	10-Oct	13-Apr	6-Jun	8-Oct	12-Oct	13-May	6-Dec
	CL1	17-Feb	27-May	13-Apr	1-May	1-Apr	27-May	-	-	12-May	1-Dec
	NM1	3-Mar	3-May	14-Mar	2-Apr	3-Mar	6-Apr	-	-	7-May	16-Dec
2018	CC2	16-Feb	25-Jul	31-Mar	23-Apr	30-Mar	13-May	-	-	15-May	NaN

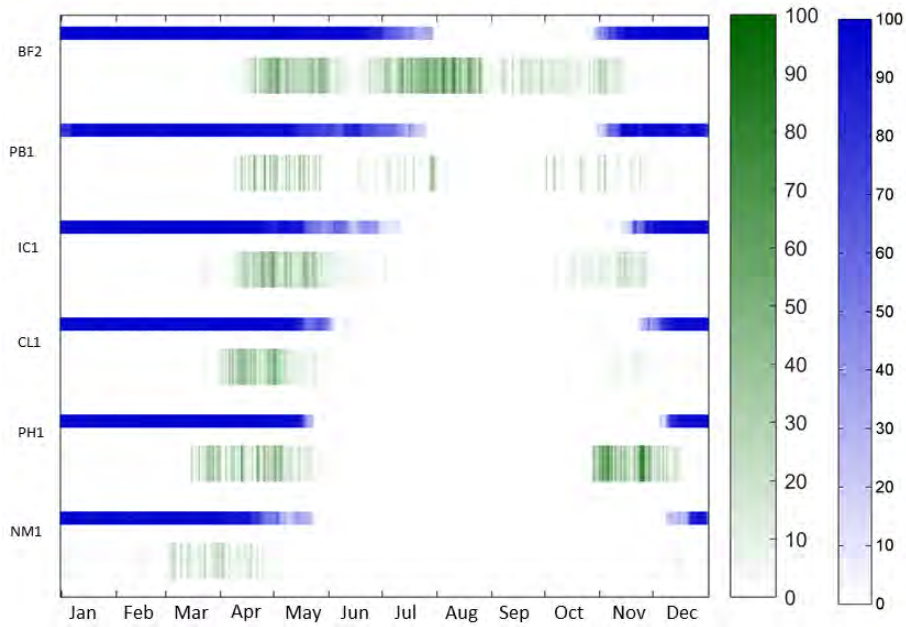

Figure 9. Preliminary percent daily average beluga presence (green) and percent daily average ice concentration (blue) for six mooring locations along the beluga whale migration corridor, 2010-2018.

Walrus

The main story to be told with walrus is that overwinter acoustic detections at the offshore Icy Cape site (IC3) in the 2016-18 time period increased back to the levels seen in 2010-11 (Figure 10). An increased calling presence was also seen (Figure 11) just after ice break up in 2016 at the northern three sites (BF2, WT1, PB1). These increased daily levels continued for WT1 and PB1 through open water season of 2016; the same can be said for the 2017 open water season at WT1 and IC3.

Similar to the results from 2010-2015, walrus were detected on all moorings analyzed for this report (Table 2, Table 10, and Figure 3). With the exception of some lingering ice at the PB1 mooring, the open water season expanded over time (Figure 12). With this came an expansion of days with calling activity at all sites except IC1, CL1, and NM1, which saw decreases, and IC3 which remained the same. For all mooring locations, however, there was an increase in the proportion of days with peak calling, as compared to the 2010-15 period. Nonetheless, the southernmost sites still had the highest overall percentage of days with walrus detections, while the mooring off Barrow Canyon (BF2) had the lowest (Table 10).

As expected, walrus were detected at higher and more sustained calling activity levels (Figure 11) in the summer than in the winter at the northern Chukchi sites (IC1-BF2), with the opposite true at the more southern sites (KZ1 and NM1). The middle sites, from the Central Channel to Point Hope (CC1-PH1), saw a more typical spring/fall migration, although there was also walrus presence overwinter in 2017-18. Looking at the monthly anomaly in the numbers of days with walrus calling per month (Figure 13), the summer period June through September shows the most inter-annual differences in general, especially for the moorings between Barrow and Icy Cape (IC1, WT, BF2).

Months with peak calling range from March/April at the southernmost site, May for the site north of Bering Strait, June off Icy Cape, and July close to Barrow Canyon (Table 11). Walrus calling activity did not fit into tidy spring/fall migration or summer/winter presence as nicely as other species, and so all four categories were used. Because this system was different than that included in Vate Brattström et al. (2019), all nine years are included in this supplemental report (Appendix B: Table 34 and Table 35). Dates varied quite a bit among years and mooring locations; refer to Table 34 and Table 35 for more precise details on the start and end dates of the migration past a particular mooring. The most consistent trend was that the start of the spring migration occurred earlier in the later (2016-18) years than the earlier (2010-14) years at the northeastern (BF2) and southern (KZ1, NM1) mooring sites.

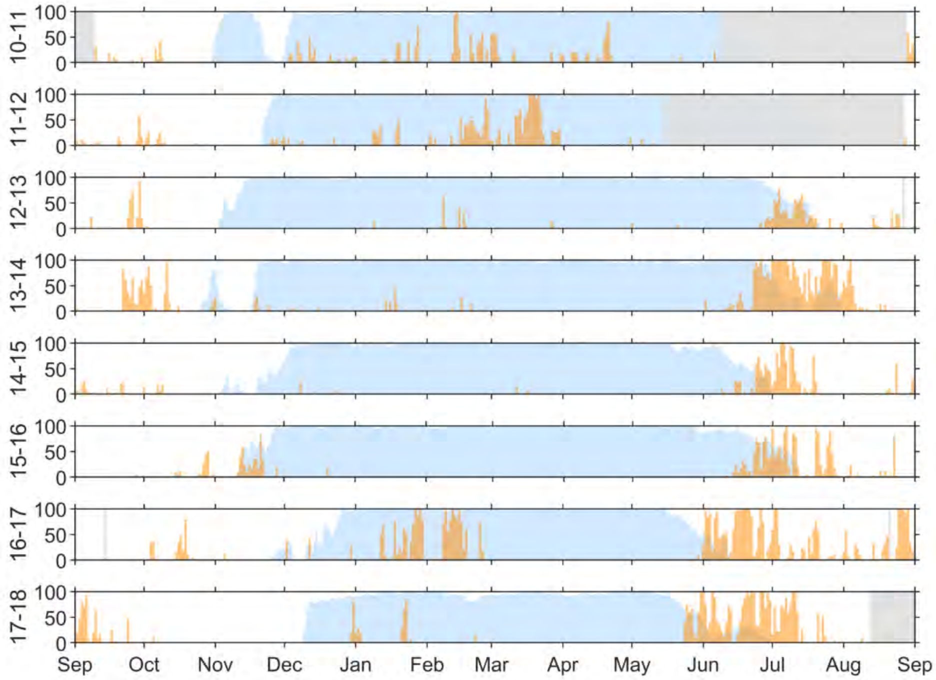

Figure 10. Overwinter walrus calling activity (presented as the percentage of ten-minute time intervals with calls) at the IC3 mooring site 2010-2018. Blue shading indicates percent ice concentration. Light gray shading indicates either no data available or not yet analyzed.

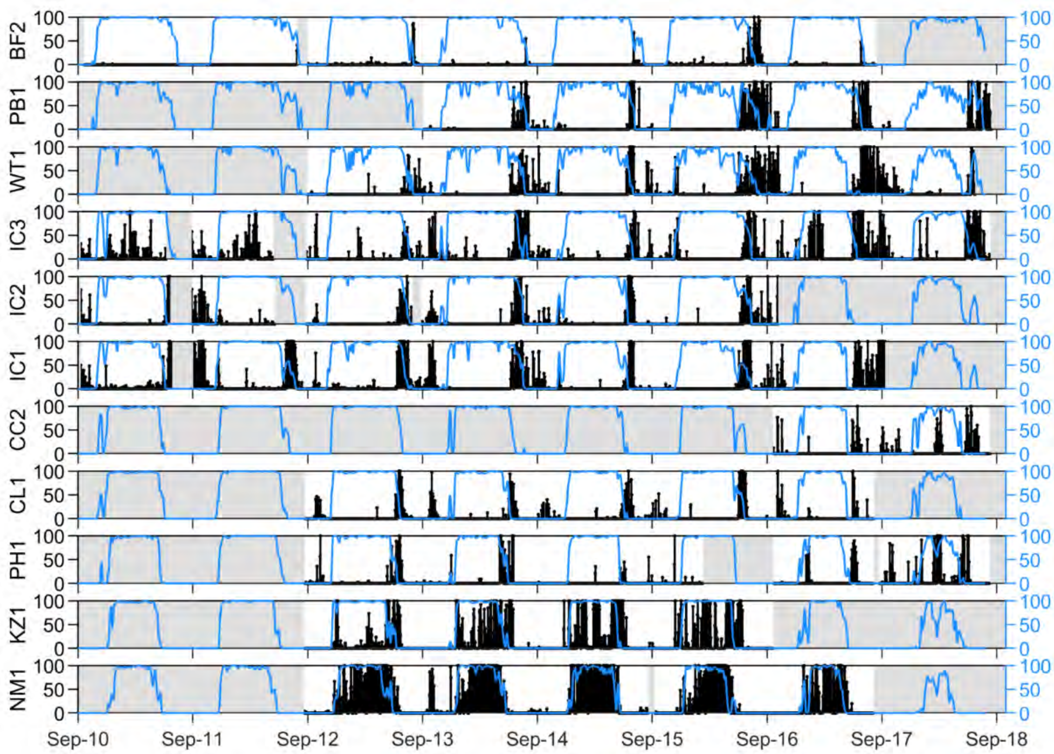

Figure 11. Walrus calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 10. Total walrus calling activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	#pk	%	%pk	#pk/#
BF2	1891	66	8	3	<1	12
PB1	850	93	29	11	3	31
WT1	1219	180	45	15	4	25
IC3	1752	460	96	26	5	21
IC2	1745	288	67	17	4	23
IC1	1869	444	143	24	8	32
CC2	-	-	-	-	-	-
CL1	1225	189	33	15	3	17
PH1	1226	128	35	10	3	27
KZ1	1227	418	182	34	15	44
NM1	1209	573	335	47	28	58

Mooring	Eff	#	#pk	%	%pk	#pk/#
BF2	591	62	17	10	3	27
PB1	957	187	87	20	9	47
WT1	905	237	73	26	8	31
IC3	953	251	109	26	11	43
IC2	279	54	19	19	7	35
IC1	619	144	72	23	12	50
CC2	690	92	27	13	4	29
CL1	583	72	32	12	5	44
PH1	712	111	44	16	6	40
KZ1	265	106	58	40	22	55
NM1	583	253	151	43	26	60

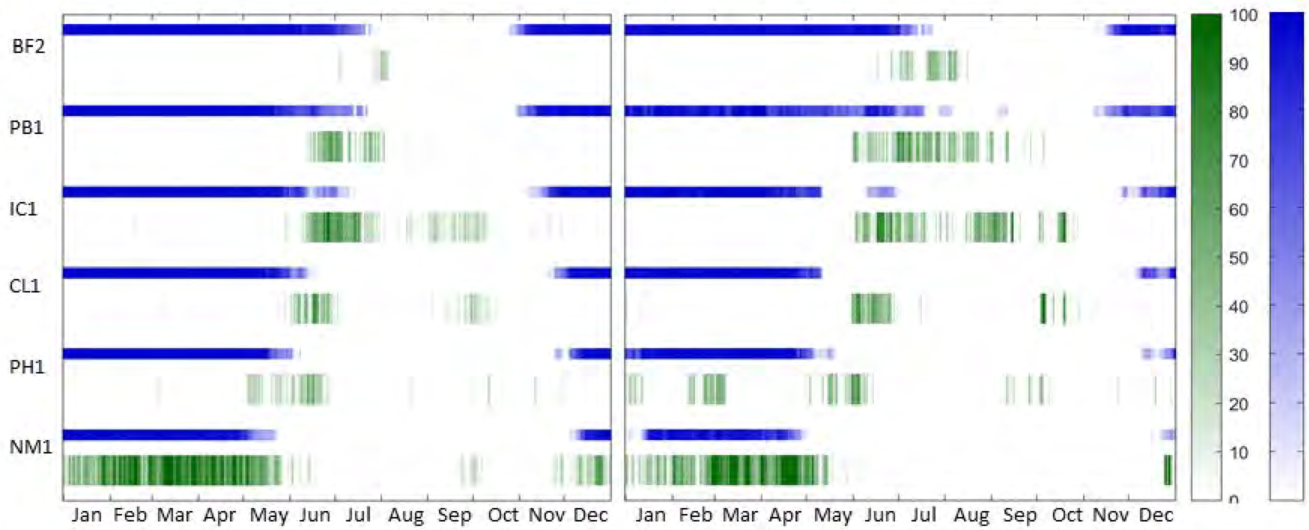

Figure 12. Percent daily average walrus presence (green) and percent daily average ice concentration (blue) for six mooring locations, 2010-2015 (left) and 2016-2018 (right). Number scale is valid for both color bars.

Table 11. Monthly walrus calling activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	NM1			KZ1			PH1			CC2			CL1			IC3			IC2			IC1			WT1			PB1			BF2		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	43	62	**69**	11	31	**35**	16	93	**17**	1	62	**2**	6	62	**10**	24	93	**26**	1	31	**3**	0	62	**0**	3	93	**3**	0	93	**0**	4	62	**7**
Feb	46	57	**81**	22	29	**76**	16	66	**19**	8	56	**15**	1	57	**2**	16	85	**19**	0	29	**0**	0	57	**0**	4	85	**5**	0	85	**0**	3	57	**6**
Mar	60	62	**97**	15	31	**48**	10	62	**16**	10	62	**16**	0	62	**0**	0	93	**0**	0	31	**0**	0	62	**0**	1	93	**1**	0	93	**0**	2	62	**3**
Apr	57	60	**95**	13	30	**43**	4	60	**7**	0	60	**0**	0	59	**0**	0	90	**0**	0	30	**0**	0	60	**0**	0	90	**0**	0	90	**0**	1	60	**2**
May	38	62	**62**	29	31	**94**	24	62	**39**	10	62	**16**	1	62	**2**	9	93	**10**	0	31	**0**	3	62	**5**	6	93	**6**	1	93	**1**	0	62	**0**
Jun	1	60	**2**	15	30	**50**	19	60	**32**	31	60	**52**	42	60	**70**	76	90	**84**	19	30	**63**	45	60	**75**	54	84	**64**	56	90	**62**	8	60	**13**
Jul	0	62	**0**	1	31	**3**	0	62	**0**	3	62	**5**	3	62	**5**	62	93	**66**	17	31	**55**	34	62	**55**	53	62	**86**	81	93	**87**	27	62	**44**
Aug	0	36	**0**	0	31	**0**	0	24	**0**	2	41	**4**	1	37	**2**	29	73	**35**	6	31	**19**	24	62	**39**	50	61	**82**	34	77	**44**	15	45	**26**
Sep	0	30	**0**	0	21	**0**	9	39	**15**	9	41	**18**	0	30	**0**	16	59	**27**	8	29	**28**	21	40	**67**	44	60	**74**	13	59	**23**	0	29	**0**
Oct	0	31	**0**	0	0	-	6	62	**10**	16	62	**26**	16	31	**52**	12	62	**19**	3	6	**50**	17	31	**55**	18	62	**29**	2	62	**3**	0	31	**0**
Nov	0	30	**0**	0	0	-	1	60	**2**	1	60	**2**	2	30	**7**	2	60	**3**	0	0	-	0	30	**0**	2	60	**4**	0	60	**0**	1	30	**3**
Dec	8	31	**26**	0	0	-	6	62	**10**	1	62	**2**	0	31	**0**	5	62	**8**	0	0	-	0	31	**0**	2	62	**3**	0	62	**0**	1	31	**3**

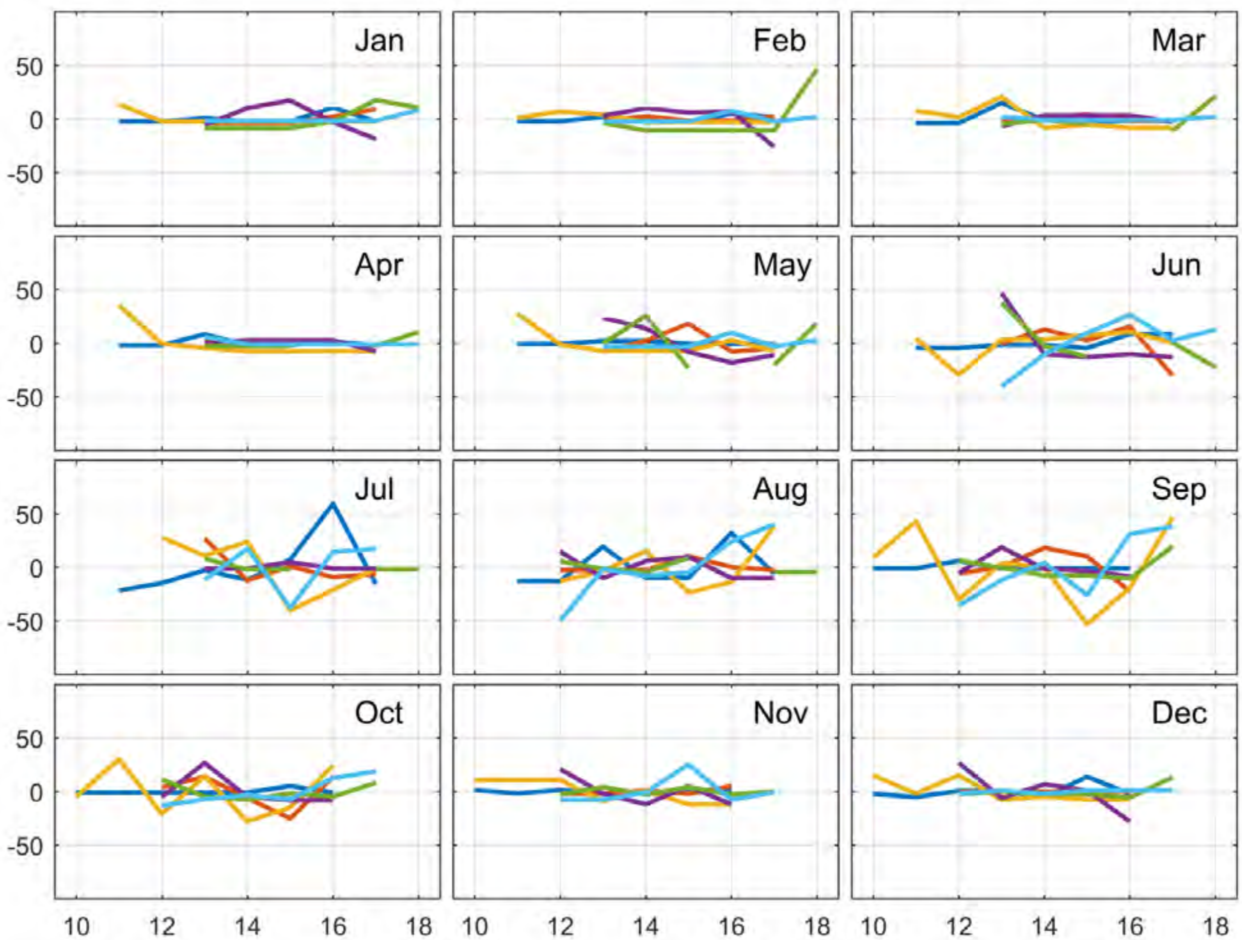

Figure 13. Monthly walrus calling activity anomaly from 2010 to 2018 (See Equation 1). Colors indicate mooring site; yellow=IC1, dark blue = BF2, light blue = WT1, green = PH1, orange = CL1, and purple = NM1. X-axis is two-digit year.

Bearded Seals

Because bearded seals are analyzed in the same frequency band as beluga, there are still quite a few moorings left to analyze. However, bearded seals were detected every year on all moorings that were analyzed (Table 12). Also, as can be seen from Figure 14, bearded seal sounds still remain ubiquitous among years and mooring sites. Similar to bowhead and beluga whales, although the percent of days with bearded seal calling did not change between the two study periods (2010-15 and 2016-18), the proportion of days with calling that was peak calling (Table 12) increased substantially at all mooring sites (with the exception of the Barrow Canyon (BF2) site). Two differences were seen (Figure 14) between the two study periods. First, trending with the reduced ice season, the main pulse of overwinter calling decreased in duration at the southern mooring site (NM1). Second, the smaller pulse of calling that precedes the main pulse, is reduced or absent in many of the 2016-18 mooring sites, especially those to the south (KZ1, NM1). It will be interesting to investigate the trends seen with this smaller pulse once the results from the other mooring sites in this later time period are completed.

Table 13 lists the monthly calling activity levels by mooring site for those moorings where some analysis was completed from 2016-2018. Months where 100% of days had calling present included February through May at the southern mooring sites, January through May at the IC1/WT1 sites in the northeastern Chukchi, and March through June off Barrow Canyon (BF2). Figure 15, which includes all data from 2010 through 2018, shows that although there are differences in the timing of ice break up for the various sites, the end of the bearded seal calling period is in June. It also shows that there are sporadic detections of bearded seals during the open water season at the northern-most sites, and quite a range of starting times for the beginning of the calling season. Similar to what was done for beluga whales, the monthly calling activity anomaly plot for bearded seals (e.g., Figure 5) was omitted due to the number of moorings still to be analyzed. In addition, bearded seal calling activity also did not fit into the standard migration/feeding grounds/wintering grounds as other species, we included dates for the main pulse and the dates for when the calling began to ramp up/end. Like with the walrus results, since this is summarized differently than in Vate Brattström et al. (2019), the details for all nine years are included (Appendix B: Table 35); because dates varied among years and mooring locations, no generalization will be attempted here.

Table 12. Preliminary bearded seal calling activity, 2010-2015 (left) versus 2016-2018 (right, preliminary). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	#pk	%	%pk	#pk/#
BF2	1891	1345	784	71	41	58
PB1	742	605	353	82	48	58
WT1	1212	834	491	69	41	59
IC3	1647	1079	651	66	40	60
IC2	1636	1246	764	76	47	61
IC1	1869	1204	698	64	37	58
CC2	-	-	-	-	-	-
CL1	1225	719	393	59	32	55
PH1	1124	752	619	67	55	82
KZ1	1227	679	456	55	37	67
NM1	842	374	297	44	35	79

Mooring	Eff	#	#pk	%	%pk	#pk/#
BF2	252	192	117	76	46	61
PB1	0	0	0	-	-	-
WT1	291	196	168	67	58	86
IC3	-	-	-	-	-	-
IC2	-	-	-	-	-	-
IC1	284	179	151	63	53	84
CC2	690	382	272	55	39	71
CL1	583	393	294	67	50	75
PH1	0	0	0	-	-	-
KZ1	265	168	135	63	51	80
NM1	583	292	271	50	46	93

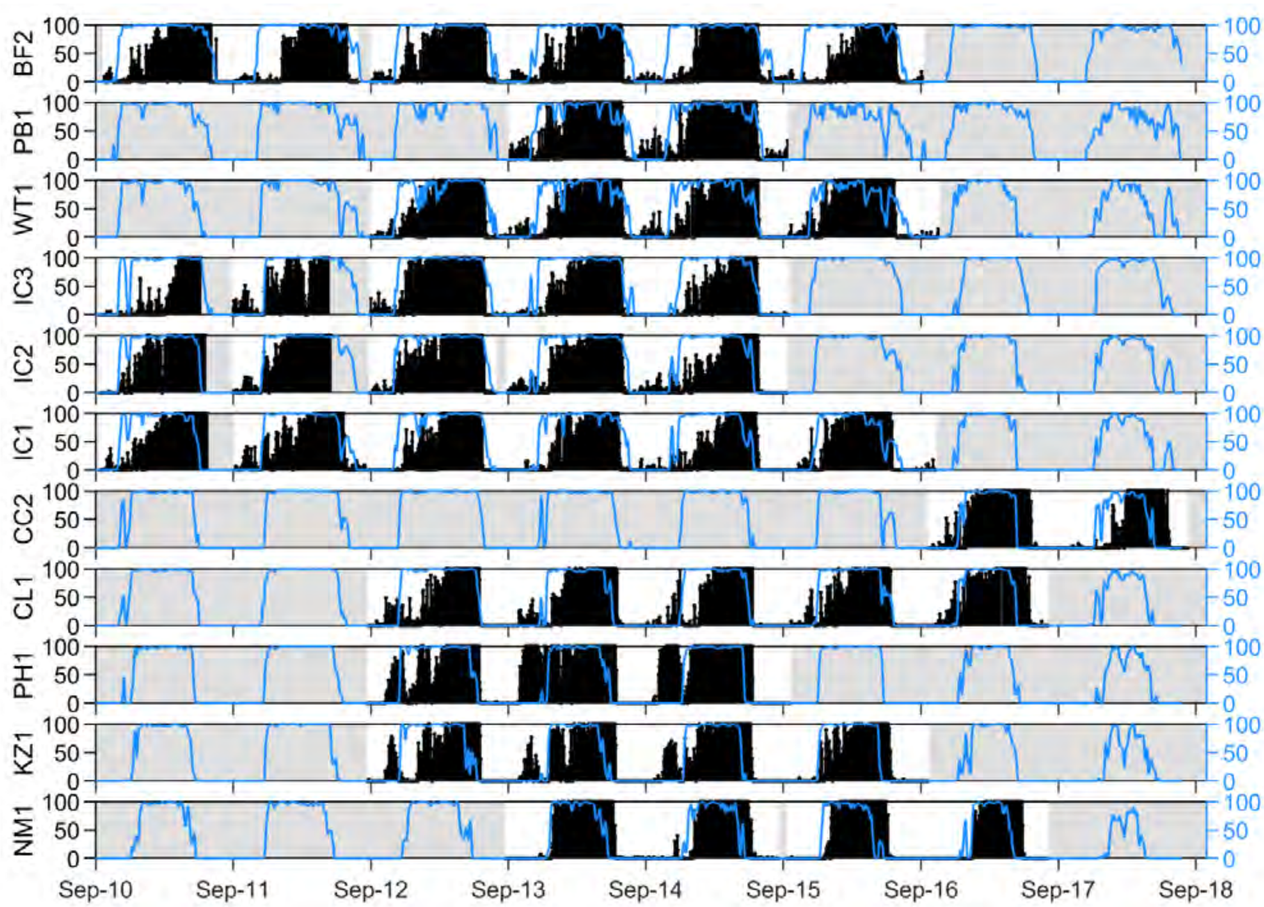

Figure 14. Preliminary bearded seal calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 13. Preliminary monthly bearded seal calling activity, 2016-2018. Analyses are still ongoing for NM1, IC1, WT1, and BF2 (Figure 3). KZ1 and CL1 were not deployed for 2017-18. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	NM1			KZ1			CC2			CL1			IC1			WT1			BF2		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	46	62	75	30	31	97	45	62	73	59	62	95	31	31	100	31	31	100	27	31	87
Feb	57	57	100	29	29	100	51	56	91	57	57	100	29	29	100	29	29	100	28	29	97
Mar	62	62	100	31	31	100	62	62	100	62	62	100	31	31	100	31	31	100	31	31	100
Apr	60	60	100	30	30	100	60	60	100	59	59	100	30	30	100	30	30	100	30	30	100
May	60	62	97	31	31	100	62	62	100	62	62	100	31	31	100	31	31	100	31	31	100
Jun	7	60	12	16	30	53	43	60	72	36	60	60	17	30	57	27	30	90	30	30	100
Jul	0	62	0	1	31	3	2	62	3	1	62	2	0	31	0	4	31	13	3	31	10
Aug	0	36	0	0	31	0	0	41	0	0	37	0	1	31	3	2	31	6	6	31	19
Sep	0	30	0	0	21	0	0	41	0	0	30	0	6	29	21	5	27	19	6	8	75
Oct	0	31	0	0	0	-	12	62	20	7	31	23	3	11	27	6	20	30	0	0	-
Nov	0	30	0	0	0	-	23	60	38	21	30	70	0	0	-	0	0	-	0	0	-
Dec	0	31	0	0	0	-	22	62	36	29	31	94	0	0	-	0	0	-	0	0	-

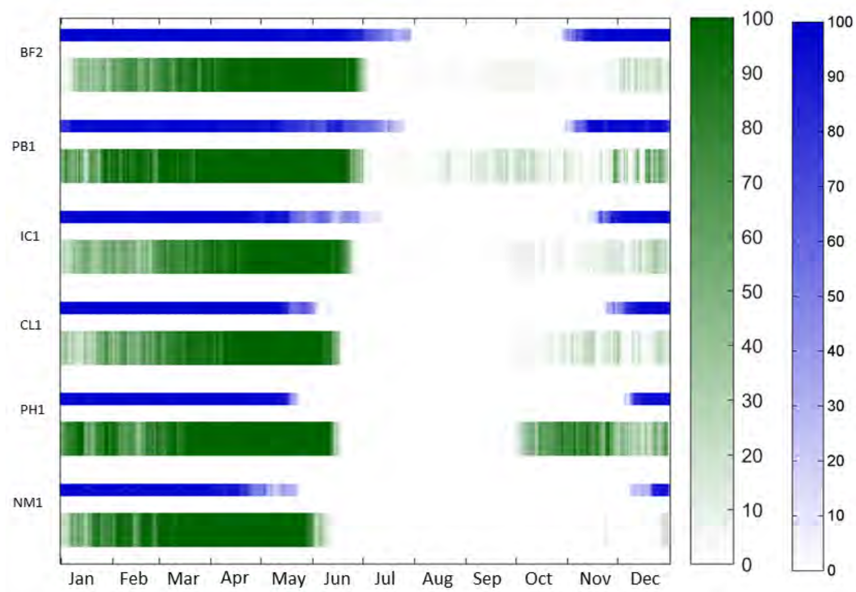

Figure 15. Preliminary percent daily average bearded seal presence (green) and percent daily average ice concentration (blue) for six mooring locations, 2010-2018.

Gray whales

Gray whale were the only Arctic species not found at all mooring sites in all years (Table 2, Table 14, Figure 3). Similar to the earlier study period (2010-15), calling activity was present on only the southern mooring sites and in the area around Wainwright, AK. The only difference is that there was more calling activity present at the WT1 site than at PB1 (Table 14, Figure 16). Overall daily calling activity at the NM1 and PH1 mooring sites in the earlier study period was almost double that of the results from 2016-

18 (Table 14). The proportion of days with peak calling levels were only slightly larger during the earlier study period, however.

There were no differences for most mooring sites between the months with gray whale calling activity during the 2010-15 and the 2016-18 study periods (Table 15). For the southern mooring sites, June-August were the main months with calling. For the Point Hope area, a prime gray whale hotspot, calling was detected June through October. July through September were the months with calling for the Wainwright (WT1) site. The PB1 site, between Wainwright and Barrow Canyon, did not have many days with calling in the later study period. However, there was only one open water season (2015) where substantial amounts of calling were detected in the previous study period, so the lack of calling is not surprising. The majority of days with gray whale calling activity were during the open water period, especially at the southern mooring sites; there was, however, a slight overlap in timing of grays off Wainwright (WT1) with the ice break up period in 2016 (Figure 16). Figure 17 shows the overall differences between the two study periods. In 2010-15 there was a more concentrated presence of gray whale calling activity in at the southern mooring sites during a shorter open water period, while in 2016-18 calling activity is more spread out in the south and less consistently present in the Wainwright area. The trends in the monthly anomaly in number of days with gray whale calling per month (Figure 18) are expected for a species that migrates out of Alaska in the winter and has low levels of calling activity otherwise. Very little anomaly is seen in the winter, with large variations seen in the open water season. Details on the annual date range of gray whale calling activity (and peak calling activity) can be found in Table 37.

Table 14. Total gray whale calling activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	# pk/#
BF2	1891	0	0	0	0	-
PB1	850	60	10	7	1	17
WT1	1219	2	0	0	0	0
IC1	1869	25	0	1	0	0
IC2	1745	1	0	0	0	-
IC3	1752	2	0	0	0	-
CC2	0	0	0	-	-	-
CL1	1225	51	0	4	0	0
PH1	1226	375	153	31	12	41
KZ1	1227	108	1	9	0	1
NM1	1209	435	50	36	4	11

Mooring	Eff	#	# pk	%	% pk	# pk/#
BF2	591	1	0	<1	0	0
PB1	957	4	0	<1	0	0
WT1	905	42	0	5	0	0
IC1	619	9	1	1	<1	11
IC2	279	0	0	0	0	-
IC3	953	0	0	0	0	-
CC2	690	0	0	0	0	-
CL1	583	4	0	1	0	0
PH1	712	133	44	19	6	33
KZ1	265	38	0	14	0	0
NM1	583	102	7	17	1	7

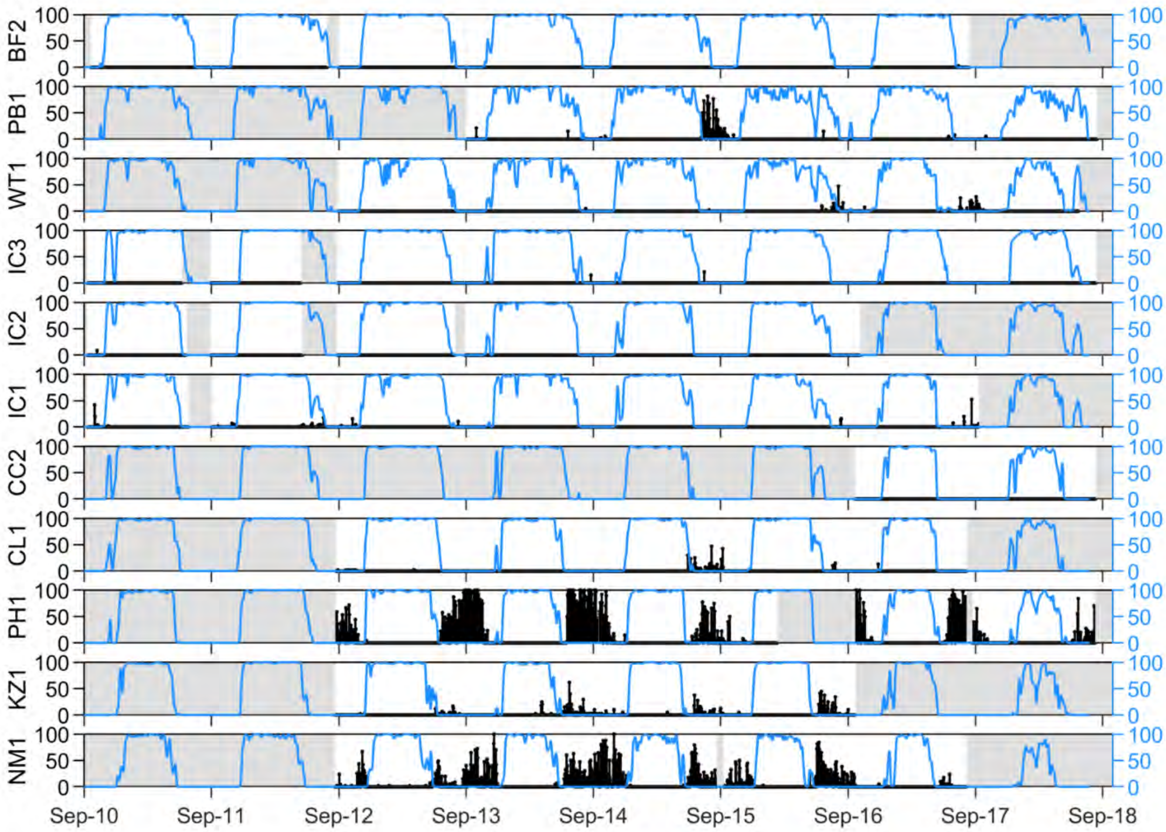

Figure 16. Gray whale calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 15. Monthly gray whale calling activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	NM1			KZ1			PH1			CL1			CC2			IC1			IC2			IC3			WT1			PB1			BF2		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	1	62	2	0	31	0	0	93	0	0	62	0	0	62	0	0	62	0	0	31	0	0	93	0	0	93	0	0	93	0	0	62	0
Feb	0	57	0	0	29	0	0	66	0	0	57	0	0	56	0	0	57	0	0	29	0	0	85	0	0	85	0	0	85	0	0	57	0
Mar	0	62	0	0	31	0	0	62	0	0	62	0	0	62	0	0	62	0	0	31	0	0	93	0	0	93	0	0	93	0	0	62	0
Apr	0	60	0	0	30	0	0	60	0	0	59	0	0	60	0	0	60	0	0	30	0	0	90	0	0	90	0	0	90	0	0	60	0
May	7	62	12	0	31	0	0	62	0	0	62	0	0	62	0	0	62	0	0	31	0	0	93	0	0	93	0	0	93	0	0	62	0
Jun	37	60	62	17	30	57	30	60	50	0	60	0	0	60	0	1	60	2	0	30	0	0	90	0	4	84	4	2	90	2	0	60	0
Jul	29	62	47	16	31	52	39	62	63	3	62	5	0	62	0	2	62	3	0	31	0	0	93	0	11	62	18	1	93	1	1	62	2
Aug	18	36	29	4	31	13	14	24	56	0	37	0	0	41	0	4	62	6	0	31	0	0	73	0	17	61	28	0	77	0	0	45	0
Sep	9	30	30	1	21	5	23	39	70	0	30	0	0	41	0	2	40	9	0	29	0	0	59	0	9	60	15	0	59	0	0	29	0
Oct	0	31	0	0	0	-	21	62	34	0	31	0	0	62	0	0	31	0	0	6	0	0	62	0	1	62	2	1	62	2	0	31	0
Nov	1	30	3	0	0	-	6	60	10	1	30	3	0	60	0	0	30	0	0	0	-	0	60	0	0	60	0	0	60	0	0	30	0
Dec	0	31	0	0	0	-	0	62	0	0	31	0	0	62	0	0	31	0	0	0	-	0	62	0	0	62	0	0	62	0	0	31	0

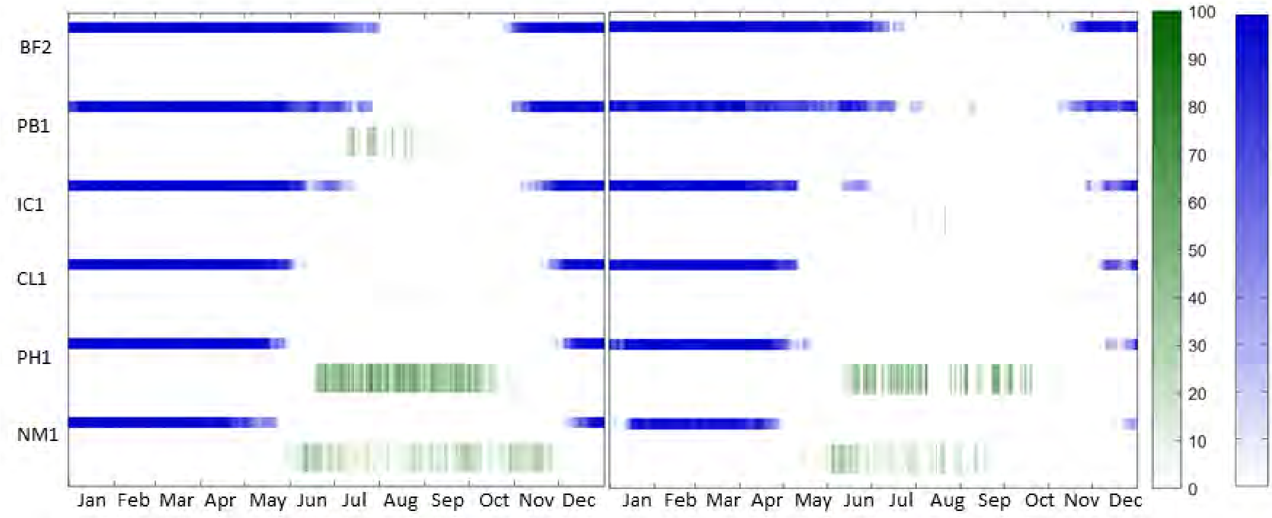

Figure 17 . Percent daily average gray whale presence (green) and percent daily average ice concentration (blue) for six mooring locations along the gray whale migration corridor 2010-2015 (left) and 2016-2018 (right). Number scale is valid for both color bars.

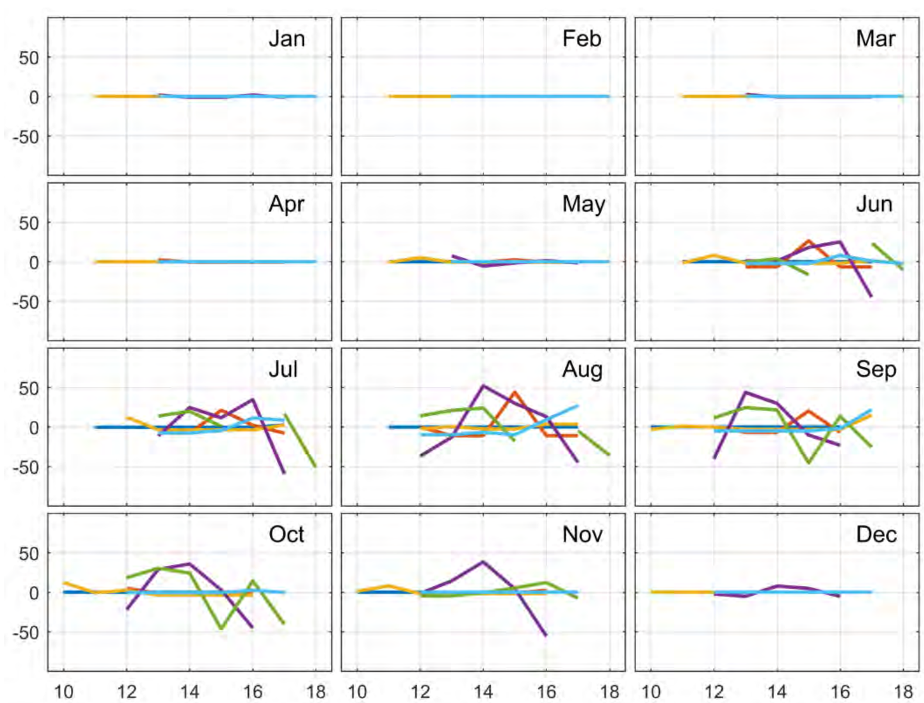

Figure 18. Monthly gray whale calling activity anomaly from 2010 to 2018 (See Equation 1). Colors indicate mooring site; yellow=IC1, dark blue = BF2, light blue = WT1, green = PH1, orange = CL1, and purple = NM1. X-axis is two-digit year.

Subarctic species

Because the study area included in the analysis for this report included the southern Chukchi Sea, several subarctic species (i.e., humpback, killer, and minke whales, and ribbon seals) were detected (similar to the results seen in Vate Brattström et al. (2019)). As was also seen in Vate Brattström et al. (2019), a variety of pinniped grunts, yelps, and barks were detected but not identified to species. These detections are lumped together as unidentified pinnipeds and most likely include species such as ringed and spotted seals as well as less common call types from bearded and ribbon seals and walrus. The seasonality (primarily overwinter) of this set of calls aligns most closely with that of bearded seals and so their calling distribution maps and tables are not included in this report. No fin whale analysis was conducted on the 2016-18 data.

Humpback whales

As would be expected of a subarctic species, humpback whales were predominantly detected on the southern three moorings (Table 2, Figure 3; PH1, KZ1, and NM1) between 2016 and 2018 (Table 16, Figure 19), as was found for 2010-15. Although the percentage of days with calling dropped by half at the Point Hope (PH1) site, the proportion of the days with calling that had peak levels of calling increased threefold. The next mooring south (KZ1), however, saw a drop in the proportion of peak level calling days although the same percentage of days had calls detected. The NM1 site saw a substantial decrease both in the number of days and the proportion of days with peak level calling. Detections were made on a small number of days each at WT1, IC3, IC1, and CL1, all at below-peak levels. As seen in Figure 19, no humpbacks were detected during the ice season at any mooring site during the period 2016-18. Humpback calling (2016-18) was detected from May through November from Point Hope south, and sporadically in July and August from Cape Lisburne north to WT1 (Table 17). There were no detections at the far northern sites (PB1, BF2). No consistent trends were seen in the start and end dates for the calling activity pulses among mooring sites or years; see Table 38 for details. This can also be seen with the more diluted plot of average daily calling in 2016-18 vs. 2010-15 (Figure 20).

Table 16. Total humpback whale calling activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	0	0	0	0	-
PB1	850	0	0	0	0	-
WT1	1219	6	0	<1	0	0
IC3	1752	1	0	<1	0	0
IC2	1745	0	0	0	0	-
IC1	1869	0	0	0	0	-
CC2	-	-	-	-	-	-
CL1	1225	45	3	4	<1	7
PH1	1226	139	18	11	1	13
KZ1	1227	244	57	20	5	23
NM1	1209	366	91	30	8	25

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	591	0	0	0	0	-
PB1	957	0	0	0	0	-
WT1	905	1	0	<1	0	0
IC3	953	2	0	<1	0	0
IC2	279	0	0	0	0	-
IC1	619	1	0	<1	0	0
CC2	690	0	0	0	0	-
CL1	583	2	0	<1	0	0
PH1	712	34	12	5	2	35
KZ1	265	49	4	18	2	8
NM1	583	73	5	13	1	7

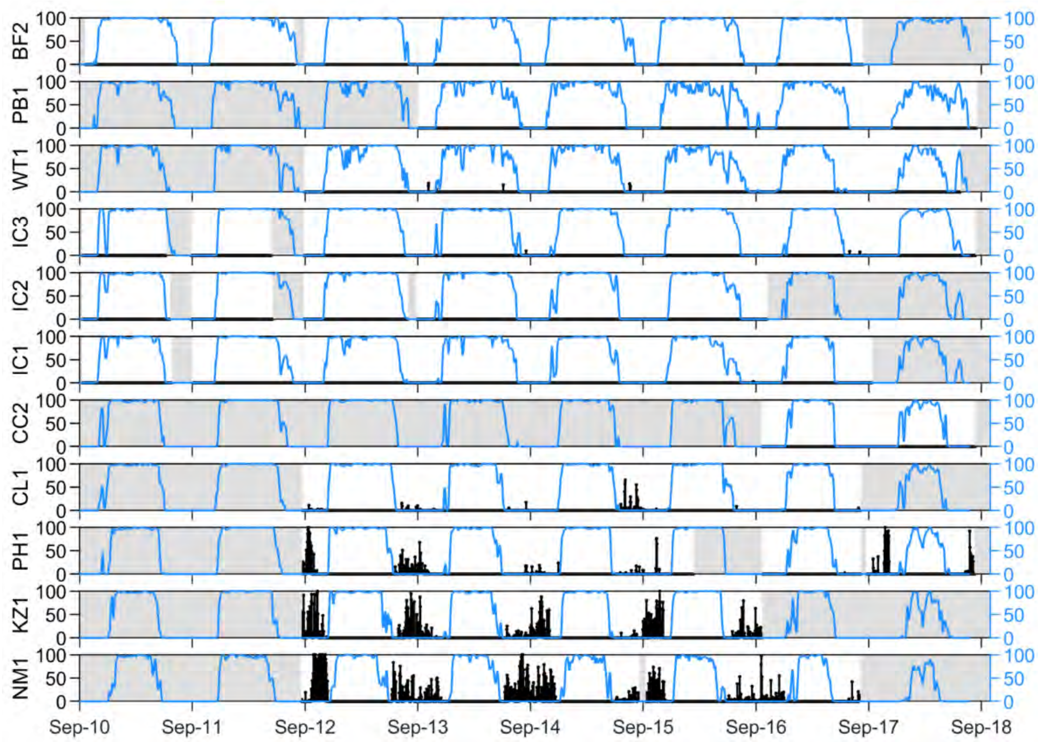

Figure 19. Humpback whale calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 17. Monthly humpback whale calling activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	NM1			KZ1			PH1			CL1			CC2			IC1			IC2			IC3			WT1			PB1			BF2		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	0	62	0	0	31	0	0	93	0	0	62	0	0	62	0	0	62	0	0	31	0	0	93	0	0	93	0	0	93	0	0	62	0
Feb	0	57	0	0	29	0	0	66	0	0	57	0	0	56	0	0	57	0	0	29	0	0	85	0	0	85	0	0	85	0	0	57	0
Mar	0	62	0	0	31	0	0	62	0	0	62	0	0	62	0	0	62	0	0	31	0	0	93	0	0	93	0	0	93	0	0	62	0
Apr	0	60	0	0	30	0	0	60	0	0	59	0	0	60	0	0	60	0	0	30	0	0	90	0	0	90	0	0	90	0	0	60	0
May	2	62	3	0	31	0	0	62	0	0	62	0	0	62	0	0	62	0	0	31	0	0	93	0	0	93	0	0	93	0	0	62	0
Jun	8	60	13	5	30	17	1	60	2	1	60	2	0	60	0	0	60	0	0	30	0	0	90	0	0	84	0	0	90	0	0	60	0
Jul	19	62	31	19	31	61	8	62	13	1	62	2	0	62	0	0	62	0	0	31	0	1	93	1	0	62	0	0	93	0	0	62	0
Aug	15	36	66	12	31	39	4	24	20	0	37	0	0	41	0	1	62	2	0	31	0	1	73	1	1	61	2	0	77	0	0	45	0
Sep	10	30	33	13	21	62	5	39	9	0	30	0	0	41	0	0	40	0	0	29	0	0	59	0	0	60	0	0	59	0	0	29	0
Oct	7	31	23	0	0	-	10	62	16	0	31	0	0	62	0	0	31	0	0	6	0	0	62	0	0	62	0	0	62	0	0	31	0
Nov	12	30	40	0	0	-	6	60	10	0	30	0	0	60	0	0	30	0	0	0	-	0	60	0	0	60	0	0	60	0	0	30	0
Dec	0	31	0	0	0	-	0	62	0	0	31	0	0	62	0	0	31	0	0	0	-	0	62	0	0	62	0	0	62	0	0	31	0

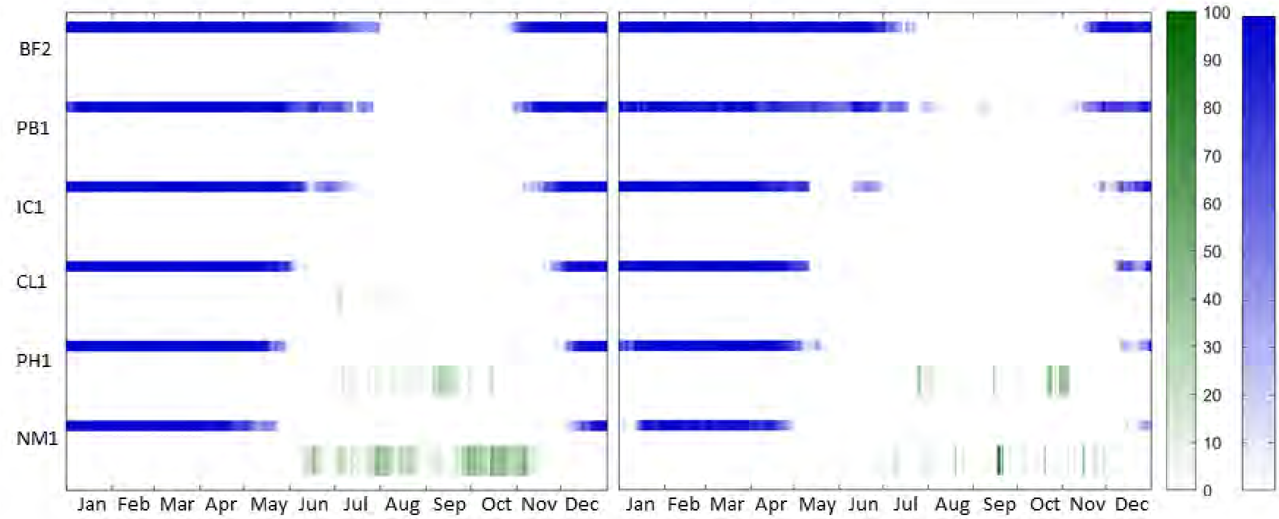

Figure 20. Percent daily average humpback whale presence (green) and percent daily average ice concentration (blue) for six mooring locations, 2010-2015 (left) and 2016-2018 (right). Number scale is valid for both color bars.

Killer whales

Although killer whales were detected at every mooring site in the 2010-15 study period, they were only detected at five sites in 2016-18 (primarily the southern sites; Table 18). However, killer whales are part of the frequency band with beluga and bearded seals that is not completely analyzed for the time period 2016-18, and so interpretation of these results should wait until all moorings/years are finished. At the moment, the trend of the southern sites having the higher proportion of days with calling seen for earlier time period (2010-15) holds here. Also similar is the result that peak calling is minimal with levels at 1% of days with calling or less. In general, Figure 21 shows that calling at the three southernmost sites seems to be trending toward lower calling activity levels per day. The new site in the Central Channel (CC2) shows a short but higher-level pulse of killer whale calling activity in the open water season of 2018. Table 19 shows that killer whale calls were detected May through October. No clear pattern in the timing of calling activity was evident (Table 39).

Minke whales

Similar to the results reported in Vate Brattström et al. (2019), no minke whale pulsed calls were detected in the 2016-18 data set; however, minke whale boing calls were detected. Because the analysis for these calls is not complete, the results described here will be brief. Minke whale boings were detected so far only at the Central Channel (CC2) and Cape Lisburne (CL1) sites (Table 20); no peak calling has been detected. Calling activity levels were higher during the 2010-15 versus the 2016-18 time period (Figure 22). Calls were detected from July through October at CC2 and June and July, as well as January, at CL1. Even with low numbers of days with detections, no consistent timing of start or end dates of the calling were seen (Table 40).

Table 18. Preliminary killer whale calling activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	7	0	<1	0	0
PB1	742	16	0	2	0	0
WT1	1212	1	0	<1	0	0
IC3	1647	1	0	<1	0	0
IC2	1636	1	0	<1	0	0
IC1	1869	8	0	<1	0	0
CC2	-	-	-	-	-	-
CL1	1225	5	0	<1	0	0
PH1	1124	110	7	10	1	6
KZ1	1227	102	3	8	<1	3
NM1	842	171	4	20	<1	2

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	252	0	0	0	0	-
PB1	0	0	0	-	-	-
WT1	291	0	0	0	0	-
IC3	0	0	0	-	-	-
IC2	0	0	0	-	-	-
IC1	284	6	0	2	0	0
CC2	690	9	1	1	<1	11
CL1	583	4	0	1	0	0
PH1	0	0	0	-	-	-
KZ1	265	25	0	9	0	0
NM1	583	56	0	10	0	0

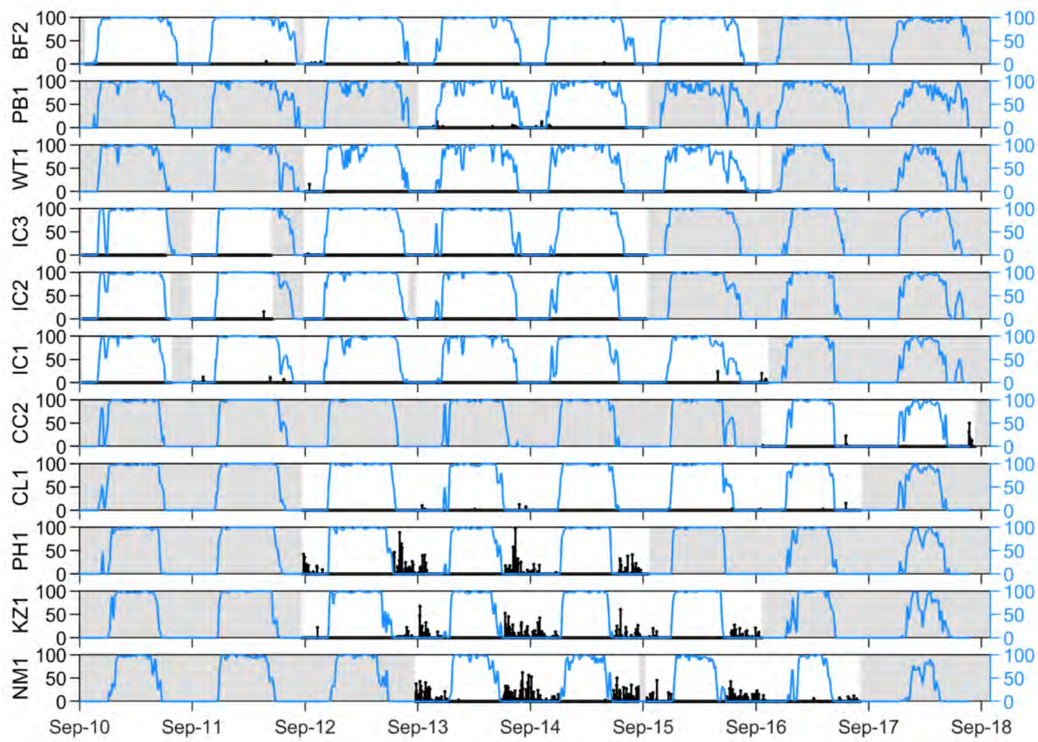

Figure 21. Preliminary killer whale calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 19. Preliminary monthly killer whale calling activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	BF2			WT1			IC1			CC2			CL1			KZ1			NM1		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Feb	0	29	0	0	29	0	0	29	0	0	56	0	0	57	0	0	29	0	0	57	0
Mar	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	1	62	2
Apr	0	30	0	0	30	0	1	30	3	0	60	0	1	59	2	0	30	0	0	60	0
May	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	3	62	5
Jun	0	30	0	0	30	0	0	30	0	2	60	4	2	60	3	8	30	27	15	60	25
Jul	0	31	0	0	31	0	0	31	0	5	62	8	0	62	0	8	31	26	20	62	33
Aug	0	31	0	0	31	0	0	31	0	1	41	5	0	37	0	5	31	16	11	36	18
Sep	0	8	0	0	27	0	2	29	7	1	41	5	1	30	3	4	21	19	6	30	20
Oct	0	0	-	0	20	0	3	11	27	0	62	0	0	31	0	0	0	-	0	31	0
Nov	0	0	-	0	0	-	0	0	-	0	60	0	0	30	0	0	0	-	0	30	0
Dec	0	0	-	0	0	-	0	0	-	0	62	0	0	31	0	0	0	-	0	31	0

Table 20. Preliminary minke whale boing call activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	0	0	0	0	-
PB1	742	0	0	0	0	-
WT1	1212	0	0	0	0	-
IC3	1647	0	0	0	0	-
IC2	1636	0	0	0	0	-
IC1	1869	2	0	<1	0	0
CC2	-	-	-	-	-	-
CL1	1225	27	0	2	0	0
PH1	1124	2	0	<1	0	0
KZ1	1227	5	0	<1	0	0
NM1	842	4	0	<1	0	0

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	252	0	0	0	0	-
PB1	0	0	0	-	-	-
WT1	291	0	0	0	0	-
IC3	0	0	0	-	-	-
IC2	0	0	0	-	-	-
IC1	284	0	0	0	0	-
CC2	690	9	0	1	0	0
CL1	583	3	0	1	0	0
PH1	0	0	0	-	-	-
NM1	583	0	0	0	0	-
KZ1	265	0	0	0	0	-

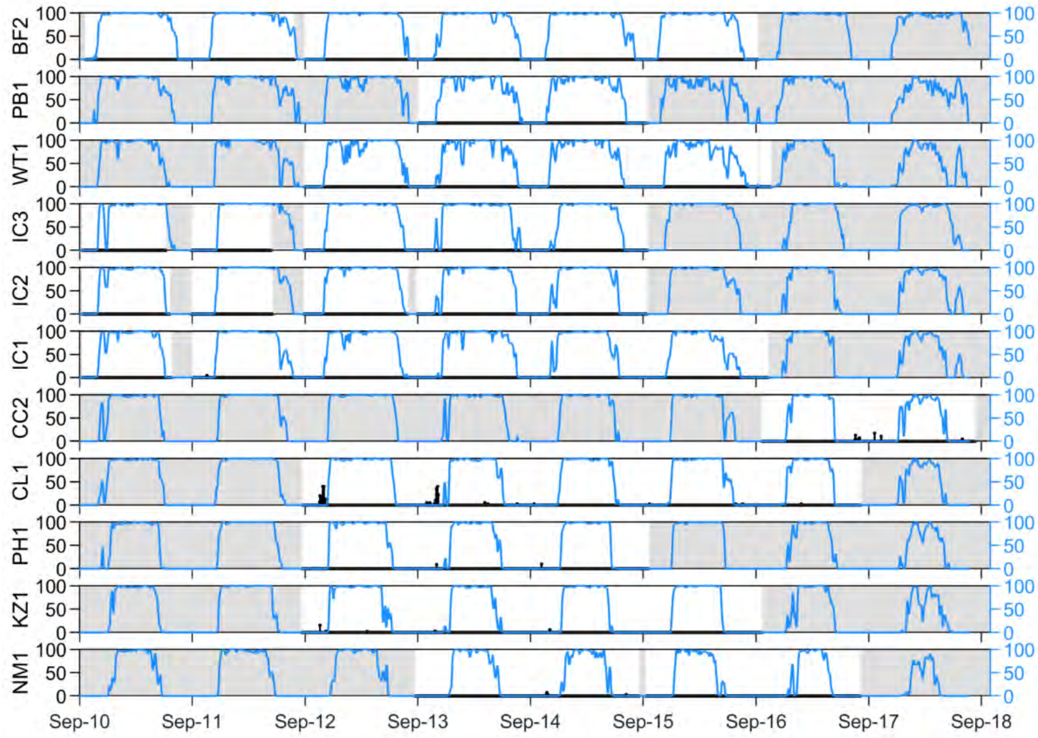

Figure 22. Preliminary minke whale boing call activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 21. Preliminary monthly minke whale boing call activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	BF2			WT1			IC1			CC2			CL1			KZ1			NM1		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	0	31	0	0	31	0	0	31	0	0	62	0	1	62	2	0	31	0	0	62	0
Feb	0	29	0	0	29	0	0	29	0	0	56	0	0	57	0	0	29	0	0	57	0
Mar	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Apr	0	30	0	0	30	0	0	30	0	0	60	0	0	59	0	0	30	0	0	60	0
May	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Jun	0	30	0	0	30	0	0	30	0	0	60	0	1	60	2	0	30	0	0	60	0
Jul	0	31	0	0	31	0	0	31	0	5	62	8	1	62	2	0	31	0	0	62	0
Aug	0	31	0	0	31	0	0	31	0	2	41	4	0	37	0	0	31	0	0	36	0
Sep	0	8	0	0	27	0	0	29	0	1	41	2	0	30	0	0	21	0	0	30	0
Oct	0	0	-	0	20	0	0	11	0	1	62	2	0	31	0	0	0	-	0	31	0
Nov	0	0	-	0	0	-	0	0	-	0	60	0	0	30	0	0	0	-	0	30	0
Dec	0	0	-	0	0	-	0	0	-	0	62	0	0	31	0	0	0	-	0	31	0

Ribbon Seals

The analysis for the 2016-18 ribbon seal data is also not complete; therefore, the results will be kept brief. Ribbon seal calls were detected at all moorings where analyses were conducted except for the IC1 and KZ1 sites. In general, the percent of days with calling are lower for the 2016-18 time period as compared with the 2010-15 time period. Unlike the earlier time period, however, the Barrow Canyon mooring site (BF2) did not have the highest proportion of days with calling (but again, two of the mooring years for BF2 have not been completed yet). Instead the Central Channel area (CC2) had the most days with calling detected. Furthermore, out of the days with calling, CC2 also had the highest proportion of days with peak calling. Ribbon seal calling detections are limited to the periods of ice break up and formation. From Icy Cape and east, detections occurred during ice formation, and from the Central Channel and southwest, detections occurred also during ice break up. A more complete analysis of all mooring sites is needed to determine trends. Months with ribbon seal calls detected included April and May as well as September through December (Table 23). No consistency was seen for the start and end dates of ribbon seal movements through the study area (Table 41).

Table 22. Preliminary ribbon seal calling activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with calling activity (#), number of days with calling activity > 50% (#pk), percent of days with calling activity (%), percent of days with calling activity > 50% (%pk), percent of peak vs. regular calling (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	137	28	7	1	20
PB1	742	2	0	<1	0	0
WT1	1212	13	0	1	0	0
IC3	1647	10	0	1	0	0
IC2	1636	14	4	1	<1	29
IC1	1869	18	0	1	0	0
CC2	-	-	-	-	-	-
CL1	1225	40	1	3	<1	3
PH1	1124	41	6	4	1	15
KZ1	1227	17	1	1	<1	6
NM1	842	17	7	2	1	41

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	252	4	1	2	0	25
PB1	0	0	0	-	-	-
WT1	291	4	0	1	0	0
IC3	0	0	0	-	-	-
IC2	0	0	0	-	-	-
IC1	284	0	0	0	0	-
CC2	690	25	9	4	1	36
CL1	583	12	3	2	1	25
PH1	0	0	0	-	-	-
KZ1	265	0	0	0	0	-
NM1	583	8	0	1	0	0

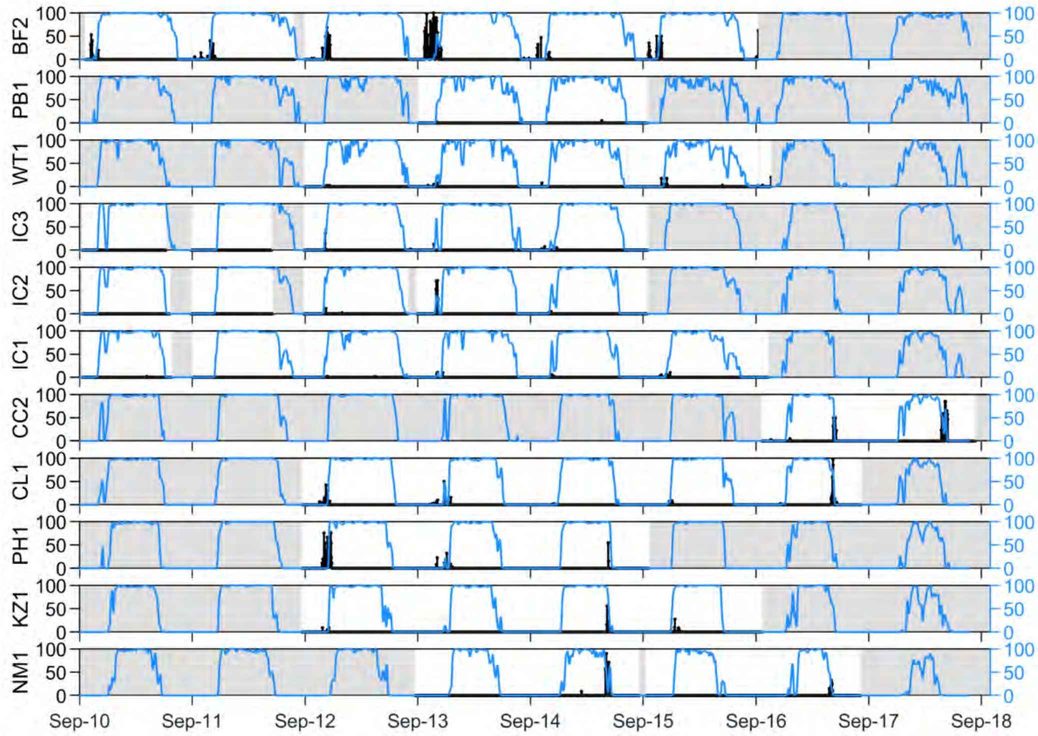

Figure 23. Preliminary ribbon seal calling activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 23. Preliminary monthly ribbon seal calling activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	BF2			WT1			IC1			CC2			CL1			KZ1			NM1		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Feb	0	29	0	0	29	0	0	29	0	0	56	0	0	57	0	0	29	0	0	57	0
Mar	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Apr	0	30	0	0	30	0	0	30	0	3	60	5	0	59	0	0	30	0	2	60	4
May	0	31	0	1	31	3	0	31	0	20	62	33	11	62	18	0	31	0	6	62	10
Jun	0	30	0	0	30	0	0	30	0	0	60	0	0	60	0	0	30	0	0	60	0
Jul	0	31	0	0	31	0	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Aug	0	31	0	0	31	0	0	31	0	0	41	0	0	37	0	0	31	0	0	36	0
Sep	4	8	50	1	27	4	0	29	0	0	41	0	0	30	0	0	21	0	0	30	0
Oct	0	0	-	2	20	10	0	11	0	1	62	2	0	31	0	0	0	-	0	31	0
Nov	0	0	-	0	0	-	0	0	-	0	60	0	1	30	3	0	0	-	0	30	0
Dec	0	0	-	0	0	-	0	0	-	1	62	2	0	31	0	0	0	-	0	31	0

Note on double knocks

Found during both the ARCWEST and CHAOZ-X studies (Mocklin and Friday 2018; Vate Brattström et al. 2019), the double knock sound was also present for the years included in this report (2016-18). Still unattributed, this sound was flagged for all moorings and years during the mid-frequency analysis. A quick visual comparison of this sound type with other detected sounds shows that although it seems to occur when ice is present (Figure 24, but see September 2016 at the BF2 mooring), it is not correlated with ice noise. It is also not correlated with walrus (another species that knocks) calling presence. The best match, so far, appears to be with beluga whale calling presence; however, since a number of moorings are not yet analyzed for beluga whales, further investigation has been postponed.

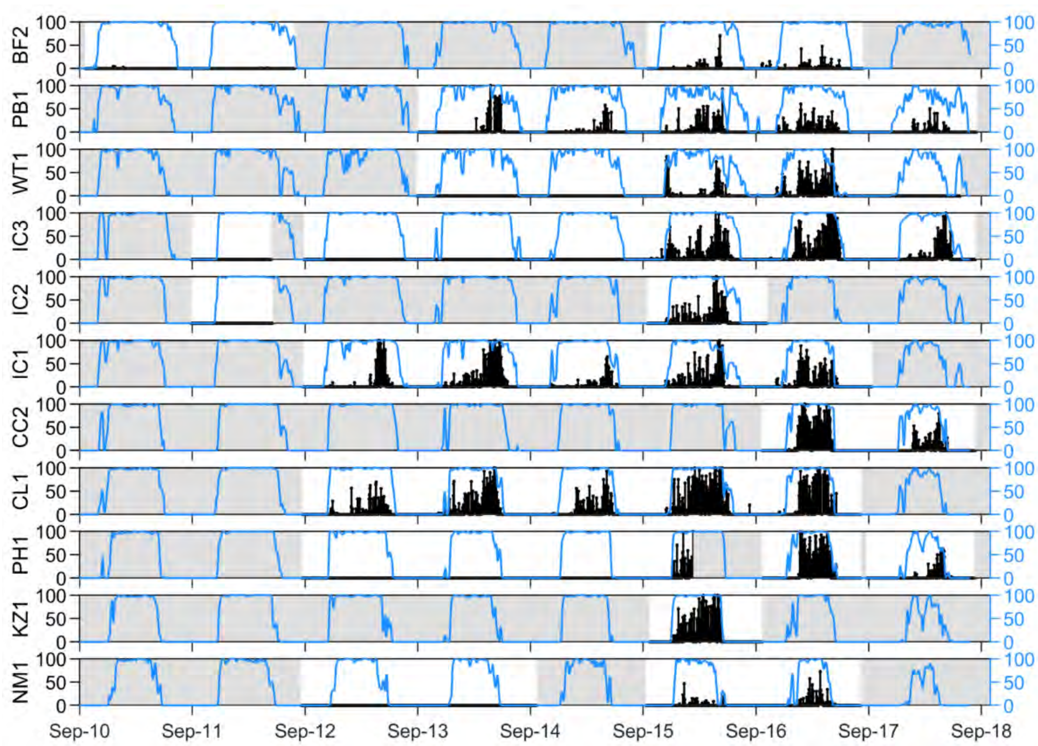

Figure 24. Double knock sound activity (presented as the percentage of ten-minute time intervals with calls) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Environmental and anthropogenic sources

The presence of environmental (ice) and anthropogenic (airgun and vessel) noise sources were also noted during the analyses. Both airgun and vessel sounds occur in the same frequency band as bowheads and so are mostly complete; ice noise, however, is in the high frequency band with beluga whales and the analysis for several moorings remains. We use *noise activity* here as the equivalent of *calling activity* for these non-biological signal types.

Seismic airguns

Seismic airgun noise activity, while not as ubiquitous as was seen during the 2013 open water season, was present occasionally during the 2016-18 time period (Table 24, Figure 25). Detections were made near Barrow Canyon (BF2) in 2015 and 2016, at the offshore Icy Cape site (IC3) in 2015, and in the Cape Lisburne (CL1)/Point Hope (PH1) area in 2015 and 2016. Airgun sounds were detected during the open water season between August and November (but primarily in August and September, Table 25).

Table 24. Seismic airgun noise activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with noise activity (#), number of days with noise activity > 50% (#pk), percent of days with noise activity (%), percent of days with noise activity > 50% (%pk), percent of peak vs. regular activity (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	125	74	7	4	59
PB1	850	40	10	5	1	25
WT1	1219	42	18	3	1	43
IC3	1752	114	76	7	4	67
IC2	1745	103	70	6	4	68
IC1	1869	95	61	5	3	64
CC2	-	-	-	-	-	-
CL1	1225	36	15	3	1	42
PH1	1226	11	3	1	<1	27
KZ1	1227	0	0	0	0	-
NM1	1209	0	0	0	0	-

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	591	22	11	4	2	50
PB1	957	0	0	0	0	-
WT1	905	0	0	0	0	-
IC3	953	1	0	<1	0	0
IC2	279	0	0	0	0	-
IC1	619	0	0	0	0	-
CC2	690	0	0	0	0	-
CL1	583	11	2	2	<1	18
PH1	712	0	0	0	0	-
KZ1	265	1	0	<1	0	-
NM1	583	0	0	0	0	-

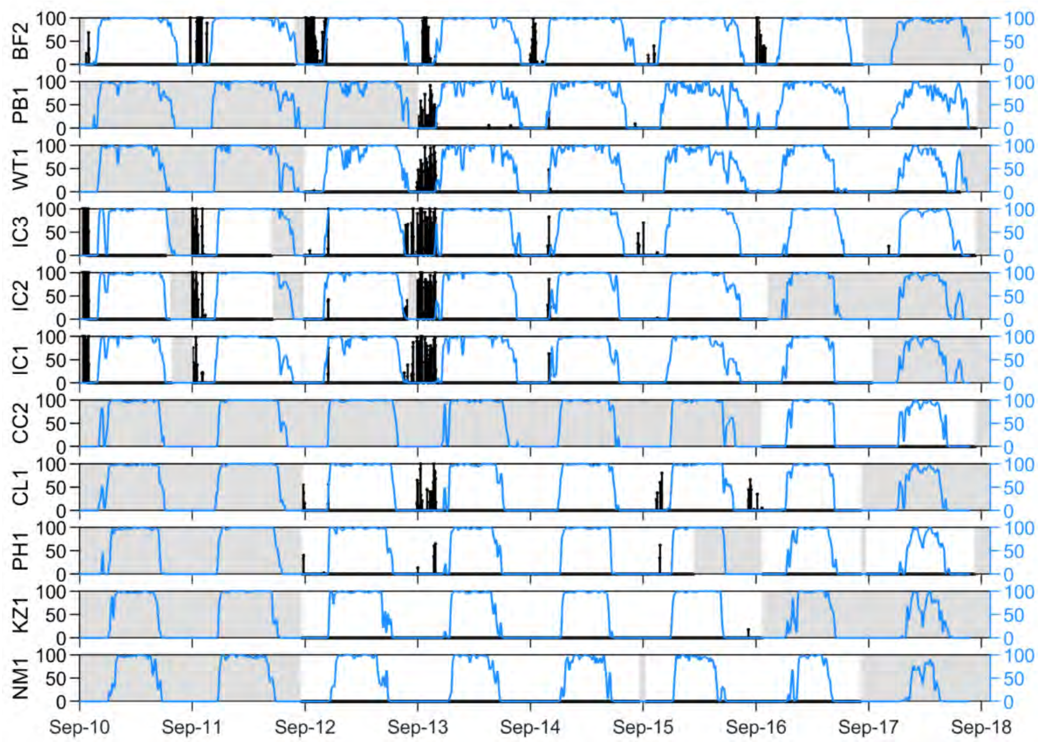

Figure 25. Seismic airgun noise activity (presented as the percentage of ten-minute time intervals with airguns) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 25. Monthly seismic airgun noise activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	BF2			IC3			CL1			KZ1		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	0	62	0	0	93	0	0	62	0	0	31	0
Feb	0	57	0	0	85	0	0	57	0	0	29	0
Mar	0	62	0	0	93	0	0	62	0	0	31	0
Apr	0	60	0	0	90	0	0	59	0	0	30	0
May	0	62	0	0	93	0	0	62	0	0	31	0
Jun	0	60	0	0	90	0	0	60	0	0	30	0
Jul	0	62	0	0	93	0	0	62	0	0	31	0
Aug	0	45	0	0	73	0	9	37	15	1	31	3
Sep	21	29	72	0	59	0	2	30	7	0	21	0
Oct	1	31	3	0	62	0	0	31	0	0	0	-
Nov	0	30	0	1	60	2	0	30	0	0	0	-
Dec	0	31	0	0	62	0	0	31	0	0	0	-

Vessels

Unlike the seismic airgun noise, vessel noise was detected at all moorings during the study period (2016-18), peaking in 2015 and 2016 (Figure 26). Similar percentages of days with vessel noise detected, percentages of days with peak vessel noise detected, and the proportion of days with vessel detected that were at peak levels were all similar between the 2010-15 and 2016-18 study periods. Also similar to the earlier study period, the moorings with the most days with vessels detected were those in the southern Chukchi Sea. All detections were made in the open water period, primarily from July through October at the northeastern mooring sites and June through November at the southern mooring sites (Table 27).

Table 26. Vessel noise activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with noise activity (#), number of days with noise activity > 50% (#pk), percent of days with noise activity (%), percent of days with noise activity > 50% (%pk), percent of peak vs. regular activity (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	154	30	8	2	19
PB1	850	132	25	16	3	19
WT1	1219	222	76	18	6	34
IC3	1752	115	38	7	2	33
IC2	1745	201	103	12	6	51
IC1	1869	296	176	16	9	59
CC2	-	-	-	-	-	-
CL1	1225	145	18	12	1	12
PH1	1226	186	38	15	3	20
KZ1	1227	233	33	19	3	14
NM1	1209	274	44	23	4	16

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	591	46	12	8	2	26
PB1	957	132	35	14	4	27
WT1	905	129	42	14	5	33
IC3	953	18	3	2	<1	17
IC2	279	37	16	13	6	43
IC1	619	90	35	15	6	39
CC2	690	36	2	5	<1	6
CL1	583	48	5	8	1	10
PH1	712	85	22	12	3	26
KZ1	265	53	11	20	4	21
NM1	583	108	27	19	5	25

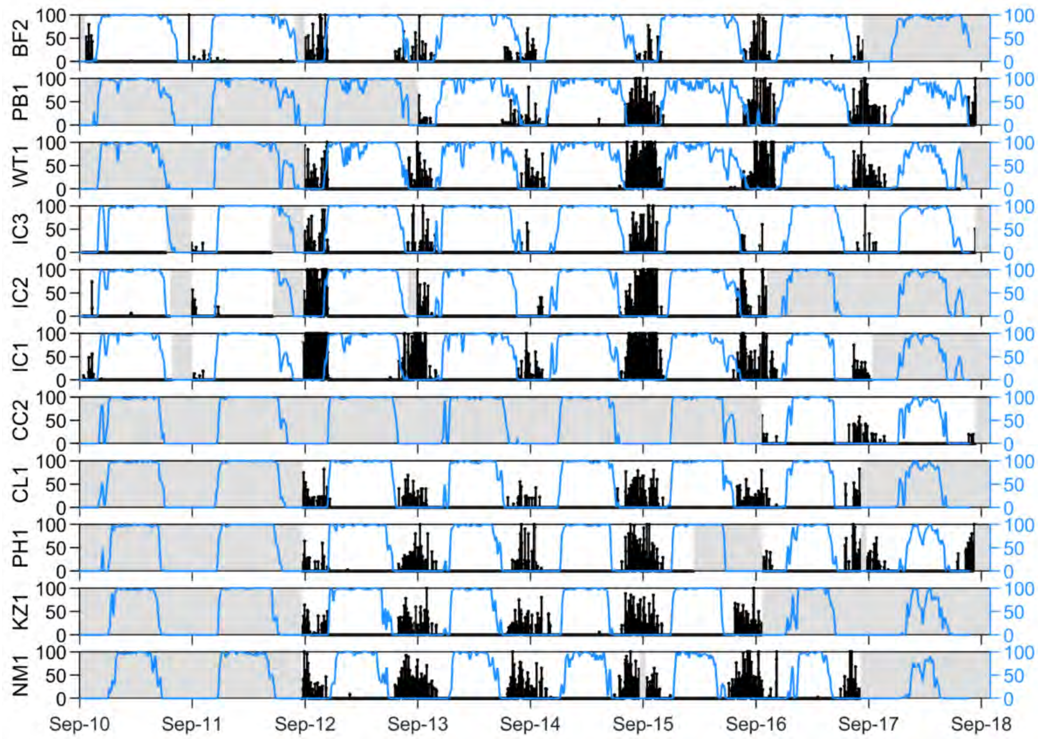

Figure 26. Vessel noise activity (presented as the percentage of ten-minute time intervals with vessel noise) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 27. Monthly vessel noise activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	BF2			PB1			WT1			IC1			IC2			IC3			CC2			CL1			PH1			KZ1			NM1		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	0	62	0	0	93	0	0	93	0	0	62	0	0	31	0	0	93	0	0	62	0	0	62	0	0	93	0	0	31	0	0	62	0
Feb	0	57	0	0	85	0	0	85	0	0	57	0	0	29	0	0	85	0	0	56	0	0	57	0	0	66	0	0	29	0	0	57	0
Mar	0	62	0	0	93	0	0	93	0	0	62	0	0	31	0	0	93	0	0	62	0	0	62	0	0	62	0	0	31	0	1	62	2
Apr	0	60	0	0	90	0	0	90	0	0	60	0	0	30	0	0	90	0	0	60	0	0	59	0	0	60	0	0	30	0	0	60	0
May	1	62	2	0	93	0	0	93	0	0	62	0	0	31	0	0	93	0	0	62	0	0	62	0	0	62	0	0	31	0	0	62	0
Jun	0	60	0	0	90	0	4	84	4	1	60	2	0	30	0	0	90	0	1	60	2	2	60	4	6	60	10	7	30	23	21	60	35
Jul	7	62	12	23	93	25	17	62	28	32	62	52	20	31	65	10	93	11	11	62	18	22	62	36	31	62	50	21	31	68	43	62	70
Aug	16	45	36	53	77	69	38	61	63	26	62	42	4	31	13	3	73	5	11	41	21	11	37	38	16	24	70	15	31	48	25	36	57
Sep	16	29	55	38	59	65	42	60	70	15	40	29	10	29	34	5	59	9	8	41	22	9	30	30	20	39	49	10	21	48	13	30	43
Oct	6	31	19	18	62	29	28	62	46	14	31	45	3	6	50	0	62	0	4	62	7	3	31	10	11	62	18	0	0	-	2	31	6
Nov	0	30	0	0	60	0	0	60	0	2	30	7	0	0	-	0	60	0	1	60	2	1	30	3	1	60	2	0	0	-	3	30	10
Dec	0	31	0	0	62	0	0	62	0	0	31	0	0	0	-	0	62	0	0	62	0	0	31	0	0	62	0	0	0	-	0	31	0

Ice

Similar to the 2010-15 study period, ice produced a substantial amount of noise on all moorings analyzed for the 2016-18 study period (Figure 27), including popping, cracking, and whining sounds. As noted in Vate Brattström et al. (2019), the lower levels of ice noise from the Icy Cape moorings in 2010 and 2011 (IC1-3) were due to a miscommunication with the analysts and should be considered artificially low. Preliminary results for the moorings that have been analyzed for ice in the 2016-18 time period are shown in Table 28; here the percentage of days with ice noise, and the proportion of those days with peak levels of ice noise activity are shown to be higher for the more northern moorings (as was the case for the 2010-15 data). Ice noise, as expected, was confined to the ice season, and extended from January through August at the northern moorings, December through June at the middle sites, and January through May at the southern sites.

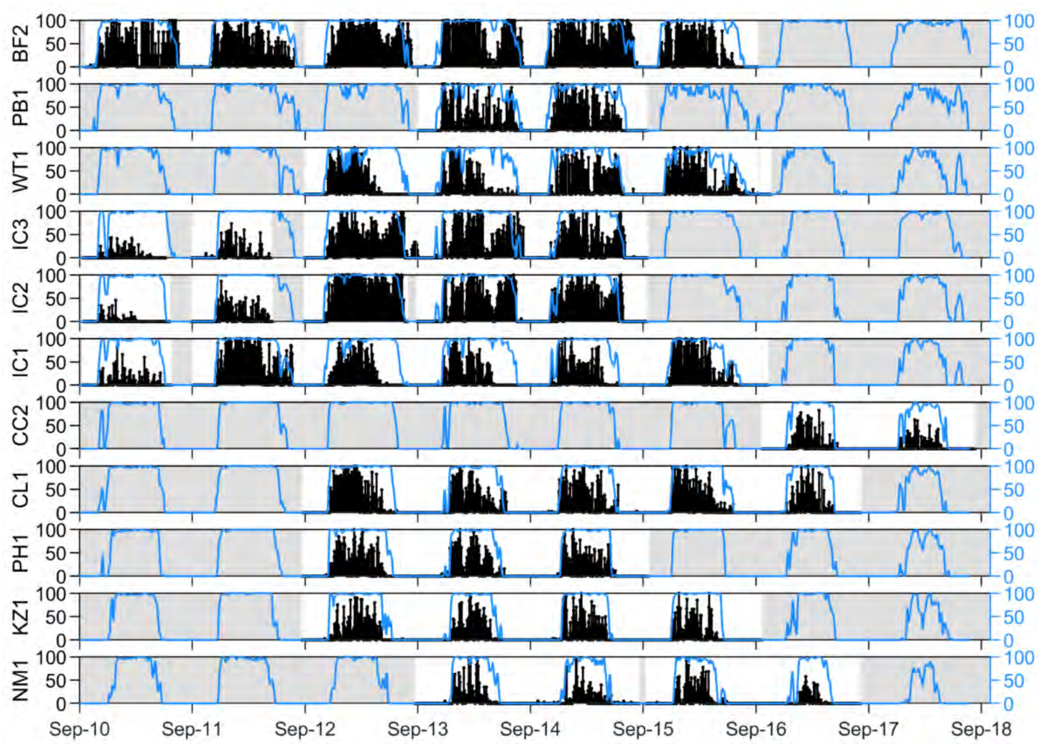

Figure 27. Preliminary ice noise activity (presented as the percentage of ten-minute time intervals with ice noise) for the eleven mooring locations included in this report (Figure 3), 2010-2018. Blue line indicates percent ice cover (zero-phase, three-day moving average). Gray shading indicates either no data available or not yet analyzed.

Table 28. Preliminary ice noise activity, 2010-2015 (left) versus 2016-2018 (right). Number of days with recordings (Eff), number of days with noise activity (#), number of days with noise activity > 50% (#pk), percent of days with noise activity (%), percent of days with noise activity > 50% (%pk), percent of peak vs. regular activity (#pk/#).

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	1891	1289	635	68	34	49
PB1	742	379	120	51	16	32
WT1	1212	489	197	40	16	40
IC3	1647	891	289	54	18	32
IC2	1636	879	424	54	26	48
IC1	1869	763	238	41	13	31
CC2	-	-	-	-	-	-
CL1	1225	503	171	41	14	34
PH1	1124	446	104	40	9	23
KZ1	1227	398	75	32	6	19
NM1	842	235	25	28	3	19

Mooring	Eff	#	# pk	%	% pk	#pk/#
BF2	252	143	63	57	25	44
PB1	-	-	-	-	-	-
WT1	291	141	32	48	11	23
IC3	-	-	-	-	-	-
IC2	-	-	-	-	-	-
IC1	284	144	54	51	19	38
CC2	690	179	18	26	3	10
CL1	583	221	54	38	9	24
PH1	-	-	-	-	-	-
KZ1	265	90	15	34	6	17
NM1	583	139	19	24	3	14

Table 29. Preliminary results of monthly ice noise activity, 2016-2018, for all moorings shown in Figure 3. # = # days with calling activity, Eff = # days with recordings, % = % days with calling activity/ days with recordings.

Month	BF2			WT1			IC1			CC2			CL1			KZ1			NM1		
	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Jan	30	31	97	25	31	81	31	31	100	49	62	79	53	62	86	29	31	94	29	62	47
Feb	29	29	100	25	29	86	29	29	100	38	56	68	53	57	93	27	29	93	49	57	86
Mar	30	31	97	22	31	71	27	31	87	42	62	68	42	62	68	14	31	45	46	62	75
Apr	27	30	90	11	30	37	20	30	67	27	60	45	40	59	68	20	30	67	10	60	17
May	16	31	52	16	31	52	19	31	61	6	62	10	15	62	25	0	31	0	5	62	8
Jun	11	30	37	25	30	83	18	30	60	0	60	0	7	60	12	0	30	0	0	60	0
Jul	0	31	0	14	31	45	0	31	0	0	62	0	0	62	0	0	31	0	0	62	0
Aug	0	31	0	3	31	10	0	31	0	0	41	0	0	37	0	0	31	0	0	36	0
Sep	0	8	0	0	27	0	0	29	0	0	41	0	0	30	0	0	21	0	0	30	0
Oct	0	0	-	0	20	0	0	11	0	0	62	0	0	31	0	0	0	-	0	31	0
Nov	0	0	-	0	0	-	0	0	-	0	60	0	0	30	0	0	0	-	0	30	0
Dec	0	0	-	0	0	-	0	0	-	17	62	28	11	31	35	0	0	-	0	31	0

2. Shipboard

Because MML was involved in all 2017 and 2018 field cruises in a piggybacked capacity, passive acoustic monitoring via sonobuoys was done opportunistically with one or two technicians per cruise; results are included below. Opportunistic visual monitoring was conducted (if at all) by either the seabird observer from the U.S. Fish and Wildlife Service or marine mammal observers from other organizations and will not be included here.

A total of 87 sonobuoys were deployed (with an 85% success rate) during the 2017 and 2018 Arctic field surveys (Table 30). The limiting factor during the 2017 cruise was technician availability; in 2018, an entire crate of sonobuoys ended up being not deployable, despite our best efforts with duct tape to salvage them[5]. Because of this, buoys were rationed, with preference given to the deep basin off the Beaufort shelf because it was an area previously unsurveyed, and the more southern study area, between Cape Lisburne and Bering Strait, to monitor for subarctic species encroachment. Figure 28 and Figure 29 show the species that were detected on the sonobuoys deployed on the 2017 IERP and 2018 Healy cruises in the Arctic, respectively. The most common species detected were fin whales and walrus, with occasional detections of bearded seals and bowhead, humpback, beluga, killer, and gray whales. There were no surprises as to the locations of the detections. Fin whales were detected primarily in the southern Chukchi, but a few detections were made on sonobuoys deployed off Wainwright. Walrus were detected in both years in the vicinity of the benthic hotspot off Wainwright. Bowheads were detected east of Point Barrow. Beluga whales and bearded seals were heard in the deep waters of the Beaufort basin. Gray, killer, and humpback whales were heard near the Hope Basin hotspot. For complete details of each sonobuoy deployment and the species detected, please see Appendix D.

Table 30. Total number of successful sonobuoys (total number deployed) and number of buoys with detections for each species detected for the 2017 and 2018 Arctic field seasons.

Year	# Successful (total) buoys	# Bowhead	#Gray	#Walrus	#Bearded	#Fin	#Humpback	#Killer whale	#Beluga
2017	39 (43)	0	1	4	0	8	1	0	0
2018	35 (44)	1	0	2	1	1	0	1	1
Total (% of buoys)	74 (87)	1 (1%)	1 (1%)	6 (8%)	1 (1%)	9 (12%)	1 (1%)	1 (1%)	1 (1%)

[5] Although they were relatively new buoys, they were most likely stored out on a tarmac in Florida leading to premature delamination of the floats. After this was discovered, no more deployments were attempted, and so the success rate of sonobuoys on the cruise overall was high.

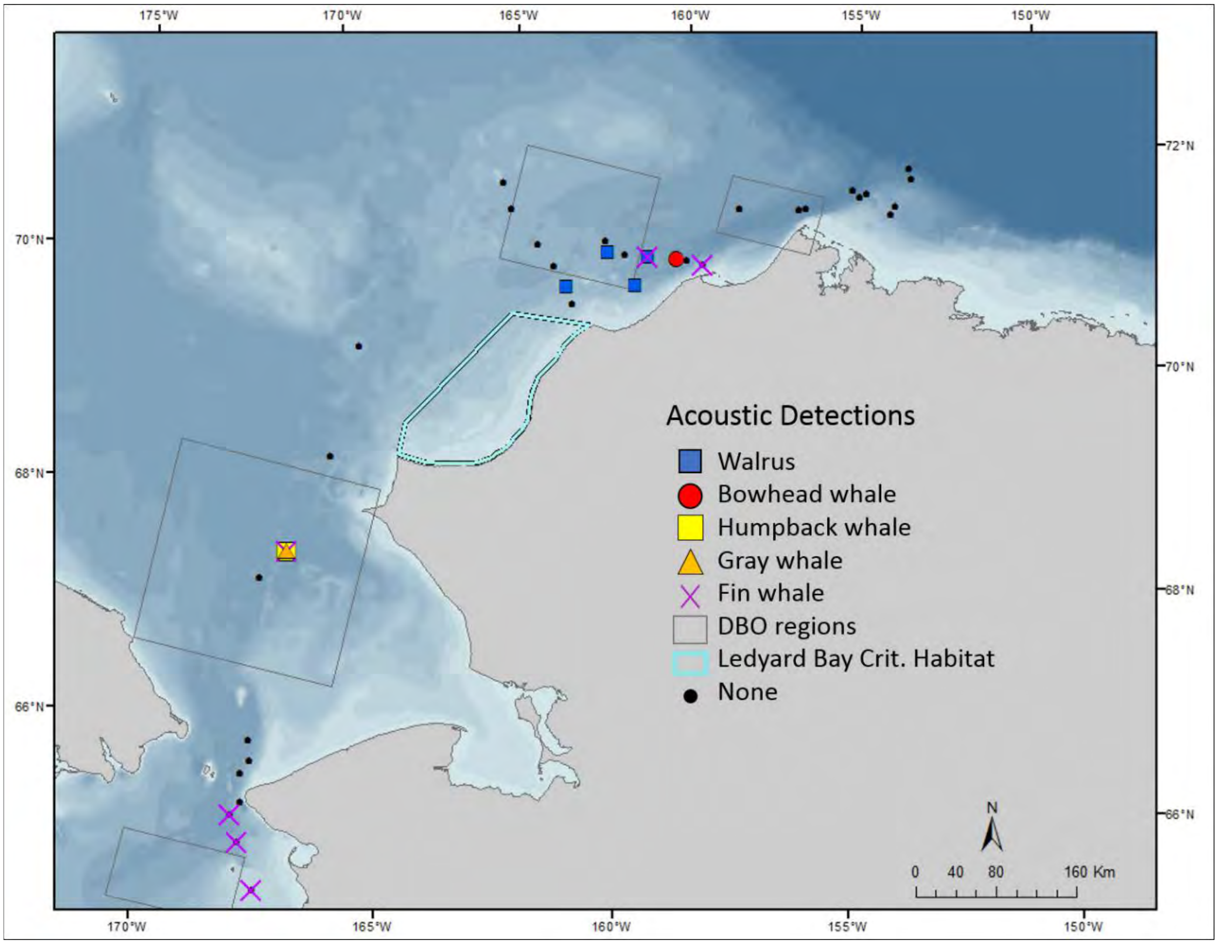

Figure 28. Location and species detected on all sonobuoy deployments during Leg 1 of the 2017 IERP survey in the Chukchi Sea. Sonobuoys were deployed opportunistically and so even distribution along the track was not attained.

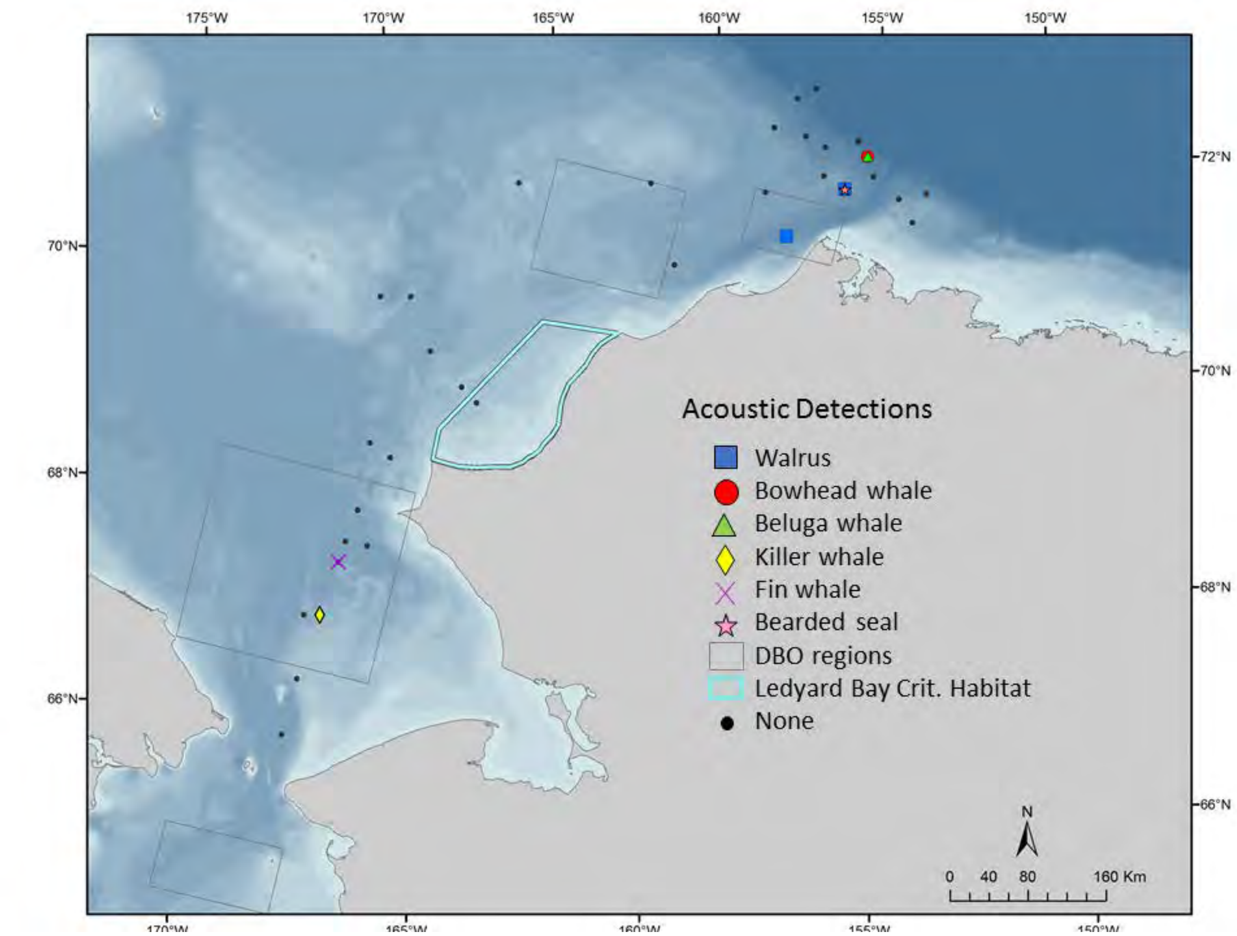

Figure 29. Location and species detected on all sonobuoy deployments during the 2018 HLY18-1 survey in the Chukchi Sea. Sonobuoys were deployed opportunistically and so even distribution along the track was not attained.

A summary of the passive acoustic monitoring effort during the 2017 and 2018 Arctic field surveys is shown in Figure 28 and Figure 29, as well as in Table 30.

C. Discussion

As an extensive discussion was included in Vate Brattström et al. (2019), a condensed version is included here, with an emphasis on any differences that were seen between the results from the ARCWEST time period (2010-2015) and those from the current time span (2016-2018).

1. Arctic Species

Bowhead whales

The bowhead whales detected in this study are part of the Bering-Chukchi-Beaufort (BCB) stock that migrate annually between their wintering grounds in the Bering Sea and their summer feeding grounds in the Canadian Beaufort Sea (see Quakenbush et al. 2010 for an extensive literature review of this migration). In the spring they migrate close to the shore, following leads that develop in the ice; in the fall they fan out over the Chukchi once they pass Point Barrow. Both this spatial pattern, and the relative timing of detections among mooring sites, was seen in all years from 2010 through 2018. The most interesting result seen for bowhead whales is that there was sustained overwinter calling activity (at peak levels) far north of Bering Strait, at the Point Hope and Central Channel mooring sites in 2018 (Figure 4, PH1 and CC2).

It is unknown whether there was a decrease in calling activity at the northern Bering Sea mooring sites during this same time period (but analyses should be complete by fall of 2019). The trend in bowhead whale calling at the mooring south of Bering Strait (NM1) is that the number of days with calling activity present is decreasing with a reduction in the length of the ice season. Although the NM1 mooring has not been completed for the 2017-18 deployment (analysis is currently underway), the very reduced ice concentration seen at that site for that year suggests that bowhead calling will be similarly reduced. If this is the case, a decrease in the number of days with calling activity could indicate that the whales are spending less time in the northern Bering before turning around and heading back up into the Arctic, or even that they are not migrating that far south. Alternatively, an unchanged presence in the northern Bering might indicate a more dispersed winter distribution of bowheads – with some individuals migrating to and residing in the northern Bering overwinter and other individuals stopping further upstream, or a more drawn-out migration. The increased presence of calling activity at the northeastern mooring sites (BF2, PB1, WT1) overwinter suggests that there is at least a noticeable time shift in the migrations. In any case, the calling activity levels reported here indicate persistence of the population, not actual numbers of individuals. However, as advances are made with passive acoustic-based density estimation techniques (e.g., Harris et al. 2018), the data collected for this study will allow this issue to be investigated.

Regardless of what the bowhead migration is doing, the presence of bowheads north of the Bering Strait in winter is not surprising given the oceanographic conditions measured during this time period (see Section VI.B.1), including late ice arrival and an extensive period with open water and warmer temperatures. If there is a reduced presence of bowhead whales in the Bering Sea, the lack of ice driving bowheads into the Bering Sea is interesting. Is it an innate reflex for bowheads to push back to the Beaufort Sea as soon as possible, so they are historically in the northern Bering basically against their will, or did the open water and higher temperatures in the southern Chukchi Sea create further opportunities for feeding? It will also be interesting to see what impact (if any) a wintering population of bowheads in the Hope Basin will have on the ecosystem in that hotspot area.

Also interesting is the reappearance of what seems to be the triple pulse that was present at the Icy Cape sites in 2010; in the current study a triple pulse was seen for the fall migration at PB1 and WT1 in the northeastern part of the study area. As discussed in Vate Brattström et al. (2019), Traditional Ecological Knowledge (TEK) describes the fall bowhead migration as segregated by age class; smaller whales lead the migration, followed by large adults including cow/calf pairs (Braham et al., 1984a). This finding has been supported by more recent photogrammetric work (Koski and Miller, 2009), although another paper on TEK (i.e., Huntington and Quakenbush 2009) reported larger whales leading the fall migration. This latter paper described the fall migration past Barrow as 'tenuous' which may explain the discrepancy. Further exploration of call type present in the different bowhead whale calling activity pulses may reveal differences in the cohorts making up the migration pulses. The pattern seen in the earlier study period of a small pulse of gunshot calling occurring during the end of the fall migration did not carry over to the current study period. Gunshot calling was either absent entirely, or (as in the PB1 mooring), present during the start of the spring migration. Examination of sea ice images, and ice thickness measurements from the co-located oceanographic moorings (see Section VI.B.1) from these time periods may reveal whether this call type is used by the bowhead to navigate through more concentrated ice fields (Ellison et al. 1987; George et al. 1989). See Vate Brattström et al. (2019) for further details.

Beluga whales

There is not much about beluga whales that was not discussed already in Vate Brattström et al. (2019); however, analysis for beluga whales is ongoing, and so the results presented in this report are preliminary. The main points are that there are two populations of beluga whales (eastern Chukchi Sea and eastern Beaufort Sea) that migrate through the study area at overlapping times (Hauser et al. 2014). Both spring and fall beluga whale migrations were observed, fitting with TEK and many scientific studies (see Vate Brattström et al. (2019) for details). The spring migration pulse of calling activity is longer and has more days with peak calling present than the fall pulse; this was seen across all mooring and years from 2010 through 2018. Unlike what was seen for bowhead whales, all completed beluga whale analyses show a similar pattern of calling activity between the earlier and current study periods. However, it remains to be seen whether there is a similar increase in overwinter occupation of sites north of Bering Strait (analyses of those mooring sites are ongoing). The higher and more consistent calling seen into the open water season at the BF2 mooring site is in line with telemetry results that show the Barrow Canyon area is a core summer concentration area for the Eastern Chukchi Sea population (Hauser et al. 2014).

Walrus

For the ARCWEST and CHAOZ-X Final Reports (Mocklin and Friday 2018; Vate Brattström et al. 2019), an overwintering presence of walrus at the offshore Icy Cape site (IC3) was a surprise, with consistently high levels of calling activity during the ice seasons of 2011-12 and 2012-13, decreasing through the winter of 2014-15. Here, levels again increased with a pulse of sustained and saturated levels in 2016, and a shorter duration pulse (but still with peak levels) in 2017-18. Walrus can maintain breathing holes in the ice with their tusks, breaking through up to 20 cm of ice, and were reported to require open water; they were not found in ice concentrations greater than 80% (Fay 1982). Review of satellite ice images shows that although the ice concentrations measure at 100% for these time periods with walrus present, the quality of the ice is quite diminished, with numerous leads and polynyas. However, overwintering walrus in the Arctic is not a new occurrence. In Fay (1982), J. Burns is cited as saying that '…solitary [walrus] … occasionally overwinter … near Point Hope…'. There is a collection of persistent polynyas in the Arctic (see Stringer and Groves 1991) that would provide the open water access needed by this species; however, there are none noted for the offshore Chukchi shelf except for very small ones on Hanna and Herald Shoals.

Figure 30 plots transport levels (calculated as the mean across the Icy Cape line by P. Stabeno; e.g., see Figure 32) against walrus calling activity. Two interesting trends are seen. First, there is a positive correlation between northeast transport and walrus calling activity in December through February. Second, there is also higher walrus calling activity seen from March through June with higher transport to the southwest. The reason for these trends is unknown at this time, but northeast transport could bring warmer temperatures that would create or maintain leads or polynyas. Southwest transport could indicate an increase in ice advection or simply stronger transport providing a mechanism for increased ice break up. Because the PMEL ice profiler mooring was not deployed between the end of the CHAOZ and start of the CHAOZ-X projects (i.e., 2012-13 through 2014-15 deployments) there were no data available on ice thickness to compare with these walrus results. However, once the current dataset of ice profiler measurements are QA/QCed (expected end of summer 2019), the newer trend in increased walrus presence can be investigated with finer scale *in situ* measurements.

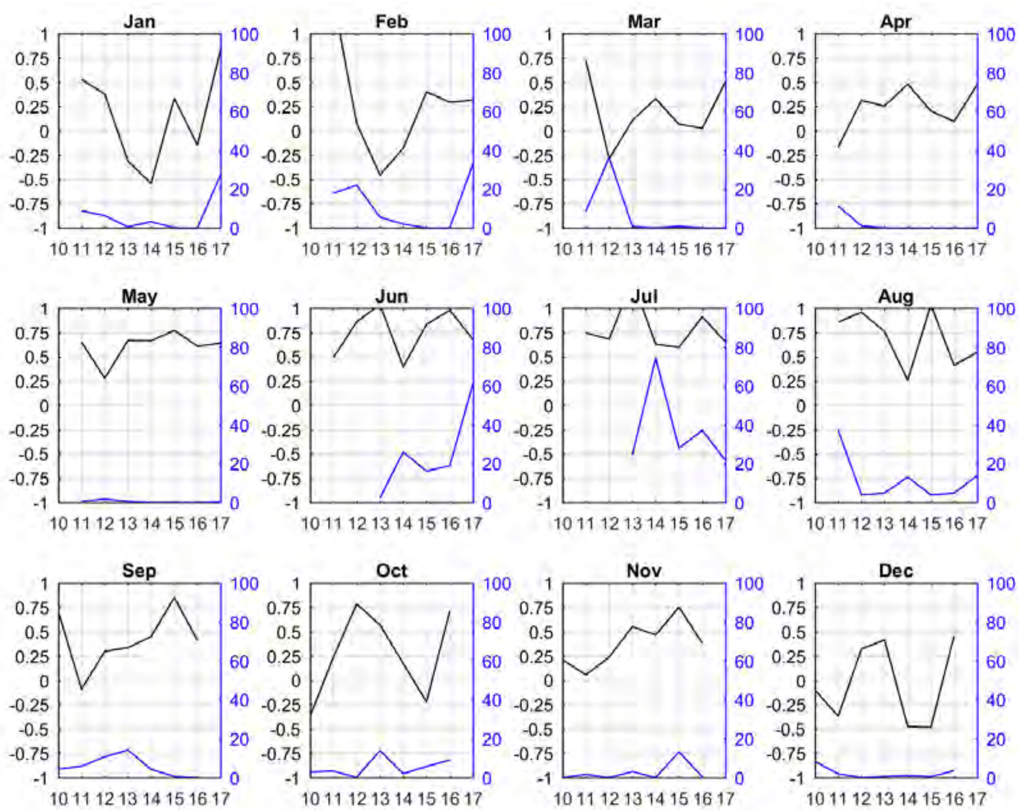

Figure 30. Monthly transport (Sverdrup, left axes) versus walrus calling activity levels (%, right axes) for the years 2010 through 2017. Positive values mean transport is to the northeast, negative values mean transport to the southwest.

The ice profiler data will allow testing of the hypothesis of how walrus are overwintering 140 nm off Icy Cape, but it will not answer why. Walrus are thought to migrate (between October and November) down to the Bering Sea for their breeding season that occurs from December through February (Jay et al. 2008). Their spring migration occurs in April and May, with females and their young moving up to prime feeding grounds in the Chukchi Sea and males choosing summering grounds mostly in the Bering, but also in the Chukchi Sea (Jay et al. 2008). Together, this means that walrus would not be expected north of the Bering Strait from November through April, right when our detections are occurring offshore Icy Cape. Which walrus are remaining on the Chukchi shelf overwinter? It could be subadults that are not sexually mature enough to participate in the breeding season and who are saving energy by foregoing the migration south. Fay (1982) states that '…subadults… seem most inclined to wander or be diverted by irregular ice movements', so perhaps they are just unintentionally there. In either case, overwintering in this area could also be beneficial. They would potentially have access (if enough open water exists) to the benthic hotspots that are becoming further away from ice haul outs during the summer. It also could be adults that are choosing to remain in the Arctic to feast on the more easily accessible prey fields.

A third possibility remains, however. Although walrus are most commonly known to eat bivalves, work with stable isotopes (Seymour et al. 2014) and stomach contents (Sheffield and Grebmeier 2009) find that at least a portion of all walrus also feed on upper trophic level species including seals and birds (Mallory et al. 2014). Fay (1960) described two types of walrus, facultative and obligate seal eaters. He cited TEK that described obligate seal eaters as rogue males that had a different physical appearance (i.e., lean with large powerful forelimbs, yellow and greasy tusks and chests, and unworn tusks). These rogue males were also avoided by hunters because of their bitter taste, although they were shot when seen near beaches because they drove other seal species away. There is definitely not a lack of upper trophic level species (i.e., see Figure 14) in this region overwinter, so whether or not a separate seal-eating ecotype exists, there is prey available, and evidence that walrus do eat seals. Future work with the walrus detected here will involve finer-scale call type and song structure analyses that may help determine whether ecotype-level differences exist.

Bearded seals

Like beluga whales, there are still several moorings that remain to be analyzed for bearded seals and the results presented here should be considered preliminary. However, a few changes are seen across time. First, the pulse of bearded seal calling at the southernmost mooring site (NM1) is decreasing in duration as the ice season shrinks (Figure 14). As a species that uses ice to give birth, whelp their pups, and molt (Burns and Eley 1978), this trend is expected. Similar to belugas, however, more of the moorings north of Bering Strait (and in the northern Bering) need to be completed before investigation into shifts in distribution can be undertaken. As mentioned in Vate Brattström et al. (2019), there appears to be a small pulse of bearded seal calling prior to the main saturated and sustained pulse. While the main pulse has a start date that is relatively consistent among mooring sites, the smaller preliminary pulse appears to show some evidence of occurring earlier in the northern sites and later in the southern, suggesting there is a migratory component to its presence. The data included here show some mooring sites where this preliminary pulse is either absent or possibly occurring concurrent with the main pulse, and is not apparent. Inclusion of all later-year mooring results, as well as analysis of the call types that occur in the preliminary versus the main pulse of calling may help identify whether a particular repertoire is associated with the smaller pulse. If so, then these call types can be used to track the smaller pulse of calling if it occurs concurrently with the main pulse, potentially allowing tracking of the migration of bearded seals from the Arctic.

Gray whales

Gray whales migrate close to shore (see Vate Brattström et al. (2019) for details), in waters where the potential of damage from ice keels is high and so moorings are not deployed. However, on the handful of moorings where gray whales are detected, the number of days with detections decreased from the earlier (2010-15) to the current (2016-18) study periods, although the proportion of those data with peak calling levels stayed about the same. In general, moorings with gray whale detections were centered around the known benthic hotspots in the northeastern Chukchi (near Wainwright) and the southern Chukchi in the Hope and Chirikov Basins (Clarke et al. 2015; Grebmeier et al. 2015). For the later time period, the large pulse of detection at the PB1 spot was not found from 2016 on; smaller pulses were seen at WT1, a site to the west of PB1, in the open water seasons of 2016 and 2017. The southern mooring sites saw a decrease in calling activity that was half that of the earlier study period (i.e., 2016-18 vs. 2010-15). Gray whales are known to migrate out of the Arctic for the winter (Swartz 1986). Although there is evidence some remain (Stafford, 2007), the oceanographic findings below (Section VI.B.1) for the overwinter period do not directly apply to the calling presence we found, since calling occurred during the open water period. Future investigation of drivers behind the shifts in occurrence will be difficult given the low sample sizes present.

2. Subarctic species

As conditions continue to change in the Arctic, the increased presence of subarctic species will bring additional competition for changing food resources for Arctic species. Trends for humpback, killer, and minke whales, ribbon seals, and the double knock mystery sound are discussed below. As mentioned earlier, fin whale detectors never materialized, and so this species is not included here. However, time has been allotted for an in-house autodetection routine to be tested in the spring/summer of 2019. No detections of right or sperm whales were made and these species will not be discussed below. Recent detections of right whales on moorings in the northern Bering Sea (Wright et al. 2018), however, mean that care should be taken to monitor for right whales on southern Chukchi moorings in the future.

Humpback whales

The majority of humpback whale detections were made on the more southern moorings of this study – from Cape Lisburne south to below the Bering Strait, with only a few days of calling present off Wainwright (WT1) and Icy Cape (IC3). As mentioned in Vate Brattström et al. (2019), it is unknown how much the humpback whale presence in the Arctic is increasing. From the passive acoustic data included here, humpback whales have been a constant presence in the Hope/Chirikov Basins for at least seven years. For the Point Hope mooring (PH1), a more concentrated presence of humpback whale detections were found – at fewer days, but with higher levels. Future work with passive acoustic density estimation (see the bowhead whale discussion section above) may provide quantitative data to investigate whether humpback numbers are increasing. No evidence of further encroachment north has been apparent from the recordings collected by this study, however (Figure 19). Humpback whales, as expected, continue to avoid areas with ice concentrations.

Killer whales

For the analysis of killer whale calling activity that has been completed (additional mooring analysis is currently underway), the majority of killer whale detections continued to occur at the southern mooring sites, concurrently with gray and humpback whales. As mentioned in Vate Brattström et al. (2019), killer whales in the Arctic are most likely transients (Clarke et al. 2018). As such, they would be fairly silent, vocalizing mostly after a kill (Deecke et al. 2015). However, low sighting results from shipboard and aerial surveys as well as opportunistic sightings (George and Suydam 1998; Aerts et al. 2013; Clarke et al. 2018) combined with low vocalization rates, means low levels of detections are not unexpected. A recent note on increasing killer whale presence in the Bering Strait (Stafford 2019) found an increase in the number of days with killer whale calls detected from September 2009 to July 2016 at one location (i.e., slightly north of Bering Strait, between our NM1 and KZ1 sites). Interestingly we did not see the same increase in number of days with killer whale calls, from 2010 through 2015, at either of those sites (Appendix A.2). We also had detections of killer whales, albeit south of Bering Strait, in March and in May through September, as compared with the June through November reported by Stafford (2019). Furthermore, killer whales were detected April through October from Icy Cape to Cape Lisburne, suggesting that either these animals were missed by Stafford (2019) because of the low duty cycle or perhaps that they never migrated south through Bering Strait in those years.

Minke whales

Detections of minke whale boing calls continued to be centered in the area off Cape Lisburne (CL1), although analysis of the new recordings in the Central Channel (CC2) show a more dispersed, lower-level presence there. While other studies (Delarue et al. 2013) hypothesized that the boing call is a reproductive display because they were detected only in October (although minke whales were visually seen throughout the summer and fall), the preliminary data analyzed for this project show detections from June through October. Currently a fine-scale analysis of the pulse repetition rate of approximately 4,000 individual boing calls detected so far in this study is underway. This analysis will help identify whether they are the eastern or central boing call type (Rankin and Barlow 2005), which will be useful in future stock structure assessments, especially given the debate on whether minke whales found in the Bering Sea and north are a separate migratory stock from those in the North Pacific (Clarke et al. 2013). Since the individual calls have been extracted, more detailed information on the spatio-temporal production of boing calls will also be provided. Analysis of several moorings for minke whale boing calls, like for other higher-frequency species, is still underway.

Ribbon Seals

Like the rest of the high-frequency species, results for ribbon seals are not complete. It will be interesting to compare the results from the Barrow Canyon (BF2) and Central Channel (CC2) sites for 2016 through 2018 to see if there was a shift in ribbon seal distribution (or just another known site added with increasing passive acoustic coverage). It was also interesting to see the shift at the southern mooring sites for detections to be made during ice formation in earlier years and ice break up in the later years (Figure 23). The results from Frouin-Mouy (2019)[6] show a spatial dichotomy in ribbon seal seasonal detection for the 2012-13 deployment season. Arctic moorings had detections during ice formation, while the majority of detections on moorings south of Bering Strait were clustered during the

[6] MML Bering Sea passive acoustic recorders (funded by BOEM) were used in this ribbon seal study.

ice break up period. Further investigation of both the Arctic and Bering Sea moorings will be needed to determine to what extent this seasonal shift is present in later years. Frouin-Mouy et al. (2019) also provided evidence that ribbon seals use the northeastern Chukchi Sea as a migration corridor between the Chukchi Plateau and/or Beaufort Sea. In addition, they found that the number of calls, proportion of downsweep calls, and bandwidth of the downsweep calls all increased during the breeding season (March to June); a further example of how more fine-scale analyses can extract additional information from passive acoustic data than simply presence/absence.

Double knocks

As mentioned in the results, the seasonal occurrence of the double knock sound does not correspond to ice noise or walrus calling. The closest correlation is with beluga whale calling. A colleague at the Marine Mammal Laboratory (MML) who studies Cook Inlet beluga whales, and who has also studied beluga whales in captivity says he has not heard a double knock sound of this type from beluga whales (M. Castellote, pers. comm.). The hypothesis from Eric Braen (MML) that this is a fish sound has not yet been disproven. A few anecdotal stories from scuba divers and fish acousticians (Riera et al. 2018) seem to relay that fish are capable of making knocking sounds. If indeed these are fish sounds, it may explain the presence of beluga whales, who prey upon fish species, among other things. Further investigation, however, is delayed until the remaining moorings can be analyzed for beluga whale calling presence.

3. Environmental and anthropogenic sounds

Seismic airguns

As oil and gas exploration pulled out of the Chukchi Sea, decreased detections of airguns were expected and seen (Figure 25). Isolated occurrences were detected in the Beaufort Sea (BF2), off Cape Lisburne (CL1), and in the Hope Basin (PH1) in 2015 and 2016. In 2015, Hilcorp Alaska, LLC conducted shallow geohazard surveys in the Beaufort Sea in the vicinity of Prudhoe Bay, AK (Cate et al. 2015). Other seismic work conducted between 2014 and 2017 can be attributed to scientific exploration by other nations in the Beaufort Basin[7]. Although it is possible that the airguns detected on the Cape Lisburne mooring (CL1) are from airguns fired in the eastern Beaufort Sea, it is highly unlikely. More reasonably, it is likely that these signals were from seismic exploration conducted off the coast of Russia, or from other non-permitted activities in the Chukchi Basin (i.e., not listed on the website https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-oil-and-gas).

Vessel noise

The open water season of 2015 saw the drill rig stationed at the Burger drill site (Ireland and Bisson 2016). Because the closest ports were Nome and Prudhoe Bay, support vessels had to be staged near the drill rig in the event of an oil spill (or incoming ice field). From a distance, this flotilla looked like a

[7] For example, Canada has had a number of seismic surveys in the Arctic including in 2015 (http://science.gc.ca/eic/site/063.nsf/eng/h_5C9B2416.html) and in 2016 (http://science.gc.ca/eic/site/063.nsf/eng/h_5666A052.html). South Korea also has had seismic surveys as part of joint US-Canada-Korea expeditions to the eastern Beaufort Sea in 2014, 2014, and 2017 (https://www.mbari.org/at-sea/expeditions/canadian-arctic-2017-expedition/#toggle-id-1).

small village out in the middle of the Chukchi shelf at night. Not surprisingly, vessel noise activity peaked in this year, centered on the mooring sites around the drill site (i.e., IC1, IC2, WT1). In more recent years, vessel presence was mostly due to scientific research cruises from a variety of nations, and (in 2016) industry efforts to recover the anchoring system for the rig. Once the analysis for all frequency bands is complete, noise metrics will be computed using the Cornell University's noise analysis software tool, the Acoustic Ecology Toolbox (AET: originally referred to as SEDNA [Dugan et al. 2011]) following Vate Brattström et al. (2019).

Ice noise

The only environmental sound noted by the analysts was that of ice. It should be noted that care must be taken when analyzing passive acoustic data in the presence of ice noise as it can be easily confused with vessel noise and marine mammals such as bowhead and beluga whales. A summary of sources and characteristics of the different types of ice noise is included in Vate Brattström et al. (2019) and not repeated here. Results are provided for completeness, although ice noise is analyzed in the high frequency band and all moorings/years from this study period are not yet finished.

D. Conclusions and recommendations

Year-round, long-term monitoring of marine mammal populations, as well as anthropogenic disturbances, is critical in a region that is undergoing rapid environmental change. This supplemental report describes a near-decadal record of all vocalizing marine mammals from the Bering Strait to Barrow Canyon. These species include baleen and toothed whales as well as various pinnipeds. They include Arctic endemic as well as subarctic species that are beginning (or continuing to) summer in the productive Arctic waters. They include benthic feeders, pelagic feeder, planktivores, piscivores, and mammal eaters. They include many important species relied upon for subsistence by the native communities along the Alaskan coastline. These data, combined with those from aerial surveys as well as telemetry studies, present a comprehensive picture of when these species are present and where they are distributed. The why and how of these distributions are beginning to be investigated as trends emerge from concurrent oceanographic and prey data sampled over the same temporal and spatial scales. As ecological models are created from these data, it will be important to include these apex predators for top-down control.

Finally, it is important to reiterate that passive acoustic data do not expire. As better techniques are developed, or calls are attributed to species (both mammal and otherwise) and behaviors, the data collected as part of this suite of BOEM studies will be able to be reanalyzed from the very first recording made. As it stands, density estimation and population/ecotype differentiation are currently being explored and will add enormous value to this already available set of results. It is strongly recommended that these time series continue to be collected until environmental conditions restabilize. The cost of collecting these data is low, the cost of forgoing their collection is high; retroactively collecting these data is impossible.

VI. Oceanographic

A. Methods

1. Moorings

The oceanographic moorings consisted of an anchor, chain, acoustic release and subsurface float, and several different types of oceanographic sensors (see Table 3 for details). All moorings were taut-wire moorings, measuring temperature (T; SEACAT, RCM9, RCMsg), conductivity from which salinity (S; SEACAT, RCM-9) is derived, currents (RCM-9, RCMsg, Acoustic Doppler Current Profiler [ADCP]) and chlorophyll fluorescence (Wetlabs Eco Fluorometer). Nitrate concentrations were measured using Atlantic ISUS or SUNA (see following section). Oxygen was measured using Aanderaa Oxygen Optode 3835 that was measured on the RCM-9. The ASL IPS-5 instrument acoustically measures ice keel depth. To avoid ice keels, the top of each mooring was <10 m off the bottom (or ~30 m below the surface). Mooring designs were identical for each year. Data were collected at least hourly, and all instruments were calibrated prior to deployment. The physical and chemical data were processed according to manufacturers' specifications. CTDs (including Niskin bottles) were conducted following or preceding mooring recoveries and deployments to provide quality control of the data collected by some of the instruments on the moorings (e.g., temperature, salinity, PAR, dissolved oxygen, chlorophyll fluorescence, and nitrate).

Nitrate sensors

Nitrate time series are derived from optical sensors purchased from Satlantic (*In Situ* Ultraviolet Spectroscopy [ISUS] or Submersible Ultraviolet Nitrate Analyzer [SUNA]; instrument used will be identified in the metadata sent with the archived data). These sensors are accurate to ~2 µM, and do not have internal standards. The data were calibrated against reference field samples that were collected while the sensor was deployed. The calibrations included both an offset and drift correction. After these adjustments, several times had periods with negative values, and a secondary offset or drift correction was applied.

Ice Profilers

Ice-draft time-series data were collected from upward-looking IPS5 sonar ice profilers (ASL Environmental Sciences) during year-long deployments in the Chukchi Sea. The devices were mounted near the ocean floor, and used a high-frequency 420 kHz transducer with a narrow, 1.8° beam width. These instruments ping the under-surface of ice and waves measuring the travel time. These data, together with temperature and pressure data, are used to calculate the ice draft. Raw data were extracted from compact flash cards using IPS5extract™, and data were processed using the IPS Processing Toolbox™, both proprietary MATLAB tools developed by the manufacturer. Range and sensor data were trimmed to exclude pre- and post-deployment data, and early- and late-season waves. NCEP 6-hourly mean sea-level pressure data were used to remove atmospheric pressure. Tilt corrections were applied using sensor tilt and magnitude data. Range null targets were recovered from amplitude data. Range data were de-spiked in 2 passes: for 1-2 point, and 3-4 point outliers. Further linear interpolation was applied to obvious outliers of up to 10 data points. Daily ice-draft data were averaged from 1-second preliminary ice draft starting at time 00:00:00 UTC each day. Statistics (e.g., means, medians, standard deviations) were calculated within the MATLAB environment. These daily ice draft data include ice cover and exclude waves and ice-free data segments. Data from the 2016-17 deployments are processed and QA/QCed; those daily data will be sent to BOEM with final submission of this supplemental report. Data from 2017-18, however, are still being processed and will not be available until the end of 2019.

2. Shipboard

Hydrographic data were collected during cruises in 2017 and 2018 (Figure 31, Table 31). The primary design of the hydrographic survey was to collect temperature, salinity, chlorophyll fluorescence, oxygen and PAR using a Sea-Bird SBE 911plus platform and to collect samples of oxygen, chlorophyll, nutrients (nitrate, phosphate, silicate, nitrite and ammonium), and salinity at alternate stations (Figure 31). In addition, CTD casts were collected at the moorings sites and other sites when time permitted. The primary purpose of the salinity and oxygen samples was to calibrate the instruments on the CTD. In addition, CTD casts were made following or preceding mooring recoveries and deployments; these measurements were used for quality control of the data collected by instruments on the moorings.

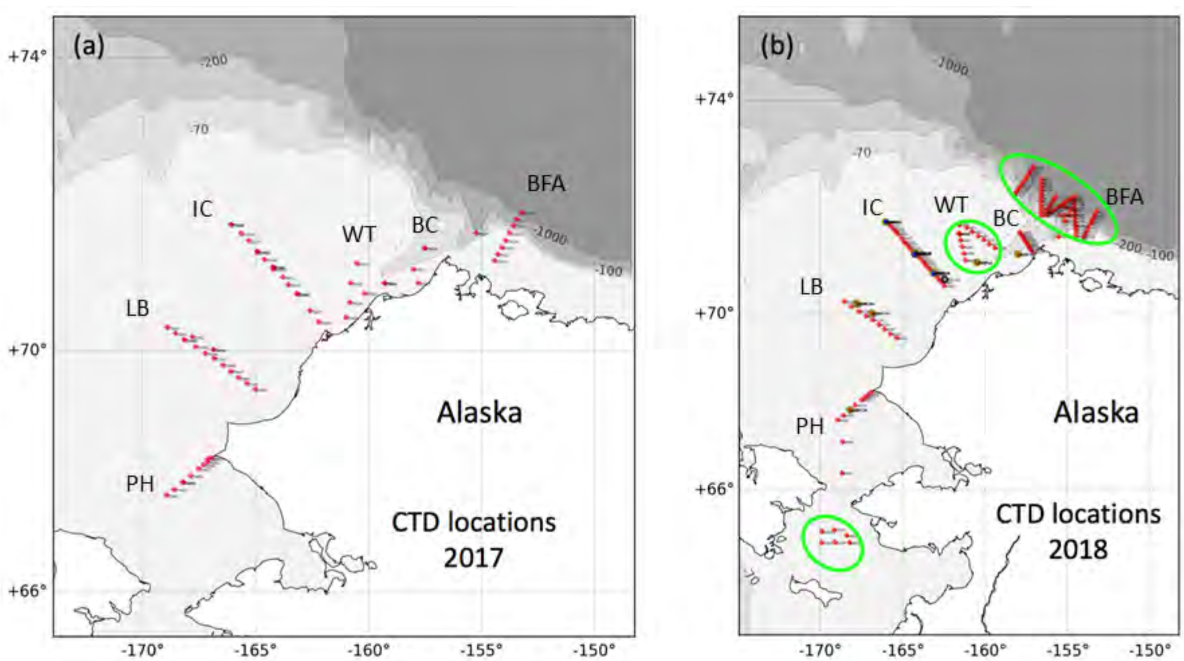

Figure 31. Locations of the CTD stations in (a) 2017 on the R/V Ocean Starr and (b) 2018 on the USCGC Healy in 2018. Note that the CTDs circled in green were collected as part of the DBO/NCIS program, who we partnered with on this cruise, and are not included in this report. PH = Point Hope (DBO3), LB = Ledyard Bay, IC = Icy Cape, WT = Wainwright (approximate because this is the DBO4 line that changes every year), BC = Barrow Canyon, BFA= Beaufort Sea Line A.

Sampling was fully successful, with Sea-Bird SBE 911plus system with dual temperature and salinity sensors, oxygen (SBE-43) sensors, a PAR sensor (Biospherical Instruments QSP-200 L4S or QSP-2300), and a chlorophyll fluorescence (WET Labs WETStar WS3S) sensor. Nutrients and chlorophyll samples were collected approximately every 10 meters and at the bottom of the cast. The chlorophyll samples were collected by the DBO/NCIS project and will not be included in this supplemental report.

Nutrient samples were taken from each bottle, processed and frozen in the – 80°C freezer for processing in the laboratories at PMEL in Seattle, Washington. Salinity calibration samples were taken on approximately a third of the casts and analyzed using a laboratory salinometer at PMEL. Oxygen samples were taken on most casts and titrated using the Winkler method. The number of CTD stations and the number of nutrient samples collected are shown in Table 31.

Table 31. The number of hydrographic stations occupied in the Chukchi Sea, the number of nitrate samples collected and processed, and the hydrographic lines where those samples were collected. PH = Point Hope (DBO3), LB = Ledyard Bay, IC = Icy Cape, WT = Wainwright, BC = Barrow Canyon, BFA= Beaufort Sea Line A (see Fig. CTD). X = line occupied, P = line partially occupied. Note that some lines were occupied as part of the DBO/NCIS project and will not be included in this supplemental report.

Dates	CTD	Nitrate	Ship	PH	LB	IC	WT	BC	BFA
1-24 Aug 2017	52	~200	R/V Ocean Starr	x	x	x	P		x
4-24 Aug 2018	62	~250	USCGC Healy	x	x	x	P	x	P

3. Remote sensing

Sea-ice data used in this project were version-2 Bootstrap algorithm files described by Comiso (2007). Bootstrap data from 1978 through 2017 files were obtained from the National Snow and Ice Data Center (NSIDC; http://nsidc.org/data/docs/daac/nsidc0079_bootstrap_seaice.gd.html). The version-2 Bootstrap algorithm was enhanced by comparison with the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) data. Note that the AMSR-E satellite was launched in May 2002 and failed in October 2011. For the years presented in this report, data were derived from the Special Sensor Microwave Imager/Sounder (SSMI/S) flown on an F17.

Bootstrap files are not yet available for 2018; for that year we use the near-real-time NSIDC 0081 files (Maslanik and Stroeve 1999). These files are derived using the SSMI/S instrument aboard the DMSP F17 and F18 satellites. Both datasets are on the 25km Polar stereographic grid. The time series of percent areal coverage were calculated in ~50 km x ~50 km boxes around each of the mooring sites.

Satellite-tracked drifters

The satellite-tracked drifters deployed in the Chukchi Sea were funded by the NOAA Fisheries-Oceanography Coordinated Investigation (FOCI). Six were deployed in 2017 and an additional six in 2018. The drogues were “holey socks” centered at a depth of ~30 m, which was below the summer mixed layer depth. Each drifter was instrumented with a temperature sensor at the bottom of a float (i.e., just below the sea surface). At these high latitudes, more than 14 position-fixes per day were obtained from Argos, until the drifter was caught in the ice in the fall after which time the fixes became erratic. Once the data were received from Argos, spurious data were deleted from the time series. Data collected after the drogue was lost or entered into ice (determined from maps of ice extent) were noted.

B. Results

1. Moorings

Sea ice arrived late in southern Chukchi in 2017, with freeze-up not occurring until almost January. The cause of this was two-fold. First, ocean temperatures were well above average; and second, there were strong warm winds out of the south. This delayed the ice by "blowing" it northward, but this also strengthened the transport on the northern shelf (Figure 32), which directly transported the ice northward. Ice was advected southward in December and January, but a second occurrence of persistent winds out of the south created open water in the Chukchi during February and into March (Figure 33).

The extremely warm water in the Chukchi was evident at C2 in the near-bottom temperature record. Notice that usually from January through early June, bottom temperatures are at the freezing point (approximately -1.7°C). Most years, heating occurs in August when winds mix the near-surface warm water to the bottom. Not only were there short periods of warm water, but that water persisted from June through November. This heat had to be lost to the system before ice formation, thus contributing to the delayed arrival of ice in fall 2017 (Figure 34). A similar pattern appeared on the southern shelf (Figure 35). Warm bottom water appeared early (May) and persisted through November.

Ice keel depth has been measured at C2 almost continuously since September 2010. Figure 36 shows the timing of ice retreat and arrival. Note that ice is arriving later and departing earlier at this station. This is the trend that has been observed over the last several decades in the Arctic Ocean as a whole.

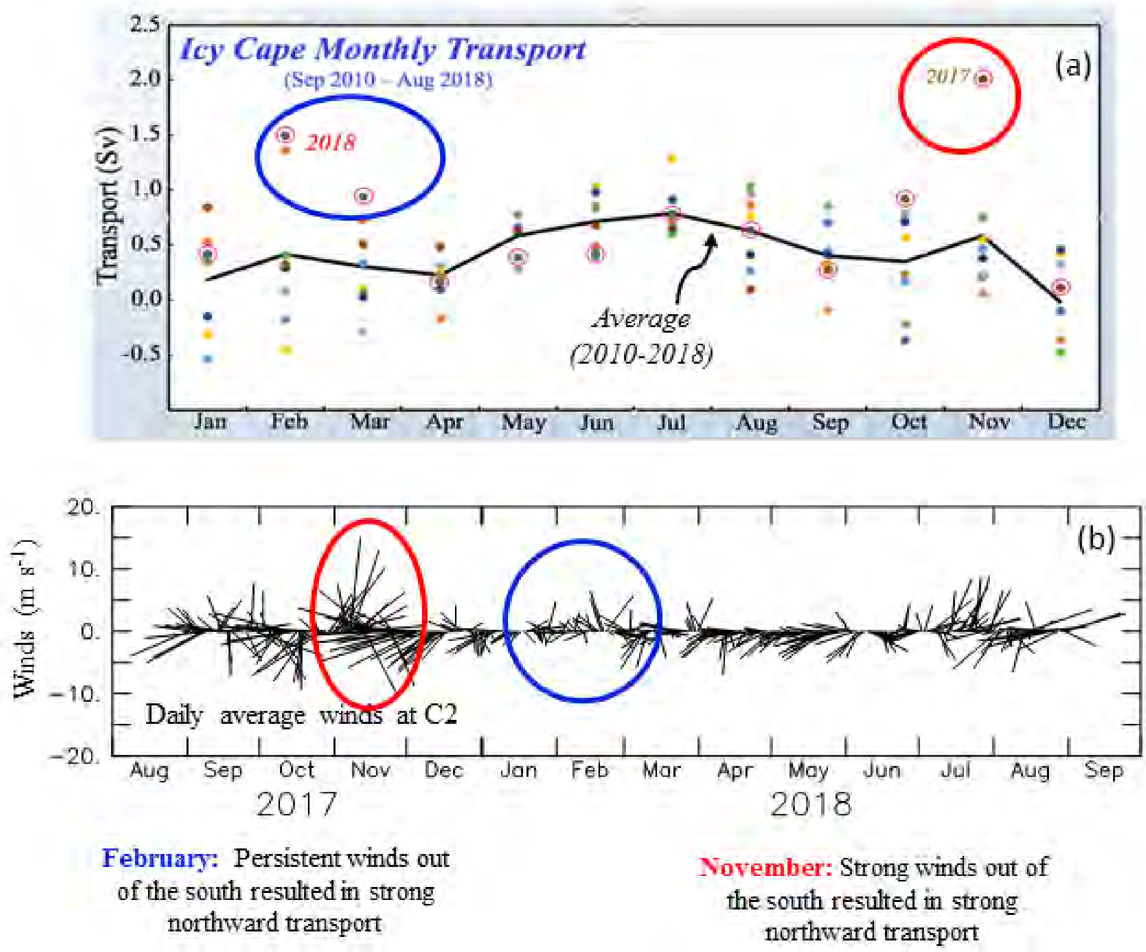

Figure 32. Transport and winds at Icy Cape. (a) Transport estimated from three moorings (C1, C2, C3) deployed at Icy Cape (2010-2018). Positive transport is flow toward the northeast. The black line is the average over all deployments. (b) Wind vectors centered on C2 at Icy Cape from NARR. Upward indicates northward winds.

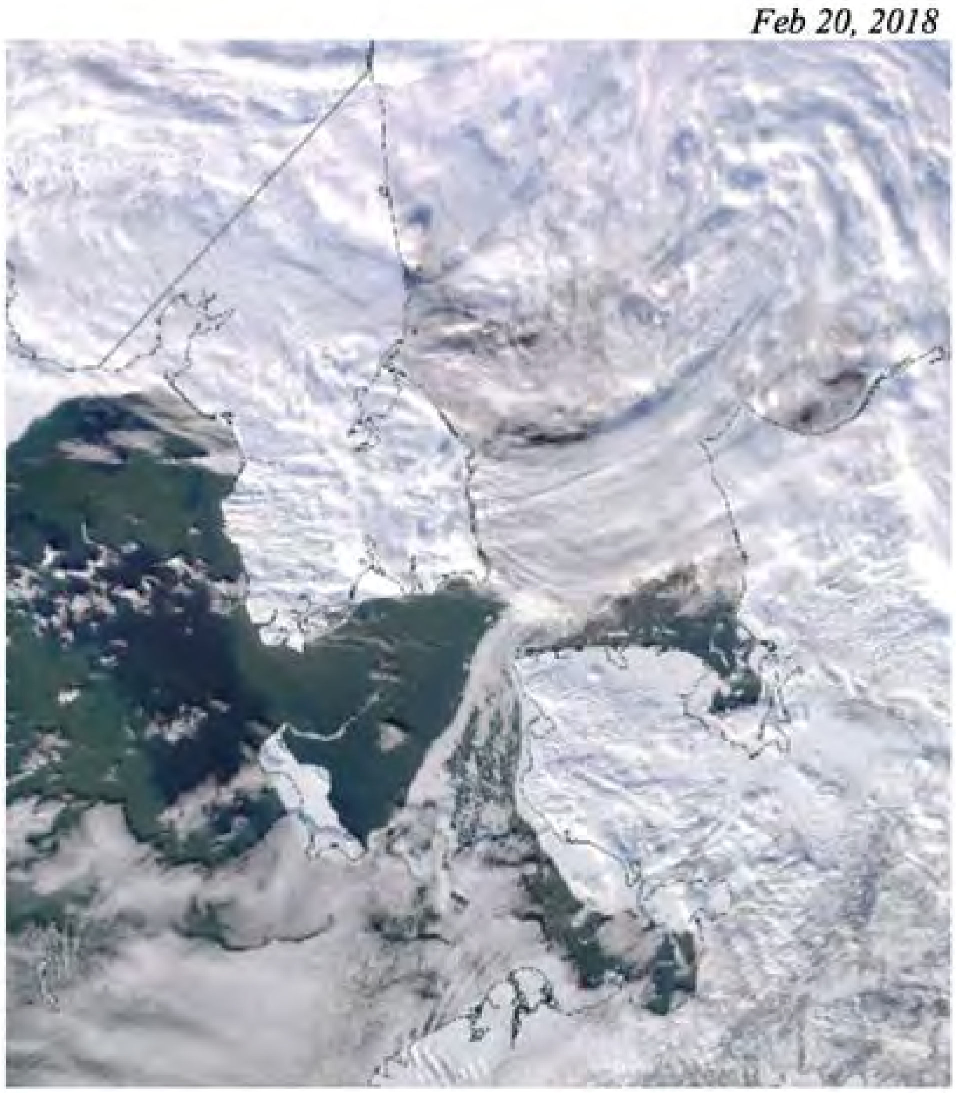

Figure 33. Satellite ice image. Atmospheric conditions shown in Figure 32 resulted in abnormally low ice extent in the Bering Sea in the 2017-18 ice season. The Chukchi froze late due to warm water and strong winds out of the south in November. The southerly winds in February resulted in ice retreat shown in this satellite image.

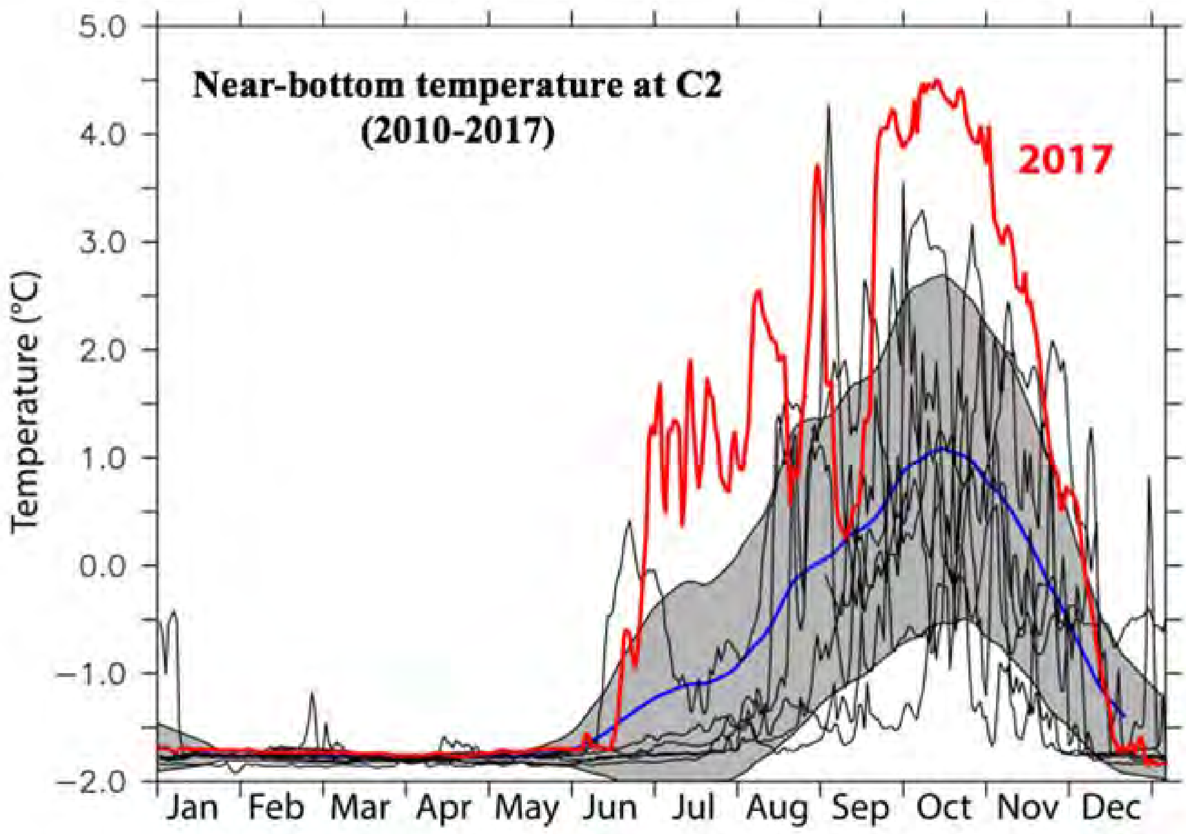

Figure 34. Time series of bottom temperature at C2 for each year since 2010. The blue line is the average annual signal (September 2010-December 2017). The extreme conditions observed in 2017 are indicated in red. The grey indicates +/- 1 standard deviation.

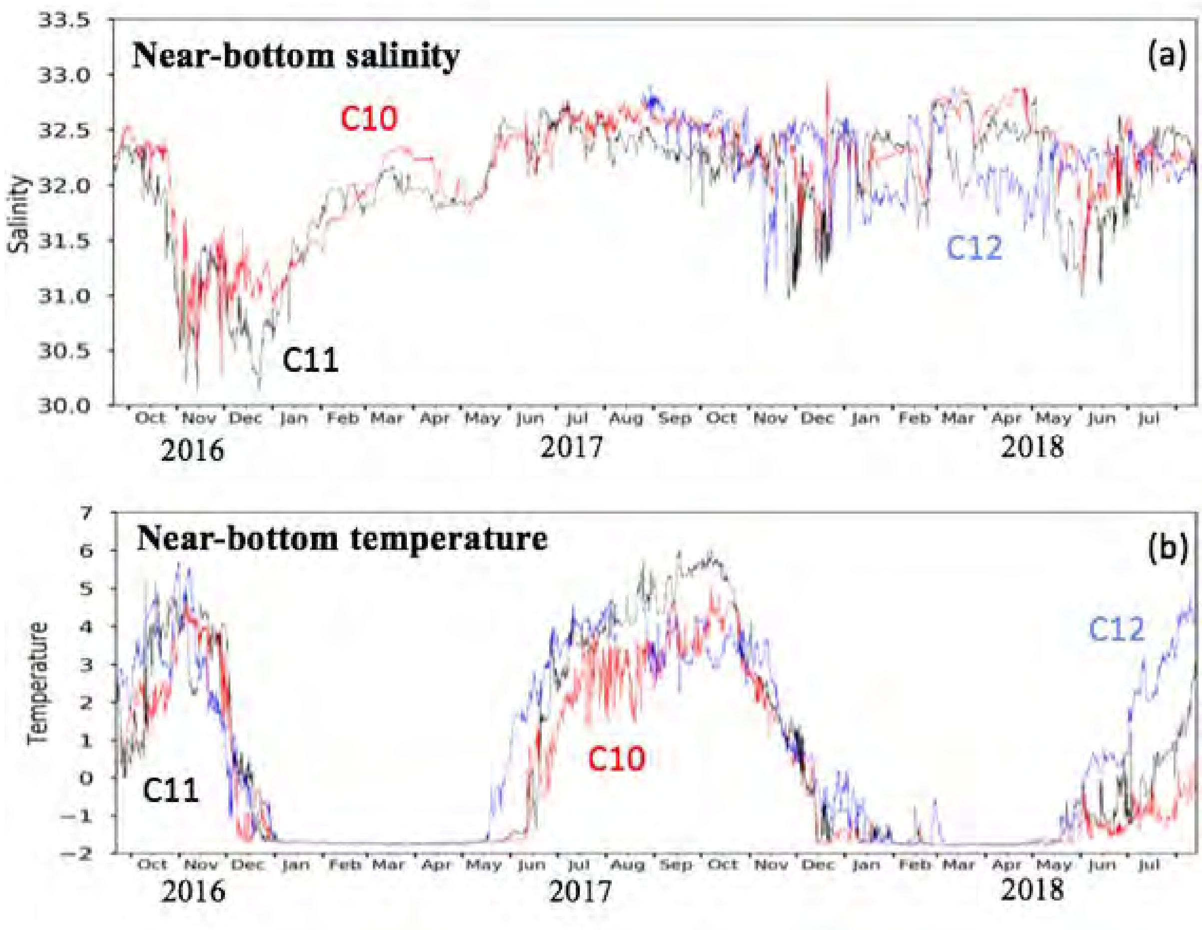

Figure 35. Time series of (a) salinity and (b) temperature collected at the three southern-most oceanographic moorings in the Chukchi Sea: C10 (red), C11 (black), and C12 (blue). These oceanographic moorings were first deployed in 2016. This is hourly data.

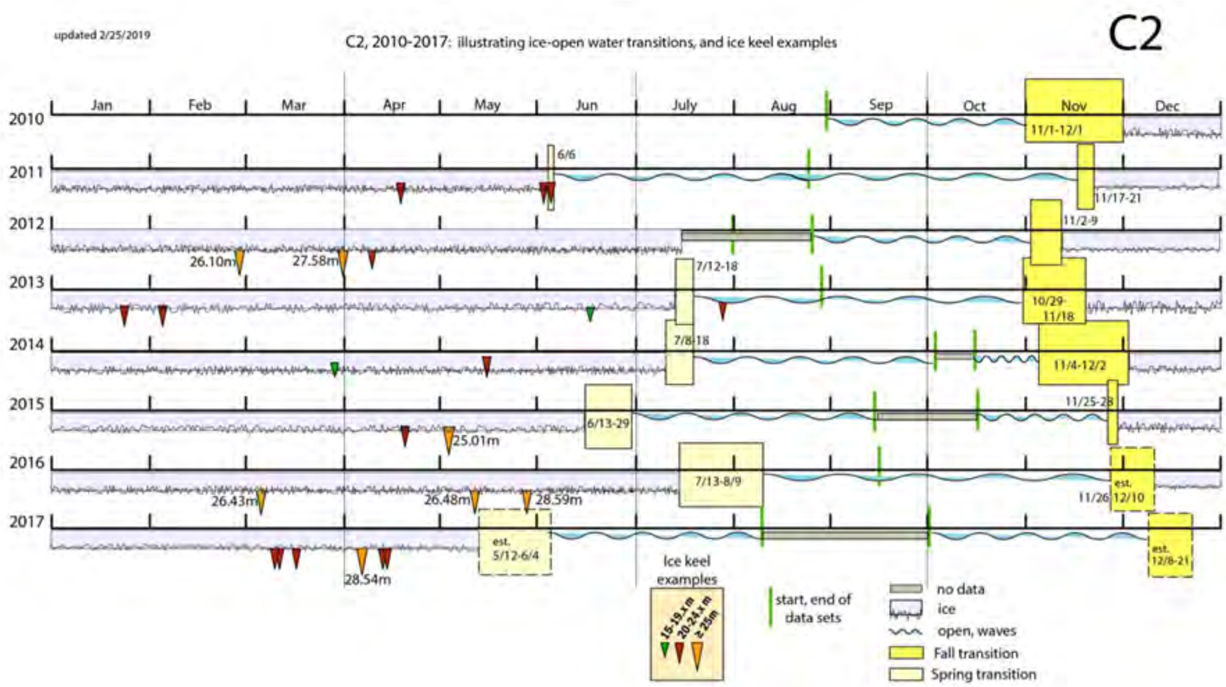

Figure 36. Ice keels at C2. Since 2010, there has been an ice profiler deployed at C2. Shown here is a schematic showing the timing of freeze-up (yellow), and melt-back (pale yellow). The timing of deep ice keels is also indicated. The data from 2017-2018 are still pending. From Sullivan et al., 2018 (poster, see Section VIII.B).

2. Shipboard

In 2017 and 2018, satellite-tracked drifters were deployed in Chukchi Sea. The general flow patterns are similar to what has been observed in previous years – a generally northward flow along the Alaskan coast which intensifies at Icy Cape. It is interesting that in 2017 none of the drifters traveled westward to exit into the Arctic Basin through Herald Canyon. Historically about half the water flowing through Bering Strait in the summer exits through Herald Canyon and the other half through Barrow Canyon. In 2018, the orange trajectory indicates that the drifter traveled westward and down Herald Canyon (the float failed to transmit for ~15 days, so the trajectory is broken).

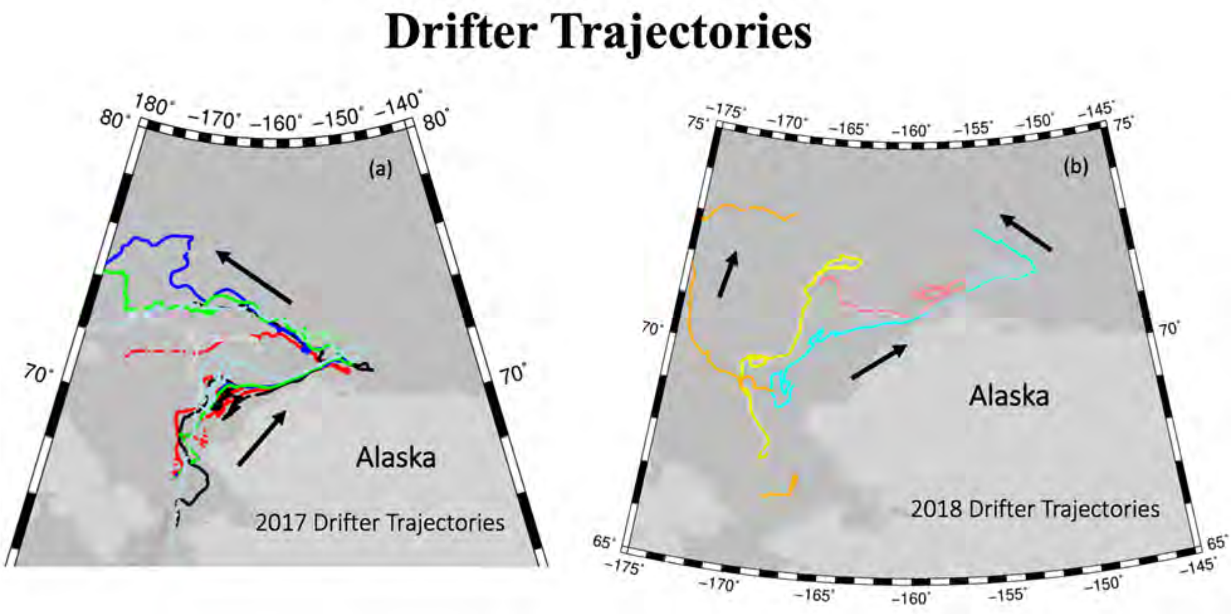

Figure 37. Trajectories of drifters deployed in (a) 2017 and (b) 2018. Each color represents a different drifter and the black arrows indicate the general direction of flow. The drogues on these drifters was centered at ~32 m.

C. Discussion

Annual transport down Barrow Canyon appears to be increasing; this is not surprising since transport through Bering Strait has also increased (Woodgate et al. 2012). Bottom temperatures vary greatly from year to year, but 2017 had the warmest bottom temperatures of the decade. While ocean temperature cannot totally prevent the advance sea ice, it can delay it, especially on such a shallow shelf.

There has been a marked increase in the period of open water in the Chukchi Sea, especially the southern part of the shelf. There is an indication that 2019 will continue this decrease in sea ice during the winter months. In the Bering Sea, there was a massive retreat of ice in February and early March caused by strong, warm winds out of the south. These winds also impacted the Chukchi Sea.

D. Conclusions and Recommendations

The Chukchi Sea is undergoing rapid changes. The late arrival and early retreat of sea ice is impacting the entire ecosystem. In order to understand and predict future changes, it is imperative that these data continue to be collected. The moorings deployed here are the longest continuous record of physics, chemistry, timing of chlorophyll fluorescence and ice-keel depths in the Alaskan Arctic. To quantify the changes that are occurring it is critical to maintain these time series.

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VIII. List of publications and presentations

A. Publications

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Sonobuoys

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Analysts/technicians

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Scientific advisors and colleagues

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X. Appendices

A. Yearly calling averages

1. Arctic species

Table 32. Yearly averages of calling activity for Arctic species: bowhead, beluga, and gray whales, bearded seals, and walrus, 2010-2018, for all mooring locations (see Table 2). Number of days with calling activity (#), number of days with recordings (Eff), percent of days with calling activity per month (%).

Species	Year	BF2			PB1			WT1			IC3			IC2			IC1			CC2			CL1			PH1			KZ1			NM1		
		#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
	2010	45	103	**44**	-	-	-	-	-	-	60	113	**53**	70	113	**62**	64	113	**57**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	158	363	**44**	-	-	-	-	-	-	40	284	**14**	75	297	**25**	120	298	**40**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2012	181	334	**54**	-	-	-	75	124	**60**	82	261	**31**	72	267	**27**	115	363	**32**	-	-	-	47	131	**36**	57	132	**43**	64	133	**48**	64	134	**48**
	2013	209	363	**58**	76	121	**63**	177	365	**48**	97	364	**27**	128	338	**38**	156	365	**43**	-	-	-	122	365	**33**	117	365	**32**	134	364	**37**	98	365	**27**
Bowhead	2014	156	364	**43**	147	364	**40**	133	365	**36**	84	365	**23**	100	365	**27**	131	365	**36**	-	-	-	113	364	**31**	116	364	**32**	157	365	**43**	131	365	**36**
	2015	159	364	**44**	153	365	**42**	150	365	**41**	101	365	**28**	71	365	**19**	118	365	**32**	-	-	-	134	365	**37**	140	365	**38**	168	365	**46**	166	345	**48**
	2016	181	365	**50**	137	365	**38**	153	366	**42**	142	365	**39**	61	279	**22**	170	365	**47**	44	103	**43**	74	366	**20**	65	142	**46**	72	265	**27**	135	366	**37**
	2017	119	226	**53**	136	364	**37**	139	364	**38**	100	364	**27**	-	-	-	67	254	**26**	103	364	**28**	61	217	**28**	125	348	**36**	-	-	-	92	217	**42**
	2018	-	-	-	106	228	**46**	96	175	**55**	15	224	**7**	-	-	-	-	-	-	115	223	**52**	-	-	-	126	222	**57**	-	-	-	-	-	-
	2010	35	103	**34**	-	-	-	-	-	-	8	113	**7**	23	113	**20**	26	113	**23**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	100	363	**28**	-	-	-	-	-	-	19	284	**7**	32	297	**11**	71	298	**24**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2012	166	334	**50**	-	-	-	27	124	**22**	30	261	**11**	36	267	**13**	71	363	**20**	-	-	-	20	131	**15**	48	132	**36**	25	133	**19**	-	-	-
	2013	174	363	**48**	32	121	**26**	74	365	**20**	57	364	**16**	67	338	**20**	86	365	**24**	-	-	-	42	365	**12**	135	365	**37**	63	364	**17**	10	132	**8**
Beluga	2014	163	364	**45**	93	364	**26**	100	364	**27**	92	365	**25**	68	365	**19**	100	365	**27**	-	-	-	51	364	**14**	118	364	**32**	85	365	**23**	68	365	**19**
	2015	161	364	**44**	55	257	**21**	79	359	**22**	21	260	**8**	30	256	**12**	91	365	**25**	-	-	-	37	365	**10**	53	263	**20**	62	365	**17**	64	345	**19**
	2016	118	252	**47**	-	-	-	49	291	**17**	-	-	-	-	-	-	66	284	**23**	9	103	**9**	64	366	**17**	-	-	-	37	265	**14**	33	366	**9**
	2017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65	364	**18**	49	217	**23**	-	-	-	-	-	-	25	217	**12**
	2018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	223	**22**	-	-	-	-	-	-	-	-	-	-	-	-
	2010	68	103	**66**	-	-	-	-	-	-	26	113	**23**	52	113	**46**	64	113	**57**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	225	363	**62**	-	-	-	-	-	-	224	284	**79**	252	297	**85**	258	298	**87**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2012	287	334	**86**	-	-	-	74	124	**60**	226	261	**87**	226	267	**85**	234	363	**64**	-	-	-	67	131	**51**	74	132	**56**	45	133	**34**	-	-	-
	2013	277	363	**76**	96	121	**79**	253	365	**69**	223	364	**61**	261	338	**77**	188	365	**52**	-	-	-	223	365	**61**	265	365	**73**	221	364	**61**	15	132	**11**
Bearded	2014	247	364	**68**	296	364	**81**	258	364	**71**	203	365	**56**	275	365	**75**	228	365	**62**	-	-	-	226	364	**62**	250	364	**69**	227	365	**62**	183	365	**50**
	2015	241	364	**66**	213	257	**83**	249	359	**69**	177	260	**68**	180	256	**70**	232	365	**64**	-	-	-	203	365	**56**	163	263	**62**	186	365	**51**	176	345	**51**
	2016	192	252	**76**	-	-	-	196	291	**67**	-	-	-	-	-	-	179	284	**63**	49	103	**48**	221	366	**60**	-	-	-	168	265	**63**	156	366	**43**
	2017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	181	364	**50**	172	217	**79**	-	-	-	-	-	-	136	217	**63**
	2018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	152	223	**68**	-	-	-	-	-	-	-	-	-	-	-	-
	2010	2	103	**2**	-	-	-	-	-	-	38	113	**34**	20	113	**18**	35	113	**31**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	0	363	**0**	-	-	-	-	-	-	106	284	**37**	76	297	**26**	110	298	**37**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2012	7	334	**2**	-	-	-	1	124	**1**	76	261	**29**	21	267	**8**	79	363	**22**	-	-	-	18	131	**14**	13	132	**10**	18	133	**14**	40	134	**30**
	2013	31	363	**9**	4	121	**3**	50	365	**14**	81	364	**22**	68	338	**20**	97	365	**27**	-	-	-	59	365	**16**	52	365	**14**	109	364	**30**	192	365	**53**
Walrus	2014	7	364	**2**	59	364	**16**	70	365	**19**	88	365	**24**	69	365	**19**	85	365	**23**	-	-	-	55	364	**15**	37	364	**10**	133	365	**36**	173	365	**47**
	2015	19	364	**5**	30	365	**8**	59	365	**16**	71	365	**19**	34	365	**9**	38	365	**10**	-	-	-	57	365	**16**	26	365	**7**	158	365	**43**	168	345	**49**
	2016	53	365	**15**	84	365	**23**	109	366	**30**	65	365	**18**	54	279	**19**	72	365	**20**	8	103	**8**	50	366	**14**	3	142	**2**	106	265	**40**	140	366	**38**
	2017	9	226	**4**	51	364	**14**	106	364	**29**	120	364	**33**	-	-	-	72	254	**28**	38	364	**10**	22	217	**10**	48	348	**14**	-	-	-	113	217	**52**
	2018	-	-	-	52	228	**23**	22	175	**13**	66	224	**29**	-	-	-	-	-	-	46	223	**21**	-	-	-	60	222	**27**	-	-	-	-	-	-
	2010	0	103	**0**	-	-	-	-	-	-	0	113	**0**	1	113	**1**	6	113	**5**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	0	363	**0**	-	-	-	-	-	-	0	284	**0**	0	297	**0**	5	298	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2012	0	334	**0**	-	-	-	0	124	**0**	0	261	**0**	0	267	**0**	13	363	**4**	-	-	-	5	131	**4**	56	132	**42**	2	133	**2**	30	134	**22**
	2013	0	363	**0**	2	121	**2**	0	365	**0**	0	364	**0**	0	338	**0**	1	365	**0**	-	-	-	1	365	**0**	127	365	**35**	17	364	**5**	129	365	**35**
Gray	2014	0	364	**0**	5	364	**1**	1	365	**0**	1	365	**0**	0	365	**0**	0	365	**0**	-	-	-	0	364	**0**	128	364	**35**	57	365	**16**	163	365	**45**
	2015	0	364	**0**	53	365	**15**	1	365	**0**	1	365	**0**	0	365	**0**	0	365	**0**	-	-	-	45	365	**12**	64	365	**18**	32	365	**9**	113	345	**33**
	2016	0	365	**0**	1	365	**0**	17	366	**5**	0	365	**0**	0	279	**0**	2	365	**1**	0	103	**0**	4	366	**1**	33	142	**23**	38	265	**14**	91	366	**25**
	2017	1	226	**0**	3	364	**1**	25	364	**7**	0	364	**0**	-	-	-	7	254	**3**	0	364	**0**	0	217	**0**	77	348	**22**	-	-	-	11	217	**5**
	2018	-	-	-	0	228	**0**	0	175	**0**	0	224	**0**	-	-	-	-	-	-	0	223	**0**	-	-	-	23	222	**10**	-	-	-	-	-	-

2. Subarctic species

Table 33. Yearly averages of calling activity for subarctic species: humpback and killer whales, minke whale boings, ribbon seals, and the double knock sound, 2010-2018, for all mooring locations (see Table 2). Number of days with calling activity (#), number of days with recordings (Eff), percent of days with calling activity per month (%).

Species	Year	BF2			PB1			WT1			IC3			IC2			IC1			CC2			CL1			PH1			KZ1			NM1		
		#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%	#	Eff	%
Humpback	2010	0	103	**0**	0	0	-	0	0	-	0	113	**0**	0	113	**0**	0	113	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2011	0	363	**0**	0	0	-	0	0	-	0	284	**0**	0	297	**0**	0	298	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2012	0	334	**0**	0	0	-	0	124	**0**	0	261	**0**	0	267	**0**	0	363	**0**	0	0	-	6	131	**5**	31	132	**23**	50	133	**38**	58	134	**43**
	2013	0	363	**0**	0	121	**0**	3	365	**1**	0	364	**0**	0	338	**0**	0	365	**0**	0	0	-	11	365	**3**	75	365	**21**	67	364	**18**	98	365	**27**
	2014	0	364	**0**	0	364	**0**	1	365	**0**	1	365	**0**	0	365	**0**	0	365	**0**	0	0	-	2	364	**1**	18	364	**5**	71	365	**19**	135	365	**37**
	2015	0	364	**0**	0	365	**0**	2	365	**1**	0	365	**0**	0	365	**0**	0	365	**0**	0	0	-	26	365	**7**	15	365	**4**	56	365	**15**	75	345	**22**
	2016	0	365	**0**	0	365	**0**	1	366	**0**	0	365	**0**	0	279	**0**	1	365	**0**	0	103	**0**	1	366	**0**	0	142	**0**	49	265	**18**	63	366	**17**
	2017	0	226	**0**	0	364	**0**	0	364	**0**	2	364	**1**	0	0	-	0	254	**0**	0	364	**0**	1	217	**0**	22	348	**6**	0	0	-	10	217	**5**
	2018	0	0	-	0	228	**0**	0	175	**0**	0	224	**0**	0	0	-	0	0	-	0	223	**0**	0	0	-	12	222	**5**	0	0	-	0	0	-
Killer	2010	0	103	**0**	0	0	-	0	0	-	0	113	**0**	0	113	**0**	0	113	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2011	0	363	**0**	0	0	-	0	0	-	0	284	**0**	0	297	**0**	4	298	**1**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2012	4	334	**1**	0	0	-	1	124	**1**	1	261	**0**	1	267	**0**	2	363	**1**	0	0	-	0	131	**0**	17	132	**13**	1	133	**1**	0	0	-
	2013	2	363	**1**	7	121	**6**	0	365	**0**	0	364	**0**	0	338	**0**	2	365	**1**	0	0	-	2	365	**1**	39	365	**11**	29	364	**8**	38	132	**29**
	2014	0	364	**0**	9	364	**2**	0	364	**0**	0	365	**0**	0	365	**0**	0	365	**0**	0	0	-	3	364	**1**	34	364	**9**	46	365	**13**	68	365	**19**
	2015	1	364	**0**	0	257	**0**	0	359	**0**	0	260	**0**	0	256	**0**	0	365	**0**	0	0	-	0	365	**0**	20	263	**8**	26	365	**7**	65	345	**19**
	2016	0	252	**0**	0	0	-	0	291	**0**	0	0	-	0	0	-	6	284	**2**	1	103	**1**	2	366	**1**	0	0	-	25	265	**9**	45	366	**12**
	2017	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	2	364	**1**	2	217	**1**	0	0	-	0	0	-	11	217	**5**
	2018	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	6	223	**3**	0	0	-	0	0	-	0	0	-	0	0	-
Boing	2010	0	103	**0**	0	0	-	0	0	-	0	113	**0**	0	113	**0**	0	113	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2011	0	363	**0**	0	0	-	0	0	-	0	284	**0**	0	297	**0**	2	298	**1**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2012	0	334	**0**	0	0	-	0	124	**0**	0	261	**0**	0	267	**0**	0	363	**0**	0	0	-	11	131	**8**	0	132	**0**	2	133	**2**	0	0	-
	2013	0	363	**0**	0	121	**0**	0	365	**0**	0	364	**0**	0	338	**0**	0	365	**0**	0	0	-	10	365	**3**	1	365	**0**	2	364	**1**	0	132	**0**
	2014	0	364	**0**	0	364	**0**	0	364	**0**	0	365	**0**	0	365	**0**	0	365	**0**	0	0	-	5	364	**1**	1	364	**0**	1	365	**0**	3	365	**1**
	2015	0	364	**0**	0	257	**0**	0	359	**0**	0	260	**0**	0	256	**0**	0	365	**0**	0	0	-	1	365	**0**	0	263	**0**	0	365	**0**	1	345	**0**
	2016	0	252	**0**	0	0	-	0	291	**0**	0	0	-	0	0	-	0	284	**0**	0	103	**0**	2	366	**1**	0	0	-	0	265	**0**	0	366	**0**
	2017	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	8	364	**2**	1	217	**0**	0	0	-	0	0	-	0	217	**0**
	2018	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	1	223	**0**	0	0	-	0	0	-	0	0	-	0	0	-
Ribbon	2010	10	103	**10**	0	0	-	0	0	-	0	113	**0**	0	113	**0**	0	113	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2011	25	363	**7**	0	0	-	0	0	-	0	284	**0**	0	297	**0**	1	298	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2012	22	334	**7**	0	0	-	3	124	**2**	4	261	**2**	3	267	**1**	1	363	**0**	0	0	-	20	131	**15**	29	132	**22**	3	133	**2**	0	0	-
	2013	48	363	**13**	1	121	**1**	3	365	**1**	2	364	**1**	8	338	**2**	4	365	**1**	0	0	-	15	365	**4**	10	365	**3**	0	364	**0**	0	132	**0**
	2014	13	364	**4**	0	364	**0**	1	364	**0**	4	365	**1**	3	365	**1**	5	365	**1**	0	0	-	1	364	**0**	0	364	**0**	0	365	**0**	0	365	**0**
	2015	19	364	**5**	1	257	**0**	6	359	**2**	0	260	**0**	0	256	**0**	7	365	**2**	0	0	-	4	365	**1**	2	263	**1**	14	365	**4**	17	345	**5**
	2016	4	252	**2**	0	0	-	4	291	**1**	0	0	-	0	0	-	0	284	**0**	2	103	**2**	1	366	**0**	0	0	-	0	265	**0**	0	366	**0**
	2017	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	8	364	**2**	11	217	**5**	0	0	-	0	0	-	8	217	**4**
	2018	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	15	223	**7**	0	0	-	0	0	-	0	0	-	0	0	-
dblKnck	2010	3	103	**3**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2011	1	363	**0**	0	0	-	0	0	-	0	125	**0**	0	125	**0**	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
	2012	3	211	**1**	0	0	-	0	0	-	0	261	**0**	0	140	**0**	2	129	**2**	0	0	-	12	131	**9**	0	132	**0**	0	0	-	0	134	**0**
	2013	0	0	-	0	121	**0**	0	125	**0**	0	364	**0**	0	0	-	61	365	**17**	0	0	-	79	365	**22**	0	365	**0**	0	0	-	0	365	**0**
	2014	0	0	-	46	364	**13**	0	365	**0**	0	365	**0**	0	0	-	125	365	**34**	0	0	-	106	364	**29**	0	364	**0**	0	0	-	0	264	**0**
	2015	1	107	**1**	41	365	**11**	14	365	**4**	33	365	**9**	19	109	**17**	71	365	**19**	0	0	-	113	365	**31**	13	365	**4**	16	101	**16**	1	113	**1**
	2016	36	365	**10**	85	365	**23**	58	366	**16**	108	365	**30**	93	279	**33**	115	365	**32**	1	103	**1**	142	366	**39**	35	142	**25**	120	265	**45**	26	366	**7**
	2017	35	226	**15**	72	364	**20**	104	364	**29**	131	364	**36**	0	0	-	102	254	**40**	113	364	**31**	105	217	**48**	106	348	**30**	0	0	-	61	217	**28**
	2018	0	0	-	41	228	**18**	0	175	**0**	72	224	**32**	0	0	-	0	0	-	84	223	**38**	0	0	-	49	222	**22**	0	0	-	0	0	-

B. Key timing events for marine mammals

Table 34. Key timing events for walrus calling activity (2010-2014). Underlined dates are recorder limited. Ice start and end dates were obtained from satellite-derived ice concentration data. *These dates were obtained by estimating the dates for the main pulses in Figure 11.

Year	Mooring	Calling		Peak Calling		Spring Pulse* Dates		Summer Pulse Dates*		Fall Pulse* Dates		Winter Pulse Dates*		Ice End Date	Ice Start Date
		Start	End	Start	End	Start	End	Start	End	Start	End	Start	End		
2010	BF2	20-Nov	20-Dec	-	-	-	-	-	-	-	-	-	-	26-Jul	18-Oct
	IC3	10-Sep	31-Dec	12-Dec	12-Dec	-	-	9-Sep	9-Oct	1-Dec	14-Dec	20-Dec	22-May	16-Jul	31-Oct
	IC2	10-Sep	12-Nov	10-Sep	9-Oct	-	-	10-Sep	10-Oct	-	-	17-Apr	18-Apr	4-Jun	31-Oct
	IC1	10-Sep	30-Dec	10-Sep	10-Sep	-	-	9-Sep	17-Oct	-	-	8-Nov	20-May	2-Jun	23-Oct
2011	IC3	1-Jan	23-Dec	28-Jan	29-Sep	6-Jun	6-Jun	28-Aug	28-Oct	25-Nov	9-Dec	9-Jan	20-May	5-Jul	22-Nov
	IC2	17-Apr	18-Dec	13-Jun	9-Oct	31-May	21-Jun	28-Aug	29-Oct	22-Nov	2-Dec	18-Dec	11-May	9-Jun	14-Nov
	IC1	15-Jan	4-Dec	30-May	22-Nov	28-May	27-Jun	2-Sep	3-Nov	22-Nov	3-Dec	17-Feb	11-Mar	4-Jun	12-Nov
2012	BF2	28-Jul	18-Dec	-	-	28-Jul	29-Jul	-	-	-	-	26-Nov	10-Jul	6-Aug	3-Nov
	WT1	13-Sep	13-Sep	-	-	-	-	12-Sep	12-Sep	-	-	13-Mar	31-Mar	9-Aug	1-Nov
	IC3	9-Jan	2-Oct	16-Feb	29-Sep	-	-	28-Aug	1-Oct	-	-			27-Jul	3-Nov
	IC2	4-Mar	2-Oct	-	-	-	-	19-Sep	2-Oct	-	-	-	-	24-Jul	1-Nov
	IC1	18-Feb	27-Dec	23-Jun	26-Sep	13-Jun	3-Aug	11-Aug	7-Oct	-	-	20-Nov	31-Mar	24-Jul	1-Nov
	CL1	22-Sep	24-Oct	-	-	-	-	22-Sep	24-Oct	-	-	9-Apr	9-Apr	27-Jun	14-Nov
	PH1	25-Aug	19-Dec	10-Oct	11-Oct	-	-	8-Sep	20-Oct	-	-	11-Mar	13-Mar	17-Jun	16-Nov
	KZ1	22-Nov	30-Dec	29-Nov	5-Dec	-	-	-	-	22-Nov	9-Dec	13-Dec	24-Apr	9-Jun	16-Nov
	NM1	20-Aug	31-Dec	25-Nov	28-Dec	-	-	20-Aug	5-Nov	21-Nov	4-Jan	10-Jan	18-Apr	25-May	21-Nov
2013	BF2	21-Jan	8-Dec	1-Aug	5-Aug	26-Jul	6-Aug	9-Aug	18-Aug	-	-	5-Dec	27-May	1-Aug	24-Oct
	PB1	26-Sep	13-Dec	-	-	-	-	26-Sep	26-Sep	-	-	22-Nov	12-Dec	1-Aug	31-Oct
	WT1	13-Mar	18-Dec	17-Jul	21-Aug	25-Jun	26-Jul	6-Aug	28-Sep	-	-	-	-	31-Jul	30-Oct
	IC3	9-Jan	16-Dec	8-Feb	11-Oct	26-Jun	20-Jul	25-Jul	15-Oct	29-Oct	20-Nov	24-Nov	20-Feb	21-Jul	26-Oct
	IC2	14-May	21-Nov	21-Jun	30-Sep	12-Jun	27-Jul	30-Aug	17-Oct	10-Nov	10-Nov	6-May	6-May	25-Jul	26-Oct
	IC1	8-Feb	26-Nov	12-Jun	10-Oct	10-Jun	31-Jul	10-Aug	17-Oct	-	-	-	-	27-Jul	30-Oct
	CL1	9-Apr	22-Oct	7-Jun	3-Oct	6-Jun	7-Jul	22-Sep	18-Oct	-	-	31-Jan	14-May	21-Jun	24-Nov
	PH1	6-Feb	2-Dec	26-May	1-Dec	10-May	29-Jun	6-Sep	25-Oct	27-Nov	2-Dec	1-Mar	6-Mar	11-Jun	25-Nov
	KZ1	30-Jan	31-Dec	14-Mar	25-Dec	5-May	25-Jun	-	-	29-Nov	1-Jan	2-Jan	30-Apr	8-Jun	26-Nov
	NM1	1-Jan	31-Dec	1-Jan	25-Dec	19-Apr	21-Jun	15-Sep	30-Nov	16-Dec	26-Dec	27-Dec	7-Apr	28-May	11-Dec
2014	BF2	29-Mar	6-Aug	26-Jul	26-Jul	23-Jul	6-Aug	-	-	-	-	23-Oct	24-Apr	30-Jul	20-Oct
	PB1	13-Jun	28-Nov	18-Jun	4-Aug	13-Jun	4-Aug	15-Aug	2-Oct	4-Nov	27-Nov	-	-	3-Aug	24-Oct
	WT1	7-Jun	16-Nov	13-Jun	7-Nov	7-Jun	3-Aug	10-Aug	7-Oct	7-Nov	7-Nov	-	-	24-Jul	31-Oct
	IC3	14-Jan	24-Dec	23-Jun	5-Aug	1-Jun	11-Aug	17-Aug	9-Oct	-	-	8-Dec	16-Mar	30-Jul	3-Nov
	IC2	7-May	20-Dec	21-Jun	29-Jul	10-Jun	3-Aug	23-Aug	9-Oct	7-Nov	2-Dec	-	-	17-Jul	2-Nov
	IC1	8-Jun	18-Dec	9-Jun	6-Sep	7-Jun	3-Aug	17-Aug	25-Sep	9-Nov	14-Nov	20-Mar	20-Mar	21-Jul	3-Nov
	CL1	1-Feb	9-Nov	4-Jun	17-Jun	15-May	30-Jun	4-Sep	8-Nov	-	-	6-Mar	9-Mar	7-Jun	29-Nov
	PH1	1-Mar	8-Dec	4-May	17-Jun	3-May	17-Jun	5-Sep	5-Sep	-	-	3-Mar	5-Mar	30-May	7-Dec
	KZ1	1-Jan	31-Dec	4-Jan	14-Dec	1-May	15-Jun	4-Aug	26-Nov	8-Dec	17-Dec	21-Dec	5-Apr	30-May	11-Dec
	NM1	1-Jan	31-Dec	5-Jan	27-Dec	7-Apr	31-May	14-Aug	1-Oct	7-Dec	28-Dec	31-Dec	13-Apr	24-May	7-Dec

Table 35. Key timing events for walrus calling activity (2015-2018). Underlined dates are recorder limited. Ice start and end dates were obtained from satellite-derived ice concentration data. *These dates were obtained by estimating the dates for the main pulses in Figure 11.

Year	Mooring	Calling		Peak Calling		Spring Pulse* Dates		Summer Pulse Dates*		Fall Pulse* Dates		Winter Pulse Dates*		Ice End Date	Ice Start Date
		Start	End	Start	End	Start	End	Start	End	Start	End	Start	End		
2015	BF2	3-Jul	31-Dec	4-Jul	5-Jul	3-Jul	21-Jul	-	-	-	-	23-Oct	10-Feb	5-Aug	11-Oct
	PB1	13-Jun	1-Sep	21-Jun	22-Jul	13-Jun	7-Jul	9-Jul	1-Sep	-	-	-	-	7-Jul	28-Oct
	WT1	11-Jun	10-Dec	13-Jun	22-Nov	11-Jun	6-Jul	16-Jul	25-Oct	13-Nov	22-Nov	11-Feb	12-Feb	30-Jun	9-Nov
	IC3	12-Mar	20-Dec	24-Jun	21-Nov	9-Jun	20-Jul	20-Aug	31-Oct	11-Nov	22-Nov	28-Nov	20-Dec	30-Jun	11-Nov
	IC2	26-Feb	17-Oct	17-Jun	7-Jul	6-Jun	7-Jul	18-Aug	15-Oct	-	-	25-Jan	25-Jan	15-Jun	21-Nov
	IC1	20-Mar	27-Oct	19-Jun	4-Jul	31-May	6-Jul	25-Jul	27-Oct	-	-	-	-	15-Jun	13-Nov
	CL1	6-Mar	16-Oct	7-Jun	22-Sep	23-May	2-Jul	10-Aug	16-Oct	-	-	31-Dec	1-Jan	13-Jun	20-Nov
	PH1	4-Mar	16-Dec	21-Aug	12-Nov	22-May	8-Jun	20-Aug	12-Nov	-	-	16-Dec	7-Jan	1-Jun	3-Dec
	KZ1	2-Jan	26-Dec	6-Jan	19-Dec	16-Apr	11-Jun	24-Aug	15-Nov	22-Nov	7-Dec	15-Dec	9-Apr	24-May	1-Dec
	NM1	2-Jan	31-Dec	5-Jan	13-Dec	14-Apr	23-May	25-Jul	1-Dec	5-Dec	17-Dec	25-Dec	17-Feb	21-May	9-Dec
2016	BF2	1-Jan	3-Dec	3-Jul	8-Aug	16-Jun	16-Aug	-	-	-	-	28-Nov	8-Mar	24-Jul	7-Nov
	PB1	6-Jun	6-Oct	11-Jun	12-Sep	6-Jun	12-Sep	27-Sep	6-Oct	-	-	-	-	11-Sep	7-Nov
	WT1	12-Feb	21-Dec	3-Jun	6-Oct	29-May	28-Jul	2-Aug	17-Oct	-	-	21-Dec	21-Dec	8-Sep	7-Nov
	IC3	11-Jun	30-Dec	24-Jun	19-Oct	14-Jun	30-Jul	3-Aug	5-Nov	2-Dec	30-Dec	11-Jan	25-Feb	11-Jul	26-Nov
	IC2	25-Jan	5-Oct	12-Jun	5-Oct	7-Jun	13-Jul	19-Jul	5-Oct	-	-	-	-	11-Jul	24-Nov
	IC1	25-May	28-Oct	3-Jun	20-Oct	24-May	12-Jul	27-Jul	28-Oct	-	-	-	-	11-Jul	24-Nov
	CC2	21-Sep	2-Nov	3-Oct	18-Oct	-	-	20-Sep	2-Nov	-	-	10-Jan	10-Jan	25-Jun	6-Dec
	CL1	1-Jan	8-Nov	2-Jun	18-Oct	31-May	29-Jun	2-Oct	7-Nov	-	-	10-Jan	14-Jan	20-Jun	25-Nov
	PH1	7-Jan	19-Oct	-	-	-	-	-	-	-	-	2-Jan	20-Jan	24-May	9-Dec
	KZ1	8-Jan	3-Jul	9-Jan	14-Jun	20-Apr	15-Jun	-	-	-	-	-	-	19-May	3-Dec
	NM1	2-Jan	31-Dec	15-Jan	28-Dec	18-Feb	4-Jun	-	-	24-Dec	12-Jan	16-Jan	6-Apr	23-May	13-Dec
2017	BF2	25-Feb	4-Aug	-	-	25-Jun	9-Jul	-	-	-	-	-	-	5-Jul	1-Dec
	PB1	31-May	25-Sep	1-Jun	19-Jul	31-May	1-Aug	5-Sep	25-Sep	-	-	-	-	29-Jun	1-Dec
	WT1	1-Jun	4-Dec	26-Jun	9-Oct	-	-	31-May	6-Nov	4-Dec	4-Dec	30-Jan	4-Mar	21-Jun	13-Oct
	IC3	12-Jan	31-Dec	12-Jan	31-Dec	30-May	4-Jul	8-Jul	5-Oct	-	-	30-Dec	22-Feb	12-Jun	9-Dec
	IC1	2-Jun	11-Sep	5-Jun	11-Sep	-	-	2-Jun	11-Sep	-	-	-	-	22-May	2-Dec
	CC2	11-Jan	8-Dec	30-May	24-Oct	-	-	27-May	29-Oct	7-Dec	7-Dec	15-Feb	11-Mar	13-May	6-Dec
	CL1	9-Jan	17-Jul	31-May	5-Jun	-	-	30-May	17-Jul	-	-	-	-	12-May	1-Dec
	PH1	3-Jan	31-Dec	3-Jan	19-Dec	24-May	14-Jun	11-Sep	23-Nov	14-Dec	7-Jan	10-Feb	20-Apr	20-May	10-Dec
	NM1	1-Jan	28-May	1-Jan	12-May	9-Apr	29-May	-	-	-	-	-	-	7-May	16-Dec
2018	PB1	1-Jun	11-Aug	3-Jun	8-Aug	1-Jun	11-Aug	-	-	-	-	-	-	20-Jul	NaN
	WT1	22-Jan	22-Jun	12-Jun	18-Jun	31-May	22-Jun	-	-	-	-	-	-	16-Jul	NaN
	IC3	1-Jan	9-Aug	22-Jan	23-Jul	23-May	14-Jul	21-Jul	9-Aug	-	-	-	-	30-Jun	NaN
	CC2	16-Feb	5-Jul	21-Feb	1-Jul	-	-	24-May	4-Jul	-	-	-	-	15-May	NaN
	PH1	1-Jan	9-Jun	5-Jan	4-Jun	30-Apr	8-Jun	-	-	-	-	-	-	20-May	NaN

Table 36. Key timing events for bearded seal calling activity (2010-2018). Underlined dates are recorder limited. Ice start and end dates were obtained from satellite-derived ice concentration data. Ramp up/end calling dates were obtained by estimating the dates for the main pulses in Figure 14.

Deployment year	Mooring	Ramp Up/End calling		Saturated Levels Dates		Ice Start Date	Ice End Date
		Start	End	Start	End		
2010-11	BF2	11/10/2010	7/5/2011	3/12/2011	7/6/2011	10/18/2010	7/14/2011
	IC3	12/22/2010	6/8/2011	4/7/2011	6/8/2011	10/31/2010	7/5/2011
	IC2	11/1/2010	6/21/2011	1/15/2011	6/21/2011	10/31/2010	6/9/2011
	IC1	9/20/2010	6/27/2011	2/27/2011	6/25/2011	10/23/2010	6/4/2011
2011-12	BF2	12/31/2011	7/6/2012	2/25/2012	6/26/2012	10/15/2011	8/6/2012
	IC3	11/21/2011	5/14/2012	2/22/2012	5/14/2012	11/22/2011	7/27/2012
	IC2	9/28/2011	5/19/2012	1/26/2012	5/19/2012	11/14/2011	7/24/2012
	IC1	9/28/2011	6/23/2012	4/2/2012	6/20/2012	11/12/2011	7/24/2012
2012-13	BF2	11/10/2012	7/12/2013	2/20/2013	7/1/2013	11/3/2012	8/1/2013
	WT1	11/15/2012	7/5/2013	2/11/2013	6/26/2013	11/1/2012	7/31/2013
	IC3	11/2/2012	7/2/2013	1/3/2013	6/27/2013	11/3/2012	7/21/2013
	IC2	10/30/2012	6/30/2013	3/10/2013	6/24/2013	11/1/2012	7/25/2013
	IC1	11/24/2012	6/25/2013	3/9/2013	6/17/2013	11/1/2012	7/27/2013
	CL1	1/6/2013	6/20/2013	3/20/2013	6/16/2013	11/14/2012	6/21/2013
	PH1	10/7/2012	6/18/2013	1/12/2013	6/16/2013	11/16/2012	6/11/2013
	KZ1	1/1/2013	6/19/2013	1/31/2013	6/16/2013	11/16/2012	6/8/2013
2013-14	BF2	11/25/2013	7/3/2014	2/8/2014	6/27/2014	10/24/2013	7/30/2014
	PB1	11/12/2013	7/7/2014	1/28/2014	6/28/2014	10/31/2013	8/3/2014
	WT1	11/26/2013	7/6/2014	1/28/2014	6/28/2014	10/30/2013	7/24/2014
	IC3	12/10/2013	7/1/2014	3/14/2014	6/26/2014	10/26/2013	7/30/2014
	IC2	10/29/2013	7/7/2014	3/9/2014	6/29/2014	10/26/2013	7/17/2014
	IC1	10/16/2013	6/26/2014	2/11/2014	6/20/2014	10/30/2013	7/21/2014
	CL1	12/25/2013	6/18/2014	2/8/2014	6/14/2014	11/24/2013	6/7/2014
	PH1	9/26/2013	6/15/2014	10/15/2013	6/13/2014	11/25/2013	5/30/2014
	KZ1	12/18/2013	6/13/2014	2/22/2014	6/11/2014	11/26/2013	5/30/2014
	NM1	12/22/2013	6/13/2014	1/11/2014	6/7/2014	12/11/2013	5/24/2014
2014-15	BF2	11/24/2014	7/15/2015	1/28/2015	6/26/2015	10/20/2014	8/5/2015
	PB1	10/26/2014	6/28/2015	1/3/2015	6/21/2015	10/24/2014	7/7/2015
	WT1	11/20/2014	7/1/2015	1/18/2015	6/27/2015	10/31/2014	6/30/2015
	IC3	12/13/2014	6/28/2015	3/11/2015	6/23/2015	11/3/2014	6/30/2015
	IC2	11/3/2014	6/30/2015	4/12/2015	6/13/2015	11/2/2014	6/15/2015
	IC1	11/3/2014	6/28/2015	4/1/2015	6/22/2015	11/3/2014	6/15/2015
	CL1	1/7/2015	6/14/2015	2/27/2015	6/12/2015	11/29/2014	6/13/2015
	PH1	10/4/2014	6/12/2015	10/25/2014	6/11/2015	12/7/2014	6/1/2015
	KZ1	10/14/2014	6/13/2015	1/20/2015	6/8/2015	12/11/2014	5/24/2015
	NM1	12/28/2014	6/12/2015	1/23/2015	5/31/2015	12/7/2014	5/21/2015
2015-16	BF2	12/24/2015	7/5/2016	3/27/2016	6/24/2016	10/11/2015	7/24/2016
	WT1	10/12/2015	6/27/2016	1/14/2016	6/19/2016	11/9/2015	9/8/2016
	IC1	10/11/2015	6/17/2016	2/15/2016	6/12/2016	11/13/2015	7/11/2016
	CL1	10/29/2015	6/13/2016	1/27/2016	6/8/2016	11/20/2015	6/20/2016
	KZ1	12/7/2015	6/14/2016	2/8/2016	6/6/2016	12/1/2015	5/19/2016
	NM1	12/19/2015	6/7/2016	1/30/2016	5/31/2016	12/9/2015	5/23/2016
2016-17	CC2	11/5/2016	6/23/2017	1/27/2017	6/15/2017	12/6/2016	5/13/2017
	CL1	10/17/2016	6/16/2017	3/18/2017	6/6/2017	11/25/2016	5/12/2017
	NM1	1/15/2017	6/2/2017	2/18/2017	5/28/2017	12/13/2016	5/7/2017
2017-18	CC2	1/20/2018	6/23/2018	3/4/2018	6/18/2018	12/6/2017	5/15/2018

Table 37. Key timing events for gray whale calling activity (2010-2018). Underlined dates are recorder limited. Open water season start and end dates were obtained from satellite-derived ice concentration data.

Year	Mooring	Calling Dates		Peak Calling		Open Water Season	
		Start	End	Start	End	Start	End
2010	IC2	8-Oct	8-Oct	-	-	4-Jun	31-Oct
	IC1	30-Sep	11-Oct	-	-	2-Jun	23-Oct
2011	IC1	19-Sep	5-Nov	-	-	4-Jun	12-Nov
2012	IC1	16-May	19-Oct	-	-	24-Jul	1-Nov
	CL1	29-Aug	18-Oct	-	-	27-Jun	14-Nov
	PH1	<u>22-Aug</u>	18-Nov	23-Aug	1-Oct	17-Jun	16-Nov
	KZ1	1-Nov	13-Nov	-	-	9-Jun	16-Nov
	NM1	26-Aug	23-Dec	7-Nov	7-Nov	25-May	21-Nov
2013	PB1	30-Sep	1-Oct	-	-	1-Aug	31-Oct
	IC1	8-Aug	9-Aug	-	-	27-Jul	30-Oct
	PH1	16-Jun	1-Nov	25-Jun	18-Oct	11-Jun	25-Nov
	KZ1	5-Jun	27-Nov	-	-	8-Jun	26-Nov
	NM1	23-Jan	29-Nov	15-Sep	25-Nov	28-May	11-Dec
2014	PB1	20-Jun	5-Oct	-	-	3-Aug	24-Oct
	WT1	10-Aug	10-Aug	-	-	24-Jul	31-Oct
	IC3	25-Aug	25-Aug	-	-	30-Jul	3-Nov
	PH1	17-Jun	30-Nov	18-Jun	9-Oct	30-May	7-Dec
	KZ1	19-Mar	24-Nov	24-Jun	24-Jun	30-May	11-Dec
	NM1	15-May	16-Dec	16-Jun	18-Nov	24-May	7-Dec
2015	PB1	7-Jul	8-Oct	12-Jul	20-Aug	7-Jul	28-Oct
	WT1	30-Jul	30-Jul	-	-	30-Jun	9-Nov
	IC3	16-Jul	16-Jul	-	-	30-Jun	11-Nov
	CL1	29-May	8-Sep	-	-	13-Jun	20-Nov
	PH1	11-Jun	10-Nov	10-Jul	27-Sep	1-Jun	3-Dec
	KZ1	1-Apr	23-Oct	-	-	24-May	1-Dec
	NM1	18-May	7-Dec	10-Jun	25-Oct	21-May	9-Dec
2016	PB1	22-Jun	22-Jun	-	-	11-Sep	7-Nov
	WT1	17-Jun	18-Oct	-	-	8-Sep	7-Nov
	IC1	9-Aug	12-Aug	-	-	11-Jul	24-Nov
	CL1	19-Jul	26-Nov	-	-	20-Jun	25-Nov
	PH1	22-Sep	8-Nov	22-Sep	19-Oct	24-May	9-Dec
	KZ1	8-Jun	1-Sep	-	-	19-May	3-Dec
	NM1	1-Jan	28-Nov	3-Jun	16-Jun	23-May	13-Dec
2017	BF2	14-Jul	14-Jul	-	-	5-Jul	1-Dec
	PB1	16-Jun	1-Oct	-	-	29-Jun	1-Dec
	WT1	22-Jun	24-Sep	-	-	21-Jun	13-Oct
	IC1	29-Jun	<u>11-Sep</u>	21-Aug	21-Aug	22-May	2-Dec
	PH1	5-Jun	5-Oct	19-Jun	5-Sep	20-May	10-Dec
	NM1	24-May	25-Jun	-	-	7-May	16-Dec
2018	PH1	7-Jun	<u>9-Aug</u>	21-Jun	8-Aug	20-May	-

Table 38. Key timing events for humpback whale calling activity (2012-2018). Underlined dates are recorder limited. Open water season start and end dates were obtained from satellite-derived ice concentration data.

Year	Mooring	Calling		Peak Calling		Open Water	
		Start	End	Start	End	Start	End
2012	CL1	13-Sep	25-Oct	-	-	27-Jun	14-Nov
	PH1	<u>22-Aug</u>	9-Oct	5-Sep	21-Sep	17-Jun	16-Nov
	KZ1	<u>21-Aug</u>	10-Nov	23-Aug	12-Oct	9-Jun	16-Nov
	NM1	<u>20-Aug</u>	13-Nov	27-Sep	9-Nov	25-May	21-Nov
2013	WT1	5-Oct	31-Oct	-	-	31-Jul	30-Oct
	CL1	11-Jul	23-Oct	-	-	21-Jun	24-Nov
	PH1	20-Jun	5-Oct	13-Jul	7-Sep	11-Jun	25-Nov
	KZ1	30-Jun	31-Oct	25-Jul	9-Sep	8-Jun	26-Nov
	NM1	9-Jun	15-Nov	14-Jun	3-Nov	28-May	11-Dec
2014	WT1	5-Jun	5-Jun	-	-	24-Jul	31-Oct
	IC3	18-Aug	18-Aug	-	-	30-Jul	3-Nov
	CL1	23-Jun	18-Aug	-	-	7-Jun	29-Nov
	PH1	15-Aug	30-Nov	-	-	30-May	7-Dec
	KZ1	16-Jun	2-Nov	5-Sep	31-Oct	30-May	11-Dec
	NM1	10-Jun	21-Nov	17-Jun	12-Nov	24-May	7-Dec
2015	WT1	19-Jul	22-Jul	-	-	30-Jun	9-Nov
	CL1	21-Jun	14-Oct	4-Jul	10-Aug	13-Jun	20-Nov
	PH1	19-Jun	24-Oct	14-Oct	16-Oct	1-Jun	3-Dec
	KZ1	22-Jun	5-Nov	12-Sep	5-Nov	24-May	1-Dec
	NM1	7-Jun	12-Nov	22-Sep	24-Oct	21-May	9-Dec
2016	WT1	4-Aug	4-Aug	-	-	8-Sep	7-Nov
	IC1	23-Aug	23-Aug	-	-	11-Jul	24-Nov
	CL1	30-Jun	30-Jun	-	-	20-Jun	25-Nov
	KZ1	16-Jun	<u>21-Sep</u>	17-Jul	30-Aug	19-May	3-Dec
	NM1	30-May	30-Nov	10-Jul	15-Nov	23-May	13-Dec
2017	IC3	1-Jul	3-Aug	-	-	12-Jun	9-Dec
	CL1	30-Jul	30-Jul	-	-	12-May	1-Dec
	PH1	15-Jun	6-Nov	22-Oct	5-Nov	20-May	10-Dec
	NM1	29-Jun	<u>5-Aug</u>	-	-	7-May	16-Dec
2018	PH1	12-Jul	<u>6-Aug</u>	25-Jul	26-Jul	20-May	-

Table 39. Key timing events for killer whale calling activity (2011-2018). Underlined dates are recorder limited. Open water season start and end dates were obtained from satellite-derived ice concentration data.

Year	Mooring	Calling		Peak Calling		Open Water Season	
		Start	End	Start	End	Start	End
2011	IC1	<u>3-Sep</u>	10-Oct	-	-	4-Jun	12-Nov
2012	BF2	28-Apr	22-Oct	-	-	6-Aug	3-Nov
	PH1	<u>27-Aug</u>	27-Oct	-	-	17-Jun	16-Nov
	WT1	15-Sep	15-Sep	-	-	9-Aug	1-Nov
	IC3	10-Sep	10-Sep	-	-	27-Jul	3-Nov
	IC2	20-Apr	<u>20-Apr</u>	-	-	24-Jul	1-Nov
	IC1	11-May	24-Jun	-	-	24-Jul	1-Nov
	KZ1	11-Oct	11-Oct	-	-	9-Jun	16-Nov
2013	BF2	28-Jun	2-Jul	-	-	1-Aug	24-Oct
	PB1	22-Oct	21-Nov	-	-	1-Aug	31-Oct
	IC1	1-Nov	12-Nov	-	-	27-Jul	30-Oct
	CL1	15-Sep	23-Sep	-	-	21-Jun	24-Nov
	PH1	14-Jun	30-Sep	4-Jul	12-Jul	11-Jun	25-Nov
	KZ1	27-Jun	15-Nov	8-Sep	8-Sep	8-Jun	26-Nov
	NM1	<u>22-Aug</u>	5-Dec	-	-	28-May	11-Dec
2014	PB1	1-May	5-Nov	-	-	3-Aug	24-Oct
	CL1	4-Mar	17-Aug	-	-	7-Jun	29-Nov
	PH1	12-Jun	24-Nov	7-Jul	14-Jul	30-May	7-Dec
	KZ1	11-Jun	26-Nov	11-Jun	11-Jun	30-May	11-Dec
	NM1	1-Jun	3-Dec	6-Aug	4-Sep	24-May	7-Dec
2015	BF2	28-Apr	28-Apr	-	-	5-Aug	11-Oct
	PH1	15-Jun	24-Aug	-	-	1-Jun	3-Dec
	KZ1	2-Jun	15-Oct	20-Jun	20-Jun	24-May	1-Dec
	NM1	1-May	9-Dec	8-Jun	8-Jun	21-May	9-Dec
2016	IC1	30-Apr	<u>4-Oct</u>	-	-	11-Jul	24-Nov
	CC2	<u>22-Sep</u>	22-Sep	-	-	25-Jun	6-Dec
	CL1	15-Jun	15-Sep	-	-	20-Jun	25-Nov
	KZ1	13-Jun	<u>10-Sep</u>	-	-	19-May	3-Dec
	NM1	28-May	29-Sep	-	-	23-May	13-Dec
2017	CC2	19-Jun	20-Jun	-	-	13-May	6-Dec
	CL1	6-Apr	19-Jun	-	-	12-May	1-Dec
	NM1	28-May	<u>25-Jul</u>	-	-	7-May	16-Dec
2018	CC2	23-Jul	<u>1-Aug</u>	24-Jul	24-Jul	15-May	-

Table 40. Key timing events for minke whale boing call activity (2011-2018). Underlined dates are recorder limited. Open water season start and end dates were obtained from satellite-derived ice concentration data.

Year	Mooring	Calling		Open Water Season	
		Start	End	Start	End
2011	IC1	18-Oct	19-Oct	4-Jun	12-Nov
2012	CL1	18-Oct	5-Nov	27-Jun	14-Nov
	KZ1	19-Oct	7-Nov	9-Jun	16-Nov
2013	CL1	30-Sep	6-Nov	21-Jun	24-Nov
	PH1	1-Nov	1-Nov	11-Jun	25-Nov
	KZ1	20-Mar	27-Oct	8-Jun	26-Nov
2014	CL1	5-Apr	13-Sep	7-Jun	29-Nov
	PH1	7-Oct	7-Oct	30-May	7-Dec
	KZ1	3-Nov	3-Nov	30-May	11-Dec
	NM1	23-Oct	28-Oct	24-May	7-Dec
2015	CL1	22-Sep	22-Sep	13-Jun	20-Nov
	NM1	8-Jul	8-Jul	21-May	9-Dec
2016	CL1	27-Jun	19-Jul	20-Jun	25-Nov
2017	CC2	19-Jul	11-Oct	13-May	6-Dec
	CL1	25-Jan	25-Jan	12-May	1-Dec
2018	CC2	1-Jul	1-Jul	15-May	-

Table 41. Key timing events for ribbon seal calling activity (2010-2018). Underlined dates are recorder limited. Open water season start and end dates were obtained from satellite-derived ice concentration data.

Year	Mooring	Calling		Peak Calling		Open Water Season	
		Start	End	Start	End	Start	End
2010	BF2	7-Oct	1-Nov	9-Oct	9-Oct	26-Jul	18-Oct
2011	BF2	9-Sep	15-Nov	-	-	14-Jul	15-Oct
	IC1	6-Apr	6-Apr	-	-	4-Jun	12-Nov
2012	BF2	22-Sep	22-Nov	11-Nov	20-Nov	6-Aug	3-Nov
	WT1	10-Nov	19-Nov	-	-	9-Aug	1-Nov
	IC3	3-Nov	6-Nov	-	-	27-Jul	3-Nov
	IC2	7-Nov	29-Dec	-	-	24-Jul	1-Nov
	IC1	12-Nov	12-Nov	-	-	24-Jul	1-Nov
	CL1	18-Oct	20-Nov	-	-	27-Jun	14-Nov
	PH1	26-Oct	26-Nov	1-Nov	24-Nov	17-Jun	16-Nov
	KZ1	27-Oct	17-Nov	-	-	9-Jun	16-Nov
2013	BF2	22-Sep	16-Nov	23-Sep	4-Nov	1-Aug	24-Oct
	WT1	4-Oct	4-Nov	-	-	31-Jul	30-Oct
	PB1	1-Nov	1-Nov	-	-	1-Aug	31-Oct
	IC3	8-Aug	23-Oct	-	-	21-Jul	26-Oct
	IC2	30-Oct	9-Nov	30-Oct	4-Nov	25-Jul	26-Oct
	IC1	14-Apr	21-Nov	-	-	27-Jul	30-Oct
	CL1	18-Oct	17-Dec	25-Nov	25-Nov	21-Jun	24-Nov
	PH1	31-Oct	23-Dec	-	-	11-Jun	25-Nov
2014	BF2	11-Aug	4-Nov	-	-	30-Jul	20-Oct
	WT1	8-Oct	8-Oct	-	-	24-Jul	31-Oct
	IC3	7-Oct	25-Nov	-	-	30-Jul	3-Nov
	IC2	31-Oct	7-Nov	-	-	17-Jul	2-Nov
	IC1	7-Nov	16-Nov	-	-	21-Jul	3-Nov
	CL1	16-Nov	16-Nov	-	-	7-Jun	29-Nov
2015	BF2	17-Sep	1-Nov	15-Oct	30-Oct	5-Aug	11-Oct
	WT1	30-Oct	18-Nov	-	-	30-Jun	9-Nov
	PB1	20-Apr	20-Apr	-	-	7-Jul	28-Oct
	IC1	25-Oct	28-Nov	-	-	15-Jun	13-Nov
	CL1	25-Nov	5-Dec	-	-	13-Jun	20-Nov
	PH1	11-May	12-May	11-May	11-May	1-Jun	3-Dec
	KZ1	6-May	29-Dec	7-May	7-May	24-May	1-Dec
	NM1	13-Feb	21-May	2-May	13-May	21-May	9-Dec
2016	BF2	2-Sep	<u>8-Sep</u>	8-Sep	<u>8-Sep</u>	24-Jul	7-Nov
	WT1	15-May	<u>20-Oct</u>	-	-	8-Sep	7-Nov
	CC2	19-Oct	20-Dec	-	-	25-Jun	6-Dec
	CL1	19-Nov	19-Nov	-	-	20-Jun	25-Nov
2017	CC2	9-May	19-May	10-May	16-May	13-May	6-Dec
	CL1	2-May	20-May	6-May	9-May	12-May	1-Dec
	NM1	26-Apr	7-May	-	-	7-May	16-Dec
2018	CC2	24-Apr	15-May	25-Apr	14-May	15-May	-

C. Maps of monthly calling distribution

All figures in this Appendix show the monthly distribution of calling per month. This is calculated as the number of days per month with calling (or sounds) present divided by the number of days per month with recording effort. The graduated scale in the upper left panel of each figure indicates the percentage of days with calling for that month (in that year). Red and yellow outlines show the study areas from the CHAOZ-X and ARCWEST projects, for reference. Any moorings that had less than half a month of effort are indicated with an asterisk. All years from 2010 through 2018 are included for completeness here. For the high frequency species and sound sources (i.e., beluga and killer whale, minke boing, bearded and ribbon seal, and ice), many of the 2017-18 moorings have not yet been analyzed, so the plots only go up to 2016. Updated sets of plot can be provided on request.

1. Arctic species

Bowhead whale

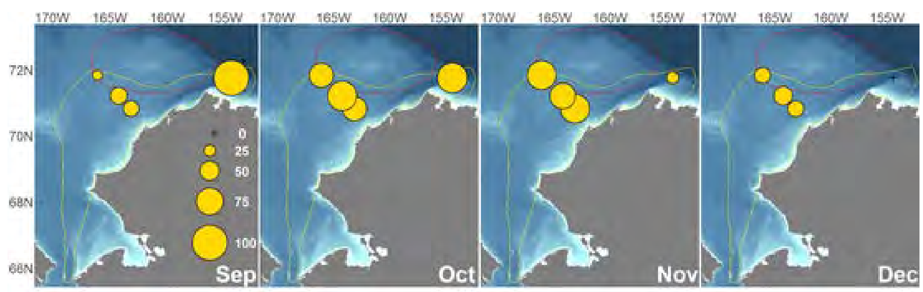

Figure B2. Monthly bowhead whale calling distribution, 2010.

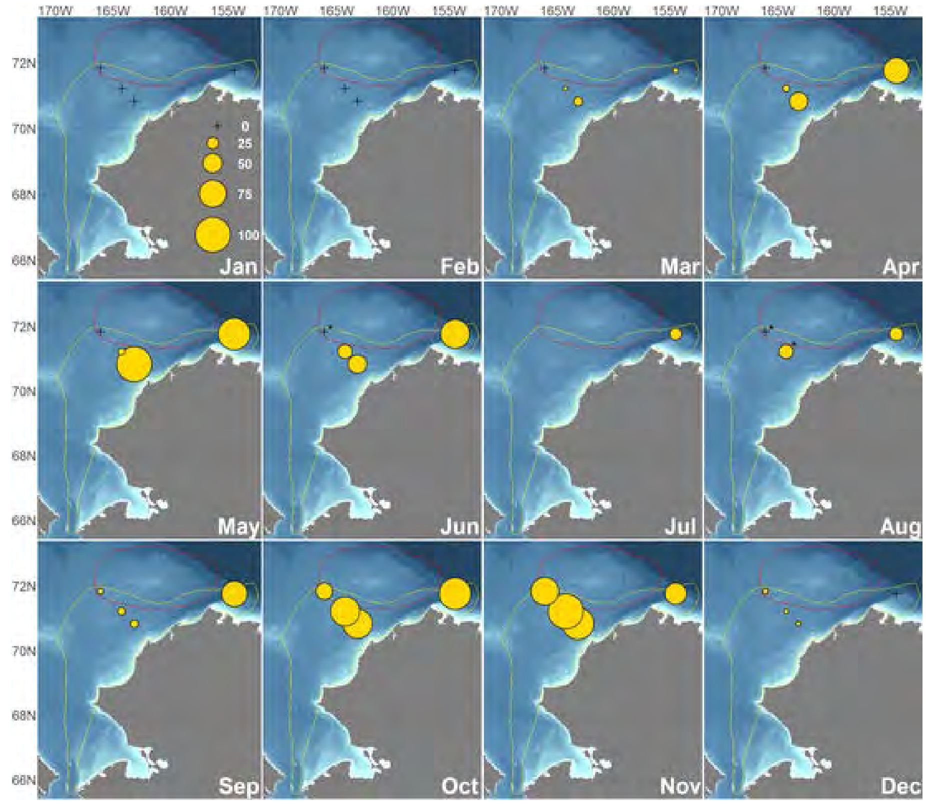

Figure 38. Monthly bowhead whale calling distribution, 2011.

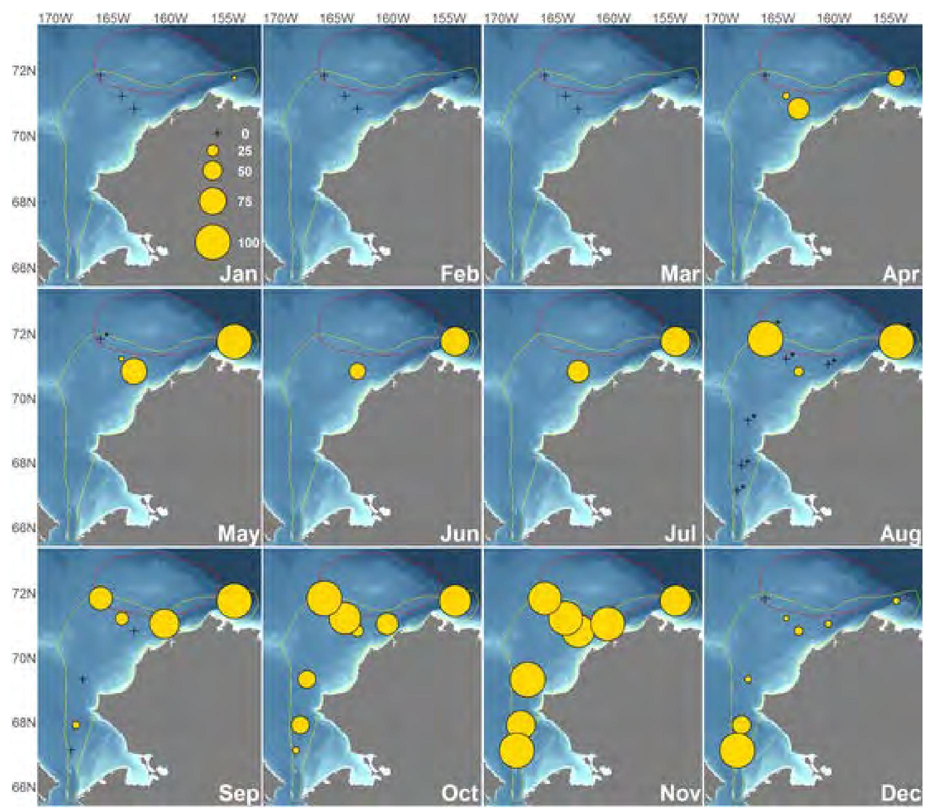

Figure 39. Monthly bowhead whale calling distribution, 2012.

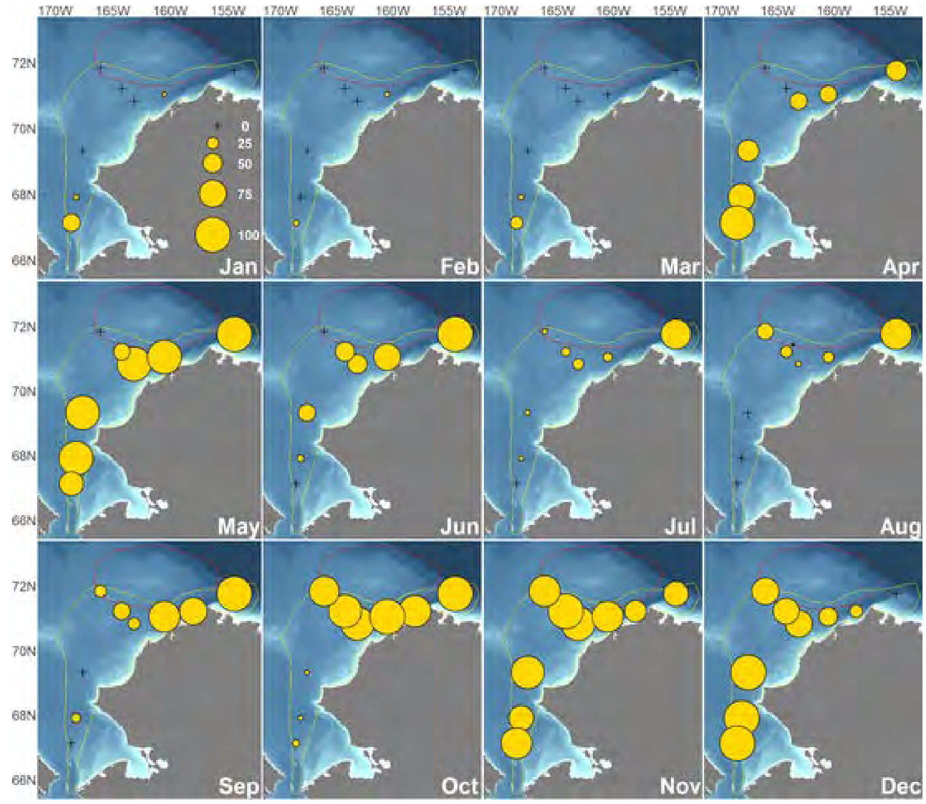

Figure 40. Monthly bowhead whale calling distribution, 2013.

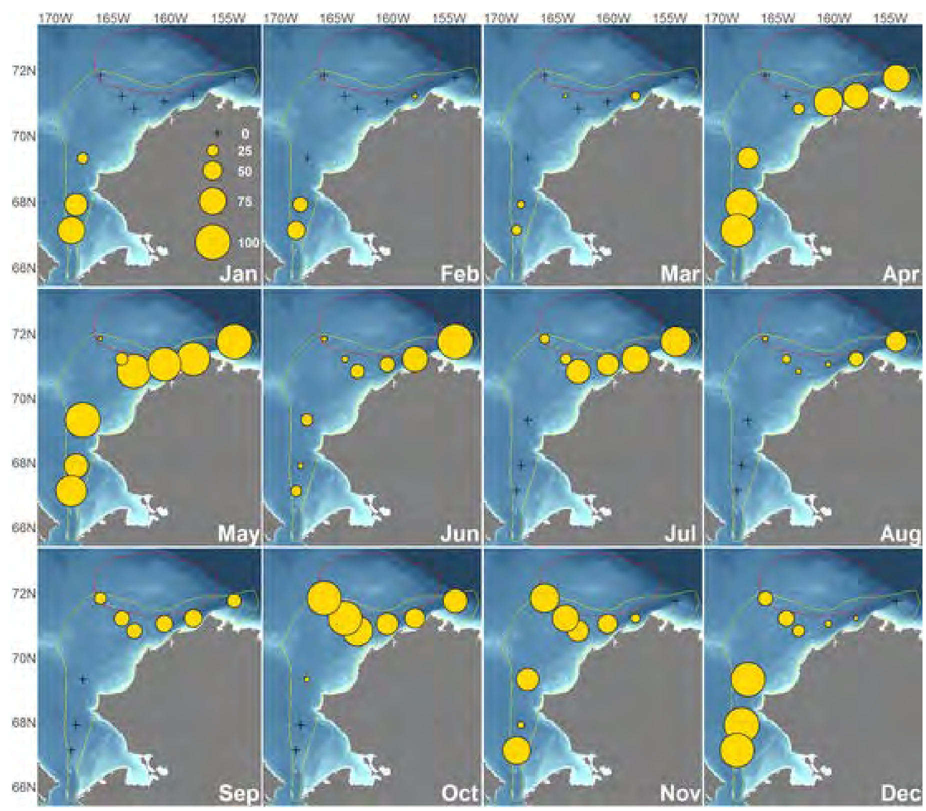

Figure 41. Monthly bowhead whale calling distribution, 2014.

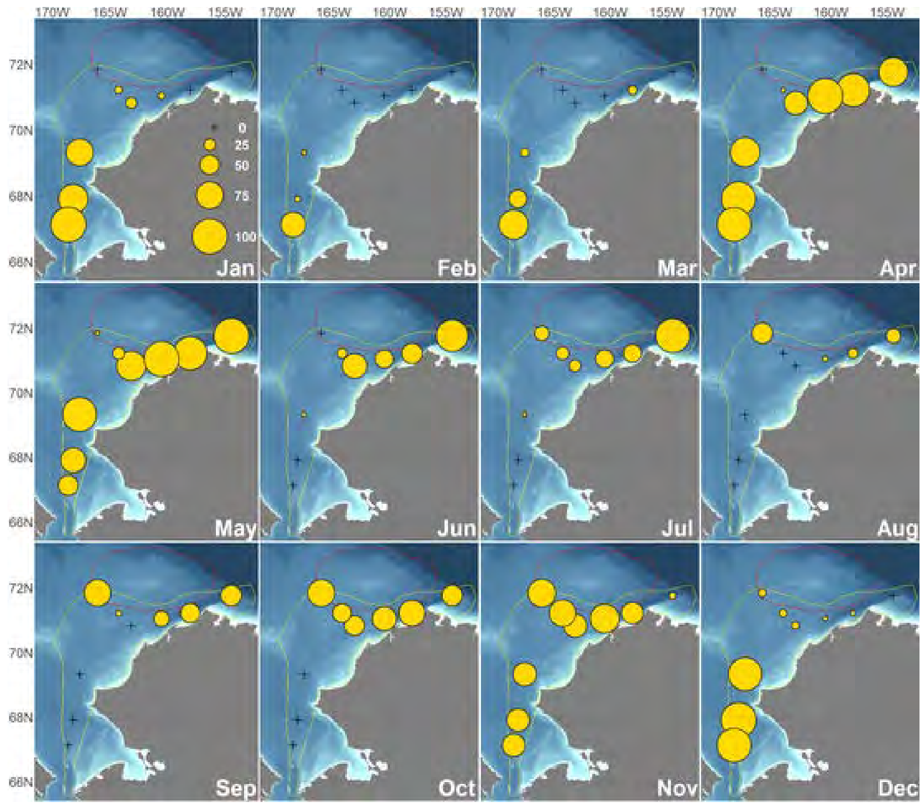

Figure 42. Monthly bowhead whale calling distribution, 2015.

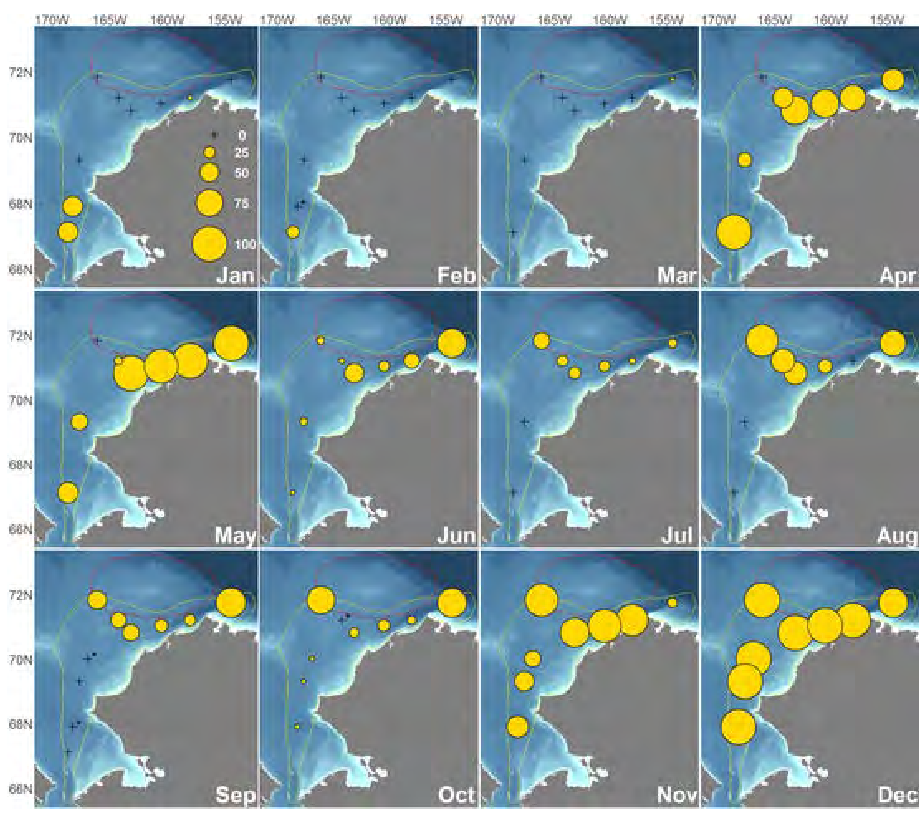

Figure 43. Monthly bowhead whale calling distribution, 2016.

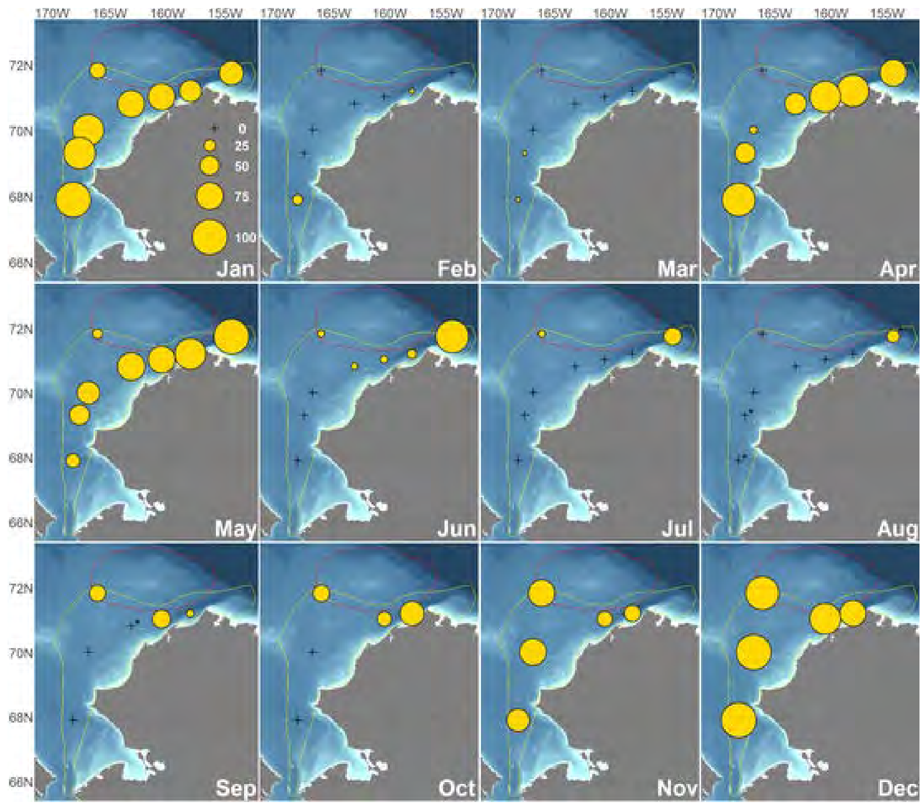

Figure 44.Monthly bowhead whale calling distribution, 2017.

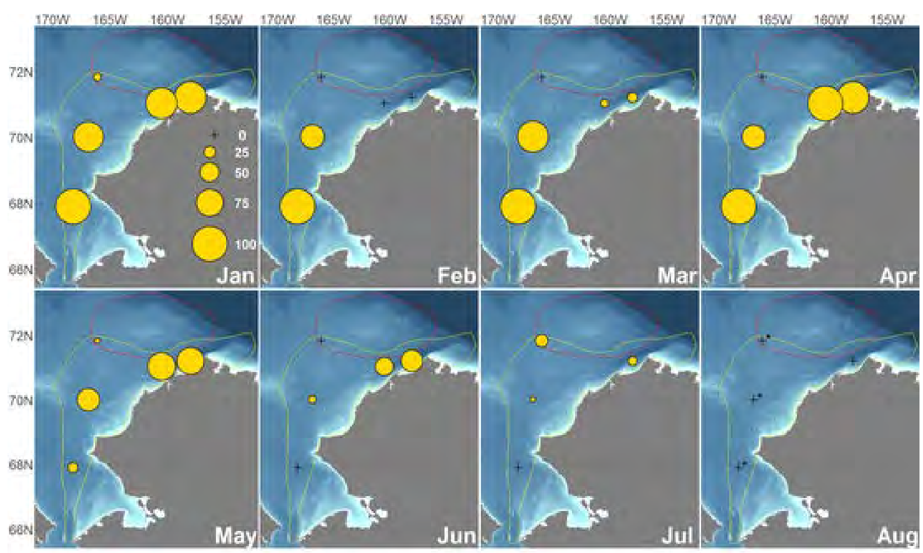

Figure 45. Monthly bowhead whale calling distribution, 2018.

Beluga whale

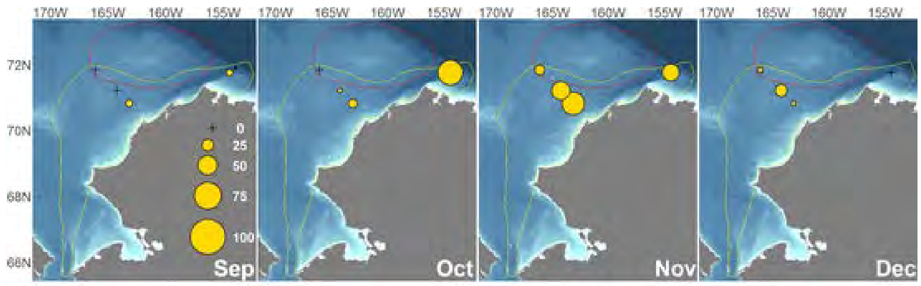

Figure 46. Monthly beluga whale calling distribution, 2010.

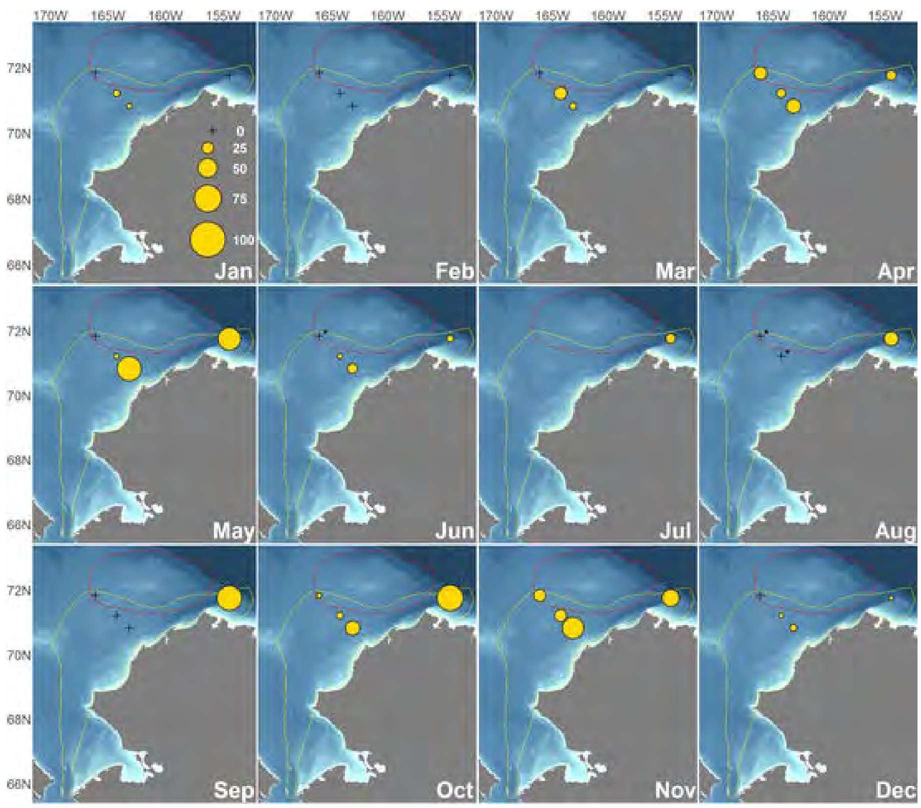

Figure 47. Monthly beluga whale calling distribution, 2011.

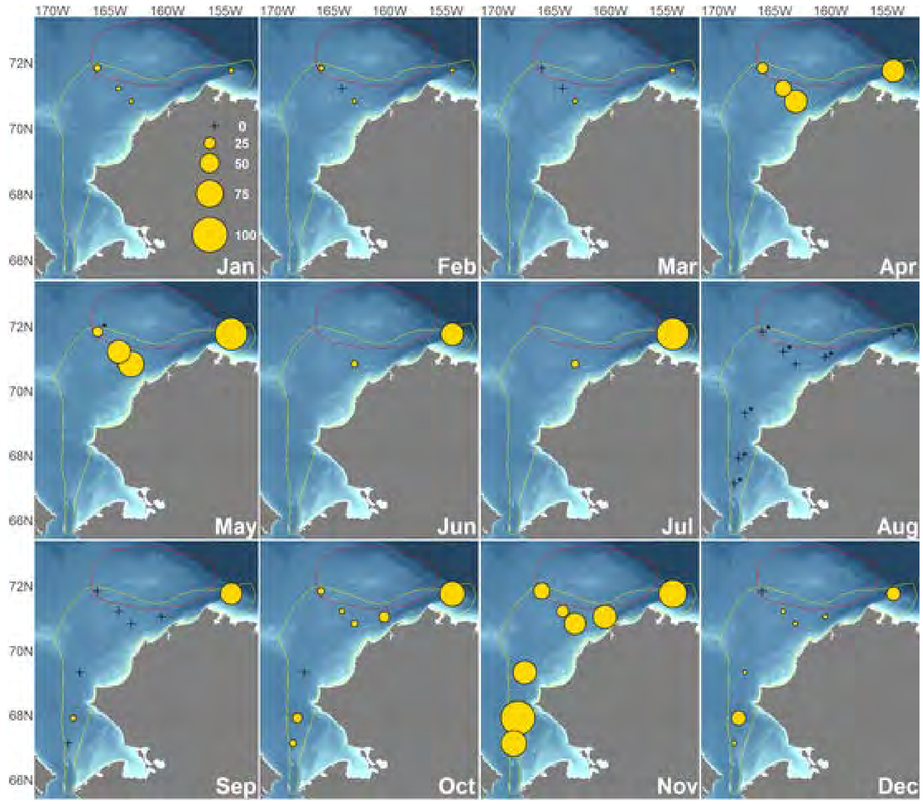

Figure 48. Monthly beluga whale calling distribution, 2012.

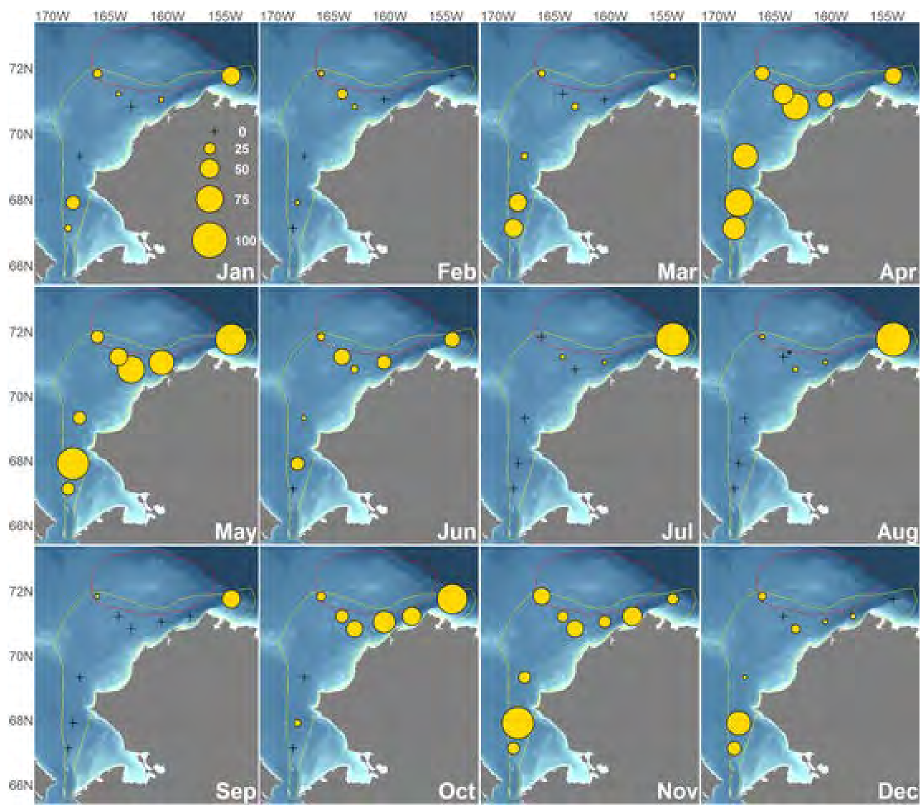

Figure 49. Monthly beluga whale calling distribution, 2013.

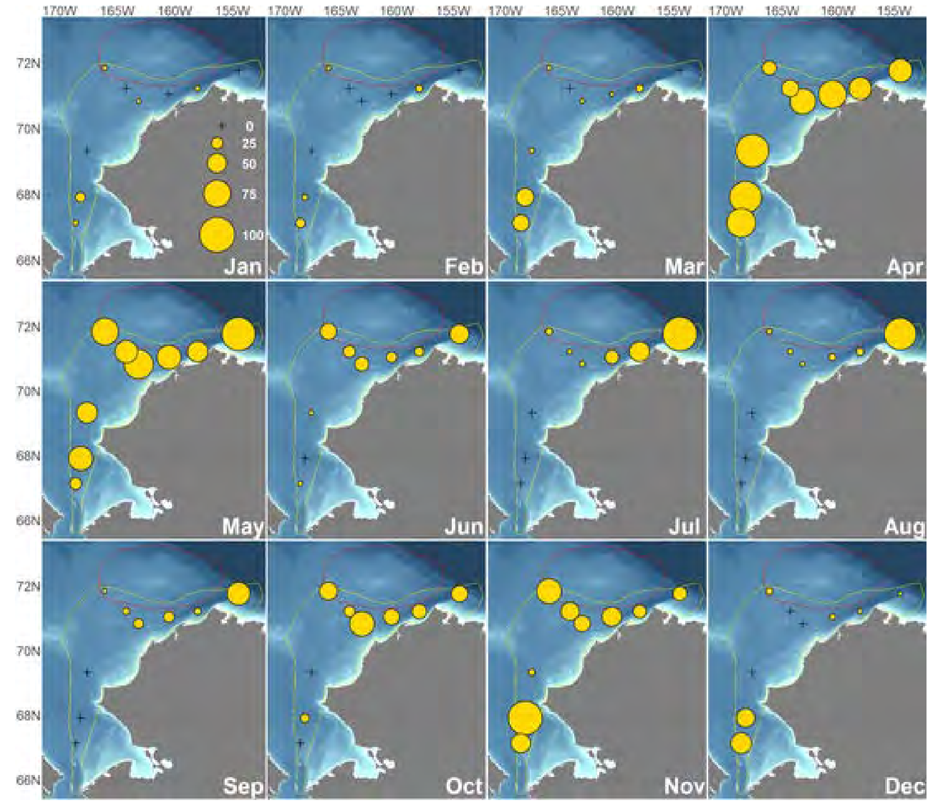

Figure 50. Monthly beluga whale calling distribution, 2014.

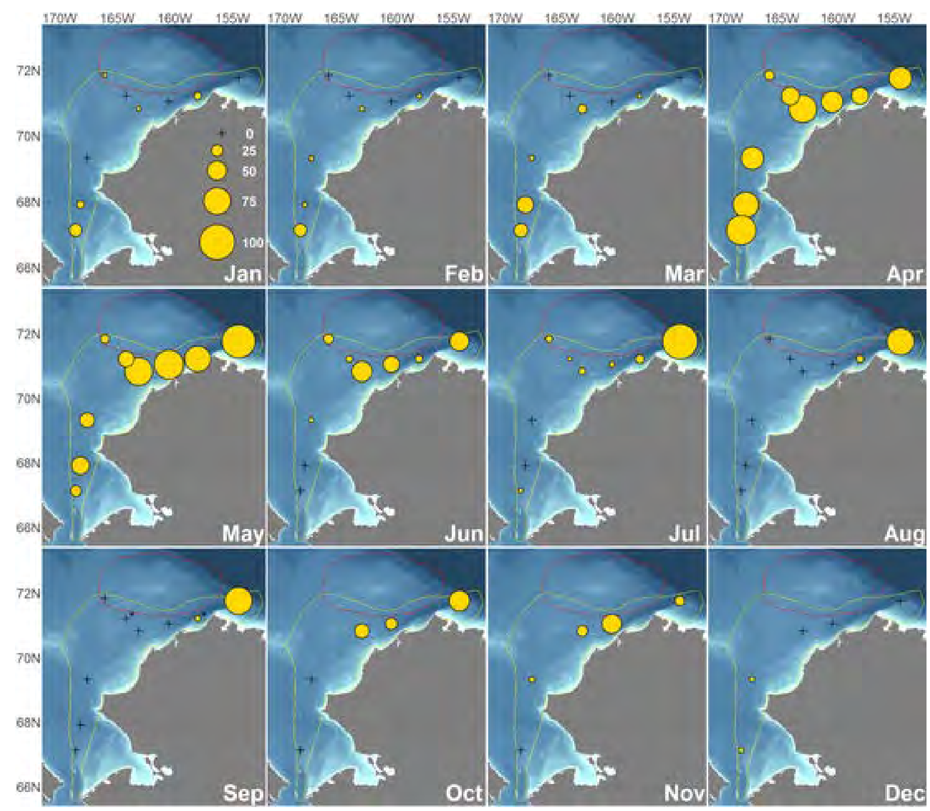

Figure 51. Monthly beluga whale calling distribution, 2015.

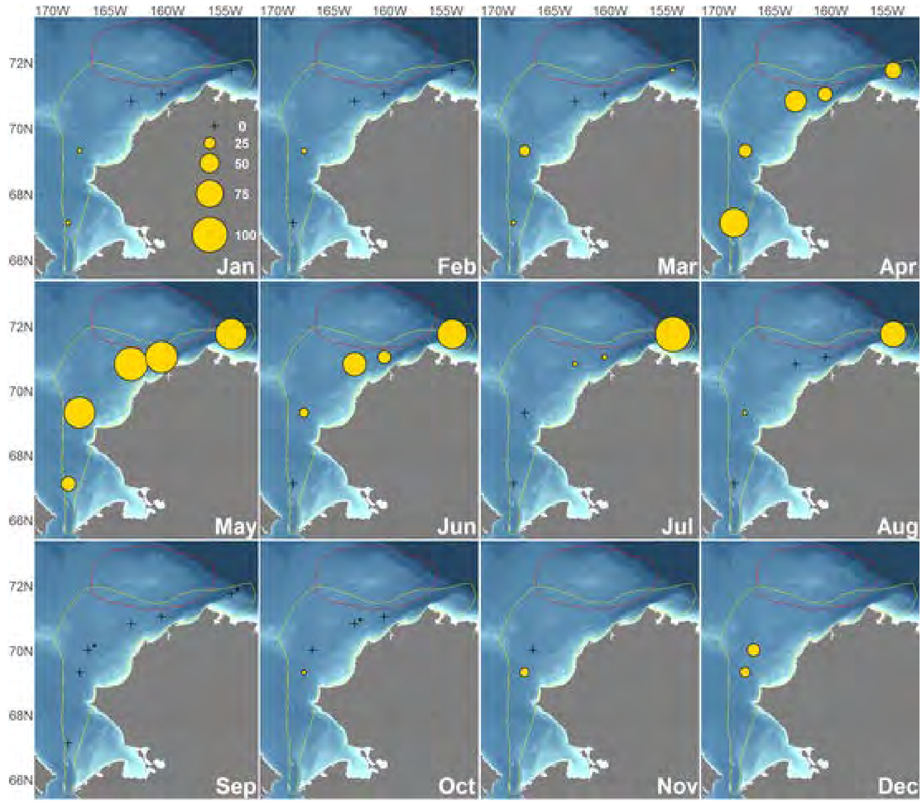

Figure 52. Monthly beluga whale calling distribution, 2016.

Walrus

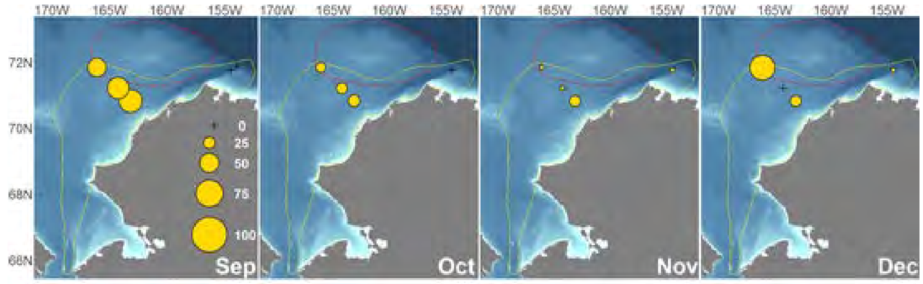

Figure 53. Monthly walrus calling distribution, 2010.

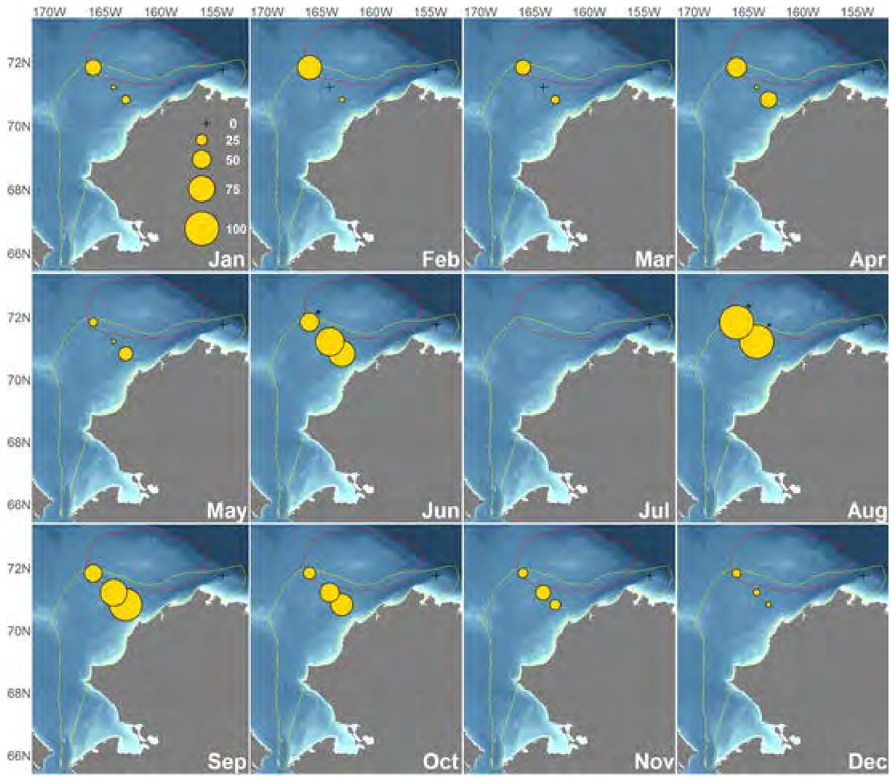

Figure 54. Monthly walrus calling distribution, 2011.

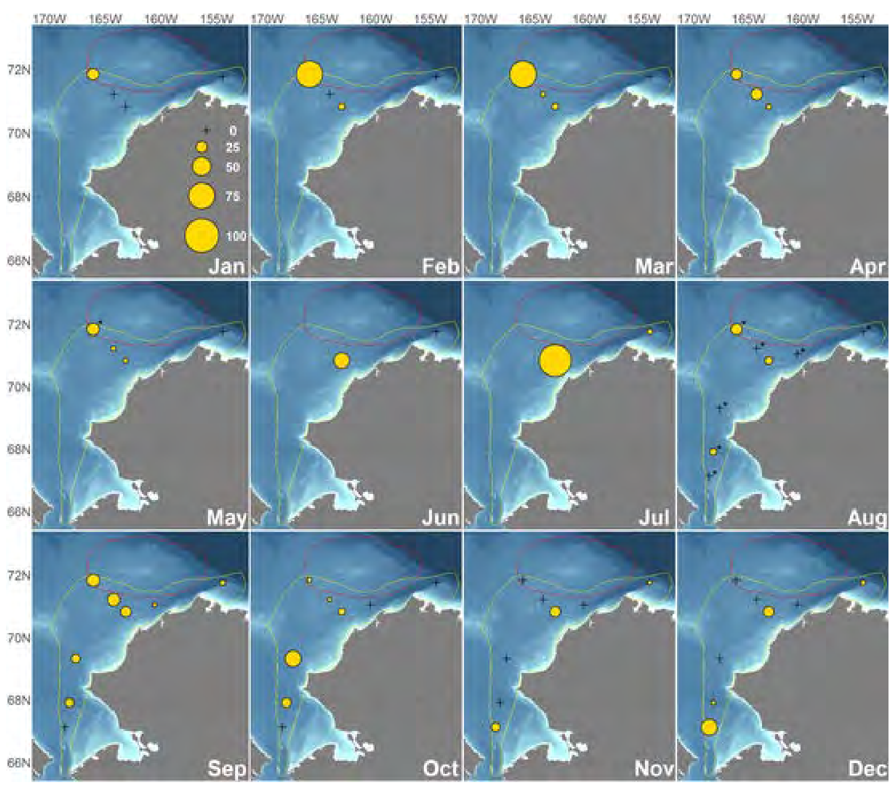

Figure 55. Monthly walrus calling distribution, 2012.

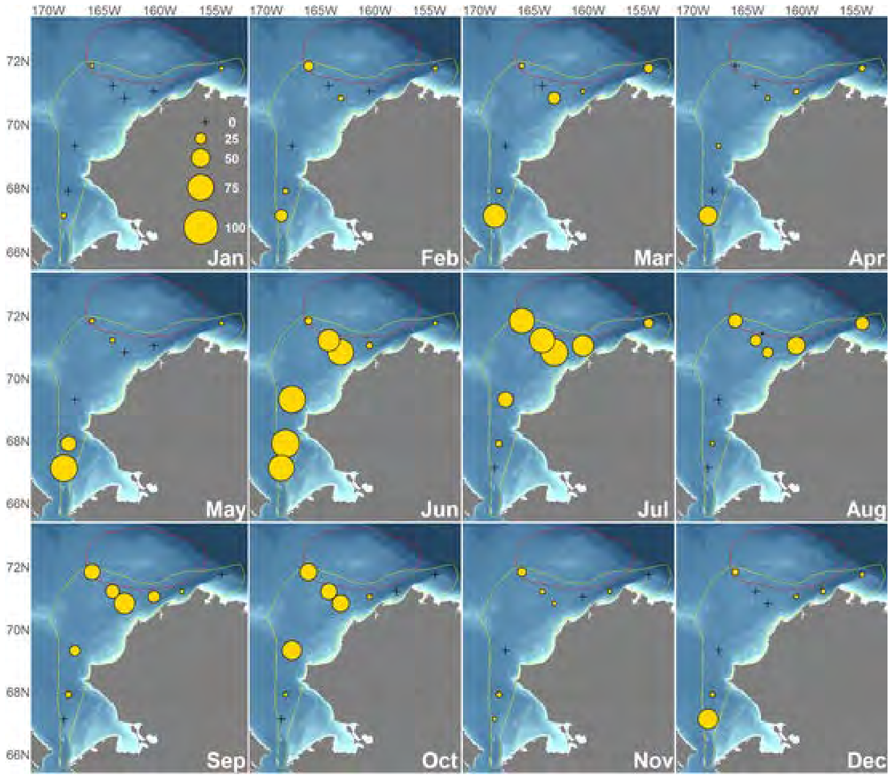

Figure 56. Monthly walrus calling distribution, 2013.

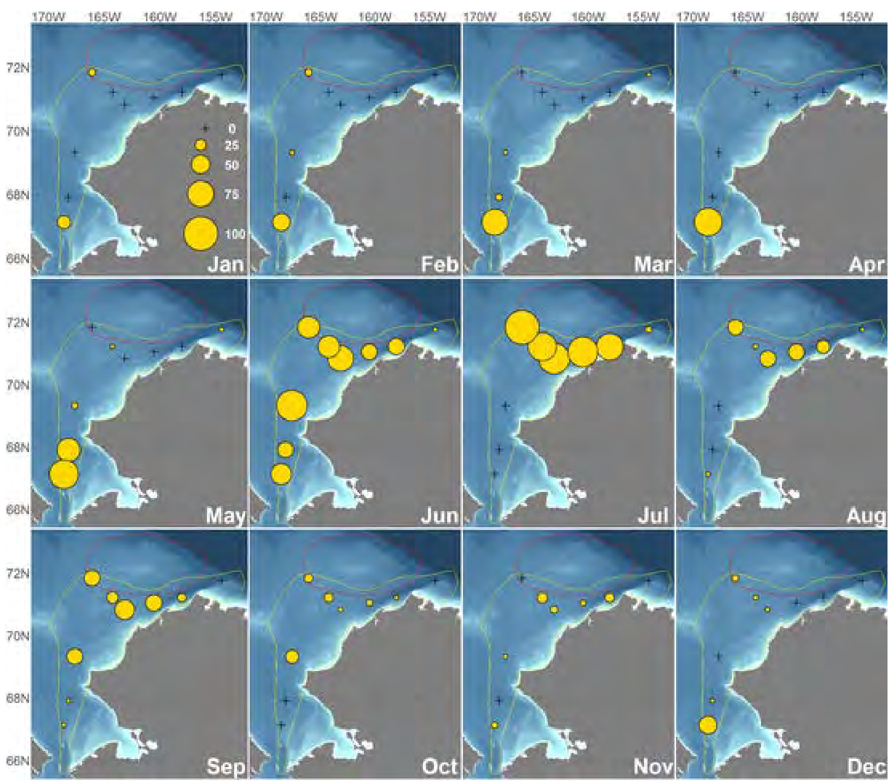

Figure 57.Monthly walrus calling distribution, 2014.

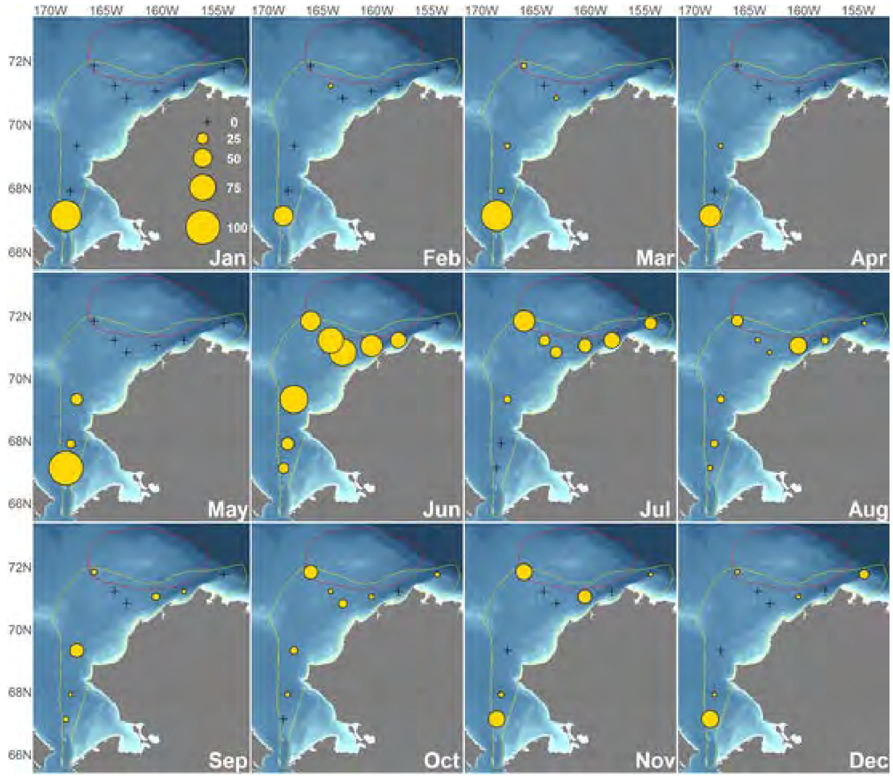

Figure 58. Monthly walrus calling distribution, 2015.

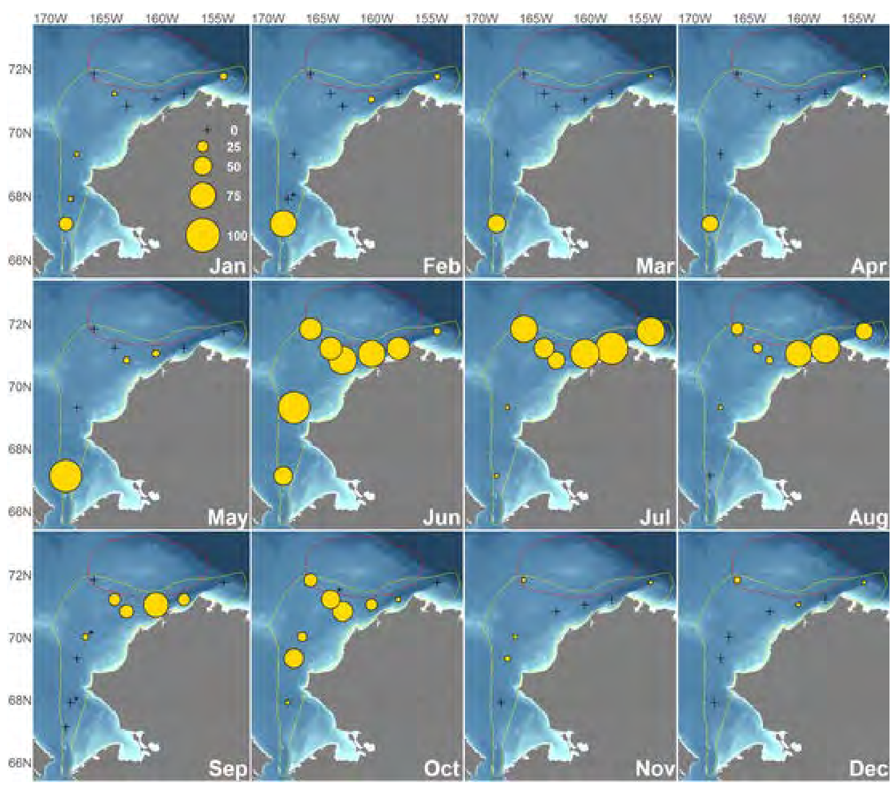

Figure 59. Monthly walrus calling distribution, 2016.

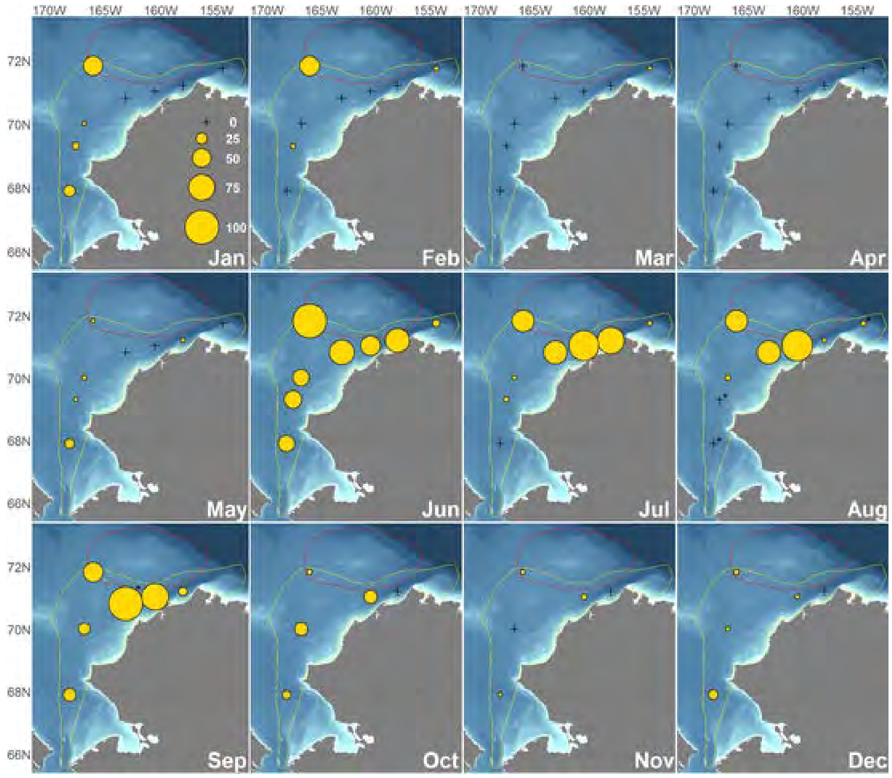

Figure 60. Monthly walrus calling distribution, 2017.

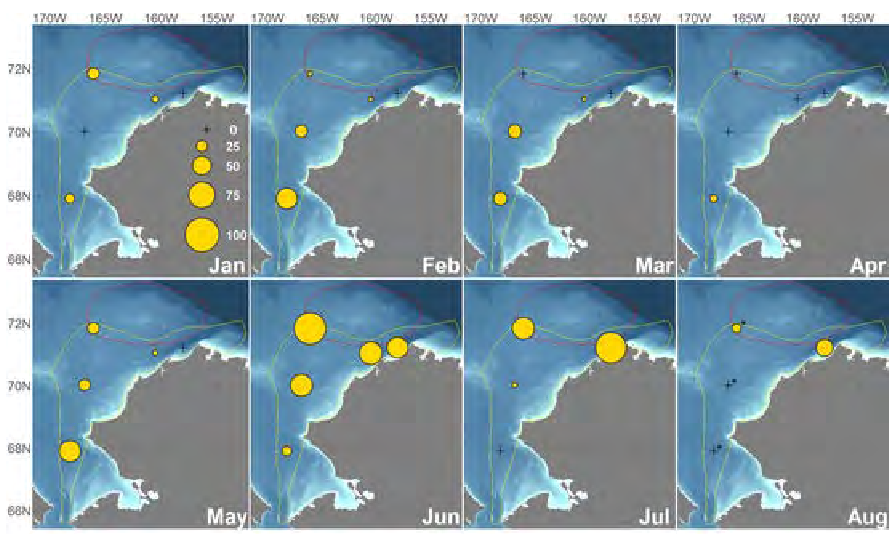

Figure 61. Monthly walrus calling distribution, 2018.

Bearded seal

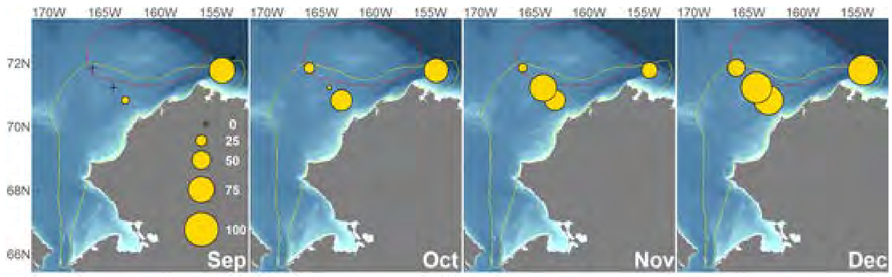

Figure 62. Monthly bearded seal calling distribution, 2010.

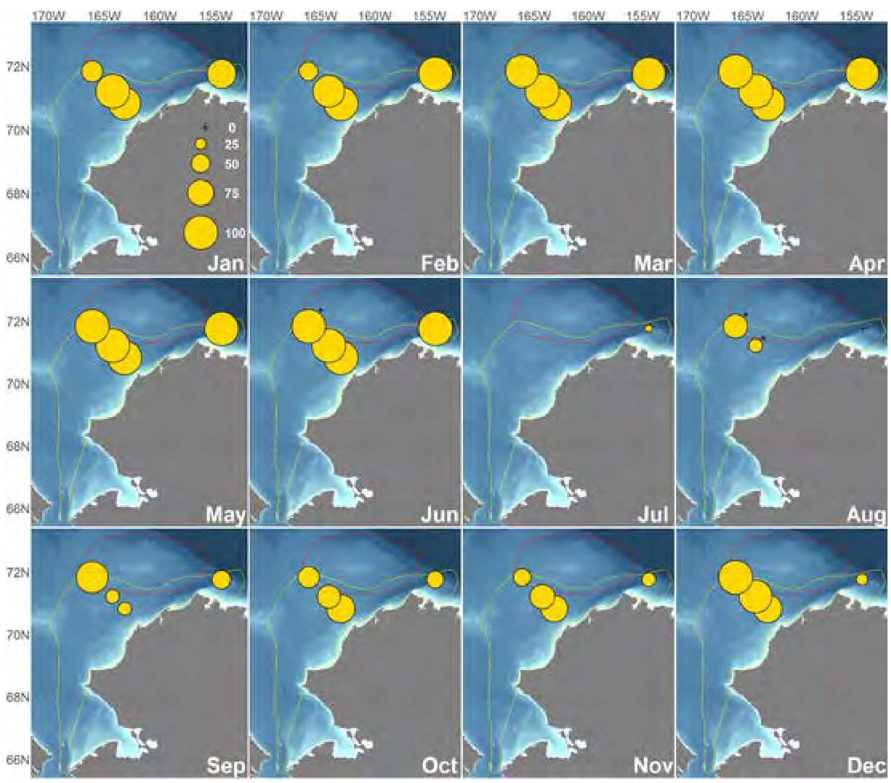

Figure 63. Monthly bearded seal calling distribution, 2011.

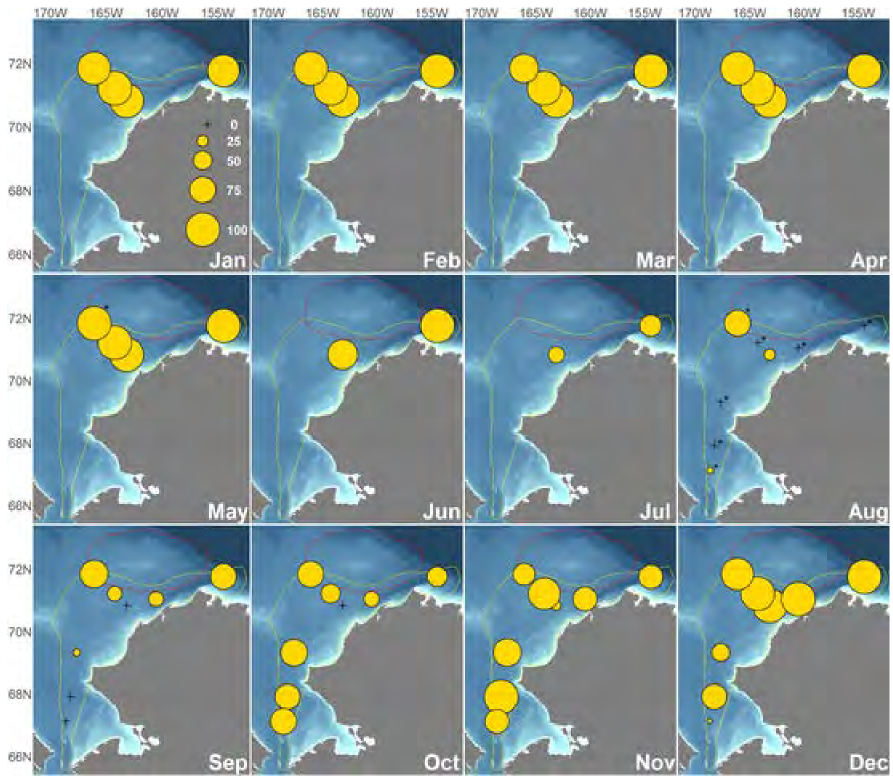

Figure 64. Monthly bearded seal calling distribution, 2012.

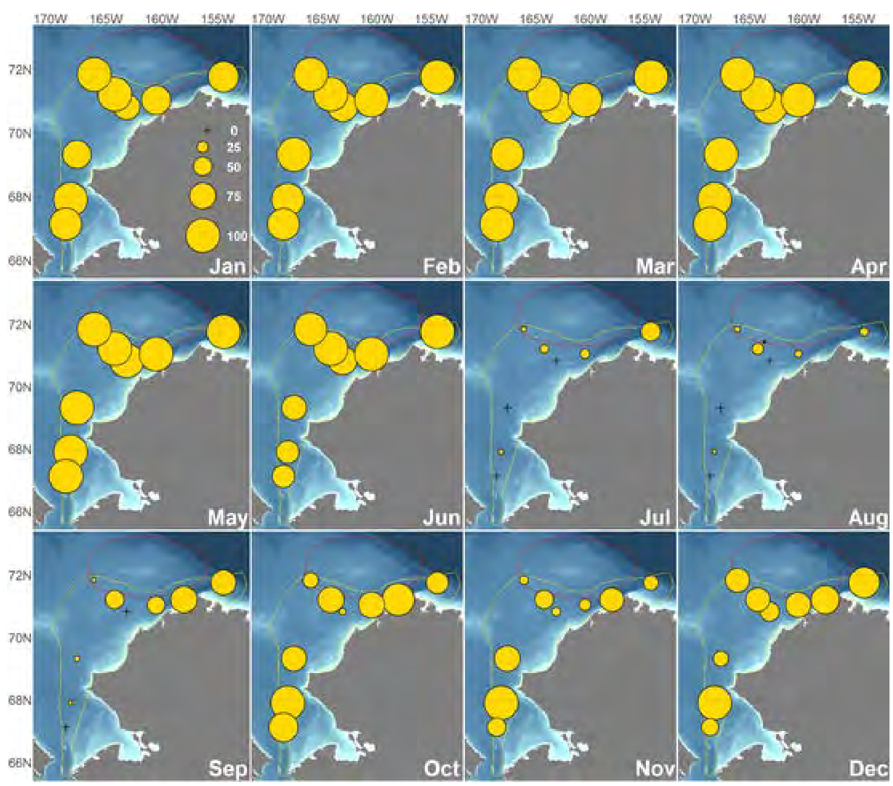

Figure 65. Monthly bearded seal calling distribution, 2013.

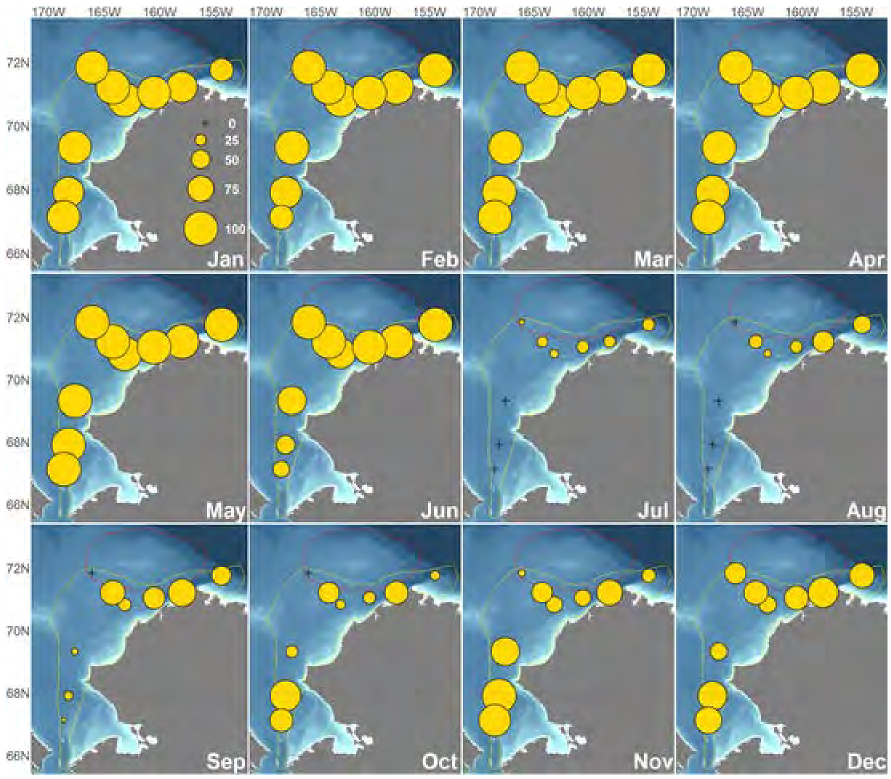

Figure 66. Monthly bearded seal calling distribution, 2014.

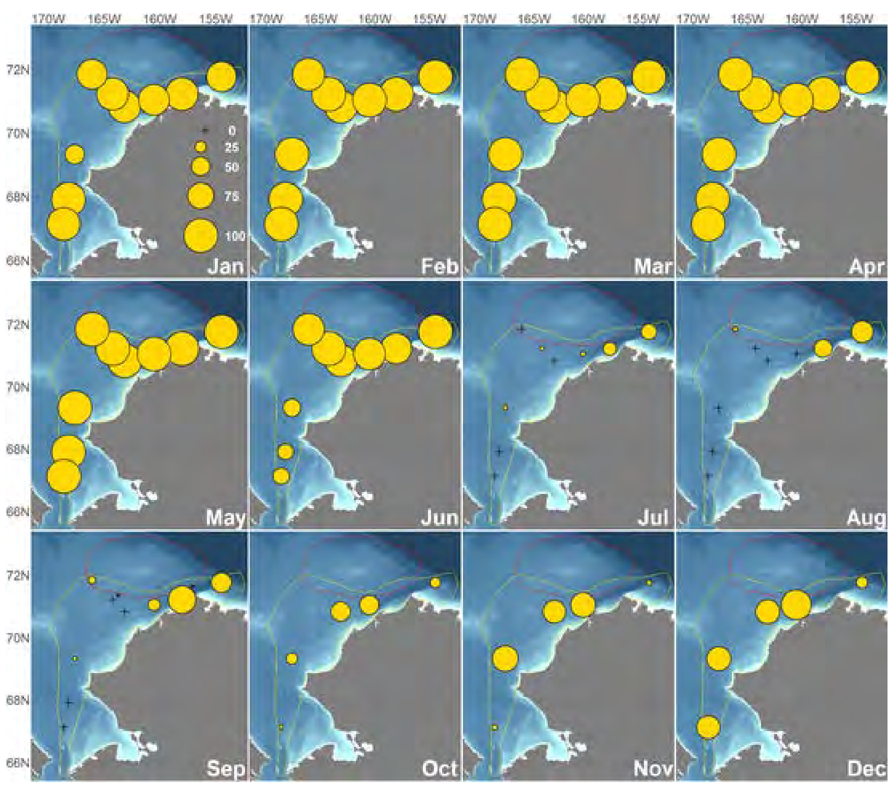

Figure 67. Monthly bearded seal calling distribution, 2015.

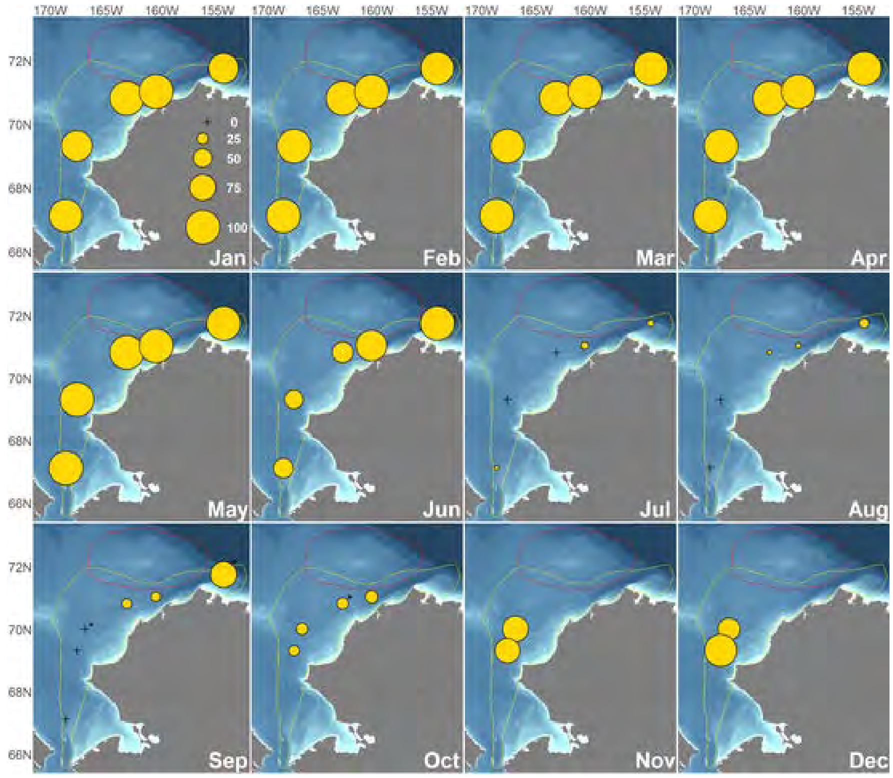

Figure 68. Monthly bearded seal calling distribution, 2016.

Gray whales

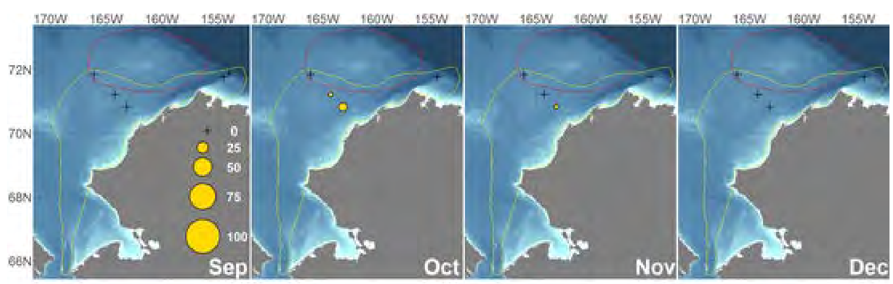

Figure 69. Monthly gray whale calling distribution, 2010

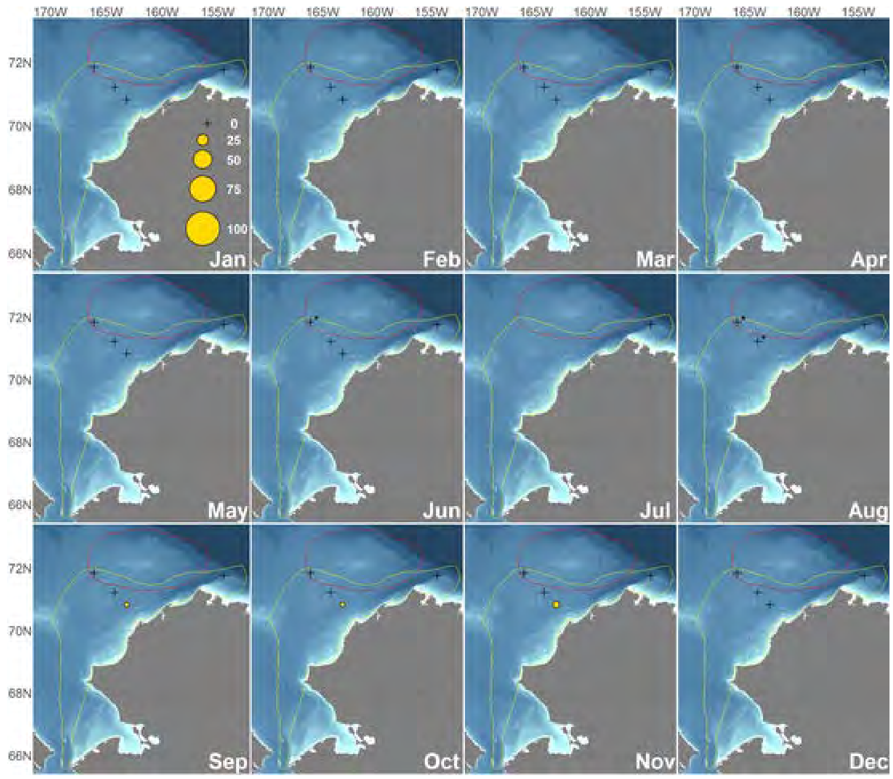

Figure 70. Monthly gray whale calling distribution, 2011.

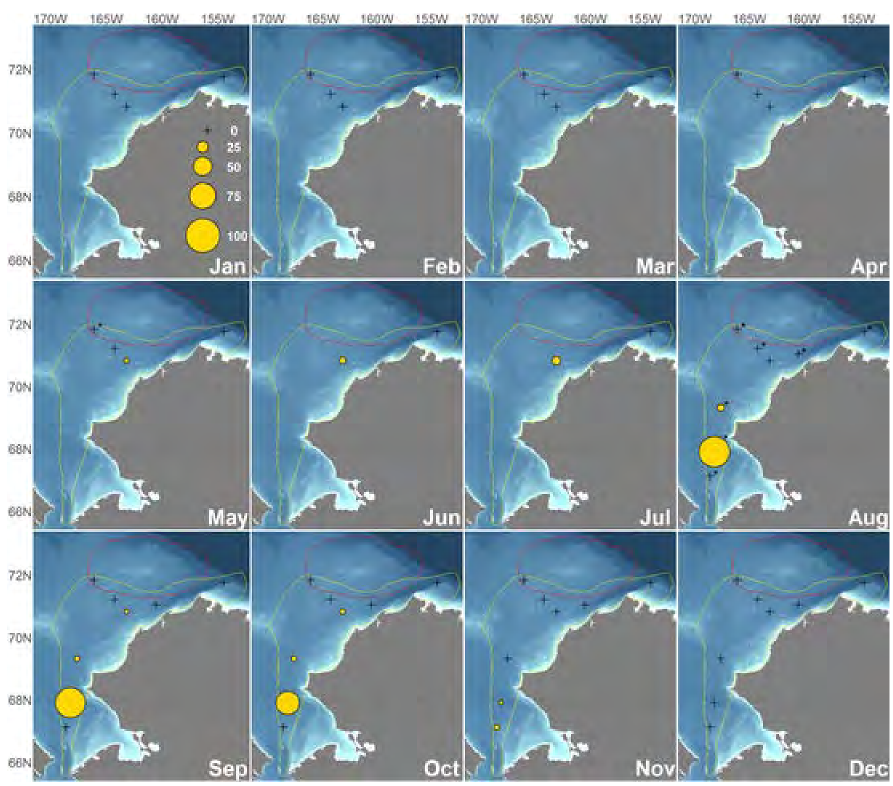

Figure 71. Monthly gray whale calling distribution, 2012.

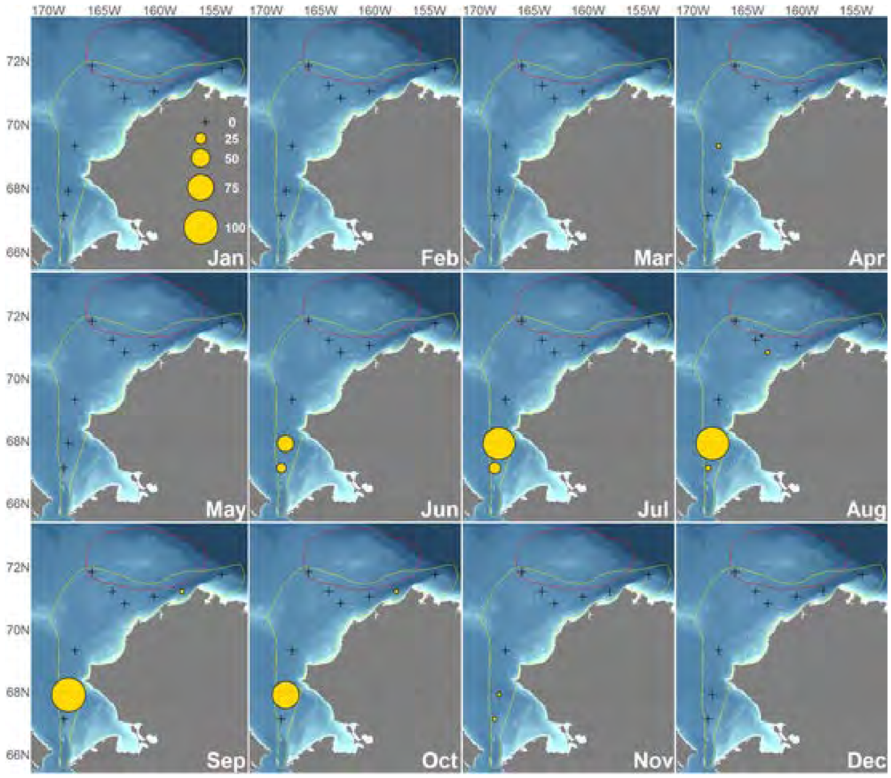

Figure 72. Monthly gray whale calling distribution, 2013.

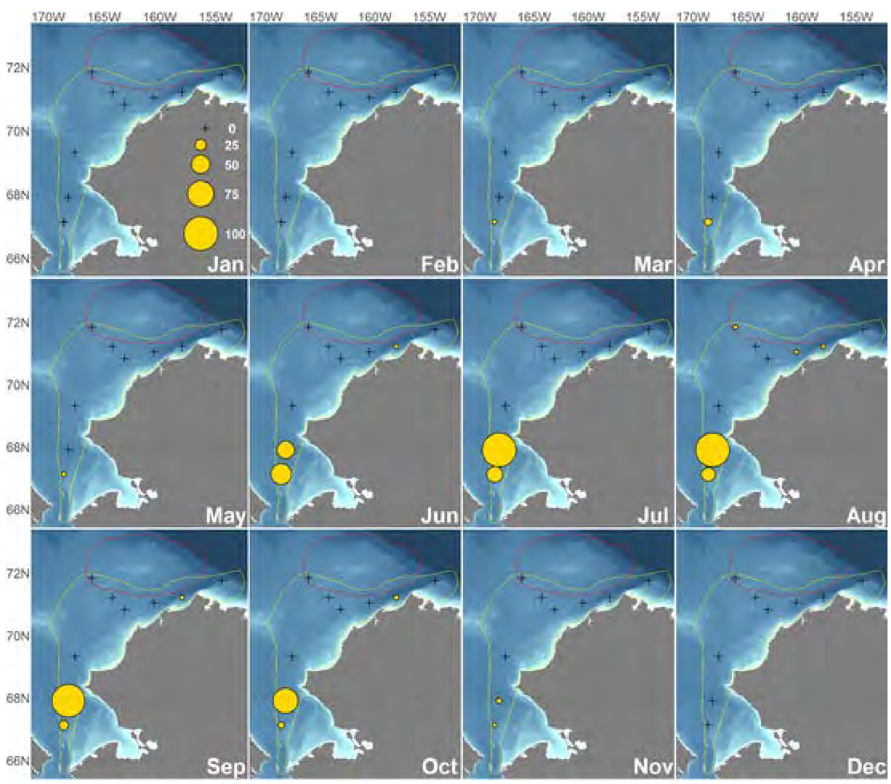

Figure 73. Monthly gray whale calling distribution, 2014.

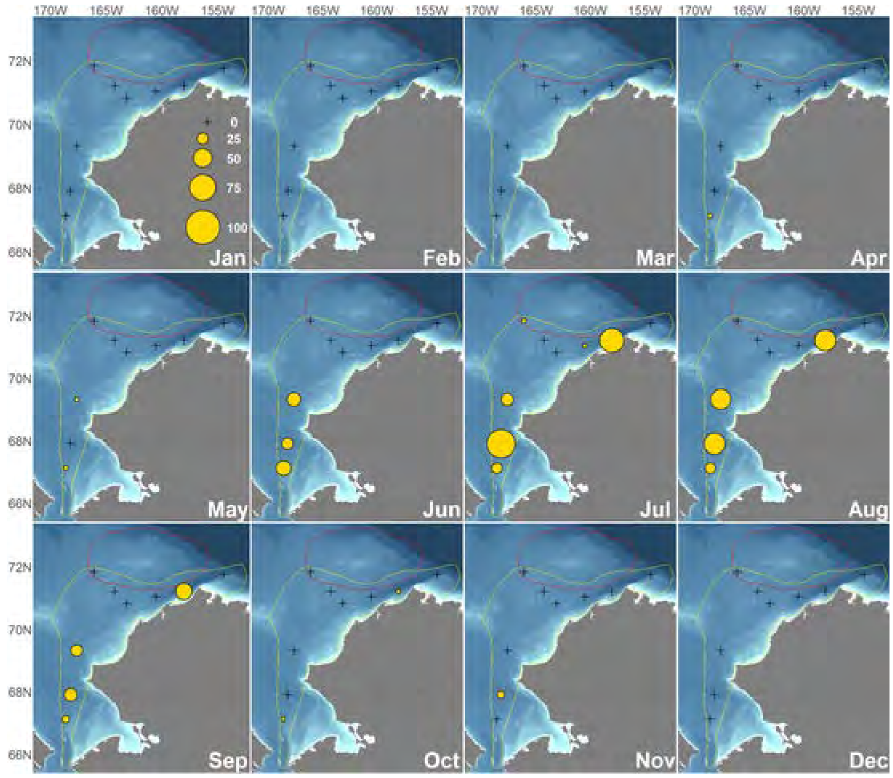

Figure 74. Monthly gray whale calling distribution, 2015.

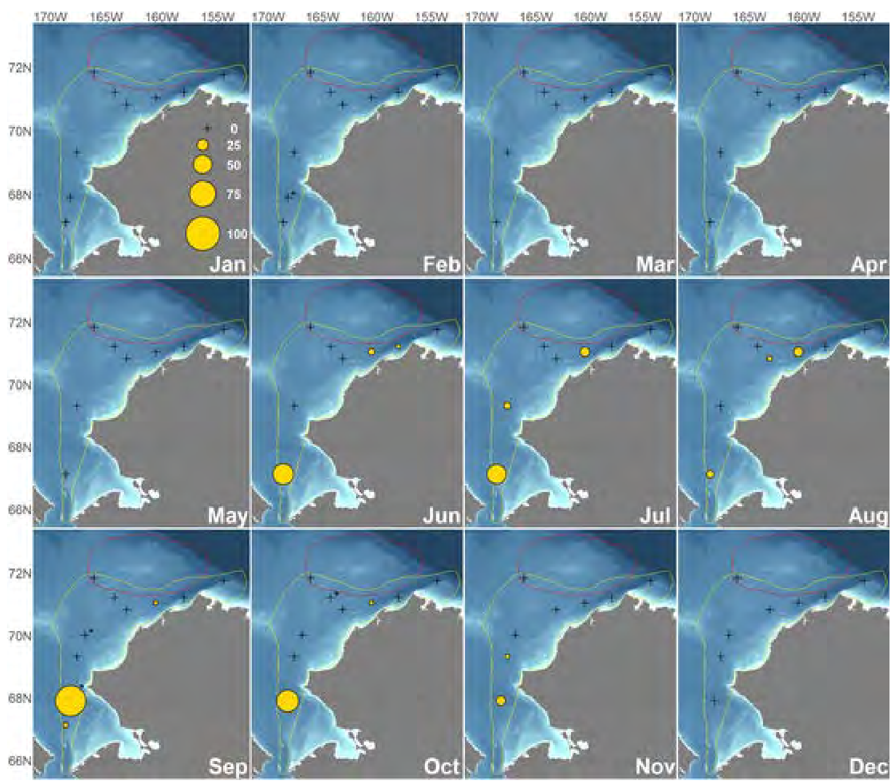

Figure 75. Monthly gray whale calling distribution, 2016.

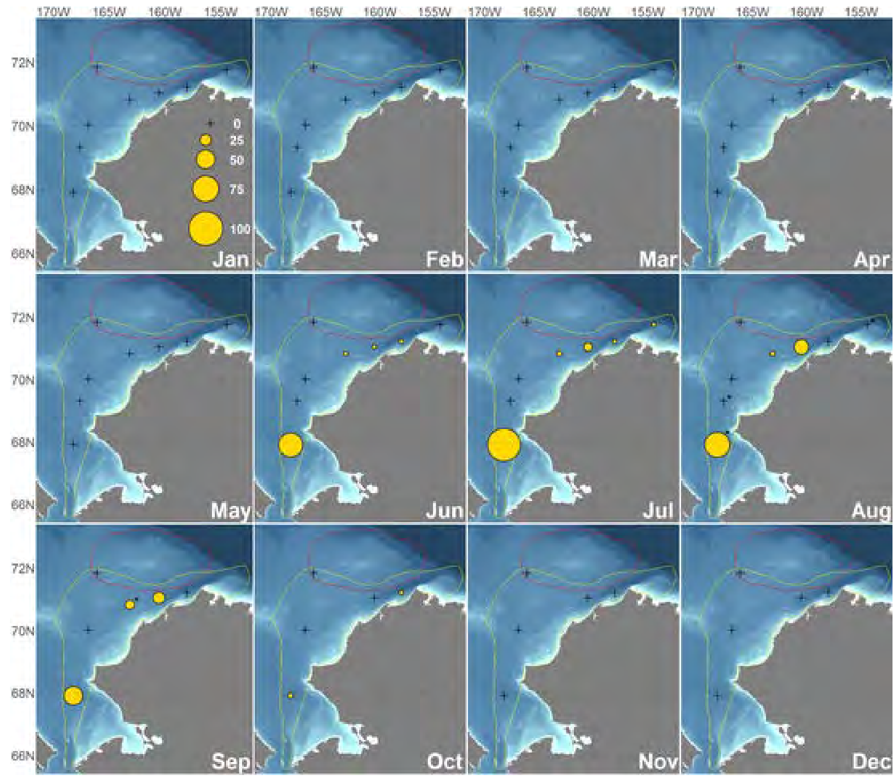

Figure 76. Monthly gray whale calling distribution, 2017.

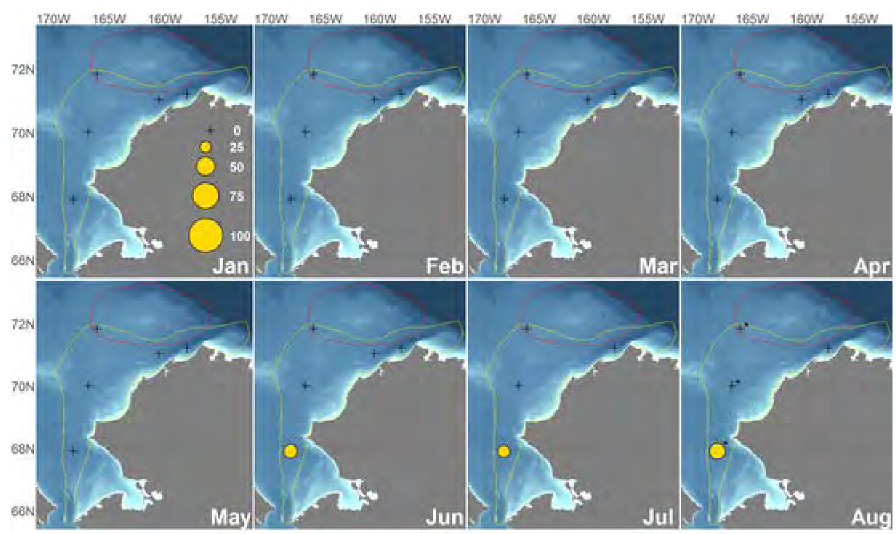

Figure 77. Monthly gray whale calling distribution, 2018.

2. Subarctic Species

Humpback whales

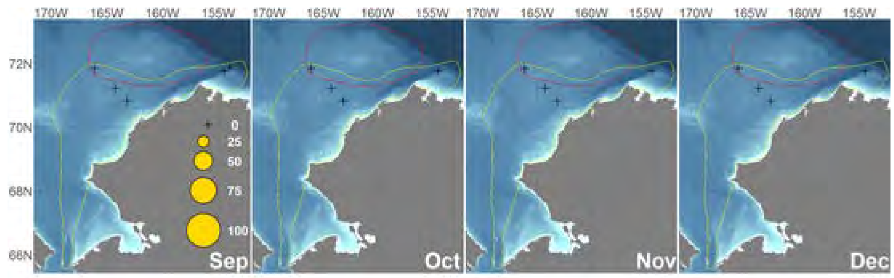

Figure 78. Monthly humpback whale calling distribution, 2010.

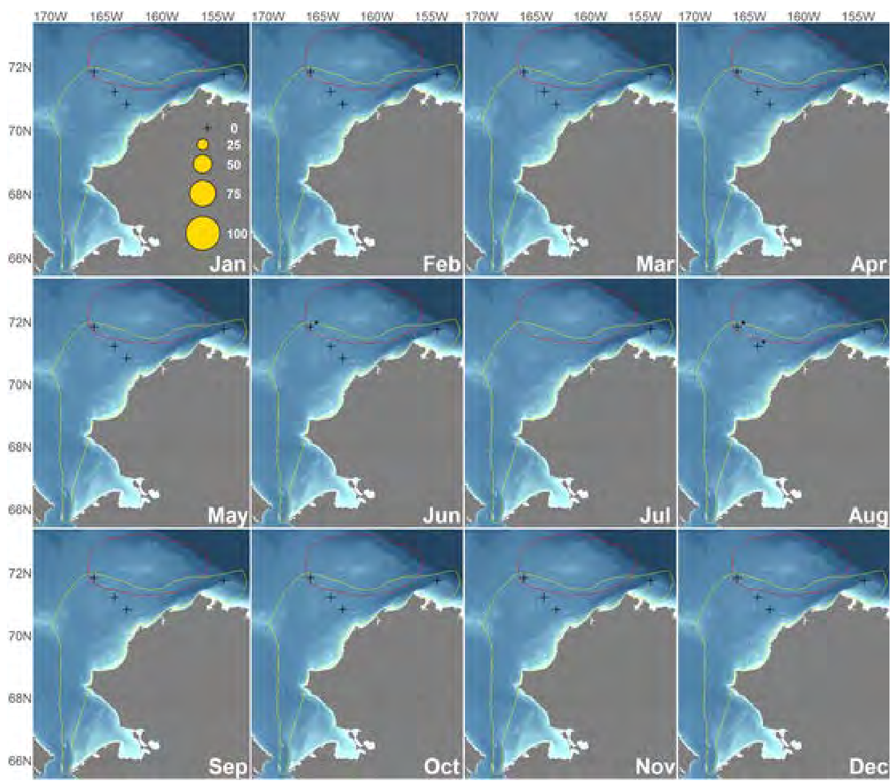

Figure 79. Monthly humpback whale calling distribution, 2011.

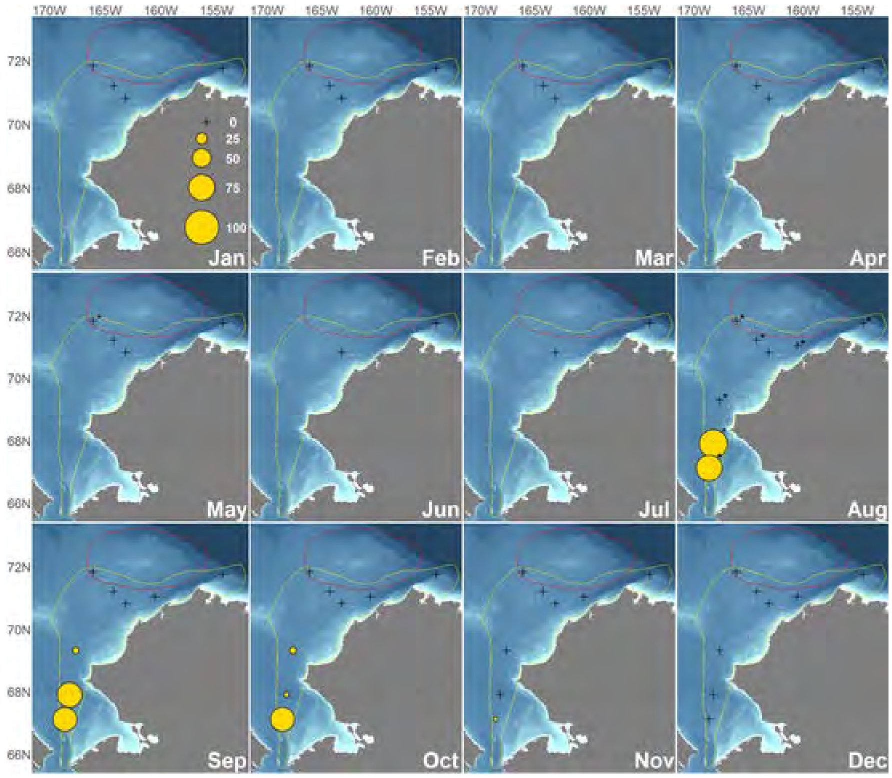

Figure 80. Monthly humpback whale calling distribution, 2012.

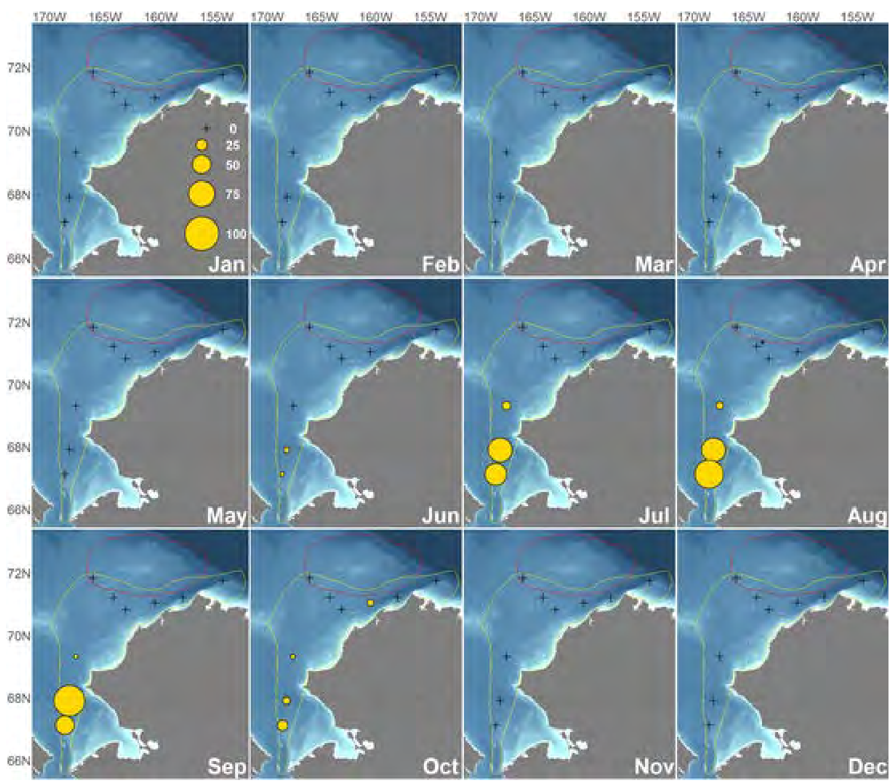

Figure 81. Monthly humpback whale calling distribution, 2013.

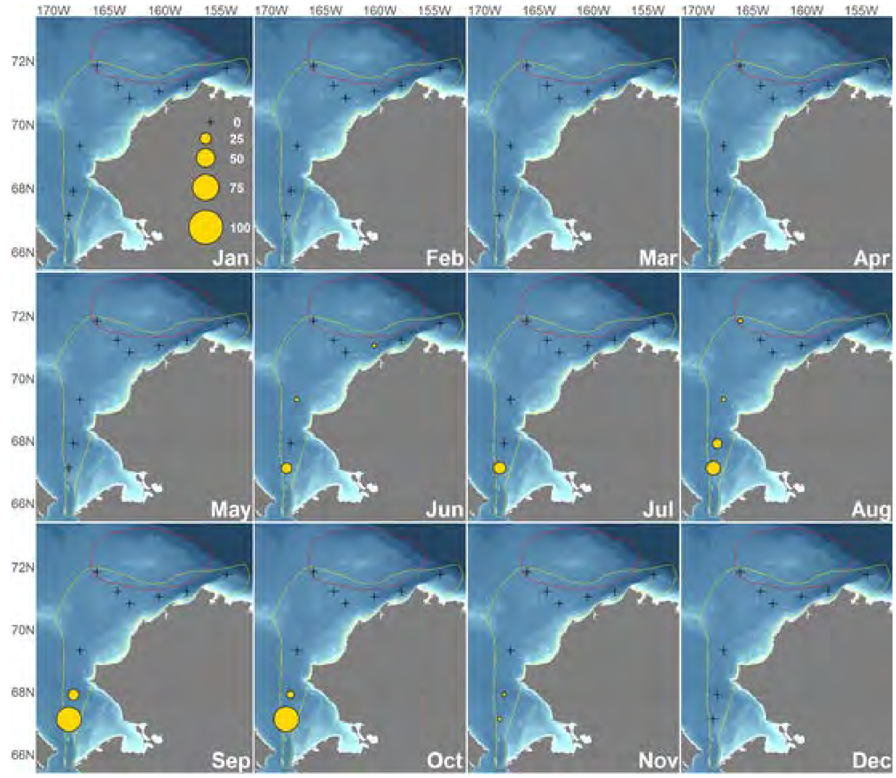

Figure 82. Monthly humpback whale calling distribution, 2014.

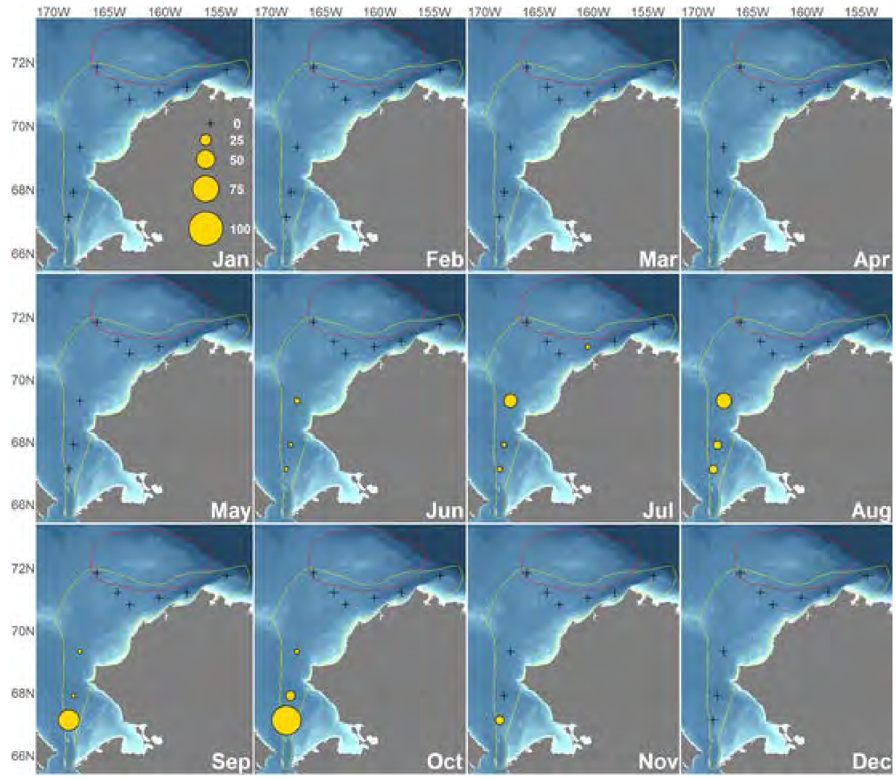

Figure 83. Monthly humpback whale calling distribution, 2015.

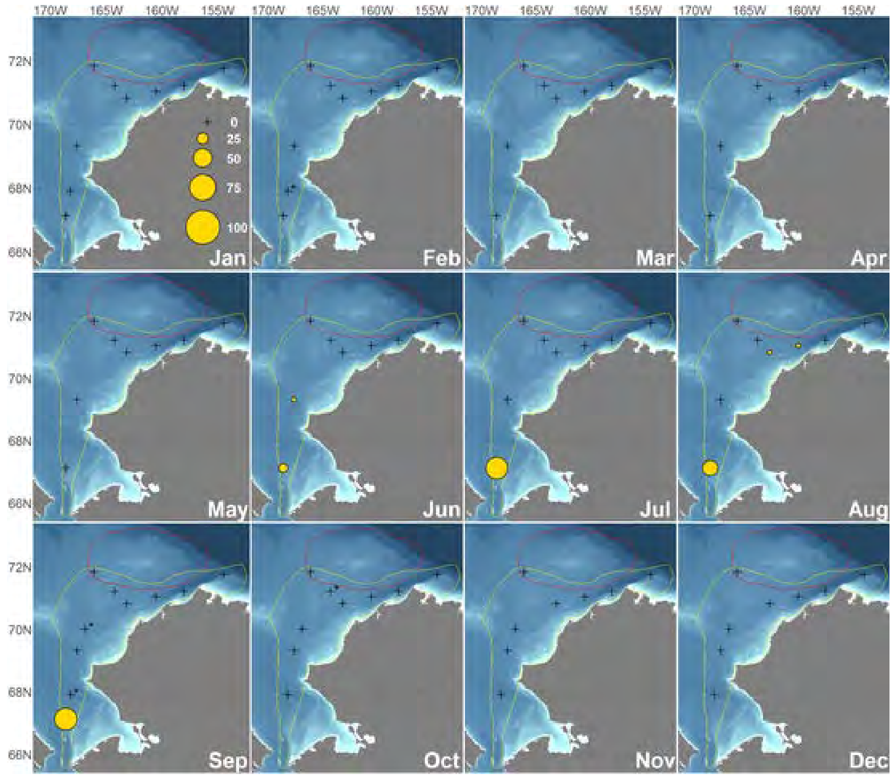

Figure 84. Monthly humpback whale calling distribution, 2016.

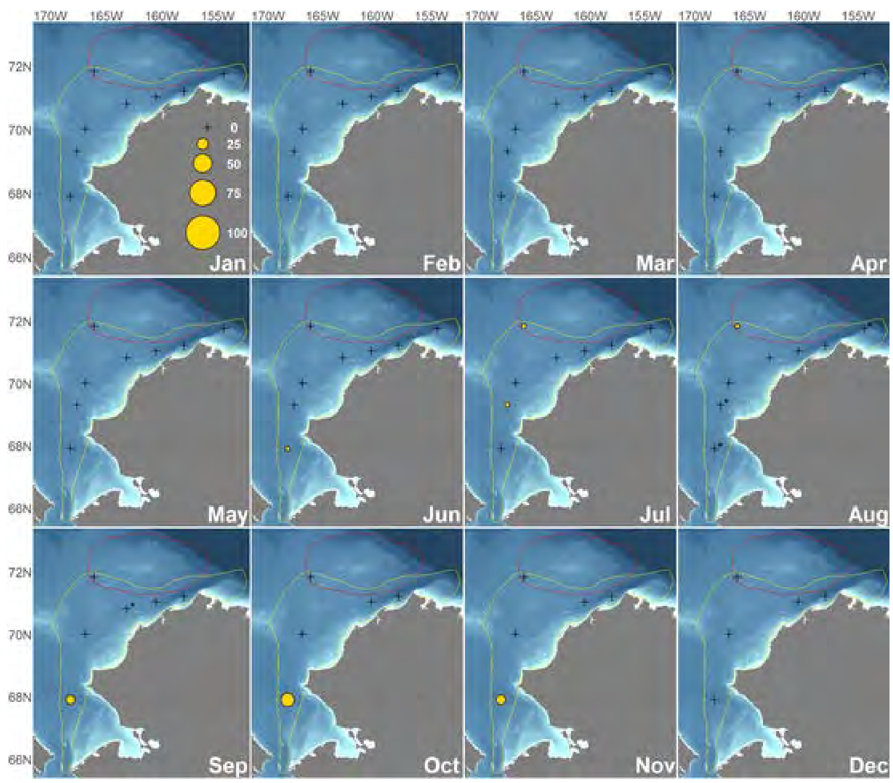

Figure 85. Monthly humpback whale calling distribution, 2017.

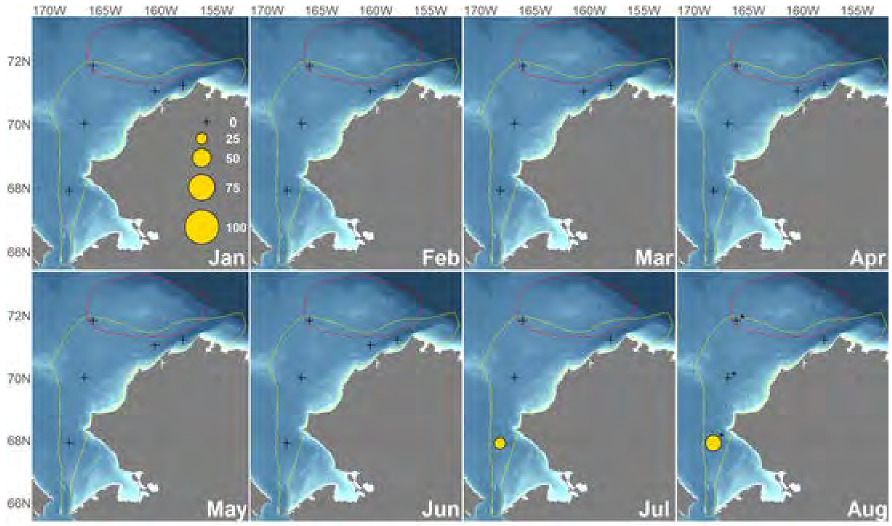

Figure 86. Monthly humpback whale calling distribution, 2018.

Killer whales

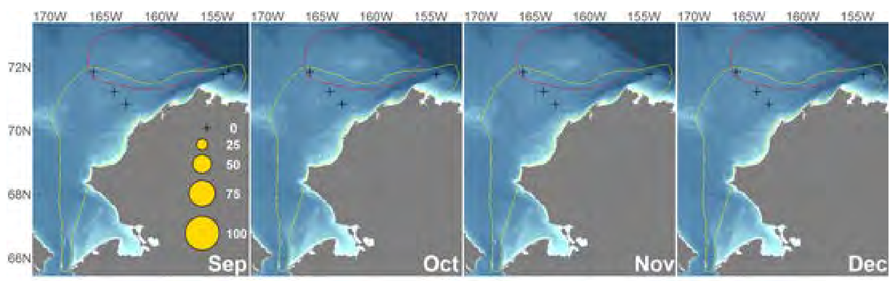

Figure 87. Monthly killer whale calling distribution, 2010.

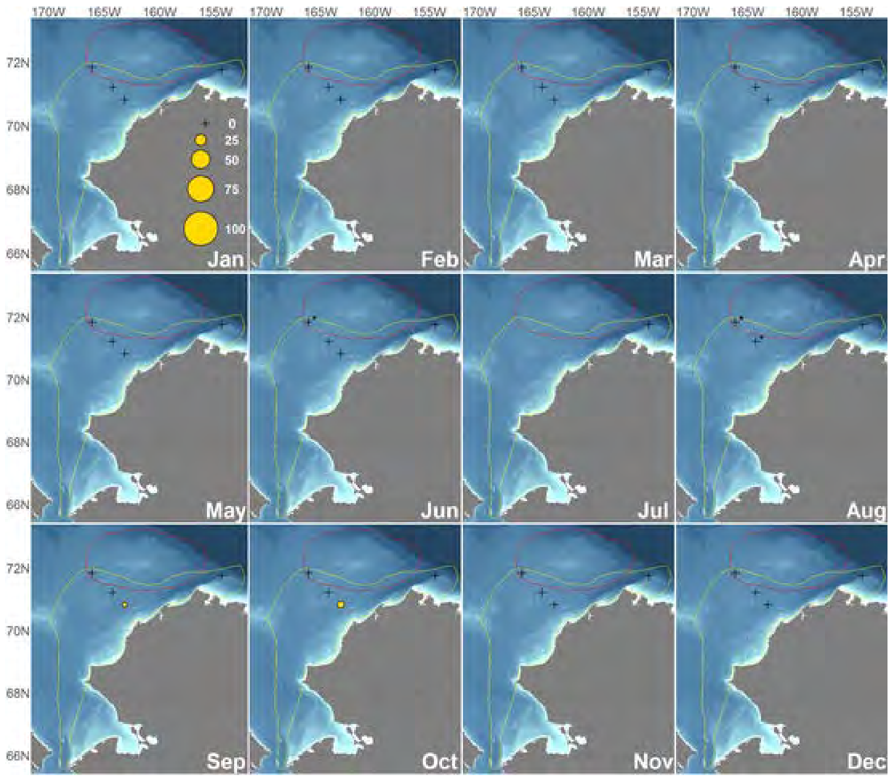

Figure 88. Monthly killer whale calling distribution, 2011.

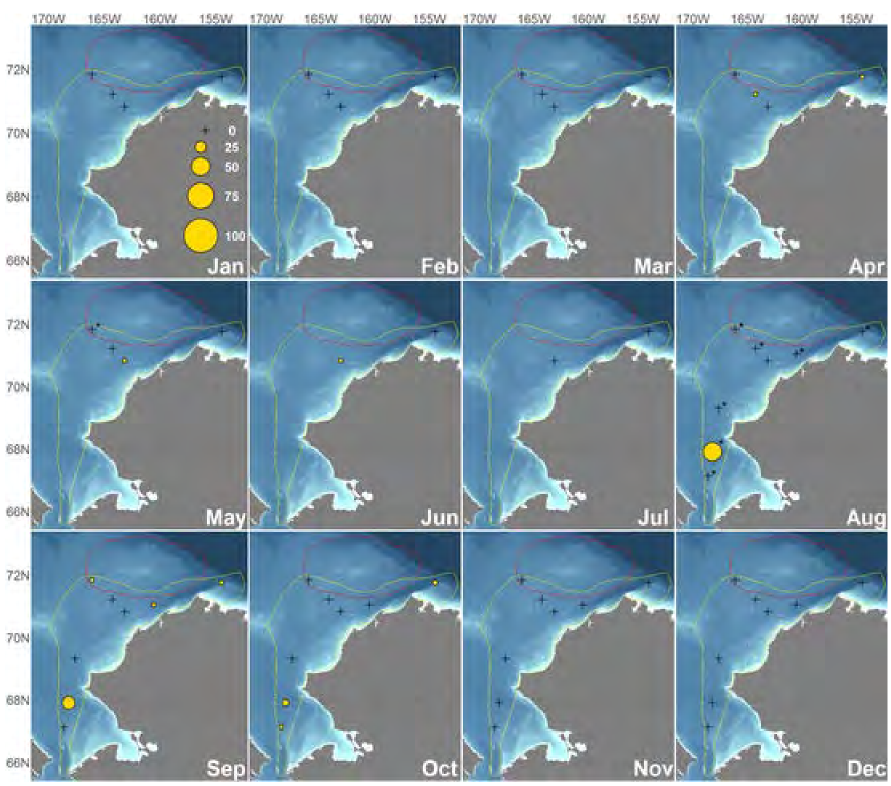

Figure 89. Monthly killer whale calling distribution, 2012.

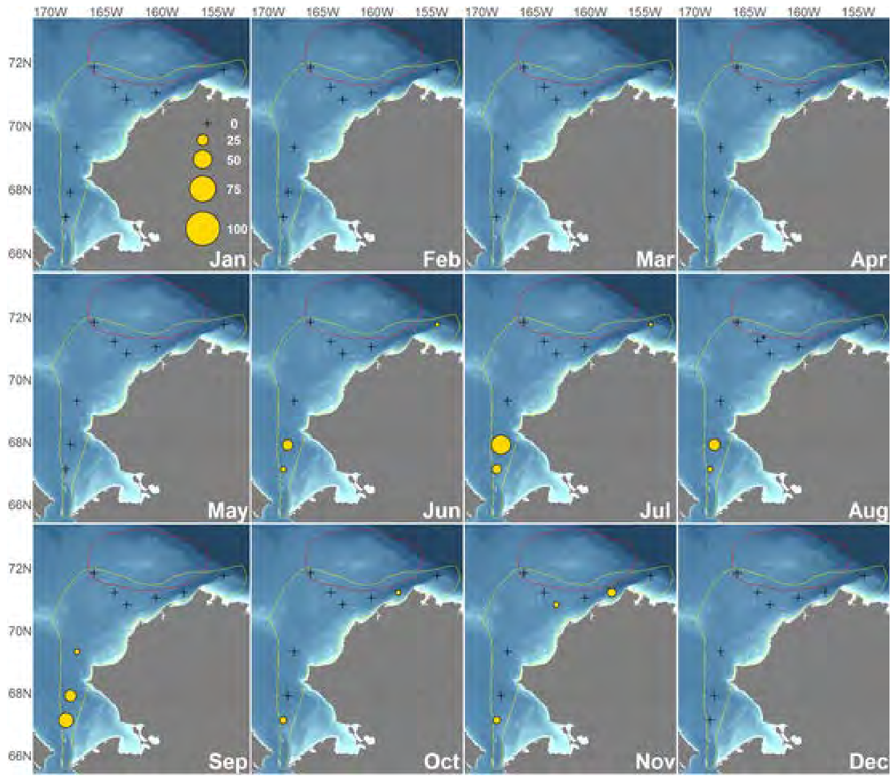

Figure 90. Monthly killer whale calling distribution, 2013.

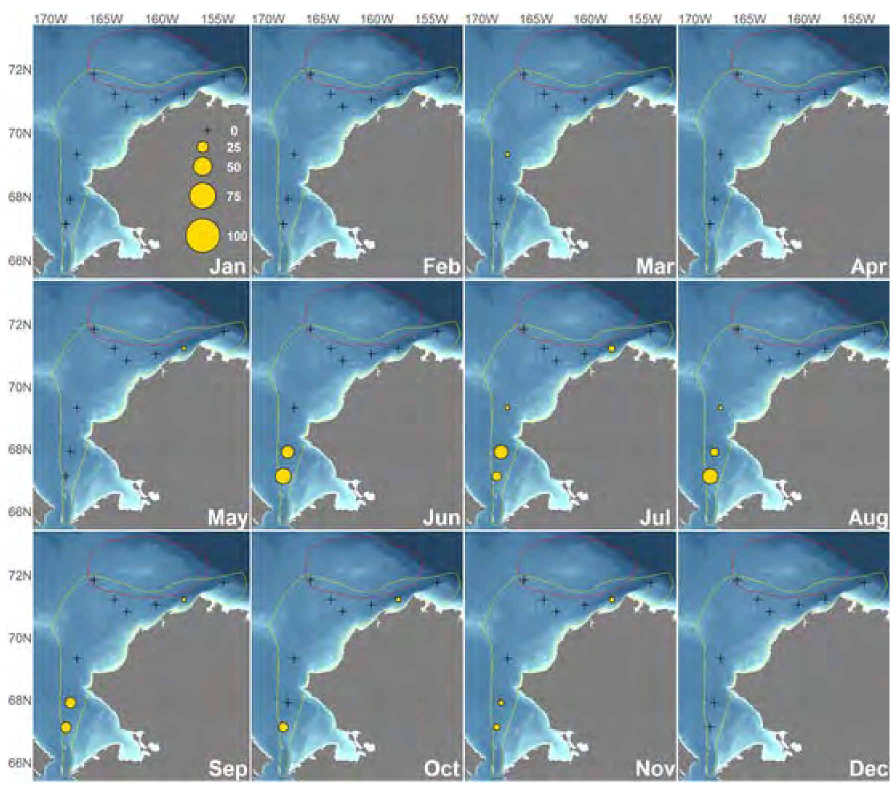

Figure 91. Monthly killer whale calling distribution, 2014.

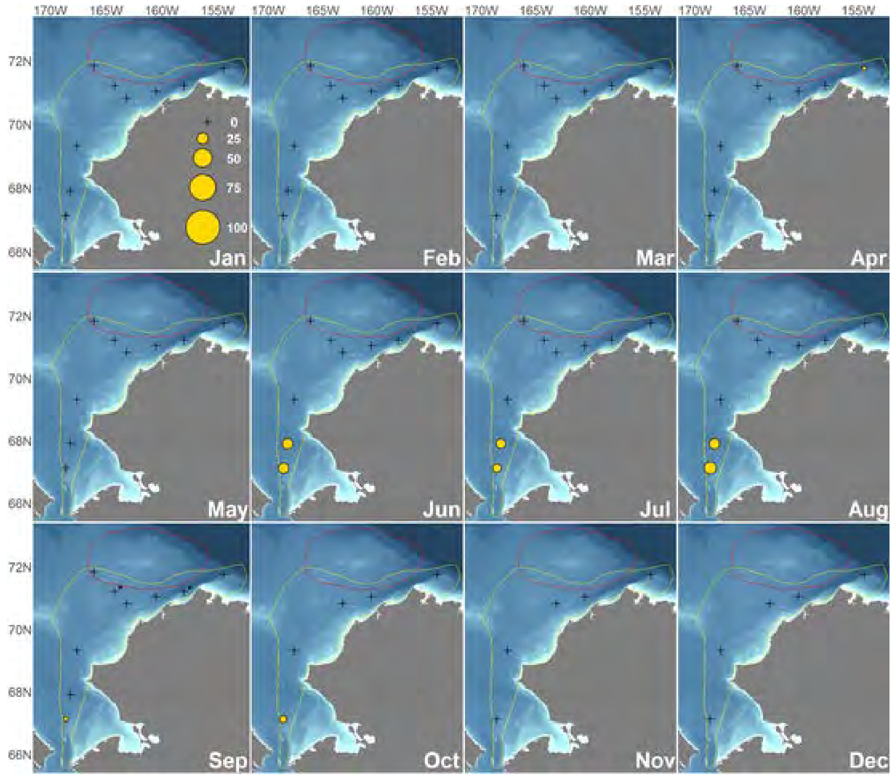

Figure 92. Monthly killer whale calling distribution, 2015.

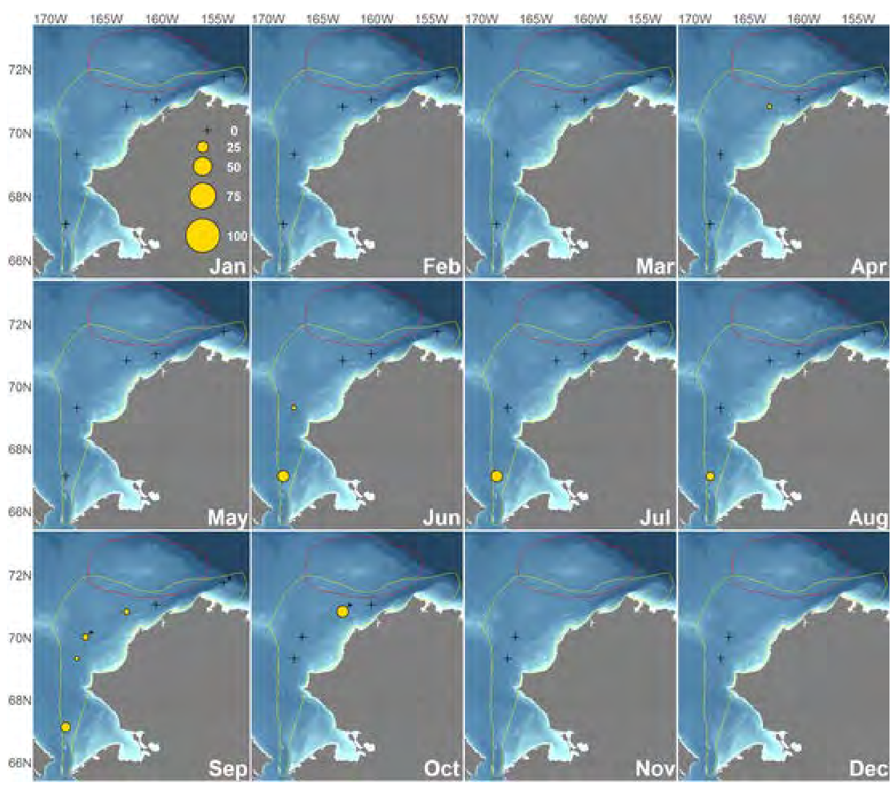

Figure 93. Monthly killer whale calling distribution, 2016.

Minke whale boings

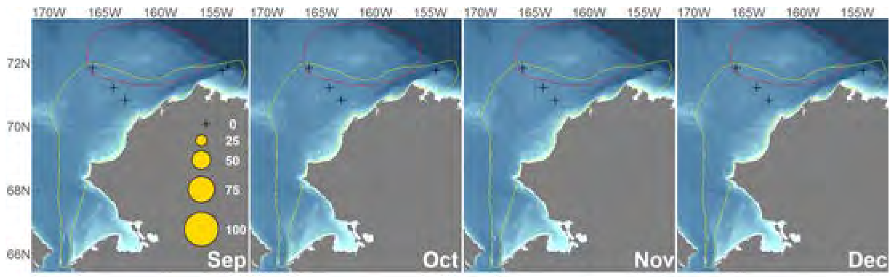

Figure 94. Monthly minke whale calling distribution, 2010.

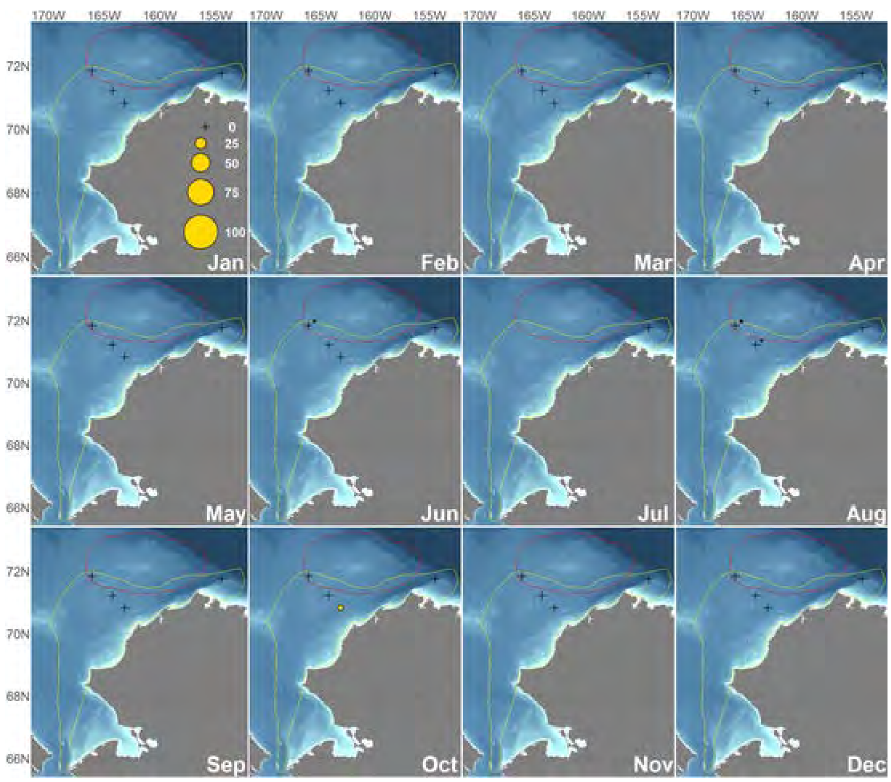

Figure 95. Monthly minke whale calling distribution, 2011.

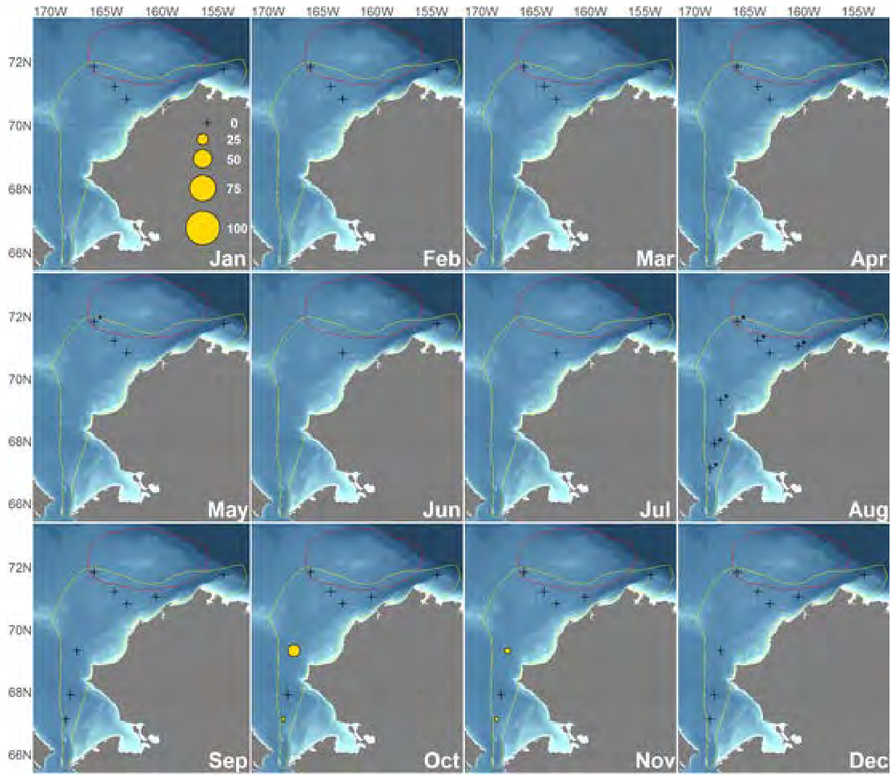

Figure 96. Monthly minke whale calling distribution, 2012.

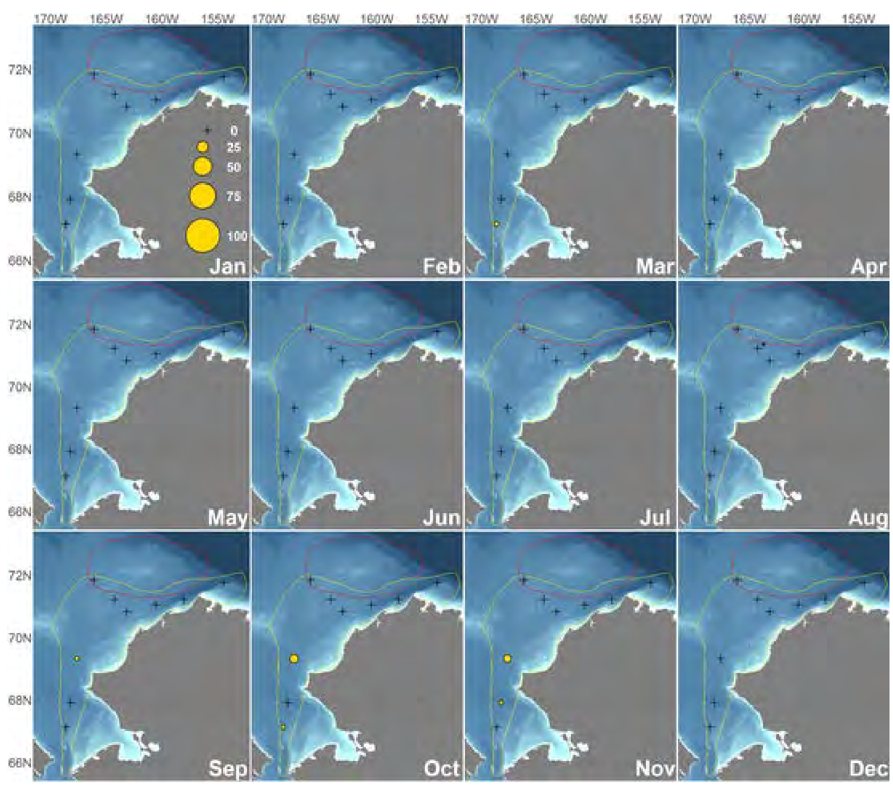

Figure 97. Monthly minke whale calling distribution, 2013.

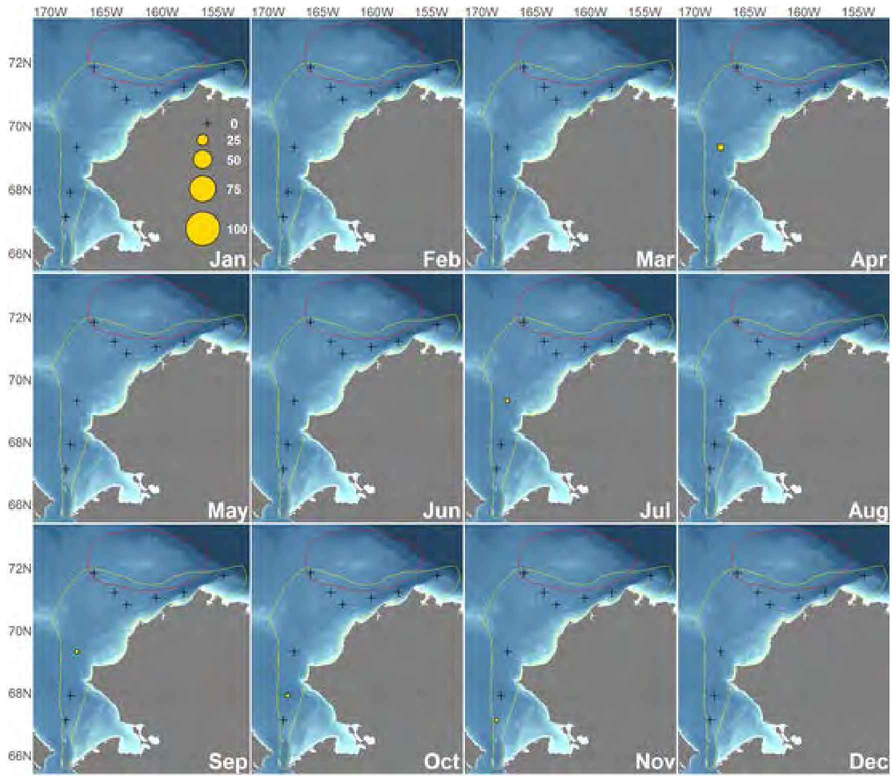

Figure 98. Monthly minke whale calling distribution, 2014.

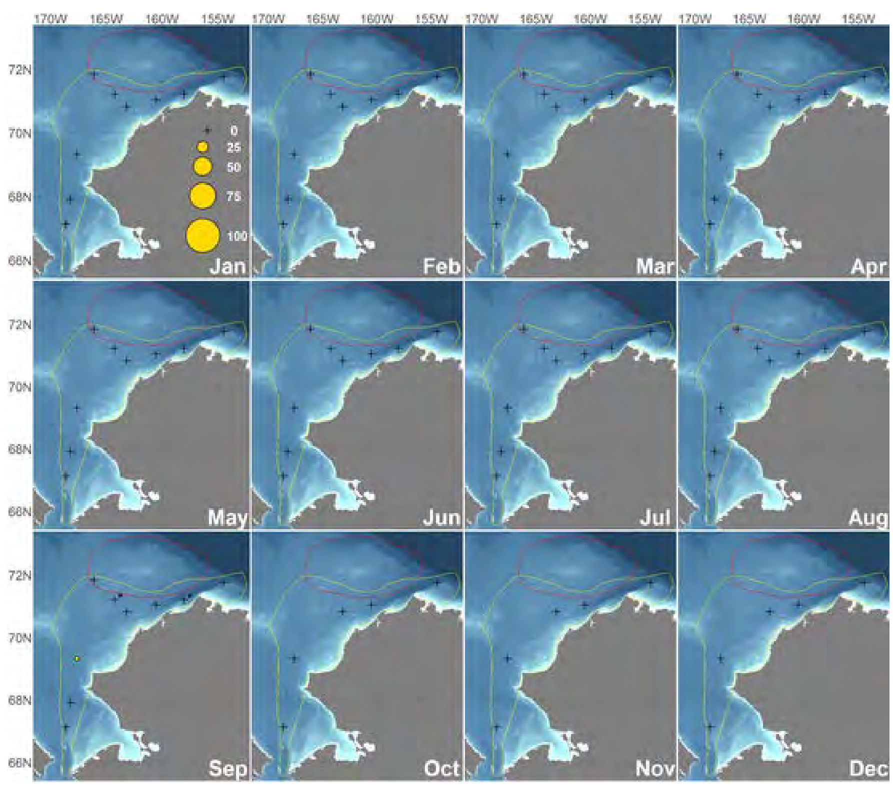

Figure 99. Monthly minke whale calling distribution, 2015.

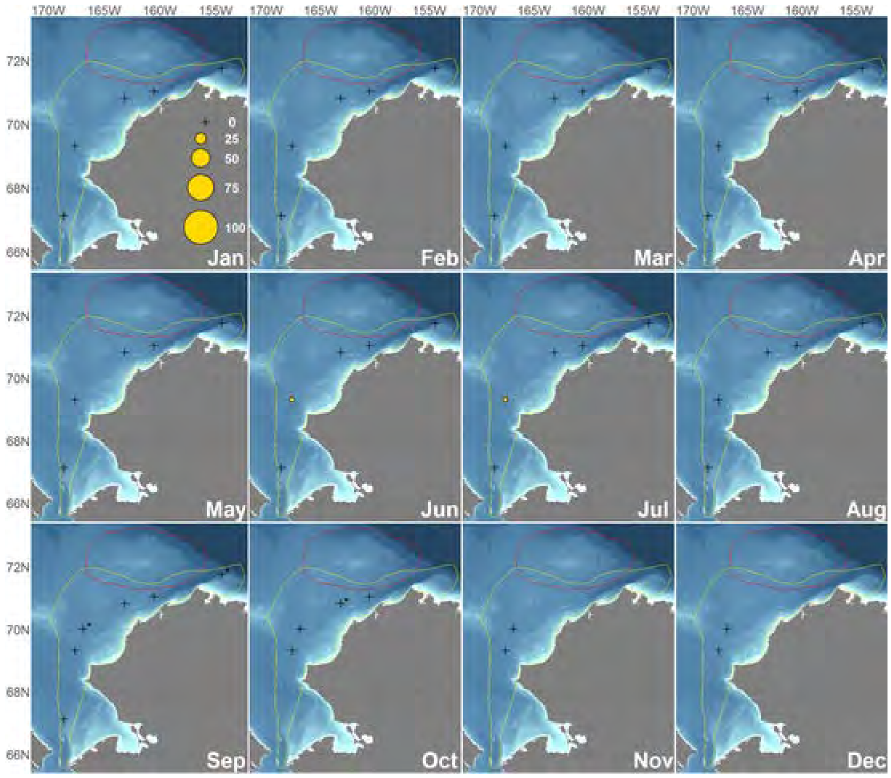

Figure 100. Monthly minke whale calling distribution, 2016.

Ribbon seals

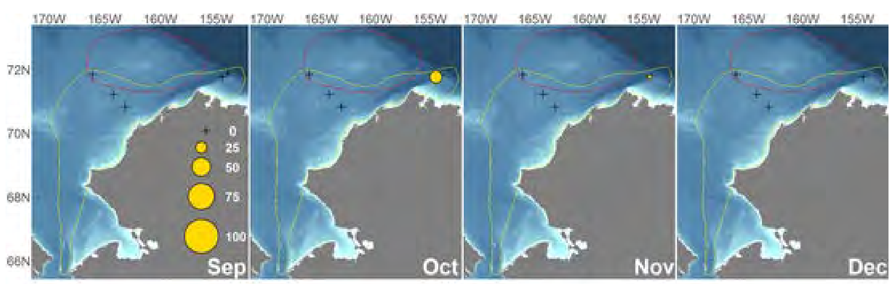

Figure 101. Monthly ribbon seal calling distribution, 2010.

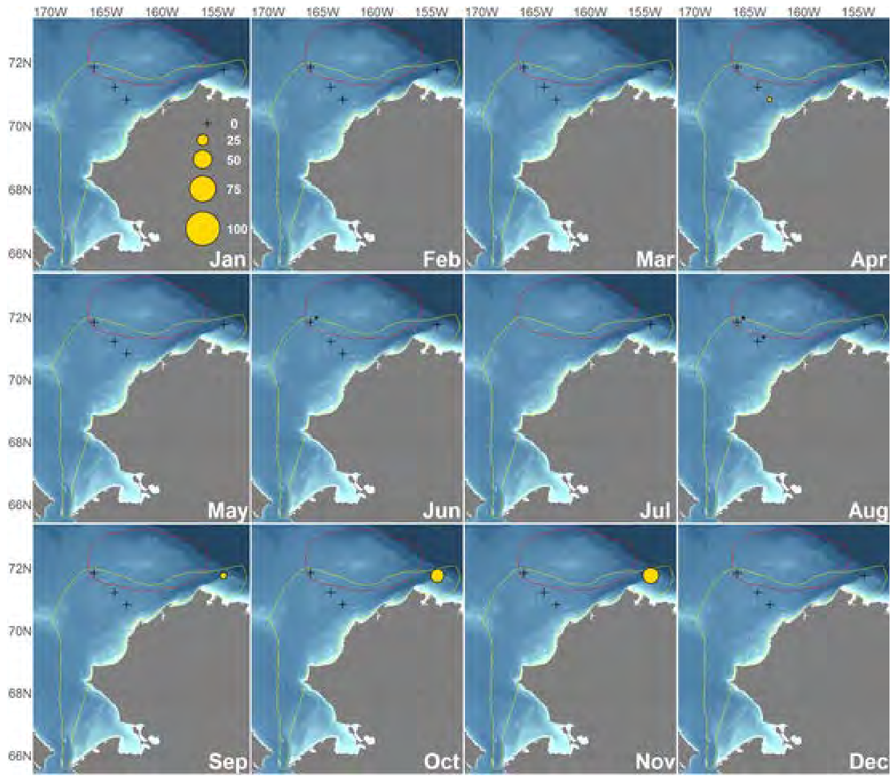

Figure 102. Monthly ribbon seal calling distribution, 2011.

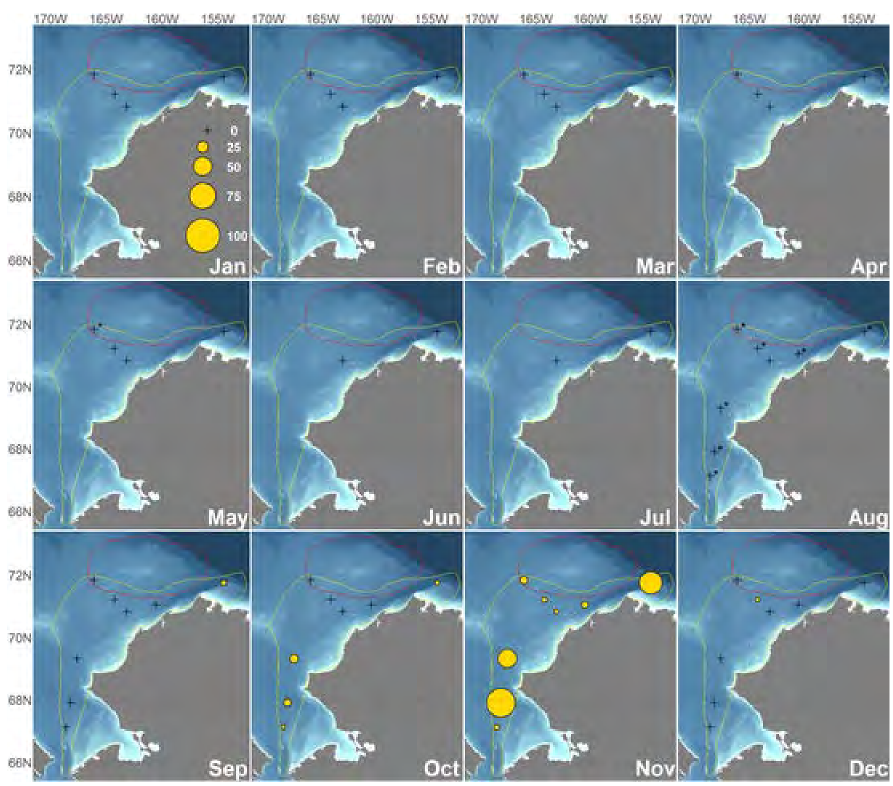

Figure 103. Monthly ribbon seal calling distribution, 2012.

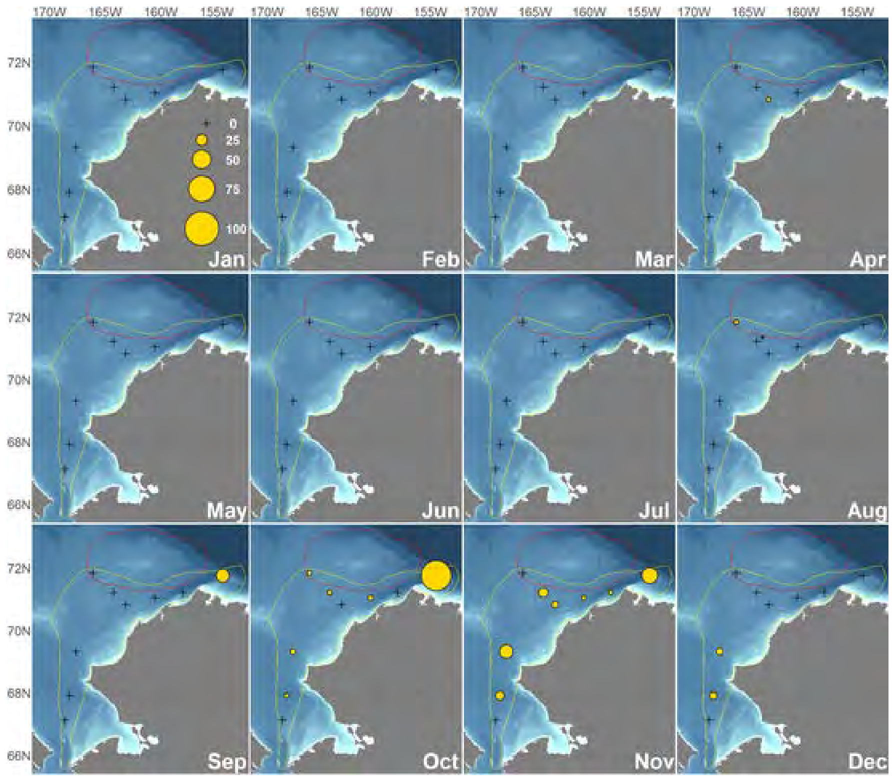

Figure 104. Monthly ribbon seal calling distribution, 2013.

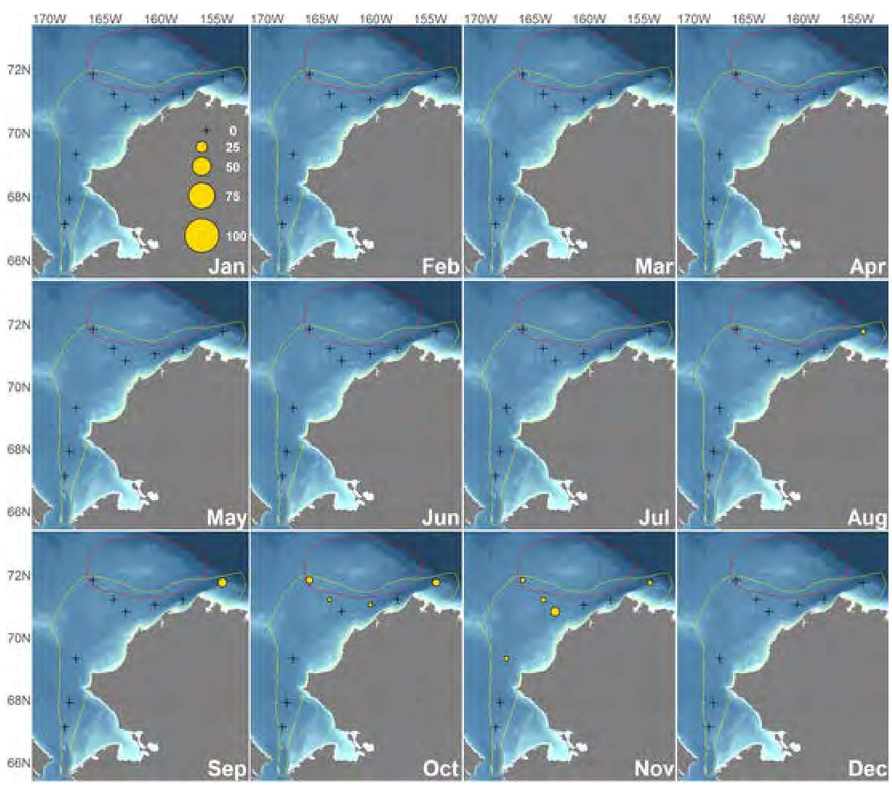

Figure 105. Monthly ribbon seal calling distribution, 2014.

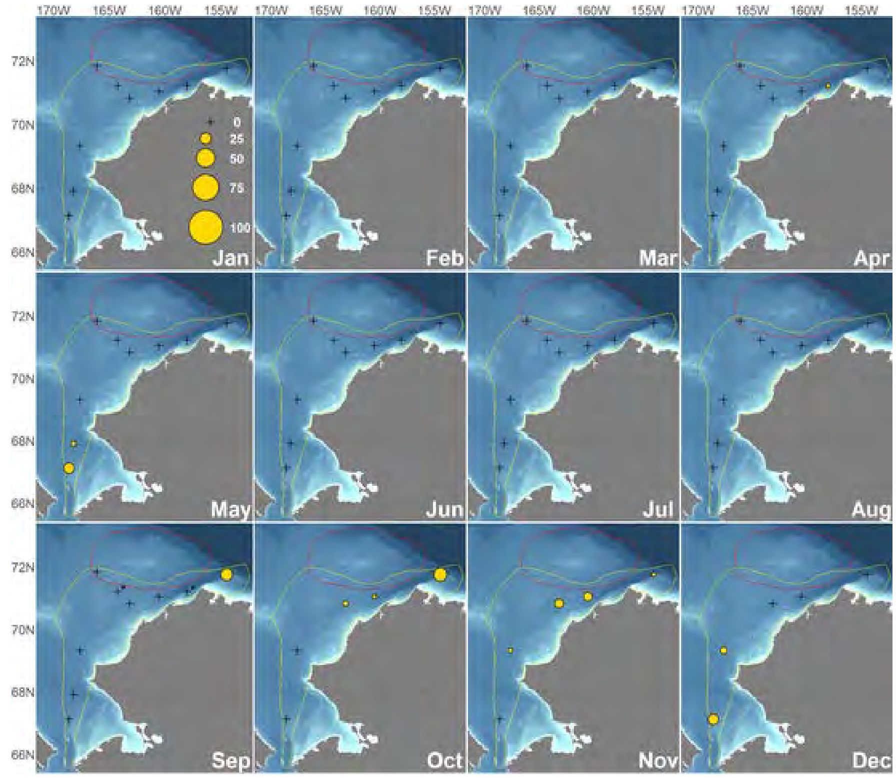

Figure 106. Monthly ribbon seal calling distribution, 2015.

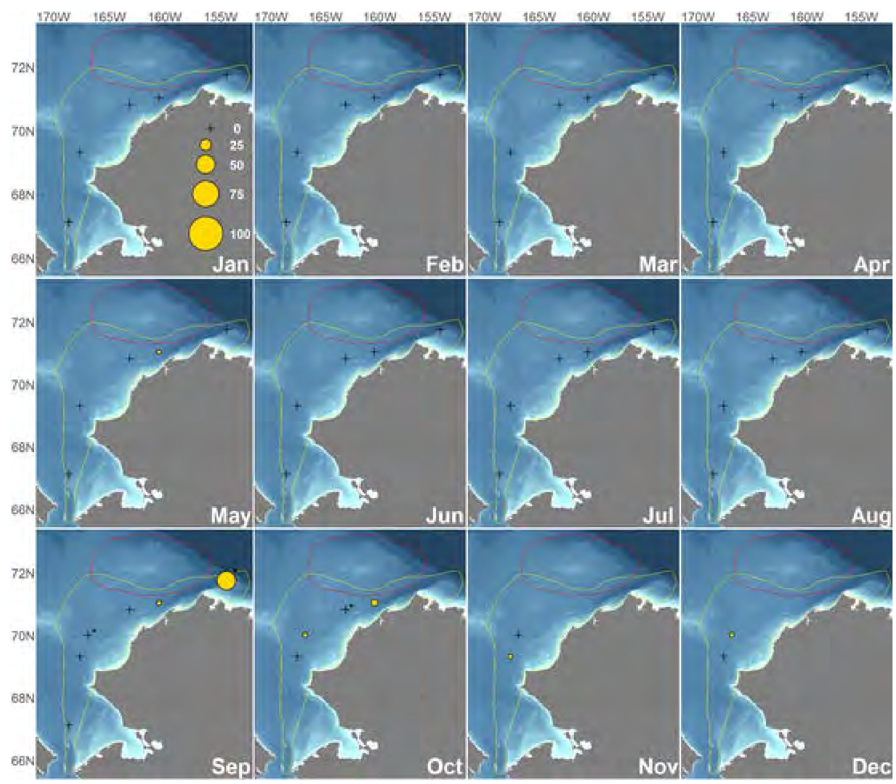

Figure 107. Monthly ribbon seal calling distribution, 2016.

Double knock

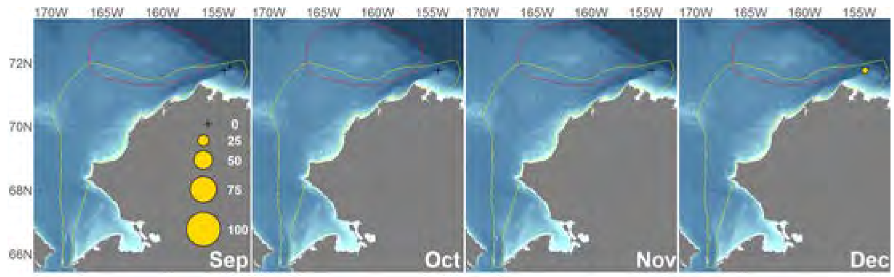

Figure 108. Monthly double knock sound distribution, 2010.

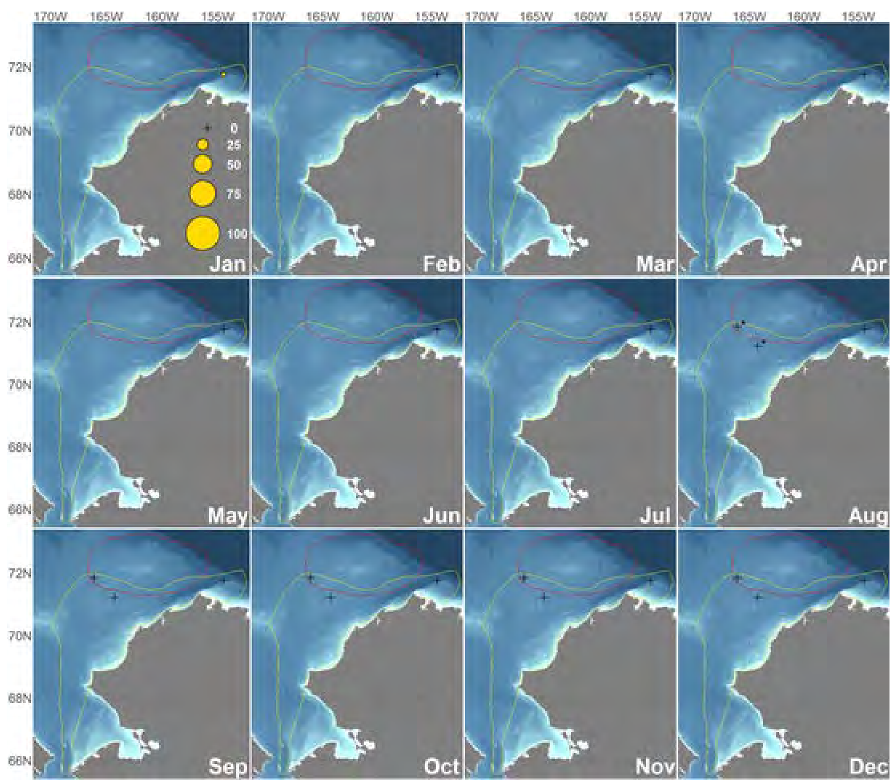

Figure 109. Monthly double knock sound distribution, 2011.

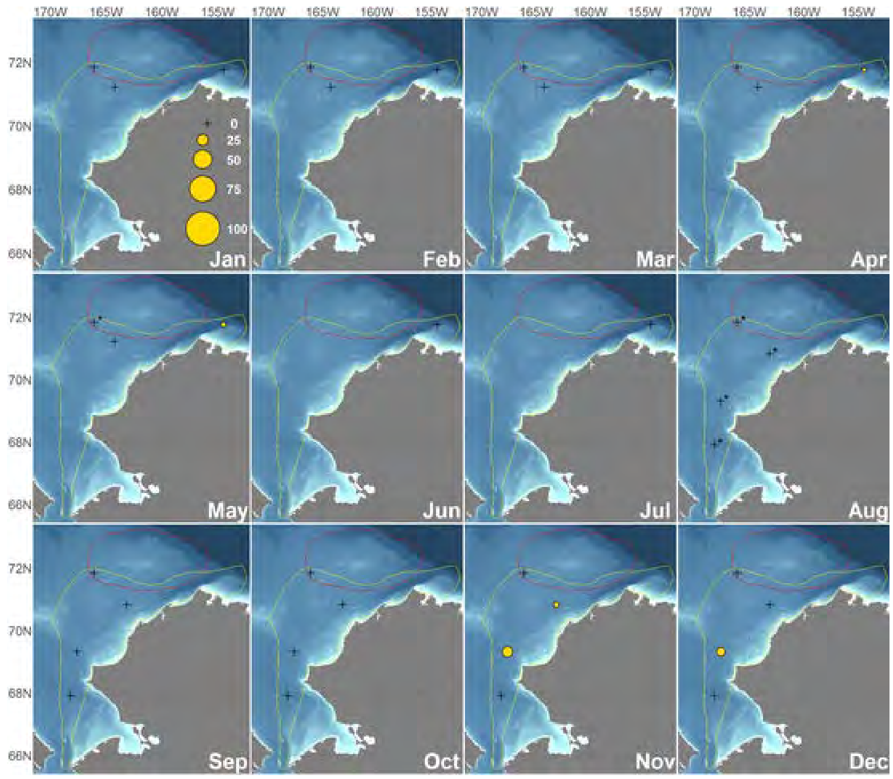

Figure 110. Monthly double knock sound distribution, 2012.

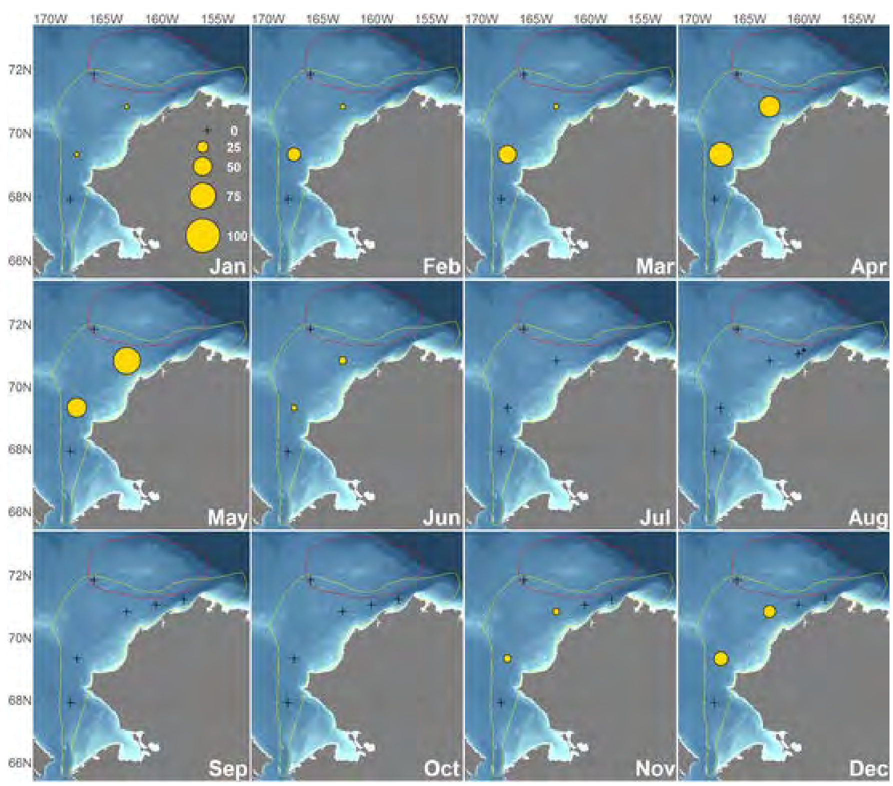

Figure 111. Monthly double knock sound distribution, 2013.

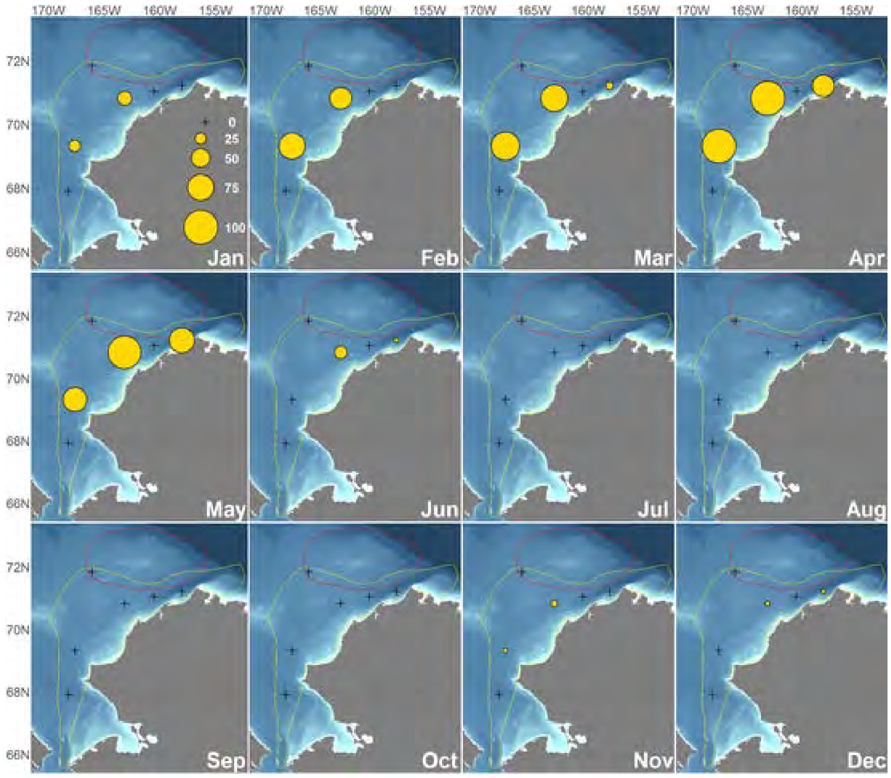

Figure 112. Monthly double knock sound distribution, 2014.

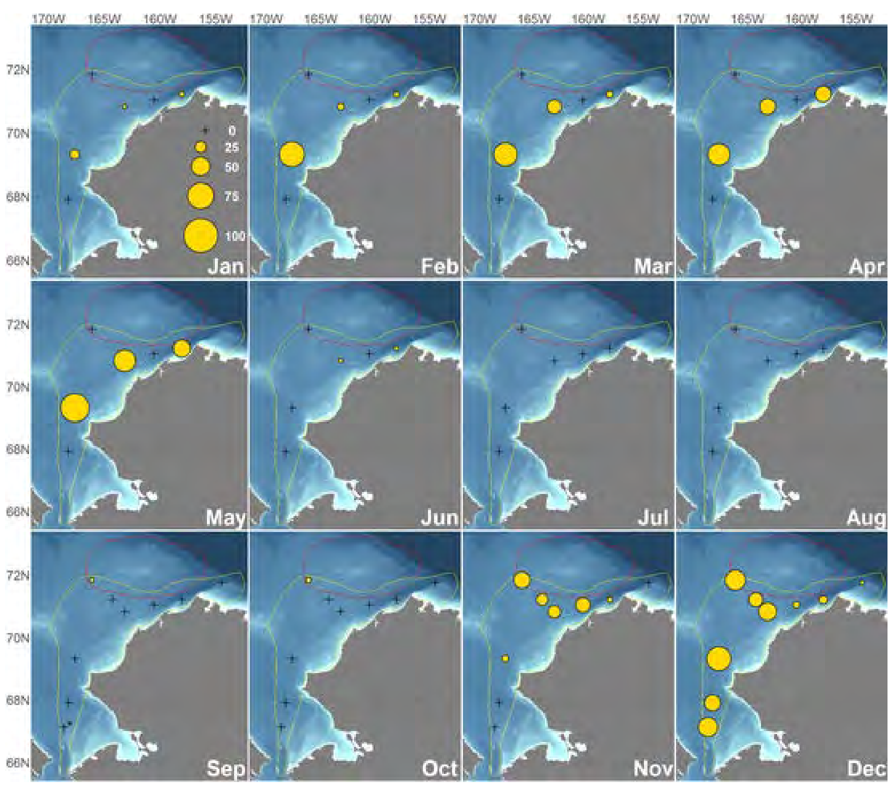

Figure 113. Monthly double knock sound distribution, 2015.

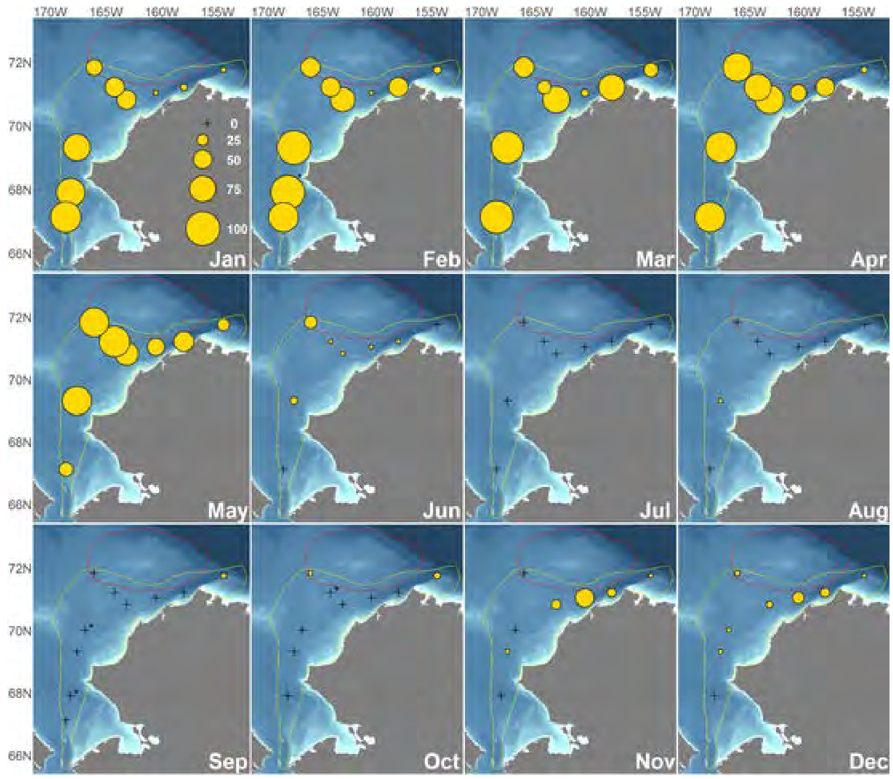

Figure 114. Monthly double knock sound distribution, 2016.

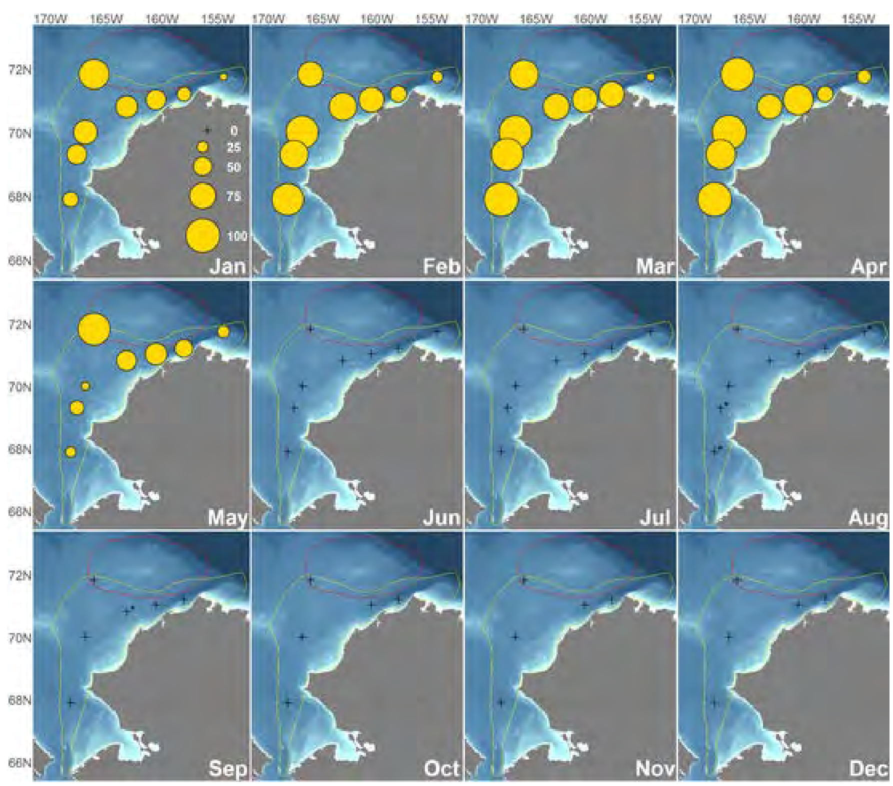

Figure 115. Monthly double knock sound distribution, 2017.

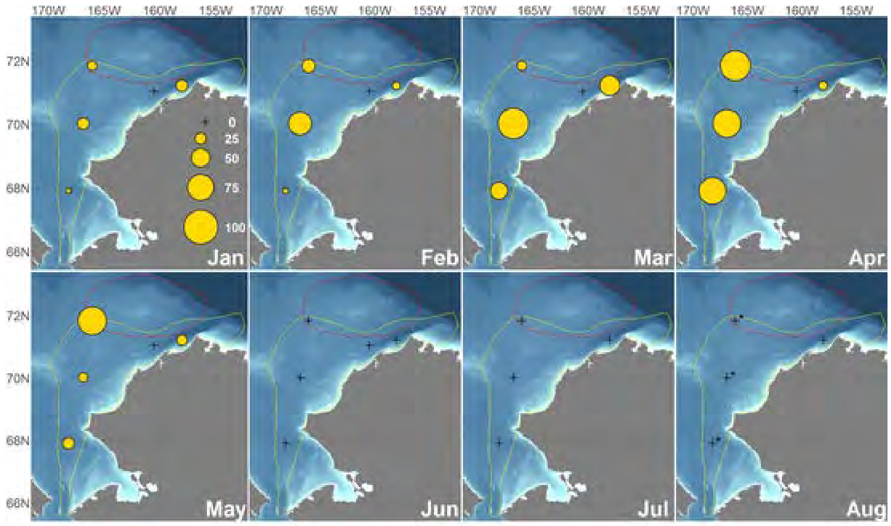

Figure 116. Monthly double knock sound distribution, 2018.

3. Environmental and anthropogenic signals

Seismic airguns

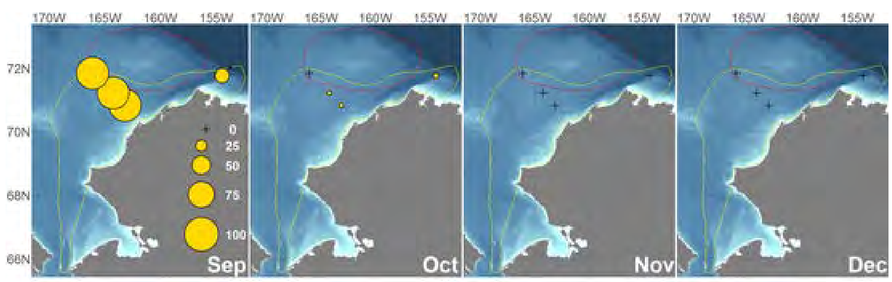

Figure 117. Monthly seismic airgun distribution, 2010.

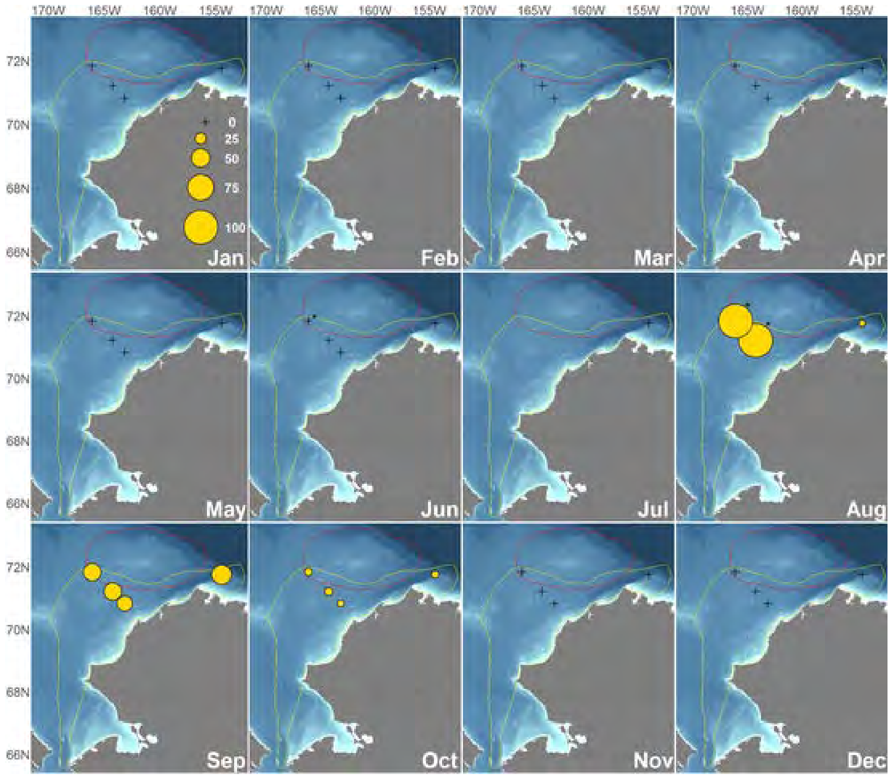

Figure 118. Monthly seismic airgun distribution, 2011.

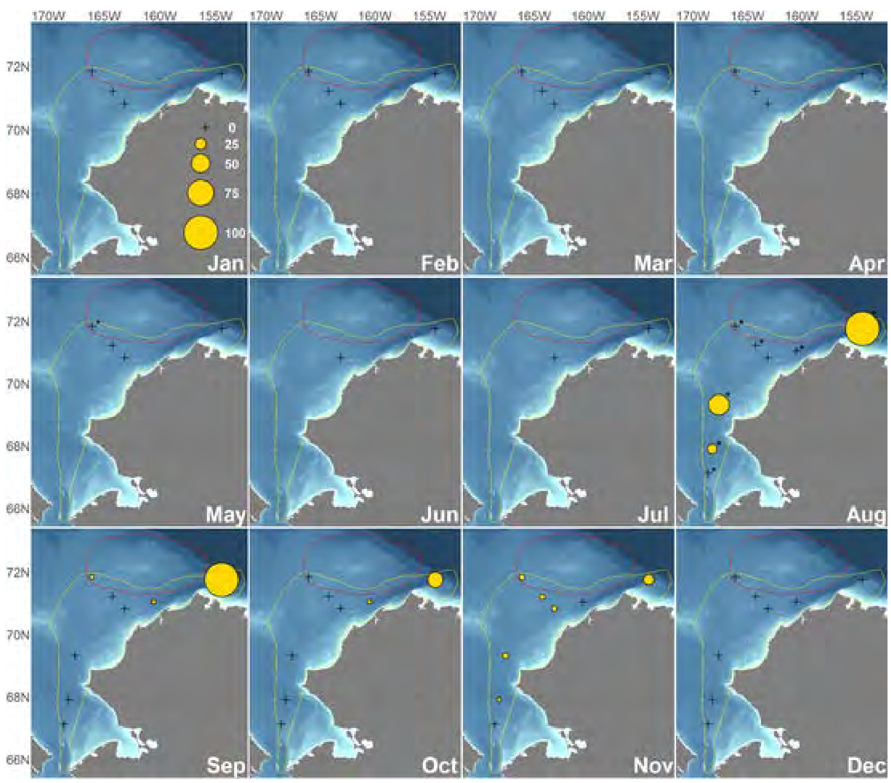

Figure 119. Monthly seismic airgun distribution, 2012.

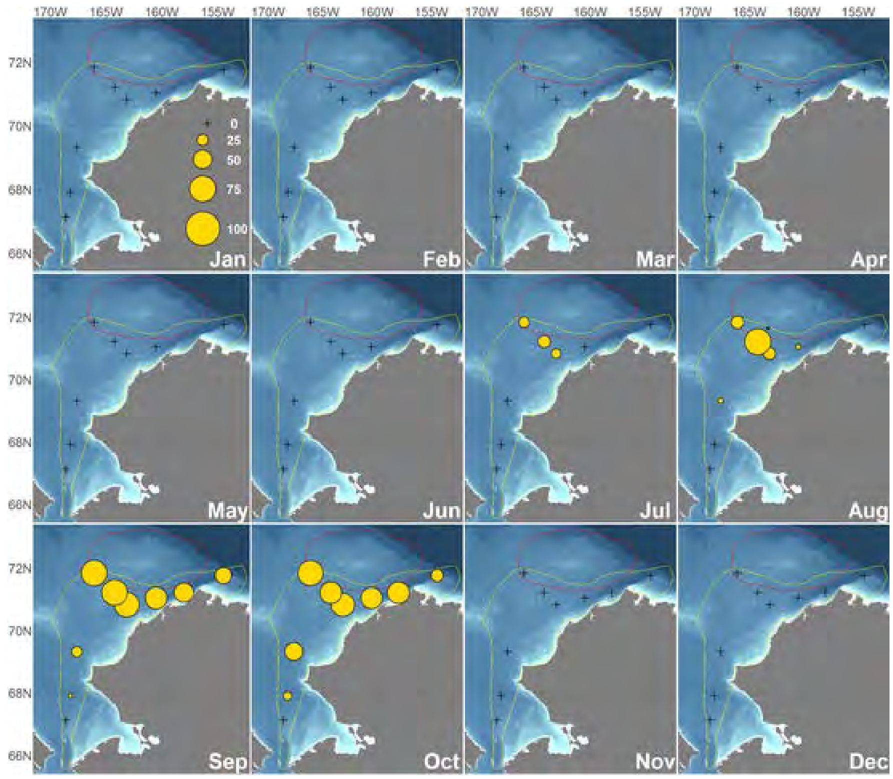

Figure 120. Monthly seismic airgun distribution, 2013.

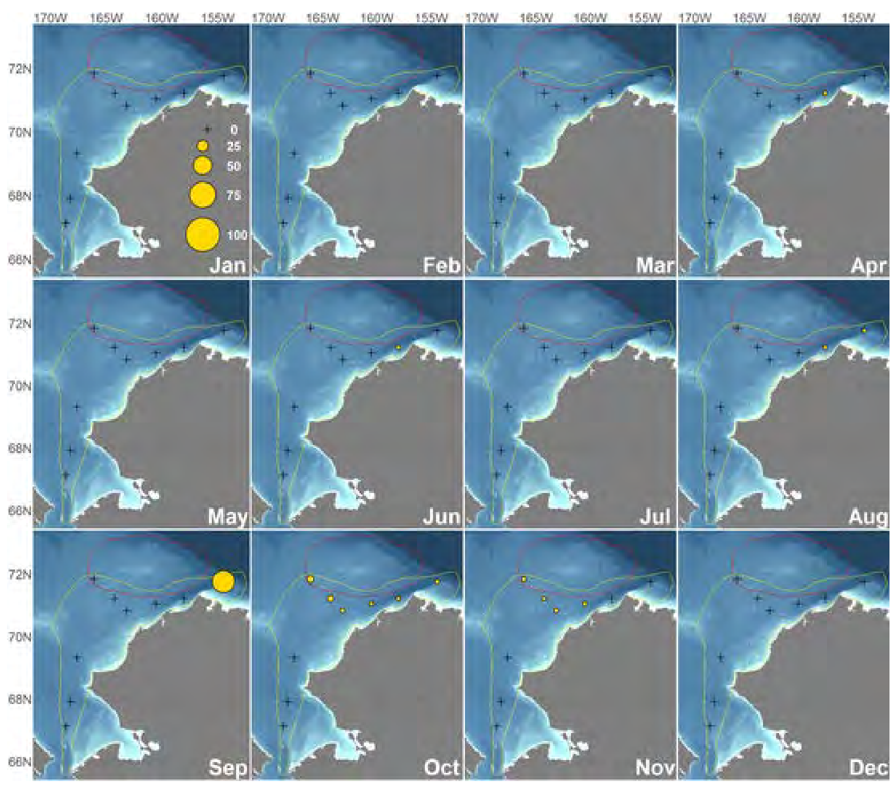

Figure 121. Monthly seismic airgun distribution, 2014.

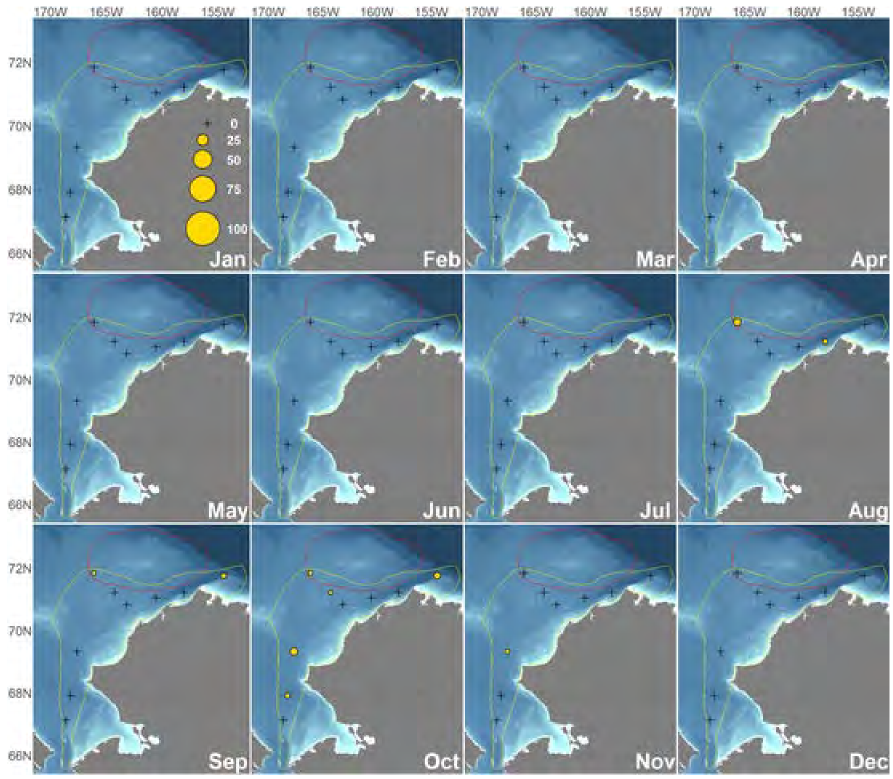

Figure 122. Monthly seismic airgun distribution, 2015.

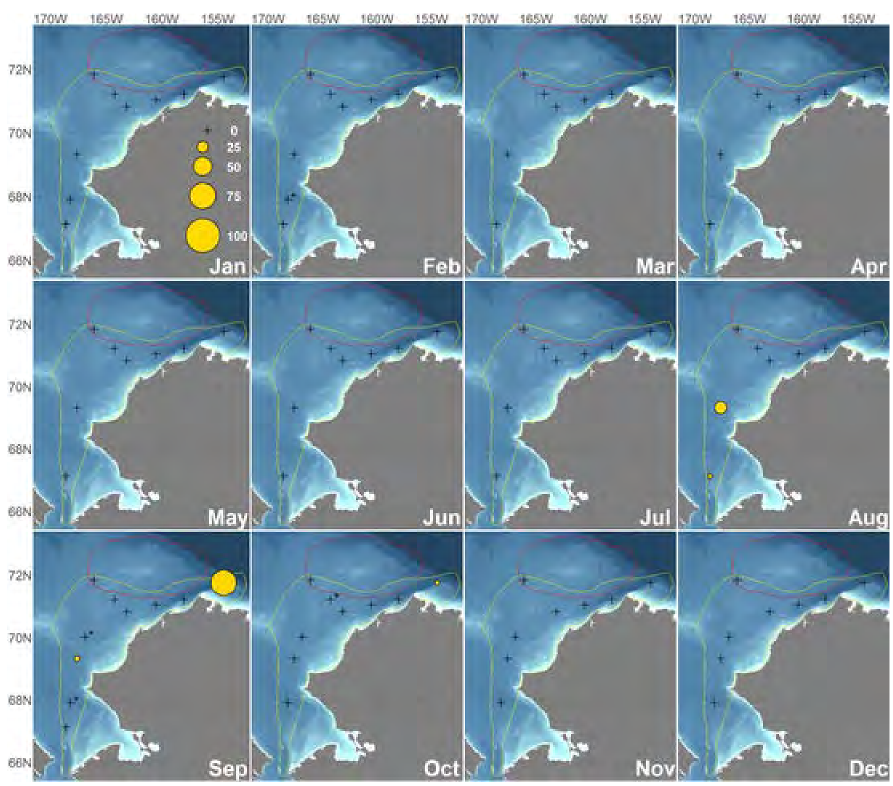

Figure 123. Monthly seismic airgun distribution, 2016.

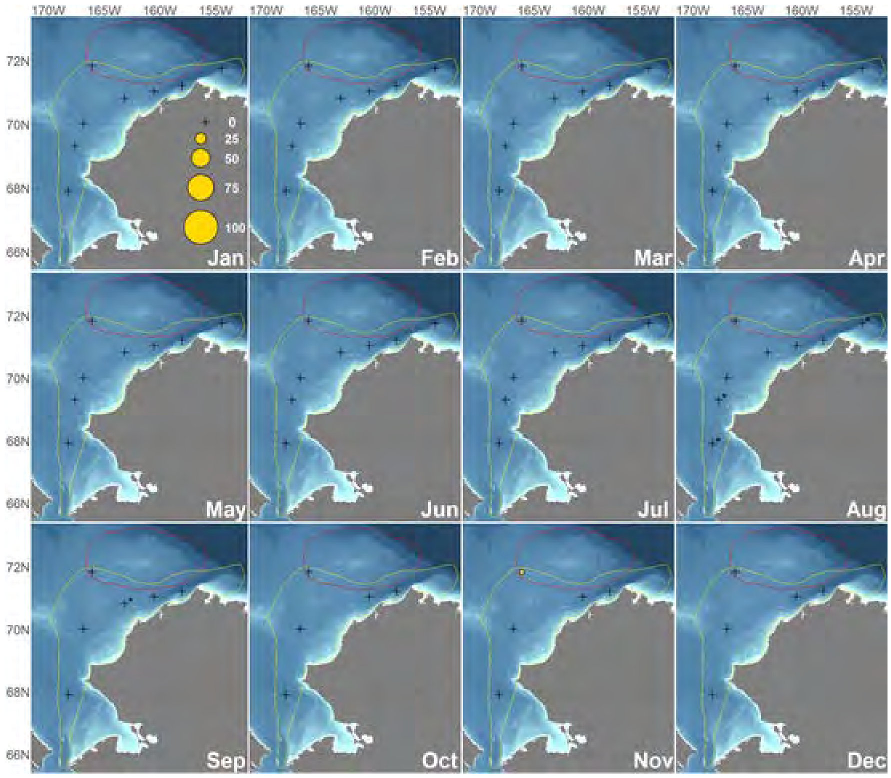

Figure 124. Monthly seismic airgun distribution, 2017.

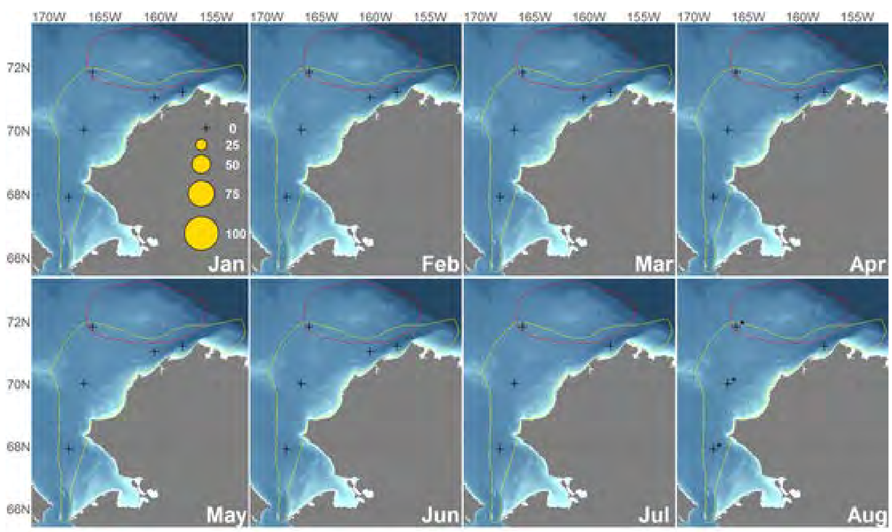

Figure 125. Monthly seismic airgun distribution, 2018.

Vessel noise

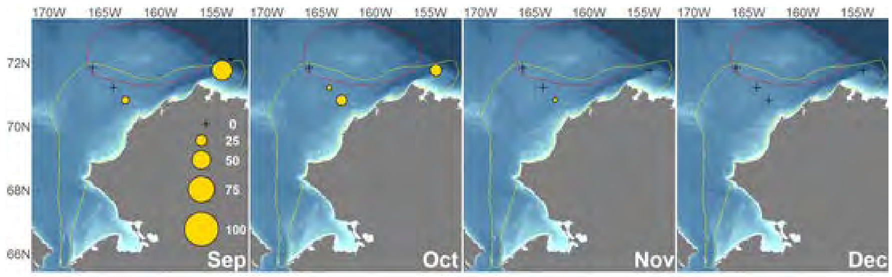

Figure 126. Monthly vessel noise distribution, 2010.

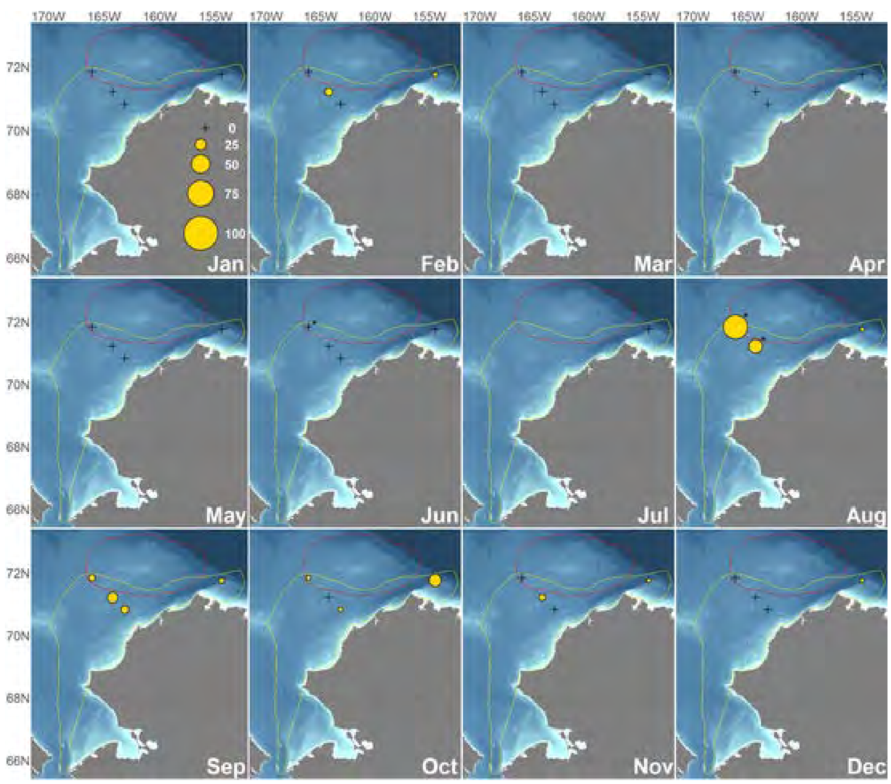

Figure 127. Monthly vessel noise distribution, 2011.

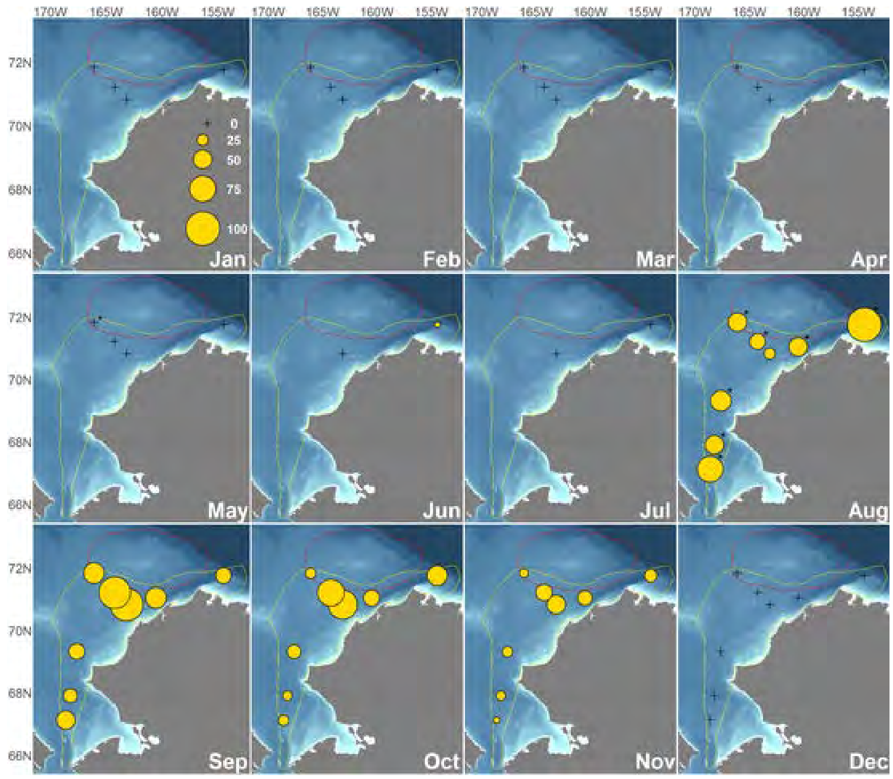

Figure 128. Monthly vessel noise distribution, 2012.

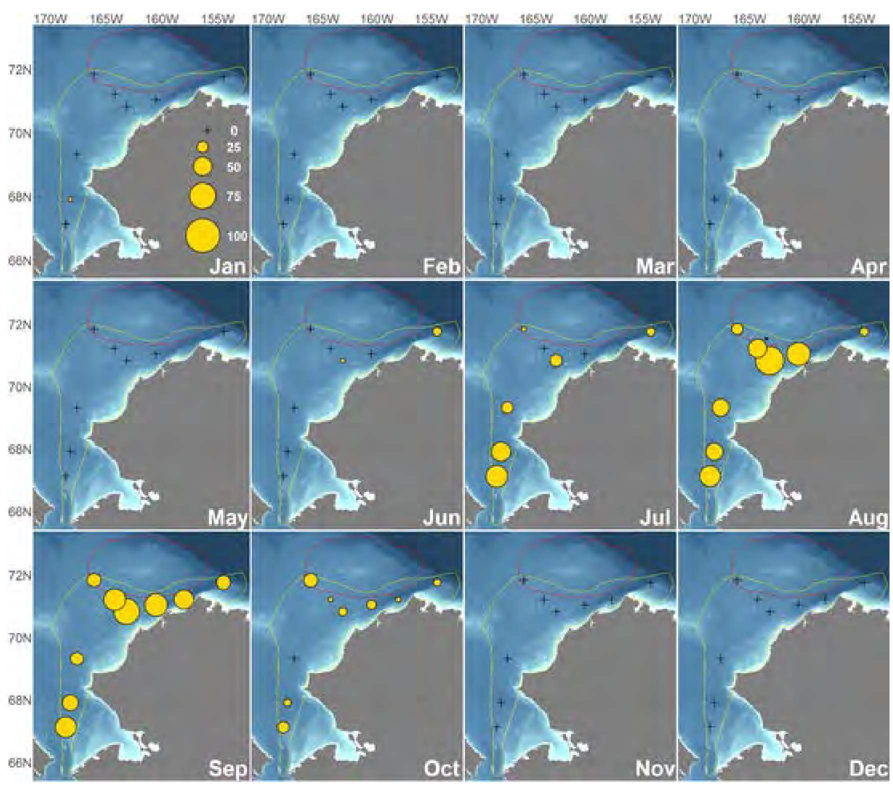

Figure 129. Monthly vessel noise distribution, 2013.

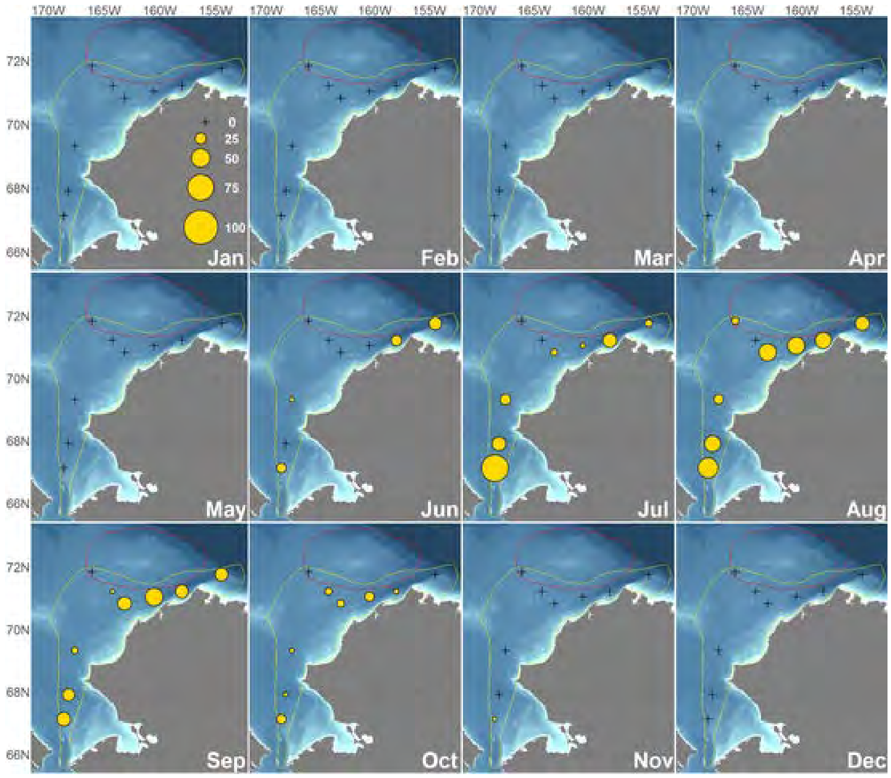

Figure 130. Monthly vessel noise distribution, 2014.

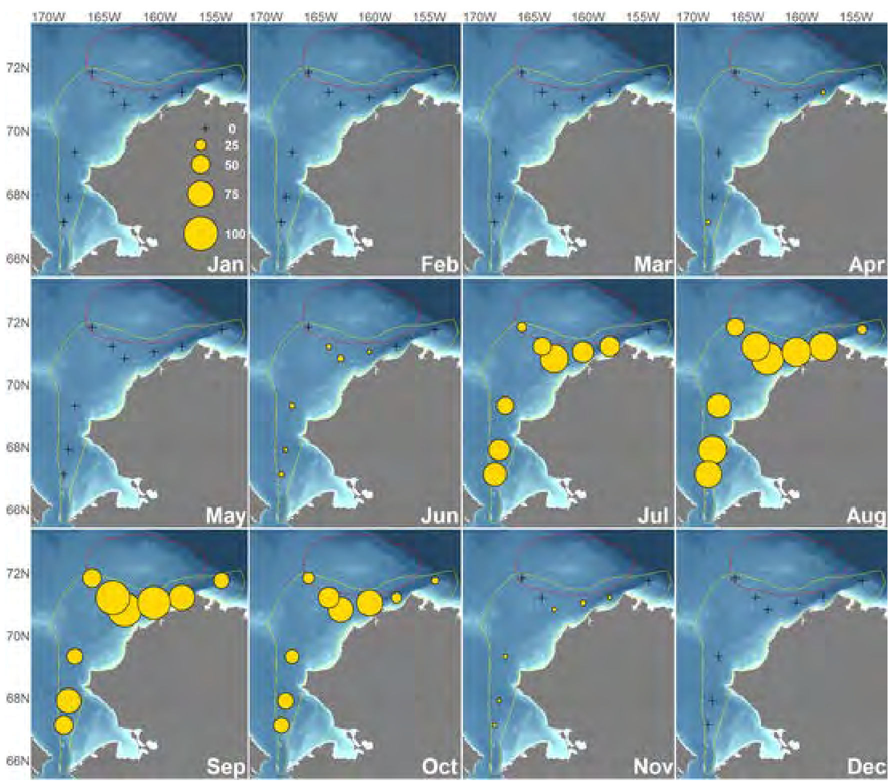

Figure 131. Monthly vessel noise distribution, 2015.

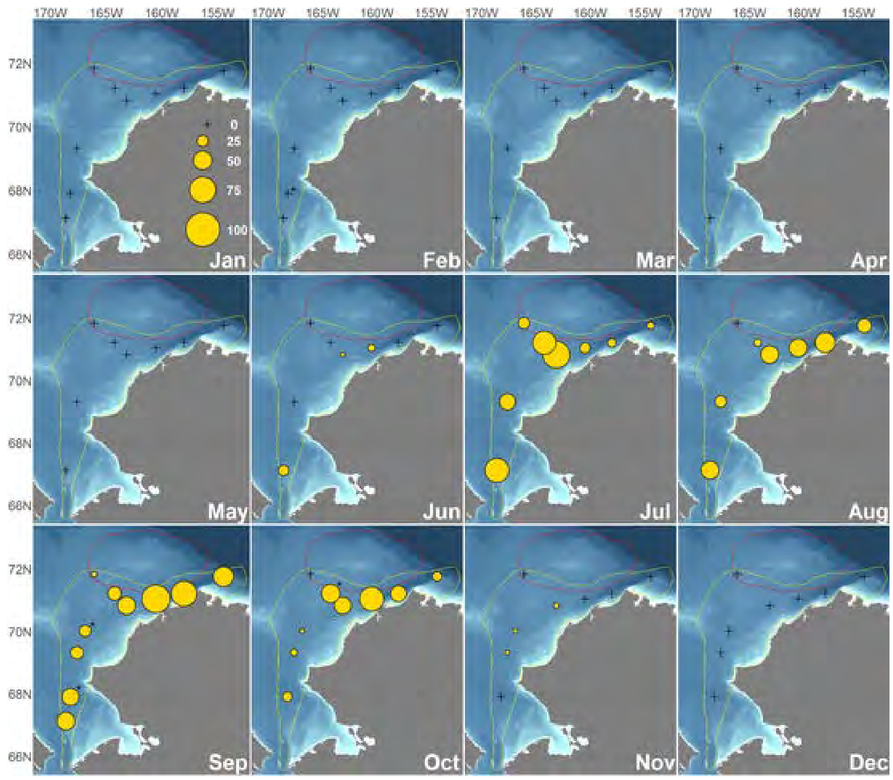

Figure 132. Monthly vessel noise distribution, 2016.

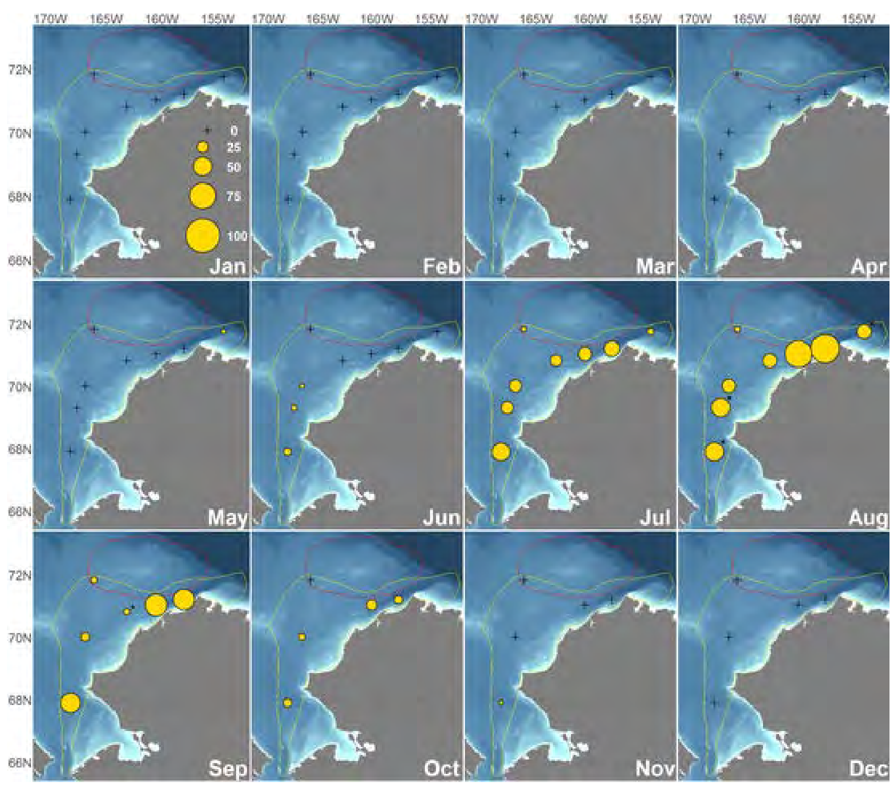

Figure 133. Monthly vessel noise distribution, 2017.

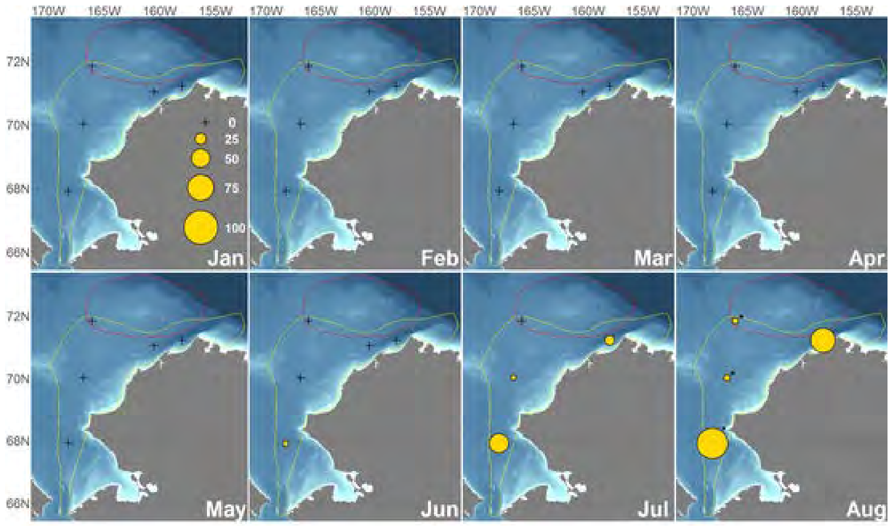

Figure 134. Monthly vessel noise distribution, 2018.

Ice noise

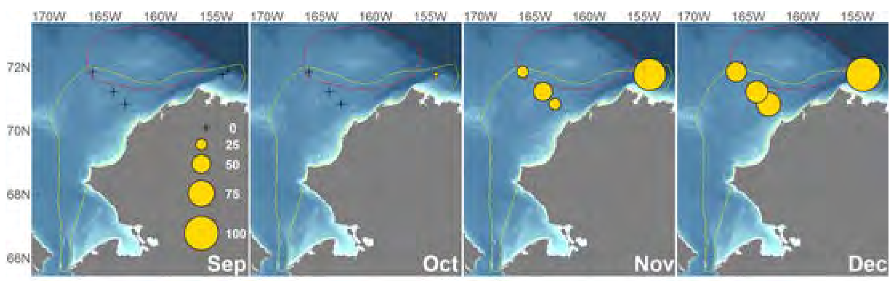

Figure 135. Monthly ice noise distribution, 2010.

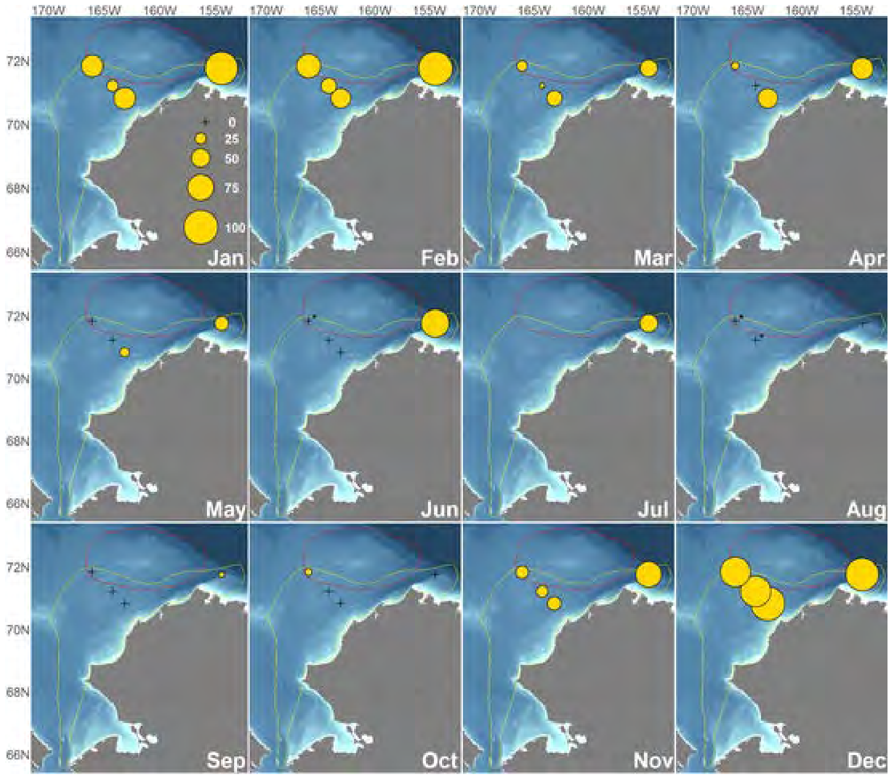

Figure 136. Monthly ice noise distribution, 2011.

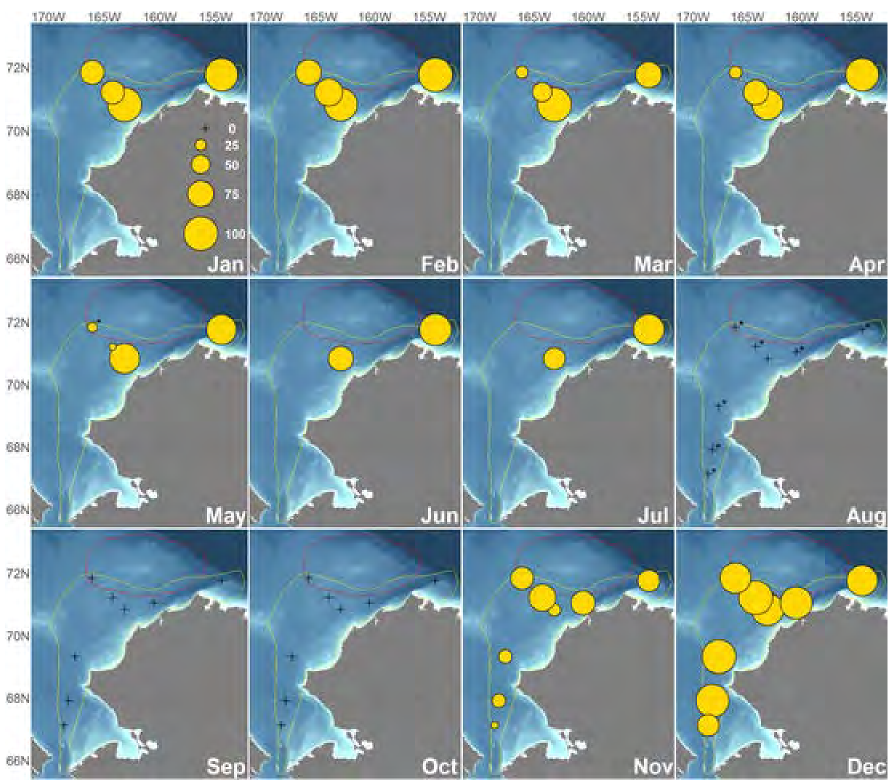

Figure 137. Monthly ice noise distribution, 2012.

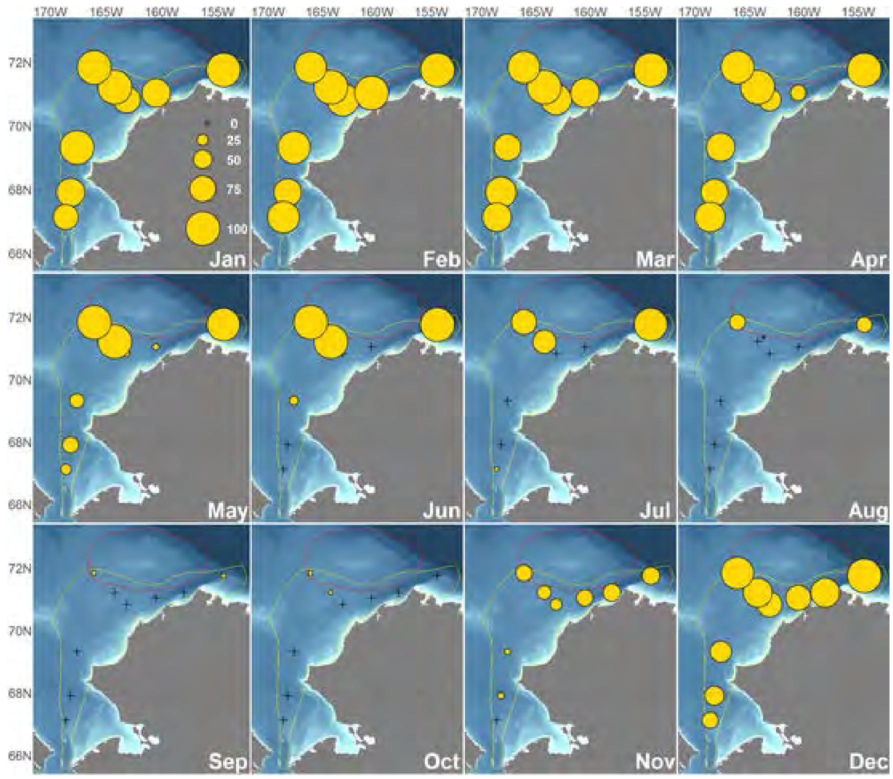

Figure 138. Monthly ice noise distribution, 2013.

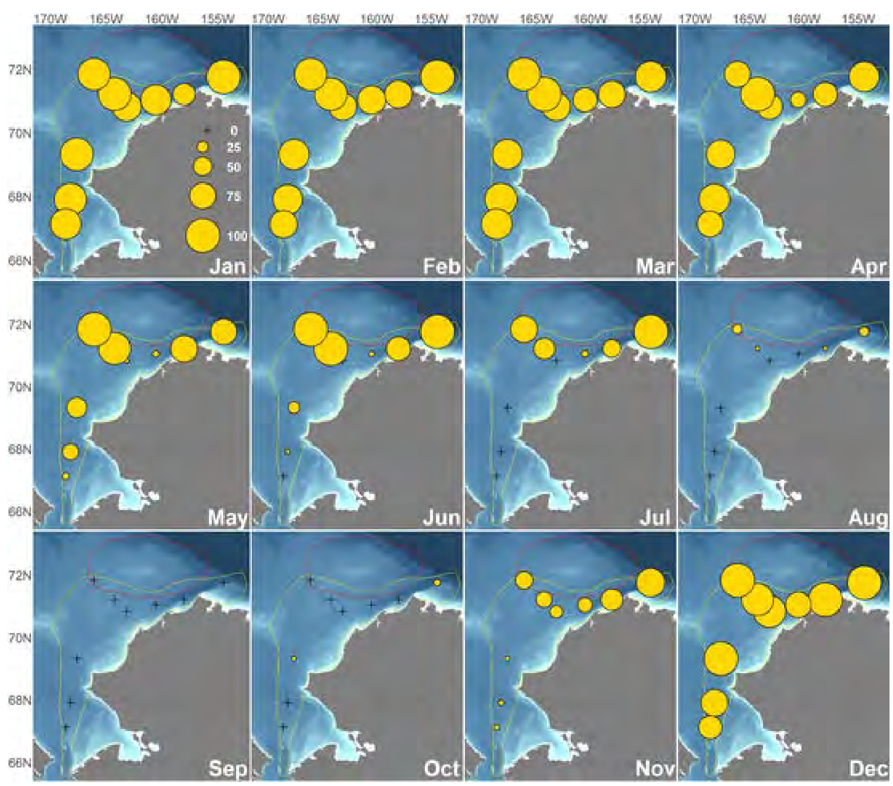

Figure 139. Monthly ice noise distribution, 2014.

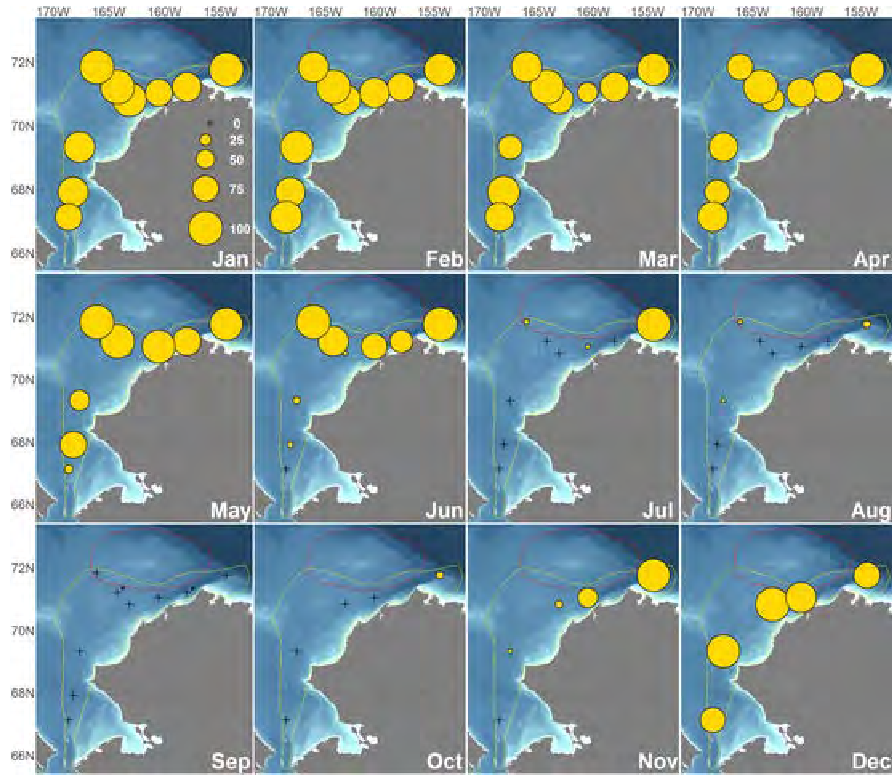

Figure 140. Monthly ice noise distribution, 2015.

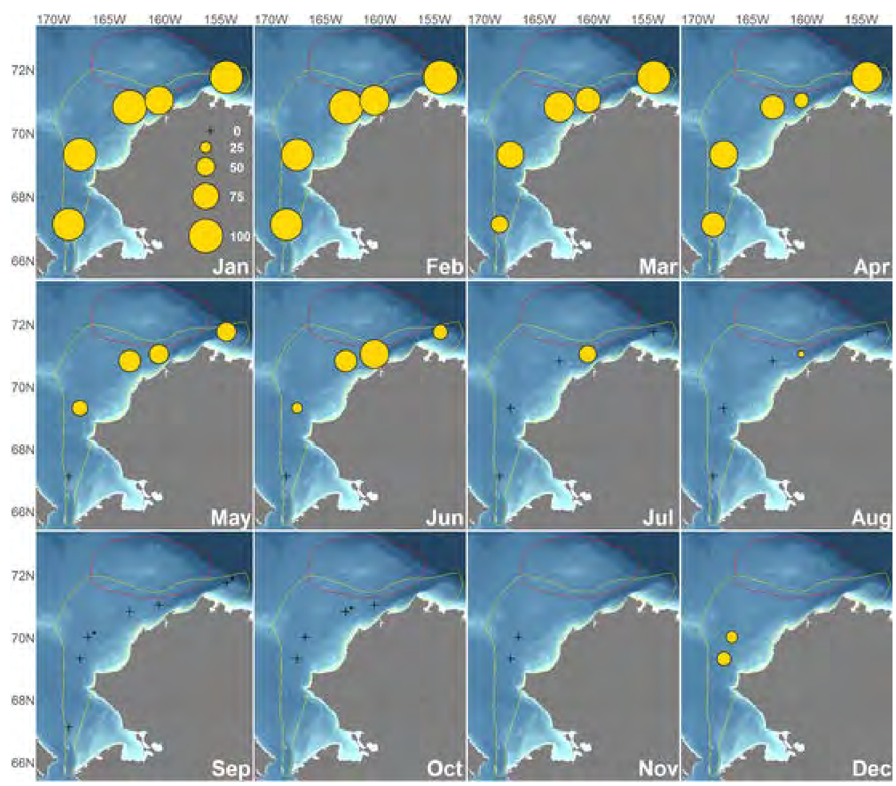

Figure 141. Monthly ice noise distribution, 2016.

D. Sonobuoy deployment data

1. 2017 Arctic IERP cruise

Complete list of all sonobuoy deployments and species detected during the 2017 Arctic IERP cruise. Detections: 0 = not detected, 1 = detected, 2 = maybe detected. Continued on next page.

Station#	Date	Time (Local)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Gunshot	Bowhead	Humpback	Fin	Orca	Walrus	Gray	Unknown
1	8/2/2017	10:10:00	56.40684	-166.931	108	0	0	0	0	0	0	0	0
2	8/2/2017	15:07:34	57.11873	-166.976	72	0	0	0	1	0	0	0	0
3	8/2/2017	19:53:54	57.80049	-166.724	66	0	0	0	2	0	0	0	0
4	8/5/2017	13:39:00	65.38658	-168.364	57	0	0	0	1	0	0	0	0
5	8/5/2017	16:26:06	65.82544	-168.326	48	0	0	0	0	0	0	0	0
6	8/5/2017	18:36:58	66.12058	-168.328	53	0	0	2	0	0	0	0	0
7	8/6/2017	13:35:52	68.76698	-167.842	49	0	0	0	0	0	0	0	0
8	8/6/2017	21:10:06	69.79559	-167.693	48	0	0	1	0	0	0	0	0
9	8/10/2017	14:58:56	71.09779	-161.793	45	0	0	0	0	0	0	0	0
10	8/10/2017	17:17:08	71.001	-161.243	50	0	0	0	0	0	0	0	0
11	8/10/2017	23:03:34	71.00252	-159.602	67	0	0	0	0	0	0	0	0
12	8/11/2017	10:03:14	70.96573	-159.162	35	0	0	1	1	0	2	1	1
13	8/11/2017	13:58:00	71.00208	-159.85	69	0	0	0	0	0	0	0	0
15	8/12/2017	16:06:26	71.50383	-158.284	63	0	0	0	0	0	0	0	0
16	8/13/2017	14:29:44	71.52541	-156.66	156	2	0	0	0	0	0	0	0
17	8/13/2017	20:34:52	71.65188	-155.004	80	0	0	0	0	0	0	0	0
18	8/14/2017	21:15:48	71.68884	-154.804	85	0	0	0	2	0	0	0	0
20	8/14/2017	10:22:44	71.91974	-153.629	950	0	0	0	0	0	0	0	0
21	8/15/2017	23:11:42	71.82619	-153.568	188	0	2	2	0	0	0	0	1
22	8/15/2017	12:34:34	71.4954	-154.125	42	0	0	0	0	0	0	0	0
24	8/15/2017	14:33:34	71.57185	-154.003	49	0	2	0	0	0	2	0	0
25	8/16/2017	10:10:34	71.71531	-155.171	250	0	0	0	0	0	0	0	0
26	8/16/2017	19:35:24	71.5303	-156.468	150	0	0	0	0	0	0	0	0
27	8/17/2017	12:45:04	71.00175	-159.861	75	1	0	0	0	0	0	0	0
28	8/17/2017	20:12:20	70.99513	-160.644	44	0	0	0	1	0	1	0	0
30	8/17/2017	23:13:02	71.00032	-161.706	46	0	0	0	2	0	1	0	0
31	8/18/2017	14:06:58	70.72109	-160.902	44	0	2	2	0	2	1	0	0
32	8/18/2017	22:35:00	70.49979	-162.474	33	0	0	0	0	0	0	0	0
33	8/19/2017	8:28:04	70.64068	-162.678	39	0	0	2	0	0	1	0	0
34	8/19/2017	10:30:40	70.8143	-163.077	44	0	0	0	0	0	0	0	0
35	8/19/2017	13:20:48	70.99172	-163.581	45	0	0	0	0	0	0	0	1
36	8/19/2017	16:50:22	71.27716	-164.424	45	0	0	0	0	0	2	0	1
37	8/19/2017	22:03:40	71.50156	-164.757	42	0	0	0	0	0	0	0	1

Station#	Date	Time (Local)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Gunshot	Bowhead	Humpback	Fin	Orca	Walrus	Gray	Unknown
38	8/22/2017	18:25:22	67.85551	-168.374	52	0	0	1	2	0	0	1	0
39	8/22/2017	22:03:58	67.57097	-168.857	49	0	0	0	0	0	0	0	0
40	8/23/2017	10:25:48	65.94993	-168.188	47	0	0	0	0	0	0	0	0
41	8/23/2017	13:07:00	65.57562	-168.195	38	0	0	0	0	0	0	0	0
42	8/23/2017	15:59:44	65.21443	-168.095	47	0	0	0	1	0	0	0	0
43	8/23/2017	20:19:54	64.82046	-167.585	32	0	0	0	1	0	0	0	0

2. 2018 Healy cruise

Complete list of all sonobuoy deployments and species detected during the 2018 Healy cruise.
Detections: 0 = not detected, 1 = detected, 2 = maybe detected.

Station #	Date	Time (Local)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Humpback	Bowhead	Bearded	Fin	Killer	Walrus	Unid Pinn.	Beluga
5	8/9/2018	14:58:01	67.24804	168.54472	46.3	0	0	0	0	0	0	0	0
6	8/9/2018	18:40:59	67.99483	167.4065	53.3	2	0	0	0	0	0	0	0
7	8/10/2018	6:58:55	67.99252	167.93881	54.9	0	0	0	2	0	0	0	0
9	8/11/2018	6:14:30	68.93449	167.84682	50.2	0	0	0	0	0	0	0	0
10	8/11/2018	22:15:40	70.34962	167.60439	50.8	0	0	0	0	0	0	0	0
11	8/12/2018	18:19:33	71.58894	165.25241	43.2	0	0	0	0	0	0	0	0
12	8/14/2018	17:04:00	71.01906	160.63544	45.8	0	0	0	0	0	0	0	0
13	8/15/2018	20:38:46	71.76143	161.53851	45	2	2	0	0	0	0	2	0
14	8/16/2018	15:22:34	71.3672	157.59066	113	0	0	0	0	0	1	0	0
15	8/17/2018	21:18:40	71.7501	154.45196	78.7	0	0	0	0	0	0	0	0
16	8/18/2018	8:35:33	71.79917	153.66272	144	0	0	0	0	0	0	0	0
17	8/18/2018	13:12:49	71.52961	154.05795	50.9	0	0	0	0	0	0	0	0
19	8/18/2018	20:39:22	71.83741	155.99488	84.7	0	0	1	0	0	1	0	0
20	8/19/2018	9:59:17	72.29189	155.64239	2082	0	0	0	0	0	0	0	0
21	8/19/2018	13:39:16	72.1489	155.3647	412.2	0	0	0	0	0	0	0	0
22	8/19/2018	13:41:12	72.1492	155.36034	414.1	0	1	0	0	0	0	0	1
23	8/19/2018	18:26:05	71.95901	155.18742	265	0	0	0	0	0	0	0	0
24	8/20/2018	6:17:07	71.9559	156.60587	80	0	0	0	0	0	0	0	0
25	8/20/2018	10:11:25	72.22511	156.5953	270	0	0	0	0	0	0	0	0
27	8/20/2018	21:19:43	72.77993	156.93959	1786.5	0	0	0	0	0	0	0	0
28	8/21/2018	1:22:19	72.67899	157.49027	446.3	0	0	0	0	0	0	0	0
29	8/21/2018	5:38:59	72.39037	158.12202	66	0	0	0	0	0	0	0	0
30	8/21/2018	8:04:00	72.32396	157.17758	200	0	0	0	0	0	0	0	0
31	8/21/2018	11:39:45	72.29362	155.6342	1200	0	0	0	0	0	0	0	0
33	8/21/2018	18:39:33	71.77397	158.25613	57.2	0	0	0	0	0	0	0	0
34	8/22/2018	10:46:05	70.29029	168.39069	45	0	0	0	0	0	0	0	0
35	8/22/2018	19:34:06	69.88473	166.80583	47.7	0	0	0	0	0	0	0	0
36	8/22/2018	23:07:32	69.60932	165.82921	39.9	0	0	0	0	0	0	0	0
37	8/23/2018	1:58:38	69.48875	165.37231	34.8	0	0	0	0	0	0	0	0
38	8/23/2018	6:05:01	68.83957	167.27946	46	0	0	0	0	0	0	0	0
39	8/23/2018	8:35:33	68.3009	167.80952	51	0	0	0	0	0	0	0	0
40	8/23/2018	10:52:08	67.79207	168.0073	55	0	0	0	1	0	0	0	0
41	8/23/2018	13:05:48	67.27912	168.17791	43	0	0	0	0	1	0	0	0
42	8/23/2018	15:41:33	66.65842	168.37969	36.1	0	0	0	0	0	0	0	0
44	8/23/2018	18:01:57	66.12548	168.44211	56.8	0	0	0	0	0	0	0	0

E. Supplemental Bering Sea data

The fall 2018 cruise was cancelled and PMEL acquired the charter vessel F/V Aquila for the mooring work. The AL17_AU_NS1 mooring, just south of Nome, was retrieved by the R/V Siquliaq in 2018, as no NOAA cruises were passing by that area. In addition, extremely bad weather reduced the number of workable days during the fall 2018 cruise and the BS1 and BS2 mooring sites could not be reached; a mooring (BS9) was deployed as close to the BS2 site as was possible given the time limitations. Drs. Craig Lee (APL/UW) and Bob Pickart (WHOI) kindly retrieved these moorings during their HLY18-02 and HLY18-03 cruises, respectively. Table 2 and Table 3 list all mooring recoveries and deployments in 2017 and 2018.

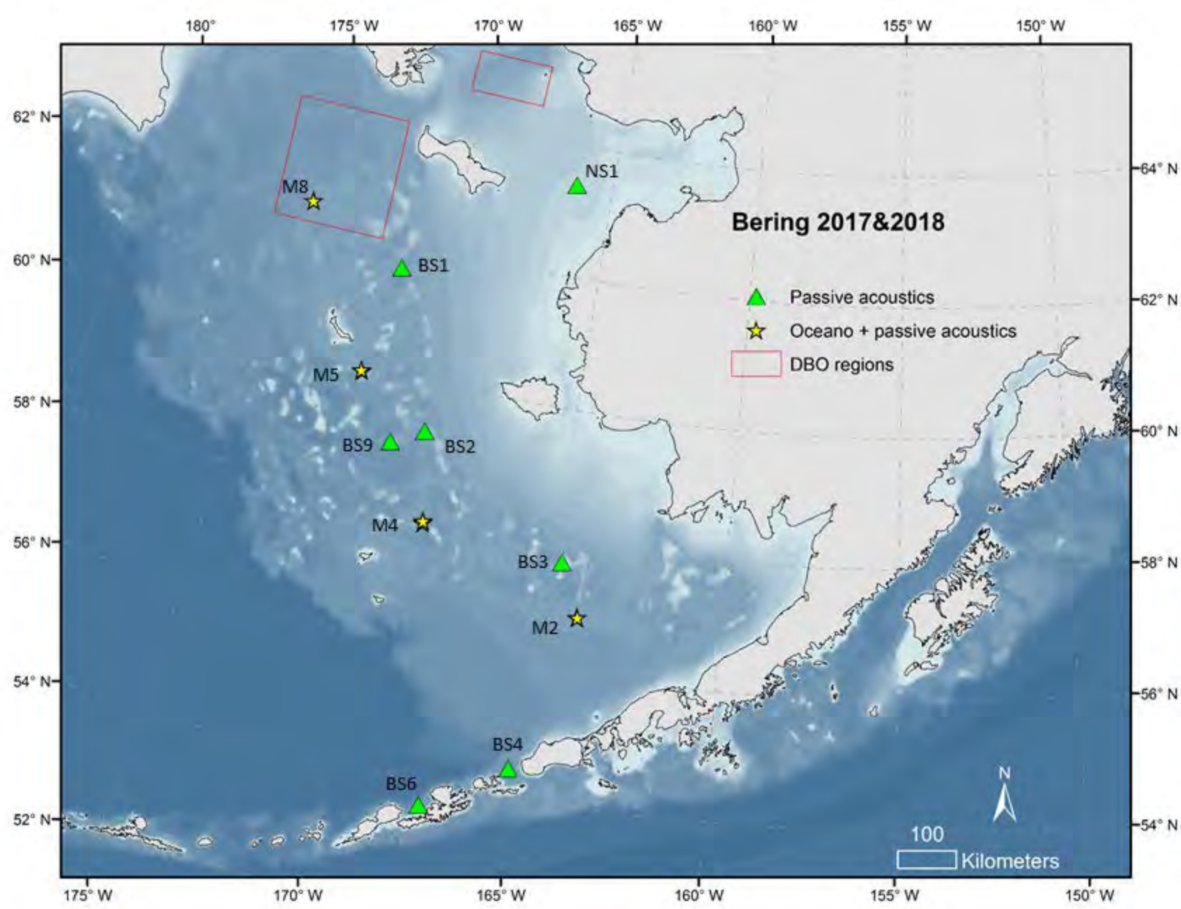

Figure 142. Moorings retrieved and deployed in the Bering Sea during the 2017 and 2018 Spring and Fall PMEL mooring cruises or by scientists on other cruises (see text for details). Passive acoustic moorings are shown with green triangles, while integrated oceanographic/passive acoustic moorings are yellow stars.

Table 42. All passive acoustic recorder and deployment information, Bering Sea 2016-2018.

Mooring	Mooring Cluster	Latitude (°N)	Longitude (°W)	Water depth (m)	Recorder Start Date	Recorder End Date	Number of Days with Data	Sampling Rate (Hz)	Duty Cycle (min on/ min total)	Deployment Date	Retrieval Date
AL16_AU_NS1	-	63.399	166.236	23.0	9/25/2016	8/4/2017	9-Nov-00	16384	80/300	9/24/2016	8/4/2017
BS16_AU_08a	M8	62.198	174.687	73	9/27/2016	9/29/2017	368	16384	80/300	9/26/2016	9/29/2017
BS16_AU_05a	M5	59.911	171.731	68	9/28/2016	9/27/2017	365	16384	80/300	9/26/2016	9/27/2017
BS16_AU_04a	M4	57.895	168.878	70	9/29/2016	10/2/2016	4	16384	80/300	9/27/2016	9/25/2017
BS16_AU_02b	M2	56.870	164.066	71	9/30/2016	2/27/2017	151	16384	80/300	9/29/2016	2/27/2017
AL17_AU_NS1	-	63.399	166.236	25	8/6/2017	6/24/2018	323	16384	80/300	8/4/2017	6/24/2018
BS17_AU_08a	M8	62.199	174.678	74.17	10/1/2017	10/11/2018	376	16384	80/300	9/29/2017	10/11/2018
AL17_AU_BS1	-	61.588	171.312	54	9/29/2017	10/16/2018	383	16384	80/300	9/28/2017	10/16/2018
BS17_AU_05a	M5	59.915	171.718	70	9/29/2017	10/9/2018	376	16384	80/300	9/28/2017	10/9/2018
AL17_AU_BS2	-	59.234	169.408	55	10/2/2017	11/17/2018	412	16384	80/300	10/1/2017	11/17/2018
BS17_AU_04a	M4	57.872	168.892	71.59	9/27/2017	10/7/2018	376	16384	80/300	9/26/2017	10/7/2018
AL17_AU_BS3	-	57.671	164.717	54	10/3/2017	MIA	-	16384	80/300	10/1/2017	MIA
BS17_AU_02b	M2	56.873	164.054	72.6	10/3/2017	5/1/2018	211	16384	80/300	10/1/2017	4/30/2018
BS17_AU_02a	M2	56.871	164.050	70	5/8/2017	10/1/2017	147	16384	180/300	4/27/2017	10/1/2017
AL17_AU_BS4	-	54.427	165.269	162	10/4/2017	10/8/2017	5	16384	80/300	10/3/2017	9/30/2018
AL17_AU_BS6	-	53.634	167.404	92	5/8/2017	DPLYD	-	16384	80/300	5/7/2017	DPLYD
BS18_AU_08a	M8	62.195	174.684	73	10/13/2018	DPLYD	-	16384	80/300	10/11/2018	DPLYD
BS18_AU_05a	M5	59.900	171.707	71	10/11/2018	DPLYD	-	16384	80/300	10/8/2018	DPLYD
AL18_AU_BS9		58.967	170.347	70	10/9/2018	DPLYD	-	16384	80/300	10/8/2018	DPLYD
BS18_AU_04a	M4	57.866	168.884	72	10/9/2018	DPLYD	-	16384	80/300	10/7/2018	DPLYD
AL18_AU_BS3		57.672	164.718	56	10/8/2018	DPLYD	-	16384	80/300	10/6/2018	DPLYD
BS18_AU_02a	M2	56.933	164.060	71.21	5/4/2018	10/1/2018	151	16384	180/300	5/2/2018	10/1/2018
BS18_AU_02b	M2	56.869	164.060	70	10/3/2018	DPLYD	-	16384	130/300	10/2/2018	DPLYD
AL18_AU_BS4		54.428	165.269	166	10/2/2018	DPLYD	-	16384	30-Aug	9/30/2018	DPLYD