CHAOZ (CHukchi Acoustic, Oceanographic, and Zooplankton) Study

2010 Cruise Report

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NOAA Fisheries, Seattle, WA

SUMMARY

The first CHAOZ (CHukchi Acoustic, Oceanographic, and Zooplankton) cruise took place on board the F/V *Alaskan Enterprise*. The cruise began in Nome, AK on August 24, 2010 and ended in Dutch Harbor on September 20, 2010. Acting as Chief Scientist was Dr. Catherine Berchok, leading a team of 12 scientists representing six different laboratories. In summary, a total of 20 passive acoustic and 7 oceanographic moorings were deployed, 50 hydrographic and zooplankton stations were conducted, 24 hour passive acoustic monitoring (via sonobuoy deployments) occurred, and over 1,750 miles were surveyed for marine mammal and bird observations.

BACKGROUND

The western Arctic physical climate is rapidly changing. The summer minimum sea ice extent in 2007 and 2008 covered an area which was 37% less than that of two decades ago. The speed of these changes was unexpected, as the consensus of the climate research community just a few years ago was that such changes would not be seen for another thirty years. As sea temperature, oceanographic currents, and prey availability are altered by this climate change, changes in baleen whale species composition 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. This combination of increasing anthropogenic impacts coupled with the steadily increasing abundance and related seasonal range expansion by the bowhead, gray, humpback, and fin whales, indicates 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.

This study has four component projects: oceanography, passive acoustics, zooplankton, and climate modeling. Each component project is a technical discipline and will be coordinated by a Project Leader with extensive experience in that discipline. Passive acoustic moorings, deployed concurrently with bio-physical moorings will provide previously unattainable year-round assessments of the seasonal occurrence of bowhead, humpback, right, fin, gray, and other whales in this planning area and their response to environmental changes (including oceanographic conditions, climate, indices of potential prey density, and anthropogenic activities). Moorings permit observations during long periods when ice covers the region, especially during the critical spring and early summer periods when spring phytoplankton blooms occur. Such measurements are virtually impossible to obtain from ships, because of the relatively short duration of cruises and severe limitations in the availability of ships able to work in ice-covered seas.

The overall goal of this multi-year IA study is to document the distribution and relative abundance of bowhead, humpback, right, fin, gray, and other whales in areas of potential seismic surveying, drilling, construction, and production activities and relate changes in those variables to oceanographic conditions, indices of potential prey density, and anthropogenic activities.

OBJECTIVES

The specific objectives are:

1. Assess the year-round seasonal occurrence of bowhead, gray, and other whale calls in the Chukchi Sea.
2. Estimate the relative abundance of these whales.

3. Obtain two full years of biophysical measurements on the shallow Chukchi shelf utilizing moorings at three sites, and collect hydrographic and lower trophic level data during deployment/recovery of the moorings.
4. Evaluate the extent to which variability in environmental conditions such as sea ice, oceanic currents, water temperature and salinity, and prey abundance influence whale distribution and relative abundance.
5. Run the National Center for Atmospheric Research (NCAR) climate model (Community Climate System Model: CCSM) for future projections using the sea ice extents from 2007/2008 as initial conditions.
6. Analyze multiple ensemble members from the NCAR model and other IPCC models to assess the future variability of sea ice cover and extended sea ice free seasons during fall for the Chukchi Sea.
7. Evaluate whether changes in seasonal sea ice extent are resulting in a northward shift of Bering Sea cetacean species such as fin, humpback, and North Pacific right whales.
8. Provide long-term estimates of habitat use for large whale species and compare this with predictions about annual ice coverage in order to establish predictive variables to describe large whale occurrence.

OVERVIEW

The track taken by the ship is represented in Figure 1. Please see the report below for a description of the stations/activities.

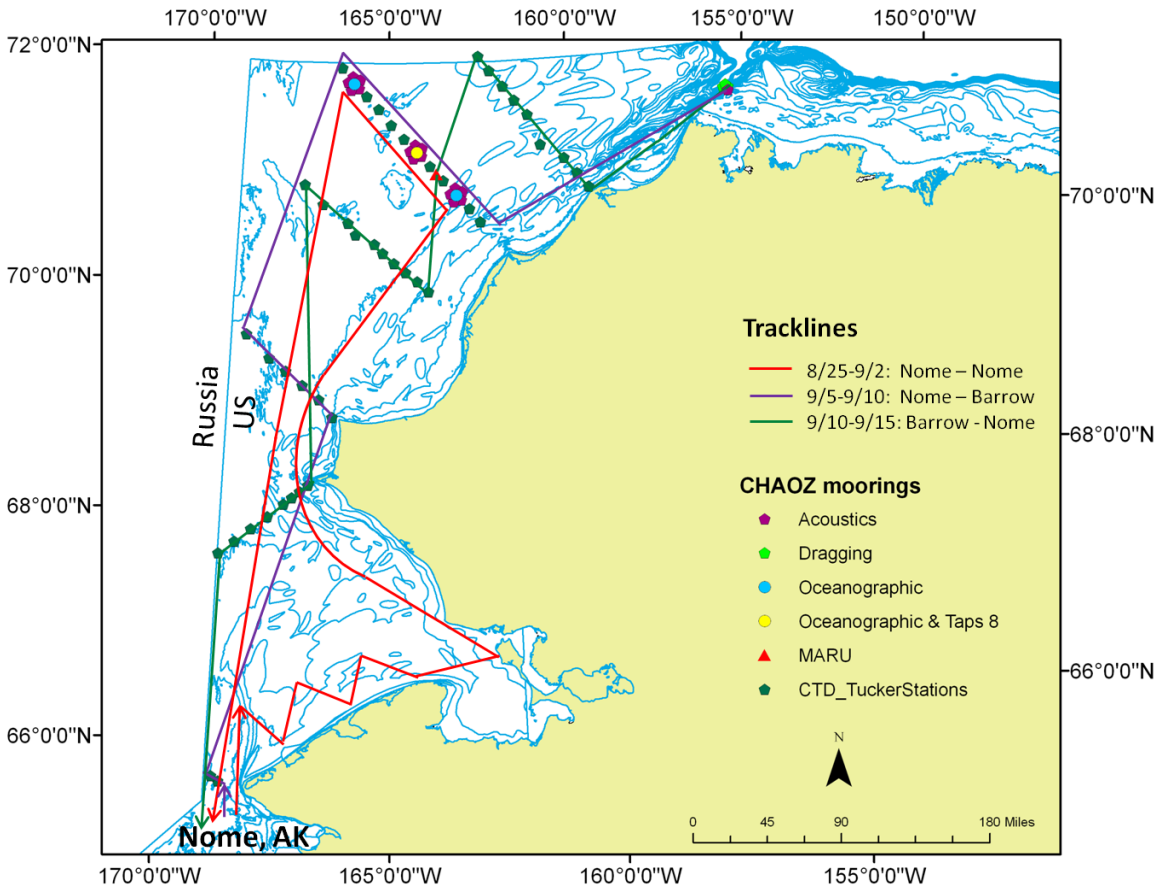


Figure 1. Trackline taken by the vessel.

RESULTS

Figure 2. Long-term passive acoustic mooring

Acoustic component

Mooring deployments

Three arrays of long-term passive acoustic recorders, shown in Figure 2, were deployed in the Chukchi Sea offshore of Icy Cape (Table 1; Figure 5, purple pentagons). These instruments (Autonomous Underwater Recorder for Acoustic Listening (AURAL), Multi-Électronique Inc.) recorded at a sampling rate of 16 kHz on a duty cycle of 1.583 hours on every 5 hours, for an entire year. 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 sample size for all time periods equally. There are five recorders in each array to reduce localization errors and increase the chance of localizations in the event of multiple recorder failures. Pingers, shown in Figure 3, were placed on four moorings of each array (moorings B-E of each array, marked with asterisk on Figure 5) to provide the calibration signals needed for calculating localization errors. We had hoped to place a pinger on each mooring frame, but faulty circuitry in the pingers resulted in three of the units catching fire during pre-deployment testing. The instruments will be refurbished and redeployed annually. See Appendix 6 for mooring designs. An additional AURAL mooring was deployed off of Barrow for the BOWhead Feeding Ecology Study (BOWFEST) project (Table 1). During transit from Nome to Dutch at the end of the cruise, three EAR (Ecological Acoustic Recorder) moorings were deployed along the 50m isobath, and one in Unimak pass (Table 1), to better understand the movements of baleen whales once they leave the Chukchi Sea.

Figure 3. Pingers being prepped for deployment on mooring

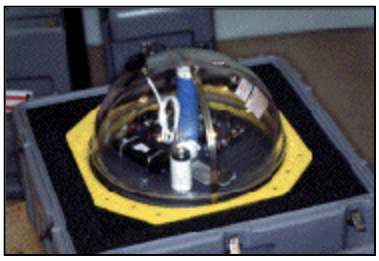


Figure 4. MARU recorder

Although deployment of the auto-detection buoy has been postponed until 2011, a double-capacity MARU (Marine Acoustic Recording Unit, Figure 4) was deployed by the Bioacoustics Research Program (BRP, Cornell University) in the original location chosen for the auto-detection buoy (Table 1; Figure 5, red triangle). As with the other moorings for this project, the MARU will be deployed for a full year, recording up to 1kHz on a duty cycle of 30 minutes on, 30 minutes off. The BRP will use the data recorded on this unit to fine-tune their auto-detection buoy in 2012.

Table 1. Date and location of passive acoustic mooring deployments

Date	Time	Mooring	Instrument	Latitude	Longitude	Depth (m)
8/29/10	01:18	CZ10_A1	AURAL	70° 54.429	-163° 14.364	42.5
8/28/10	22:34	CZ10_A2	AURAL	70° 52.303	-163° 02.650	44.3
8/28/10	23:29	CZ10_A3	AURAL	70° 47.903	-163° 04.867	43.4
8/29/10	00:08	CZ10_A4	AURAL	70° 46.956	-163° 17.235	44.3
8/29/10	00:46	CZ10_A5	AURAL	70° 51.216	-163° 22.191	42.5

8/29/10	13:27	CZ10_B1	AURAL	71° 15.165	-164° 16.621	42.5
8/29/10	14:00	CZ10_B2	AURAL	71° 14.144	-164° 11.338	42.5
8/29/10	14:37	CZ10_B3	AURAL	71° 12.122	-164° 11.534	42.5
8/29/10	15:07	CZ10_B4	AURAL	71° 11.769	-164° 17.819	43.4
8/29/10	15:34	CZ10_B5	AURAL	71° 13.715	-164° 20.666	43.4
8/31/10	8:33	CZ10_C1	AURAL	71° 51.204	-165° 59.748	44.3
8/31/10	8:55	CZ10_C2	AURAL	71° 50.037	-165° 54.198	44.3
8/31/10	9:15	CZ10_C3	AURAL	71° 48.145	-165° 55.322	44.3
8/31/10	9:36	CZ10_C4	AURAL	71° 47.893	-166° 01.812	44.3
8/31/10	9:56	CZ10_C5	AURAL	71° 49.724	-166° 04.246	44.3
9/8/10	21:28	BF10_1	AURAL	71° 33.023	-155° 33.510	69.5
9/11/10	5:38	2XB2010	MARU	71° 01.551	-163° 43.908	180
9/16/10	18:54	RW10_1	EAR	61° 35.208	-171° 19.482	51
9/17/10	10:24	RW10_2	EAR	59° 14.382	-169° 24.537	50
9/18/10	6:05	RW10_3	EAR	57° 40.212	-164° 43.424	51
9/20/10	3:23	RW10_4	EAR	54° 25.669	-165° 16.821	160

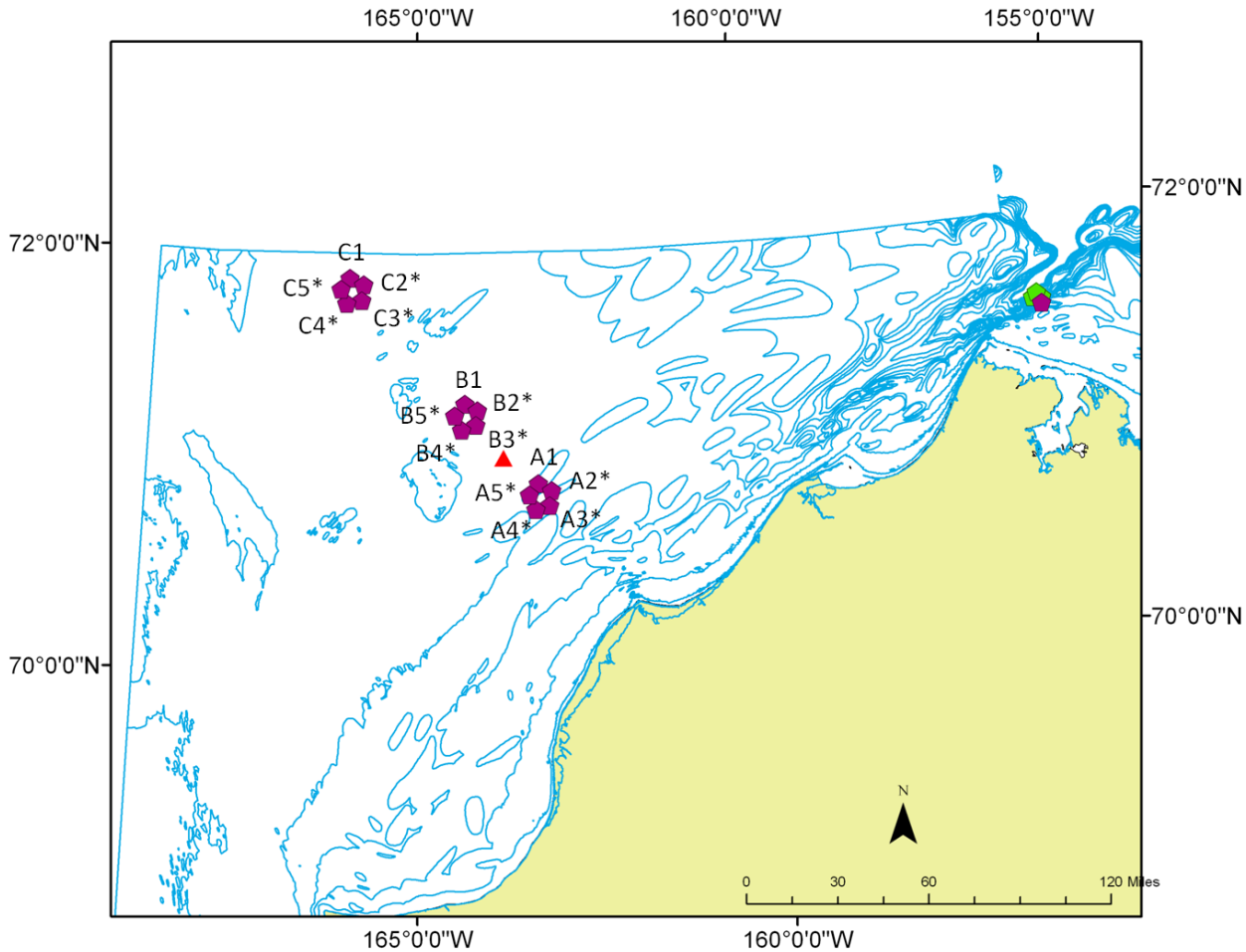


Figure 5. Location of passive acoustic moorings in the Chukchi Sea. Purple pentagons represent AURAL recorders. Red triangle represents MARU recorder.

Sonobuoy monitoring

Passive acoustic monitoring was conducted during the entire cruise using sonobuoys deployed every three hours from the starboard side of the vessel. Three types of sonobuoys were used, 77C's, 53F's and 57B's. The 57B's are an omnidirectional sonobuoy capable of recording up to 22kHz. 53F sonobuoys have either omnidirectional or DiFAR (Directional Frequency Analysis and Recording) capabilities, and the 77C sonobuoys were DiFAR only. When in DiFAR mode, the maximum frequency range is 2.5kHz, thus the buoys were often deployed in omni mode when possible (and when it was not important to get a bearing to the animal) to achieve the full bandwidth. Modifications (taping and tying) had to be made to the 77C sonobuoys since their minimum depth setting was 200 feet and most of the cruise took place in depths more shallow than that (Figure 6). After such modifications were completed, the approximate depth of the sonobuoy deployment was 70 ft.

Figure 6. Modifying the 77C. Left: taping up an additional array of sensors. Right: Tying up the depth sensors to prevent deployment to the full 200 feet.

There were two antennas installed on the vessel. One was a tuned antenna capable of receiving signals from all directions, the other was a tuned Yagi directional antenna, which helped increase reception range behind the ship while transiting. The acoustic station in the bridge is shown in Figure 7. A total of 157 sonobuoys were deployed during the cruise (Figure 8, Appendix 2). Of these, 80 were the modified 77C's, 71 were the 53F's (13 were deployed in Calibrated Omni (CO) mode), and 6 were the 57B omnidirectional buoys. The overall sonobuoy success rate was 93%, the highest of any year (2007-present). Reception range when using the omnidirectional antenna was approximately 8 miles. When the directional antenna was used, reception range almost doubled, averaging 14 miles, with a maximum of 20 miles. Species heard include humpback, fin, bowhead, gray, minke, orca, and North Pacific right whales, walrus, and a number of unidentified calls. The location of the sonobuoys and species detected are shown in Figures 9 and 10 for the Chukchi and Bering Seas respectively.

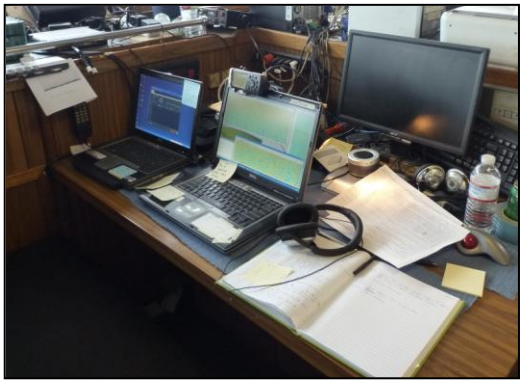


Figure 7. Acoustic station in the bridge

Figure 8. Deploying a sonobuoy

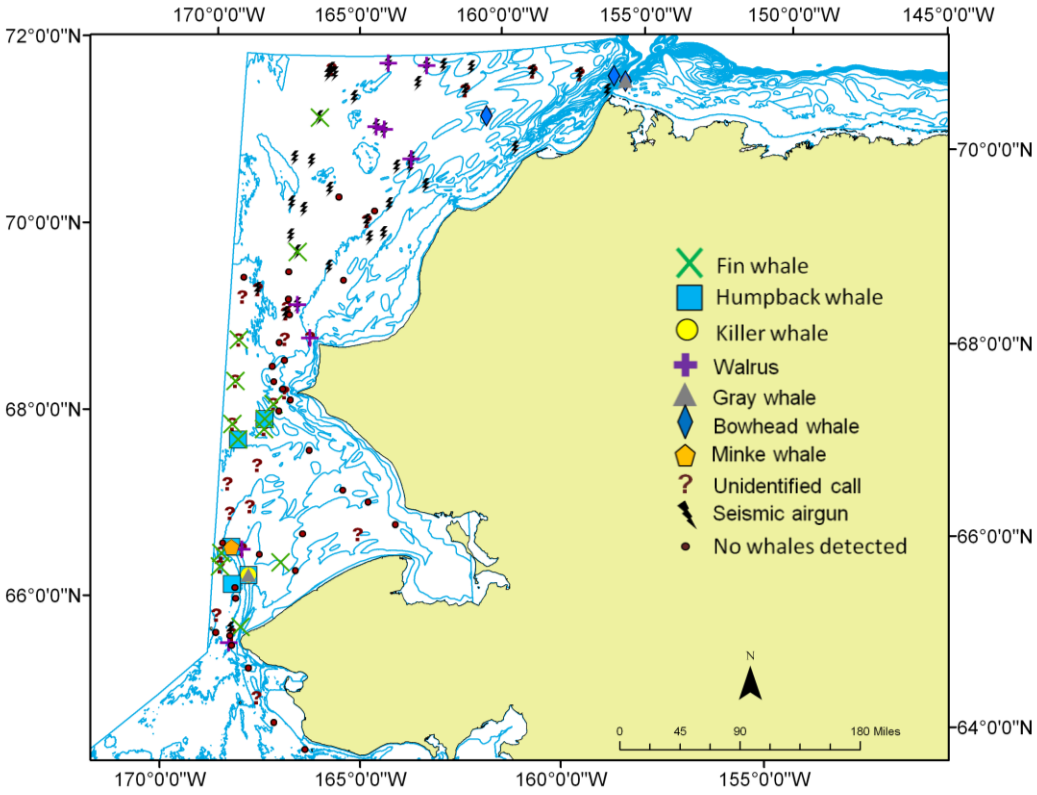


Figure 9. Sonobuoy deployment and acoustic detections in the Chukchi Sea

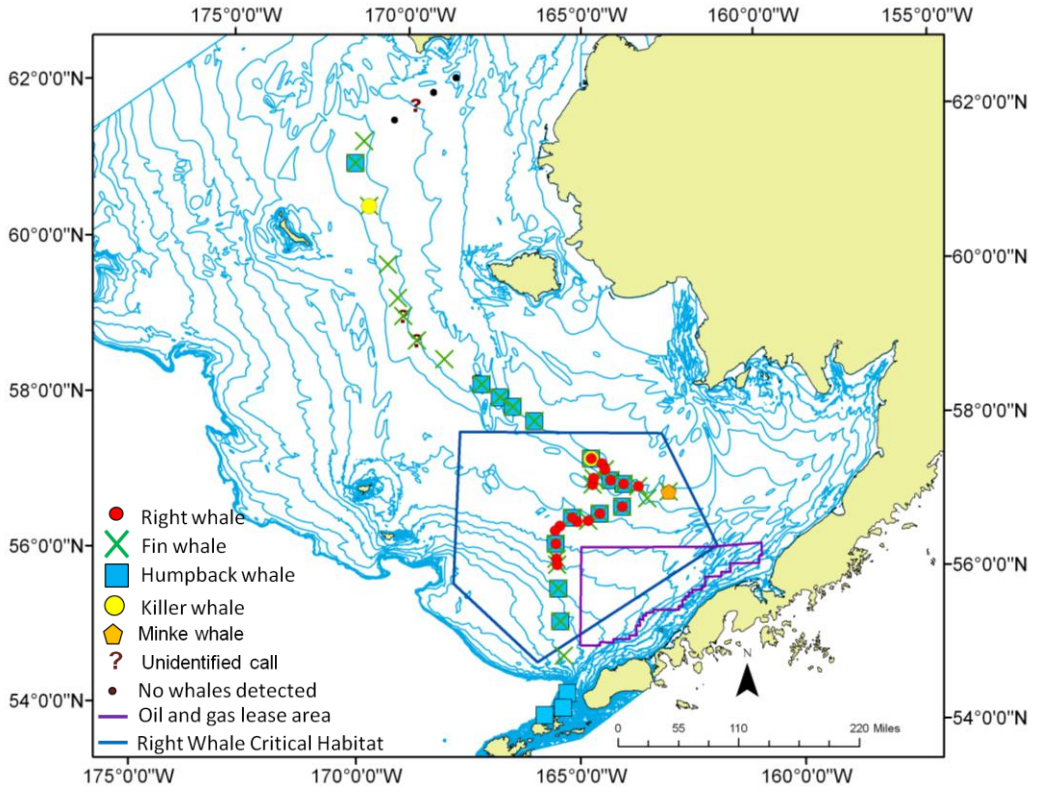


Figure 10. Sonobuoy deployment and acoustic detections in the Bering Sea

Oceanographic component

Long-term moorings

In the middle of each passive acoustic array, a cluster of oceanographic moorings, shown in Figure 11, was deployed (Table 2; Figure 12). Each cluster consisted of an "Ice mooring" containing an ASL upward-looking ice profiler and an RCM9 current meter, and a "Bio mooring" containing an RDI ADCP, and a linked set of instruments; a Seacat, an eco-fluorometer, a par sensor, and an ISUS nitrate meter. These moorings will collect various oceanographic measurements, including temperature, pressure, depth, salinity, conductivity, and fluorescence for a full year. The middle cluster also has a mooring containing a TAPS (Tracor Acoustic Profiling System) instrument to measure zooplankton bio-volume and size distribution (Figure 12, blue hexagon).

Figure 11. Oceanographic mooring being deployed

Table 2. Date and location of oceanographic mooring deployments. ADCP = Acoustic Doppler Current Meter; RCM = Recording Current Meter.

Date	Time (ALT)	Mooring name	Instrument	Latitude	Longitude
8/28/10	20:49	10CKP-1A	600 KHz ADCP	70° 50.334	-163° 11.803
8/28/10	20:32	10CKIP-1A	RCM9, ASL	70° 50.403	-163° 12.323
8/29/10	8:14	10CKP-2A	600 KHz ADCP	71° 13.178	-164° 14.971
8/29/10	9:51	10CKIP-2A	RCM9, ASL	71° 13.386	-164° 15.108
9/7/10	13:23	10CKT-2A	TAPS-8	71° 13.345	-164° 13.319
8/31/10	7:47	10CKP-3A	600 KHz ADCP	71° 49.548	-165° 58.527
8/31/10	8:10	10CKIP-3A	RCM9, ASL	71° 49.176	-165° 58.898

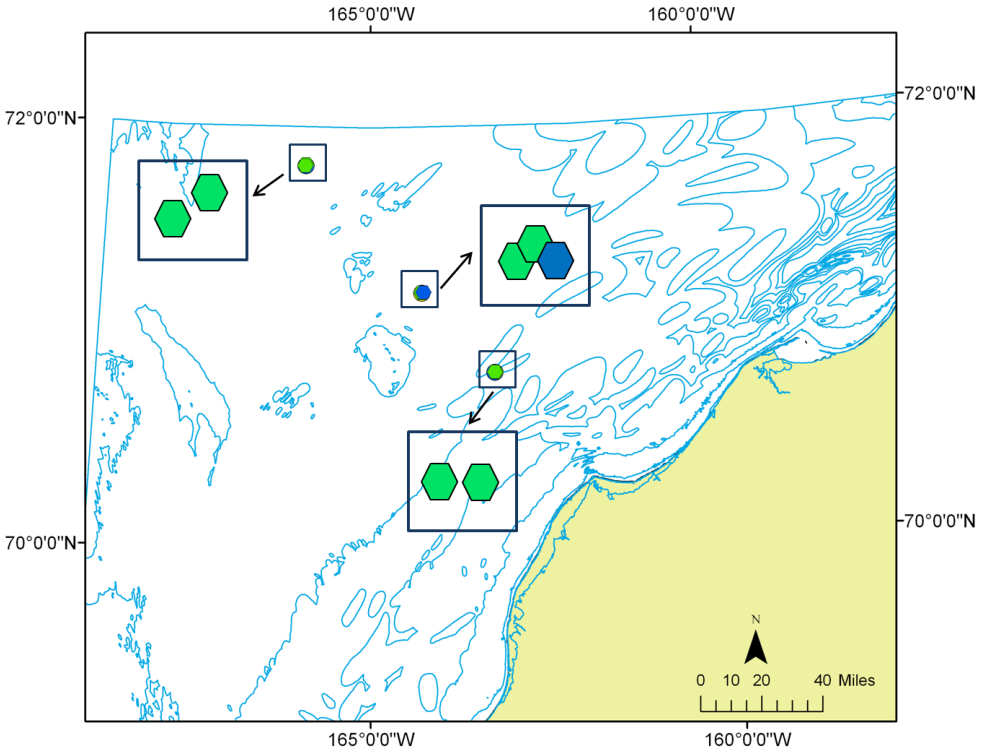


Figure 12. Location of oceanographic moorings. Blue hexagon represents the TAPS-8 mooring

Hydrography stations

Figure 13. CTD being deployed with the oceanographic winch

At each mooring site, along five transect lines in the Chukchi, and at two additional sites in the Bering Strait, hydrographic data (temperature, conductivity, nutrients, and chlorophyll) were collected (Tables 3-4; Figure 15). Initial methods included high-resolution vertical profiling of water properties (including temperature, salinity, chlorophyll fluorescence, PAR, dissolved O2) to within 4m of the bottom using a Seabird 911Plus CTD (Figure 13) with dual temperature, conductivity and oxygen sensors. Nutrient and chlorophyll samples were collected onboard and frozen for analysis at a later date at the NOAA laboratories in Seattle. A complete report on individual stations can be found in Appendix 3.

Figure 14. Manual deployment of Niskin bottles

However, after completion of only three stations and two-thirds of a 36-hour diel station, the oceanographic winch failed. We were able to rig the dragging winch to manually deploy Niskin bottles, shown in Figure 14, at three depths (1m, 15m, and 25m), but since the CTD requires a specialized conductive cable, the full host of measurements was not able to be collected for the majority of the stations. We did however collect temperature, conductivity, and pressure measurements from the entire water column by placing a SeaCAT on the frame of the Tucker sled and on the non-conducting cable used to collect the water samples.

Table 3. Summary of hydrographic and zooplankton operations

Operation	**Tows**
Seabird SeaCAT CTD (CAT)	104
CTD with bottle samples (CTDB)	10
Bottle samples (non conducting wire)	47
10" inner diameter modified Clarke-Bumpus (Lg-CB)	58
Mooring deployment or recovery (Moor; PMEL or AFSC, only)	7
Epibenthic tucker sled (Sled)	58

Table 4. Summary of hydrographic and zooplankton samples

Samples Collected	**Tows**	**Number**
Misc species in EtOH (AMGEN)	5	28
SeaBird SeaCat CTD (CAT)	104	
Extracted chlorophyll (Chlor)	58	176
SeaBird CTD (CTD)	10	
Stimulated fluorescence collected during CTD casts (Fluor)	10	
Nutrients for Calvin Mordy (PMEL) (NutPMEL)	59	181
Any other sample type (Other)	1	1
Photosynthetically Active Radiation data collected during CTD casts (PAR)	10	
Quantitative tow preserved in formalin (QTowF)	115	127
Vertical profile of acoustic backscatter from 6 freq. TAPS (TAPS6)	52	

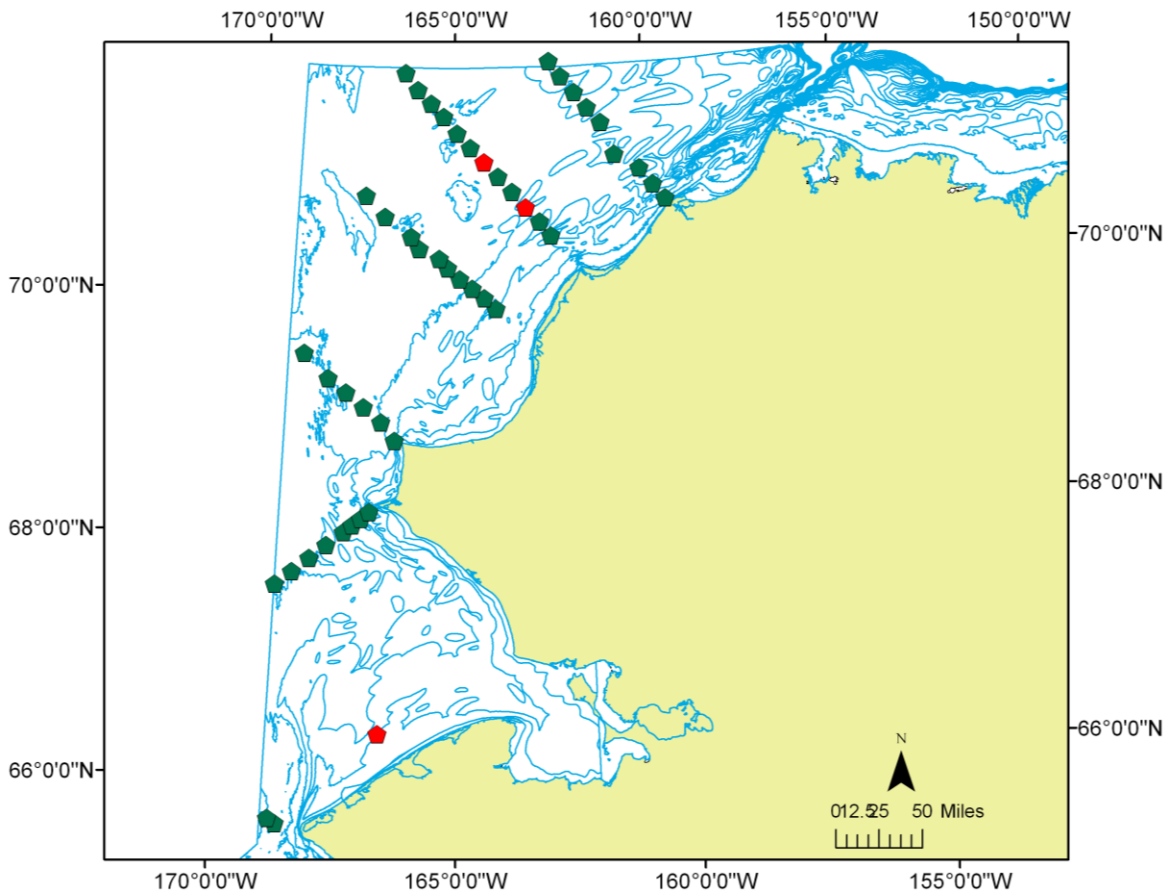


Figure 15. Location of all hydrography and zooplankton stations. Stations with full CTD represented by red dots, manual stations with a SeaCAT represented by green dots.

Zooplankton component

At each CTD station, plankton tows were conducted (Tables 3-4; Figure 15). Stratified samples for mesozooplankton and micronekton were collected with a 1m^2 Tucker Sled, shown in Figures 16 and 17, which allowed us to collect samples right next to the bottom (and does a better job of capturing larger prey such as euphausiids). The mesh size for the Tucker net was 0.333mm and the primary net had a 25cm diameter Clarke-Bumpus net frame inside it with 0.150mm mesh to capture small zooplankton. The net samples also contained ichthyoplankton (fish larvae) that will be identified and enumerated as part of the study. All processing of the

Figure 16. Tucker sled being deployed

Figure 17. Tucker sled being deployed

samples will be done after the completion of the cruise. As mentioned above, the oceanographic winch failed early on, thus requiring the net to be deployed using the dragging winch. The SeaBird SBE 19plus (SeaCAT) was attached to the top of the net sled to collect temperature, pressure, and conductivity measurements – which were downloaded at the end of each line of stations. The dragging winch worked well for towing the Tucker Sled and still allowed for the net to be deployed down to the bottom.

Visual surveys

Marine mammal observations

Rotating teams of three scientists collected sighting data using standard line transect methods during on-effort status. Operations began at 09:00 and ceased at 21:00, or as long as conditions would allow. A full observation period lasted 80 minutes (40 minutes in each position) and was followed by a 40 min rest period. One observer (starboard) was stationed on the ship's bridge wing. The observer used 25x 'big-eye' binoculars with reticles to scan from 60° port to 60° starboard (Figure 18). The computer program WINCRUZ (available at http://swfsc.nmfs.noaa.gov/PRD/softwares/software.html) was used to record all sighting and environmental data (e.g., cloud cover, wind speed and direction, and sea conditions).

Figure 18. Marine mammal observer using the Big Eye binoculars

On-effort status was defined as a visible horizon, Beaufort sea state 5 or lower, and survey speed of 10 knots through the water. Fog effort corresponded to observations conducted under poor visibility (no horizon) but with a Beaufort sea state 5 or less. Under unacceptable weather conditions (visibility ≤ 0.5 nautical miles (nmi) and/or sea state ≥ 6), off-effort watches on the bridge were conducted, in which one observer remained in the bridge to record sightings and environmental data. At the cruise leader's discretion, line transect survey effort was temporarily suspended to allow closer approaches to sightings for photo-identification. Although a biopsy sampling and satellite tagging plan was established, no sampling or tagging occurred due to the limited survey time and opportunities.

Identification photographs of target species were obtained when possible to allow evaluation of movements of animals during the survey and comparison to existing catalogs. When the observers located a target species, the visual survey effort was suspended and the primary survey vessel was directed to obtain photographs of the animals. During the CHAOZ survey, one right whale was photographed, and one attempt was made at photographing a humpback whale. Photographs were taken using Canon 50D and 5D autofocus digital cameras equipped with a 100-400 mm zoom lens.

The survey covered a total of 1484 km on-effort while fog effort legs accounted for 270 km (Table 5). There were a total of 165 sightings (218 individuals) of 13 confirmed marine mammal species; these included right, bowhead, fin, humpback, gray, and minke whales, as well as Dall's and harbor porpoise, walrus, and bearded, ringed, spotted and fur seals (Figures 19-21). Additionally, there were 101 sightings (147 individuals) of unidentified large and small whales, porpoise, and pinnipeds. For a complete list of species refer to Appendix 4. Photographs were collected of one North Pacific right whale (Figure 22) on September 18th within the right whale critical habitat. Both left and ride head photographs were obtained. No fluke photographs were captured. This individual was identified as NMML #9 ("Notchy"), an animal that has been sighted in 2008 and 2009.

Table 5. Completed visual effort for marine mammal observation

Effort type	Effort (km)
On Effort	1,484
Fog Effort	270
Total	**1,754**

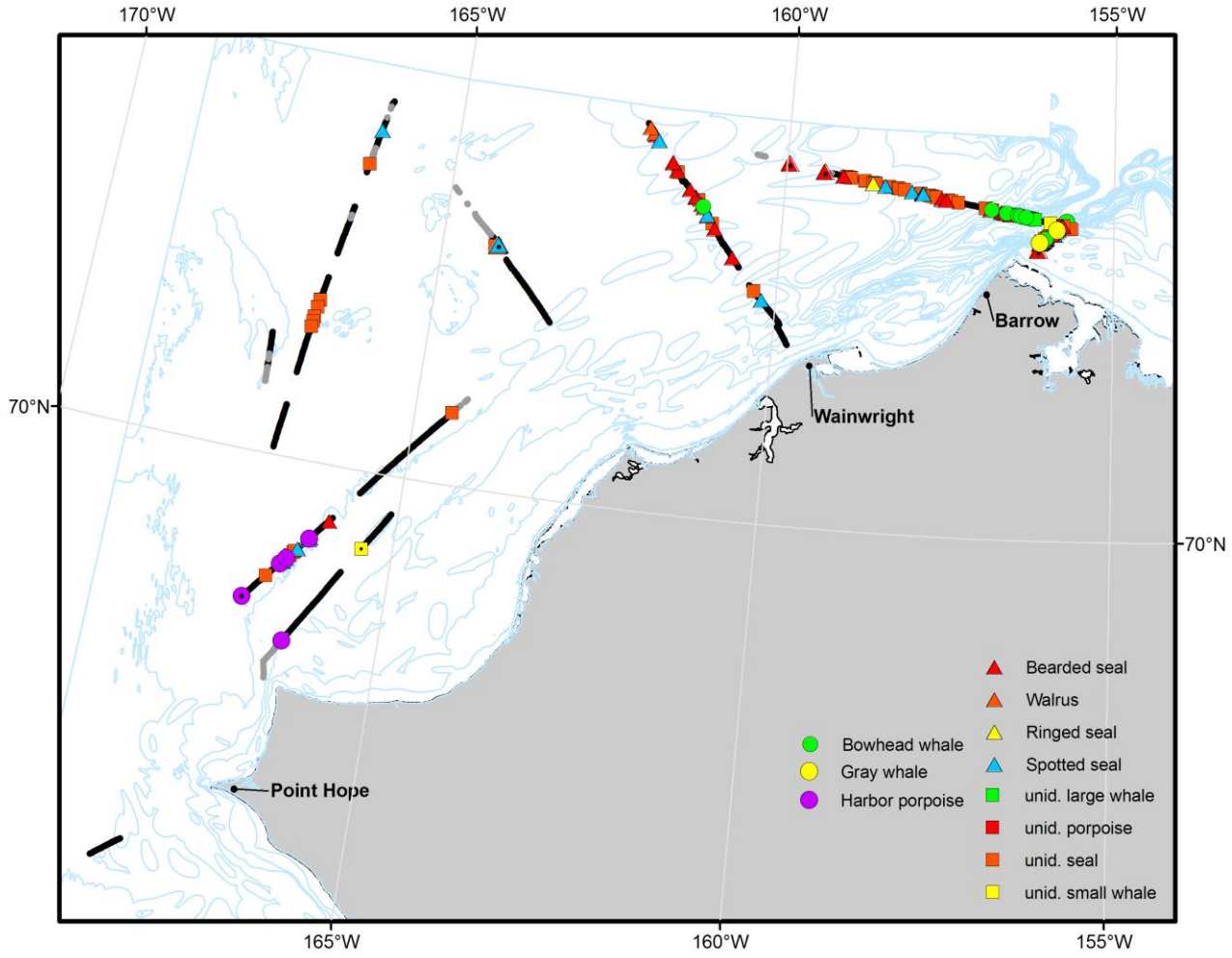


Figure 19. Marine mammal sightings and effort data from the CHAOZ 2010 research cruise, Barrow to Point Hope (open symbol = on-effort sightings, dotted symbol = off-effort sightings; on effort = black, fog effort = gray)

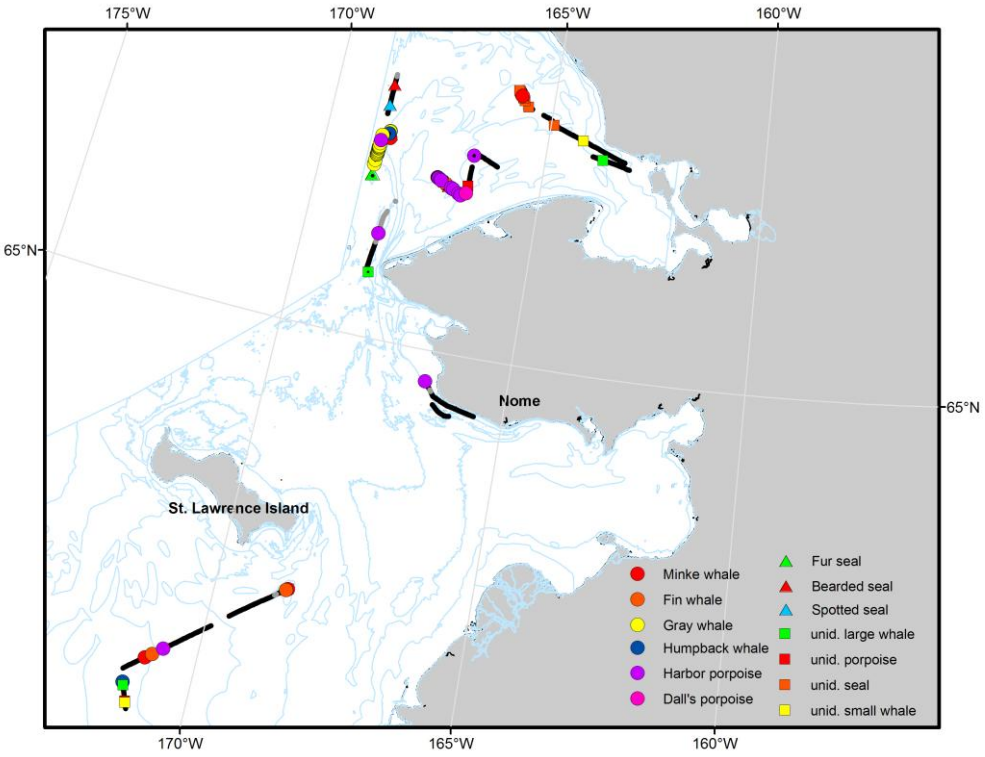


Figure 20. Marine mammal sightings and effort data from the CHAOZ 2010 research cruise, Point Hope to St. Lawrence Island (open symbol = on-effort sightings, dotted symbol = off-effort sightings; on effort = black, fog effort = gray).

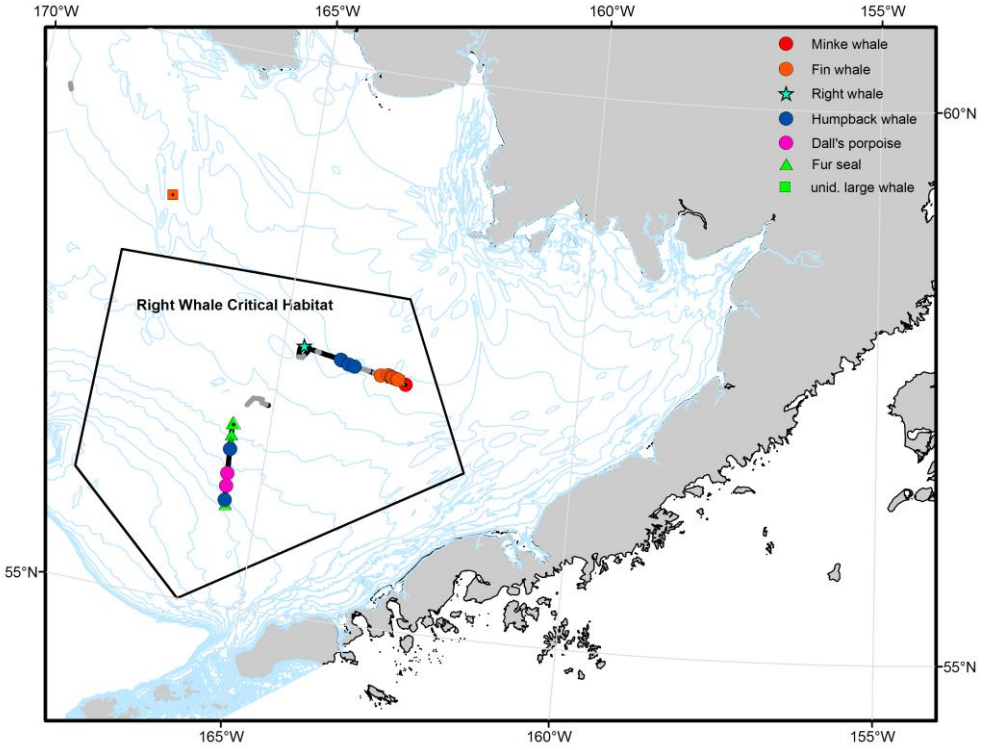


Figure 21. Marine mammal sightings and effort data from the CHAOZ 2010 research cruise, southeast Bering Sea (open symbol = on-effort sightings, dotted symbol = off-effort sightings; on effort = black, fog effort = gray).

Figure 22. North Pacific right whale, NMML 9 "Notchy", photographed on September 18th during the CHAOZ 2010 research cruise.

Birding observations

Figure 23. The bird observer Robert Ambrose

Observations were made from the bridge of the F/V *Alaskan Enterprise* during daylight hours while the ship traveled at > 5 knots between stations and during transits. The single observer (Figure 23) used hand-held 10x binoculars for identification and recorded all birds within a 300-m arc, extending 90° from the bow to the beam. Strip transect methodology was used with three distance bins. Birds on the water were counted continuously, whereas flying birds were recorded during 'scans' at approximately 1-min intervals. A DLOG3 data entry program (Ford Ecological Consultants, Inc., Portland OR) was used to record observations directly into a laptop computer interfaced with a Garmin handheld GPS. Entries made in 20-sec intervals had location, date, and time stamps, along with associated environmental and observer variables.

A total of 126 survey hours and 105 transects were completed with 24 marine bird species recorded (Appendix 5) for a total of 5,848 birds, plus additional species off transect or incidentally. Bird density was very low in general, particularly between Nome and the Bering Strait. Short-tailed shearwaters, a migratory species that breeds in the southern hemisphere, comprised 70% of all sightings. Other common species included red-necked phalaropes, black-legged kittiwakes, northern fulmars, and crested auklets. Based on observations of many of the auklets being unable to fly, certain offshore waters of the Chukchi Sea appear to be molting areas for auklets. Documenting molting areas is an important step towards identifying seasonally critical habitats for these species during a period when they are most vulnerable to disturbance.

Uncommon observations included several pairs and groups of Kittlitz's murrelets offshore of Point Lay. One juvenile whiskered auklet landed next to the ship southwest of Point Hope (not on transect), well north of its documented range. Several land and shorebirds were attracted by the ship's lights, including a long-billed dowitcher, hoary and common redpolls, and a sharp-tailed sandpiper (a Eurasian species).

Dragging and recovery attempts

A small array of three long-term passive acoustic AURAL recorders was deployed for the BOWFEST project in 2008. Recovery efforts from the USCGC *Healy* in 2009 were unsuccessful, and time constraints prevented dragging operations during that cruise. These recorders were located closer to the edge of Barrow Canyon than in previous years, and it is thought that either the strong currents worked off the floatation or a landslide occurred, the result being that two moorings were horizontal. Since the CHAOZ cruise was in the area for a crew transfer, we spent two days attempting to recover the lost moorings using our winch and a string of dragging hooks (Figures 24-25) to 'lasso' the moorings.

Figure 24. Dragging hooks used to attempt recovery of lost moorings


Figure 25. Jessica, Catherine, and 'the little dragging winch that could', Eligius.

One mooring was never located. Two were located and re-surveyed in to more accurate positions: one had moved one mile over the past two years, and one appeared to be deeply imbedded in the mud. The 'walking' mooring was hooked twice, but lost when bringing it back to the surface. The other mooring was not hooked. Discussions were made with the chief engineer and the captain on ways to improve the dragging method to try again the next year.

ACKNOWLEDGMENTS

This project would not be possible without funding from the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE). We would also like to thank Robin Brake, Theresa Yost, and Jeff Leonhard for providing the sonobuoys. We are extremely grateful to Captain Atle Remme and the crew of the F/V *Alaskan Enterprise* for their help and assistance during the cruise, and helping to make the cruise a success.

APPENDICES

Appendix 1. List of personnel

Position	Name	Nationality	Institution
Chief Scientist Lead Acoustics	Catherine Berchok	United States	NMML
Lead Oceanography	Bill Floering (on behalf of Phyllis Stabeno)	United States	PMEL
Lead Zooplankton	Jeff Napp	United States	AFSC (RACE)
Acoustician	Jessica Crance	United States	NMML
Acoustician	Elizabeth Küsel	Brazil	OSU/PMEL
Senior Mammal Observer	Amy Kennedy	United States	NMML
Mammal Observer	Brenda Rone	United States	NMML
Mammal Observer	Jessica Thompson	United States	n/a
Oceanography	Sigrid Salo	United States	PMEL
Zoo- & Ichthyoplankton	Lisa DeForest	United States	AFSC (RACE)
MARU technician	Jason Michalec	United States	Cornell Univ. (BRP)
Bird observer	Robert Ambrose	United States	US Fish and Wildlife Service

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

Buoy #	Date	Time	Latitude (N)	Longitude (W)	RW	Bow	Hump	Fin	Orca	Walrus	Gray	Minke	Unk	Airgun
1	8/25/2010	20:02:20	64.4874	166.3849	0	0	0	0	0	0	0	0	0	0
2	8/25/2010	23:17:14	64.7735	167.1888	0	0	0	0	0	0	0	0	0	0
3	8/26/2010	1:59:25	65.0355	167.6446	0	0	0	0	0	0	0	0	1	0
4	8/26/2010	4:57:12	65.33505	168.05832	0	0	0	0	0	2	0	0	0	0
5	8/26/2010	7:58:54	65.68905	168.4206	0	0	0	0	0	0	0	0	0	0
6	8/26/2010	10:15:22	66.09612	168.31893	0	0	0	0	0	0	0	0	0	0
7	8/26/2010	11:57:02	66.35643	168.00243	0	0	1	0	1	0	1	0	1	0
8	8/26/2010	13:30:13	66.58532	167.73445	0	0	0	0	0	0	0	0	0	0
9	8/26/2010	15:19:11	66.50745	167.15307	0	0	0	1	0	0	0	0	0	0
10	8/26/2010	16:28:31	66.42447	166.74812	0	0	0	0	0	0	0	0	0	0
11	8/26/2010	19:33:53	66.8231	166.5828	0	0	0	0	0	0	0	0	0	0
12	8/26/2010	23:45:02	66.8262	165.0577	0	0	0	0	0	0	0	0	1	0
13	8/27/2010	2:26:19	66.92838	164.03008	0	0	0	0	0	0	0	0	0	0
14	8/27/2010	17:18:08	67.1742	164.77918	0	0	0	0	0	0	0	0	0	0
15	8/27/2010	19:39:04	67.30365	165.48307	0	0	0	0	0	0	0	0	0	0
16	8/27/2010	23:03:18	67.7281	166.4501	0	0	0	0	0	0	0	0	0	0
17	8/28/2010	1:58:38	68.1467	167.36012	0	0	0	0	0	0	0	0	0	0
18	8/28/2010	2:28:32	68.21735	167.51948	0	0	0	1	0	2	0	0	1	0
19	8/28/2010	5:00:06	68.6252	167.6093	0	0	0	0	0	0	0	0	0	0
20	8/28/2010	8:19:56	69.18812	167.15148	0	0	0	0	0	0	0	0	0	0
21	8/28/2010	9:04:56	69.29112	166.92113	0	0	0	0	0	0	0	0	0	0
22	8/28/2010	9:08:41	69.29967	166.90168	0	0	0	0	0	1	0	0	0	1
23	8/28/2010	12:08:57	69.71667	165.95797	0	0	0	0	0	0	0	0	0	1
24	8/28/2010	16:35:08	70.32633	164.53723	0	0	0	0	0	0	0	0	0	0
25	8/28/2010	20:09:27	70.80455	163.33198	0	0	0	0	0	0	0	0	0	1
26	8/29/2010	15:57:09	71.23927	164.45342	0	0	0	0	0	1	0	0	0	1
27	8/30/2010	14:20:34	71.2098	164.1792	0	0	0	0	0	1	0	0	0	0
28	8/31/2010	10:12:07	71.80343	166.0997	0	0	0	0	0	0	0	0	0	1
29	8/31/2010	13:03:55	71.33505	166.35262	0	0	0	1	0	0	0	0	0	1
30	8/31/2010	15:57:07	70.8625	166.58977	0	0	0	0	0	0	0	0	0	1
31	8/31/2010	19:11:05	70.3362	166.7937	0	0	0	0	0	0	0	0	0	1
32	8/31/2010	22:01:05	69.8713	166.9616	0	0	0	1	0	0	0	0	0	1
33	9/1/2010	1:11:27	69.3579	167.2005	0	0	0	0	0	0	0	0	0	0
34	9/1/2010	4:06:57	68.88757	167.42488	0	0	0	0	0	0	0	0	0	0
35	9/1/2010	6:55:16	68.45865	167.53932	0	0	0	0	0	0	0	0	0	0
36	9/1/2010	10:02:51	68.0043	167.74842	0	0	0	0	0	0	0	0	0	0
37	9/1/2010	10:31:07	67.94393	167.7653	0	0	0	1	0	0	0	0	1	0
38	9/1/2010	13:02:37	67.54972	167.90962	0	0	0	0	0	0	0	0	1	0
39	9/1/2010	15:58:54	67.099	168.05563	0	0	0	0	0	0	0	0	1	0
40	9/1/2010	19:06:49	66.6311	168.2089	0	0	0	0	0	1	0	0	1	0
41	9/1/2010	22:05:30	66.2104	168.3566	0	0	0	0	0	0	0	0	0	0
42	9/2/2010	1:21:17	65.762	168.4005	0	0	0	0	0	0	0	0	0	1
43	9/2/2010	7:03:24	65.01337	167.69567	0	0	0	0	0	0	0	0	0	0
44	9/2/2010	7:19:16	6.98268	167.6349	0	0	0	0	0	0	0	0	0	0
45	9/5/2010	1:04:23	65.3488	167.9006	0	0	0	0	0	0	0	0	0	0
46	9/5/2010	2:46:18	65.5841	168.3664	0	0	0	0	0	0	0	0	0	0
47	9/5/2010	2:59:28	65.614	168.4263	0	0	0	0	0	1	0	0	0	0
48	9/5/2010	4:51:33	65.71575	168.79712	0	0	0	0	0	0	0	0	0	0
49	9/5/2010	6:59:44	65.9063	168.80215	0	0	0	0	0	0	0	0	1	0
50	9/5/2010	10:02:19	66.42978	168.78367	0	0	2	1	0	0	2	0	1	0
51	9/5/2010	10:52:02	66.57568	168.77378	0	0	0	1	0	0	2	0	1	0

52	9/5/2010	11:30:18	66.6887	168.75643	0	0	0	0	0	0	0	0	0	0
53	9/5/2010	15:13:14	67.33488	168.71183	0	0	0	0	0	0	0	0	1	0
54	9/5/2010	19:02:22	67.9795	168.6815	0	0	0	1	0	0	0	0	1	0
55	9/5/2010	22:02:47	68.4459	168.6638	0	0	0	1	0	0	0	0	1	0
56	9/6/2010	1:00:38	68.8943	168.6365	0	0	0	1	0	0	0	0	1	0
57	9/6/2010	4:09:58	69.36183	168.60825	0	0	0	0	0	0	0	0	1	0
58	9/6/2010	5:40:38	69.57467	168.5978	0	0	0	0	0	0	0	0	0	0
59	9/6/2010	7:52:34	69.45065	168.14343	0	0	0	0	0	0	0	0	1	1
60	9/6/2010	11:14:28	69.20355	167.25838	0	0	0	0	0	0	0	0	1	1
61	9/6/2010	14:05:14	68.94658	166.4993	0	0	0	0	0	1	0	0	1	0
62	9/6/2010	19:13:12	69.57495	165.5085	0	0	0	0	0	0	0	0	0	0
63	9/6/2010	23:07:50	70.0344	164.6917	0	0	0	0	0	0	0	0	0	1
64	9/7/2010	2:35:57	70.39213	164.04667	0	0	0	0	0	0	0	0	0	1
65	9/7/2010	5:57:47	70.5895	162.8577	0	0	0	0	0	0	0	0	0	1
66	9/7/2010	9:49:32	70.88258	163.30282	0	0	0	0	0	1	0	0	0	1
67	9/7/2010	12:49:05	71.20095	164.1853	0	0	0	0	0	0	0	0	0	1
68	9/7/2010	17:44:44	71.55765	165.18505	0	0	0	0	0	0	0	0	0	1
69	9/7/2010	20:48:31	71.8098	165.8689	0	0	0	0	0	0	0	0	0	1
70	9/7/2010	21:47:52	71.86108	165.97827	0	0	0	0	0	0	0	0	1	1
71	9/8/2010	4:08:30	71.92382	164.00887	0	0	0	0	0	1	0	0	0	1
72	9/8/2010	6:56:42	71.88805	162.67198	0	0	0	0	0	1	0	0	0	1
73	9/8/2010	10:02:50	71.84052	161.1304	0	0	0	0	0	0	0	0	0	1
74	9/8/2010	10:03:06	71.84042	161.12802	0	0	0	0	0	0	0	0	0	0
75	9/8/2010	14:01:05	71.7458	159.0453	0	0	0	0	0	0	0	0	1	1
76	9/8/2010	17:06:11	71.65923	157.44455	0	2	0	0	0	0	0	0	1	1
77	9/8/2010	19:11:58	71.5925	156.28512	0	1	0	0	0	0	0	0	0	0
78	9/10/2010	10:57:11	71.51813	155.92362	0	1	0	0	0	0	1	0	1	0
79	9/11/2010	0:58:04	71.457	156.495	0	0	0	0	0	0	0	0	0	0
80	9/11/2010	1:09:11	71.4437	156.5762	0	0	0	0	0	0	0	0	0	1
81	9/11/2010	9:40:54	70.93425	159.8538	0	0	0	0	0	0	0	0	0	1
82	9/11/2010	13:53:36	71.31302	160.73367	0	1	0	0	0	2	0	0	1	1
83	9/11/2010	17:14:30	71.59933	161.39792	0	2	0	0	0	0	0	0	1	1
84	9/11/2010	20:05:36	71.87928	162.09245	0	0	0	0	0	0	0	0	0	1
85	9/12/2010	0:32:01	71.69955	163.00133	0	0	0	0	0	0	0	0	0	1
86	9/12/2010	7:56:59	70.7978	163.7851	0	0	0	0	0	0	0	0	0	1
87	9/12/2010	15:44:26	70.0802	164.249	0	0	0	0	0	0	0	0	0	1
88	9/12/2010	18:04:46	70.2185	164.7752	0	0	0	0	0	0	0	0	1	1
89	9/12/2010	21:50:59	70.4718	165.65298	0	0	0	0	0	0	0	0	0	0
90	9/12/2010	21:55:57	70.4792	165.68702	0	0	0	0	0	0	0	0	0	0
91	9/12/2010	23:10:53	70.55898	165.97213	0	0	0	0	0	2	0	0	0	1
92	9/13/2010	3:09:07	70.88855	167.14125	0	0	0	0	0	0	0	0	0	1
93	9/13/2010	10:34:20	70.40242	167.19272	0	0	0	0	0	0	0	0	0	1
94	9/13/2010	13:28:06	70.04487	167.18233	0	0	0	0	0	0	0	0	0	1
95	9/13/2010	16:31:37	69.65348	167.21798	0	0	0	0	0	0	0	0	0	0
96	9/13/2010	19:35:10	69.2618	167.2338	0	0	0	0	0	0	0	0	1	0
97	9/13/2010	22:38:39	68.926	167.26167	0	0	0	0	0	0	0	0	1	0
98	9/14/2010	0:57:16	68.6948	167.2528	0	0	0	0	0	0	0	0	0	0
99	9/14/2010	4:06:55	68.38263	167.2705	0	0	0	0	0	0	0	0	0	0
100	9/14/2010	4:37:19	68.34933	167.21172	0	0	2	0	0	0	0	0	1	0
101	9/14/2010	6:34:42	68.28112	166.99942	0	0	0	0	0	0	0	0	0	0
102	9/14/2010	6:42:40	68.26898	167.03575	0	0	0	0	0	0	0	0	0	0
103	9/14/2010	10:00:43	68.05083	167.75557	0	0	1	1	0	0	0	0	1	0
104	9/14/2010	13:02:46	67.81512	168.49282	0	0	1	1	0	0	0	0	1	0
105	9/14/2010	16:35:15	67.4707	168.75593	0	0	0	0	0	2	0	0	0	0
106	9/14/2010	19:38:16	67.0153	168.6016	0	0	0	0	0	0	0	0	1	0

107	9/14/2010	22:24:45	66.6521	168.5071	0	0	1	0	0	0	0	1	1	0
108	9/15/2010	1:13:46	66.25	168.4318	0	0	1	0	0	0	0	0	1	0
109	9/15/2010	5:25:48	65.70547	168.37048	2	0	0	0	0	0	0	0	1	0
110	9/15/2010	7:31:41	65.7913	168.15163	0	0	0	1	0	0	0	0	0	0
111	9/16/2010	9:06:51	62.64532	168.58277	0	0	0	0	0	0	0	0	0	0
112	9/16/2010	11:02:26	62.4342	169.1924	0	0	0	0	0	0	0	0	0	0
113	9/16/2010	12:36:23	62.25337	169.6661	0	0	0	0	0	2	0	0	1	0
114	9/16/2010	14:33:02	62.03522	170.22765	0	0	0	0	0	0	0	0	0	0
115	9/16/2010	17:27:08	61.72618	171.02605	0	0	0	1	0	0	0	0	0	0
116	9/16/2010	19:57:58	61.4311	171.2056	0	0	1	1	0	0	0	0	1	0
117	9/17/2010	23:25:38	60.88072	170.73013	2	0	0	1	1	0	0	0	0	0
118	9/17/2010	4:13:09	60.13633	170.10707	0	0	0	1	0	0	0	0	0	0
119	9/17/2010	6:56:34	59.72047	169.78185	0	0	0	0	0	0	0	0	0	0
120	9/17/2010	7:01:13	59.70855	169.77237	0	0	0	1	0	0	0	0	0	0
121	9/17/2010	8:32:52	59.47418	169.60218	0	0	0	1	0	0	0	0	1	0
122	9/17/2010	11:22:20	59.1679	169.20972	0	0	0	1	0	0	0	0	1	0
123	9/17/2010	14:29:38	58.94045	168.4842	0	0	0	1	0	0	0	0	0	0
124	9/17/2010	17:41:46	58.67828	167.6333	0	0	0	0	0	0	0	0	1	0
125	9/17/2010	18:09:09	58.63718	167.50913	0	0	1	1	0	2	0	0	1	0
126	9/17/2010	19:54:37	58.4705	167.0379	2	0	1	1	0	0	0	0	0	0
127	9/17/2010	21:09:07	58.355	166.7097	0	0	1	1	0	0	0	0	0	0
128	9/17/2010	23:15:55	58.1716	166.1624	0	0	1	1	0	0	0	0	0	0
129	9/18/2010	6:01:34	57.68145	164.75133	1	0	1	1	1	0	0	0	0	0
130	9/18/2010	7:22:27	57.61448	164.4874	1	0	0	0	0	0	0	0	0	0
131	9/18/2010	8:10:05	57.538	164.41758	1	0	0	1	0	0	0	0	1	0
132	9/18/2010	9:28:44	57.37597	1643.6096	1	0	0	1	0	0	0	0	0	0
133	9/18/2010	10:01:38	57.34008	164.72205	1	0	0	1	0	0	0	0	0	0
134	9/18/2010	10:38:06	57.42315	164.69688	1	0	0	1	0	0	0	0	0	0
135	9/18/2010	13:42:29	57.3947	164.2781	1	0	1	1	0	0	0	0	0	0
136	9/18/2010	15:01:37	57.34462	163.96235	1	0	1	1	0	0	0	0	0	0
137	9/18/2010	16:18:25	57.312	163.6029	1	0	0	1	0	0	0	0	0	0
138	9/18/2010	19:15:46	57.2286	162.8665	2	0	2	1	0	0	0	1	1	0
139	9/18/2010	21:06:09	57.1496	163.3891	0	0	0	1	0	0	0	0	0	0
140	9/18/2010	23:15:24	57.047	164.0001	1	0	1	1	0	0	0	0	0	0
141	9/19/2010	1:04:24	56.9564	164.5441	1	0	1	1	0	0	0	0	0	0
142	9/19/2010	3:10:51	56.85288	165.0957	1	0	0	0	0	0	0	0	0	0
143	9/19/2010	5:23:06	56.86387	164.8293	1	0	2	1	0	0	0	0	0	0
144	9/19/2010	9:46:42	56.90215	165.20873	1	0	1	1	0	0	0	0	0	0
145	9/19/2010	11:14:45	56.79442	165.50693	1	0	0	0	0	0	0	0	0	0
146	9/19/2010	11:53:05	56.72947	165.61758	1	0	0	0	0	0	0	0	0	0
147	9/19/2010	13:33:27	56.55877	165.60427	1	0	1	1	0	0	0	0	0	0
148	9/19/2010	14:37:35	56.39457	165.58327	0	0	0	0	0	0	0	0	0	0
149	9/19/2010	14:52:07	56.3598	165.57915	1	0	0	1	0	0	0	0	0	0
150	9/19/2010	15:22:29	56.28377	165.56888	1	0	0	1	0	0	0	0	0	0
151	9/19/2010	17:27:10	55.97228	165.52932	0	0	1	1	0	0	0	0	0	0
152	9/19/2010	20:14:58	55.53742	165.47472	0	0	1	1	0	0	0	0	0	0
153	9/19/2010	22:55:00	55.1009	165.396	0	0	0	0	0	0	0	0	0	0
154	9/19/2010	23:00:37	55.0874	165.3932	0	0	0	1	0	0	0	0	0	0
155	9/20/2010	2:05:52	54.5975	165.3056	0	0	1	0	0	0	0	0	0	0
156	9/20/2010	4:05:36	54.4016	165.4063	0	0	1	0	0	0	0	0	0	0
157	9/20/2010	5:42:29	54.3052	165.81972	0	0	1	0	0	0	0	0	0	0

Appendix 3. CTD and net tow station report

A full report on the CTD and net tow stations can be found in the electronic document entitled "CZ10_CTD&planktonReport.pdf".

Appendix 4. Marine mammal sightings (individuals) from the CHAOZ 2010 research cruise.

Species	**On-Effort**	**Off-Effort**	**Total**
Cetaceans			
Fin Whale	10(13)	0	10(13)
Humpback Whale	5(6)	4(4)	9(10)
Gray Whale	16(18)	5(9)	21(27)
Minke Whale	3(3)	3(3)	6(6)
Dall's Porpoise	3(6)	0	3(6)
Harbor Porpoise	18(23)	2(3)	20(26)
Marine mammal	1(1)	0	1(1)
Bowhead Whale	7(12)	1(2)	8(14)
Unid Large Whale	13(15)	2(2)	15(17)
Unid. Small Whale	3(3)	1(1)	4(4)
Unid.Dolphin/Porpoise	3(4)	0	3(4)
Total Cetacean	*82(104)*	*18(24)*	*100(128)*
Pinnipeds			
Fur Seal	5(7)	2(3)	7(10)
Bearded Seal	43(58)	5(5)	48(63)
Spotted Seal	21(23)	2(2)	23(25)
Ringed Seal	1(4)	0	1(4)
Walrus	2(4)	6(19)	8(23)
Unid Pinniped	76(109)	3(3)	79(112)
Total Pinniped	*148(205)*	*18(32)*	*166(237)*
Total	**230(309)**	**36(56)**	**266(365)**

Appendix 5. Preliminary summary of all marine birds observed on transect during the CHAOZ 2010 research cruise.

Common Name	***Latin Name***	**N**	**% of Total**
Common Loon	*Gavia immer*	6	0.10
Northern Fulmar	*Fulmaris glacialis*	160	2.74
Short-tailed Shearwater	*Puffinus tenuirostris*	4135	70.71
Fork-tailed Storm-petrel	*Oceanodroma furcata*	27	0.46
Black Brant	*Branta bernicla*	10	0.17
Surf Scoter	*Melanitta perspicillata*	4	0.07
Red Phalarope	*Phalaropus fulicaria*	1	0.02
Red-necked Phalarope	*Phalaropus lobatus*	349	5.97
Unidentified Shorebird	*Charadrii (suborder)*	4	0.07
Parasitic Jaeger	*Stercorarius parasiticus*	6	0.10
Pomarine Jaeger	*Stercorarius pomarinus*	13	0.22
Glaucous Gull	*Larus hyperboreus*	32	0.55
Glaucous-winged Gull	*Larus glaucescens*	5	0.09
Unidentified Gull	*Family Laridae*	2	0.03
Black-legged Kittiwake	*Rissa tridactyla*	305	5.22
Sabine's Gull	*Xema sabini*	18	0.31
Arctic Tern	*Sterna paradisaea*	1	0.02
Common Murre	*Uria aalge*	77	1.32
Thick-billed Murre	*Uria lomvia*	80	1.37
Unidentified Murre	*Uria spp.*	16	0.27
Kittlitz's Murrelet	*Brachyramphus brevirostris*	9	0.15
Least Auklet	*Aethia pusilla*	43	0.74
Parakeet Auklet	*Aethia psittacula*	26	0.44
Crested Auklet	*Aethia cristatella*	432	7.39
Tufted Puffin	*Fratercula cirrhata*	51	0.87
Horned Puffin	*Fratercula corniculata*	25	0.43
Dovekie	*Alle alle*	5	0.09
Unid. Small Dark Alcid	*Aethia spp.*	5	0.09
Unid. Alcid	*Family Alcidae*	1	0.02
Total Birds on Transect		**5848**	100

Appendix 6. Mooring designs

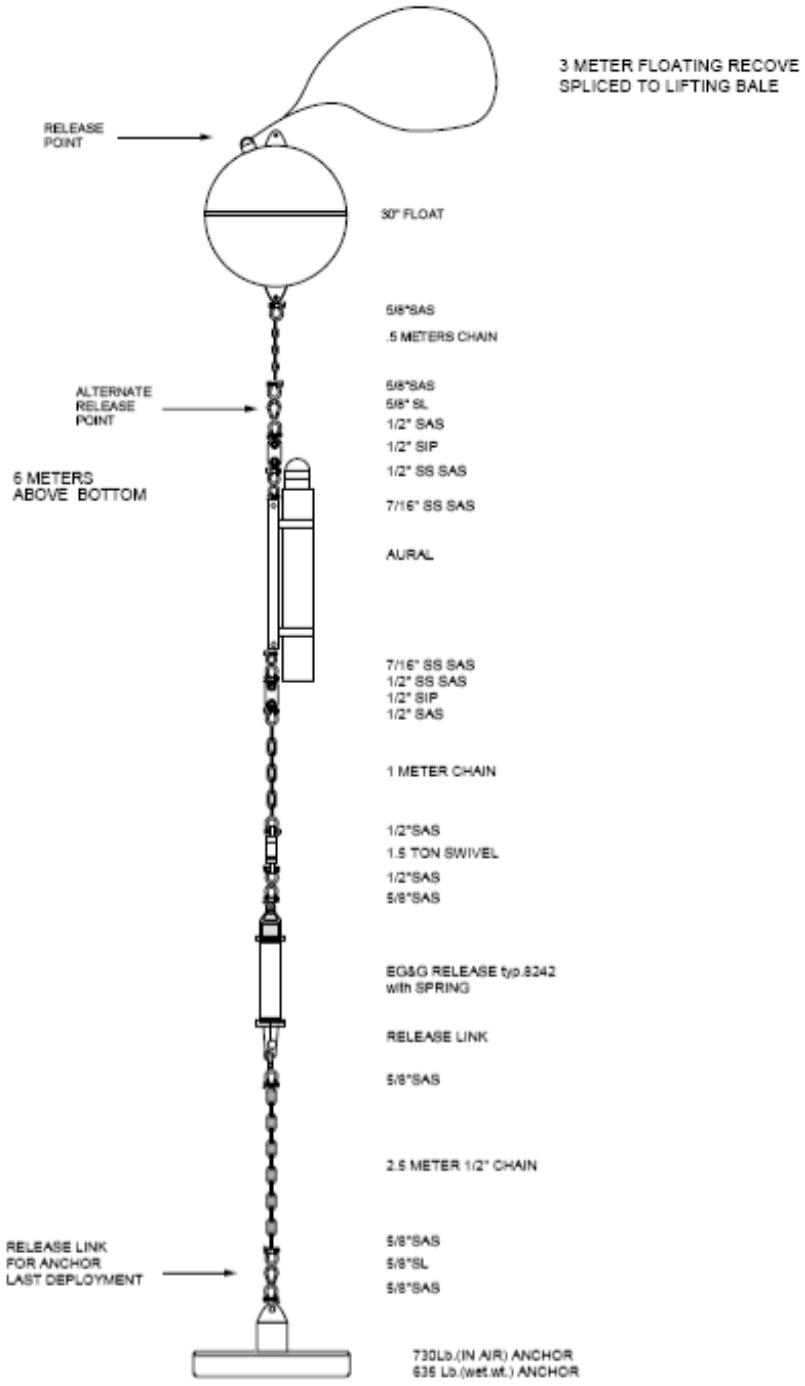
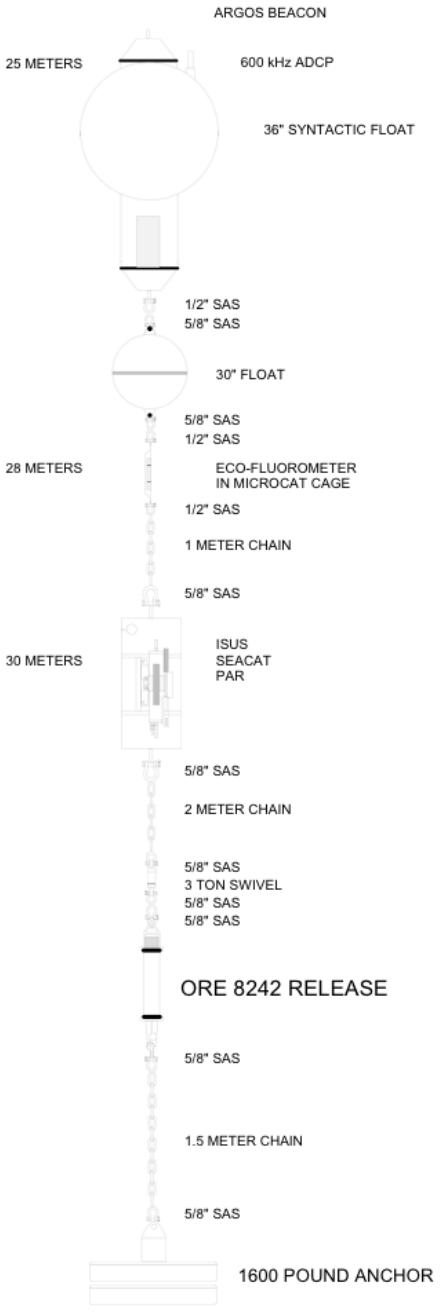


Figure 1. Mooring design for the passive acoustic moorings. Mooring designs provided by Rick Miller from the PMEL mooring shop at NOAA (Seattle, WA).



INSTRUMENT	DEPTH M	SERIAL NO.
600kHzADCP	25	
ECOFLO	28	
ISUS	30	
SEACAT	30	
PAR	30	
BOTTOM	35	

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

MOORING: 10CKP-2A

LOCATION:

DRAWN BY: Rick Miller DATE: 7 JULY 2010

APPROVED BY: DATE:

Figure 2. Mooring design for 10CKP1a, 10CKP2a and 10CKP3a. 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).

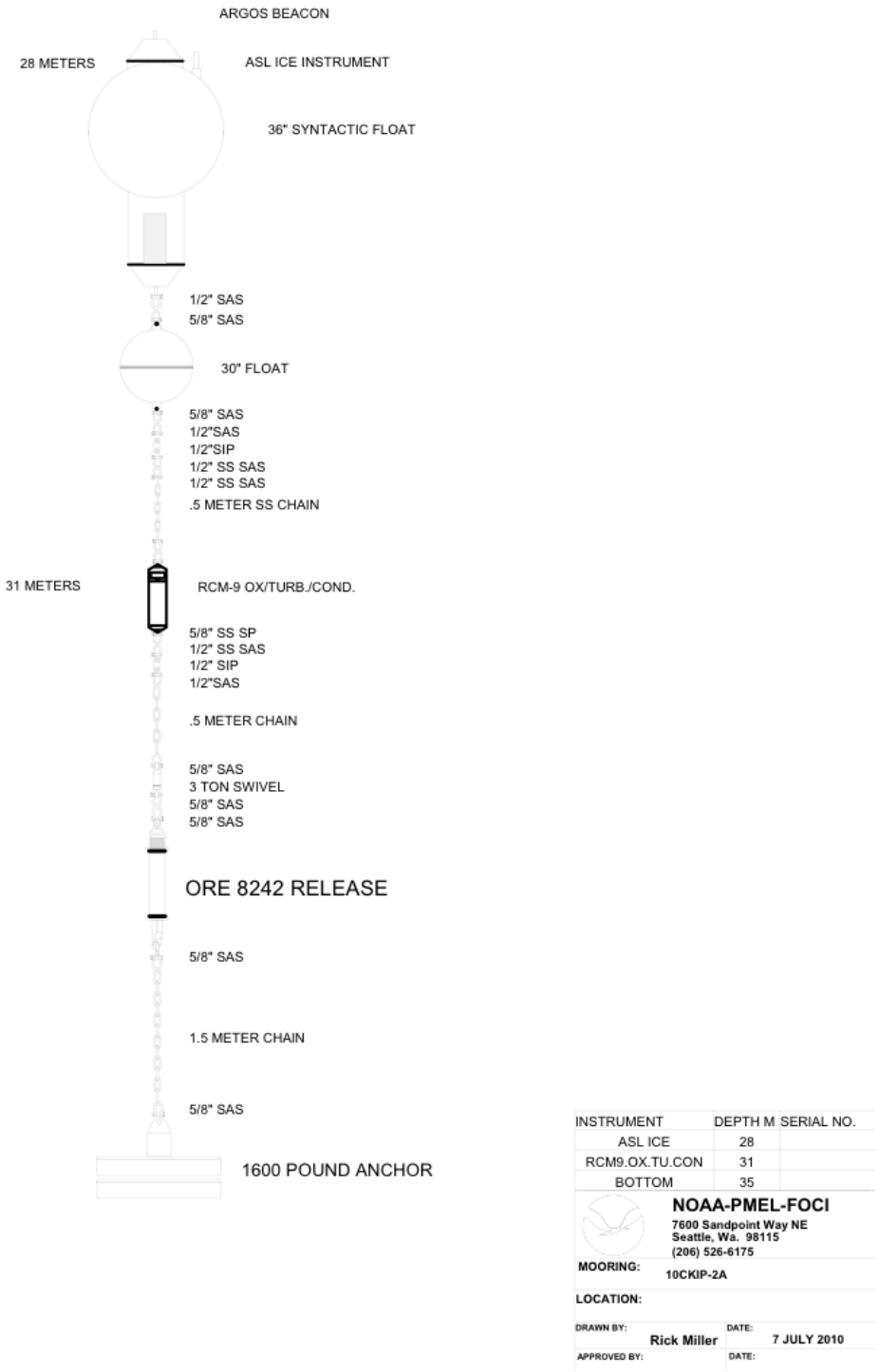


Figure 3. Mooring design for 10CKIP1a, 10CKIP2a and 10CKIP3a. In addition to the ASL ice instrument (measures ice thickness), this mooring contains RCM9 that measures currents at one depth, temperature, oxygen, and turbidity.

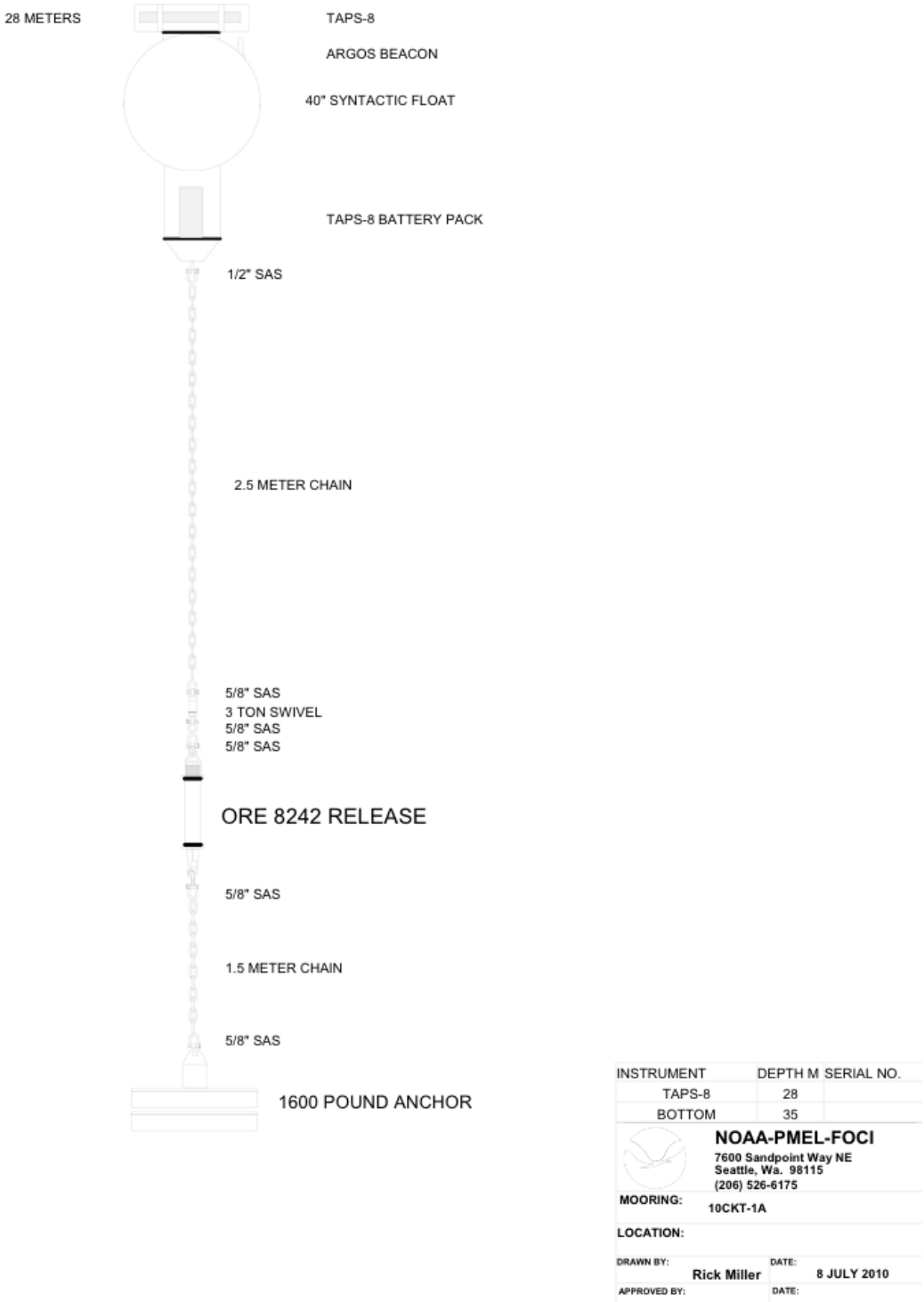


Figure 4. Design for mooring 10CKT. The TAPS-8 is an instrument that acoustically measures zooplankton bio-volume.