Arctic Long-Term Integrated Mooring Array (ALTIMA)

2016 Cruise Report

Marine Mammal Laboratory, Alaska Fisheries Science Center (AFSC)
Resource Assessment and Conservation Engineering Division, AFSC
Pacific Marine Environmental Laboratory
NOAA, Seattle, WA

Submitted to
The Bureau of Ocean Energy Management
under Inter-Agency Agreement Number
M12PG00021 (AKC 108)
October 2016

This report was prepared by:
Jessica L. Crance[1], M.S.; Catherine L. Berchok[1], Ph.D.; Brenda K. Rone[1], M.S.; Phyllis J. Stabeno[2], Ph.D.; Sigrid Salo[2], M.S.; Morgan Busby, M.S.[3]; Libby Logerwell[3], Ph.D.; Kathy Kuletz[4], Ph.D.

[1] Marine Mammal Laboratory, Alaska Fisheries Science Center
[2] Pacific Marine Environmental Laboratory, NOAA
[3]Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center
[4]U.S. Fish and Wildlife Service, Anchorage, AK

SUMMARY

The 2016 Arctic Long-Term Integrated Mooring Array (ALTIMA) cruise took place on board the F/V *Aquila*. The cruise began in Nome, AK on 3 September 2016 and ended in Dutch Harbor, AK on 29 September 2016. Chief Scientist was Dr. Catherine Berchok, and the survey team consisted of 14 scientists representing eight different laboratories or institutions (for full personnel list, see Appendix 1). In summary, a total of 18 passive acoustic, 14 oceanographic, and 5 combination (oceanographic/ passive acoustic) moorings were retrieved, and 19 passive acoustic, 18 oceanographic, and 5 combination moorings were redeployed. A total of 71 CTD casts were conducted, 48 zooplankton net tows were done, one drifter was deployed, ~2700 nm were sampled using a new underway oceanographic sampling system, and a new acrobat towfish sampled ~270 nm. A total of 142 sonobuoys were deployed for 24 hour passive acoustic monitoring, and over 1140 nm were surveyed for marine mammals and 126 hours were surveyed for seabirds.

BACKGROUND

The western Arctic physical climate is rapidly changing. The Arctic sea ice extent reached a new low in maximum extent on March 24, 2016, breaking the record for the second year in a row (http://tinyurl.com/gw5xoo8). The maximum extent was 14.52 million square kilometers which is 1.12 million square kilometers below the 1981 to 2010 average of 15.64 million square kilometers. The speed of this ice loss was unexpected, as the consensus of the climate research community was that this level of ice reduction would not be seen for another thirty years. As sea temperature, oceanographic currents, and prey availability are altered by climate change, parallel changes in baleen whale species composition, abundance and distribution are expected (and evidenced already by local knowledge and opportunistic sightings). In addition, the observed northward retreat of the minimum extent of summer sea ice has the potential to create opportunities for the expansion of oil and gas-related exploration and development into previously closed seasons and localities in the Alaskan Arctic. It will also open maritime transportation lanes across the Arctic adding (to a potentially dramatic degree) to the ambient noise in the environment. This combination of increasing anthropogenic impacts, coupled with the steadily increasing abundance and related seasonal range expansion by bowhead (*Balaena mysticetus*), gray (*Eschrichtius robustus*), humpback (*Megaptera novaeangliae*) and fin whales (*Balaenoptera physalus*), mandates that more complete information on the year-round presence of large whales is needed in the Chukchi Sea planning area. Timing and location of whale migrations may play an important role in assessing where, when, or how exploration or access to petroleum reserves may be conducted, to mitigate or minimize the impact on protected species.

The ALTIMA cruise was funded by NOAA's Office of Oceanic and Atmospheric Research (OAR), with supplemental funding from the Bureau of Ocean Energy Management (BOEM) through the Arctic Whale Ecology Study (ARCWEST). We were able to maintain our long-term datasets begun under several BOEM-funded studies: North Pacific Right Whale (PRIEST), Bowhead Feeding Ecology Study (BOWFEST), Chukchi Acoustics, Oceanography, and Zooplankton study (CHAOZ), the CHAOZ-Extension study (CHAOZ-X), and ARCWEST. There were four components to the cruise: mooring deployments (passive acoustic, oceanographic, and zooplankton), biophysical sampling stations (CTD and net tows), visual surveys for marine mammals and seabirds, and passive acoustic monitoring for marine mammals. Passive acoustic moorings provide year-round assessments of the seasonal occurrence of baleen whales. Concurrently deployed, and collocated, bio-physical moorings offer the potential of correlating whale distribution with biological and physical oceanographic conditions and indices of potential prey density. Underway surveys and sampling provide fine-scale distributional data that can be used to ground truth data from the long term moorings. Satellite-tracked ocean current drifters will examine potential pathways to the areas of high biological importance. Our goal is to use these tools to understand the mechanisms responsible for the high biological activity so that we can predict, in a qualitative way, the effects of climate change on these preferred habitats.

As in previous years, funding was provided by NOAA/OAR and ARCWEST to retrieve and deploy the oceanographic and combination oceanographic/passive acoustic moorings in the Bering Sea. Funds to retrieve two autonomous wave gliders were provided by the NOAA Arctic Research Program.

OBJECTIVES

There were nine main objectives for the ALTIMA cruise:

1. Retrieve and/or (re)deploy long-term passive acoustic, oceanographic, and zooplankton moorings in the Bering, Chukchi, and western Beaufort Seas, to continue the year-round multi-disciplinary time series started in the Arctic in 2010.
2. Conduct CTD casts and zooplankton net tows along pre-determined transect lines.
3. Deploy a towed oceanographic instrument that can survey the water column while underway.
4. Conduct 24/7 passive acoustic monitoring for marine mammals using sonobuoys.
5. Conduct marine mammal visual surveys during daylight hours using 25x Big Eye binoculars. Time allowing and species-dependent, photos will be taken for photo-identification purposes.
6. Deploy a satellite ARGOS drifter drogued to 30 m.
7. Survey along additional Distributed Biological Observatory (DBO) transect lines to add to the long-term DBO time series.
8. Recover two (2) autonomous wave gliders.
9. Conduct a sea bird survey.

OVERVIEW

An overview of the activities undertaken during the 2016 ALTIMA cruise is represented in Figure 1. Please see the report below for descriptions of the stations and activities.

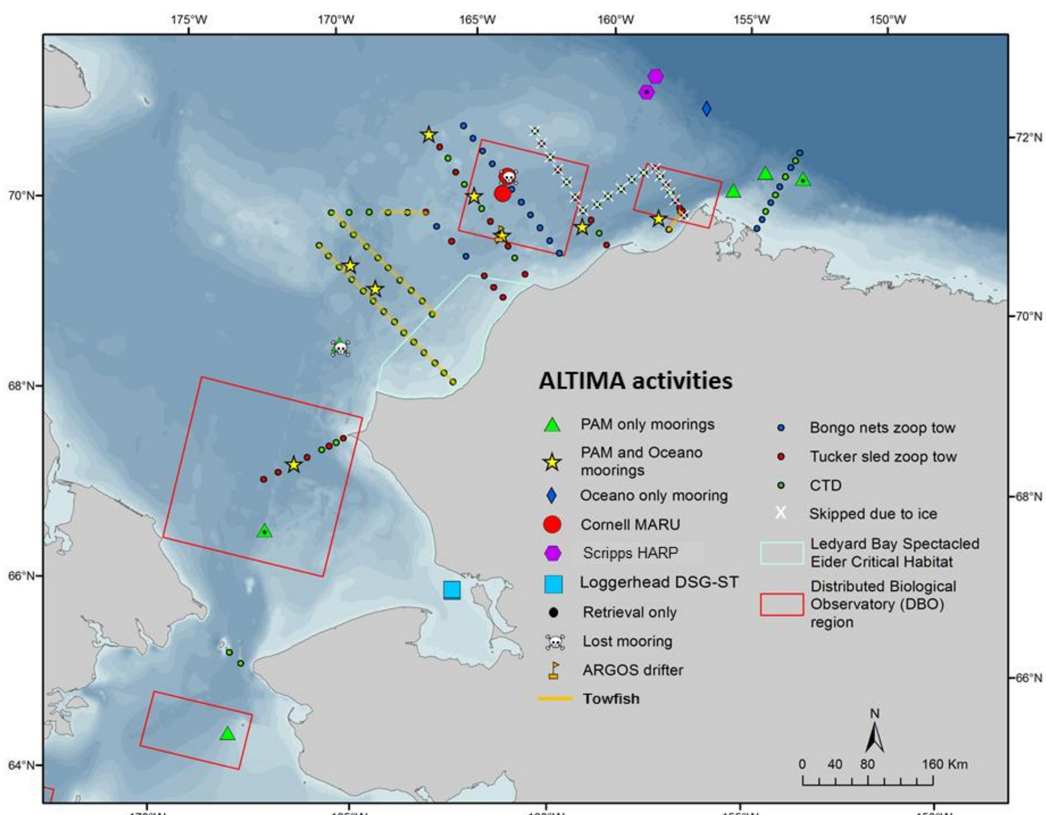


Figure 1. Overview of activities undertaken in the study area during the 2016 ALTIMA cruise.

RESULTS

Passive Acoustic Component

Mooring deployments -MML

All MML passive acoustic recorder moorings (Figure 2, Appendix 4) use Autonomous Underwater Recorder for Acoustic Listening (AURAL, Multi-Électronique, Rimouski, QC) instruments. These AURALs record for a full year at a sampling rate of 16 kHz on a duty cycle of 80 minutes of recordings made every 5 hours. This duty cycle staggers the recording loop so that the recording period advances by one hour each day. This overall pattern repeats every six days, producing a large data set for all time periods equally.

Figure 2. Long-term passive acoustic mooring being deployed.

In 2015, 17 AURAL moorings were deployed in the Bering, Chukchi, and western Beaufort (Table 1, Figures 3,4). In addition, five[1] AURAL recorders were deployed on non-BOEM, PMEL moorings in the Bering Sea (Table 1 and Figure 4, M2, M4, M5, M8), and one AURAL recorder was deployed under NOAA S&T funds in Norton Sound, for a total of 23 recorders deployed. All but one (CL1, Figure 3) of these moorings were successfully retrieved in 2016. The CL1 mooring did not respond to interogation commands and was not located after a box search was conducted. All but 2 of the moorings (KZ1, BF3) were redeployed in 2016 in the same locations (Table 2; Figure 3) using ARCWEST funding.

[1] The M2 mooring site is turned around twice a year, and so two recorders were used.

Table 1. Date and location of passive acoustic mooring retrievals. Mooring cluster refers to the oceanographic site where the AURAL is co-located.

Mooring Name	Mooring Cluster	Latitude (°N)	Longitude (°W)	Depth (m)	Instrument	Deployment Date	Recovery Date
AW15_AU_PB1	C5	71.20617	-158.015	46	AURAL	9/14/2015	9/7/2016
AW15_AU_WT1	C4	71.04697	-160.503	48	AURAL	9/13/2015	9/7/2016
AW15_AU_BF1	-	71.5523	-155.533	67	AURAL	9/14/2015	9/8/2016
AW15_AU_BF2	-	71.74977	-154.462	98	AURAL	9/14/2015	9/8/2016
AW15_AU_BF3*	-	71.68642	-153.178	123	AURAL	9/14/2015	9/8/2016
AW15_AU_IC1	C1	70.83553	-163.109	43	AURAL	9/18/2015	9/15/2016
CX15_AU_IC2	C2	71.22937	-164.226	41	AURAL	9/13/2015	9/14/2016
CX15_AU_IC3	C3	71.82948	-166.077	43	AURAL	9/17/2015	9/13/2016
AW15_AU_CL1**	-	69.31737	-167.623	49	AURAL	9/19/2015	9/20/2016
CX15_AU_PH1	C12	67.91035	-167.198	57	AURAL	9/20/2015	9/21/2016
CX15_AU_KZ1*	-	67.1236	-168.604	50	AURAL	9/21/2015	9/21/2016
AW15_AU_NM1	-	64.8476	-168.39	41	AURAL	9/9/2015	9/23/2016
ST15_AU_NS1	-	63.39908	-166.236	23	AURAL	9/23./2015	9/24/2016
AW15_AU_BS1	-	61.58592	-171.333	52	AURAL	9/23/2015	9/25/2016
AW15_AU_BS2	-	59.24278	-169.413	52	AURAL	9/26/2015	9/27/2016
AW15_AU_BS3	-	57.67503	-164.718	52	AURAL	9/27/2015	9/28/2016
AW15_AU_BS4	-	54.42883	-165.271	164	AURAL	9/28/2015	9/30/2016
Cornell_PU249	-	71.298933	-163.277183	43	Double bubble	9/18/2015	9/13/2016
Cornell_PU250**	-	71.496533	-163.190817	44	Double bubble	9/18/2015	9/13/2016
Harp Site D	-	72.61542	-158.702950	98	HARP	Unknown	9/9/2016
Harp Site C	-	72.80256	-158.4231	323	HARP	Unknown	9/9/2016
BS15_AU_08a	M8	62.189867	174.688933	70	AURAL	9/24/2015	9/25/2016
BS15_AU_05a	M5	59.913150	171.708950	70	AURAL	9/25/2015	9/26/2016
BS15_AU_04a	M4	57.882350	168.879017	70	AURAL	9/26/2015	9/27/2016
BS15_AU_02b⁺	M2	56.871117	164.054750	71	AURAL	10/19/2015	4/30/2016
BS16_AU_02a	M2	56.866667	164.066667	73	AURAL	9/28/2016	5/5/2016

*Not redeployed in 2016

**Recovery attempted but unsuccessful.

⁺Note that BS15_AU_02b was retrieved by PMEL staff on the NOAA ship *Oscar Dyson* in May 2016 and redeployed as BS16_AU_02a.

Table 2. Date and location of passive acoustic mooring deployments. Mooring cluster refers to the oceanographic site name where the AURAL is co-located.

Mooring Name	Mooring Cluster	Latitude (°N)	Longitude (°W)	Depth (m)	Instrument	Deployment Date
AL16_AU_PB1	C5	71.20558	-158.016	46	AURAL	9/7/2016
AL16_AU_WT1	C4	71.0417	-161.516	48	AURAL	9/7/2016
AL16_AU_BF1	-	71.54967	-155.539	67	AURAL	9/8/2016
AL16_AU_BF2	-	71.75407	-154.456	98	AURAL	9/8/2016
AL16_AU_IC1	C1	70.83477	-163.114	43	AURAL	9/15/2016
AL16_AU_IC2	C2	71.2293	-164.214	41	AURAL	9/14/2016
AL16_AU_IC3	C3	71.82903	-166.079	43	AURAL	9/14/2016
AL16_AU_CC1	C10	70.2063	-167.78	46	AURAL- UW	9/19/2016
AL16_AU_CC2	C11	70.01563	-166.86	47	AURAL	9/19/2016
AL16_AU_CL1	-	69.31898	-167.608	49	AURAL	9/20/2016
AL16_AU_PH1	C12	67.90683	-167.2	57	AURAL/microcat	9/21/2016
AL16_AU_NM1	-	64.84868	-168.393	41	AURAL	9/23/2016
AL16_AU_NS1	-	63.39933	-166.236	23	AURAL	9/24/2016
AL16_AU_BS1	-	61.58478	-171.319	52	AURAL	9/25/2016
AL16_AU_BS2	-	59.24147	-169.417	52	AURAL	9/27/2016
AL16_AU_BS3	-	57.67617	-164.716	52	AURAL	9/28/2016
AL16_AU_BS4	-	54.42907	-165.268	164	AURAL	9/30/2016
Harp Site C	-	72.8016	-158.418	334	HARP	9/9/2016
Kotz-44	-	66.8305	-163.134	12.1	Loggerhead	9/22/2016
Kotz-45	-	66.8475	-163.141	11.9	Loggerhead	9/22/2016
BS16_AU_08a	M8	62.194450	174.684150	72	AURAL	9/26/2016
BS16_AU_05a	M5	59.906883	171.733450	68	AURAL	9/26/2016
BS16_AU_04a	M4	57.894533	168.877750	70	AURAL	9/27/2016
BS16_AU_02b	M2	56.878417	164.068500	70	AURAL	9/29/2016

The MML passive acoustic moorings were spread out to cover as much of the migration routes of Arctic marine mammal species as possible; they extend from Umnak Pass in the Bering Sea up to Cape Halkett in the western Beaufort Sea. They also continue to be collocated with the Chukchi Sea biophysical mooring clusters (Table 2 & Figure 3, stars) deployed by Stabeno and Napp to allow for future correlations to be made between marine mammal calling presence and oceanographic and zooplankton measurements.

We are excited to report that 20 of the 22 recorders we deployed in 2015 recorded for the full duration of their deployment. One recorder (AW15_AU_BF1, Figure 3) failed to start recording, and one recorder (AW15_AU_PH1) stopped on 10 February 2016. See Figure A4.1 for mooring design.

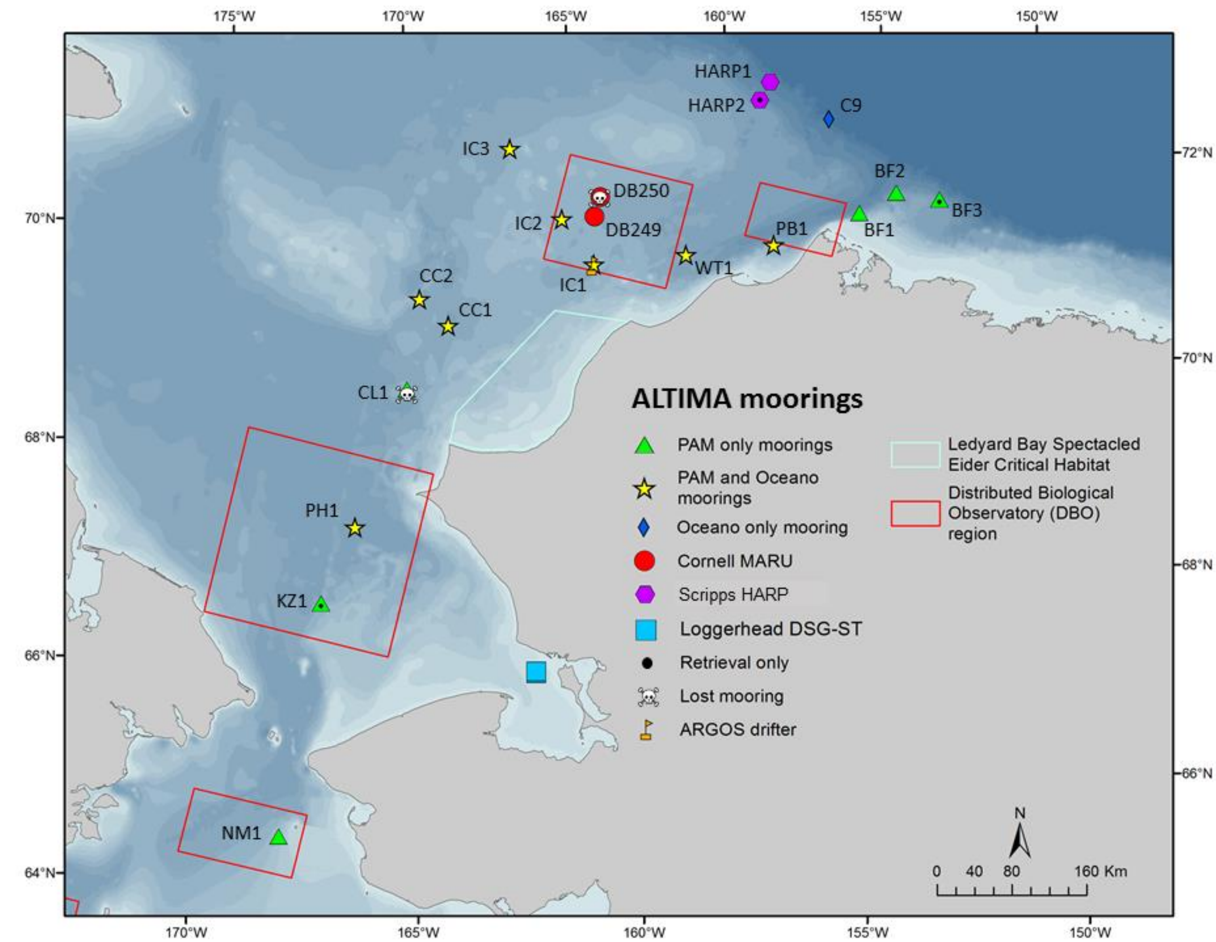


Figure 3. Location of passive acoustic moorings retrieved and deployed in the Chukchi Sea in 2016.

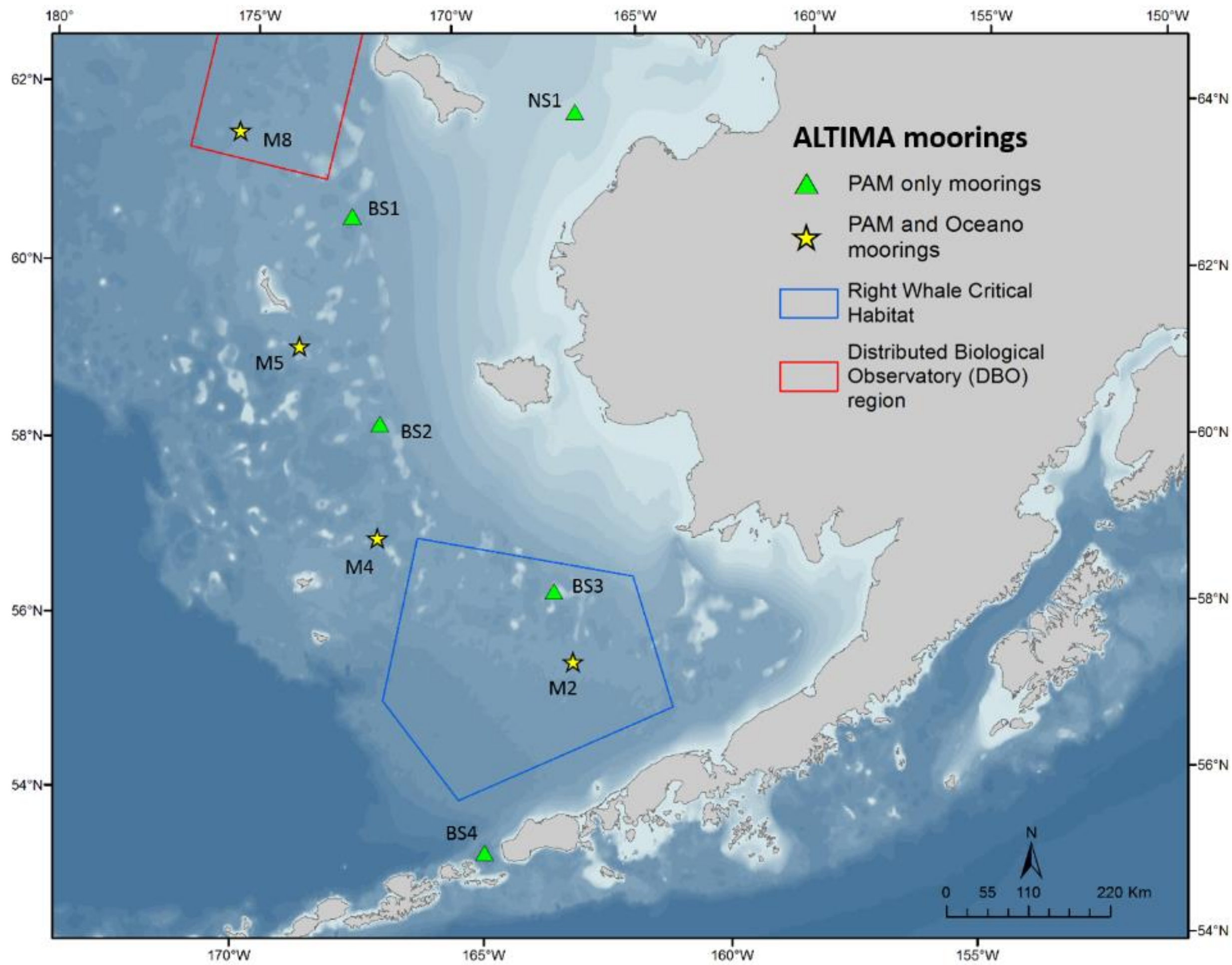


Figure 4. Location of passive acoustic moorings retrieved and deployed in the Bering Sea in 2016. All passive acoustic recorders were funded by the ARCWEST project.

Cornell

Cornell deployed two double bubble Marine Acoustic Recorder Units (MARUs) in 2015 as part of the CHAOZ-X project on either side of the Shell drill rig (Figures 3, 5). One of these was successfully retrieved (Table 1), but the other would not release from the anchor. The instrument responded to multiple “burn” commands, but failed to surface. These 2015 deployments used CHAOZ-X funds.

Figure 5. A Cornell double bubble.

The Auto-detection buoy was deployed on 23 August 2016 from the USCGC *Healy*. It is scheduled to be retrieved between 7 and 11 October, 2016. Unfortunately the real-time transmission stopped on 10 September 2016. There was considerable and persistent ice in the area for a large part of the summer, which may have caused damage to the buoy resulting in transmission failure. However, there is high confidence that the archival component of the buoy is still recording and collecting data.

Other

During the cruise, we serviced a few moorings that were along our route for other projects and/or researchers. One additional AURAL recorder was deployed at the C10/CC1 mooring site for Kate Stafford (APL-UW). Two High Frequency Acoustic Recording Package (HARP) moorings were retrieved for Scripps Institution of Oceanography researchers (Tables 1-2, Figure 3) led by John Hildebrand. One HARP was redeployed in the same location in 2016, near the Chukchi shelf break. Additionally, two shallow moorings were deployed in Kotzebue Sound for a colleague at MML (Table 2, Figure 3). These moorings were instrumented with DSG-ST recorder units from Loggerhead Instruments, and will be used to conduct ambient noise analyses of the fiber optic cable laying operation conducted by Quintillion Networks, LLC.

The grand total of passive acoustic recorders retrieved and deployed during the ALTIMA survey is therefore 23 and 24, respectively.

Sonobuoy monitoring

Figure 6. Sonobuoy being deployed.

Sonobuoys were deployed approximately every 2-3 hours while transiting (Figure 6), to obtain an evenly-sampled cross-survey census of marine mammal vocalizations. Four types of sonobuoy were used: 53F (manufactured by either Sparton (SPW) or Ultra Electronics (UND)), SPW 77C, SPW 57A, and 41B (unknown manufacturer). 77C sonobuoys are DiFAR (Directional Frequency Analysis and Recording) only, while 53F sonobuoys have either omnidirectional or DiFAR capabilities. 53F sonobuoys were deployed in DiFAR mode to obtain bearings to calling animals. 57A and 41B buoys were omnidirectional only. In 2012, we discovered that when we pulled out the top float portion during the sonobuoy programming process, we were inadvertently pulling out and disabling the depth setting pins, which was causing the sonobuoys to deploy to their deepest depth setting of 1000ft (and therefore noisily dragging the sensor across the shallow seafloor). Thus, modifications (taping and tying) had to be made to all sonobuoys except the 57A and 41B to shorten the deployment depth. Furthermore, almost all of the 53F sonobuoys had dead display batteries, which required replacement with a new battery.

There were two preamplified antennas installed on the vessel, an omnidirectional antenna as well as a Yagi directional antenna. Both antennas (and preamps) were placed up in the crow's nest of the vessel with the directional antenna facing astern (Figure 7). The omnidirectional antenna was used primarily while we were on station for mooring/sampling activities, as the vessel was frequently changing course. It was also used in the North Pacific Right Whale Critical Habitat in the SE Bering Sea, as pairs of sonobuoys were deployed in different directions in order to localize on vocalizing right whales. The Yagi antenna was used primarily during transit when the sonobuoy was guaranteed to be behind the vessel. The acoustics station in the bridge is shown in Figure 8.

Figure 7. Sonobuoy antennas placed in the crow's nest (far left mast).

Figure 8. Acoustic station.

A total of 142 sonobuoys were deployed during the cruise (Appendix 2) for a total of 191 hours of monitoring. Of these, 124 deployed and transmitted successfully for an overall success rate of 87.3%. The success rate of the 53F's was 94.5%, while the success rate of the 77C's was 75.5%. The 77C sonobuoys had a higher number of failures than seen in the past, most likely due to their advancing age. The 57A did not transmit. Although the 41A transmitted, it was very noisy, and masked any acoustic signals. These latter two failures are not surprising given the age of those buoys were 30+ years.

The location of the sonobuoys and species detected are shown in Figures 9 and 10 for the Chukchi/Beaufort and Bering Seas respectively. The most common species detected in the Chukchi/Beaufort were bearded seals and seismic airguns, detected on 11 sonobuoys (12.9%) each, followed by walrus, an unidentified anthropogenic signal (~250 Hz and 1 min long - possibly from the Canada Basin Acoustic Propagation Experiment (CANAPE)), and gray whales, detected on 7 (8.2%), 5 (5.8%), and 4 (5%) sonobuoys, respectively. Ribbon seals were detected on three buoys (3.5%), and bowhead whales and ice noise were detected on two sonobuoys each (2%). Finally, gunshot calls, humpback, fin, and killer whales, one unidentified pinniped, and one unknown signal were each detected on one sonobuoy (1.1%). The most common species detected in the Bering Sea were fin whales, detected on 48.7% of sonobuoys (19 buoys), followed by right whales (upsweeps and gunshot calls) confirmed on 7 sonobuoys (17.9%), with two possible additional unconfirmed detections (total 23%). Other species detected include killer whales (12.8%), humpback whales (5.1%, 2 sonobuoys), and seismic airguns on one sonobuoy (2.5%).

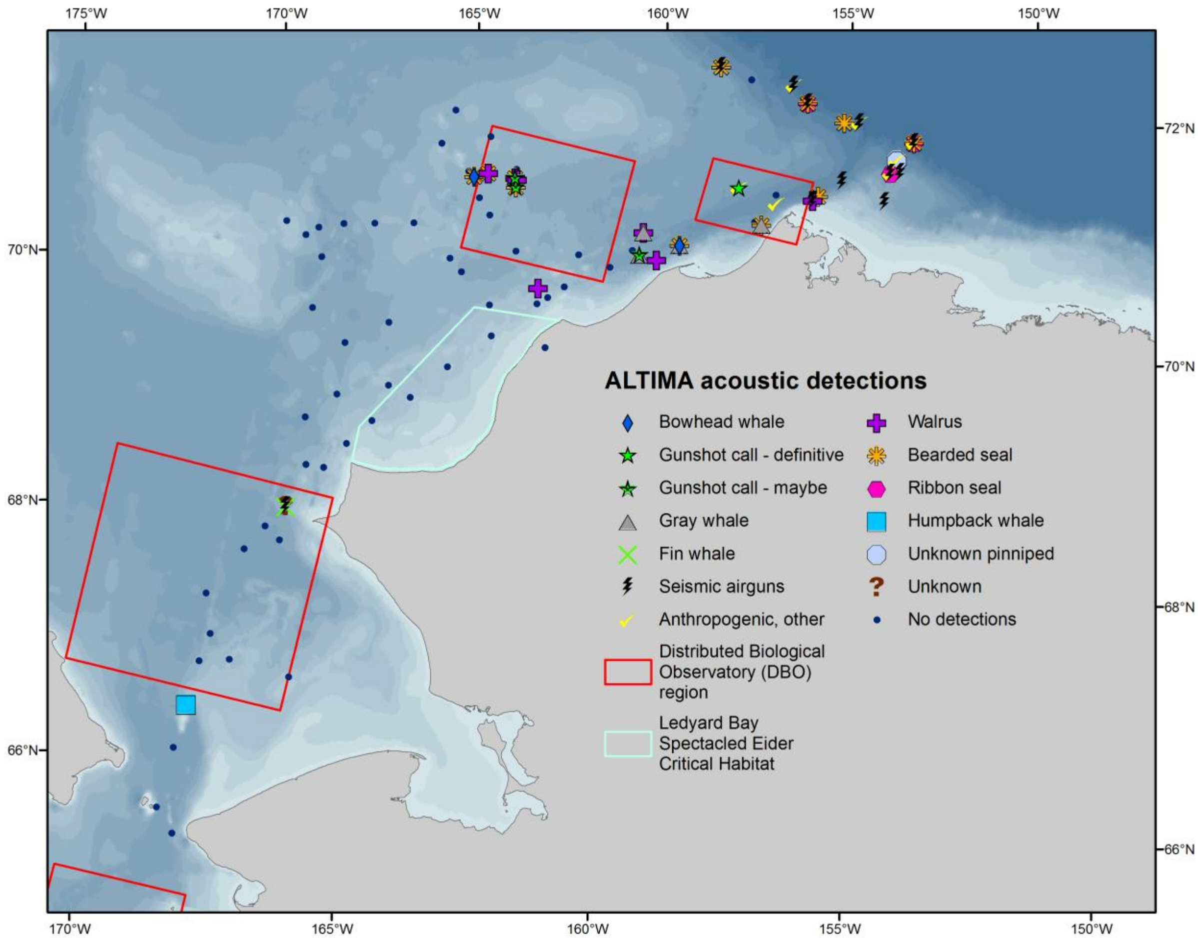


Figure 9. Sonobuoy deployment and acoustic detections in the Chukchi Sea.

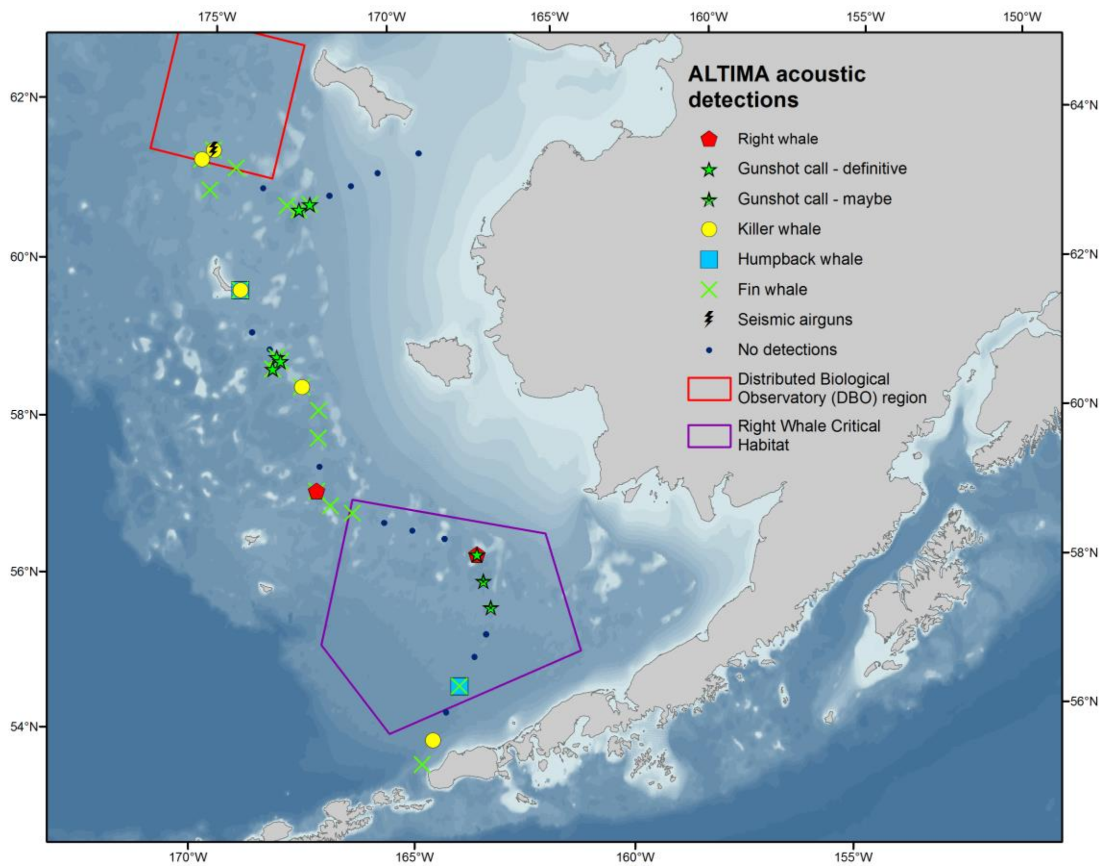


Figure 10. Sonobuoy deployment and acoustic detections in the Bering Sea.

Oceanographic Component

Long-term moorings

All moorings deployed in 2015 were successfully retrieved (Table 3) and redeployed (Table 4, Figure 13). In addition, two new locations were added (Figure 13, Table 4).

At sites C1-C5 and C9-C12, biophysical moorings were deployed, while ice moorings were deployed at sites C1-C3 (under NOAA OAR/PMEL funds; Figure 13). The ice mooring contains an ASL upward-facing profiler to measure ice thickness as well as a Recording Current Meter (RCM) 9. The biophysical moorings included an ADCP and a linked set of instruments containing a Sea-bird (SBE) SeaCAT, an ECOfluorometer, a Photosynthetically Active Radiation (PAR)

Figure 11. Oceanographic ADCP mooring being deployed.

Figure 12. TAPS-6NG being deployed.

sensor, and an *in situ* ultraviolet spectrometer (ISUS) nitrate sensor (Figure 11). For a full list of instrumentation on each mooring recovered and deployed see Tables 3-6.

In addition, at the C2 location, an upward-facing TAPS-6NG (Tracor Acoustic Profiling System Next Generation) instrument was deployed to measure zooplankton bio-volume and size distribution. The TAPS-6NG assembly consists of a PVC block at the top containing 6 transducers, a 40" syntactic foam ADCP float, an electronic controller pressure case (inside the float) and two PVC pressure cases containing batteries (Figure 12). These instruments are engineered to optimize the detection of krill.

See the EcoFOCI mooring website (http://www.pmel.noaa.gov/foci/operations/mooring_plans/[2]) for information on instrumentation and location of moorings since 2002, and Appendix 4 for all biophysical mooring diagrams. Moorings specific to the 2016 cruise can be found at: (http://www.pmel.noaa.gov/foci/operations/mooring_plans/2016/sept2016_aq1602_moorings.html).

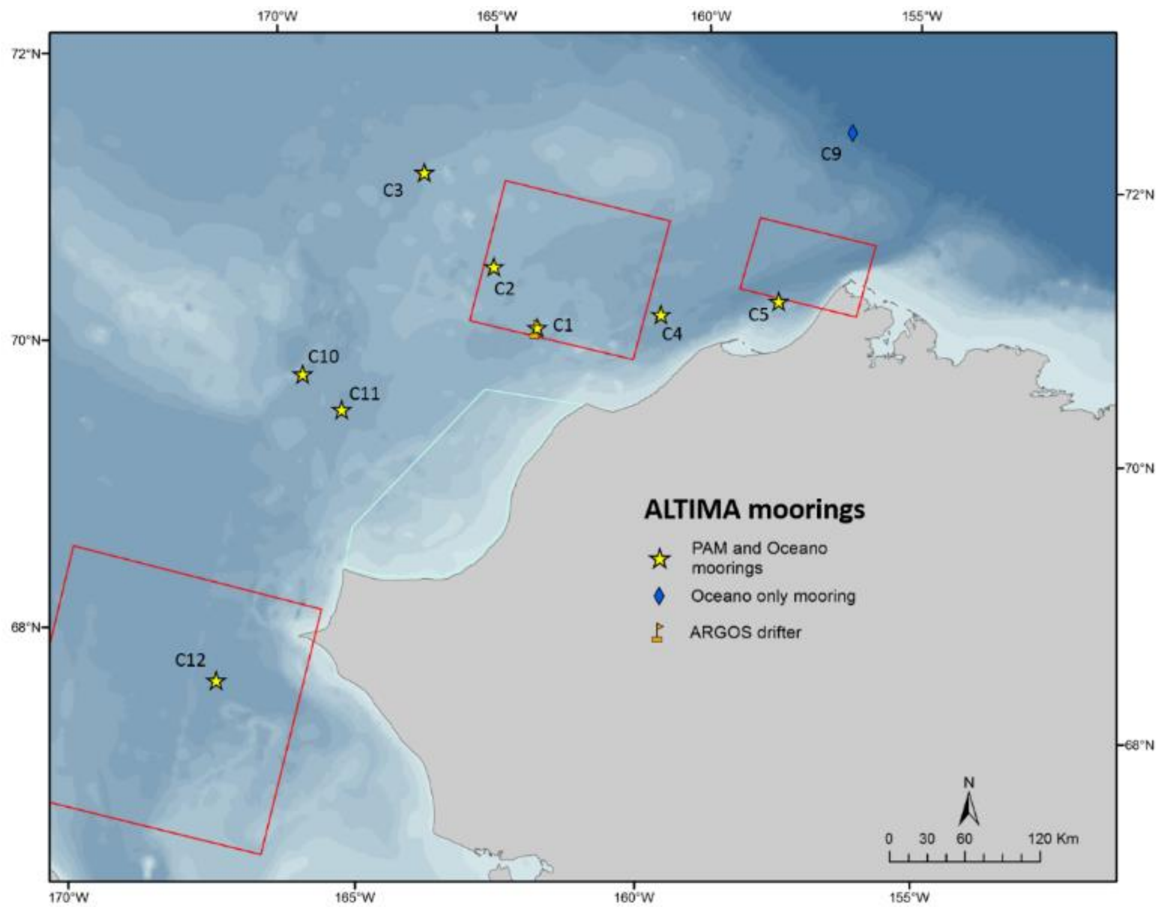


Figure 13. Location of oceanographic mooring clusters retrieved and deployed and ARGOS drifters deployed in the Chukchi Sea in 2016.

[2] On this webpage subsurface moorings relevant to this project are titled 16CK (i.e., Chukchi Sea 2016) and 16BS (i.e., Bering Sea 2016). The number on the end corresponds to the mooring clusters shown in Figure 13 for the Chukchi Sea (e.g., 15CKT-2A corresponds to C2) or Figure 4 for the Bering Sea (e.g., 16BS-2B corresponds to M2).

Table 3. Date and location of oceanographic moorings retrieved in the Chukchi Sea.

Mooring Name	Cluster	Latitude (°N)	Longitude (°W)	Instrument	Retrieval date
15CKIP-1A	C1	70.83565	-160.12385	IPS, RCM,SBE	9/15/2016
15CKP-1A	C1	70.8355	-163.10535	ADCP-IT, ISUS, SBE, PAR, FLUOR	9/15/2016
15CKIP-2A	C2	71.23048333	-164.21015	IPS, RCM,SBE	9/14/2016
15CKT-2A	C2	71.23013333	-164.2206167	TAPS, SBE	9/14/2016
15CKP-2A	C2	70.83565	-163.12385	ADCP, SUNA, SBE, PAR, FLUOR	9/14/2016
15CKIP-4A	C4	71.04785	-160.5141667	IPS, RCM,SBE	9/7/2016
15CKP-4A	C4	71.04641667	-160.5148667	ADCP, SBE, PAR, FLUOR	9/7/2016
15CKP-9A	C9	72.48351667	-156.5496167	ADCP, RCM,OP,TU,CS, SBE	9/9/2016

Table 4. Date and location of oceanographic moorings deployed in the Chukchi Sea.

Mooring Name	Cluster	Latitude (°N)	Longitude (°W)	Depth (m)	Instrument	Deployment date
16CKP-1A	C1	70.83781667	-163.11246	42	ADCP-IT, SUNA, SBE, PAR, FLUOR, MTR	9/15/2016
16CKIP-1A	C1	70.83773333	-163.12542	42	IPS, RCM, OP, SBE	9/15/2016
16CKT-2A	C2	71.23096667	-164.22566	42	TAPS	9/14/2016
16CKIP-2A	C2	71.23091667	-164.22301	41	IPS, RCM, OP, SBE	9/14/2016
16CKP-2A	C2	71.23215	-164.21703	41	ADCP, SUNA, SBE, PAR, FLUOR	9/14/2016
16CKP-3A	C3	71.8311	-166.07142	43	ADCP, SUNA, SBE, PAR, FLUOR	9/13/2016
16CKIP-3A	C3	71.82803333	-166.07033	43	IPS, RCM, SBE, OP	9/13/2016
16CKP-4A	C4	71.03815	-160.51446	48	ADCP, SBE, PAR, FLUOR	9/7/2016
16CKP-5A	C5	71.20253333	-158.01103	46	ADCP, SBE, PAR, FLUOR	9/7/2016
16CKP-9A	C9	72.46685	156.55	1033	ADCP, RCM, SBE, MTR	9/9/2016
16CKP-10A	C10	70.21091667	-167.78733	46	ADCP, SBE, FLUOR	9/19/2016
16CKP-11A	C11	70.01311667	-166.8554	46	ADCP, SBE, FLUOR	9/19/2016
16CKP-12A	C12	67.91118333	-168.19492	58	ADCP, RCM, OP, PAL, AWCP	9/21/2016

During the return transit from Nome to Dutch Harbor, we retrieved ten and redeployed nine oceanographic moorings at four different sites along the 70m isobath (M2, M4, M5, M8, Table 5; Figure 4, stars). This included the retrieval of the large surface float mooring at M2 (Figure 14). Also recovered was a 1.5m oceanographic surface mooring (Figure 15) deployed from the NOAA ship *Oscar Dyson* at the M2 site on May 10, 2016. This surface buoy is part of PMEL's Innovative Technology for Arctic Exploration (ITAE) program. This buoy is equipped with a novel radiometer package that has the ability to gather climate quality measurements and can differentiate between direct and diffuse solar irradiance. Additional meteorological sensors measure winds, air temperature, relative humidity, and estimate cloud coverage. Below the surface are other novel technologies including PMEL's PRAWLER (Profiling Crawler) and a lab on a chip (LOC) nitrate sensor from the U.K.'s National Oceanography Center at Southampton.

Figure 14. Oceanographic mooring (M2) surface float.

Figure 15. ITAE surface buoy accompanied by northern fur seals.

Table 5. Date and location of oceanographic mooring recovered in the Bering Sea. A list of the instrument abbreviations along with their full names can be found in Appendix 5.

Mooring Name	Cluster	Latitude (°N)	Longitude (°W)	Instrument	Retrieval date (UTC)
15BSP-8A	M8	62.19445	-174.68415	ADCP, AURAL	9/25/2016
15BS-8A	M8	62.19268	-174.6878	SBE, FLUOR, SBET, OX, SAMI, SeaFET	9/25/2016
15BSIP-8A	M8	62.1929	-174.6831	IPS	9/25/2016
15BS-5A	M5	59.9114	-171.7354	FLUOR, SBE, SBET	9/26/2016
15BSP-5A	M5	59.9068	-171.7334	ADCP, AURAL, AWCP, PAL	9/26/2016
15BS-4B	M4	57.88995	-168.8718	SBE, FLUOR, MTR, SBET	9/27/2016
15BSP-4A	M4	57.89453	-168.877	ADCP, AURAL	9/27/2016
16BSP-2B	M2	56.8728	-164.0528	ADCP, AURAL	9/28/2016
16BSM-2B	M2	56.86955	-164.0478	Weatherpak, Eppley, MTR, SBE, SAMI, SUNA, FLUOR, Labonachip	9/29/2016
16BS-ITAE	M2	56.868	-164.05266	SPN1, ATRH, WINDS, GoPro, Prawlet, RCM, FLUOR, SBE, OP, SBET	9/28/2016

Table 6. Date and location of oceanographic mooring deployments in the Bering Sea. A list of the instrument abbreviations along with their full names can be found in Appendix 5.

Mooring Name	Cluster	Latitude (°N)	Longitude (°W)	Depth (m)	Instrument	Deployment date (UTC)
16BS-8A	M8	62.19358	-174.6883	73	SBE, FLUOR, SAMI SeaFET, SBET	9/26/2016
16BSP-8A	M8	62.19846	-174.6867	73	ADCP, AURAL	9/26/2016
16BS-5A	M5	59.91283333	-171.7360	68	SBE, SBET, FLUOR	9/26/2016
16BSP-5A	M5	59.91076667	-171.7309	67	ADCP, AURAL, AWCP, PAL	9/26/2016
16BS-4B	M4	57.89685	-168.8819	70	SBE, SBET, FLUOR, MTR	9/27/2016
16BSP-4A	M4	57.89545	-168.8780	69	ADCP, AURAL	9/27/2016
16BS-2C	M2	56.87473333	-164.0506	69	FLUOR, SBE, RCM, OP, SBET, MTR, ISUS, SAMI, SeaFet	9/29/2016
16BSP-2B	M2	56.87003333	-164.0655	69	ADCP, AURAL, AWCP, PAL	9/29/2016
16BSV-2A	M2	56.866	-164.0557	70	RCM, OP	9/29/2016

CTD stations

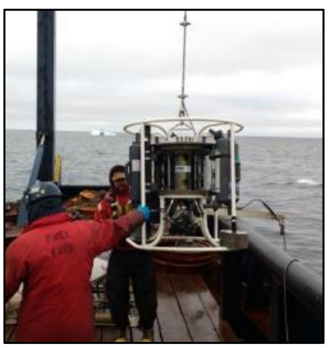


Figure 16. CTD being deployed.

At each mooring site and along several pre-determined transect lines, hydrographic data were collected and samples taken (nutrients, and chlorophyll, Tables 7 and 8, Figures 16 and 17). Methods included high-resolution vertical profiling of water properties (including temperature, salinity, chlorophyll fluorescence, PAR, and dissolved O_2) to within 1-5 m of the bottom using a Seabird 911Plus CTD (Figure 16) with dual temperature, conductivity, and oxygen sensors. Nutrient and chlorophyll samples were collected with water bottles at discrete depths and frozen for analysis at a later date at the NOAA laboratories in Seattle, WA. Dissolved oxygen samples were taken to calibrate CTD oxygen sensors. In total, 71 CTD casts were conducted (Table 7).

Table 7. Summary of hydrographic and zooplankton operations.

Gear	Number Tows/Casts
Seabird SeaCAT CTD	52
CTD with bottle samples	71
10" inner diameter modified Clarke-Bumpus	33
Mooring deployment or recovery	40
Epibenthic tucker sled	33
20/60 cm Bongo nets	18

Table 8. Summary of hydrographic and zooplankton samples collected.

Sample Type	# Tows/Casts	# Samples
Extracted chlorophyll	71	423
SeaBird CTD	71	71
Stimulated fluorescence collected during CTD casts	71	71
Nutrient samples collected from CTD casts	71	369
oxygen samples for CTD probe calibration	68	77
Photosynthetically Active Radiation data collected during CTD casts	71	71
Quantitative tow preserved in formalin	46	140
Salinity sample	11	13

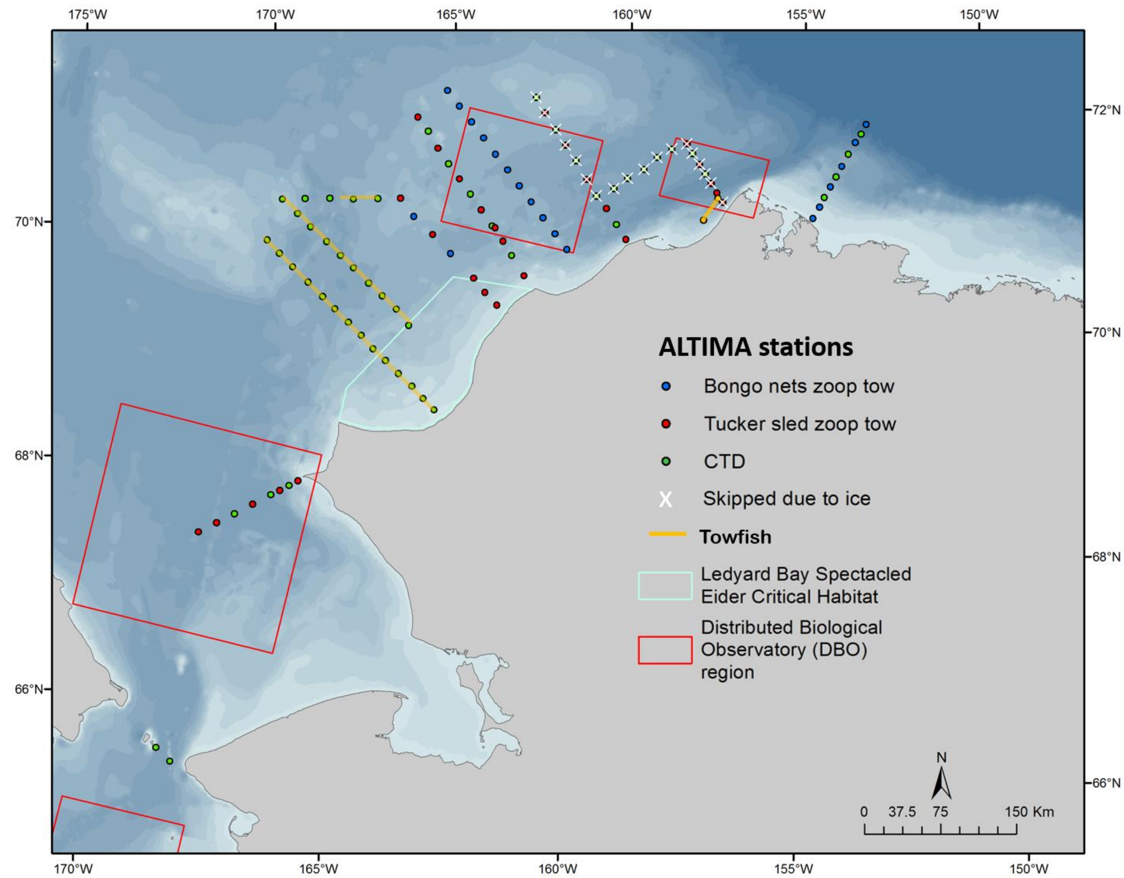


Figure 17. Location of all CTD casts, zooplankton net tows, and towfish operations in the Chukchi Sea.

During the survey, an Acrobat towed vehicle was deployed to assess its usefulness in Chukchi/Beaufort Sea cruises (Figure 18). The vehicle included a Seabird fastCAT that measured pressure, temperature, and conductivity, a Wetlabs triplet that measured fluorescence, CDOM and turbidity, and a nutrient sensor. In addition, the data are linked to GPS position and data from the ship's depth sounder. We deployed the vehicle five times; however because of communication issues with the fish, the first three tows were of short duration. The last two tows were long and successful, as shown in Figure 19 of the temperature and salinity from the fourth tow.

Additionally, an underway sampling system was installed in the vessel to measure near-surface salinity, temperature, pH, nutrients, and oxygen concentration at the ship's salt-water intake. These instruments functioned for the duration of the cruise, although the computer logging the data did have issues. Plots of the underway system data are shown in Figure 20.

Figure 18. Acrobat towfish being deployed.

Table 9. Acrobat towed vehicle summary

Deploy Date	Deploy Time (GMT)	Begin Latitude	Begin Longitude	End Latitude	End Longitude
9/11/2016	5:54	71° 17.1N	157° 17.4W	71° 04.8N	157° 39.4W
9/12/2016	5:32	71° 07.3N	160° 17.72W	71° 00.4N	160° 18.0W
9/17/2016	10:11	70° 57.2N	165° 48.6W	70° 51.7N	167° 07.3W
9/18/2016	17:26	70° 44.7N	168° 43.5W	69° 50.6N	164° 56.4W
9/19/2016	18:46	70° 20.9N	168° 54.3W	69° 34.8N	165° 40.7W

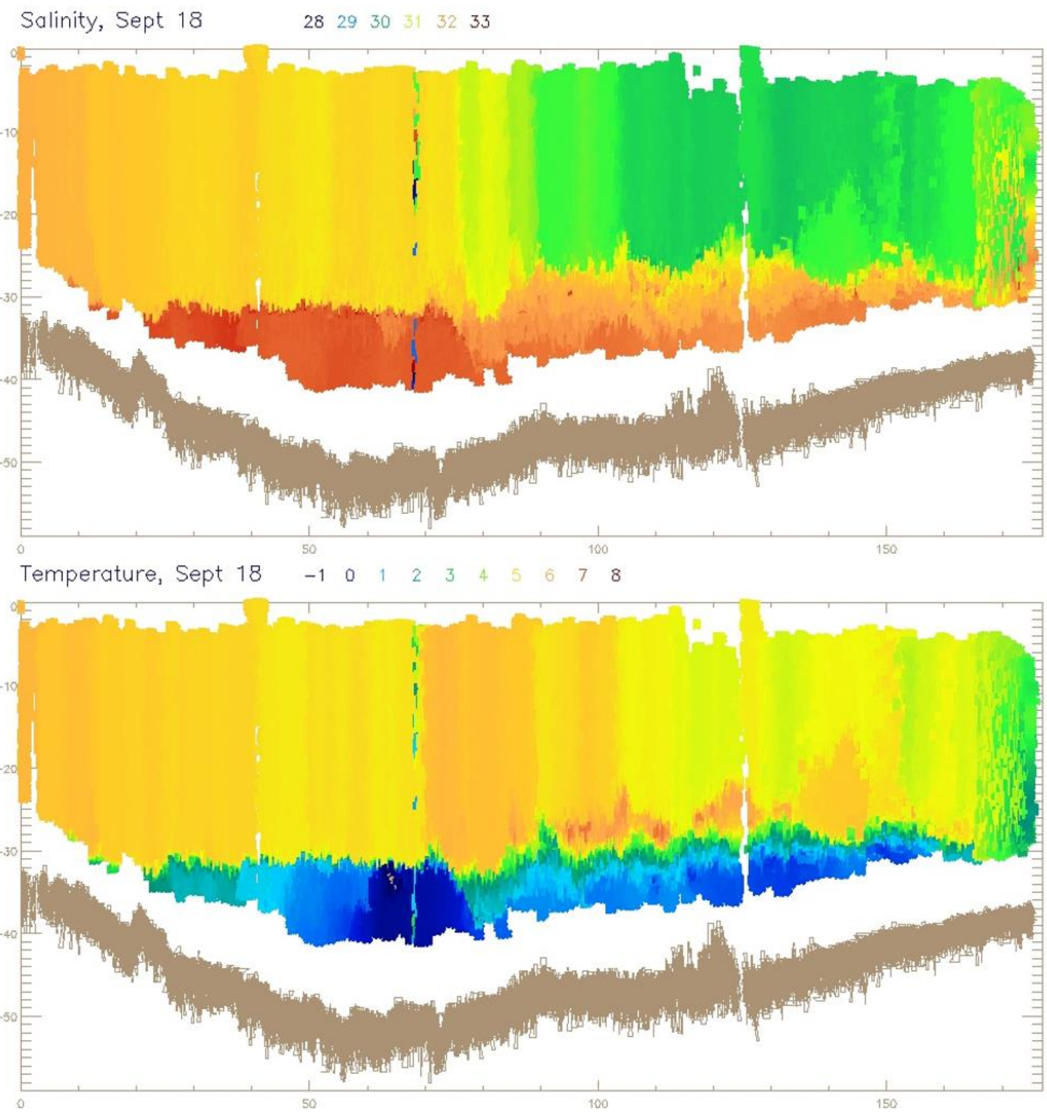


Figure 19. Data obtained from the Acrobat towed vehicle on 18 September 2016. Top: Salinity. Bottom: Temperature. Noisy brown line at the bottom of the plots is bottom depth. Plots made from raw data.

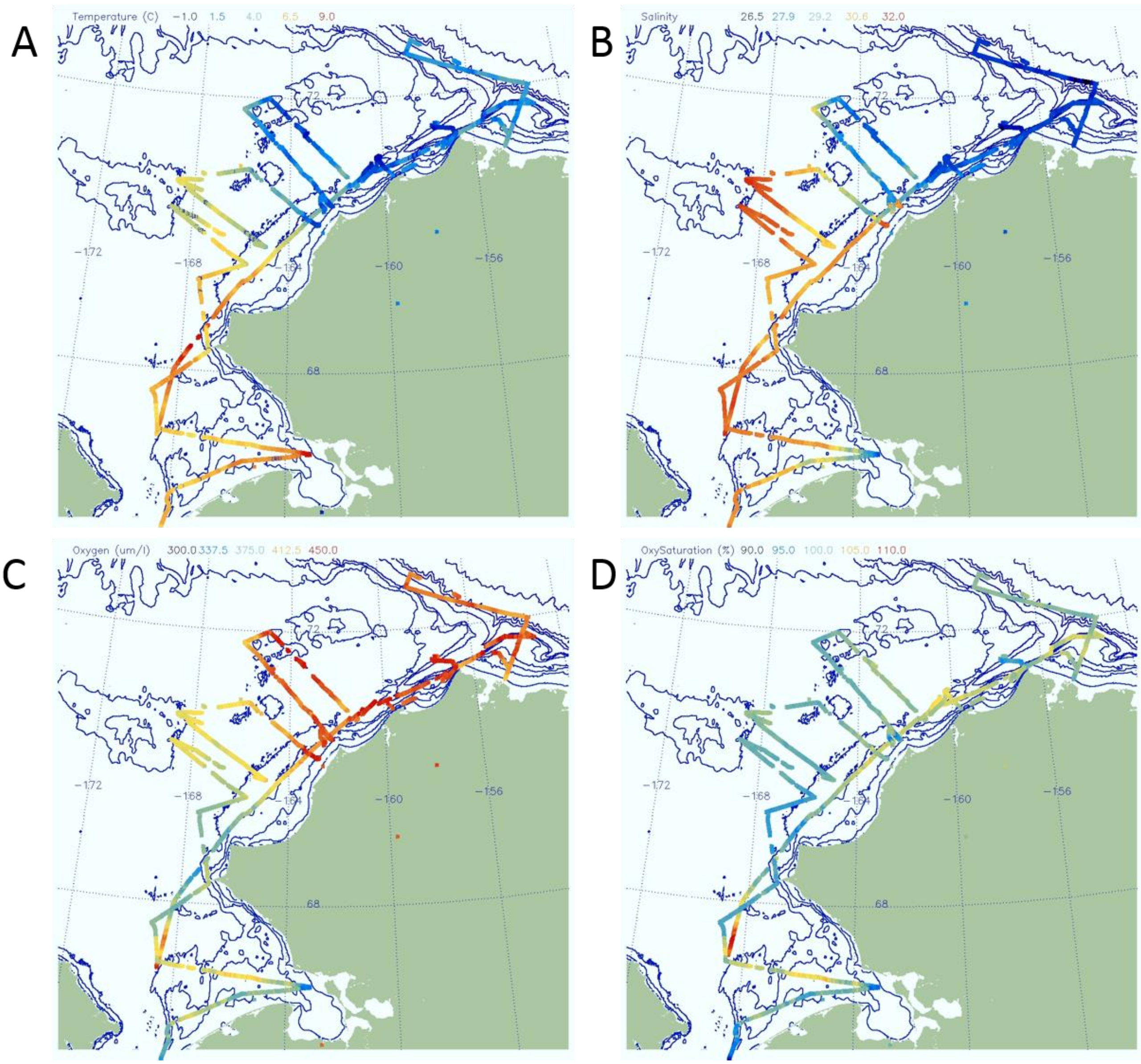


Figure 20. Data obtained from the underway sampling system. A) Temperature (°C); B) Salinity (psu); C) Oxygen (um/l); D) Oxygen saturation (%). Plots made from raw data.

One ARGOS satellite drifter was deployed on 16 September 2016 at station IC03 off Icy Cape (Figure 13). These free-floating instruments drift along with the currents, and their location is determined via satellite. These drifters will look at the advection of water from the Bering into the Chukchi Sea. An animation showing drifter tracks and ice extent (through 2015) can be viewed at the following website under the heading *Chukchi Sea drifters with Ice Movies*: http://www.ecofoci.noaa.gov/efoci_drifters.shtml. Additionally, one prototype pop-up buoy was deployed on 19 September 2016 during the cruise. The pop-up buoy is programmed to release in mid-March, float to the surface under the ice, and transmit data on position, temperature, and light levels via an Iridium link.


Figure 21. Wave glider being retrieved.

During the transit south through the Bering Sea, we retrieved one of two wave gliders that had been deployed earlier in the summer. These solar- and battery-powered autonomous mobile platforms have been surveying the Bering Sea, collecting oceanographic data. While one wave glider was retrieved successfully (Figure 21), the second wave glider stopped transmitting its location roughly one week prior to our scheduled retrieval. A search pattern was conducted in the estimated direction of travel (estimated using currents, winds, and surface waves), but the second wave glider was not found.

Ichthyo-Zooplankton Component


Figure 22. Tucker sled being deployed.


Figure 23. Bongo nets being deployed.

At 48 stations we also obtained zooplankton samples with either a 1 m^2 epibenthic Tucker sled (30 stations, Figures 17, 22) or a paired 20/60 cm bongo net array (18 stations, Figures 17, 23). A full report on the CTD and net tow stations can be found in the electronic document entitled "Eco-FOCI2016_CruiseReport.pdf" (referenced in Appendix 3). For the Tucker sled tows, two 500 µm mesh nets were used for most of the tows – one was opened and closed while the sled was on the bottom and the other was used to obtain plankton from the ocean bottom to the surface (Figure 22). A 25 cm (10") Clarke-Bumpus style net with 150 µm mesh to sample smaller zooplankton was suspended in Tucker net 2, and profiled the entire water column. On the bongo array two 150 µm mesh nets were fitted on the 20 cm frames and two 500 µm mesh nets on the 60 cm frames (Figure 23). Temperature/conductivity measurements of the water column were obtained with a SeaBird FastCat mounted horizontally on the sled behind the net mouth or vertically above the bongo nets. Both Tucker nets and all bongo nets contained a General Oceanic flow meter suspended in the net opening to estimate volume filtered. All zooplankton samples were preserved in 5% buffered formalin and were sent to the Polish Plankton Sorting and Identification Center for processing. Ichthyo- and zooplankton species data should be available by May of 2017.

Marine Mammal Component

All operations were performed according to regulations and restrictions specified in the existing permits issued by the NMFS to the Marine Mammal Laboratory (permit #14245).

Marine mammal observations

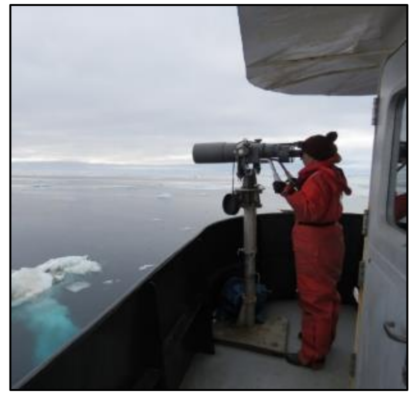


Figure 24. Marine mammal observer Coates using the Big Eye binoculars.

Visual effort was conducted by a team of three scientists. Operations were conducted during daylight hours, or as long as weather and light conditions would allow, while transiting between mooring stations. On-effort status was defined as a visibility greater than 2 nautical miles (nm), Beaufort sea state ≤ 5, and survey speed of ~8-9 knots through the water. Visual operations were considered 'on-effort' when either one or both scientists were observing inside the bridge using naked eye and 7x50 binoculars or with one observer outside using 25x 'big-eye' or 7x50 binoculars (Figure 24), and one scientist inside the bridge to observe and record. One scientist continued to observe when conditions were unacceptable (sea state 6 or greater and/or visibility less than 2 nm), but this was denoted as "off-effort" status. When a sighting was detected, the primary observer conveyed the horizontal angle and number of reticles from the horizon of the initial sighting to the recorder. Sighting cue, course and speed, species identity, and best, high, and low estimates of group size were also recorded. The computer program *WinCruz* (https://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/WinCruz.pdf) was used to record all sighting, effort, and environmental data (e.g., cloud cover, precipitation, and sea conditions).

The visual team surveyed 1140 nm of trackline (Figures 25 and 26). There were a total of 150 sightings (1,375 individuals) of 13 confirmed marine mammal species; these consisted of killer, humpback, fin, bowhead, gray, and minke whales, harbor porpoise, Northern fur, spotted, ringed, and bearded seals, walrus, and polar bears (Table 8, Figures 25 and 26). Additionally, there were 233 sightings (321 individuals) of unidentified cetaceans and pinnipeds (Table 8, Figures 25 and 26).

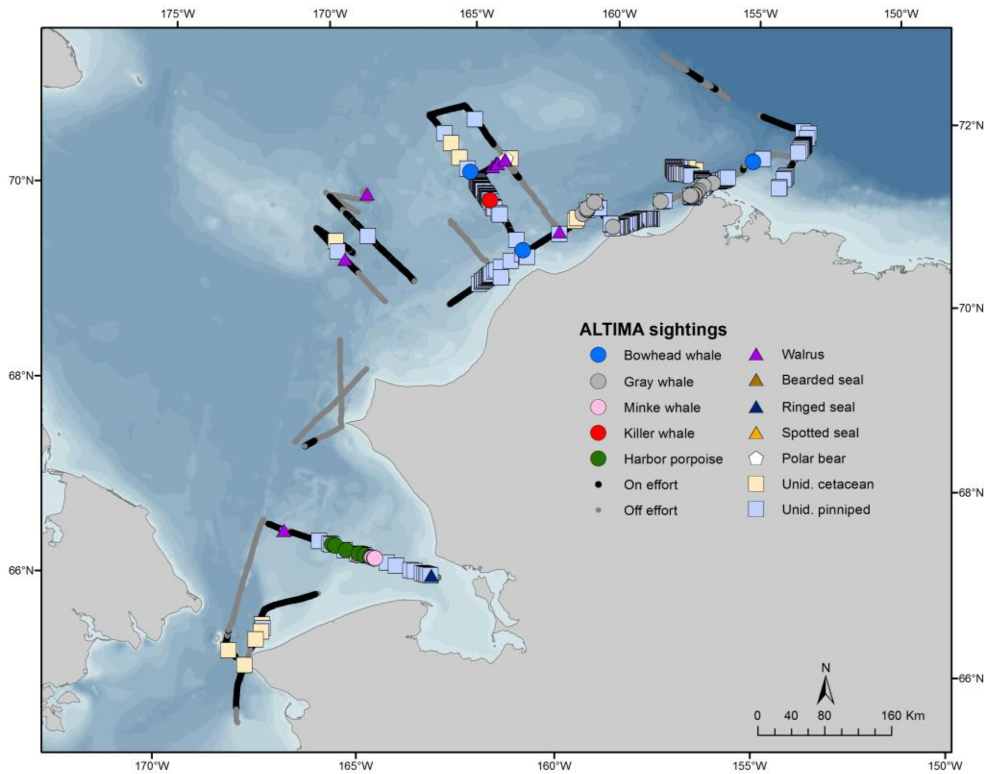


Figure 25. Marine mammal on-effort sightings and effort data from the ARCWEST/CHAOZ-X 2015 research cruise, Beaufort Sea to Bering Strait.

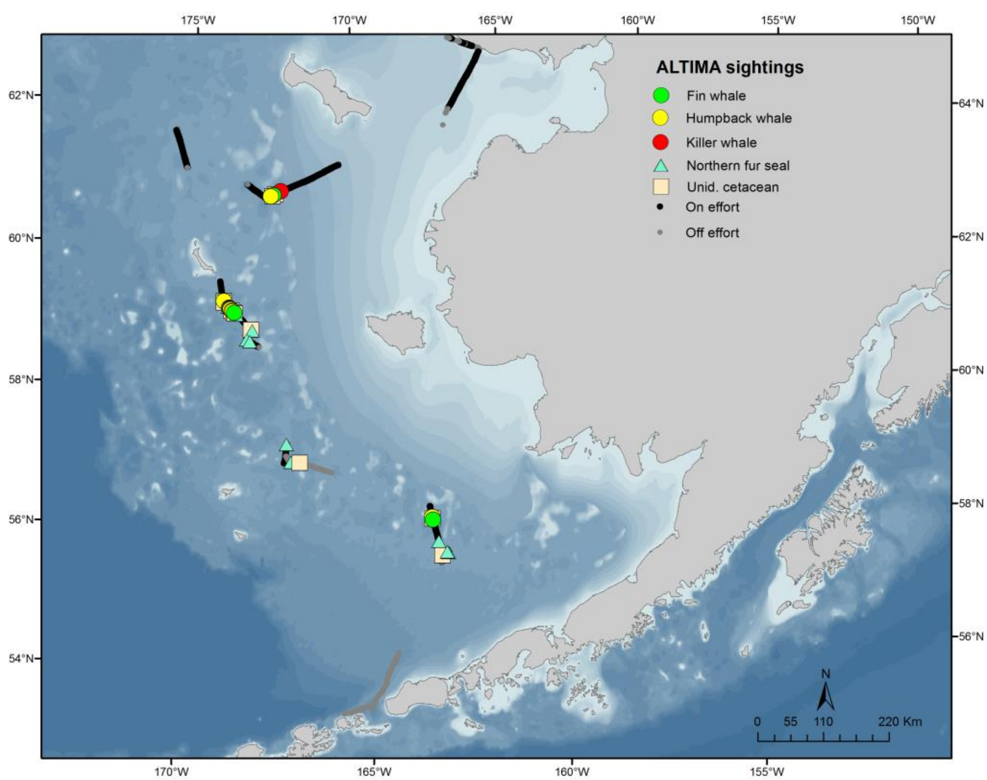


Figure 26. Marine mammal on-effort sightings and effort data from the ARCWEST/CHAOZ-X 2015 research cruise, Bering Sea.

Table 10. Marine mammal sightings (individuals) from the ALTIMA 2016 research cruise.

Species	On-Effort	Off-Effort	Total
Cetaceans			
Humpback Whale	13(15)	0	13(15)
Minke Whale	2(4)	1(1)	3(5)
Harbor Porpoise	6(7)	1(1)	7(8)
Killer Whale	2(5)	0	2(5)
Fin Whale	3(3)	0	3(3)
Bowhead Whale	3(3)	0	3(3)
Gray Whale	14(35)	5(8)	19(43)
Unid Large Whale	0	3(3)	3(3)
Unid Small Whale	0	1(1)	1(1)
Total Cetacean	*43(72)*	*11(14)*	*54(86)*
Other			
Northern Fur Seal	10(15)	1(1)	11(16)
Spotted Seal	20(46)	1(1)	21(47)
Ringed Seal	15(18)	2(2)	17(20)
Walrus	31(1188)	4(6)	35(1194)
Bearded Seal	12(12)	0	12(12)
Polar Bear	2(2)	2(2)	4(4)
Unid Pinniped	226(314)	3(3)	229(317)
Total Other	*316(1595)*	*13(15)*	*329(1610)*
Total	**359(1667)**	**24(29)**	**383(1696)**

Seabird observations

Seabird observations were conducted starting in Nome, AK on 3 September and continuing until the following Nome in port on 23 September. The seabird component of this cruise was one of several funded in 2016 by BOEM (modification No.7 of 'Seabird Distribution and Abundance in the Offshore Environment' AK-10-10) and the North Pacific Research Board (Project No. 1427b). Data will be archived in the North Pacific Pelagic Seabird Database (http://alaska.usgs.gov/science/biology/nppsd) and with the Bureau of Ocean Energy Management (BOEM).

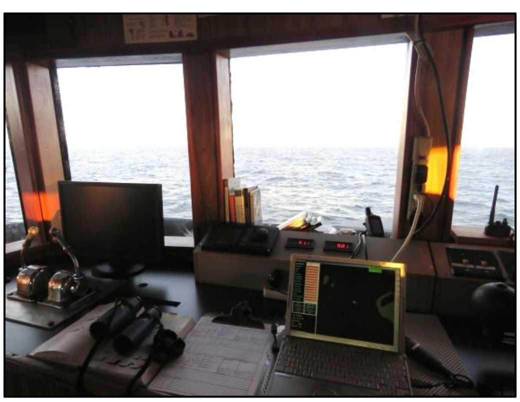


Figure 27. Seabird observation station in the bridge.

Surveys were conducted using U.S. Fish and Wildlife Service Protocols. Observations were made from the port side of the bridge during daylight hours while the ship was underway (Figure 27). The observer scanned the water ahead of the ship using hand held 10x binoculars if necessary for identification and recorded all birds and mammals within a 300 m, 90o arc from the bow to the beam. We used strip transect methodology and three distance bins extending from the vessel: 0 100 m, 101 200 m, and 201 300 m and recorded the animal's behavior (flying, on water, on ice, foraging). Weather conditions precluded surveys on 5 September and limited observations to 100 meters on some days. Due to the length of time at stations to complete oceanographic research and to deploy and retrieve moorings, observation periods varied. Sea ice was encountered on 5 days during daylight hours necessitating the ship to change course and for some oceanography stations to be abandoned, which also affected survey opportunities.

Rare birds, large flocks, and mammals beyond 300 m or on the starboard side (off transect) were also recorded but will not be included in density calculations. Birds on the water or on ice, or actively foraging were counted continuously whereas flying birds were recorded during quick 'Scans' of the transect window, with scan intervals based on ship speed (typically about 1 per min). Observations were entered directly into a GPS integrated laptop computer using the program DLOG3 (A.G. Ford Consultants, Portland, OR). Location data was also recorded automatically at 20 sec intervals, providing continuous records on weather, Beaufort Sea State, ice coverage, glare, and observation conditions.

The observer conducted 74 transects with a total survey effort of 126.8 hours. A total of 24 identifiable bird species were observed on-transect totaling 22,303 birds (Table 11). The Short-tailed Shearwater (*Puffinus tenuirostris*) was the most abundant species observed (n=20,370) making up 91% of all on-transect sightings, although most of those were in a few large aggregations; one aggregation was greater than 10,000 birds (18 September at Lat 70° 04.11N, Long 165° 51.26W). The next most abundant species on-transect (Table 11) in descending order were Crested Auklets (*Aethia cristella*), Least Auklets (*Aethia psittacula*), Thick-billed Murres (*Uria lomvia*), and Black-legged Kittiwakes (*Rissa tridactyla*).

Off-transect observations were largely opportunistic and restricted by limited effort and visibility. Large flocks of Short-tailed Shearwaters, Long-tailed Ducks (*Clangula hyemalis*), Sandhill Cranes (*Grus canadensis*), and loons (*Gavia* sp.) were observed off-transect. Short-tailed Shearwaters were observed in large aggregations often far offshore while the other species were observed more nearshore and appeared to be migrating south to southwest. The large (n=632) flock of Sandhill Cranes was observed near King Island while many of the loon species were observed as individuals or in small groups of up to 10 birds with the majority sighted off the coast of Barrow, Wainwright, and the Seward Peninsula. Reports from the visual marine mammal observers who were constantly scanning the horizon with the 'big eyes' indicated that thousands more birds of various species were moving around the area.

Other special sightings of interest included a Mandt's Black Guillemot (*Cepphus grylle mandtii*) identified via a photograph post-survey by George Divoky, a guillemot expert. This alcid is one of the few seabirds associated in all seasons with Arctic sea ice and may be at risk as the climate changes. A single Ivory Gull (*Pagophila eburnea*) was also observed on-transect flying with a group of juvenile Black-legged Kittiwakes as well as several juvenile Ross's Gulls (*Rhodostethia rosea*).

Table 11. Birds seen on-transect during the 2016 ALTIMA cruise

Common Name	**Scientific Name**	No. Birds	% Total
Pacific Loon	*Gavia pacifica*	22	0.10%
Red-throated Loon	*Gavia stellata*	2	0.01%
Yellow-billed Loon	*Gavia adamsii*	1	0.00%
Loon spp	*Gavia spp*	2	0.01%
Northern Fulmar	*Fulmarus glacialis*	21	0.09%
Short-tailed Shearwater	*Puffinus tenuirostris*	20370	91.33%
Long-tailed Duck	*Clangula hyemalis*	10	0.04%
Common Eider	*Somateria mollissima*	3	0.01%
Eider spp	*Somateria spp*	3	0.01%
Red Phalarope	*Phalaropus fulicarius*	4	0.02%
Red-necked Phalarope	*Phalaropus lobatus*	9	0.04%
Phalarope spp	*Phalaropus spp*	139	0.62%
Parasitic Jaeger	*Stercorarius parasiticus*	5	0.02%
Pomarine Jaeger	*Stercorarius pomarinus*	17	0.08%
Jaeger spp	*Stercorarius spp*	1	0.00%
Black-legged Kittiwake	*Rissa tridactyla*	200	0.90%
Glaucous Gull	*Larus hyperboreus*	11	0.05%
Sabine's Gull	*Xema sabini*	2	0.01%
Ivory Gull	*Pagophila eburnea*	1	0.00%
Ross’s Gull	*Rhodostethia rosea*	4	0.02%
Gull spp	*Laridae spp*	48	0.22%
Common Murre	*Uria aalge*	30	0.13%
Thick-billed Murre	*Uria lomvia*	202	0.91%
Murre spp	*Uria spp*	11	0.05%
Ancient Murrelet	*Synthliboramphus antiquus*	105	0.47%
Crested Auklet	*Aethia cristatella*	762	3.42%
Least Auklet	*Aethia pusilla*	223	1.00%
Parakeet Auklet	*Aethia psittacula*	71	0.32%
Auklet spp	*Aethia spp*	10	0.04%
Horned Puffin	*Fratercula corniculata*	6	0.03%
Tufted Puffin	*Fratercula cirrhata*	8	0.04%
Total		**22303**	

Dragging and recovery attempts

We successfully dragged for, and retrieved, the oceanographic mooring at the M8 site in the Bering Sea that did not release (Figure 28).

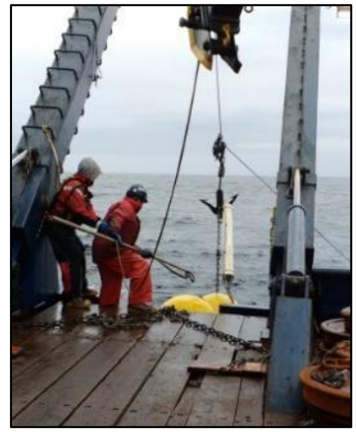


Figure 28. Successful dragging attempt and retrieval of mooring through A-frame.

ACKNOWLEDGMENTS

This project would not be possible without funding from NOAA's Office of Oceanic and Atmospheric Research (OAR). We would also like to thank Dee Williams and Carol Fairfield at the Bureau of Ocean Energy Management (BOEM) for their continued project support. We also thank Anurag Kumar (*Navy Living Marine Resources Program*), Jeff Leonhard *(Naval Surface Warfare Center, Crane Division)*, Theresa Yost *(Naval Operational Logistics Support Center)*, and Todd Mequet and Edward Rainey *(Applied Logistics Services, Inc)* for providing the sonobuoys. We are extremely grateful to Captain Bruce Greenwood and the crew of the F/V *Aquila* for their help and assistance during the cruise, their hard work and cheerful attitude made the cruise a success. Catherine Berchok would also like to personally thank the Alaskan Village liaisons, and AEWC representatives (especially Arnold Brower, Executive Director of the AEWC), for their updates, support, and kind words during the research cruise.

APPENDICES

Appendix 1. List of personnel

Position	Name	Institution
Chief Scientist, Lead Acoustics	Catherine Berchok	MML/AFSC
Lead Oceanography	Geoff Lebon (on behalf of Stabeno)	PMEL
Lead Zooplankton*	Morgan Busby (on behalf of Logerwell)	RACE/AFSC
Lead Mammal Observer	Corey Accardo (on behalf of Rone)	Provincetown Center for Coastal Studies
Acoustician	Jessica Crance	MML/AFSC
Acoustician	Stephanie Grassia	MML/AFSC
Mammal Observer	Shannon Coates	Independent contractor
Mammal Observer	Bernardo Alps	California Whales & Wildlife
Oceanography	Giovanni Learned	PMEL
Oceanography	Sigrid Salo	PMEL
Oceanography*	Eric Wisegarver	PMEL
Seabird observer*	Tamara Zeller	U.S. Fish and Wildlife Service
Independent acoustician**	Kerri Seger	Univ. New Hampshire
Independent oceanographer**	Dan Naber	Univ. Alaska Fairbanks

*On board for Chukchi Sea leg only, 3-23 September
**On board for Bering Sea leg only, 23-29 September

Appendix 2. Sonobuoy deployment date, time, position (decimal degrees), and species detected (1=detected, 0=not detected, 2=maybe)

Station #	Date	Time	Latitude	Longitude	Depth (m)	Gunshot	Right whale	Bowhead	Humpback	Fin	Orca	Gray	Bearded	Walrus	Unk. Pinn.	Ribbon	Airguns	Other	Unknown
1	9/4/2016	0:11:44	64.62453	-167.10645	27.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	9/4/2016	2:13:07	64.87613	-167.51685	31.5	0	0	0	0	0	1	0	0	0	0	0	0	0	0
3	9/4/2016	5:39:57	65.36228	-168.12382	45	0	0	0	0	2	0	0	0	0	0	0	0	0	0
4	9/4/2016	7:24:41	65.57817	-168.39795	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	9/4/2016	10:26:36	65.7589	-168.81365	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	9/4/2016	14:16:09	66.27277	-168.74577	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	9/4/2016	17:18:18	66.64472	-168.67828	42	0	0	0	1	0	0	0	0	0	0	0	0	0	0
8	9/4/2016	20:36:05	67.01797	-168.61772	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	9/4/2016	23:10:28	67.25647	-168.51553	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	9/5/2016	8:02:03	68.00607	-168.18997	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	9/5/2016	11:01:27	68.22652	-167.84473	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	9/5/2016	14:09:28	68.42463	-167.49272	54	0	0	0	0	1	0	0	0	0	0	0	1	0	1
13	9/5/2016	20:01:34	68.80033	-166.8305	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	9/5/2016	23:14:53	69.03425	-166.4222	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	9/6/2016	2:08:04	69.26112	-165.95343	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	9/6/2016	5:07:40	69.50688	-165.17323	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	9/6/2016	8:01:12	69.80903	-164.43555	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	9/6/2016	11:03:22	70.11123	-163.54688	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	9/6/2016	11:09:48	70.12175	-163.51342	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	9/6/2016	14:25:10	70.4395	-162.53445	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	9/6/2016	15:10:20	70.50198	-162.29678	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	9/6/2016	16:18:48	70.60808	-161.93295	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	9/7/2016	2:06:00	70.94568	-160.17492	56	2	0	2	2	0	0	1	0	2	0	0	0	0	0
24	9/7/2016	5:14:59	71.05372	-159.21208	68	0	0	1	0	0	0	1	1	2	0	0	0	0	0
25	9/7/2016	11:26:15	71.29105	-157.38892	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	9/7/2016	15:04:17	71.49382	-155.94662	40	0	0	0	0	0	0	0	0	1	0	0	1	0	0
27	9/7/2016	18:26:23	71.66095	-155.21007	164	0	0	0	0	0	0	0	0	0	0	0	1	0	0
28	9/7/2016	22:04:59	71.73025	-153.9874	54	0	0	2	0	0	0	0	0	0	0	1	1	1	0
29	9/8/2016	1:43:56	71.8405	-153.8265	188	0	0	2	0	0	0	0	0	0	1	2	0	1	0
30	9/8/2016	5:09:05	72.15862	-155.18507	800	0	0	0	0	0	0	0	1	0	0	0	0	0	0
31	9/8/2016	15:36:20	72.46267	-156.53235	1050	0	0	0	0	0	0	0	0	0	0	0	1	1	0
32	9/9/2016	0:20:00	72.58883	-158.47992	134	0	0	0	0	0	0	0	1	0	0	0	1	0	0
33	9/9/2016	2:03:02	72.4925	-157.6624	205	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	9/9/2016	5:13:15	72.3178	-156.14945	751	0	0	0	0	0	0	0	1	0	0	1	1	0	0
35	9/9/2016	8:07:41	72.15608	-154.78568	1250	0	0	0	0	0	0	0	0	0	0	0	1	1	0
36	9/9/2016	11:21:42	71.989	-153.37595	1600	0	0	0	0	0	0	0	1	0	0	1	1	1	0

Station #	Date	Time	Latitude	Longitude	Depth (m)	Gunshot	Right whale	Bowhead	Humpback	Fin	Orca	Gray	Bearded	Walrus	Unk. Pinn.	Ribbon	Airguns	Other	Unknown
37	9/9/2016	16:30:48	71.73685	-153.73973	64	0	0	0	0	0	0	0	0	0	0	0	1	0	0
38	9/9/2016	20:27:28	71.4908	-154.13617	41	0	0	0	0	0	0	0	0	0	0	0	1	0	0
39	9/10/2016	5:10:00	71.53167	-155.81105	84	0	0	0	0	0	0	0	1	0	0	0	0	0	0
40	9/10/2016	8:05:54	71.5247	-156.88312	184	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	9/10/2016	11:44:47	71.56925	-157.82625	64	1	0	0	0	0	0	0	0	0	0	0	0	1	0
42	9/10/2016	15:59:16	71.45477	-156.86785	138	0	0	2	2	0	0	2	0	0	0	0	0	1	0
43	9/10/2016	20:34:58	71.27242	-157.20933	53	0	0	0	0	0	0	1	1	0	0	0	0	0	0
44	9/11/2016	14:48:04	70.9136	-159.74713	50	0	0	0	0	0	0	0	0	1	0	0	0	0	0
45	9/11/2016	20:24:36	71.13925	-160.13088	54	0	0	0	0	0	0	1	0	1	0	0	0	0	0
46	9/11/2016	23:11:07	70.9738	-160.36927	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	9/12/2016	2:04:31	70.8161	-160.87515	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	9/12/2016	11:14:23	70.89012	-161.67698	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	9/12/2016	13:36:12	70.08155	-162.20782	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	9/12/2016	20:03:36	71.53808	-163.47758	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	9/13/2016	5:48:06	71.3826	-163.40892	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	9/13/2016	5:53:37	71.39365	-163.4252	42	2	0	0	0	0	0	0	1	2	0	0	0	0	0
53	9/13/2016	10:29:51	71.78068	-164.25828	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	9/13/2016	13:59:29	71.95448	-165.25108	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	9/13/2016	19:47:17	71.65773	-165.46402	38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	9/13/2016	22:56:38	71.45908	-164.79873	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	9/13/2016	23:03:06	71.46062	-164.74697	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	9/13/2016	23:13:01	71.4628	-164.6674	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	9/14/2016	2:32:54	71.46825	-163.47607	41	2	0	2	0	0	0	0	1	1	0	0	0	0	0
60	9/14/2016	11:24:03	71.25643	-164.30002	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	9/14/2016	22:05:54	71.45472	-163.43125	41	0	0	0	0	0	0	0	0	1	0	0	0	0	0
62	9/15/2016	1:58:17	71.47593	-164.17362	43	0	0	0	0	2	0	0	1	1	0	0	0	2	0
63	9/15/2016	5:13:06	71.4307	-164.50342	41	0	0	1	0	0	0	0	1	0	0	0	0	0	0
64	9/15/2016	9:51:30	71.1249	-163.9781	43	0	0	2	0	0	0	0	0	0	0	0	0	0	0
65	9/15/2016	13:35:43	70.85437	-163.21303	43	0	0	0	0	0	0	0	0	2	0	0	0	0	0
66	9/15/2016	20:01:37	70.57348	-162.55368	36	0	0	0	0	0	0	0	0	1	0	0	0	0	0
67	9/16/2016	14:08:46	70.37505	-163.66583	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	9/16/2016	17:25:15	70.61432	-164.45893	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	9/16/2016	21:26:57	70.71253	-164.78683	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	9/17/2016	2:08:10	70.95368	-165.80347	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	9/17/2016	5:14:06	70.89047	-166.74397	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	9/17/2016	8:22:08	70.8356	-167.49328	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	9/17/2016	15:36:57	70.76222	-168.07562	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	9/17/2016	5:12:29	70.6785	-168.33533	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station #	Date	Time	Latitude	Longitude	Depth (m)	Gunshot	Right whale	Bowhead	Humpback	Fin	Orca	Gray	Bearded	Walrus	Unk. Pinn.	Ribbon	Airguns	Other	Unknown
75	9/18/2016	5:16:47	70.67835	-168.34215	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	9/18/2016	9:31:00	70.76022	-168.87252	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	9/18/2016	13:47:28	70.52715	-167.85555	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	9/18/2016	20:17:00	70.10342	-166.01042	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	9/18/2016	20:21:42	70.09973	-165.99268	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	9/18/2016	20:26:59	70.09542	-165.97238	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	9/19/2016	0:27:35	69.84338	-164.9614	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	9/19/2016	0:37:03	69.84767	-165.0158	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	9/19/2016	7:07:09	70.0318	-166.92363	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	9/19/2016	11:02:13	70.26938	-168.2584	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	9/19/2016	16:09:25	70.09113	-167.81928	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	9/19/2016	18:59:45	69.86055	-166.9046	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	9/19/2016	22:57:56	69.57427	-165.71542	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	9/20/2016	1:46:02	69.42365	-166.85267	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	9/20/2016	9:04:53	69.1834	-167.465	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	9/20/2016	12:00:13	68.79723	-167.23672	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	9/20/2016	19:37:22	68.13695	-167.4739	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	9/21/2016	5:13:51	67.57953	-168.78925	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	9/21/2016	10:09:14	67.08418	-167.9999	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	9/21/2016	13:26:33	67.03772	-166.70488	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	9/23/2016	1:23:15	64.73145	-167.64672	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96	9/24/2016	5:10:27	62.73488	-168.22652	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97	9/24/2016	9:17:43	62.35927	-169.27452	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
98	9/24/2016	11:55:04	62.10427	-169.93213	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99	9/24/2016	14:07:46	61.90715	-170.46748	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	9/24/2016	16:19:41	61.73052	-170.94483	49	1	0	0	0	1	0	0	0	2	0	0	0	0	0
101	9/24/2016	17:31:18	61.62243	-171.20405	51	1	0	0	0	1	0	0	0	2	0	0	0	0	0
102	9/24/2016	20:07:33	61.6327	-171.56422	54	0	0	0	0	1	0	0	0	0	0	0	0	0	0
103	9/24/2016	22:58:30	61.77462	-172.36422	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0
104	9/25/2016	1:58:41	61.92422	-173.19772	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0
105	9/25/2016	2:13:08	61.93507	-173.259	61	0	0	0	0	1	0	0	0	0	0	0	0	0	0
106	9/25/2016	5:13:34	62.07548	-174.03073	63	0	0	0	2	1	1	0	0	0	0	0	1	0	0
107	9/25/2016	20:14:02	61.91152	-174.27368	72	0	0	0	0	1	1	0	0	0	0	0	0	0	0
108	9/25/2016	23:02:05	61.55255	-173.79127	72	0	0	0	0	1	0	0	0	0	0	0	0	0	0
109	9/26/2016	2:01:31	61.18397	-173.27313	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	9/26/2016	2:13:34	61.15973	-173.23937	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
111	9/26/2016	2:28:21	61.12907	-173.19745	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
112	9/26/2016	2:39:21	61.10657	-173.16733	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station #	Date	Time	Latitude	Longitude	Depth (m)	Gunshot	Right whale	Bowhead	Humpback	Fin	Orca	Gray	Bearded	Walrus	Unk. Pinn.	Ribbon	Airguns	Other	Unknown
113	9/26/2016	5:28:05	60.75923	-172.67683	64	0	0	0	0	0	0	2	0	0	2	0	0	0	0
114	9/26/2016	8:17:03	60.37425	-172.19393	66	0	0	0	1	1	1	0	0	0	0	0	0	0	0
115	9/26/2016	14:51:55	59.89427	-171.68877	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0
116	9/26/2016	15:14:29	59.86777	-171.59348	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
117	9/26/2016	15:49:41	59.82607	-171.44447	70	0	0	0	2	0	2	0	0	0	0	0	0	0	0
118	9/26/2016	17:28:52	59.70698	-171.01608	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
119	9/26/2016	18:25:54	59.63197	-170.76862	67	1	0	0	0	1	0	0	0	0	0	0	0	0	0
120	9/26/2016	18:57:26	59.59108	-170.64863	66	1	0	0	0	1	0	0	0	0	0	0	0	0	0
121	9/26/2016	20:04:31	59.46257	-170.7909	68	1	0	0	0	1	2	0	0	0	0	0	0	0	0
122	9/26/2016	23:01:50	59.32442	-169.93293	61	0	0	0	0	1	1	0	0	0	0	0	0	0	0
123	9/27/2016	2:45:16	59.07428	-169.35192	53	0	0	0	2	1	0	0	0	0	0	0	0	0	0
124	9/27/2016	5:09:49	58.72947	-169.20507	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	9/27/2016	5:18:37	58.70845	-169.19683	61	0	0	0	0	1	0	0	0	0	0	0	0	0	0
126	9/27/2016	7:56:54	58.3362	-169.00152	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127	9/27/2016	9:35:58	58.09045	-168.95237	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	9/27/2016	10:07:12	58.01043	-168.93108	69	0	1	0	0	1	0	0	0	0	0	0	0	0	0
129	9/27/2016	18:09:04	57.85408	-168.50148	70	0	0	0	0	1	0	0	0	0	0	0	0	0	0
130	9/27/2016	20:06:32	57.82523	-167.92307	66	0	0	0	0	1	0	0	0	0	0	0	0	0	0
131	9/27/2016	23:12:09	57.7827	-167.08893	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
132	9/28/2016	1:57:19	57.74962	-166.34768	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0
133	9/28/2016	5:03:00	57.71808	-165.51182	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	9/28/2016	9:18:52	57.5821	-164.63052	56	1	1	0	2	0	0	0	0	0	0	0	0	0	0
135	9/28/2016	11:44:48	57.24383	-164.36525	64	2	0	0	0	2	0	0	0	0	0	0	0	0	0
136	9/28/2016	14:13:51	56.90955	-164.08162	67	2	0	0	0	0	0	0	0	0	2	0	0	0	0
137	9/28/2016	23:16:10	56.54497	-164.10742	77	0	0	0	2	0	0	0	0	0	0	0	0	0	0
138	9/29/2016	2:07:22	56.21847	-164.30188	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	9/29/2016	5:12:43	55.79787	-164.54403	93	0	0	0	1	1	0	0	0	0	0	0	0	0	0
140	9/29/2016	7:59:52	55.42122	-164.76307	103	0	0	0	0	0	0	0	0	0	0	0	0	0	0
141	9/29/2016	11:04:09	55.02025	-164.9613	104	0	0	0	0	0	1	0	0	0	0	0	0	0	0
142	9/29/2016	14:02:01	54.67238	-165.1126	78	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Appendix 3. CTD and zooplankton report

A report on the CTD and ichthyo-zooplankton stations between 3 and 23 September can be found in the electronic document entitled “Eco-FOCI2016_CruiseReport.pdf”.

Appendix 4. Mooring designs (all mooring designs provided by Mike Craig from the PMEL mooring shop at NOAA (Seattle, WA)).

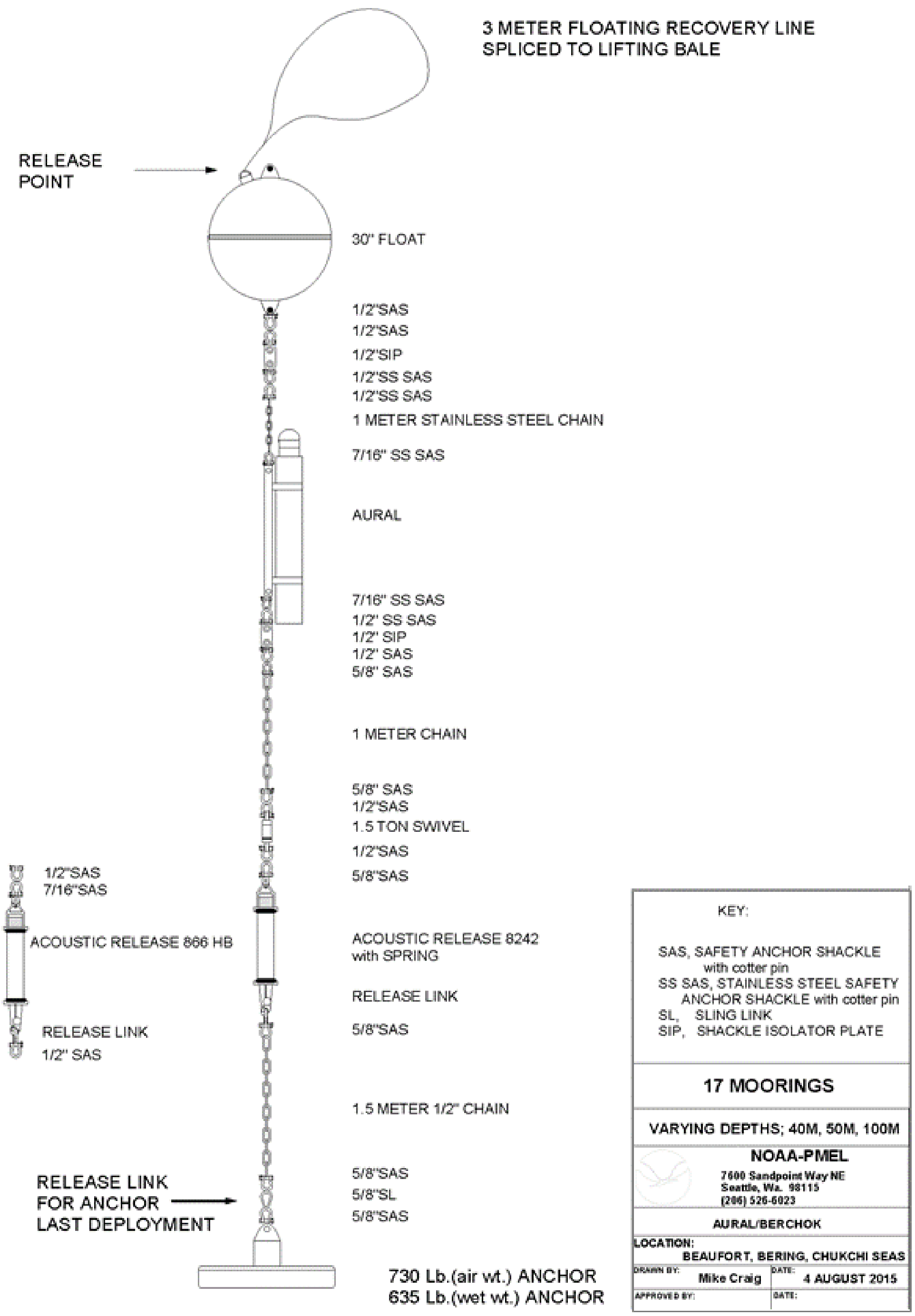
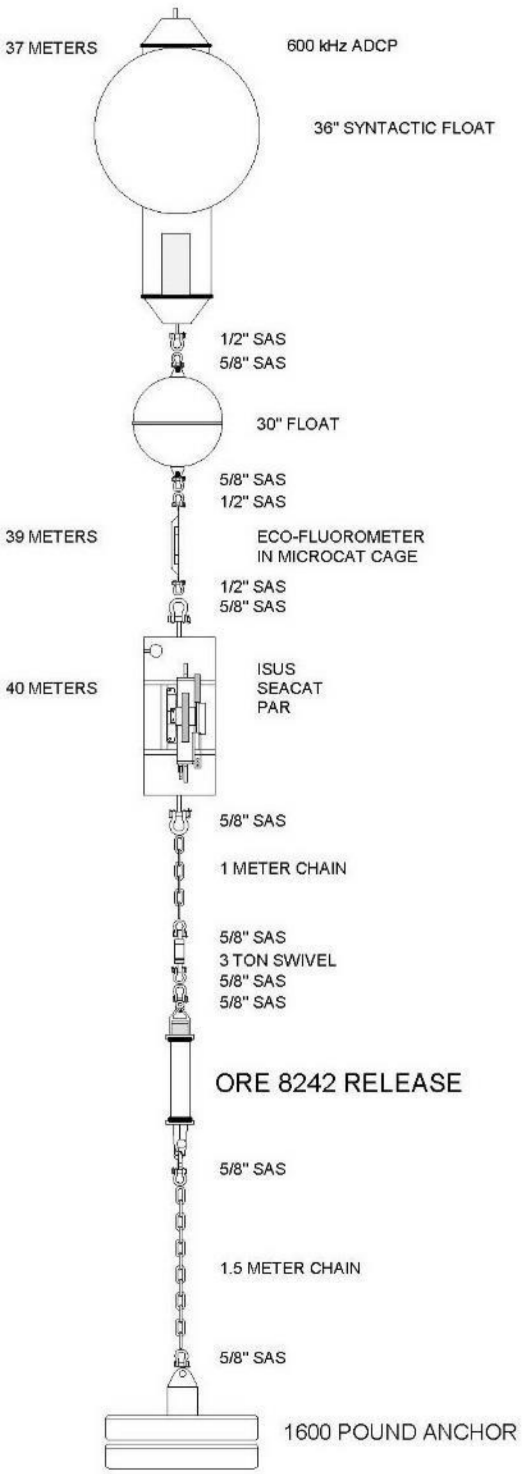


Figure A 4.1. Mooring design for the passive acoustic moorings. Two different types of acoustic releases were used among the moorings.



INSTRUMENT	DEPTH M	SERIAL NO.
600kHzADCP	37	
ECOFLO	39	
ISUS	40	
SEACAT	40	
PAR	40	
BOTTOM	44	

NOAA-PMEL-FOCI
7600 Sandpoint Way NE
Seattle, Wa. 98115
(206) 526-6175

MOORING: 12CKP-2A

LOCATION:

DRAWN BY: Rick Miller | DATE: 9 MAY 2012

APPROVED BY: | DATE:

Figure A 4.2. Mooring design for 16CKP moorings. In addition to the 600 kHz ADCP (currents), this mooring contains instruments to measure nitrate (ISUS), temperature and salinity (Seacat), fluorescence (EcoFluorometer) and Photosynthetically Active Radiation (PAR).

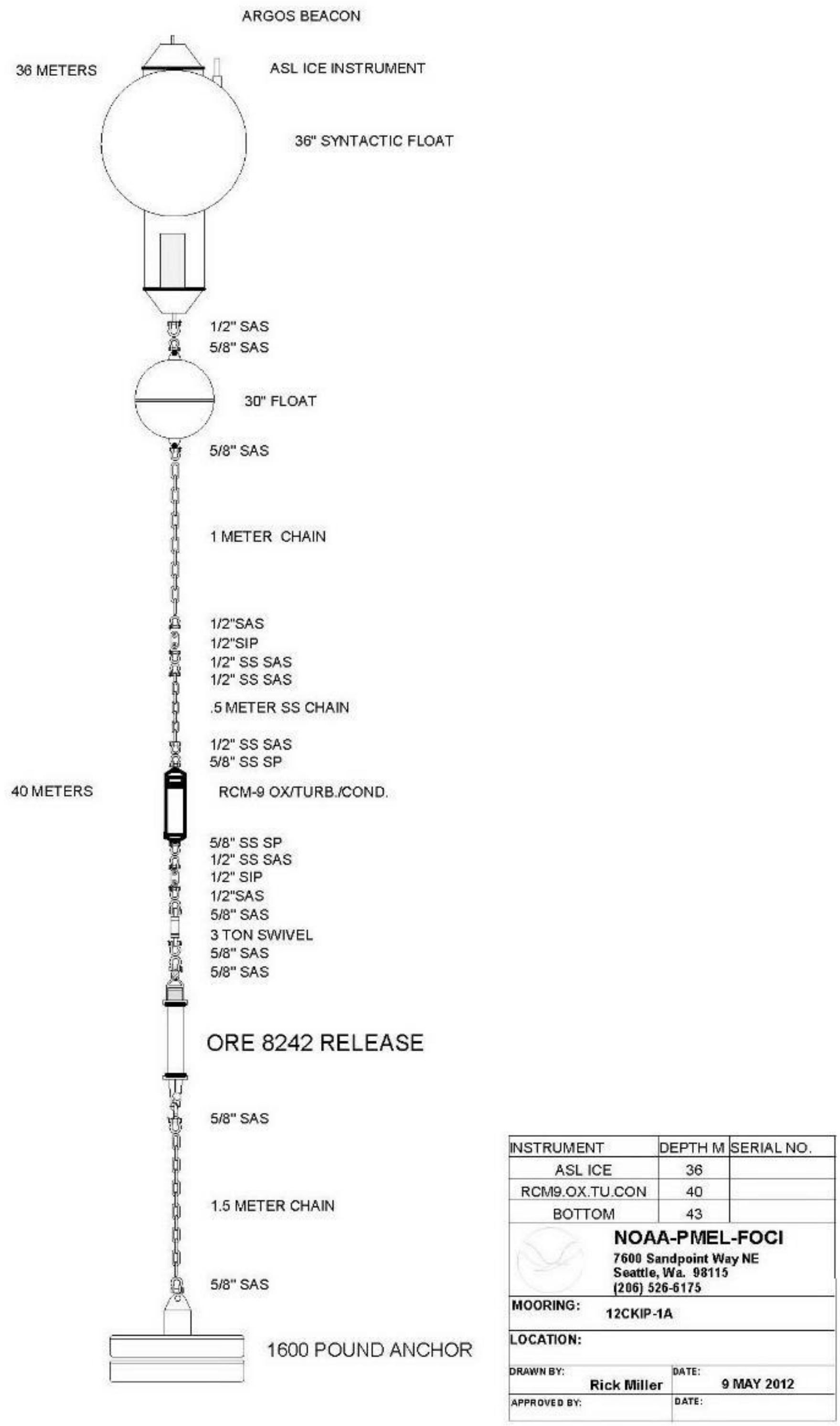


Figure A 4.3. Mooring design for 16CKIP moorings. In addition to the ASL ice instrument (measures ice thickness), this mooring contains an RCM9 that measures currents, temperature, oxygen, and turbidity.

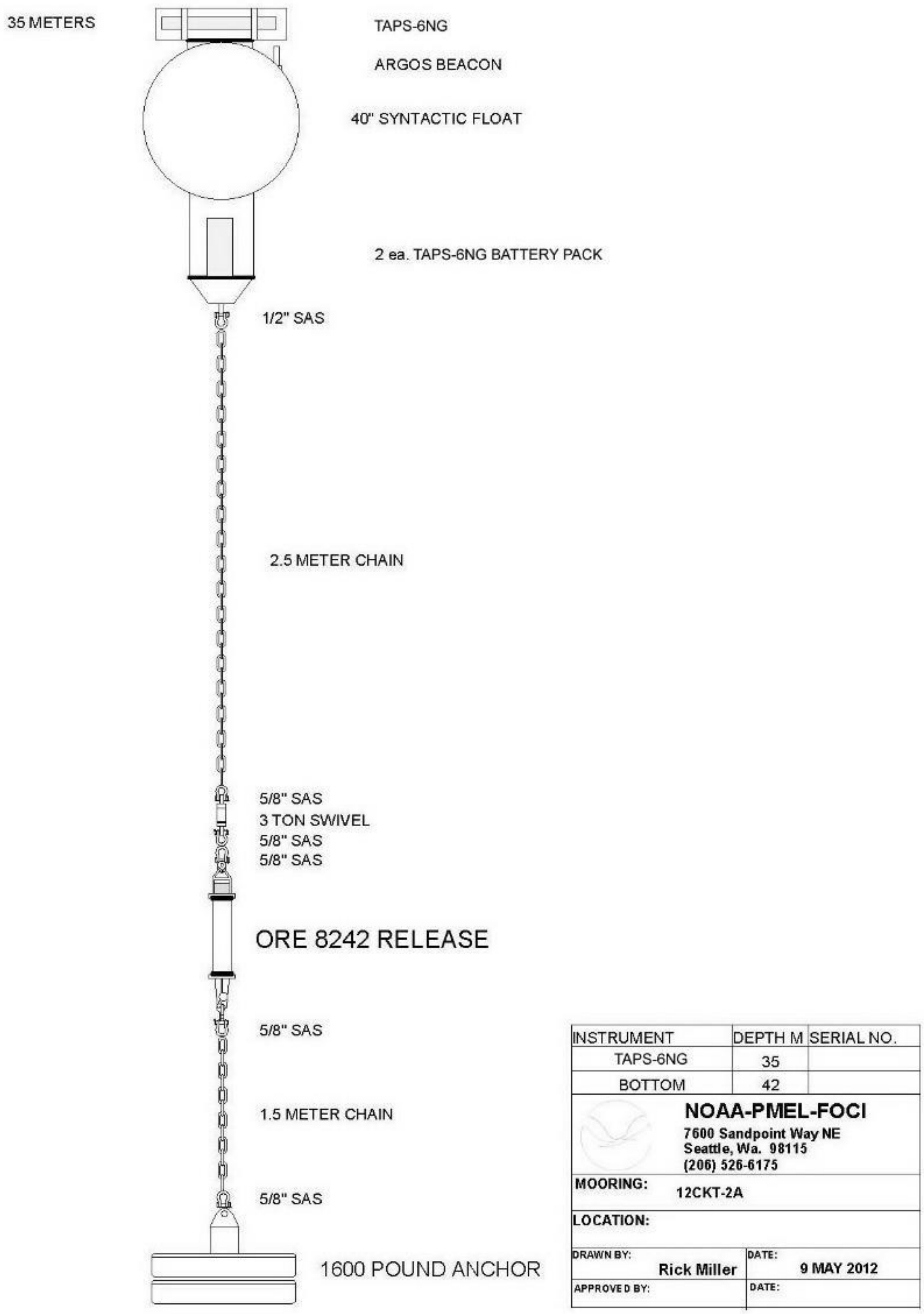


Figure A 4.4. Design for moorings 16CKT moorings. The TAPS-6NG is an instrument that acoustically measures zooplankton bio-volume and is optimized to detect krill.

Appendix 5. Instrument abbreviations

Abbreviation	Name of Instrument
IPS	ASL Environmental Sciences Ice Profiler
TAPS	Tracor Acoustic Profiler System
ADCP	Acoustic Doppler Current Profiler (-IT indicates it was in ice-tracking mode)
PAR	Photosynthetically active radiation
SUNA	Submersible Ultraviolet Nitrate Analyzer
RCM	Aanderaa current meters, RCM9, RCM11 or Seaguard
SBE	Seabird Electronics instruments SBE 16 or SBE 37 (conductivity, temperature, some with pressure)
SBET	Seabird Electronics Temperature Recorder SBE 39 or SBE 56
OP	Optode oxygen sensor on Aanderaa current meter or SBE instrument
TU	Turbidity sensor on Aanderaa current meter
CS	Conductivity sensor on Aanderaa current meter
OX	Seabird SBE43 oxygen sensor
ISUS	In situ ultraviolet spectrometer nitrate sensor
FLUOR	Environmental Characterization Optics Fluorometer
MTR	Mini Temerature Recorder
MC	MicroCAT Conductivity and Temperature Recorder
SAMI	Submersible Autonomous Moored Instrument for pH and pCO2
SeaFET	Sea field effect transistor pH Sensor
AURAL	MML Autonomous Underwater Recorder for Acoustic Listening
Eppley	Eppley Radiometer Package
Labonachip	Lab on a chip set up to measure nitrate
SPN1	Spn1 pyranometer (radiometer)
ATRH	Air temperature, relative humidity instruments
WINDS	Windsonic wind sensor
Prawler	PMEL wave-powered instrument, crawls up mooring line and measures temperature and salinity