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Results of Cooperative Research Acoustic Surveys of Walleye Pollock (*Theragra chalcogramma*) in the Western Gulf of Alaska from September 2007 to September 2011

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ABSTRACT

In 2007, the Alaska Fisheries Science Center (AFSC) initiated a cooperative survey to assess the abundance of walleye pollock *(Theragra chalcogramma*) with local fishermen in the western Gulf of Alaska. The purpose of the survey was to estimate the abundance and distribution of walleye pollock in relatively small bathymetrically-complex areas using local fishing vessels active in the pollock fishery. The use of fishing vessels as a sampling platform provides more extended seasonal coverage in a restricted spatial area, in contrast to the large-scale assessment surveys conducted by the AFSC. The AFSC contracted and equipped a local 58 foot (18 m) trawler for the project. Originally the scope of the project was to evaluate the feasibility of conducting acoustic-trawl surveys of pollock using local fishing vessels. This was successfully completed and the project expanded to include other objectives: evaluation of transect density in bathymetrically complex regions in the western Gulf of Alaska, temporal variability of pollock density during replicate transects, including day/night transects, the timing of fish migration to spawning areas, and relationships between pollock adult, young-of-the-year, and euphausiid density, and the distribution of foraging humpback whales (*Megaptera novaeangliae*). This report summarizes the estimates of abundance and distribution of walleye pollock in areas covered by cooperative acoustic-trawl surveys conducted aboard the fishing vessel FV *Temptation* during September and January in 2007-2011. It also summarizes physical oceanographic and biological composition observations, initial findings from ancillary data collections of marine mammal observations, and dual-frequency differencing techniques to discriminate different types of acoustic backscatter.

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INTRODUCTION

In May of 2006, scientists from the Alaska Fisheries Science Center participated in a pilot outreach program in Sand Point, Alaska (Dorn 2006). At the meetings, fishermen raised a number of concerns about the adequacy of walleye pollock (*Theragra chalcogramma*) assessment. The issues appeared to be related to the contrasting observational scales of fishermen and National Marine Fisheries Service (NMFS) scientists responsible for conducting assessment surveys and population modeling. NMFS resource assessment surveys have a large spatial scale (i.e., the entire Gulf of Alaska) and occur infrequently (every 2 years for summer bottom trawl and acoustic-trawl surveys, and annually for the winter acoustic-trawl surveys (von Szalay et al. 2010, Guttormsen and Yasenak 2007, Guttormsen and Jones 2010). Assessment surveys are used in the stock assessment model for pollock, which estimates stock abundance for the Central and Western Gulf of Alaska (Dorn et al. 2011). In contrast, the observational scale of fishermen is spatially restricted but temporally extensive since they are on the water fishing throughout the year. Fishermen questioned whether NMFS assessment activities were appropriately designed to monitor the status of pollock in their area. They noted that additional surveys in different seasons and a more comprehensive acoustic-trawl survey effort in winter could help address seasonal issues such as movement between spawning and feeding areas. Cooperative research projects with the Sand Point fishing community were identified as a potential approach for addressing some of these issues, but fishermen wanted the assurance that their investment of time and effort will lead to improvements in stock assessment.

The acoustic-trawl surveys described in this report resulted from collaboration between NMFS scientists, the Aleutian East Borough, and local fishermen to address issues raised during the outreach program. Acoustic-trawl surveys were conducted from a local fishing vessel in the western Gulf of Alaska during 2007-2011. To some extent, the surveys carried out during this period reflected shifting program objectives. The initial objective was simply to demonstrate the feasibility of using local fishing vessels to conduct acoustic-trawl surveys and to collect acoustic and biological information sufficient to estimate walleye pollock biomass and spatial pattern. Once this was demonstrated, the focus of the project expanded to include other objectives. It is likely that the project will continue to evolve given continued funding for cooperative research. Specific objectives of the project were the following:

- Evaluate the feasibility of conducting acoustic-trawl surveys of pollock using local fishing vessels, including assessment of day and night differences in pollock density from replicate transects.
- Evaluate the quality of acoustic data collected from the Simrad ES60 echosounder.
- Evaluate the appropriateness of the design of the current winter NMFS acoustic-trawl surveys in the western Gulf of Alaska. Specific issues to be addressed included 1) transect density in bathymetrically complex regions in the western Gulf of Alaska, 2) temporal variability of pollock density during replicate transects.
- Evaluate the timing of the Midwater Assessment and Conservation Engineering (MACE) Program's acoustic-trawl survey (mid-February) in Sanak Trough by conducting a survey in January prior to the MACE survey.
- Evaluate relationships between adult pollock density, young-of-the-year pollock density, euphausiid density, and the distribution of foraging humpback whales (*Megaptera novaeangliae*).

This report summarizes the estimates of abundance and distribution of walleye pollock in areas covered by cooperative acoustic-trawl surveys conducted aboard the fishing vessel FV *Temptation* during the months of September and January during the years 2007-2011 in the western Gulf of Alaska. It describes the use of a fishing vessel as an acoustic survey platform. It also summarizes physical oceanographic and biological composition observations, initial findings from ancillary data collections of marine mammal observations, and dual-frequency differencing techniques to discriminate different types of acoustic backscatter.

METHODS

Small-scale acoustic surveys were conducted between 2007 and 2011 (Table 1) aboard the fishing vessel FV *Temptation*, a 60-ft multipurpose fishing vessel based in Sand Point, Alaska, that participates the midwater-trawl fishery for walleye pollock, as well as several other fisheries in the western Gulf of Alaska. Some surveys used the same transect lines as sampled by the MACE acoustic-trawl surveys (i.e., Sanak), while transect lines for other surveys were designed to cover areas of interest identified by local fisherman.

Acoustic Equipment, Calibrations, and Data Collection

The vessel was equipped with a Simrad ES38-12 38 kHz split beam transducer that was installed at the start of the project. In 2010, an ES120-7C 120 kHz split beam transducer was added. Both transducers are installed in a fabricated fiberglass pod adjacent to the keel about a third of the way from the bow to the stern.

Raw acoustic data were collected using a Simrad ES60 echosounder and saved on external hard drives throughout the survey. In September 2010 the system was upgraded to a Simrad ES70 echosounder. Echoview (v. 4.9, Myriax, Pty. Ltd.) was used in conjunction with Simrad ER60 Lobes (v. 2.1.1) and a Java utility (Keith et al. 2005) to analyze calibrations and acoustic survey data. The ES60 and ES70 introduce a systematic error wave into acoustic data (Ryan and Kloser 2004). This error wave was removed using the ES60 Adjust V. 1.6 Java utility. Corrected raw data files collected from calibrations were analyzed in Echoview. Sound speed and absorption coefficient for calibrations were calculated using the algorithms in Echoview (Mackenzie 1981, Francois and Garrison 1982).

Calibrations were conducted in accordance with standard sphere calibration methods (Foote et al. 1987). Majority of calibrations were done in Squaw Harbor, located at 55°13.90 N. 160°33.14 W., although other sites were also used occasionally (Elliott Bay in Washington; King Cove and Balboa Bay in the survey area). A tungsten carbide sphere (38.1 mm diameter) or a copper sphere (60 mm diameter) for calibration of 38 kHz and 120 kHz frequencies was suspended below the vessel while at anchor, at a consistent depth ranging from 14 to 16 m. A tungsten carbide sphere was used on all system calibrations except the January 2010 survey, when the copper sphere was used. To estimate transducer gains, target strength, and echo integration, measurements were collected while spheres were suspended on axis. An attempt was made to move the sphere through a grid of angular coordinates to model transducer beam characteristics, but several calibrations had a limited number of detections throughout beam quadrants. In 2011, a sufficient number of detections were collected, and data for all years were analyzed in lobes regardless of the number of detections recorded. The theoretical S_a and gain were calculated and were compared to the lobes results for S_a and gain. The results from the lobes model for a S_a correction factor and gain were applied to the data. Passive recording was conducted in 2007, 2010, and 2012 to assess noise relative to the survey vessel.

Temperature and salinity were measured during calibrations. Temperature profiles were collected using a Seabird Electronics SBE 37-SI MicroCAT. Conductivity, temperature, and depth profiles collected on adjacent MACE surveys with a Seabird SBE 19 SEACAT were also utilized when the survey vessel could not collect oceanographic data. The calibration for the 2008 January survey was performed in 20 December, 2007 in Elliot Bay, Washington, and a Seabird SB19 was deployed to collect oceanographic data.

Survey Design

The cooperative research study area is in the western Gulf of Alaska management area 610 and includes two Steller sea lion (SSL) rookeries and five SSL haulouts (Fig. 1 and 2). Regions were surveyed to describe pollock distribution and abundance using systematic, parallel transect acoustic surveys similar to those described in Simmonds and MacLennan (2005). In the Sanak area the vessel followed the same cruise tracks surveyed by the MACE acoustic surveys. Sampling occurred during daylight hours, with comparative surveys performed at night in the Guillemot area to assess diel variability in abundance estimates. Trawl hauls were conducted to ground truth observed acoustic backscatter layers with biological data using a commercial midwater trawl fitted with a 9.5 mm (0.38 in) nylon mesh codend liner. Trawls were sampled for species composition by sorting and weighing all species in the catch. Length frequency data were collected for walleye pollock and other common species to the nearest centimeter. During the September 2010 and 2011 surveys, marine mammal observations were made according to protocols developed by National Marine Mammal Laboratory (NMML) and logged using the WinCruz program (Holland 1996).

Data Analysis

The sounder-detected bottom determined by an Echoview bottom detection algorithm was used for the initial assessment of bottom depth. This line was visually assessed and manually edited based on relative SV to prevent inclusion of backscatter from the bottom in echo integration. Areas of acoustic shadow resulting from complex bathymetry were identified visually as acoustic dead zone (ADZ) areas and were not included in abundance estimates. Areas of incomplete transmissions or missing pings were minimal and removed manually. Echosign was categorized by species into pollock and non-pollock regions based on trawl catch species composition for surveys with 38 kHz data. Surveys conducted using both 38 kHz and 120 KHz were analyzed for differences in backscatter. A dual-frequency classification Echoview template (version 4.90.48, May 2010), was utilized to examine differences in frequency response between 120 kHz and 38 kHz, using Z-score ranges measured for walleye pollock and euphausiids developed by De Robertis et al. (2010) for application in the eastern Bering Sea. The differences in backscatter for all years with two frequency collections were visually analyzed to augment identification of backscatter attributed to pollock, a technique that enhanced discrimination of some bottom features from fish.

In situ target strength was calculated for pollock using length data from the survey biological samples. Average weight of pollock was calculated from samples collected during the surveys to scale backscatter to biomass in tons. The target strength TS_l at fork length l (cm) was estimated by using the pollock target strength to length relationship equation at 38 kHz frequency (Traynor 1996):

$$TS_l = 20 \log_{10} l - 66.$$

The proportion p_l of backscatter attributable to pollock at fork length l was then estimated as:

$$p_l = \frac{f_l\left(10^{TS_l/10}\right)}{\sum f_l\left(10^{TS_l/10}\right)} \quad ,$$

where f_l is the number of pollock at fork length l in the length frequency sample.

The estimated backscatter, the s_A, nautical area scattering coefficient, m^2/nmi^2, of pollock in a survey was processed using Echoview, and then used to obtain the number (N_l) of pollock at length l for an elementary distance sampling unit (EDSU) of 0.5 nautical mile (nmi)

$$N_l = \frac{p_l \times s_A}{4\pi \times 10^{TS_l/10}} \quad .$$

Biomass (B) for each survey was then estimated as:

$$B = \sum N_l \times \frac{\hat{W}_l}{1000} \times SD \text{ nmi}^2,$$

where W is the average pollock weight in kilograms obtained from survey samples which is then divided by 1000 to express biomass in metric tons (t), and SD is the EDSU of 0.5 nmi multiplied by one-half the distance between transects, which varied by regions.

To account for observed spatial structure, geostatistical methods were used to compute relative estimation error, defined as the ratio of the square root of the estimation variance to the estimate of biomass. A one-dimensional (1D) geostatistical method (Petitgas 1993, Williamson and Traynor 1996, Petitgas and Lafont 1997) was used to calculate relative estimation errors for the acoustic-based estimates for areas with surveys that met the minimum area requirements and 1D EVA assumptions of parallel transects of relatively equal length. For surveys conducted in smaller areas, standard variance estimates were calculated. These errors quantify only transect sampling variability and do not account for other sources of known error such as uncertainties in target strength, trawl sampling efficiency, or error resulting from equipment and collection issues.

RESULTS

Oceanographic Conditions

Temperature and salinity observations conducted during calibration indicated that there was little variation within a season (Table 2). The mean temperature from the September surveys ranged from 9.7°C to 9.9°C, and the mean salinity ranged from 31.4 to 31.5 PSU. The mean temperature for the January surveys calibrations ranged from 3.6°C to 4.5°C, and the mean salinity ranged from 30.8 to 31.7 PSU. The temperature and salinity observations used for the 2007 September survey and the 2008 January survey were obtained from the Midwater Assessment and Conservation Engineering (MACE) surveys in the area that occurred in August 2007 and February 2008, respectively (Guttormsen et al. 2010). No observations of temperature or salinity were made for the 2009 September survey.

Acoustic Calibration

Calibration results showed insignificant variation in estimated gain parameters between years (Tables 3 and 4, Fig. 3). The average theoretical s_v gain for all years was 20.87 and the average of the lobes gain combined with S_a correction was 20.93. It is likely that the variations between the surveys reflect measurement error rather than changes in system characteristics. Calibrations from September 2007, December 2007, and September 2009 had equipment setting and collection technique issues that complicate interpretation. In September 2007, excess power was transmitted at 38 kHz, and a 50 kHz Furuno sounder was running during calibrations. The excess power can create a situation where the linear relationship between the source level and return signal is lost due to issues with harmonics (Urick 1993, Tichy 2003). The calibration for the January 2008 survey was performed in December 2007 in Puget Sound, WA, rather than in the western GOA, therefore oceanographic conditions significantly differed between the calibration and the survey. In September 2009, the tungsten carbide sphere and connecting swivel were close enough that the two could not be separated reliably in the acoustic data and sound speed had to be estimated due to a lack of environmental measurements; gain correction values from the September 2010 surveys were used for analysis of 2009 acoustic data. The January 2011 calibration results for the 38 kHz frequency appeared consistent with subsequent calibrations; however, the model had a high RMS value of 0.49. Overall, the on-axis data from

2010 and 2011 calibrations do not indicate any major malfunctions in the acoustic systems. The September 2010 calibration had full coverage of a grid of angular coordinates utilized by the Simrad lobes program for modeling beam characteristics, a sufficient number of on-axis readings, and environmental data collected during the calibration. This calibration compared well to the calibrations that had less complete collections.

Noise was removed in the Echoview software for 120 kHz using techniques described by De Robertis and Higgenbottom (2007). Analysis of passive measurements conducted indicated that the -70db threshold on the 38 kHz data would account for all noise on this frequency.

Biological Sampling

Biological data were collected from verification trawls conducted throughout the survey areas (Table 5). An attempt was made to make a least one trawl in each area surveyed, however this was not always possible due to weather conditions and the absence of sufficiently concentrated pollock aggregations. The majority of the catch composition by weight was walleye pollock (Tables 6 and 7), although eulachon and capelin were occasionally caught in relatively high numbers, particularly in close association with age-0 pollock.

Length samples were collected from pollock during every survey and samples from all regions were combined and used to describe the target strength of observed backscatter layers identified as pollock (Fig. 4 and 5).

In September of 2010, verification trawls conducted in Nagai Strait to identify backscatter indicated substantial aggregations of age-0 pollock at depths of 130 m or shallower, with larger adults caught at 160 m and deeper (Fig. 6). The tows targeted two distinct aggregations which were observed throughout the Nagai transects, and distribution pattern remained consistent throughout, with a dense school located above a more diffused aggregation close to the bottom. The aggregations that visually resembled the sample at 130 m ranged in depth from approximately 110 m to 140 m and appeared as dense layer on the echogram. The aggregations that resembled the 160 m sample ranged from the bottom to approximately 140 m depending on bottom depth. The distribution of adults close to bottom and age-0 above indicated are consistent with patterns observed in more data rich surveys (Brodeur and Wilson 1996*)* and distinct differences in appearance could be observed on the echograms (Fig. 7). An average weight obtained from all pollock samples was used to scale the backscatter to biomass.

Distribution and Abundance

Acoustic data from transects were collected over areas ranging from approximately 8 nmi^2 to 140 nmi^2. Biomass and relative estimation error was calculated for most surveys (Table 8). Surveys in Korovin Strait and King Cove contained too few transects for one-dimensional (1D) geostatistical method to be employed. Instead the error was calculated using the standard formula for sample variance.

Biomass estimates for surveys conducted in the Guillemot area in 2008 was 8,287 t, with differences in estimates observed between two transects surveyed during daylight hours of 2,751 t compared to 3,697 t observed at night. Day and night comparative survey differences were less extreme in 2011, with 1,182 t estimated for day time abundance and 1,275 t at night. In the Korovin Strait region the highest biomass estimate of 3,050 t was observed in 2007, with subsequent years having less pollock (Fig. 8). In the Whale region, biomass did not vary greatly between the total estimate in September of 3,067 t, and the January 2008 estimate of 4,187 t, with high-density measurements occurring essentially in the same place (Fig. 9). In the Morzhovoi region, 262 t of pollock was observed in January of 2010 and 1,949 t in September 2011(Fig. 10). In the Pavlof area, 5,539 t was observed in September 2007, increasing to 8,478 t in September 2011 (Fig. 11). In Sanak Gully, much of the observed biomass occurred in no trawl zones (Fig. 12), but overall was consistent with MACE estimates conducted a month later. Differences biomass between years in the Unga Strait and Guillemot regions were not analyzed as the overall area sampled and transect orientation were different. The highest biomass of 30,646 t was seen in a full survey of the Nagai area in 2010, with only 3,283 t observed along the same transect lines in 2011.

Mean nominal euphausiid s_A was calculated from the 120 kHz data in 2010 for backscatter that showed a frequency response within the range for euphausiids based on De Robertis et al. (2010) (Table 9). Areas of interest in 2010 included Nagai Strait and surrounding areas of

Korovin Strait, Popof Strait, as each area had aggregations of age-0 and adult walleye pollock, and possible aggregations of euphausiids, in addition to high numbers of marine mammal sightings, primarily humpback whales (*Megaptera novaeangliae*) (Fig. 13). The high abundance of both forage species (euphausiids and age-0 pollock) and predator species such as humpback whales suggests that these were areas where strong biological interactions were occurring. Without *in situ* zooplankton sampling, it is impossible to say what kinds of organisms were falling into the euphausiid response range, as the material properties of many species of zooplankton are unknown and the differences backscatter responses may fall into the same range (Smith et al. 2010). The September 2011 surveys did not observe the same high biomass and had very few humpback whale sightings overall.

A zooplankton tow was conducted in September 2011 in Pavlof Bay using a 500 µ ring net attached to the codend of the commercial pollock net and streamed approximately 7 m behind the codend. The tow was a test to see if this towing configuration would be effective in capturing zooplankton to ground truth the 120 kHz data. The species composition did show presence of euphasiids, primarily *Thysanoessa* species, but the species composition was dominated by the small planktonic mollusk *Limacina*, known commonly as a sea butterfly (Table 10). It is unclear whether this was a chance occurrence, or if this species is unusually common in the area.

DISCUSSION

Representational acoustic data are dependent on accurate measurements of oceanographic conditions, equipment properties, biological factors, and appropriate survey design. Although there are some challenges to using a fishing vessel to conduct acoustic surveys, they are not insurmountable. Initial problems with calibration and equipment were resolved and quality acoustic data were collected during this project. There are some intrinsic limitations to using a 60-foot vessel to conduct acoustic surveys in the Gulf of Alaska. Weather conditions are often severe, particularly in winter, which can limit the time available for surveying, doing sample tows, and on-deck recording of information. The availability of the charter vessel depends on fishing seasons for pollock, Pacific cod (*Gadus macrocephalus*) and

Tanner crab (*Chionoecetes bairdi*), which put limits on both timing and duration of survey work. Nevertheless, usable acoustic data and biological samples were collected during both September and January.

The pollock biomass estimates for Sanak in early January 2010 of 1,199 t and January 2011 of 1,374 t suggested that spawning aggregations had not yet formed in this area. Scientific surveys conducted in mid- to late February have consistently shown high percentages of females in post-spawning condition, suggesting that peak spawning occurs earlier in this area (Guttormsen and Jones 2010). The biomass estimate in February 2010 was 26,678 t (Guttormsen and Jones 2010), but no scientific survey was conducted in this area in 2011. Identifying the time of peak spawning would require surveys to be conducted between early January and mid-February, which would be difficult under cooperative research arrangements, given the current fishing seasons for pollock, Pacific cod, and Tanner crab.

Walleye pollock are extremely patchy in the western Gulf of Alaska. High-density aggregations are frequently associated with bathymetric features of the continental shelf, such as depressions and troughs. The spatial distribution and temporal variability of walleye pollock in this study is similar to the results of Walline et al. (2012), which surveyed walleye pollock in troughs near Kodiak Island. The strong dependence of pollock density and bathymetric features creates complications for designing surveys since a set of parallel transects would not necessarily be effective in surveying fish populations with irregular spatial structure. One useful outcome of these small-scale surveys is the identification of these areas of high density that are well known to fishermen, but which may not be surveyed adequately by current MACE surveys, given their broader geographic scale. Nevertheless the small-scale surveys conducted to date have not found large aggregations of pollock outside of the areas surveyed by the current MACE survey design. Very patchy and very dense aggregations of pollock in areas such as Korovin Strait and Popof Strait cannot be surveyed effectively by a single transect, as in the current MACE survey design. However, since these areas are not large, the biomass found in these areas is a small percentage of the total biomass in the western Gulf of Alaska.

Use of frequency differencing between 38 and 120 kHz echosounders to identify echosign that is characteristic of euphausiids provided interesting but preliminary results (Fig. 7). Additional work is planned to evaluate spatial pattern and potential interactions between age-0 pollock, adult pollock, euphausiids, and humpback whales**.** Current sampling methods are not effective in capturing either age-0 pollock or euphausiids, which limits the ability to confirm acoustic targets other than juvenile and adult pollock. Given that the material properties of species falling into the euphausiid range can be similar in backscatter response, backscatter alone is completely insufficient to identify whether the return encountered in 2010 were actually euphausiids. Alternative sampling methods are under consideration, but novel approaches may be needed given the difficulty of deploying conventional zooplankton samplers on a commercial fishing vessel.

During the 2010 pollock D-season starting 1 October, there was a spike in the bycatch of Chinook salmon in area 610. The observer estimate of Chinook salmon bycatch in area 610 was 28,000 fish, which is about 20 times the average (since 2003) during this time of the year (NPFMC 2011). Since the pollock fleet was primarily fishing in the western part of Nagai Strait, the acoustic surveys in this area provided information on the distribution of adult pollock and forage species just prior to the D-season pollock opening. Qualitative evaluation of survey results indicates that there was strong overlap between adult pollock and high densities of forage species, such as age-0 pollock and euphausiids. The high density of forage species may have attracted other predators such as Chinook salmon into the area. While these results are suggestive, a single observation does not provide information about whether conditions in the fall of 2010 were exceptional. This highlights the value of an ongoing, economical, and flexible program to monitor major ecosystem components in the western Gulf of Alaska.

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Table 1.--Itinerary and scientific personnel for the 2007-2011 cooperative research acoustic surveys in the western Gulf of Alaska.

Itinerary	Areas Surveyed
24- 28 September 2007	Korovin Strait, Pavlof, Unga Strait, Whale
17-21 January 2008	Guillemot Island, The Whale
27-28 September 2009	Korovin Strait, Unga Strait, Nagai Strait
8-13 January 2010	King Cove, Morzhovoi Bay, Sanak, Unga Strait
19-24 September 2010	Nagai Strait (partial), Popof Strait, Korovin Strait,
4-11 January 2011	Sanak, Guillemot Island, Nagai Strait
16-24 September 2011	Whale, Korovin, Nagai Popof, Morzhovoi, Pavlof

Scientific Personnel	Position	Organization	Nation	Survey
Martin Dorn	Chief Scientist	AFSC[1]	USA	All
Vidar Wespestad	Fishery Biologist	RAI[2]	USA	All
Abigail McCarthy	Fishery Biologist	AFSC[1]	USA	Sept. 2009
Cherilyn Lundgren	Marine Mammal Technician	AEB[3]	USA	Sept. 2010

[1] AFSC - Alaska Fisheries Science Center, Seattle WA.
[2] RAI-Resource Analysts International, Lynnwood WA.
[3] AEB-Aleutians East Borough, Alaska.

Table 2.--Mean values of temperature and salinity measurements utilized for calibrations.

Year	Month	Temp (C°)	Salinity (PSU)	Source
2007	September	9.85	31.5	SB19
2008	January	3.6	31.5	SB19
2009	September	no data	no data	no data
2010	January	4.45	30.83	SBE 37-SI
2010	September	9.66	31.43	SBE 37-SI
2011	January	3.92	31.65	SBE 37-SI
2011	September	3.92	31.65	SBE 37-SI

Table 3.--Simrad ES60 38 kHz acoustic system description, settings, and results from sphere acoustic system calibrations for the western Gulf of Alaska cooperative research acoustic surveys.

	Survey	Calibration						
	System Settings	Sept.-07 *	Dec.-07 **	Sept.-09 ***	Jan.-10	Sept.-10	Jan.-11	Sept.-11
Echosounder:	Simrad ES60	Simrad ES60	Simrad ES60	Simrad ES60	Simrad ES60	Simrad ES70	Simrad ES70	Simrad ES70
Transducer:	ES38-12							
Frequency (kHz):	38							
Transducer depth (m):	3.4							
Pulse length (ms):	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024
Transmitted power (W):	1000	2000*	1000	1000	1000	1000	1000	1000
Angle sensitivity:	12.5							
2-way beam angle (dB):	-15.5	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2
Gain (dB):	21.5	21.09	21.45	20.63	21.81	21.33	21.62	21.52
Sa correction (dB):	0	-0.67	-0.64	-0.46	-0.66	-0.62	-0.66	-0.63
3 dB beam width (degree):								
Along:	12.5	7.48	12.75	11.58	19.08	14.16	10.84	17.60
Athwart:	12.5	14.17	11.91	12.84	11.57	13.98	13.72	7.29
Angle offset (degree):								
Along:	0	-0.52	0.04	-0.07	-0.26	-0.34	0.01	0.18
Athwart:	0	-0.86	-0.29	-0.04	0.03	0.19	0.14	0.18
RMS (from Simrad lobes model):		.26	.34	.15	.05	.13	.49	.01
Sv Threshold (dB)		-70	-70	-70	-70	-70	-70	-70
Reference standard sphere TS dB):		-42.3	-42.3	-42.3	-42.3	-33.6	-42.3	-42.3
Sphere range from transducer (m):		14.7	14.7	8.38	16.1	15.46	15.85	15.2
Absorption coefficient (dB/m):	0.009937	0.009929	0.00878	0.00917	0.00953	0.00917	0.009782	0.0091280
Sound velocity (m/s):	1470	1470.6	1482.6	1484.55	1463.37	1484.55	1462.21	1485.06

* Maximum power for the Simrad ES60 38 kHz in hull-mounted configuration is specified as 1,000 W.

** Calibration performed In Elliot Bay, Washington.

*** The physical calibration set up did not allow enough separation between the target and rigging/no CTD.

Table 4.--Simrad ES120 kHz acoustic system description and settings during the western Gulf of Alaska cooperative research acoustic surveys.

		Survey System Settings	Sept.-2010	Jan.-2011	Sept.-2011
Echosounder:		Simrad ES70	Simrad ES70	Simrad ES70	Simrad ES70
Transducer:		ES120-7C			
Frequency (kHz):		120			
Transducer depth (m):		3.4			
Pulse length (ms):		1.024			
Transmitted power (W):		1000	1000	1000	1000
Angle sensitivity		23			
2-way beam angle (dB):		-21	-21	-21	-21
Gain (dB):		27	26.01	26.06	25.87
Sa correction (dB):			0	-0.08	-0.12
3 dB beam width (degree):					
	Along:	7	8.71	6.38	7.08
	Athwart:	7	6.22	6.6	6.76
Angle offset (degree):					
	Along:	0	0.89	-0.02	0.16
	Athwart:	0	-0.02	-0.03	-0.02
Reference standard sphere TS (dB):		---	-39.5	-39.5	-39.5
Sphere range from transducer (m):		---	15.48	15.37	14.74
Absorption coefficient (dB/m):			0.0349200	.028594	0.0351270
Sound velocity (m/s):			1484.55	1462.21	1485.06
RMS			0.76	0.26	0.16

Table 5.--Midwater trawl hauls for 2007 through 2011 cooperative research acoustic surveys.

Area	Year	Date (local)	Gear Type	Time (local)	Duration (minutes)	Position		Depth (m)		Temperature (°C)		Total catch	Pollock
						Latitude	Longitude	Footrope	Bottom	Gear	Surface		%
Unga	200	24-	AW	12:49	22	55° 27.69	160° 26.14	132	164	5.2	11	1.637	89.97
Unga	200	24-	AW	12:49	10	55° 26.86	160° 31.18	82	144	5.9	11	1.555	99.44
Korovin	200	25-	AW	12:49	11	55° 23.18	160° 16.85	109	200	5.8	10.5	3.999	99.97
Pavlof	200	26-	AW	12:49	8	55° 24.2	161° 40.28	90	105	6.2	11.1	4.486	99.69
Whale	200	27-	AW	12:49	3	55° 32.18	160° 15.54	85	186	5.1	10.8	2.428	97.10
Korovin	200	28-	AW	12:49	24	55° 22.85	160° 17.82	137	198	6.3	10.8	0.494	98.70
Guillemot	200	18-Jan	AW	12:49	15	55° 33.31	160° 09.44	180	181	n/a	3.6	4.986	99.72
Guillemot	200	20-Jan	AW	12:49	16	55° 33.73	160° 15.29	165	189	5.9	3.5	0.498	99.60
Unga	200	28-	AW	18:04	28	55° 28.13	160° 24.95	105	175	n/a	10.1	n/a	n/a
King	201	11-Jan	AW	13:34	31	55°00.29	162°21.24	84	123	4.9	n/a	0.0187	0
Unga	201	13-Jan	AW	11:58	49	55°28.64	160°23.97	175	205	5.4	n/a	1.50	99
Nagai	201	19-	AW	16:54	25	55° 16.98	160° 11.33	132	183	7.5	9.4	0.011	0.02
Nagai	201	20-	AW	14:15	41	55° 06.81	160° 21.01	198	218	7.4	10.7	9.074	99.99
Popof	201	21-	AW	12:53	29	55°13.25	160° 22.44	123	174	7.6	10.5	0.014	99.34
Popof	201	21-	AW	14:15	34	55° 13.75	160° 22.86	157	172	7.6	10.2	1.500	99.97
Nagai	201	22-	AW	14:24	35	55° 12.27	160° 12.43	199	227	7.7	10.4	0.500	99.93
Nagai	201	24-	AW	15:48	32	55° 03.03	160° 26.09	128	155	7.7	10.3	0.002	99.04
Guillemot	201	9-Jan	AW	1002	18	55° 57.69	160° 25.45	162	190	5.4	n/a	13.612	99.98
Nagai	201	11-Jan	AW	1414	15	55° 12.94	160° 19.91	193	230	4.3	n/a	3.000	99.99
Whale	2011	16-	AW	18:51	40	55°32'00	160°15'59	184	231	n/a	n/a	0.32	92.7
Korovin	2011	17-	AW	12:10	11	55°22'51	160°18'33	124	231	3.8	9.6	0.00	3.17
Nagai	2011	17-	AW	18:36	25	55°13'43	160°23'05	100	210	6.5	7.7	0.27	36.24
Nagai	2011	20-	AW	20:22	21	55°08'56	160°19'40	97	115	6.1	n/a	0.36	90.54
Morzhovo	2011	22-	AW	17:30	20	54°52'54	163°02'25	59	98	6.1	8.1	0.23	90.16
Pavlof	2011	24-	AW	15:27	20	55°21'52	161°40'00	83	129	6.7	7.7	2.50	87.77

Table 6.--Species composition for midwater trawl hauls for all winter cooperative research acoustic surveys.

January 2008

Common Name	**Scientific Name**	**Number**	**Weight (kg)**
walleye pollock	*Theragra chalcogramma*	13,906	5,484.00
eulachon	*Thaleichthys pacificus*	149	10.00
arrowtooth flounder	*Atheresthes stomias*	2	4.00
squid	*Teuthoidea*	42	2.00

January 2010

Common Name	**Scientific Name**	**Number**	**Weight (kg)**
walleye pollock	*Theragra chalcogramma*	1,422	1,439.80
eulachon	*Thaleichthys pacificus*	627	33.20
Chinook salmon	*Oncorhynchus tshawytscha*	1	18.60
arrowtooth flounder	*Atheresthes stomias*	11	7.60
flathead sole	*Hippoglossoides elassodon*	17	7.35
smooth lumpsucker	*Aptocyclus ventricosus*	4	6.20
Pacific cod	*Gadus macrocephalus*	2	5.90
herring	*Clupea pallasii*	1	3.40

January 2011

Common Name	**Scientific Name**	**Number**	**Weight (kg)**
walleye pollock	*Theragra chalcogramma*	18,472	13,429.92
Pacific cod	*Gadus macrocephalus*	19	89.30
arrowtooth flounder	*Atheresthes stomias*	52	66.10
flathead sole	*Hippoglossoides elassodon*	63	22.60
eulachon	*Thaleichthys pacificus*	172	9.50
Chinook salmon	*Oncorhynchus tshawytscha*	1	7.00
smooth lumpsucker	*Aptocyclus ventricosus*	3	5.20
prickleback	*Stichaeidae*	2	0.10
capelin	*Mallotus villosus*	5	0.10
sand lance	*Ammodytidae*	1	0.001

Table 7.--Species composition for midwater trawl hauls for all fall cooperative research acoustic surveys.

September 2007

Common Name	**Scientific Name**	**Number**	**Weight (kg)**
walleye pollock	*Theragra chalcogramma*	41,653	14,597.80
salmon shark	*Lamna ditropis*	1	159.10
eulachon	*Thaleichthys pacificas*	394	50.10
arrowtooth flounder	*Atheresthes stomias*	28	37.60
jellyfish	*Cnidaria*	30	20.80
Pacific cod	*Gadus macrocephalus*	4	7.70
squid	*Teuthoidea*	7	3.51
smooth lumpsucker	*Aptocyclus ventricosus*	5	3.70
Chinook salmon	*Oncorhynchus tshawytscha*	1	3.40

September 2010

Common Name	**Scientific Name**	**Number**	**Weight (kg)**
walleye pollock	*Theragra chalcogramma*	9,581	7,946.86
Pacific cod	*Gadus macrocephalus*	24	52.90
eulachon	*Thaleichthys pacificas*	134	47.50
jellyfish	*Cnidaria*	55	28.10
Chinook salmon	*Oncorhynchus tshawytscha*	4	14.50
smooth lumpsucker	*Aptocyclus ventricosus*	12	14.41
arrowtooth flounder	*Atheresthes stomias*	43	11.90
flathead sole	*Hippoglossoides elassodon*	2	8.20
capelin	*Mallotus villosus*	207	1.23
salps	*Tunicates*	9	1.11
squid	*Teuthoidea*	2	0.01

September 2011

Common Name	**Scientific Name**	**Number**	**Weight (kg)**
walleye pollock	*Theragra chalcogramma*	3,899	3,178.04
Pacific cod	*Gadus macrocephalus*	114	166.36
arrowtooth flounder	*Atheresthes stomias*	24	33.51
flathead sole	*Hippoglossoides elassodon*	7	2.71
eulachon	*Thaleichthys pacificas*	361	18.62
Chinook salmon	*Oncorhynchus tshawytscha*	2	1.16
smooth lumpsucker	*Aptocyclus ventricosus*	7	3.93
capelin	*Mallotus villosus*	27	0.10
sand lance	*Ammodytidae*	155	3.50
jellyfish	*Cnidaria*	485	269.52
salmon shark	*Lamna ditropis*	3	537.79
snailfish	*Liparidae*	1	0.02
squid	*Teuthoidea*	3	0.03

Table 8.--Estimates of walleye pollock biomass for all surveys in all years**.**

Date	Survey Area	nmi²	Biomass (t)	Relative Error %
September 2007	Korovin *	9	3,050	1.62
September 2007	Korovin 2nd pass*	9	2,002	2.28
September 2009	Korovin*	9	851	0.31
September 2010	Korovin*	9	541	1.30
September 2011	Korovin	9	538	5.2
September 2007	Pavlof	90	5,539	25.21
September 2011	Pavlof	90	8,478	7.2
September 2007	Unga	58	1,222	1.72
September 2009	Unga	35	516	4.88
January 2010	Unga	40	994	7.09
September 2011	Unga	58	1,391	5.4
September 2007	Whale	8	3,067	5.66
January 2008	Whale	8	4,187	5.67
January 2008	Guillemot day	25	8,287	3.00
January 2008	Guillemot day (partial)	4	2,715	6.42
January 2008	Guillemot night (partial)	4	3,697	6.16
January 2011	Guillemot day	25	1,182	17.26
January 2011	Guillemot night	25	1,275	11.79
September 2011	Guillemot	50	1,066	2.1
September 2009	Nagai (partial)	17	6,846	8.67
September 2010	Nagai	110	30,646	8.60
September 2010	Nagai (partial)	92	26,808	7.38
September 2010	Nagai (partial)	57	23,860	6.71
January 2011	Nagai (partial)	57	1,223	16.19
September 2011	Nagai	110	3,283	11.1
January 2010	King Cove*	5	4	12.32
January 2010	King Cove 2nd pass*	5	2	29.94
January 2010	Morzhovoi	60	262	3.61
September 2011	Morzhovoi	60	1,949	8.5
September 2010	Popof	20	5,258	4.97
January 2010	Sanak	124	1,199	2.95
January 2011	Sanak	143	1,374	3.71

*EVA variance model was not applied for Korovin Strait or King Cove surveys because there were too few transects; standard errors are shown instead for this area.
**Unga and Guillemot regions had different area coverage and transect orientation between years.

Table 9.--Backscatter within the euphausiid range of frequency response.

Date	Survey Region; Area Sampled in nmi²	Euphausiid s_A
September 2010	Nagai; 110	18183.1
September 2010	Korovin; 9	5635.4
September 2010	Popof; 20	3279.1
January 2011	Sanak	11934.6
January 2011	Guillemot day	18133.6
January 2011	Guillemot night	9935.3
September 2011	Nagai(partial)	28633.9
September 2011	Guillemot	12467.3
September 2011	Morzhovoi	2223.2
September 2011	Pavlof	32939.4
September 2011	Unga	6624.7

Table 10.--Species composition for a zooplankton tow conducted in September 2011 in Pavlof Bay.

Species	Number
Limacina sp.	672,011
Copepoda	5,600
Unidentifed euphausiids	1,552
Thysanoessa sp.	531
Clione limacine	317
Chaetognaths	303
Brachyura megalopa	33
Hyperiid amphipods	16
Unidentified amphipods	2
Lumpenus maculates	3
Unidentified mysids	1
Unidentified polychaete	1

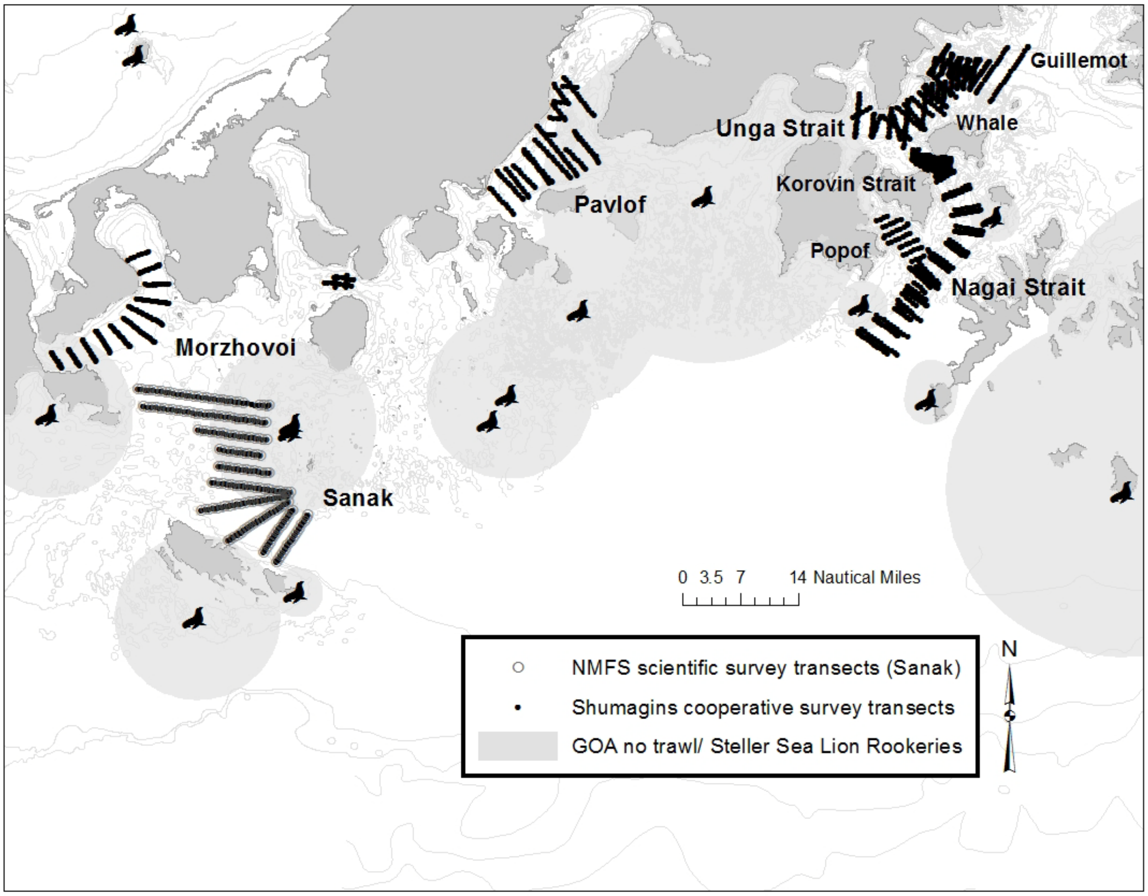

Figure 1.--Survey locations and cruise tracks for western Gulf of Alaska cooperative research acoustic surveys from 2007 through 2011.

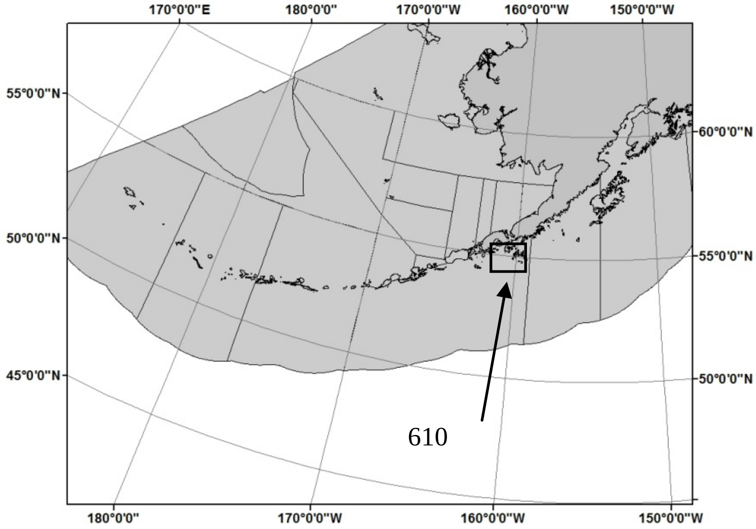

Figure 2.--Cooperative survey location in NMFS Management area 610.

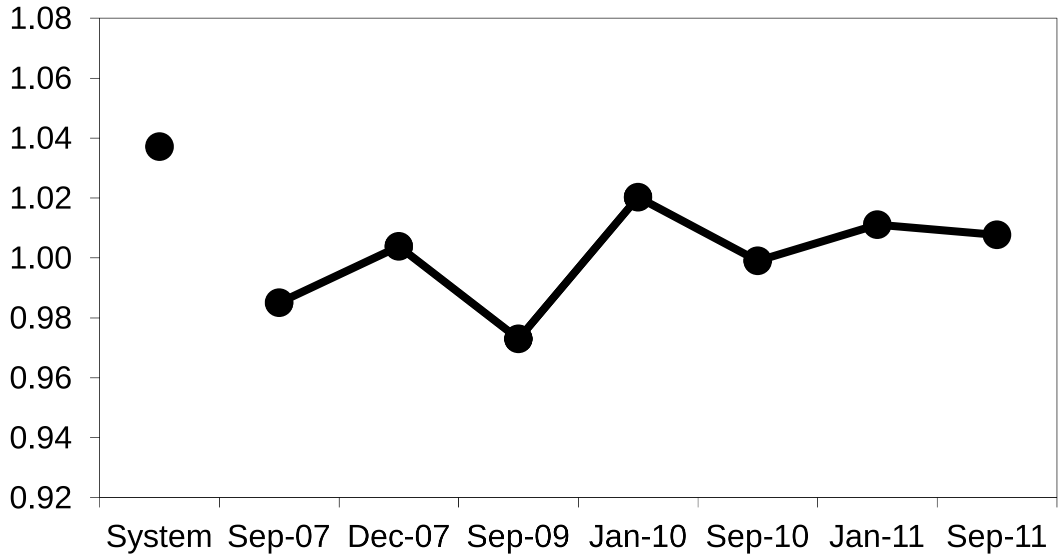

Figure 3.--Integration gain measured by standard sphere calibrations normalized to the average over the period. System settings (relative to the average) are also shown. The December 2007 calibration was performed in Elliott Bay, Washington.

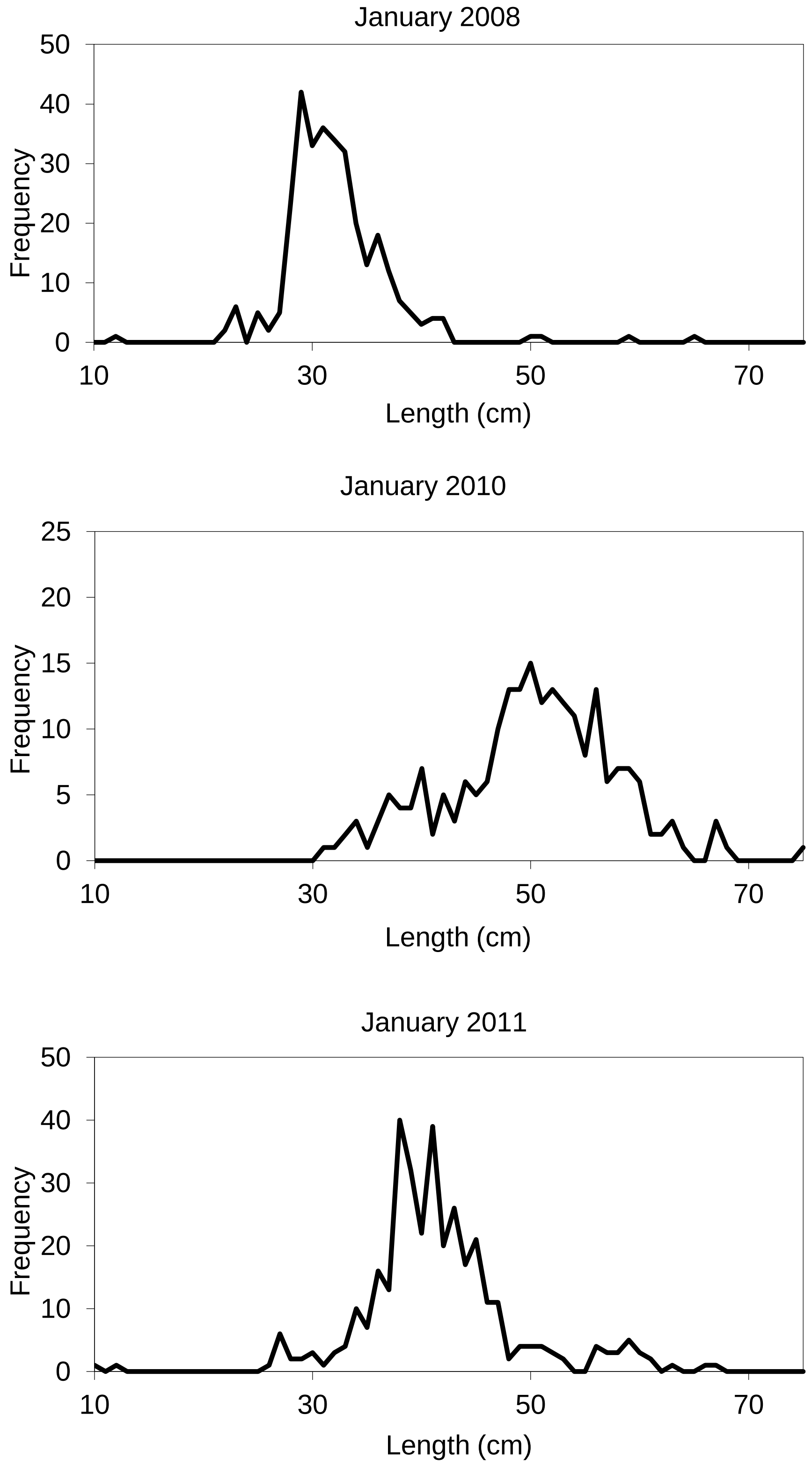

Figure 4.--Walleye pollock length composition in the all areas during January surveys.

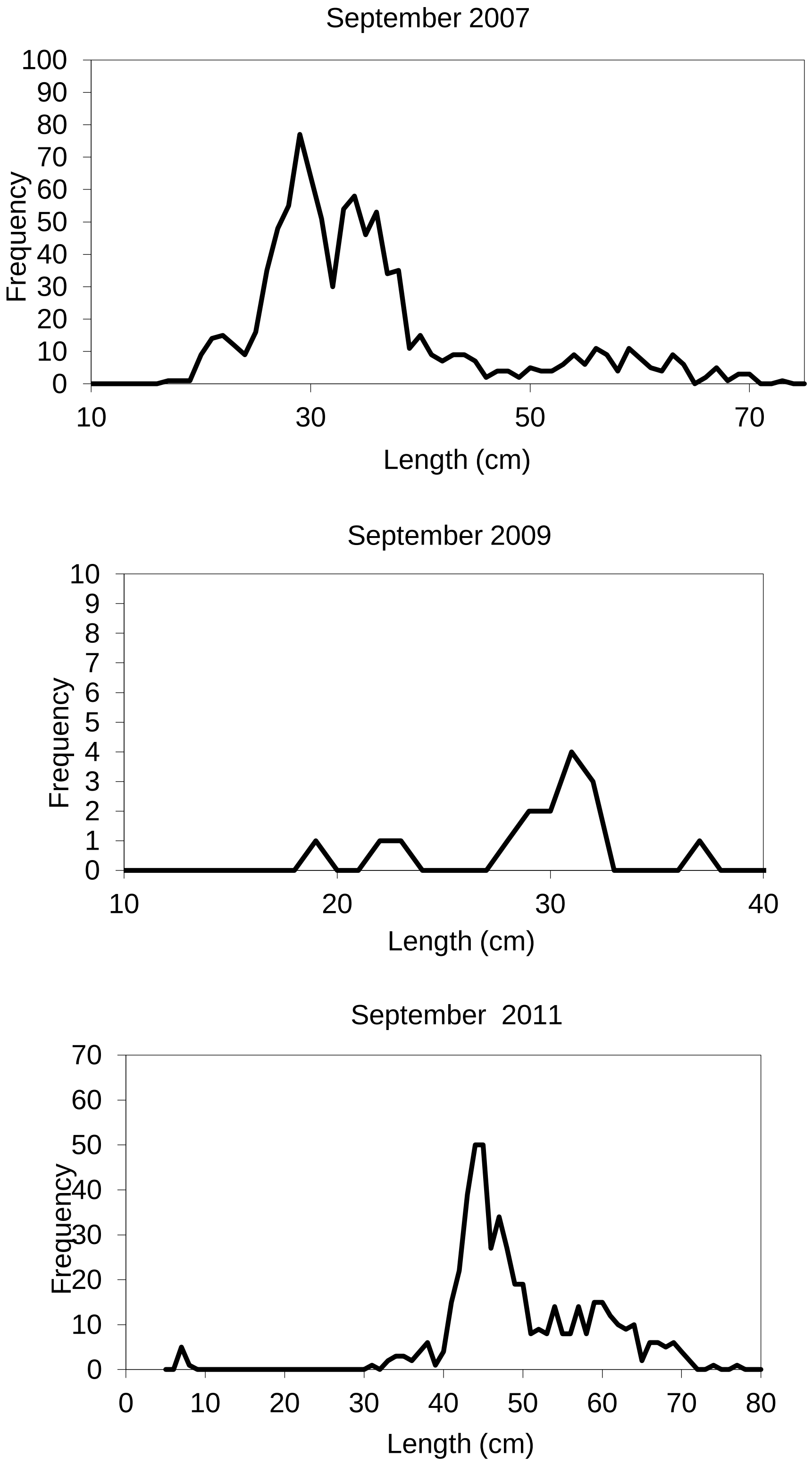

Figure 5.--Walleye pollock length composition in all areas during September surveys.

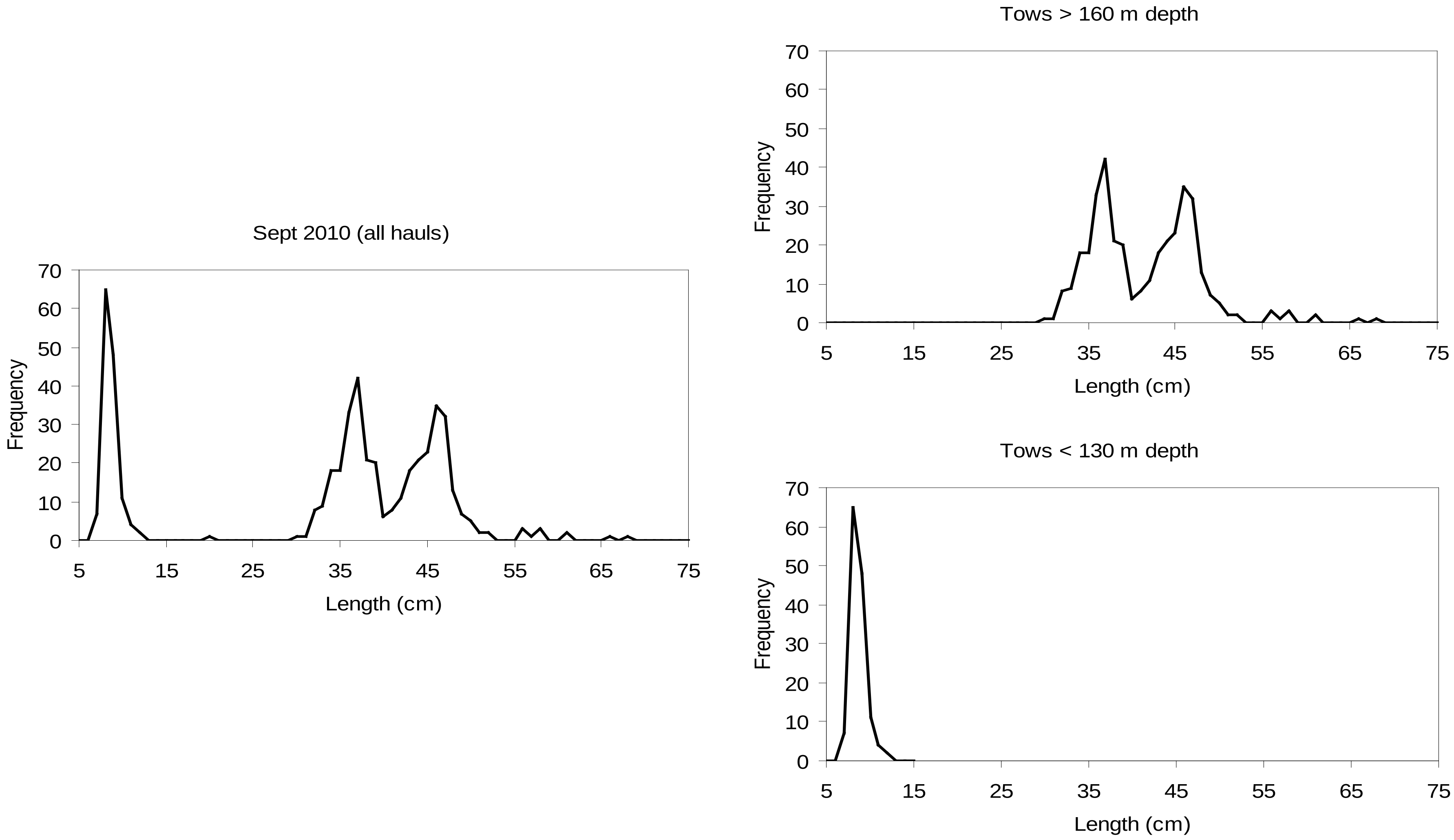

Figure 6.--Walleye pollock length composition in September 2010.

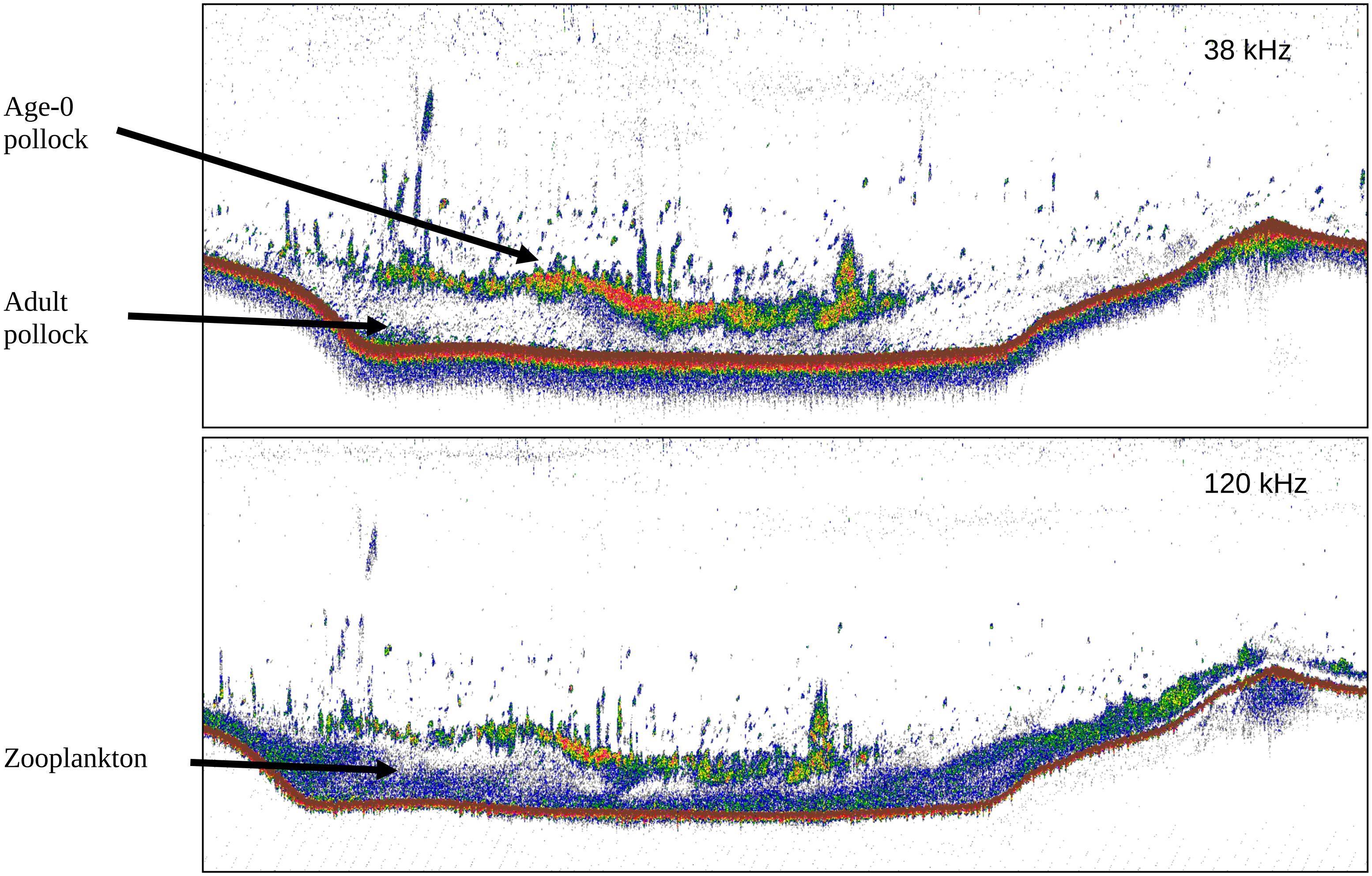

Figure 7.--Comparison of backscatter on an example echogram at 38 and 120 kHz on a portion of a transect in the western part of Nagai Strait in September 2010.

Figure 8.--Distribution of walleye pollock biomass for surveys in the Korovin area in September 2007-2011.

Figure 9.-- Distribution of walleye pollock biomass for surveys in the Whale area in 2007 and 2008.

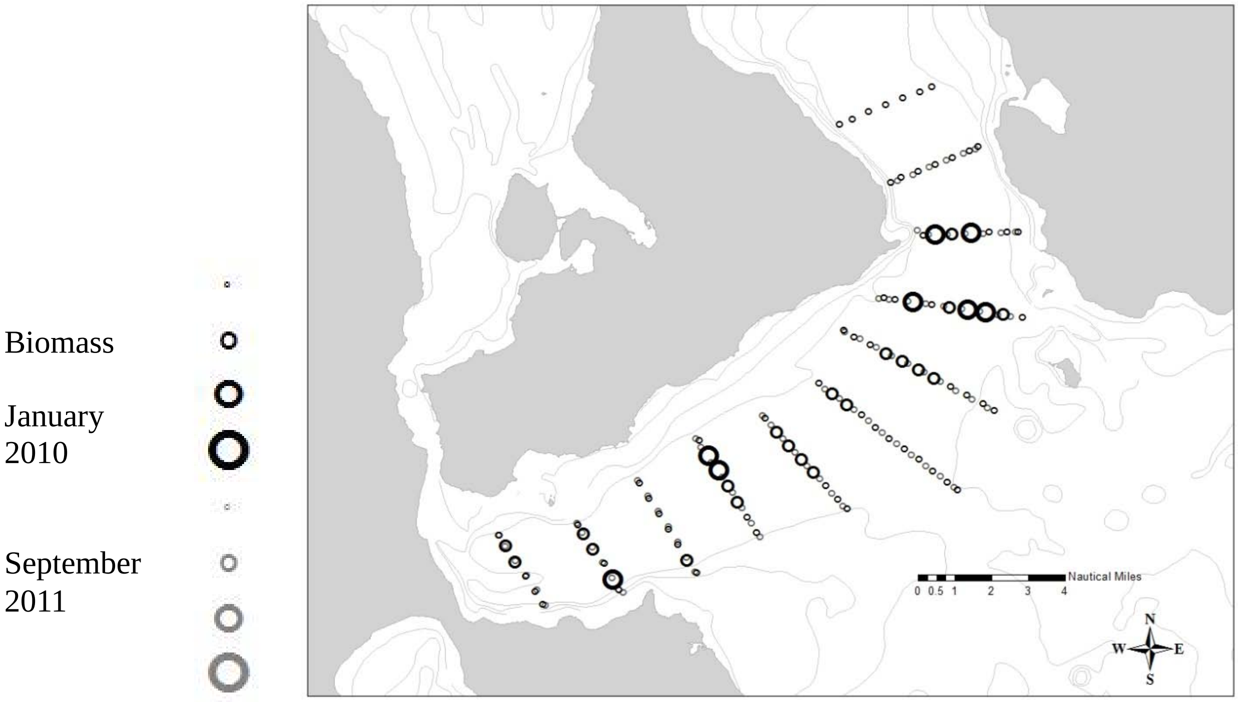

Figure 10.--Distribution of walleye pollock biomass for surveys in the Morzhovoi area in 2010 and 2011.

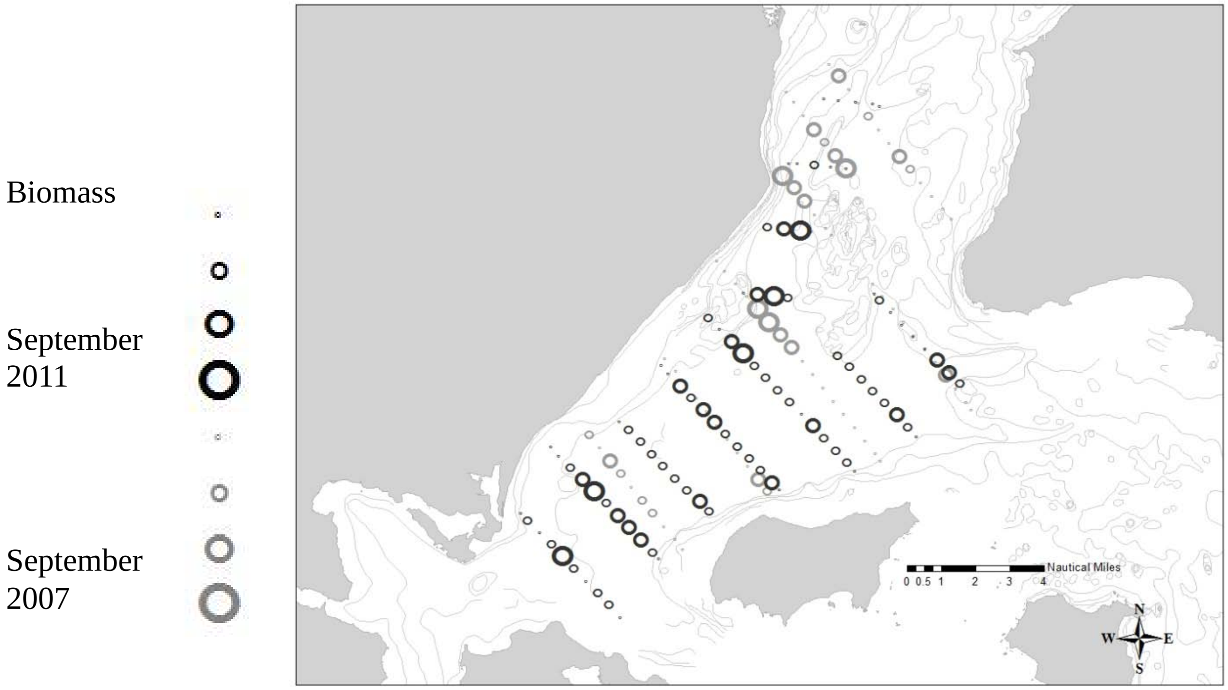

Figure 11.--Distribution of walleye pollock biomass for surveys in the Pavlof area.

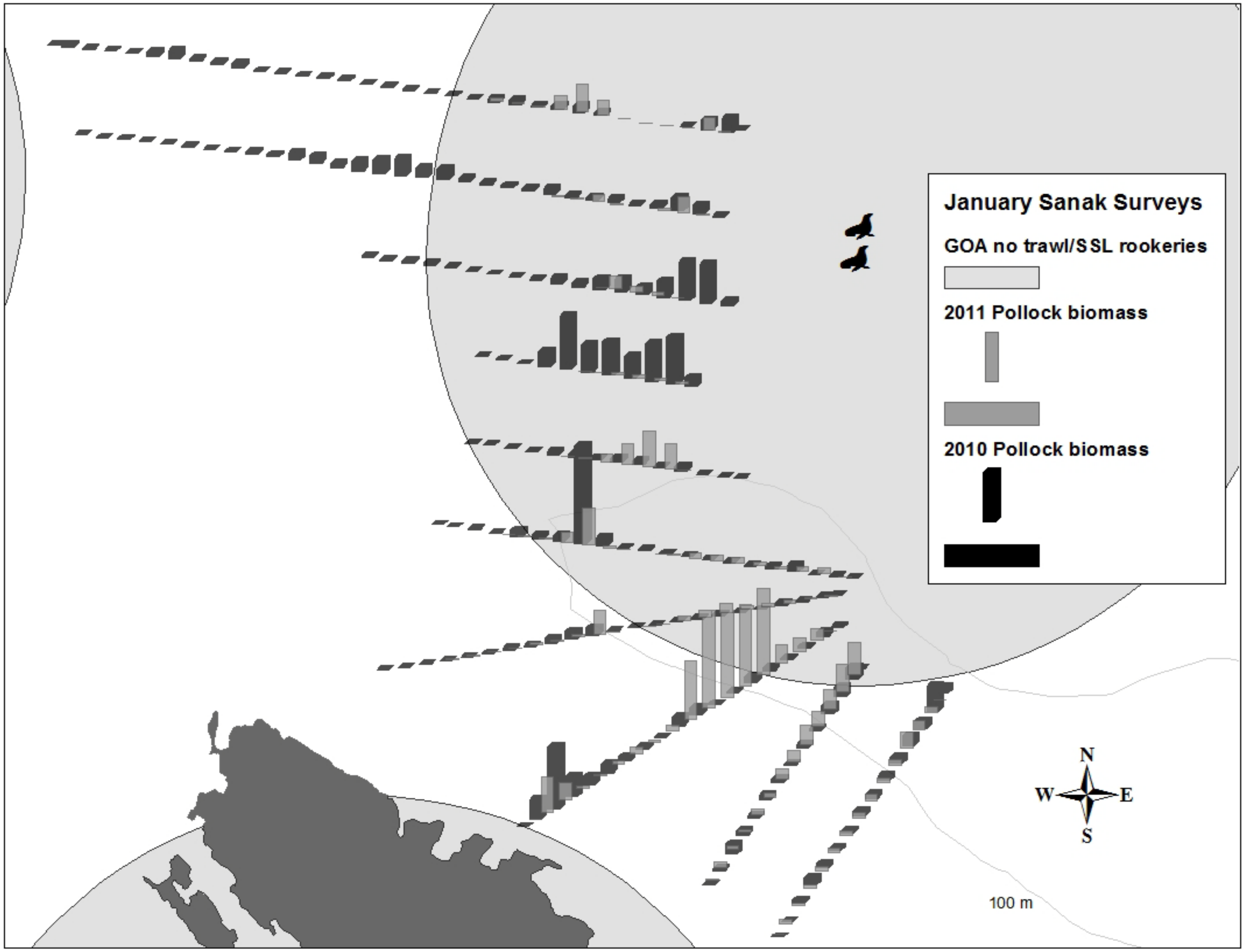

Figure 12.-- Distribution of walleye pollock biomass for surveys in the Sanak area in 2010 and 2011.

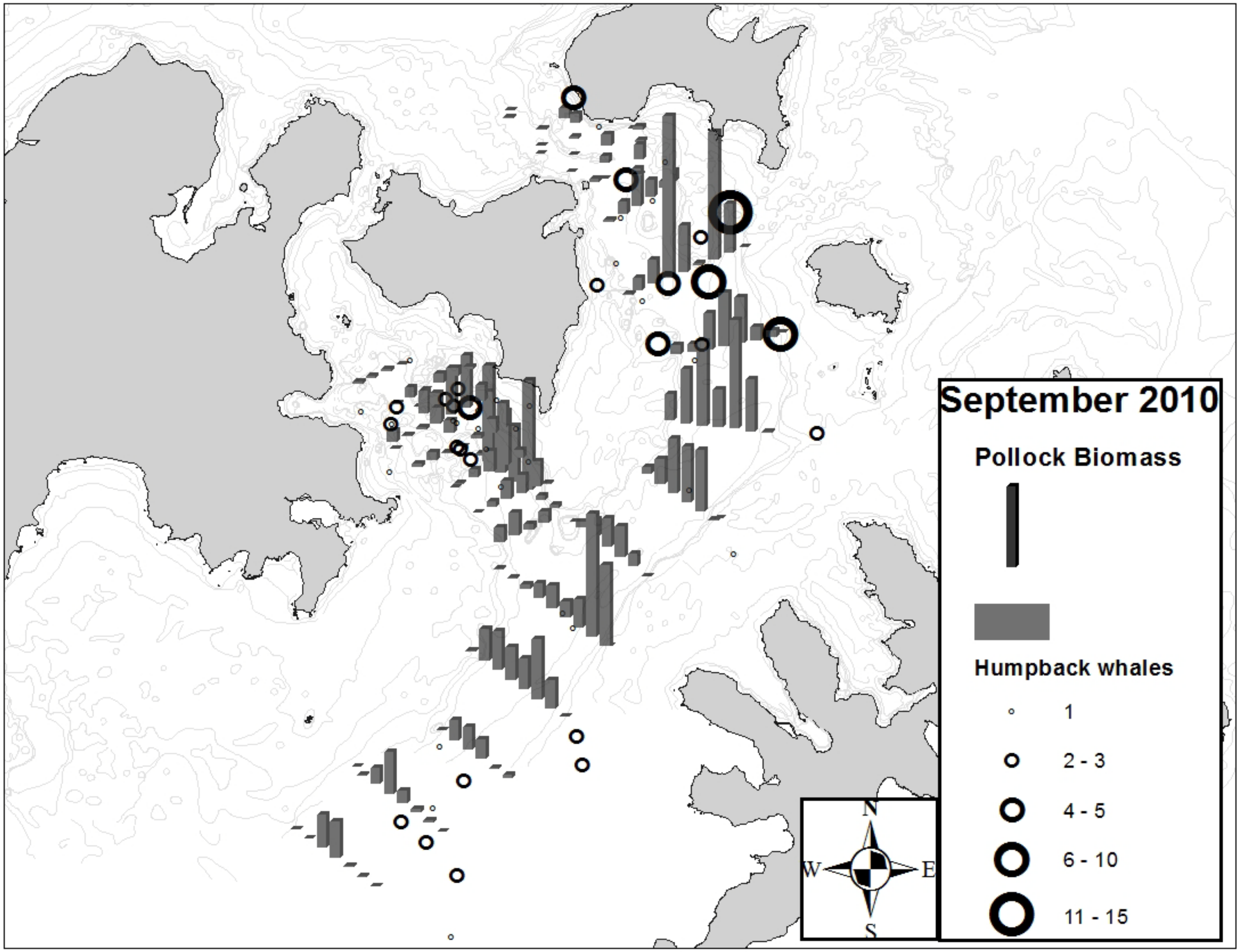

Figure 13.--Distribution of walleye pollock biomass and marine mammal observations in Nagai Strait and surrounding areas in September 2010.

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