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Results of the Acoustic-Trawl Surveys of Walleye Pollock (*Gadus chalcogrammus*) in the Gulf of Alaska, February-March 2016 (DY2016-02 and DY2016-04)

by

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ABSTRACT

Scientists from the Midwater Assessment and Conservation Engineering (MACE) Program of the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division conducted acoustic-trawl (AT) stock assessment surveys in the Gulf of Alaska (GOA) during late winter and early spring 2016 to estimate the distribution and abundance of walleye pollock (*Gadus chalcogrammus*) within several of their main spawning grounds. These pre-spawning pollock surveys covered the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof Bays (DY2016-02; 13-17 February) and Shelikof Strait and Marmot Bay (DY2016-04; 14-24 March). Prior to 2001, these efforts have focused on the Shelikof Strait area, which has been surveyed annually since 1981 (except 1982, 1999, 2011). The shelf break near Chirkof Island and Marmot Bay are also regularly surveyed during the Shelikof survey cruises. The first survey of the Shumagins occurred in 1994, and this area has been surveyed annually since 2001 (except 2004, 2011). Sanak Trough, Morzhovoi Bay, and Pavlof Bay have also been regularly surveyed during the Shumagin survey cruises. Average surface water temperatures ranged from 3.9 °C (Pavlof Bay) to 5.7 °C (Marmot Bay) in these areas. Mean temperatures declined by about 0.3 °C in the Shumagin Islands and increased about 0.7 °C in Shelikof Strait compared to 2015. The walleye pollock biomass estimate for the winter 2016 Shumagin Islands survey was 20,706 metric tons (t), with an additional 17,098 t estimated for the Sanak, Morzhovoi, and Pavlof areas. The walleye pollock biomass estimate for the winter 2016 Shelikof Strait area was 665,059 t, with an additional 37,161 t estimated for the Marmot area. This breaks down to estimates of 34,619 t, 530,438 t, and 174,967 t in International North Pacific Fisheries Commission areas 610, 620, and 630, respectively. Pollock between 35 and 45 cm fork length (FL), which is indicative of age-4 fish, contributed to most of the biomass in all areas. For example, 90% of pollock biomass from the Shumagin Islands survey area and 88% of pollock biomass from the Shelikof Strait survey area came from this age class. Fish weight at length was lower in fish > 40 cm FL compared to winter GOA surveys in previous years. A second abundance analysis was conducted in which backscatter was attributed to other species where possible.

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INTRODUCTION

The Midwater Assessment and Conservation Engineering (MACE) Program of the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division conducts annual acoustic-trawl (AT) stock assessment surveys in the Gulf of Alaska (GOA) during late winter and early spring to estimate the distribution and abundance of walleye pollock (*Gadus chalcogrammus*) within several of their main spawning grounds (i.e., pre-spawning surveys). Prior to 2001, most of these efforts have focused on the Shelikof Strait area, which has been surveyed annually since 1981, except when no survey was scheduled (1982), and when all winter GOA surveys were cancelled due to vessel repair (1999, 2011). The Shumagin Islands area has been surveyed annually since 2001 (except 2004, 2011) with prior surveys in 1994-1996, and Sanak Trough has been surveyed annually since 2002 (except 2004, 2011). Pre-spawning surveys have been conducted in Marmot Bay eight times (1989, 1990, 1992, 2007, 2009, 2010, 2014, and 2015), in Morzhovoi Bay four times (2006, 2007, 2010, and 2013), and in Pavlof Bay twice (2002, 2010). The GOA continental shelf break east of Chirikof Island to Barnabas Trough was not surveyed this year due to bad weather and time constraints, although it has been surveyed annually since 2002 (except 2011, 2014). This report presents the results from AT surveys conducted in the aforementioned areas of the GOA during February and March 2016.

METHODS

Two cruises were conducted to survey several GOA pollock spawning areas. The first cruise (DY2016-02) surveyed the Shumagin Islands area (i.e., Shumagin Trough, Stepovak Bay, Renshaw Point, Unga Strait, and West Nagai Strait; 13-15 February), Sanak Trough (16 February), Morzhovoi Bay (16-17 February), and Pavlof Bay (17 February). The second cruise (DY2016-04) covered Shelikof Strait (14-21 March) and Marmot Bay (22-24 March). Work was conducted aboard the NOAA ship *Oscar Dyson*, a 64-m stern trawler equipped for fisheries and oceanographic research. Surveys followed established AT methods as specified in

NOAA protocols for fisheries acoustics surveys and related sampling.[1] The acoustic units used here are defined in MacLennan et al. (2002). Survey itineraries are listed in Appendix I and scientific personnel in Appendix II.

Acoustic Equipment, Calibration, and Data Collection

Acoustic measurements were collected with a Simrad EK60 scientific echosounding system (Simrad 2008, Bodholt and Solli 1992). System electronics were housed inside the vessel in a permanent laboratory space dedicated to acoustics. Five split-beam transducers (18-, 38-, 70-, 120-, and 200-kHz) were mounted on the bottom of the vessel's retractable centerboard, which extended 9 m below the water surface.

Two standard sphere acoustic system calibrations were conducted to measure acoustic system performance. The calibrations were conducted just prior to the start of cruise DY2016-02 and during the middle of cruise DY2016-04. The vessel dynamic positioning system was used to maintain the vessel location during calibrations. A tungsten carbide sphere (38.1 mm diameter) suspended below the centerboard-mounted transducers was used to calibrate the 38-, 70-, 120-, and 200-kHz systems. The tungsten carbide sphere was then replaced with a 64 mm diameter copper sphere to calibrate the 18-kHz system. A two-stage calibration approach was followed for each frequency. On-axis sensitivity (i.e., transducer gain and s_A correction) was estimated from measurements with the sphere placed in the center of the beam following the procedure described in Foote et al. (1987). Transducer beam characteristics (i.e., beam angles and angle offsets) were estimated by moving the sphere in a horizontal plane through the beam and fitting these data to a second order polynomial model of the beam pattern using the ER60's calibration utility (Simrad 2008, Jech et al. 2005). The equivalent beam angle (which is used to characterize the volume sampled by the beam) cannot be estimated from the calibration approach used (knowledge is required of the absolute position of the sphere, see Demer et al. 2015). Thus, the

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[1] National Marine Fisheries Service (NMFS) 2013. NOAA protocols for fisheries acoustics surveys and related sampling (Alaska Fisheries Science Center), 23 p. Prepared by Midwater Assessment and Conservation Engineering Program, Alaska Fish. Sci. Center, Natl. Mar. Fish. Serv., NOAA. Available online: http://www.afsc.noaa.gov/RACE/midwater/AFSC%20AT%20Survey%20Protocols_Feb%202013.pdf

transducer-specific equivalent beam angle measured by the echosounder manufacturer, and corrected for the local sound speed (see Bodholt 2002), was used in data processing.

Acoustic data were recorded at five split-beam frequencies using ER60 software (version 2.4.3). Acoustic telegram data were also logged with Echoview EchoLog 500 (version 4.70.1.14256) software as a backup. Acoustic measurements were collected from 16 m below the sea surface to within 0.5 m of the sounder-detected bottom or a maximum of 1,000 m in deep water. Data were analyzed using Echoview post-processing software (version 6.1.59.27435).

Trawl Gear and Oceanographic Equipment

General trawl gear specifications for the sampling of acoustic backscatter are described below. Detailed trawl gear specifications are reported in Guttormsen et al. (2010). An Aleutian Wing 30/26 Trawl (AWT) was used to sample all (i.e., midwater and near-bottom) backscatter during the Gulf of Alaska winter surveys. This trawl was constructed with full-mesh nylon wings and polyethylene mesh in the codend and aft section of the body. The headrope and footrope each measured 81.7 m (268 ft). Stretch mesh sizes tapered from 325.1 cm (128 in) in the forward section of the net to 8.9 cm (3.5 in) in the codend, which was fitted with a single 12 mm (0.5 in) codend liner. The net was fished with 5 m^2 Fishbuster trawl doors each weighing 1,089 kg (2,400 lb) at an approximate trawling speed of 1.6 m/sec (3.0 knots). All trawl vertical openings and depths were monitored with a Simrad FS70 third-wire netsonde attached to the headrope. The vertical net opening ranged from 15 to 29 m (49-95 ft) and averaged 24 m (79 ft) while fishing.

The trawl hauls conducted in the GOA winter surveys included a CamTrawl stereo camera (Williams et al. 2010b) attached to the net forward of the codend. The CamTrawl was used to capture stereo images for species identification and fish length measurements as fishes passed through the net toward the codend. Images were viewed and annotated using procedures described in Williams et al. (2010a). Lengths obtained from CamTrawl were used primarily in comparisons with lengths measured from fish caught in the net to evaluate the performance of an algorithm that estimates fish length from stereo image pairs. However, stereo images captured by CamTrawl were occasionally used to determine the fish species and length composition of very dense backscatter when it was aggregated into discrete layers. A permanently attached, small-mesh (12 mm) recapture net was affixed to the bottom panel of the AWT approximately 26 m forward of the codend. Pocket net catch data were recorded independently from the catch in the codend. These data are being used in ongoing work to estimate the trawl selectivity of the AWT for pollock and other common fish species (i.e., eulachon; Williams et al. 2011). Pocket net data were not used to adjust trawl codend catches or other estimates reported here.

Physical oceanographic data collected during the cruises included temperature profiles obtained with a Sea-Bird Electronics temperature-depth probe (SBE-39) attached to the trawl headrope, and conductivity-temperature-depth (CTD) observations collected with a Sea-Bird CTD (SBE 9-11 plus) system at calibration sites. Sea surface temperature data were measured using the ship’s Furuno T-2000 sea surface temperature system located mid-ship, approximately 1.4 m below the surface. These and other environmental data were recorded using the ship’s Scientific Computing Systems (SCS). Surface water temperatures were plotted as 1 nautical mile (nmi) averages along the vessel’s cruise track.

Survey Design

The survey design consisted of a series of predetermined transects in each survey area, parallel to one another except in areas where it was necessary to reorient transects to maintain a perpendicular alignment to the isobaths and to navigate around landmasses. Coverage and transect spacing were chosen to be consistent with previous surveys in each area. To add an element of randomization to this systematic transect design, the position of the first transect in each area was randomly jittered by an amount less than or equal to the intertransect distance, and then subsequent transects were laid out with uniform spacing from this point (Rivoirard et al. 2000). Survey activities were conducted 24 hours/day.

Trawl hauls were conducted to identify the species composition of acoustically observed fish aggregations and to determine biological characteristics of walleye pollock and other specimens. Catches were sorted to species. When large numbers of juvenile and adult walleye pollock were encountered, the predominant size groups were subsampled separately (e.g., age-1 vs. large adults). Sex, length, body weight, maturity, age, and gonad measurements were taken from a random subset of walleye pollock within each size group. Walleye pollock and other fishes were measured to the nearest 1 mm fork length (FL), or for capelin (*Mallotus villosus*) to the nearest 1 mm standard length (SL), with an electronic measuring board (Towler and Williams 2010). Gonadosomatic index [GSI: ovary weight/(ovary weight + body weight)] was calculated for pre-spawning females. Maturity was determined by visual inspection of the gonads and was categorized as immature, developing, pre-spawning, spawning, or post-spawning[2]. The ovary weight was determined for mature, pre-spawning females. An electronic motion-compensating scale (Marel M60) was used to weigh individual walleye pollock and selected ovaries to the nearest 2 g. Trawl station information and biological measurements were electronically recorded to the Catch Logger for Acoustic Midwater Surveys (CLAMS). Pocket net contents were logged in a manner similar to, but separate from, the codend contents.

For each trawl in cruise DY2016-02, sex and length measurements from an average of 392 randomly selected walleye pollock were collected, with an average of 72 individuals more extensively sampled for body weight, maturity, and age (Table 1). For each haul in cruise DY2016-04, sex and length measurements from an average of 433 randomly selected walleye pollock were collected, with an average of 98 individuals more extensively sampled for body weight, maturity, and age (Table 2). Age-1 pollock were not used in any maturity calculations.

Data Analysis

Walleye pollock abundance was estimated by combining acoustic and trawl information. Acoustic backscatter was classified as walleye pollock, rockfishes, unidentified fishes, or an undifferentiated mixture of primarily macrozooplankton, based on the depth distribution and appearance of the aggregations and on catch composition in nearby trawl hauls. The sounder-detected bottom was calculated using the mean of sounder-detected bottom lines for all five frequencies (Jones et al. 2011). Although acoustic data were recorded at five frequencies, the results of this report and the survey time series are based on the 38 kHz data. A minimum S_v threshold of –70 dB re 1 m^{-1} was applied to the 38 kHz acoustic data, which were then averaged at 0.5 nmi horizontal by 10 m vertical resolution and exported to a database.

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[2] ADP Codebook. 2013. RACE Division, AFSC, NMFS, NOAA; 7600 Sand Point Way NE, Seattle, WA 98115. Available online: http://www.afsc.noaa.gov/RACE/groundfish/adp_codebook.pdf.

Within a surveyed area (e.g., Shumagin Islands, Sanak Trough, Shelikof Strait, Marmot Bay) the mean fish weight-at-length in each 1 cm length interval was estimated from the trawl information when six or more walleye pollock were measured within a length interval. Otherwise, weight-at-length was estimated using a linear regression of the natural logs of all length-weight data (De Robertis and Williams 2008). Walleye pollock length compositions were combined from trawl hauls into regional length strata based on geographic proximity, similarity of length composition, and backscatter characteristics. Surveyed areas were composed of 1-3 length strata.

Abundance for each length stratum was estimated as follows. The echosounder measures backscattering strength, which is integrated vertically to produce the nautical area scattering coefficient, s_A (units of m^2 nmi^{-2}; MacLennan et al. 2002).The acoustic return from an individual fish is referred to as its backscattering cross-section, σ_{bs} (m^2), or in more familiar (logarithmic) terms as its target strength, TS (dB re 1 m^2), where,

$$TS = 10 \log_{10} \sigma_{bs}. \qquad \text{Eqn (1)}$$

The estimated TS-to-length relationship for walleye pollock (Foote and Traynor 1988, Traynor 1996) is

$$TS = 20 \log_{10} L - 66, \qquad \text{Eqn (2)}$$

where L = fork length (FL) in centimeters. Biological information available from the trawl hauls includes:

P_i, the proportion of pollock by number at length i,

$\overline{W}_i$, mean weight-at-length i, and

$Q_{i,j}$ is the proportion of j-aged fish of length i.

For a given geographic length stratum, the abundance of pollock in the area (A, nmi^2) is estimated from the mean areal backscatter attributed to walleye pollock ($\bar{s}_A$, $m^2\ nmi^{-2}$), the mean backscattering cross-section ($\bar{\sigma}_{bs}$, m^2) of pollock, and the biological information as follows:

$$\bar{\sigma}_{bs} = \Sigma_i (P_i \times \sigma_{bs,i}), \text{ where } \sigma_{bs,i} = 10^{((20 \log_{10} L_i - 66)/10)} \quad \text{Eqn (3)}$$

$$\text{Numbers at length } i\text{: } N_i = P_i \times \bar{s}_A \times A / 4\pi\bar{\sigma}_{bs} \quad \text{Eqn (4)}$$

$$\text{Biomass at length } i : B_i = \bar{W}_i \times N_i \quad \text{Eqn (5)}$$

$$\text{Numbers at age } j : N_j = \Sigma_i Q_{i,j} \times N_i \quad \text{Eqn (6)}$$

$$\text{Biomass at age } j : B_j = \Sigma_i Q_{i,j} \times B_i . \quad \text{Eqn (7)}$$

The abundance in each survey area was estimated by adding the estimates for all the length strata in the area. The mean pollock depth for each 0.5 nmi horizontal sampling interval was calculated as

$$\bar{D} = \frac{\sum_D D \cdot B_D}{\sum_D B_D}, \quad \text{Eqn (8)}$$

where D is depth (m) and B_D is the biomass in the depth interval from D-1 to D. Length-at-age data were used to convert abundance-at-length estimates to abundance-at-age (Jones et al. in prep.).

In all areas except for outer Marmot Bay, relative estimation errors for the acoustic-based estimates were derived using a one-dimensional (1-D) geostatistical method (Petitgas 1993, Williamson and Traynor 1996, Rivoirard et al. 2000, Walline 2007). Relative estimation error is defined as the ratio of the square root of the estimation variance to the estimate of biomass:

$$\textit{Relative estimation error} = \frac{\sqrt{variance}}{biomass}. \quad \text{Eqn (9)}$$

Relative estimation error among n survey areas with different transect spacings was computed by summing the estimation variance for each area j and then dividing by the sum of the biomass over all areas, assuming independence among estimation errors for each survey area (Rivoirard et al. 2000):

$$\textit{Relative estimation error}_{survey} = \frac{\sqrt{\sum_{j=1}^{n} variance_j}}{\sum_{j=1}^{n} biomass_j}. \qquad \text{Eqn (10)}$$

A two-dimensional (2-D) geostatistical method (Petitgas 1993, Rivoirard et al. 2000) was used for outer Marmot Bay as one zig-zag transect was used there. Mean biomass density is multiplied by the surveyed area (nmi^2) to obtain the biomass estimate for that area (kg); likewise, relative estimation error is obtained as:

$$\textit{Relative estimation error} = \frac{\sqrt{variance * area}}{mean\,biomass * area}. \qquad \text{Eqn (11)}$$

The biomass estimate for the entire Marmot area was obtained by summing biomass for both inner and outer Marmot. However, the variance for that sum includes only the 1-D relative estimation error, as it is not appropriate to combine 1-D and 2-D variance estimates since they involve different assumptions and may not be strictly comparable (Petitgas 1993).

Geostatistical methods were used for computation of error because they account for the observed spatial structure in the fish distribution. These errors quantify only the transect sampling variability of the acoustic data. Other sources of error (e.g., target strength, trawl selectivity, species classification) were not evaluated.

Otoliths were used to estimate walleye pollock ages, and were collected from the Shumagin Islands (n = 189), Sanak Trough (n = 60), Morzhovoi Bay (n= 30), Pavlof Bay (n = 50), Shelikof Strait (n = 610), and Marmot Bay (n = 155) areas (Tables 1 and 2). The samples were stored in a 50% glycerol/thymol-water solution. Only otoliths from the Shelikof Strait survey area (Shelikof and Marmot) were processed by AFSC Age and Growth Program researchers to determine ages.

RESULTS and DISCUSSION

Calibration

Pre- and post-survey calibration measurements of the 38-kHz transducer showed no significant differences in gain parameters or beam pattern characteristics between calibrations, confirming that the acoustic system was stable throughout the survey (Table 3). The difference in integration gain measured before and after the survey was < 0.1 dB, and the average of all results from both calibrations (averages calculated in the linear domain for dB quantities) were used in the final analysis (Table 3).

Shumagin Islands

Acoustic backscatter was measured along 756 km (408 nmi) of transects. The survey transects were spaced 1.9 km (1.0 nmi) apart directly south and east of Renshaw Point and in the eastern half of Unga Strait, 3.7 km (2.0 nmi) apart in the western half of Unga Strait, 4.6 km (2.5 nmi) apart in Stepovak Bay and West Nagai Strait, and 9.3 km (5.0 nmi) apart in Shumagin Trough (Fig. 1). Bottom depths did not exceed 225 m, and transects generally did not extend into waters less than about 50 m depth.

<u>Water Temperature</u>

Surface water temperatures averaged 5.2 °C throughout the Shumagin Islands survey area (Fig. 2), about a quarter degree lower than last year's average of 5.5 °C. Mean water temperature ranged 0.45 °C between the surface and deepest trawl depth across all hauls (Fig. 3).

<u>Trawl Samples</u>

Biological data and specimens were collected in the Shumagin Islands from eight AWT hauls conducted in midwater (Tables 1, 4; Fig. 1) on backscatter attributed to walleye pollock (Fig. 4). Walleye pollock was the most abundant species caught by weight and numbers in the AWT hauls, contributing 98.5% and 95.7% to the total catch, respectively (Table 5).

The majority of walleye pollock in the Shumagin Islands were between 35 and 45 cm fork length (FL) in 2016, with a predominant length mode at 38 cm FL (Fig. 5). This size range accounted for 93% of the numbers and 90% of the biomass of all pollock observed in this area. The size range is characteristic of age-4 walleye pollock, and suggests the continued success of the 2012 year class (Fig. 6). Smaller fish (< 35 cm FL) made up a very small portion of the biomass (2%), and no pollock were observed less than 25 cm FL. Large adults (≥ 45 cm) also contributed little (8%) to overall biomass in 2016 (Fig. 5).

The maturity composition of males > 40 cm FL (n = 71) was 17% immature, 20% developing, 38% pre-spawning, 24% spawning, and 1% spent (Fig. 7a). The maturity composition of females longer than 40 cm FL (n = 133) was 17% immature, 29% developing, 53% pre-spawning, 0% spawning, and 1% spent (Fig. 7a). Findings from the 1994 Shelikof survey indicated that estimated walleye pollock biomass declined as the proportion of adult females in spawning and spent stages of maturity increased (Wilson 1994). This suggested that substantial emigration of adults from the surveyed area occurred following spawning and resulted in a negative bias to abundance estimates (Wilson 1994). Based on this, the high percentage of pre-spawning females and the low percentage of spawning and spent females in the 2016 Shumagin area suggests that survey timing was likely appropriate. A logistic model fit to the female maturity-at-length data predicted that 50% of females were mature (L_{50}) at 40.95 cm FL (Fig. 7b), which was 8 cm FL lower than that observed in 2015. This may have been due to the dominance of the 2012 year class. The average GSI of pre-spawning females, based on 60 samples, was 0.07 (Fig. 7c). The estimate was lower than recent surveys: 0.09 (2015), 0.13 (2014), 0.11 (2013), 0.13 (2012), 0.11 (2010), and much lower than the historical mean of all surveys between 1994 and 2015 (0.124). This result likely reflects the single, dominant, relatively younger year class of reproductive age. It also may indicate that there could be less reproductive potential per unit biomass of these fish.

Distribution and Abundance

Walleye pollock between 35 and 45 cm FL were present in the inner portion of Shumagin Trough, off Renshaw Point, in Stepovak Bay, and in the West Nagai Strait area (Fig. 8). Although adult pollock > 45 cm FL have historically been detected off Renshaw Point, they were basically absent from this area in 2016. The majority of the pollock were scattered throughout the water column below 25 m (Fig. 9), and occasionally formed small, very dense (i.e., “cherry ball”) schools.

The biomass estimate of 20,706 t is nearly one-third of last year's estimate (61,369) and 26% of the historical mean of 79,351 t for this survey (Table 6; Fig. 10). The relative estimation error of the biomass based on the one-dimensional (1-D) geostatistical analysis was 7.2%.

Sanak Trough

Acoustic backscatter in Sanak Trough was measured along 191 km (103.0 nmi) of transects spaced 3.7 km (2 nmi) apart (Fig. 1). Bottom depths ranged from 45 m at the transect end points to 160 m along the deepest part of the southernmost transects.

Water Temperature

Surface water temperatures in the Sanak Trough survey area averaged 4.7 °C overall (Fig. 2) which was about half a degree cooler than temperatures recorded in 2015 but above the 3.3 °C average for surveys in this area since 2003. Mean water temperature ranged 0.4 °C between the surface and deepest trawl depth across both hauls (Fig. 11).

Trawl Samples

Biological data and specimens were collected in Sanak Trough from two AWT hauls (Tables 1, 4; Fig. 1) on backscatter attributed to walleye pollock (Fig. 4). Walleye pollock and Pacific cod, *Gadus macrocephalus*, were the most abundant species by weight and numbers in AWT hauls, contributing 81.8% and 14.6% by weight, and 90.5% and 2.6% by numbers, respectively (Table 7). Walleye pollock ranged between 24 and 70 cm FL with a dominant length mode between 35 and 45 cm FL (Fig. 5). This mode accounted for 81% of the numbers and 72% of the biomass of all pollock observed in Sanak Trough and likely represents age-4 fish. Pollock > 45 cm (Fig. 5) accounted for 27% of the pollock biomass in this area.

The maturity composition for males > 40 cm FL (n = 37) was 0% immature, 30% developing, 57% pre-spawning, 14% spawning, and 0% spent (Fig. 12a). The maturity composition for females longer than 40 cm FL (n = 31) was 0% immature, 39% developing, 55% pre-spawning, 6% spawning, and 0% spent (Fig. 12a). The fact that none of the females were spent suggests that the timing of the 2016 survey of Sanak Trough was appropriate and likely coincided with the onset of spawning for fish in this area. The logistic model fit to the female maturity-at-length data predicted that 50% of females were mature at 41.15 cm FL (Fig. 12b), considerably lower than 49.3 cm FL in 2015. The average GSI of pre-spawning females was 0.09 (Fig. 12c), lower than the mean of 0.15 for the entire time series. These latter two results likely reflect the dominance of the 2012 year class.

Distribution and Abundance

The majority of walleye pollock biomass was generally located in the eastern portion of the middle of the surveyed Trough (Fig. 8). The majority of the pollock were scattered throughout the water column below 40 m (Fig. 13).

The biomass estimate of 3,556 t is 20% of last year's biomass estimate (17,863 t) and 8% of the historic mean of 43,107 t for this survey (Table 6; Fig. 14). The relative estimation error based on the 1-D geostatistical analysis of the biomass was 6.9%.

Morzhovoi Bay

Acoustic backscatter was measured along 70 km (37.8 nmi) of transects in Morzhovoi Bay. The transects were spaced 3.7 km (2 nmi) apart (Fig. 1), and the depths ranged from about 40-150 m.

Water Temperature

Surface water temperatures in the Morzhovoi Bay survey area averaged 3.9 °C overall (Fig. 2) which was over 2 degrees warmer than temperatures recorded in 2013 and well above the 2.1 °C average for surveys in this area since 2006. Mean water temperature ranged 0.3 °C between the surface and trawl depth (78 m) at the one haul location in Morzhovoi Bay (Table 4).

Trawl Samples

Biological data and specimens were collected in Morzhovoi Bay from one AWT haul (Tables 1, 4; Fig. 1). Except for 3 Pacific cod, walleye pollock was the only species caught, contributing 99.7% by weight and 99.9% by numbers (Table 8). Walleye pollock ranged between 28 and 65 cm FL with a dominant length mode between 35 and 45 cm FL (Fig. 5). This mode accounted for 65% of the numbers and 50% of the biomass of all pollock observed in Morzhovoi Bay and likely represents age-4 fish. More adults larger than 45 cm were observed in Morzhovoi Bay than all other areas surveyed during this cruise (Fig. 8) and accounted for 49% of the pollock biomass in this area.

The maturity composition for males > 40 cm FL (n = 14) was 0% immature, 14% developing, 36% pre-spawning, 29% spawning, and 21% spent (Fig. 15a). The maturity composition for females longer than 40 cm FL (n = 41) was 15% immature, 12% developing, 51% pre-spawning, 15% spawning, and 7% spent (Fig. 15a). The fact that almost a quarter of the measured females were in spawning and spent stages of maturity suggests that the timing of the 2016 survey of Morzhovoi Bay was likely a bit late to coincide with the onset of spawning for fish in this area. The logistic model fit to the female maturity-at-length data predicted that 50% of females were mature at 39.1 cm FL (Fig. 15b). The average GSI of pre-spawning females was 0.10 (Fig. 15c), which is lower than that measured in 2010 and 2013 (0.20 and 0.16, respectively). This result likely reflects the large, relatively younger year class of reproductive age.

Distribution and Abundance

The majority of walleye pollock biomass in Morzhovoi Bay was located in the southern portion of the surveyed area (Fig. 8) and was scattered throughout the water column below 40 m (Fig. 16).

The biomass estimate in Morzhovoi Bay of 11,412 t is comparable to the biomass estimate observed during the first year the Bay was surveyed (2006 = 11,700 t) and 5 times higher than the three estimates generated between 2007 and 2013 (mean = 2,259 t; standard deviation = 397 t; Fig. 14). The relative estimation error based on the 1-D geostatistical analysis of the biomass was 12.0%.

Pavlof Bay

Acoustic backscatter was measured along 84 km (45.2 nmi) of transects in Pavlof Bay. The transects were spaced 3.7 km (2 nmi) apart (Fig. 1), and the depths ranged from about 40-150 m.

Water Temperature

Surface water temperatures in the Pavlof Bay survey area averaged 4.4 °C overall (Fig. 2), and mean water temperature ranged 0.2 °C between the surface and trawl depth (98 m) at the one haul location (Table 4). No temperature data were collected in Pavlof Bay in previous surveys (i.e., in 2002 or 2010).

Trawl Samples

Biological data and specimens were collected in Pavlof Bay from one AWT haul (Tables 1, 4; Fig. 1). Walleye pollock was the most abundant species caught, contributing 99.0% by weight and 97.1% by numbers (Table 9). Walleye pollock ranged between 33 and 67 cm FL with a dominant length mode between 35 and 45 cm FL (Fig. 5). This mode accounted for 78% of the numbers and 66% of the biomass of all pollock observed in Pavlof Bay and likely represents age-4 fish. Adults larger than 45 cm accounted for 33% of the pollock biomass in this area.

The maturity composition for males > 40 cm FL (n = 30) was 0% immature, 10% developing, 40% pre-spawning, 40% spawning, and 10% spent (Fig. 17a). The maturity composition for females longer than 40 cm FL (n = 77) was 8% immature, 12% developing, 61% pre-spawning, 12% spawning, and 8% spent (Fig. 17a). The fact that a fifth of the measured females were in spawning and spent stages of maturity suggests that the timing of the 2016 survey of Pavlof Bay was likely a bit late to coincide with the onset of spawning for fish in this area. The logistic model fit to the female maturity-at-length data predicted that 50% of females were mature at 36 cm FL (Fig. 17b), and the average GSI of pre-spawning females was 0.11 (Fig. 17c). No biological data were collected in Pavlof Bay in previous surveys (i.e., in 2002 or 2010).

Distribution and Abundance

The majority of walleye pollock biomass in the surveyed area of Pavlof Bay was generally located in the mouth of the Bay (Fig. 8) and was scattered throughout the water column below 60 m (Fig. 18). Significant densities of echosign believed to be pollock were observed off Black Point (farther north in the Bay) in 2002, and minimal backscatter was measured throughout Pavlof Bay in 2010.

The biomass estimate of Pavlof Bay is 2,130 t. A survey of Pavlof Bay was also conducted in 2002 and 2010, but an equipment malfunction and inclement weather, respectively, prevented trawling. The relative estimation error based on the 1-D geostatistical analysis of the biomass was 14.7%.

Shelikof Strait

Acoustic backscatter was measured along 1,496 km (808 nmi) of transects spaced 13.9 km (7.5 nmi) apart (Fig. 19). Bottom depths in the survey area ranged from 45 to 335 m.

<u>Water Temperature</u>

Surface water temperatures in Shelikof Strait averaged 5.6 °C overall (Fig. 20), 0.7 degrees higher than last year and 1.9 °C higher than the historic mean of the prior 33 surveys conducted in this area since 1981. Mean water temperature ranged 0.6 °C between the surface and deepest trawl depth across all hauls (Fig. 21).

<u>Trawl Samples</u>

Biological data and specimens were collected in the Shelikof Strait area from 19 AWT hauls (Tables 2, 10; Fig. 19) on backscatter attributed to walleye pollock (Fig. 22). Walleye pollock and eulachon, *Thaleichthys pacificus*, were the most abundant species by weight and numbers in AWT hauls, contributing 98.4% and 1.2% by weight, and 83.0% and 14.0% by numbers, respectively (Table 11). However, eulachon were less prevalent than in previous years when they contributed up to 47% of the total catch by weight (i.e., in 2008).

The majority of walleye pollock in the Shelikof Strait were between 35 and 45 cm FL (Fig. 23). This size range accounted for 90% of the numbers and 88% of the biomass of all pollock observed in this area (Fig. 24). This size range indicates the continued success of the 2012 year class (Tables 12-13, Fig. 25). Smaller fish (< 35 cm FL) made up a very small portion of the biomass (3%), and no pollock less than 22 cm FL were observed. Large adults (≥ 45 cm) also contributed little (9%) to overall biomass in 2016 (Fig. 23).

The maturity composition in the Shelikof Strait area for males longer than 40 cm FL (n = 237) was 4% immature, 3% developing, 12% pre-spawning, 80% spawning, and 2% spent (Fig. 26a). The maturity composition of females longer than 40 cm FL (n = 259) was 10% immature, 14% developing, 64% pre-spawning, 5% spawning, and 5% spent (Fig. 26a). The small fraction of spawning and spent females relative to pre-spawning females suggests that the survey was reasonably well-timed to coincide with the onset of spawning for the majority of fish that spawn in Shelikof. The female L_{50} of 38.9 cm FL (n = 2,166; Fig. 26b) was much smaller than the two previous years (44.3 and 47.2 cm FL in 2015 and 2014, respectively). The average GSI from 224 pre-spawning females was 0.11 (Fig. 26c) and was less than that observed the previous year (0.13) and less than the historical mean (0.14). These latter two results likely reflect the dominance of the 2012 year class.

Distribution and Abundance

Walleye pollock biomass was observed throughout the surveyed area and was most abundant in the north-central part of the surveyed area (Fig. 24) between 75 and 250 m (Fig. 27). Dense midwater pollock aggregations of 35-45 cm FL pollock were encountered throughout the survey area. However, near bottom aggregations observed on the western half of the central Strait had a higher proportion of larger fish (46-65 cm FL), and dense near surface (30-40 m depth) backscatter observed in the southern half of the surveyed area consisted of slightly smaller fish (30-40 cm FL). Spawning aggregations historically observed in the northwestern part of the Strait were not seen in 2016, which is in contrast to previous years.

The Shelikof Strait biomass estimate of 665,059 t is 79% of that observed in 2015 and very similar to the historic mean of 665,487 t (Table 6; Fig. 28). It is 37% higher than the mean of 486,391 t observed since 1992 (Table 6, Fig. 28). The relative estimation error of the biomass based on the 1-D geostatistical analysis was 6.5%.

The progression of the strong 2012 year class is clearly visible in the time series of both biomass and numbers of fish in the survey area beginning in 2013 (Fig. 25). The size of the 2012 year class as 4-year-olds is over 6 times the historical mean for this age group. Additionally, 2016 saw the highest number and biomass of age-4 fish detected since 1981 (Tables 14-15). McKelvey (1996) showed that there was a strong relationship between the estimated number of age-1 fish form the Shelikof Strait AT survey and year-class strength for GOA pollock. The 2012 year class is considered high in the context of the McKelvey index.

Marmot Bay

Acoustic backscatter was measured along 139 km (75 nmi) of transects spaced 3.7 km (2.0 nmi) apart in the Spruce Island Gully and inner Marmot Bay (Fig. 29). Weather and time available prevented a thorough survey of the outer Marmot Bay area. Thus, acoustic data in the outer Bay were collected along 43 km (23 nmi) of zig-zag trackline (Fig. 29). Bottom depths ranged from 70 to 275 m.

Water Temperature

Surface water temperatures averaged 5.7 °C throughout the Marmot Bay survey area (Fig. 30), about a half degree warmer than last year's mean of 5.2 °C. Mean water temperature ranged 0.2 °C between the surface and deepest trawl depth across all hauls (Fig. 31).

Trawl Samples

Biological data and specimens were collected in Marmot Bay from three AWT hauls and one CamTrawl-only (i.e., open codend) haul on very dense backscatter which was aggregated in two layers (Table 10, Figs. 29, 32). Walleye pollock and eulachon were the most abundant species by weight and numbers in AWT hauls, contributing 98.0% and 0.9% by weight, and 76.0% and 22.0% by numbers, respectively (Table 16). However, eulachon were less prevalent than in previous years (e.g., 56% of the total catch by numbers in 2015).

Walleye pollock ranged from 24 to 66 cm FL with a clear mode centered at 40 cm and extending between 35 and 45 cm FL (Fig. 23). This size range accounted for 77% of the numbers and 65% of the biomass of all pollock observed in this area. Smaller fish (< 35 cm FL) made up a very small portion of the biomass (2%). For the second year in a row, there were no age-1 pollock seen in Marmot Bay. Large adults (≥ 45 cm) in Marmot contributed 32% to the overall biomass (Fig. 23).

The maturity composition in Marmot Bay for males > 40 cm FL (n = 66) was 0% immature, 0% developing, 0% pre-spawning, 91% spawning, and 9% spent (Fig. 34a). The maturity composition of females > 40 cm FL (n = 108) was 0% immature, 6% developing, 35% pre-spawning, 28% spawning, and 31% spent (Fig. 33a). The fact that almost 60% of the measured females were in spawning and spent stages of maturity suggests that the timing of the 2016 survey of Marmot Bay was likely late. The female L_{50} was 37 cm FL (Fig. 33b), which was 5.5 cm smaller than last year and 9 cm smaller than 2014. This may have been due to the dominance of the 2012 year class. The average GSI for pre-spawning females was 0.11, which was the same as in 2015, and was slightly below the historical mean (Fig. 33c).

Distribution and Abundance

The majority of the pollock biomass occurred in aggregations in the inner Bay north of Spruce Island and in Spruce Gully (Fig. 34). These aggregations were scattered throughout the water column below about 30 m depth (Fig. 35).

The biomass estimate for Marmot Bay was 37,161 t (Table 6). This estimate is the highest in the history of the Marmot survey and 24,481 t higher than the historic mean for this survey (12,680 t, Fig. 36). The relative estimation error of the biomass in the inner Bay based on the 1-D geostatistical analysis was 9.9%, and the relative estimation error of the biomass in the outer Bay based on the 2-D geostatistical analysis was 17.9%.

Nearest Haul Sensitivity Analysis

A sensitivity analysis investigated the effect of estimating pollock abundance in Shelikof Strait and Marmot Bay by replacing the subjective trawl assignments with size compositions from the geographically nearest trawl (e.g., De Robertis et al. 2016). That is, the survey abundance estimates described above were calculated by constructing length strata based on similarities in fish length compositions from the trawl catches, and then assigning the strata to portions of the backscatter based on fish aggregation behavior and depth distribution (i.e., the “traditional approach”). Whereas the nearest haul sensitivity assigns length information from the nearest haul to the backscatter, irrespective of length distributions in the trawl catches, aggregation behavior, and depth distribution. A similar analysis was not conducted for DY2016-02, because of the low numbers of hauls within the various geographically separate Troughs and Bays.

Differences between the traditional and nearest haul approaches were negligible for pollock abundance (- 0.6%) and biomass (+ 0.3%) estimates in Shelikof Strait (19 trawl hauls) compared to the traditional approach (Fig. 37). These low differences could reflect the dominance of the 2012 year class, which produced relatively similar length strata. The nearest haul approach produced higher abundance (+7.2%) and biomass (+7.6%) estimates in Marmot Bay (3 trawl hauls), notably with the observance of more fish in the 38-43 cm FL range (Fig. 37). Differences in abundance and biomass likely reflect the area of high backscatter north of Spruce Island

(Fig. 32) being largely assigned to length compositions caught in haul 22 (Fig. 29) in the nearest haul approach versus being assigned to an average of length compositions caught in all trawls (i.e., only 1 length stratum was used) in the traditional approach.

Proportional Allocation of the Biomass by Species

As in all prior surveys of these areas, biomass estimates generated for areas surveyed during winter 2016 assumed that backscatter measured within each length stratum and assigned to walleye pollock contained 100% pollock. In other words, the acoustic contributions from other species within the trawl catches were assumed to be zero. This, however, is often not the case. For example, during the 2016 winter AT surveys, Pacific cod made up almost 15% of the total weight of species caught in Sanak Trough, and eulachon made up 14% and 22% of total numbers of fish caught in the trawls in Shelikof Strait and Marmot Bay, respectively.

To fully evaluate the acoustic contributions of these other species, a second abundance analysis was conducted in which a fraction of the backscatter was allocated between walleye pollock and non-pollock catch (De Robertis et al. 2016); that is, the "proportional allocation approach". A series of five TS relationships from the literature were used to estimate the acoustic scattering in the trawl catches for non-pollock specimens: fishes with swim bladders, fishes without swim bladders, jellyfish, squid, and pelagic crustaceans (Table 17, Fig. 38). Because both Pacific cod and eulachon contributed more than 5% of the catch in an area (i.e., Sanak Trough and Shelikof and Marmot Bays, respectively) by weight or numbers, a more specific TS relationship was used for these two species. That is, the TS-to-length relationship of walleye pollock (Traynor 1996) was used for Pacific cod, also a gadiid:

$$TS = 20 \log_{10} L - 66, \qquad \text{Eqn (12)}$$

and the TS-to-length relationship developed by Gauthier and Horne (2004) with a fixed slope of 20 was used for eulachon:

$$TS = 20 \log_{10} L - 84.5, \qquad \text{Eqn (13)}$$

where L is the fork length in centimeters.

The number of individuals of a given species and length class ($N_{s,l}$) that would be expected from an unselective sampler was estimated within a trawl from the observed catch and the estimated selectivity,

$$N_{s,l} = \frac{C_{s,l}}{S_{s,l}}, \qquad \text{Eqn (14)}$$

where $C_{s,l}$ is the catch of species s in the 1 cm length class l, and $S_{s,l}$ is the selectivity. $S_{s,l}$ was set to = 1. $N_{s,l}$ was calculated for each trawl and then converted to a proportion ($P_{s.l}$),

$$P_{s,l} = \frac{N_{s.l}}{\sum_{s,l} N_{s.l}}, \text{ where } \sum_{s.l} P_{s,l} = 1. \qquad \text{Eqn (15)}$$

The $P_{s.l}$ s were averaged within a length stratum q ($P_{s,l,q}$),

$$P_{s,l,q} = \frac{\sum_1^t P_{s,l}}{t}, \qquad \text{Eqn (16)}$$

where t is the total number of trawls within length stratum q.

The mean backscattering cross section (a measure of acoustic scattering in m^2 – MacLennan et al., 2002) of species s of size class l is

$$\sigma_{bs_{s,l}} = 10^{(0.1 \cdot TS_{s,l})}, \qquad \text{Eqn (17)}$$

where TS is the target strength (dB re m^2) computed using the relationships in Table 17 and in equations 12-13.

The proportion of backscatter (PB) from species s of size class l in length stratum q is computed from the proportion ($P_{s,l,q}$) of individuals of species s and size class l estimated from length stratum q and their backscattering cross section,

$$PB_{s,l,q} = \frac{P_{s,l,q} \cdot \sigma_{bs_{s,l}}}{\sum_{s,l} P_{s,l,q} \cdot \sigma_{bs_{s,l}}} \, . \qquad \text{Eqn (18)}$$

The measured nautical area backscattering coefficient (s_A) at location i (where length stratum q is assigned to represent the species composition) was allocated to species and size as follows:

$$s_{A_{s,l,i}} = s_{A_i} \cdot PB_{s,l,q} \, . \qquad \text{Eqn (19)}$$

Results of the proportional allocation approach indicate that the potential uncertainties introduced by backscatter from other species during the winter GOA 2016 surveys are likely quite small. For the first cruise (DY2016-02), the walleye pollock biomass estimate in the Shumagin area decreased from 20,706 t to 20,629 t, and the walleye pollock biomass estimate in Sanak Trough decreased from 3,556 t to 3,436 t when acoustic contributions from other species were also considered. That is, backscatter from non-pollock species was estimated to account for 0.4% and 3.4% of the original (i.e., “traditional”) pollock biomass estimate for the Shumagin area and Sanak Trough, respectively. Similarly, the walleye pollock biomass estimate in Morzhovoi Bay decreased from 11,412 t to 11,399 t, and the walleye pollock biomass estimate in Pavlof Bay decreased from 2,130 t to 2,122 t when acoustic contributions from other species were also considered. That is, backscatter from non-pollock species was estimated to account for < 0.1% of the original (i.e., “traditional”) pollock biomass estimate for both areas.

Potential uncertainties introduced by backscatter from other species during the second winter cruise (DY2016-04) are also likely quite small. The walleye pollock biomass estimates in Shelikof Strait and Marmot Bay were decreased from 665,059 t to 663,659 t and from 37,931 t to 37,781 t, respectively, when acoustic contributions from other species were also considered. That is, non-pollock species were estimated to account for 0.2% of the original (i.e., “traditional”) pollock biomass estimate for Shelikof Strait and 0.4% of the original (i.e., “traditional”) pollock biomass estimate for Marmot Bay. In all areas surveyed during the winter GOA survey, the differences in the pollock biomass estimates when estimates of species mixtures are considered fall within the relative estimation errors for the respective areas (Table 6).

Pollock Length and Weight at Age

Walleye pollock caught and measured during the 2016 winter surveys (n = 3,006) in the Gulf of Alaska were within the length and weight range of pollock sampled in previous winter surveys since 2003 (n = 10,300). However, the mean weight at length of pollock caught in winter 2016 was slightly less than those from previous surveys (Fig. 39). Most pollock (91% by number) observed during winter 2016 were between 34 and 43 cm FL, and weighed an average of 50 g less (29% less) compared to similarly sized fish observed during 2003-2015.

Special Projects

Several collections of specimens were made to support studies by other investigators. Ovaries were collected from pre-spawning walleye pollock to investigate interannual variation in fecundity of mature females (contact Sandi Neidetcher for more information: Sandi.Neidetcher@noaa.gov). Ovaries were also collected from female walleye pollock of all maturity stages for a histological study (contact Martin Dorn for more information: Martin.Dorn@noaa.gov). Walleye pollock, Pacific cod, arrowtooth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), several species of rockfishes, and *Myoxocephalus* spp. (sculpins in the family Cottidae) stomachs were collected in support of a winter food habits study (contact Troy Buckley for more information: Troy.Buckley@noaa.gov). Fin clips were collected from spawning or near-spawning Pacific cod in the Shumagins to use as genetic baseline data for a proposed study (contact Mike Canino for more information: Mike.Canino@noaa.gov). Spawning walleye pollock were collected and spawned, and the fertilized eggs were transported to Seattle to examine genomic evidence of localized adaptation and for developing a model to estimate the growth of walleye pollock larvae (contact Steve Porter for more information: Steve.Porter@noaa.gov). Results for all special projects will be reported elsewhere.

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TABLES AND FIGURES

APPENDIX I. ITINERARY

DY2016-02

Shumagin Islands\Sanak Trough\Morzhovoi Bay\Pavlof Bay

11 Feb.	Depart Kodiak, AK.
11-12 Feb.	Acoustic sphere calibration in Kalsin Bay, Kodiak Island, AK.
13-15 Feb.	Acoustic-trawl survey of Shumagin Islands.
16 Feb.	Acoustic-trawl survey of Sanak Trough.
16-17 Feb.	Acoustic-trawl survey of Morzhovoi Bay.
17 Feb.	Acoustic-trawl survey of Pavlof Bay.
18 Feb.	Additional haul in Unga Strait.
20 Feb.	Arrive Kodiak, AK. End cruise.

DY2016-04

Shelikof Strait\Marmot Bay

14 Mar.	Depart Kodiak, AK.
14-17 Mar.	Acoustic-trawl survey of Shelikof Strait.
18 Mar.	Acoustic sphere calibration in Alitak Bay, Kodiak Island, AK.
19-21 Mar.	Resume and complete acoustic trawl survey of Shelikof Strait.
22-24 Mar.	Acoustic-trawl survey of Marmot Bay.
24 Mar.	Arrive Kodiak, AK. End cruise.

APPENDIX II. SCIENTIFIC PERSONNEL

DY2016-02

Shumagin Islands\Sanak Trough\Morzhovoi Bay\Pavlof Bay

Name	Position	Organization
Taina Honkalehto	Chief Scientist	AFSC-RACE
Kresimir Williams	Fishery Biologist	AFSC-RACE
Scott Furnish	Computer Spec.	AFSC-RACE
Nathan Lauffenburger	Fishery Biologist	AFSC-RACE
Robert Levine	Fishery Biologist	AFSC-RACE
Heather Kenney	Fishery Biologist	AFSC-RACE
Claire Armistead	Fishery Biologist	AFSC-RACE

DY2014-04

Shelikof Strait\Marmot Bay

Name	Position	Organization
Patrick Ressler	Chief Scientist	AFSC-RACE
Darin Jones	Fishery Biologist	AFSC-RACE
Scott Furnish	Computer Spec.	AFSC-RACE
Robert Levine	Fishery Biologist	AFSC-RACE
Matthew Phillips	Fishery Biologist	AFSC- FMA
Annette Dougherty	Fishery Biologist	AFSC-RACE
Wes Strasburger	Fishery Biologist	AFSC-ABL
Kim Sawyer	Fishery Biologist	UW
Virginia Warren	Teacher at Sea	NOAA

AFSC – Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA

RACE – Resource Assessment and Conservation Engineering Division

FMA – Fisheries Monitoring and Analysis Division

ABL – Auke Bay Laboratories

UW – University of Washington, Seattle, WA

NOAA –National Oceanic and Atmospheric Administration

Table 1. -- Numbers of walleye pollock measured and biological samples collected during the winter 2016 acoustic-trawl surveys of Shumagin Islands (hauls 1-7 and 12), Sanak Trough (hauls 8-9), Morzhovoi Bay (haul 10), and Pavlof Bay (haul 11).

	Walleye pollock					
Haul no.	Catch lengths	CamTrawl lengths	Weights	Maturities	Otoliths	Ovary weights
1	328	9	53	53	24	-
2	403	121	89	89	25	-
3	346	239	58	56	30	-
4	311	171	56	56	30	-
5	386	179	91	91	25	-
6	293	300	61	61	25	-
7	306	157	55	55	30	-
8	387	72	83	83	30	27
9	470	84	44	44	30	2
10	420	301	91	91	30	26
11	431	74	89	89	50	35
12	618	69	89	89	-	60
Totals	4,699	1,776	859	857	329	150

Table 2. -- Numbers of walleye pollock measured and biological samples collected during the winter 2016 acoustic-trawl surveys of Shelikof Strait (hauls 1-19) and Marmot Bay (hauls 20-23).

	Walleye pollock					
Haul no.	Catch lengths	CamTrawl lengths	Weights	Maturities	Otoliths	Ovary weights
1	640	588	98	98	40	26
2	471	255	124	124	40	6
3	458	232	117	117	36	6
4	358	155	82	71	31	16
5	365	251	93	93	30	22
6	518	229	107	107	23	4
7	571	252	125	125	45	1
8	372	185	71	71	22	15
9	362	267	99	99	30	29
10	421	225	104	104	31	6
11	459	217	100	100	30	20
12	420	117	88	88	30	17
13	444	234	85	85	35	2
14	484	134	106	106	33	15
15	396	277	72	72	30	5
16	420	221	126	126	32	35
17	454	276	77	77	27	1
18	388	218	70	70	30	1
19	404	509	95	95	35	1
20	426	158	123	123	55	27
21	406	109	108	108	47	7
22	---[1]	637	---[1]	---[1]	---[1]	---[1]
23	292	233	79	79	53	11
Totals	9,529	5,979	2,149	2,138	765	273

[1] CamTrawl haul, in which the codend was left open, provides species identification and fish length estimates.

Table 3. -- Simrad ER60 38 kHz acoustic system description and settings used during the winter 2016 Gulf of Alaska acoustic-trawl surveys of walleye pollock. Also presented are results from standard sphere acoustic system calibrations conducted in association with the survey, and final values used to calculate biomass and abundance data.

	Winter 2016 system settings	11 Feb Kalsin Bay Alaska	18 Mar Alitak Bay Alaska	Final analysis parameters
Echosounder	Simrad ER60	--	--	Simrad ER60
Transducer	ES38B	--	--	ES38B
Frequency (kHz)	38	--	--	38
Transducer depth (m)	9.15	--	--	9.15
Pulse length (ms)	1.024	--	--	1.024
Transmitted power (W)	2000	--	--	2000
Angle sensitivity along	22.83	--	--	22.83
Angle sensitivity athwart	21.43	--	--	21.43
2-way beam angle (dB re 1 steradian)	-20.77	--	--	-20.77
Gain (dB)	22.56	22.56	22.59	22.58
Sa correction (dB)	-0.64	-0.64	-0.64	-0.64
Integration gain (dB)	21.92	21.92	21.95	21.94
3 dB beamwidth along	6.82	6.82	6.77	6.80
3 dB beamwidth athwart	7.24	7.24	7.17	7.21
Angle offset along	-0.03	-0.03	-0.05	-0.04
Angle offset athwart	-0.03	-0.03	-0.08	-0.06
Post-processing S_v threshold (dB re 1 m^{-1})	-70	--	--	-70
Standard sphere TS (dB re 1 m^2)	--	-42.19	-42.12	--
Sphere range from transducer (m)	--	20.72	21.87	--
Absorption coefficient (dB/m)	0.0099	0.0097	0.0097	0.0099
Sound velocity (m/s)	1466	1468.2	1466.6	1466
Water temp at transducer (°C)	--	5.3	5.0	--

Note: Gain and beam pattern terms are defined in the Operator Manual for Simrad ER60 Scientific echosounder application, which is available from Simrad Strandpromenaden 50, Box 111, N-3191 Horten, Norway.

Table 4. -- Trawl station and catch data summary from the winter 2016 acoustic-trawl survey of walleye pollock in Shumagins Islands, Sanak Trough, Morzhovoi Bay, and Pavlof Bay.

Haul			Date	Time	Duration	Start position		Depth (m)		Water temp. (^oC)		Catch			
												Pollock		Eulachon	Other
No.	Area	Gear type[1]	(GMT)	(GMT)	(minutes)	Latitude (N)	Longitude (W)	Footrope	Bottom	Headrope	Surface[2]	(kg)	Number	(kg)	(kg)
1	Shumagins	AWT	13-Feb	23:13:09	36	55.50	-159.26	---[3]	131	---[3]	---[3]	516.8	1263	0.1	22.8
2	Shumagins	AWT	14-Feb	6:02:52	22	55.53	-159.75	120	165	5.5	5.2	597.6	1372	1.2	33.2
3	Shumagins	AWT	14-Feb	15:16:42	27	55.64	-159.79	80	134	5.5	5.0	1421.2	3315	1.8	10.3
4	Shumagins	AWT	14-Feb	23:09:25	1	55.58	-160.24	123	188	5.5	5.3	1192.8	2579	0.0	2.0
5	Shumagins	AWT	15-Feb	3:29:33	21	55.52	-160.33	135	167	5.6	5.1	614.8	1320	0.4	1.0
6	Shumagins	AWT	15-Feb	8:38:24	20	55.43	-160.54	87	134	5.3	5.0	792.2	1836	0.2	11.0
7	Shumagins	AWT	15-Feb	12:41:44	4	55.32	-160.19	103	202	5.5	5.4	747.4	1639	1.1	4.9
8	Sanak	AWT	16-Feb	8:41:03	9	54.60	-162.48	100	133	5.2	4.9	207.0	387	0.0	14.0
9	Sanak	AWT	16-Feb	15:06:37	23	54.71	-162.57	108	120	5.0	4.8	391.8	842	0.1	108.5
10	Morzhovoi	AWT	16-Feb	23:11:30	15	54.85	-163.10	78	96	4.5	4.2	2303.7	3878	0.0	2.6
11	Pavlof	AWT	17-Feb	15:47:20	24	55.24	-161.76	98	108	4.8	4.6	567.2	1049	0.2	20.0
12	Shumagins	AWT	18-Feb	13:31:34	4	55.29	-160.18	108	194	5.4	5.3	457.4	1161	0.2	7.0

[1]Gear type: AWT = Aleutian wing trawl.

[2]Average temperature between 1-5 m from SBE readings.

[3]Gear depth and water temperature data were not collected on this haul.

Table 5. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the eight Aleutian Wing midwater trawl hauls during the winter 2016 acoustic-trawl survey of walleye pollock in the Shumagin Islands.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	6,340.2	98.5	14,484	95.7	2,991	552
Pacific cod	*Gadus macrocephalus*	60.5	0.9	13	0.1	13	13
northern sea nettle	*Chrysaora melanaster*	16.4	0.3	17	0.1	13	13
moon jellyfish	*Aurelia* sp.	5.7	0.1	35	0.2	17	12
black rockfish	*Sebastes melanops*	5.5	0.1	3	0.0	3	3
eulachon	*Thaleichthys pacificus*	3.9	0.1	551	3.6	127	135
flathead sole	*Hippoglossoides elassodon*	2.5	0.0	12	0.1	12	12
hydrozoans	*Aequorea* spp.	1.5	0.0	6	0.0	6	6
arrowtooth flounder	*Atheresthes stomias*	0.2	0.0	1	0.0	1	1
sturgeon poacher	*Podothecus acipenserinus*	0.1	0.0	1	0.0	1	1
squid unident.	Teuthoidea (order)	0.0	0.0	3	0.0	3	3
shrimp unident.	Decapoda (order)	0.0	0.0	1	0.0	1	1
Total		6,436.4		15,128		3,188	752

Table 6. -- Estimates of walleye pollock biomass (in metric tons) and relative estimation error for the Shelikof Strait, Shumagin Islands, Sanak Trough, and Marmot Bay acoustic-trawl surveys.

Year	Shelikof Strait		Shumagin Islands		Chirikof shelf break		Sanak Trough		Marmot Bay	
	Biomass	Est. error	Biomass	Est. error	Biomass	Est. error	Biomass	Est. error	Biomass	Est. error
1981	2,785,800									
1982	no survey									
1983	2,278,200									
1984	1,757,200									
1985	1,175,300									
1986	585,800									
1987	no estimate [1]									
1988	301,700									
1989	290,500								2,400	no est.
1990	374,700								no estimate	--
1991	380,300								no survey	--
1992	713,400	3.6%							no estimate	--
1993	435,800	4.6%							no survey	--
1994	492,600	4.5%	112,000 [2]						no survey	--
1995	763,600	4.5%	290,100						no survey	--
1996	777,200	3.7%	117,700 [3]						no survey	--
1997	583,000	3.7%	no survey						no survey	--
1998	504,800	3.8%	no survey						no survey	--
1999	no survey	--	no survey						no survey	--
2000	448,600	4.6%	no survey						no survey	--
2001	432,800	4.5%	119,600						no survey	--
2002	256,700	6.9%	135,600	27.1%	82,100	12.2%			no survey	--
2003	316,500	5.2%	67,700	17.2%	30,900	20.7%	80,500	21.6%	no survey	--
2004	326,800	9.2%	no survey	--	30,400	20.4%	no survey	--	no survey	--
2005	356,100	4.1%	52,000	11.4%	77,000	20.7%	65,500	7.4%	no survey	--
2006	293,600	4.0%	37,300	10.1%	69,000	11.0%	127,200	10.4%	no survey	--
2007	180,900	5.8%	20,000	8.6%	36,600	6.7%	60,300	5.7%	3,600	5.0%
2008	208,000	5.6%	30,600	9.8%	22,100	9.6%	19,800	6.7%	no survey	--
2009	266,000	5.9%	63,300	10.8%	400	32.3%	31,400	17.4%	19,800	no est.
2010	429,700	2.6%	18,200	11.6%	9,300	15.0%	26,700	11.6%	5,600	no est.
2011	no survey	--	no survey	--	no survey	--	no survey	--	no survey	--
2012	335,800	7.9%	15,500	5.2%	21,200	16.4%	24,300	15.6%	no survey	--
2013	891,261	5.3%	91,300	17.3%	63,000	31.4%	13,300	5.1%	19,900	4.1%
2014	842,138	4.7%	37,346	18.2%	no survey	--	7,319	9.0%	14,992	9.4%
2015	845,306	4.3%	61,369	17.1%	12,685	14.2%	17,863	10.0%	22,470	3.1%
2016	**665,059**	**6.5%**	**20,706**	**7.2%**	no survey	--	**3,556**	**6.9%**	**37,161**	**9.9%** [4]

[1]Shelikof Strait surveyed in 1987, but no estimate was made due to an equipment malfunction.

[2]Survey conducted after peak spawning had occurred.

[3]Partial survey.

[4]Only includes the 1-D estimation of error for biomass within the inner bay.

Table 7. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the two Aleutian Wing midwater trawl hauls during the winter 2016 acoustic-trawl survey of walleye pollock in Sanak Trough.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	598.8	81.8	1,229	90.5	857	127
Pacific cod	*Gadus macrocephalus*	106.8	14.6	35	2.6	35	35
southern rock sole	*Lepidopsetta bilineata*	15.8	2.2	56	4.1	35	35
flathead sole	*Hippoglossoides elassodon*	4.5	0.6	16	1.2	16	16
northern sea nettle	*Chrysaora melanaster*	3.1	0.4	3	0.2	3	3
rock sole sp.	*Lepidopsetta* sp.	2.2	0.3	5	0.4	5	5
arrowtooth flounder	*Atheresthes stomias*	0.3	0.0	2	0.1	2	2
hydrozoans	*Aequorea* spp.	0.3	0.0	5	0.4	5	5
eulachon	*Thaleichthys pacificus*	0.1	0.0	6	0.4	6	6
Pacific herring	*Clupea pallasi*	0.1	0.0	1	0.1	1	1
Total		731.9		1,358		965	235

Table 8. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the one Aleutian Wing midwater trawl haul during the winter 2016 acoustic trawl survey of walleye pollock in Morzhovoi Bay.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	2,303.7	99.7	3,878	99.9	420	91
Pacific cod	*Gadus macrocephalus*	6.2	0.3	3	0.1	1	1
Total		2,309.9		3,880		421	92

Table 9. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the one Aleutian Wing midwater trawl haul during the winter 2016 acoustic-trawl survey of walleye pollock in Pavlof Bay.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	567.2	99.0	1,049	97.1	431	89
Chinook salmon	*Oncorhynchus tshawytscha*	1.8	0.3	2	0.2	2	2
Pacific cod	*Gadus macrocephalus*	1.5	0.3	1	0.1	1	1
southern rock sole	*Lepidopsetta bilineata*	1.3	0.2	2	0.2	2	2
flathead sole	*Hippoglossoides elassodon*	0.5	0.1	1	0.1	1	1
sturgeon poacher	*Podothecus acipenserinus*	0.4	0.1	4	0.4	4	4
eulachon	*Thaleichthys pacificus*	0.2	0.0	11	1.0	11	11
Pacific herring	*Clupea pallasi*	0.2	0.0	5	0.5	5	5
jellyfish unident.	Cnidaria (phylum)	0.0	0.0	4	0.4	4	4
shrimp unident.	Decapoda (order)	0.0	0.0	1	0.1	1	1
Total		573.0		1,080		462	120

Table 10. --Trawl station and catch data summary from the winter 2016 acoustic-trawl survey of walleye pollock in Shelikof Strait and Marmot Bay.

Haul			Date	Time	Duration	Start position		Depth (m)		Water temp. (°C)		Catch			
												Pollock		Eulachon	Other
No.	Area	Gear type[1]	(GMT)	(GMT)	(minutes)	Latitude (N)	Longitude (W)	Footrope	Bottom	Headrope	Surface[2]	(kg)	Number	(kg)	(kg)
1	Shelikof	AWT	14-Mar	18:03:29	18	58.24	-153.32	176	216	6.4	6.1	2,591.5	6,081	55.2	5.0
2	Shelikof	AWT	15-Mar	1:03:20	8	58.20	-153.64	95	189	6.5	6.3	442.1	1,069	2.0	3.0
3	Shelikof	AWT	15-Mar	8:23:39	7	57.95	-153.82	133	214	6.4	6.2	688.0	1,489	30.0	5.0
4	Shelikof	AWT	15-Mar	15:53:20	48	57.95	-154.61	242	261	6.4	5.2	682.1	1,135	57.4	12.0
5	Shelikof	AWT	15-Mar	20:26:40	5	57.80	-154.18	96	227	6.3	6.1	554.9	1,448	0.0	3.0
6	Shelikof	AWT	16-Mar	1:37:56	21	57.86	-154.87	246	270	6.3	5.3	719.7	1,449	103.0	12.0
7	Shelikof	AWT	16-Mar	6:06:47	13	57.67	-154.69	189	217	6.3	6.2	1,801.4	4,268	285.7	4.8
8	Shelikof	AWT	16-Mar	14:18:41	18	57.58	-155.26	239	278	6.3	5.9	621.1	1,334	82.3	20.0
9	Shelikof	AWT	16-Mar	17:41:18	1	57.41	-154.82	75	136	6.0	5.8	522.1	1,349	0.0	2.0
10	Shelikof	AWT	17-Mar	1:00:57	8	57.34	-155.33	236	248	6.1	5.4	783.3	1,853	1,829.9	307.7
11	Shelikof	AWT	17-Mar	4:04:14	28	57.28	-154.95	43	177	5.4	5.5	375.4	1,113	39.2	31.0
12	Shelikof	AWT	17-Mar	11:52:58	9	57.16	-155.83	236	269	6.0	5.6	1,488.9	3,542	368.0	5.6
13	Shelikof	AWT	19-Mar	8:49:57	14	56.79	-155.27	56	182	6.0	5.8	1,063.9	3,252	3.0	3.0
14	Shelikof	AWT	19-Mar	12:59:30	9	56.72	-155.67	233	258	6.1	5.7	930.0	2,231	1,724.2	849.0
15	Shelikof	AWT	19-Mar	22:22:59	12	56.58	-155.56	55	146	5.9	5.7	392.3	1,136	0.0	6.0
16	Shelikof	AWT	20-Mar	8:15:03	8	56.43	-156.19	244	269	6.2	5.5	590.5	1,296	689.9	24.0
17	Shelikof	AWT	20-Mar	17:58:05	7	56.10	-156.00	72	176	6.0	5.6	926.4	2,827	5.0	3.0
18	Shelikof	AWT	20-Mar	23:48:33	4	55.90	-156.38	65	234	5.9	5.7	933.4	2,549	0.0	2.0
19	Shelikof	AWT	21-Mar	4:37:00	8	55.78	-156.35	236	246	6.4	5.7	695.7	1,906	1,709.8	169.8
20	Marmot	AWT	22-Mar	21:08:52	3	57.98	-152.29	226	280	5.9	5.7	1,450.0	2,748	502.1	7.0
21	Marmot	AWT	23-Mar	3:39:43	10	58.06	-152.39	182	224	6.0	5.8	345.7	751	282.0	34.0
22	Marmot	CamTrawl	23-Mar	5:41:12	40	58.06	-152.43	151	211	5.9	5.8	---[3]	---[3]	---[3]	---[3]
23	Marmot	AWT	23-Mar	11:27:40	9	58.00	-152.54	170	199	5.9	5.7	617.8	1,140	556.8	80.6

[1]Gear type: AWT = Aleutian wing trawl.

[2]Average temperature between 1-5 m from SBE readings.

[3]Codend left open: CamTrawl provides species identification and fish length estimates.

Table 11. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the 19 Aleutian Wing midwater trawl hauls during the winter 2016 acoustic-trawl survey of walleye pollock in Shelikof Strait.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	16,802.8	98.4	41,328	83.0	8,405	1,839
eulachon	*Thaleichthys pacificus*	203.4	1.2	6,985	14.0	320	250
northern sea nettle	*Chrysaora melanaster*	29.2	0.2	42	0.1	42	42
Chinook salmon	*Oncorhynchus tshawytscha*	6.1	0.0	7	0.0	7	7
magistrate armhook squid	*Berrytheuthis magister*	4.8	0.0	17	0.0	17	16
Pacific herring	*Clupea pallasi*	3.2	0.0	23	0.0	22	22
Pacific cod	*Gadus macrocephalus*	3.0	0.0	2	0.0	2	2
northern smoothtongue	*Leuroglossus schmidti*	2.6	0.0	437	0.9	43	33
arrowtooth flounder	*Atheresthes stomias*	2.3	0.0	6	0.0	6	6
blackspotted rockfish	*Sebastes melanostictus*	2.3	0.0	1	0.0	1	1
starry flounder	*Platichthys stellatus*	2.2	0.0	1	0.0	1	1
gonatus squid	*Gonatus* sp.	2.1	0.0	29	0.1	15	15
hydrozoans	*Aequorea* sp.	1.8	0.0	16	0.0	0	0
lanternfish unident.	Myctophidae (family)	1.3	0.0	69	0.1	1	0
smooth lumpsucker	*Aptocyclus ventricosus*	1.3	0.0	1	0.0	1	1
flathead sole	*Hippoglossoides elassodon*	1.1	0.0	5	0.0	5	5
lumpsucker unident.	Cyclopteridae (family)	0.8	0.0	1	0.0	1	0
Pacific ocean perch	*Sebastes alutus*	0.7	0.0	1	0.0	1	1
shrimp unident.	Decapoda (order)	0.6	0.0	420	0.8	2	2
humpy shrimp	*Pandalus goniurus*	0.5	0.0	136	0.3	43	0
Pacific glass shrimp	*Pasiphaea pacifica*	0.4	0.0	180	0.4	20	0
squid unident.	Teuthoidea (order)	0.4	0.0	64	0.1	17	3
southern rock sole	*Lepidopsetta bilineata*	0.4	0.0	1	0.0	1	1
moon jellyfish	*Aurelia sp.*	0.3	0.0	3	0.0	3	3
coonstripe shrimp	*Pandalus hypsinotis*	0.1	0.0	4	0.0	3	3
Total		17,073.6		49,780		8,979	2253

Table 12. -- Numbers-at-length estimates (millions) from acoustic-trawl surveys of walleye pollock in the Shelikof Strait area.

No surveys were conducted in 1982, 1999, or 2011, and no estimate was produced for 1987 due to mechanical problems.

Length	1981	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	<1	0	0	0	<1	0	0	0	0	0	<1	0	0	1	<1	0
9	0	0	0	21	60	0	4	1	1	<1	<1	4	163	0	3	4	29	4	0	0	<1	6	4	<1	7	1	1	<1	82	6	0	0
10	0	0	0	310	175	0	47	5	0	4	3	32	1,120	3	3	16	372	33	0	1	10	106	36	4	25	16	10	2	801	65	1	0
11	2	0	1	581	206	4	133	16	4	27	16	51	3,906	12	20	70	1,162	87	0	8	15	476	61	14	161	74	20	8	1,935	152	1	0
12	10	1	60	810	102	8	153	16	9	74	26	60	3,779	20	21	140	1,565	87	5	14	24	621	39	20	407	134	28	22	2,240	185	2	0
13	26	1	0	278	32	4	50	9	4	79	13	33	1,538	18	15	104	999	52	2	20	3	296	13	11	412	74	21	34	800	122	2	0
14	31	0	1	79	1	1	9	1	4	36	3	6	157	4	7	49	320	24	1	8	1	98	5	4	265	30	7	18	321	32	1	0
15	5	0	0	13	0	<1	3	<1	<1	6	1	<1	25	<1	1	10	30	2	1	1	<1	19	2	1	77	2	1	9	104	9	0	0
16	5	0	0	1	3	0	<1	0	<1	1	0	<1	1	5	<1	2	7	2	0	<1	<1	4	1	0	11	1	<1	2	34	3	0	0
17	1	1	0	<1	7	0	0	4	<1	0	0	0	1	51	<1	<1	1	20	0	<1	<1	<1	7	2	2	0	<1	0	8	35	0	0
18	5	1	0	1	41	1	<1	36	1	0	<1	1	4	249	1	<1	10	185	<1	0	<1	1	23	8	0	6	<1	0	<1	114	0	0
19	12	8	0	2	187	2	1	165	7	<1	<1	<1	16	634	1	1	32	808	3	1	1	2	75	24	5	7	9	11	1	492	1	0
20	70	70	0	6	444	8	2	341	12	1	4	2	39	945	8	3	81	1,407	15	3	4	8	141	54	5	77	16	55	2	1,014	1	0
21	280	177	<1	20	535	26	7	362	33	2	8	5	68	772	23	10	147	1,043	36	11	10	20	203	60	20	179	36	156	4	967	9	0
22	733	221	1	75	431	32	17	198	48	5	17	7	92	441	50	16	196	460	29	15	20	29	161	42	38	347	64	184	13	488	17	<1
23	952	198	7	152	267	29	23	75	41	8	20	6	93	131	48	20	176	107	43	17	23	38	107	20	83	293	89	189	11	326	21	0
24	695	142	15	151	136	9	19	21	23	10	14	5	73	54	48	21	68	20	56	16	18	30	66	9	117	181	50	142	15	102	17	<1
25	389	37	21	75	46	4	11	7	23	6	7	4	53	18	89	10	30	22	128	11	12	16	27	6	76	80	27	65	19	58	17	<1
26	219	28	12	36	23	11	5	1	59	5	5	2	36	9	208	8	11	31	239	8	9	7	14	7	36	20	16	34	29	29	39	<1
27	90	6	5	16	11	40	3	6	108	3	1	3	27	9	275	6	6	60	250	9	4	2	6	11	30	9	8	9	12	6	85	<1
28	70	6	6	6	9	107	3	3	142	3	1	1	17	11	268	5	10	85	210	23	2	3	3	15	19	14	9	10	11	8	168	<1
29	83	3	9	3	15	158	6	9	123	8	1	1	5	22	205	10	13	91	124	52	3	1	5	23	13	6	28	1	9	1	281	<1
30	235	7	26	5	31	191	12	16	72	19	1	3	2	23	104	25	18	50	74	107	4	8	6	30	11	6	55	6	29	1	300	<1
31	420	3	48	6	34	129	23	19	32	25	2	6	6	15	59	42	32	37	42	153	7	8	6	23	27	9	91	2	46	1	271	2
32	492	24	67	4	38	92	27	17	22	37	3	7	4	15	31	78	37	15	25	185	16	2	6	23	38	13	108	5	49	2	209	3
33	490	65	68	11	29	85	24	11	8	48	5	11	8	13	21	102	34	14	29	145	25	10	6	19	42	24	91	6	80	4	142	11
34	499	141	53	22	18	89	28	10	8	67	6	6	6	6	16	99	28	7	20	122	41	3	8	16	31	24	66	6	89	3	66	22
35	592	195	27	27	12	63	37	8	7	85	10	7	11	4	11	103	22	6	17	77	56	10	5	12	32	19	32	6	133	4	49	51
36	665	258	21	41	9	41	53	12	8	83	9	6	15	4	10	84	13	8	7	57	59	4	4	8	17	17	25	6	124	4	28	91
37	541	339	20	44	7	28	62	19	9	84	17	3	14	3	10	66	9	9	5	38	54	18	3	5	19	8	14	5	127	6	24	139
38	403	368	35	53	3	24	66	23	8	65	26	3	20	2	9	45	8	9	6	28	47	10	2	4	7	12	11	4	68	8	16	209
39	352	341	87	64	4	12	57	21	6	36	40	2	9	2	5	26	7	11	6	23	39	11	1	4	3	16	8	3	49	15	15	274

Table 12. -- Continued.

Length	1981	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016
40	339	343	138	77	3	13	52	33	10	30	53	3	15	2	8	15	11	9	2	14	35	23	2	4	8	10	9	4	27	28	7	271
41	231	290	170	82	8	8	46	34	9	22	57	5	5	2	4	16	13	12	2	13	35	22	2	3	7	14	9	6	16	42	7	204
42	224	326	219	96	8	5	36	37	13	15	57	9	7	2	5	6	19	8	3	7	38	32	2	2	4	16	10	9	13	59	7	138
43	178	311	271	106	12	5	22	32	14	14	48	16	17	4	4	7	19	7	2	6	32	33	4	3	4	15	11	12	11	59	9	76
44	145	304	309	113	22	3	16	37	19	14	37	23	18	6	5	5	18	7	2	5	27	41	5	2	3	14	11	13	13	57	13	40
45	116	256	316	119	35	2	12	34	21	17	33	36	35	7	3	2	19	8	3	3	24	39	7	3	4	12	15	17	5	42	18	22
46	84	201	283	148	39	2	6	25	24	22	23	39	53	13	4	2	22	5	2	3	18	33	9	2	3	9	14	17	7	27	24	13
47	113	171	213	140	50	2	6	23	22	21	19	46	62	25	4	3	19	5	3	3	17	37	11	3	1	6	11	19	9	17	26	10
48	62	116	158	139	57	2	4	20	26	32	17	37	74	37	6	4	17	6	4	2	11	33	14	3	1	5	12	18	14	13	33	7
49	75	91	104	117	52	3	5	16	20	38	16	33	73	53	13	6	13	9	3	2	8	22	15	4	1	3	10	16	15	11	30	7
50	58	52	68	83	51	4	5	15	19	46	17	29	66	64	20	13	16	8	3	2	7	28	18	6	<1	3	12	17	15	14	25	9
51	50	49	40	52	42	4	4	8	20	40	15	24	51	69	30	18	10	5	4	2	5	14	19	8	<1	3	11	13	27	15	23	6
52	25	23	25	28	21	3	4	8	14	38	14	21	40	64	36	24	11	9	4	2	4	7	19	6	1	4	10	13	19	27	19	4
53	12	17	13	23	18	3	5	7	13	35	14	24	30	53	37	26	10	6	3	2	2	6	16	9	1	2	6	11	23	27	20	5
54	9	7	4	9	6	2	4	5	9	35	13	18	22	39	34	23	9	4	3	1	3	4	12	7	2	2	7	9	31	28	19	3
55	15	9	3	4	11	2	2	7	10	30	11	18	16	29	28	20	9	5	2	1	3	3	13	8	2	2	8	10	23	28	25	3
56	5	2	2	2	2	2	1	2	6	15	9	18	14	19	24	19	8	5	1	<1	2	2	7	6	4	3	6	8	31	32	21	2
57	7	2	1	2	<1	1	1	2	3	18	7	13	7	13	12	12	9	3	1	<1	1	1	5	5	1	2	5	8	22	24	21	3
58	3	1	1	1	1	<1	1	1	5	14	7	11	6	10	8	9	6	2	1	<1	1	1	3	4	2	1	6	8	19	19	21	3
59	1	1	<1	1	<1	<1	1	1	2	4	4	9	3	6	5	8	5	3	1	1	1	1	3	3	3	1	6	5	19	14	16	1
60	0	1	<1	2	1	0	1	1	2	2	3	7	2	5	3	4	2	3	<1	1	<1	1	2	2	2	1	4	5	22	13	15	1
61	0	1	<1	<1	1	<1	<1	<1	1	2	2	5	1	3	2	2	1	1	<1	1	<1	<1	2	2	3	1	5	2	10	9	9	1
62	0	0	1	1	<1	<1	<1	<1	<1	3	1	2	2	2	1	2	2	<1	<1	<1	<1	0	1	1	1	1	4	1	10	7	8	<1
63	0	0	1	1	<1	0	<1	<1	1	1	1	1	<1	1	1	2	1	1	<1	<1	<1	1	1	1	1	1	4	2	14	3	4	1
64	0	0	<1	0	<1	0	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	1	4	1	3	4	2	0
65	0	0	0	0	<1	0	0	<1	1	0	<1	1	<1	<1	<1	<1	<1	<1	<1	0	<1	<1	<1	<1	<1	<1	4	1	2	2	3	0
66	0	0	0	<1	<1	0	<1	<1	0	<1	<1	<1	0	<1	<1	<1	<1	1	0	0	0	<1	<1	<1	1	1	3	<1	3	2	3	0
67	0	0	0	0	<1	<1	0	<1	<1	<1	<1	<1	0	<1	<1	0	<1	0	<1	<1	0	0	<1	<1	<1	1	3	<1	<1	1	1	0
68	0	0	0	0	0	0	0	<1	0	0	<1	0	0	<1	<1	<1	0	<1	<1	0	<1	0	<1	<1	<1	<1	1	<1	1	1	1	0
69	0	0	0	0	0	0	0	<1	1	0	<1	<1	0	<1	<1	0	0	0	0	0	0	0	0	<1	<1	<1	<1	0	0	<1	<1	0
70	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	<1	1	<1	0	0
71	0	0	0	0	0	0	0	<1	0	0	0	<1	0	0	0	0	0	0	<1	0	0	0	0	<1	0	<1	<1	0	1	<1	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	<1	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0
Total	10,121	5,211	2,928	4,259	3,352	1,266	1,119	1,782	1,109	1,339	740	729	11,931	4,024	1,866	1,425	5,742	4,931	1,424	1,224	780	2,252	1,240	575	2,100	1,832	1,165	1,245	7,668	4,885	2,212	1,633

Table 13. -- Biomass-at-length estimates (thousands of metric tons) from acoustic-trawl surveys of walleye pollock in the Shelikof Strait area. No surveys were conducted in 1982, 1999, or 2011, and no estimate was produced for 1987 due to mechanical problems.

Length	1981	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0	< 1	0	0	0	0	0	<1	0	0	<1	<1	0
9	0	0	0	< 1	< 1	0	< 1	< 1	< 1	< 1	< 1	< 1	1	0	< 1	< 1	< 1	< 1	0	0	< 1	< 1	< 1	< 1	<1	<1	<1	<1	<1	<1	0	0
10	0	0	0	2	1	0	< 1	< 1	0	< 1	< 1	< 1	7	< 1	< 1	< 1	3	< 1	0	< 1	< 1	1	< 1	< 1	<1	<1	<1	<1	5	<1	<1	0
11	< 1	0	< 1	6	2	< 1	1	< 1	< 1	< 1	< 1	< 1	35	< 1	< 1	1	11	1	0	< 1	< 1	4	< 1	< 1	2	1	<1	<1	15	1	<1	0
12	< 1	< 1	1	10	1	< 1	2	< 1	< 1	1	< 1	1	44	< 1	< 1	1	20	1	< 1	< 1	< 1	7	< 1	< 1	4	1	<1	<1	21	2	<1	0
13	< 1	< 1	0	4	< 1	< 1	1	< 1	< 1	1	< 1	< 1	23	< 1	< 1	1	16	1	< 1	< 1	< 1	4	< 1	< 1	6	1	<1	<1	10	2	<1	0
14	1	0	< 1	2	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	3	< 1	< 1	1	7	< 1	< 1	< 1	< 1	2	< 1	< 1	5	1	<1	<1	5	1	<1	0
15	< 1	0	0	< 1	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	2	<1	<1	<1	2	<1	<1	0
16	< 1	0	0	< 1	< 1	0	< 1	0	< 1	< 1	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1	< 1	< 1	< 1	<1	<1	<1	<1	1	<1	<1	0
17	< 1	< 1	0	< 1	< 1	0	0	< 1	< 1	0	0	0	< 1	2	< 1	< 1	< 1	1	0	< 1	< 1	< 1	< 1	< 1	<1	0	<1	0	<1	1	<1	0
18	< 1	< 1	0	< 1	2	< 1	< 1	1	< 1	0	< 1	< 1	< 1	9	< 1	< 1	< 1	6	< 1	0	< 1	< 1	< 1	< 1	<1	<1	<1	0	<1	4	<1	0
19	1	< 1	0	< 1	8	< 1	< 1	7	< 1	< 1	< 1	< 1	1	27	< 1	< 1	2	33	< 1	< 1	< 1	< 1	3	1	<1	<1	<1	<1	<1	22	<1	0
20	4	4	0	< 1	23	< 1	< 1	16	1	< 1	< 1	< 1	2	48	< 1	< 1	5	68	1	< 1	< 1	< 1	7	3	<1	4	<1	3	<1	50	<1	0
21	18	11	< 1	1	33	1	< 1	21	2	< 1	< 1	< 1	4	46	1	1	10	59	2	1	1	1	12	4	1	11	2	10	<1	56	1	0
22	53	16	< 1	6	31	2	1	13	3	< 1	1	1	7	30	4	1	16	31	2	1	1	2	11	3	3	25	4	13	1	33	1	<1
23	78	16	1	14	22	2	2	6	3	1	2	1	8	10	4	2	17	8	4	1	2	3	8	2	7	23	7	15	1	25	2	0
24	65	13	2	15	13	1	2	2	2	1	1	1	7	5	5	2	7	2	5	2	2	3	6	1	11	16	5	13	1	9	2	<1
25	41	4	2	9	5	< 1	1	1	2	1	1	< 1	6	2	10	1	4	2	14	1	1	2	3	1	8	8	3	6	2	6	2	<1
26	26	3	2	5	3	1	1	< 1	7	1	1	< 1	5	1	25	1	1	4	29	1	1	1	2	1	5	2	2	4	3	4	5	<1
27	12	1	1	2	2	5	< 1	1	14	< 1	< 1	< 1	4	1	38	1	1	8	35	1	< 1	< 1	< 1	1	4	1	1	1	1	1	11	<1
28	11	1	1	1	1	16	< 1	< 1	21	< 1	< 1	< 1	3	2	42	1	2	13	33	3	< 1	< 1	< 1	2	3	2	1	2	2	1	25	<1
29	14	1	2	1	3	26	1	1	20	1	< 1	< 1	1	4	36	2	2	15	22	9	1	< 1	< 1	4	2	1	5	<1	2	<1	45	<1
30	44	1	5	1	6	35	2	3	13	4	< 1	1	< 1	4	20	5	4	9	15	20	1	2	1	5	2	1	11	1	6	<1	54	<1
31	86	1	10	1	7	27	5	4	7	5	< 1	1	1	3	13	9	8	8	9	32	1	2	1	5	6	2	19	<1	10	<1	55	<1
32	111	5	16	1	9	21	6	4	5	9	1	2	1	3	7	19	10	3	6	43	4	1	1	5	10	3	25	1	12	1	47	1
33	122	16	18	3	7	22	6	3	2	12	1	3	2	3	5	26	10	4	8	37	7	3	2	5	12	6	23	2	21	1	36	2
34	136	39	15	6	5	25	8	3	2	19	2	2	2	2	5	28	9	2	6	34	12	1	2	5	10	7	18	2	26	1	18	5
35	176	59	9	9	4	19	11	2	2	27	3	2	4	1	4	33	8	2	6	24	18	3	2	4	11	6	9	2	43	1	15	13
36	216	84	7	14	3	14	18	4	3	29	3	2	5	1	3	29	5	3	2	19	20	1	1	3	6	6	9	2	43	1	9	26
37	191	121	7	17	2	11	23	7	3	32	6	1	5	1	4	25	4	3	2	14	21	7	1	2	8	3	5	2	49	2	9	44
38	154	142	14	21	1	10	26	9	3	26	11	1	8	1	4	19	4	4	2	11	20	4	< 1	2	3	5	4	1	29	3	6	72
39	146	143	38	28	2	5	25	9	3	16	18	1	4	1	2	12	3	5	3	10	18	5	< 1	2	2	7	4	1	22	7	7	103

Table 13. -- Continued.

Length	1981	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016
40	152	155	66	37	1	6	24	15	5	15	26	2	7	1	4	7	6	4	1	7	17	12	1	2	4	5	4	2	17	13	3	108
41	112	142	87	42	4	4	23	17	4	11	30	3	3	1	2	8	7	6	1	7	19	13	1	2	4	8	5	3	9	21	4	88
42	117	172	121	53	4	3	20	20	7	9	32	5	4	1	3	3	11	5	2	4	22	19	1	1	3	9	6	5	8	32	4	64
43	100	176	161	63	7	3	13	19	9	9	29	10	10	2	2	4	13	5	1	4	20	21	2	2	3	9	7	8	7	35	5	37
44	87	185	197	72	14	2	10	24	12	9	24	16	12	4	3	3	13	5	1	3	19	27	4	2	2	10	8	8	9	36	9	22
45	75	167	215	81	24	2	8	23	15	12	23	26	24	5	2	2	15	6	2	2	17	27	5	2	3	9	11	12	4	29	13	13
46	58	140	206	107	29	2	4	19	18	17	18	31	39	10	3	1	17	4	2	3	15	24	7	2	2	7	11	12	5	20	18	8
47	83	127	166	108	40	1	5	18	18	17	16	39	49	20	3	3	16	4	2	3	14	29	10	3	1	5	10	15	8	13	22	7
48	49	92	131	115	49	2	3	17	22	29	15	34	63	32	6	4	15	6	3	2	10	28	12	3	1	4	11	15	13	11	29	5
49	63	77	92	102	47	2	4	15	19	36	15	32	66	48	13	6	13	8	3	2	8	19	15	4	1	3	11	15	15	10	28	6
50	51	46	63	78	49	4	4	15	19	47	17	30	63	62	20	13	16	8	3	2	8	28	18	6	<1	3	13	17	16	14	25	7
51	47	47	40	52	43	4	4	8	21	43	16	26	52	71	32	20	12	6	4	2	5	14	22	9	<1	3	12	14	30	16	25	5
52	25	23	26	29	24	3	4	8	15	44	15	24	43	70	41	27	13	10	5	2	5	8	23	7	2	5	12	15	24	32	21	4
53	13	19	15	26	21	4	5	8	15	43	17	29	34	62	45	32	12	8	4	2	3	7	20	11	1	3	9	13	30	34	25	5
54	11	8	5	10	7	3	5	6	12	45	17	23	26	48	44	30	13	6	4	1	4	5	16	10	3	4	10	11	43	36	24	3
55	18	11	4	5	14	3	2	9	14	41	15	24	20	38	38	27	12	7	3	2	4	4	19	11	3	3	13	14	33	38	33	3
56	6	2	2	3	3	2	2	3	9	22	13	27	19	27	35	28	12	8	2	< 1	3	3	10	9	6	4	10	12	46	47	31	2
57	10	3	2	3	< 1	1	2	4	5	28	11	21	10	20	19	18	13	5	2	< 1	1	1	8	8	2	3	9	12	34	36	31	3
58	4	1	1	1	2	1	1	2	7	24	12	19	10	15	13	15	11	4	2	1	2	2	6	8	4	2	11	14	33	30	34	3
59	1	1	< 1	2	1	1	1	2	3	8	7	16	4	11	8	13	8	6	2	2	1	1	6	5	5	3	11	8	33	24	26	2
60	0	1	< 1	3	1	0	1	2	4	4	5	13	3	9	5	8	4	6	1	1	< 1	1	4	4	4	2	7	8	42	25	27	1
61	0	1	1	< 1	1	< 1	1	1	1	4	3	9	3	5	4	4	2	3	1	1	< 1	< 1	4	3	6	3	11	4	19	16	17	2
62	0	0	2	1	1	1	< 1	< 1	1	5	2	4	3	3	2	3	3	1	1	< 1	< 1	0	2	2	3	2	9	3	21	13	16	<1
63	0	0	2	2	< 1	0	< 1	< 1	1	3	1	3	< 1	2	2	4	1	3	< 1	< 1	1	1	2	2	3	2	8	3	31	6	9	1
64	0	0	1	0	< 1	0	< 1	< 1	< 1	1	< 1	2	1	1	< 1	1	1	1	< 1	1	< 1	< 1	1	1	4	2	9	2	7	8	4	0
65	0	0	0	0	< 1	0	0	< 1	3	0	< 1	2	< 1	1	< 1	1	< 1	< 1	< 1	0	< 1	< 1	< 1	1	1	1	9	2	6	4	6	0
66	0	0	0	< 1	1	0	< 1	< 1	0	1	< 1	< 1	0	< 1	< 1	1	< 1	3	0	0	0	1	< 1	< 1	2	3	6	<1	7	4	6	0
67	0	0	0	0	1	1	0	< 1	< 1	1	< 1	1	0	< 1	< 1	0	< 1	0	< 1	< 1	0	0	< 1	< 1	1	2	7	1	1	1	2	0
68	0	0	0	0	0	0	0	< 1	0	0	< 1	0	0	< 1	1	< 1	0	1	< 1	0	< 1	0	< 1	< 1	<1	1	4	<1	2	1	3	0
69	0	0	0	0	0	0	0	< 1	2	0	< 1	< 1	0	< 1	< 1	0	0	0	0	0	0	0	0	< 1	<1	1	2	0	0	<1	<1	0
70	0	0	0	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	3	<1	3	<1	0	0
71	0	0	0	0	0	0	0	< 1	0	0	0	< 1	0	0	0	0	0	0	< 1	0	0	0	0	< 1	0	1	2	0	4	<1	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	<1	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<1	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<1	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0
Total	2,786	2,278	1,757	1,175	586	302	290	375	380	713	436	493	764	777	583	505	449	433	257	317	331	356	294	181	208	266	430	336	891	842	845	665

Table 14. -- Numbers-at-age estimates (millions) from acoustic-trawl surveys of walleye pollock in the Shelikof Strait area.

No surveys were conducted in 1982, 1999, or 2011, and no estimate was produced for 1987 due to mechanical problems

Age	1981	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	Mean
1	78	1	62	2,092	575	17	399	49	22	228	63	186	10,690	56	70	395	4,484	289	8	48	53	1,626	162	54	1,368	332	90	95	6,324	576	7	0	953
2	3,481	902	58	544	2,115	110	90	1,210	174	34	76	36	510	3,307	183	89	755	4,104	163	94	94	157	836	232	391	1,205	306	852	149	3,640	104	2	813
3	1,511	380	324	123	184	694	90	72	550	74	37	49	79	119	1,247	126	217	352	1,107	205	58	56	41	175	250	110	532	43	803	19	1,636	79	354
4	769	1,297	142	315	46	322	216	63	48	188	72	32	78	25	80	474	16	61	97	800	159	35	12	30	53	99	84	77	61	295	72	1,447	236
5	2,786	1,171	635	181	75	78	249	116	65	368	233	155	103	54	18	136	67	42	16	56	357	173	17	10	12	60	79	96	69	87	152	43	242
6	1,052	698	988	347	49	17	43	180	70	84	126	84	245	71	44	14	132	23	16	8	48	162	56	17	2	10	29	46	114	58	62	34	154
7	210	599	450	439	86	6	14	46	116	85	27	42	122	201	52	32	17	35	8	4	3	36	75	34	4	3	12	29	65	100	57	15	94
8	129	132	224	167	149	6	4	22	24	171	36	27	54	119	98	36	13	13	7	2	3	4	32	21	11	1	5	4	49	55	68	4	53
9	79	14	41	43	60	4	2	8	29	33	39	44	17	40	53	74	10	6	1	1	3	2	7	2	7	5	5	1	12	26	30	6	22
10	25	12	3	6	11	9	1	8	2	56	16	48	11	13	14	26	8	3	1	< 1	< 1	0	< 1	1	2	6	11	< 1	5	18	11	2	12
11	2	4	0	2	1	2	10	1	4	2	8	15	15	11	2	14	14	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	9	< 1	6	7	6	0	6
12	0	2	1	1	0	2	1	3	1	15	3	7	6	5	3	7	7	2	< 1	0	0	0	< 1	0	0	< 1	3	1	1	1	4	0	3
13	0	0	0	0	0	< 1	< 1	2	4	1	2	1	2	3	1	< 1	2	1	< 1	< 1	< 1	0	0	0	0	0	0	0	2	2	1	0	1
14	0	0	0	0	0	0	0	1	0	< 1	< 1	2	< 1	< 1	< 1	1	1	< 1	< 1	0	0	0	0	0	0	0	0	0	5	0	1	0	0
15	0	0	0	0	0	0	0	< 1	0	0	1	< 1	0	0	0	1	0	< 1	0	0	0	0	0	0	0	0	0	0	3	1	1	0	0
16	0	0	0	0	0	0	0	< 1	0	0	1	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
17	0	0	0	0	0	0	0	0	0	0	< 1	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	10,122	5,212	2,928	4,260	3,351	1,267	1,119	1,781	1,109	1,339	740	728	11,932	4,024	1,865	1,425	5,743	4,932	1,424	1,220	777	2,252	1,240	576	2,100	1,832	1,165	1,245	7,668	4,885	2,212	1,633	2,941

Table 15. -- Biomass-at-age estimates (thousands of metric tons) from acoustic-trawl surveys of walleye pollock in the Shelikof Strait area. No surveys were conducted in 1982, 1999, or 2011, and no estimate was produced for 1987 due to mechanical problems

Age	1981	1983	1984	1985	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	Mean
1	1	< 1	1	24	4	< 1	4	< 1	< 1	3	1	2	114	1	1	4	57	2	< 1	< 1	< 1	18	1	< 1	19	4	1	1	59	7	0	0	14
2	309	71	6	54	139	8	8	67	12	3	6	3	46	180	15	8	63	214	13	8	8	13	55	15	39	94	24	68	19	211	10	<1	58
3	342	117	83	41	40	130	21	15	85	16	11	14	23	24	195	28	60	60	164	42	14	17	11	39	67	29	127	12	279	6	327	23	77
4	255	529	78	159	17	91	86	23	13	60	34	20	41	12	28	153	9	25	29	222	77	19	5	13	26	51	57	50	38	175	39	564	94
5	1,068	650	373	109	56	31	111	61	33	144	136	127	83	50	13	53	54	27	12	25	179	132	14	9	10	44	86	89	80	62	134	24	127
6	496	455	684	253	41	9	27	120	54	68	90	75	220	73	53	12	107	24	16	7	35	119	63	22	3	11	37	62	157	76	66	25	111
7	133	332	331	353	76	6	12	36	106	92	28	48	116	212	61	39	17	40	9	5	4	29	87	47	8	5	22	43	104	133	81	13	82
8	92	94	161	138	140	6	4	24	23	194	43	34	55	132	120	47	17	18	8	2	3	4	43	30	20	2	11	7	87	84	101	4	55
9	68	11	36	35	58	5	3	9	36	36	46	64	19	48	67	95	15	8	2	2	4	3	10	3	13	11	12	2	22	41	48	8	26
10	19	12	3	6	11	11	1	11	3	71	21	68	15	17	20	33	11	5	1	1	< 1	0	1	2	4	13	22	1	11	29	17	2	14
11	1	5	0	2	2	2	12	1	6	3	10	21	20	16	3	21	22	2	1	< 1	< 1	1	2	1	< 1	3	22	< 1	13	11	9	0	8
12	0	1	1	1	0	3	1	4	1	21	4	10	7	7	5	10	11	3	1	0	0	0	1	0	0	< 1	9	< 1	2	1	6	0	4
13	0	0	0	0	0	< 1	< 1	2	7	1	3	2	3	4	1	< 1	4	1	< 1	< 1	< 1	0	0	0	0	0	0	0	4	5	2	0	1
14	0	0	0	0	0	0	0	1	0	1	1	4	1	< 1	1	1	2	1	< 1	0	0	0	0	0	0	0	0	0	11	0	1	0	1
15	0	0	0	0	0	0	0	< 1	0	0	1	< 1	0	0	0	1	0	< 1	0	0	0	0	0	0	0	0	0	0	6	1	2	0	0
16	0	0	0	0	0	0	0	< 1	0	0	1	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
17	0	0	0	0	0	0	0	0	0	0	< 1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2,786	2,278	1,757	1,175	586	302	290	375	380	713	436	493	764	777	583	505	449	433	257	316	327	356	294	181	208	266	430	336	891	842	845	665	665

Table 16. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the three Aleutian Wing midwater trawl hauls during the winter 2016 acoustic-trawl survey of walleye pollock in Marmot Bay.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	2,413.5	98.0	4,638	76.0	1,124	310
eulachon	*Thaleichthys pacificus*	22.0	0.9	1,341	22.0	58	44
Pacific cod	*Gadus macrocephalus*	9.8	0.4	2	0.0	2	2
northern sea nettle	*Chrysaora melanaster*	7.8	0.3	11	0.2	11	11
Pacific herring	*Clupea pallasi*	4.0	0.2	35	0.6	35	35
Chinook salmon	*Oncorhynchus tshawytscha*	3.5	0.1	1	0.0	1	1
arrowtooth flounder	*Atheresthes stomias*	1.9	0.1	3	0.0	3	3
flathead sole	*Hippoglossoides elassodon*	0.4	0.0	1	0.0	1	1
shrimp unident.	Decapoda (order)	0.4	0.0	65	1.1	6	6
moon jellyfish	*Aurelia* sp.	0.3	0.0	1	0.0	0	0
hydrozoans	*Aequorea* sp.	0.1	0.0	1	0.0	0	0
humpy shrimp	*Pandalus goniurus*	0.0	0.0	2	0.0	0	0
Total		2,463.6		6,101		1,241	413

Table 17. -- Target strength (TS) to size relationships from the literature used to allocate 38 kHz acoustic backscatter to most species in this report. The symbols in the equations are as follows: *r* is the bell radius in cm and *L* is length in cm for all groups except pelagic crustaceans, in which case L is in m. The species for which the TS was derived is given.

Group	**TS** (dB re a m^2)	**TS derived for which species**	**Reference**
Fish with swim bladders	$TS = 20 \log_{10} L - 67.5$	Physoclist fishes	Foote 1987
Fish without swim bladders	$TS = 20\log_{10}L - 83.2$	*Pleurogrammus monopterygius*	Gauthier and Horne 2004
Jellyfish	$TS = 10\log_{10}(\pi r^2) - 86.8$	*Chrysaora melanaster*	De Robertis and Taylor 2014
Squid	$TS = 20\log_{10}L - 75.4$	*Todarodes pacificus*	Kang et al. 2005
Pelagic crustaceans	[1,2,3] $TS=A*(\log10(BkL)/(BkL))^C + D((kL)^6) + E((kL)^5) + F((kL)^4) + G((kL)^3) + H((kL)^2) + I(kL) + J + 20\log_{10}(L/Lo);$	*Euphausia superba*	Demer and Conti 2005

[1]A = -930.429983; B = 3.21027896; C = 1.74003785; D = 1.36133896 x 10^{-8}; E = -2.26958555 x 10^{-6}; F=1.50291244 x 10^{-4}; G = -4.86306872 x 10^{-3}; H = 0.0738748423; I = -0.408004891; J=-73.9078690; and Lo = 0.03835.
[2]If L < 1.5, TS = -105 dB; and if L > 6.5, TS = -73 dB.
[3]$k = 2\pi(n_u 10^3)/c$, where n_u = 38 (frequency in kHz) and c = 1470 (sound speed in m/s).

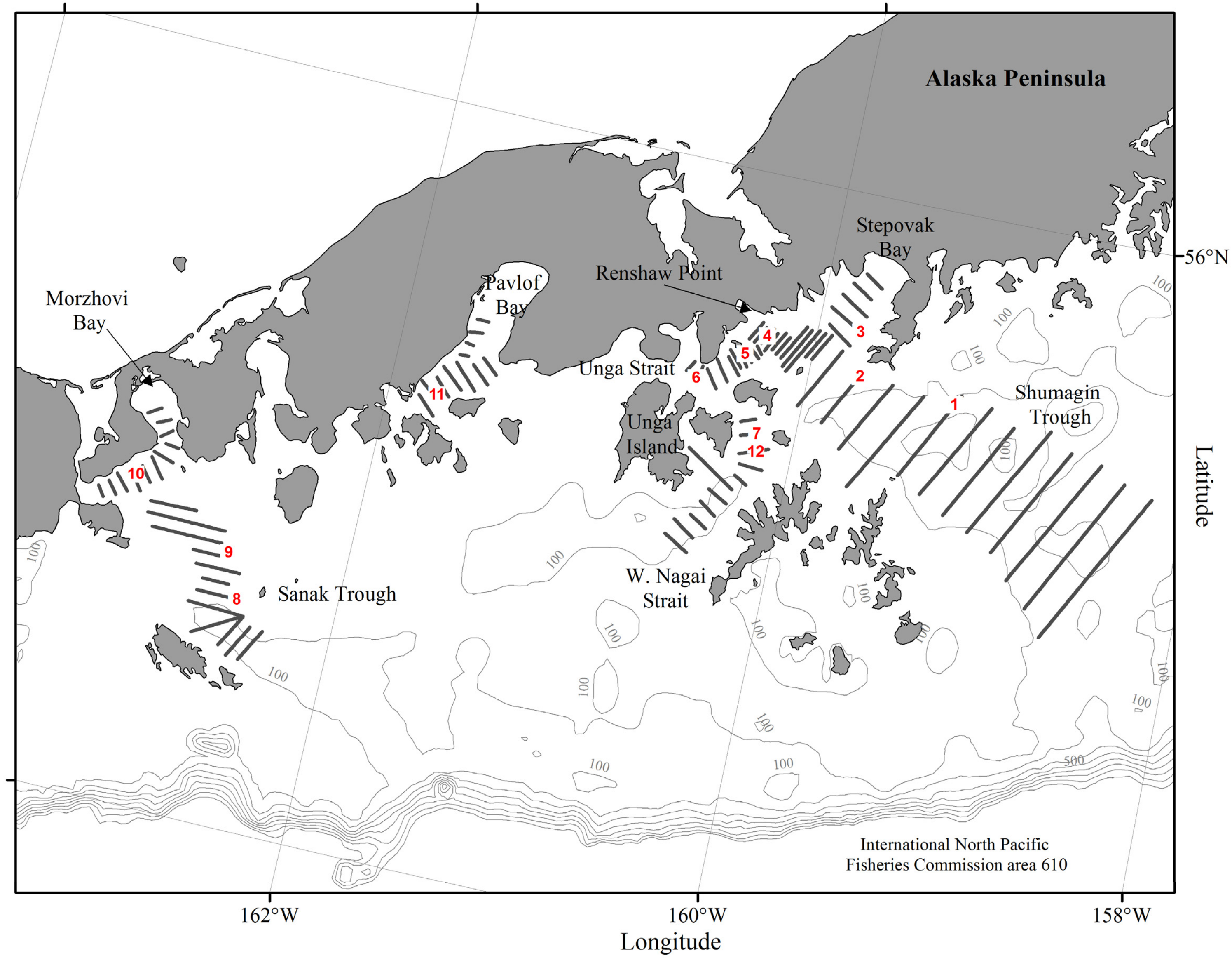


Figure 1. -- Transect lines and locations of Aleutian wing trawl (AWT) hauls (denoted by red numbers) during the winter 2016 acoustic-trawl survey of walleye pollock in the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof Bays.

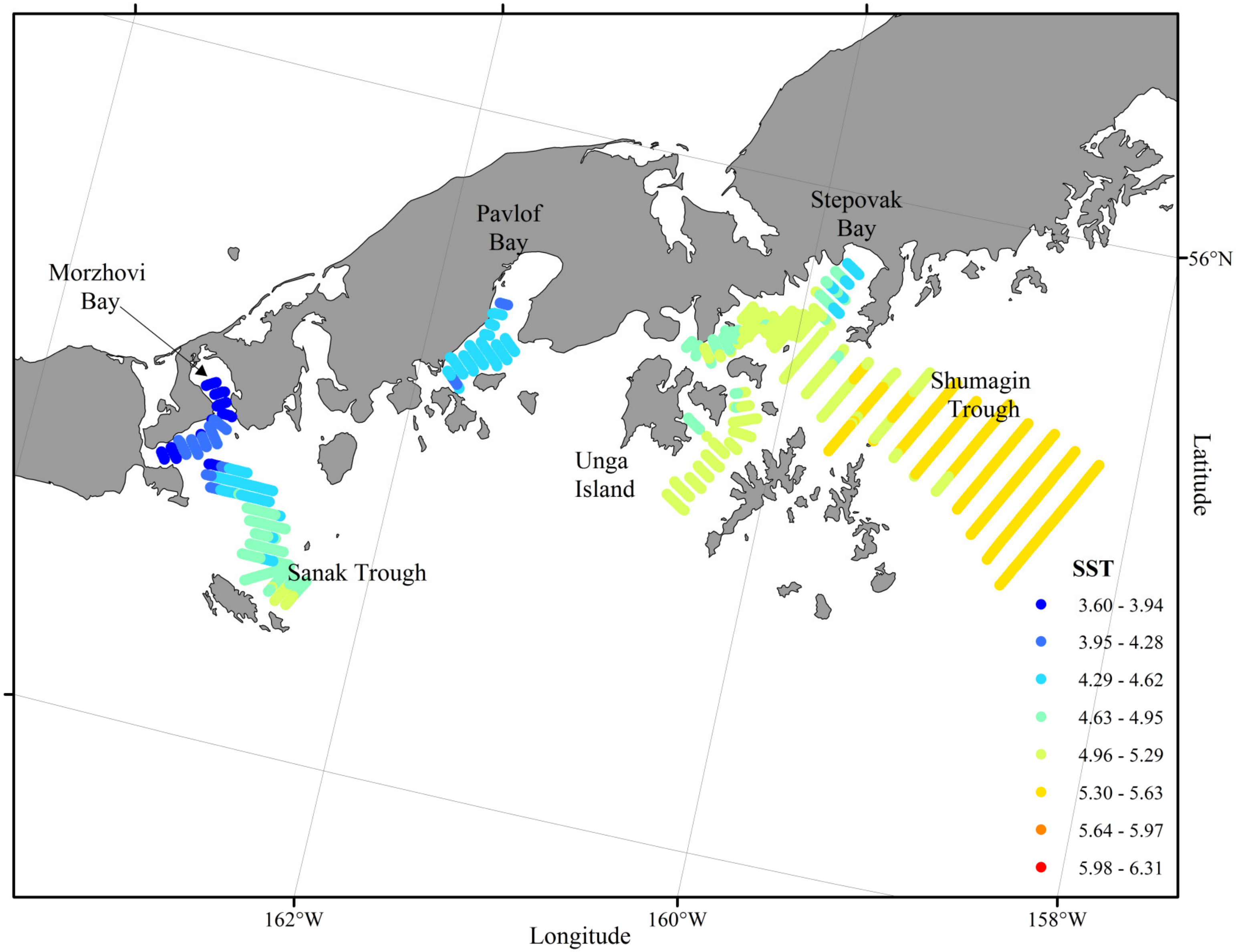


Figure 2. -- Surface water temperatures (°C) recorded during the winter 2016 acoustic-trawl survey of the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof Bays.

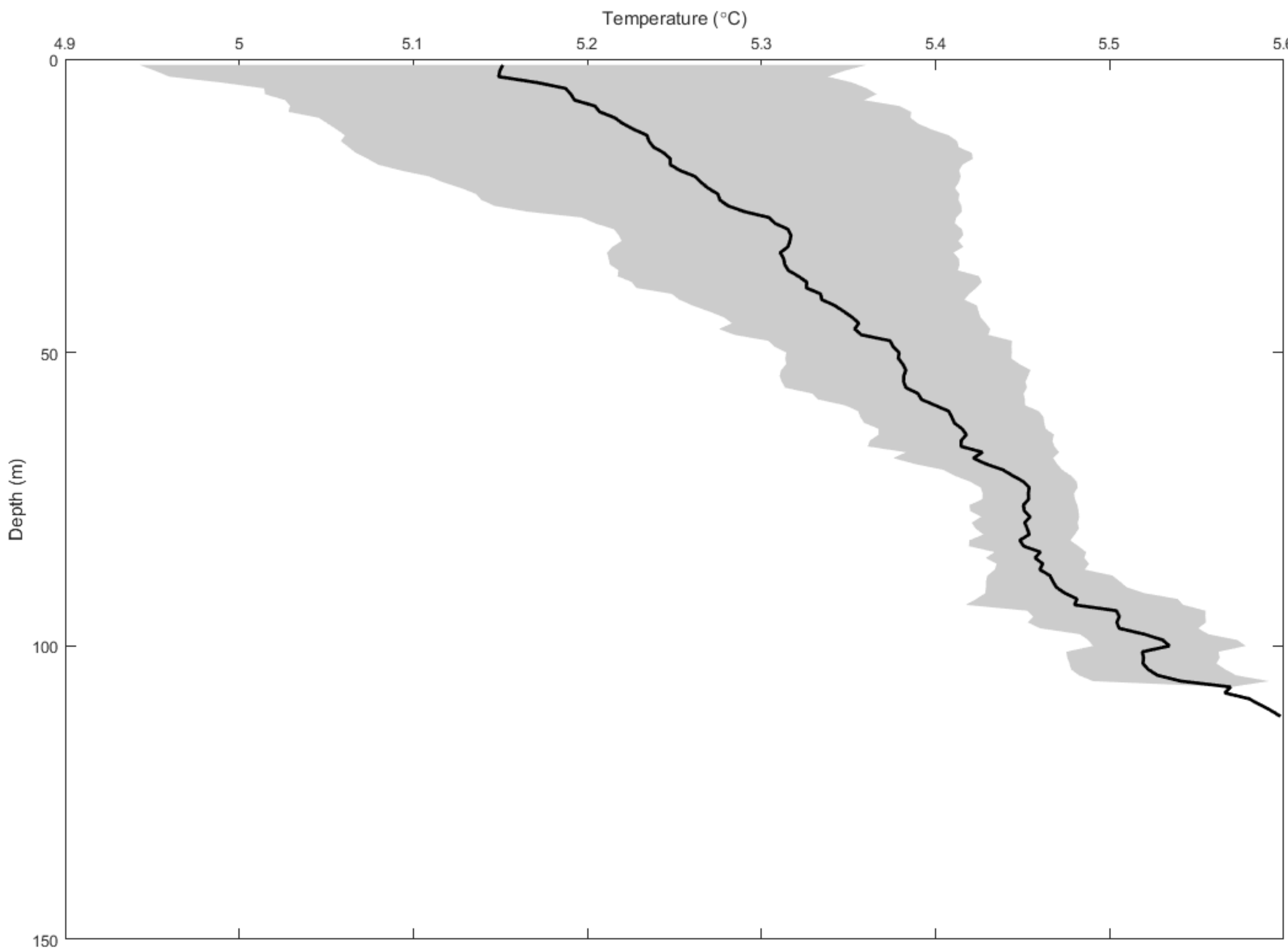


Figure 3. -- Mean water temperature (°C; solid line) by 1 m depth intervals for the eight trawl haul locations for which temperature data were collected during the winter 2016 acoustic-trawl survey of walleye pollock in the Shumagin Trough region. Shaded area represents one standard deviation.

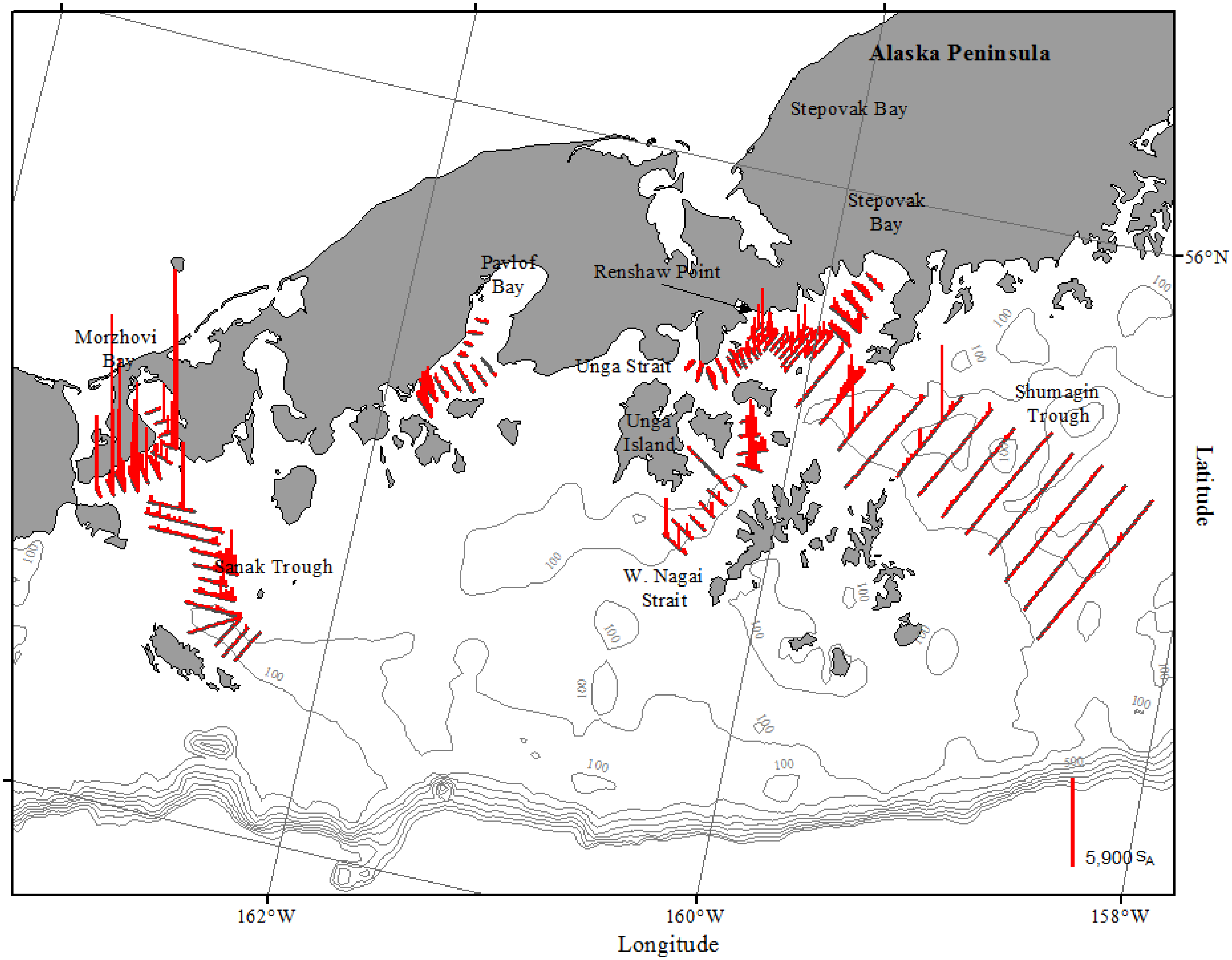


Figure 4. -- Backscatter (s_A) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2016 acoustic-trawl survey of the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof Bays.

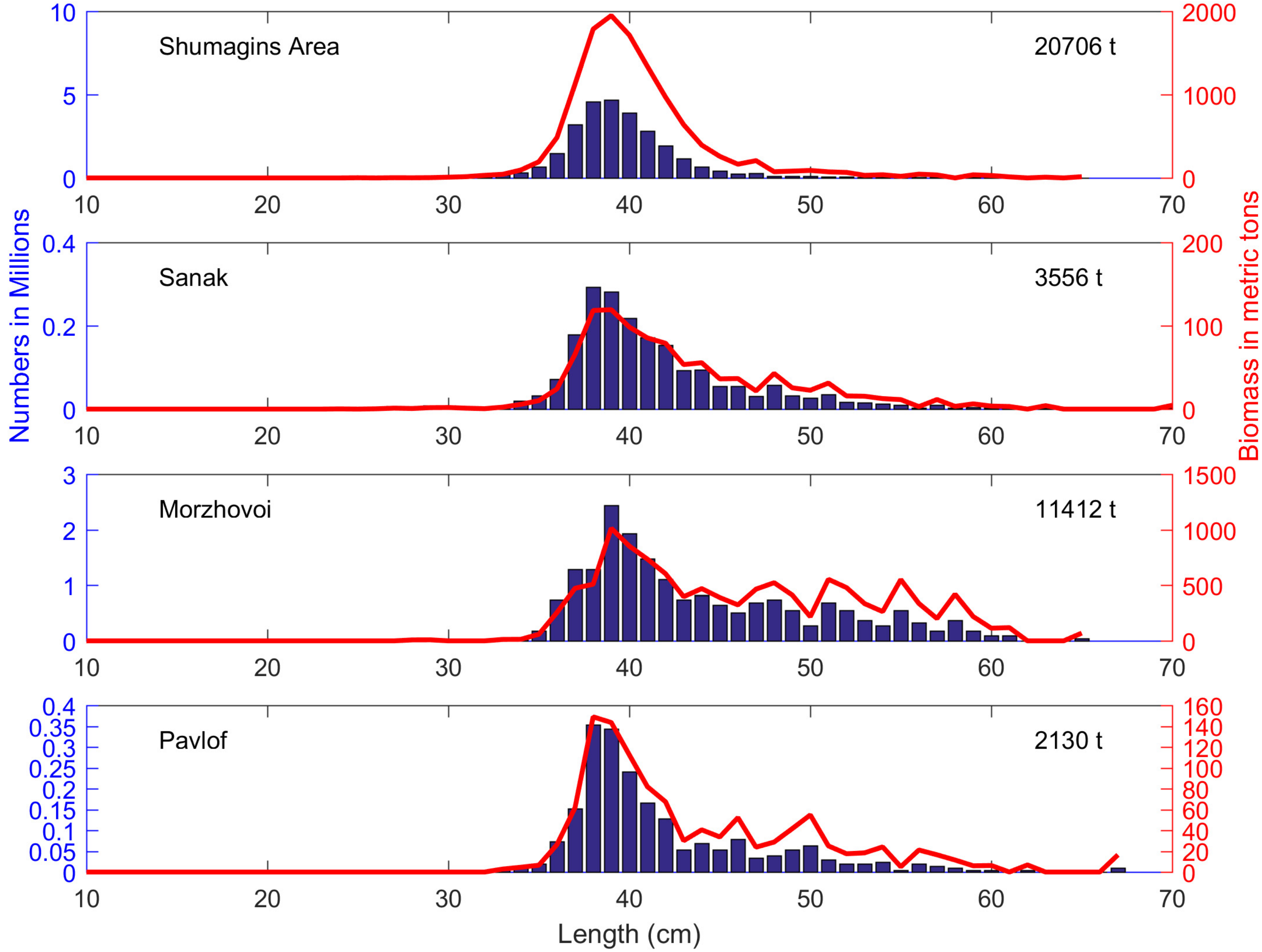


Figure 5. -- Length distributions of walleye pollock are shown with bars (numbers) and biomass estimates are shown with a solid red line (metric tons, t) for the 2016 acoustic-trawl survey of Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlov Bays.

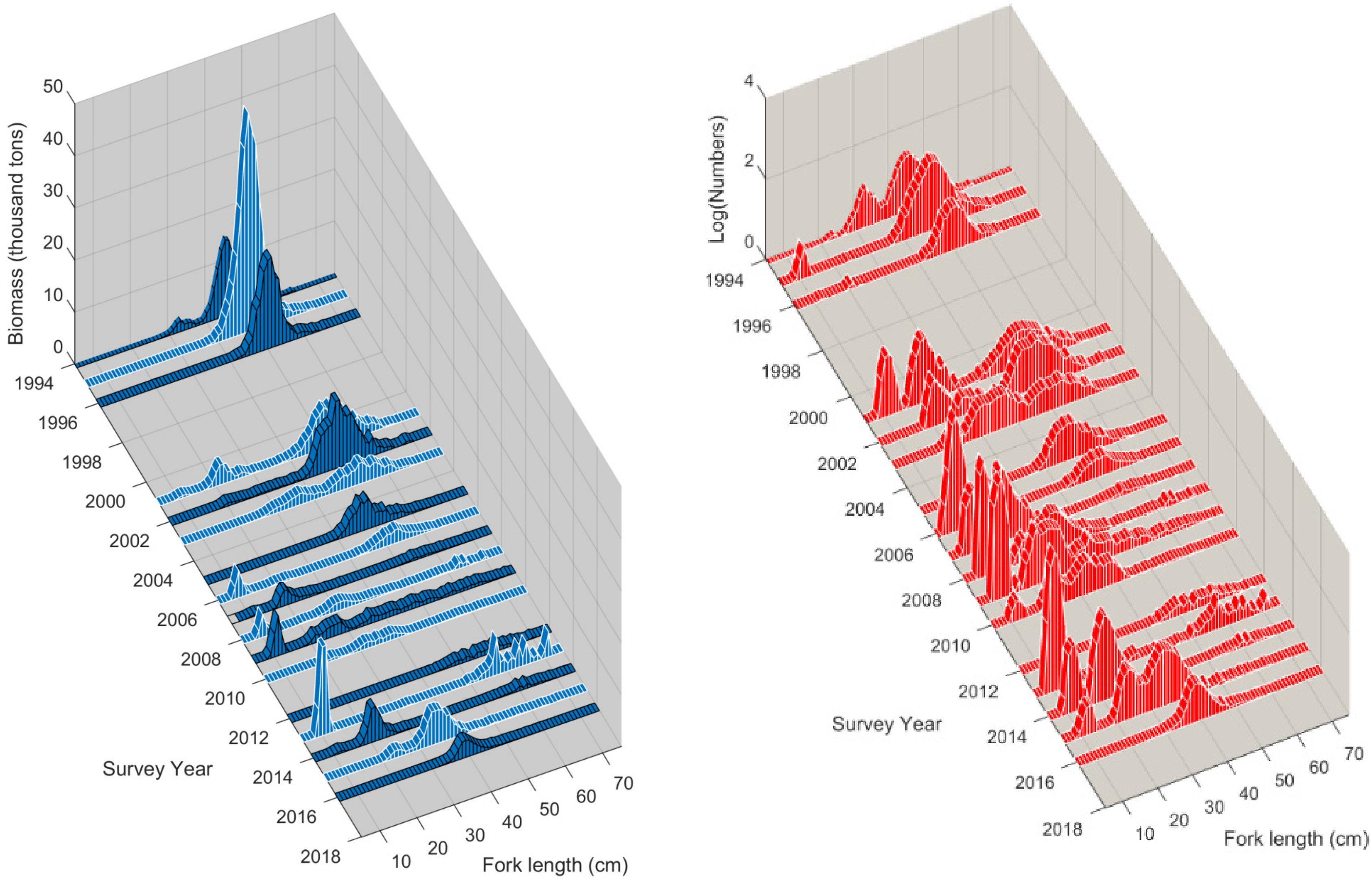


Figure 6. -- Walleye pollock biomass in thousands of metric tons (left) and log-transformed numbers in millions (right) at length from the Shumagin Islands acoustic-trawl surveys since 1994. No surveys were conducted in 1997-2000, 2004, or 2011.

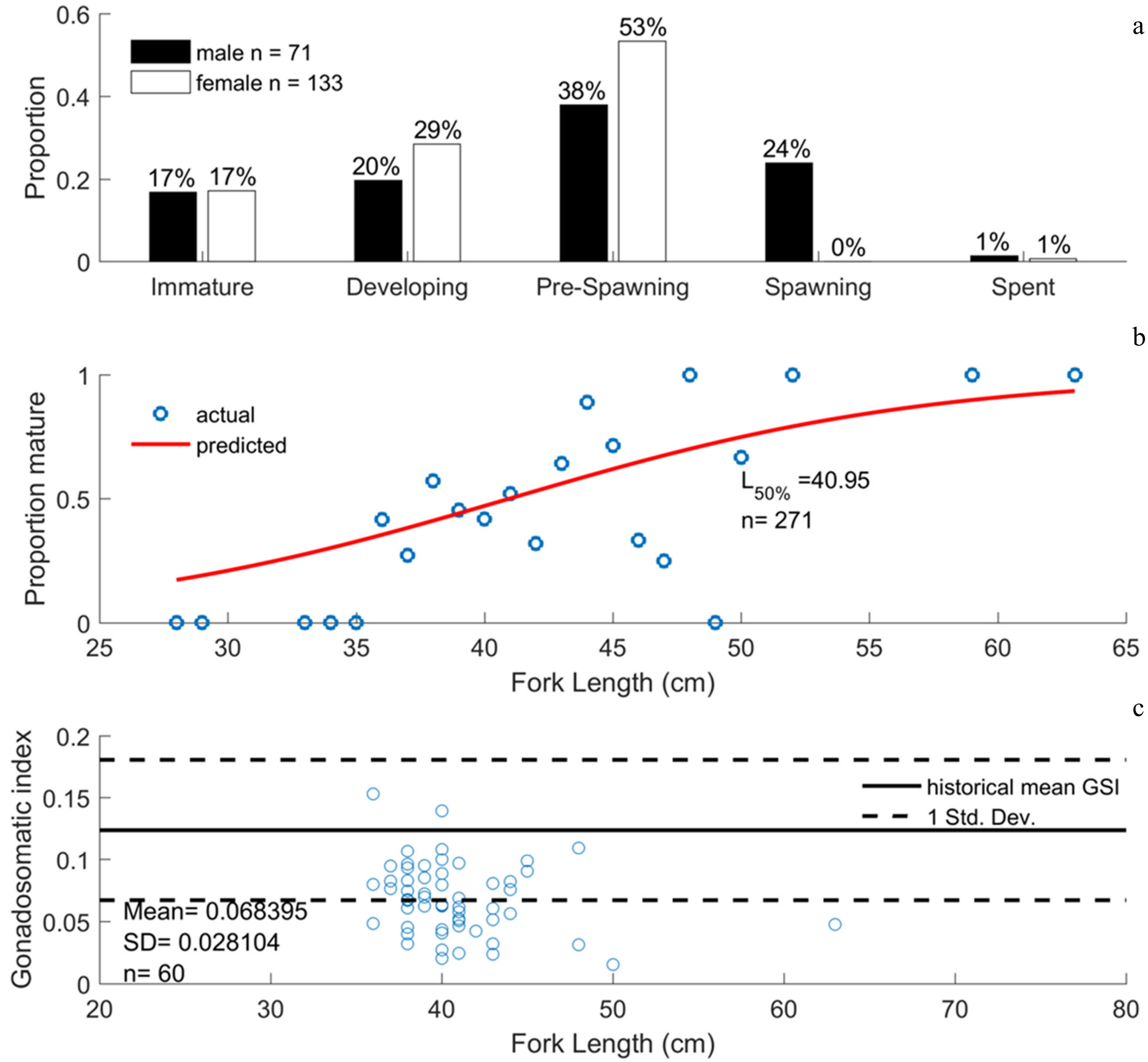


Figure 7. -- (a) Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage; (b) proportion mature (i.e., pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; and (c) gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2016 acoustic-trawl survey of the Shumagin Islands. Note: these graphs do not include data from age-1 fish.

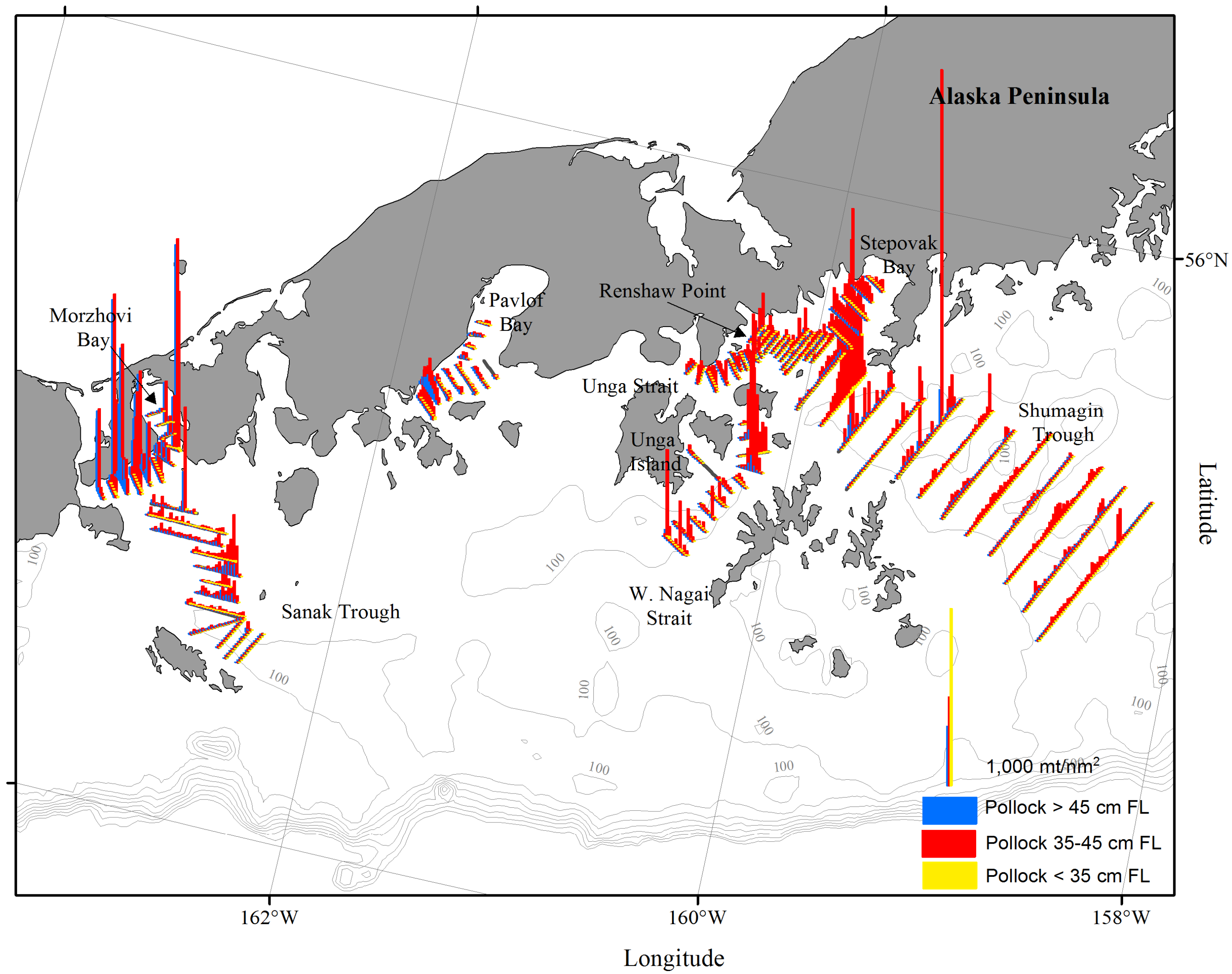


Figure 8. -- Biomass (t/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2016 acoustic-trawl survey of the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof Bays. Red bars represent fish between 35 and 45 cm FL, blue bars fish greater than 45 cm FL, and yellow bars represent fish less than 35 cm FL.

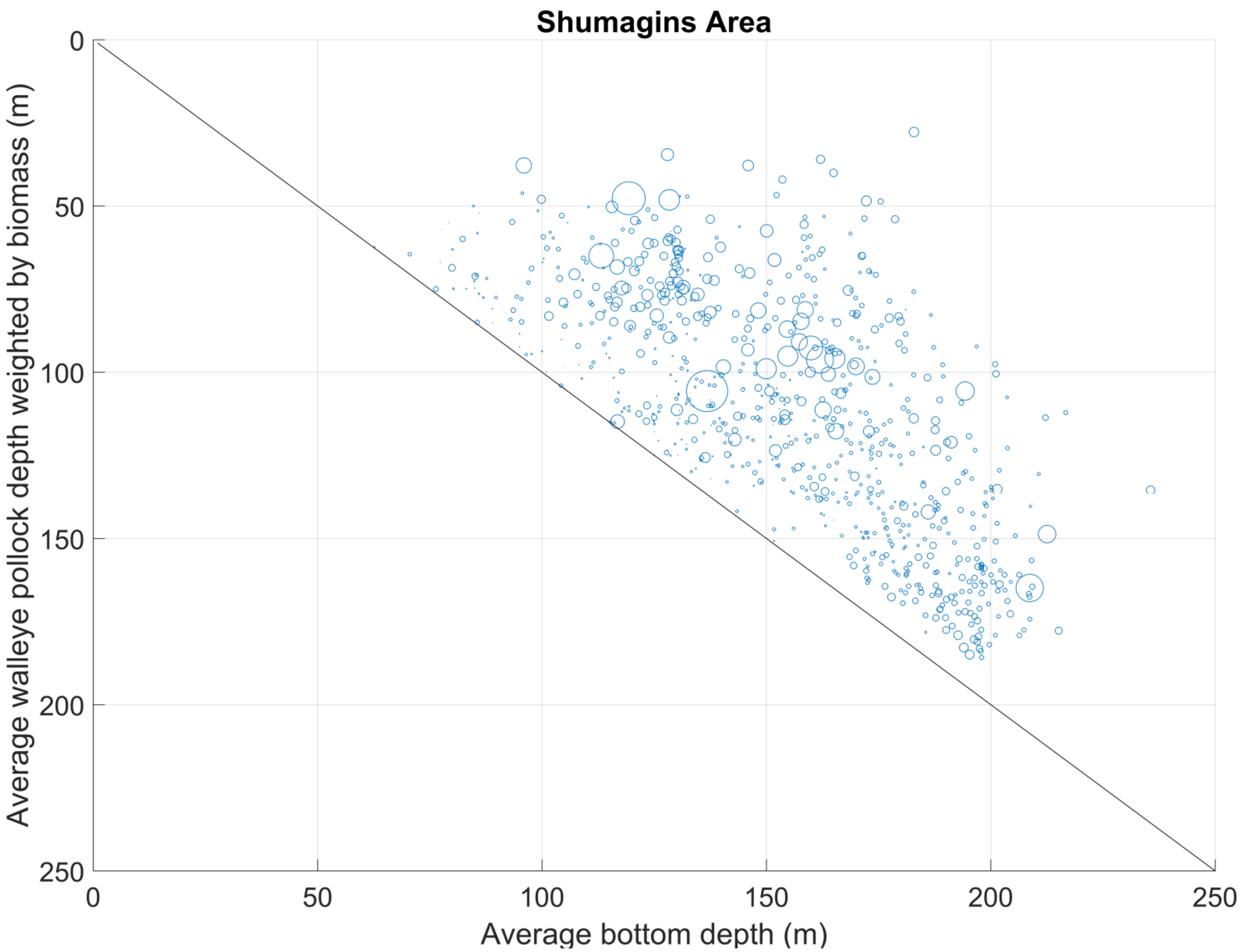


Figure 9. -- Average walleye pollock depth (weighted by biomass) versus bottom depth (m) during the winter 2016 acoustic-trawl survey of the Shumagin Islands area. Circle size is scaled to the maximum biomass per 0.5 nautical mile survey track interval. The diagonal line indicates where the average pollock depth equals bottom depth.

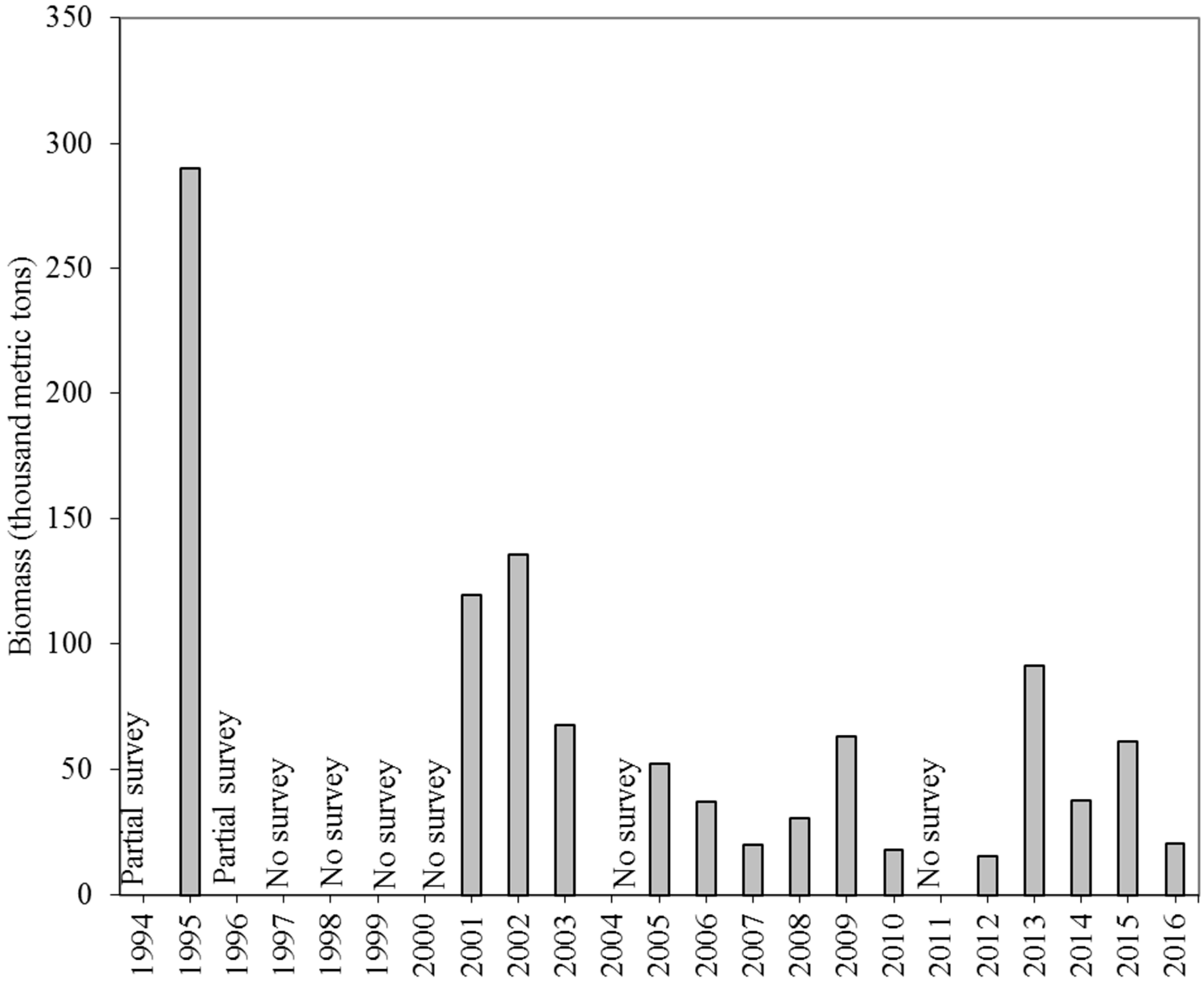


Figure 10. -- Summary of walleye pollock biomass estimates (thousand metric tons) based on acoustic-trawl surveys of the Shumagin Islands area.

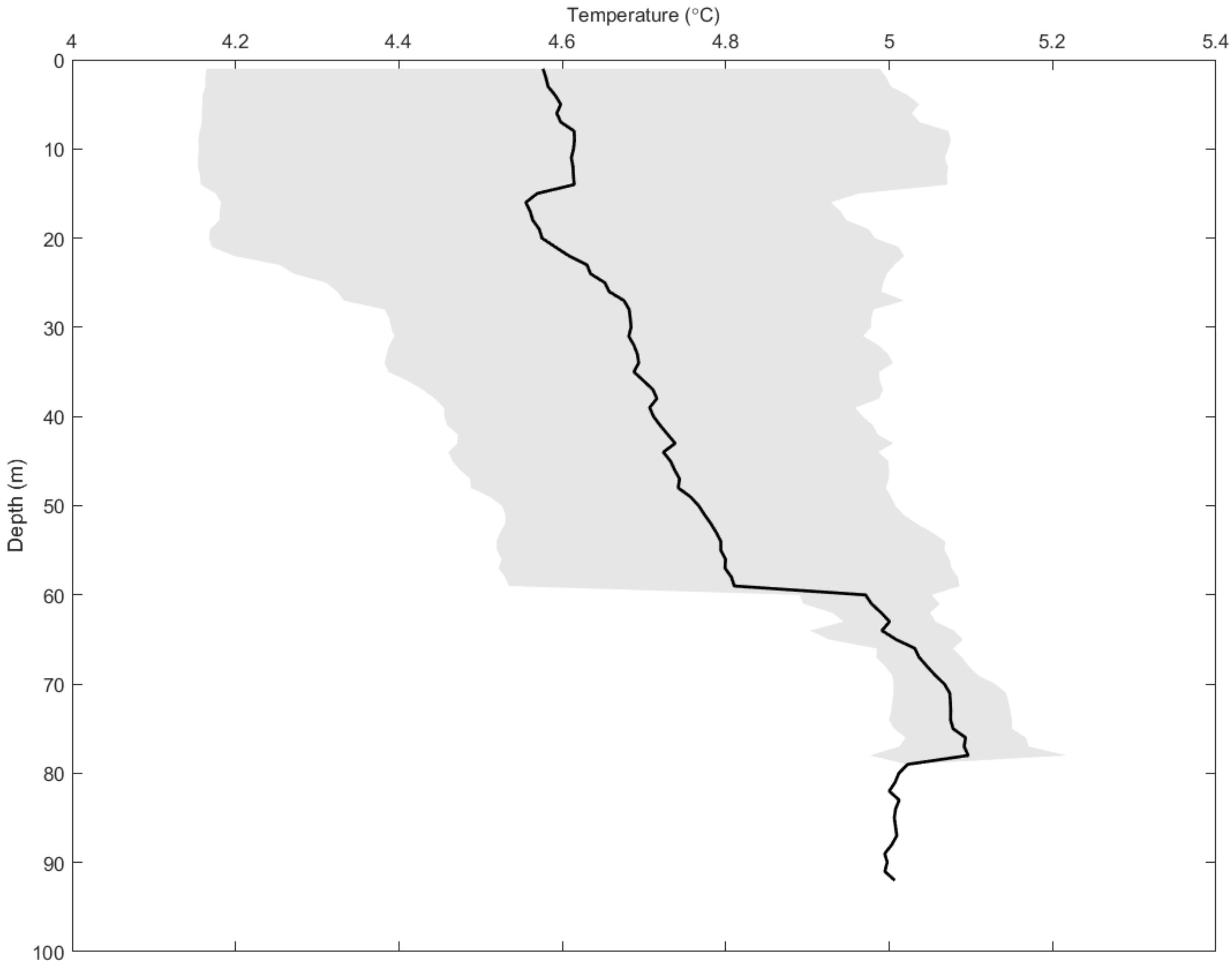


Figure 11. -- Water temperature (°C) by 1-m depth intervals for the two trawl haul locations observed during the winter 2016 acoustic-trawl survey of walleye pollock in Sanak Trough, shaded area represents one standard deviation.

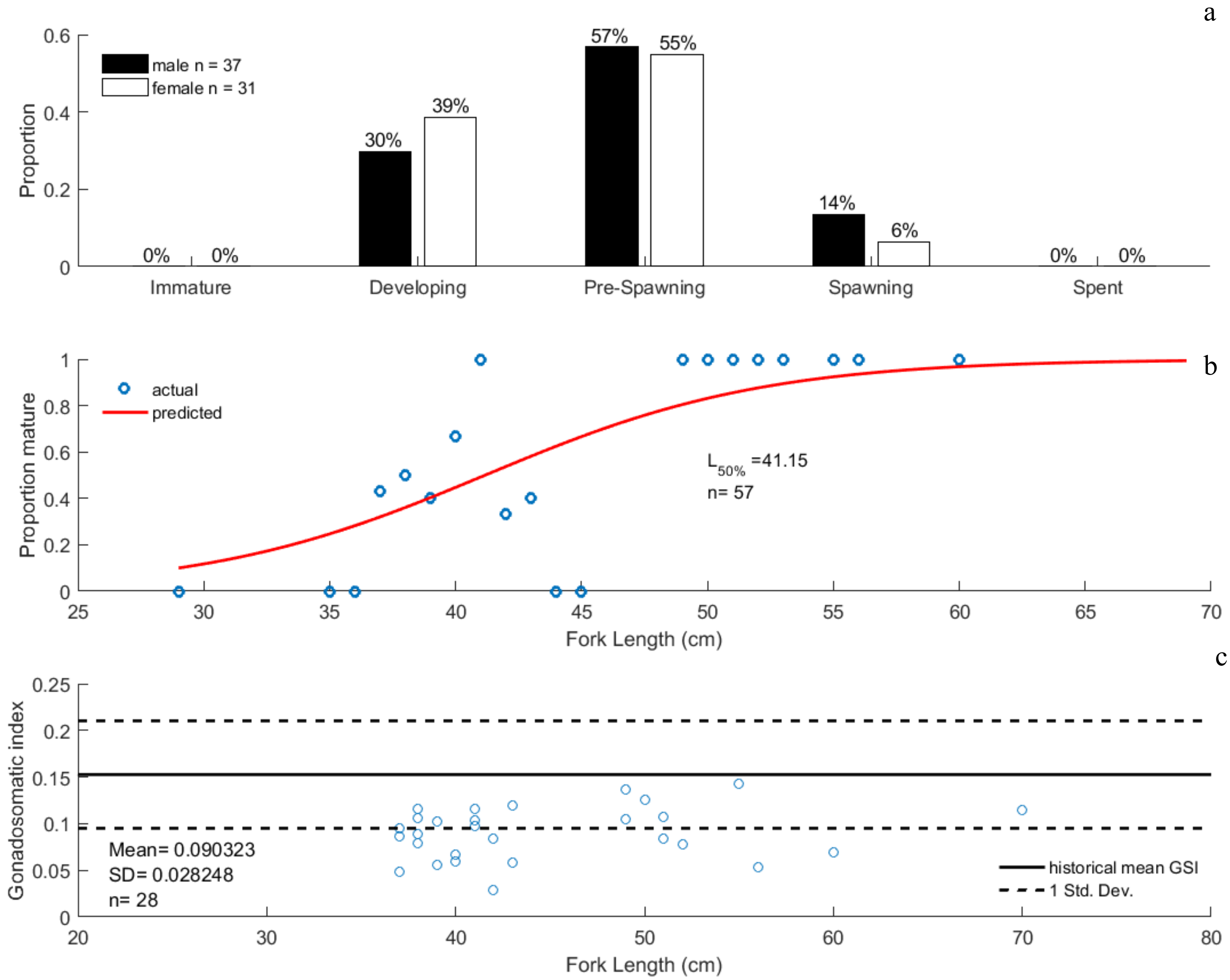


Figure 12. -- (a) Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage; (b) proportion mature (i.e., pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; and (c) gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2016 acoustic-trawl survey of the Sanak Trough. Note: these graphs do not include data from age-1 fish.

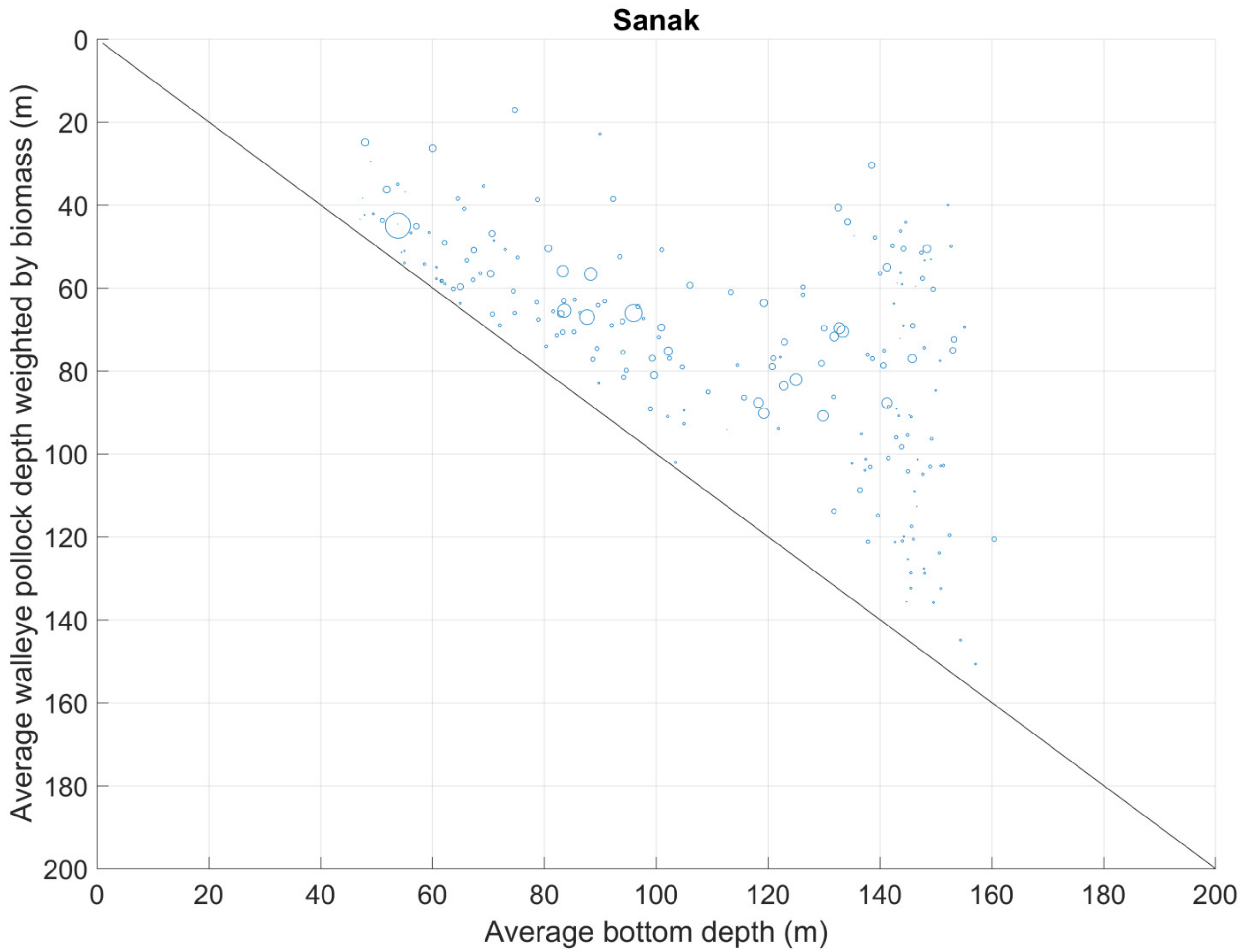


Figure 13. -- Average walleye pollock depth (weighted by biomass) versus bottom depth (m) during the winter 2016 acoustic-trawl survey of the Sanak area. Circle size is scaled to the maximum biomass per 0.5 nautical mile survey track interval. The diagonal line indicates where the average pollock depth equals bottom depth.

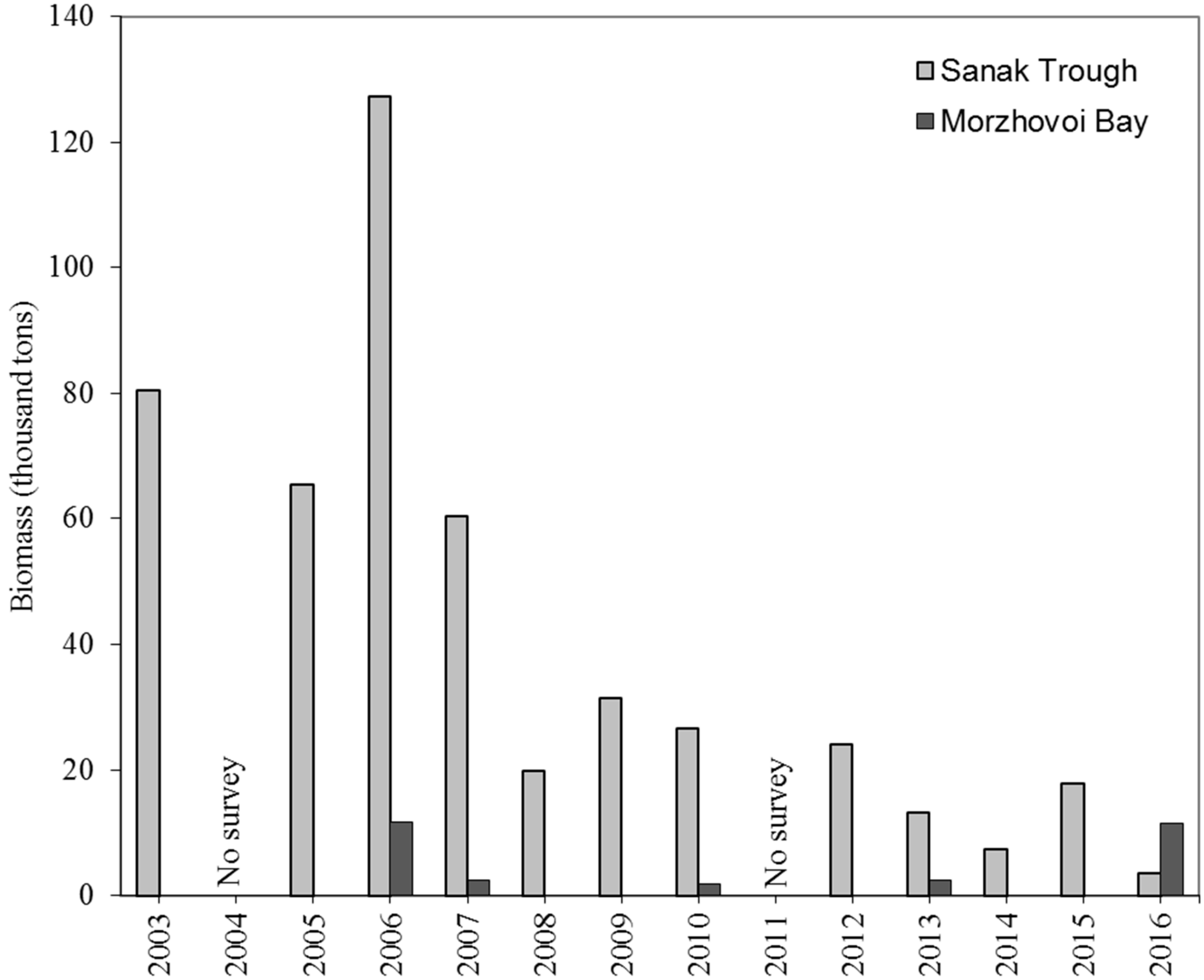


Figure 14. -- Summary of walleye pollock biomass estimates (thousand metric tons) based on acoustic-trawl surveys of the Sanak Trough and Morzhovi Bay areas.

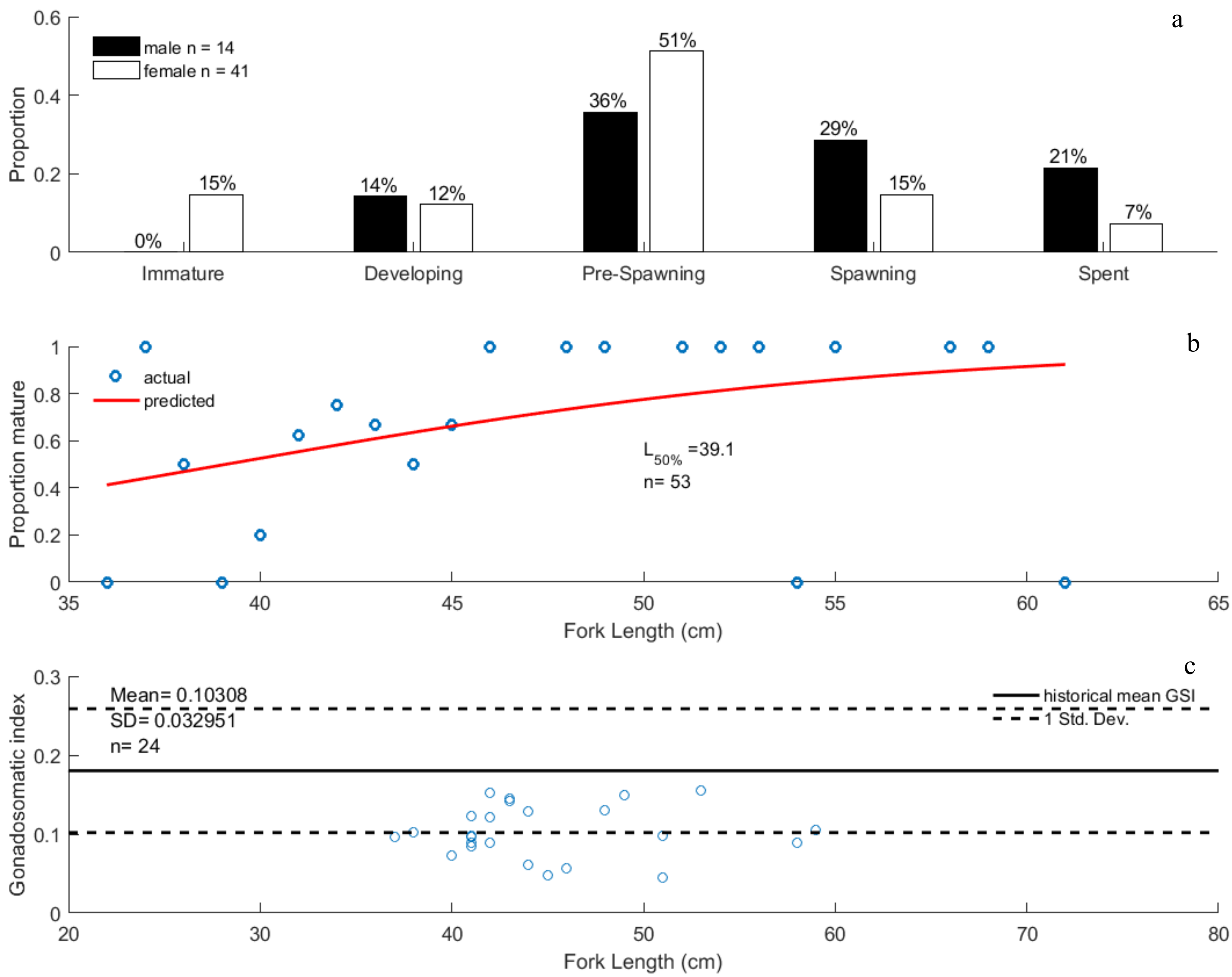


Figure 15. -- (a) Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage; (b) proportion mature (i.e., pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; and (c) gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2016 acoustic-trawl survey of Morzhovoi Bay. Note: these graphs do not include data from age-1 fish.

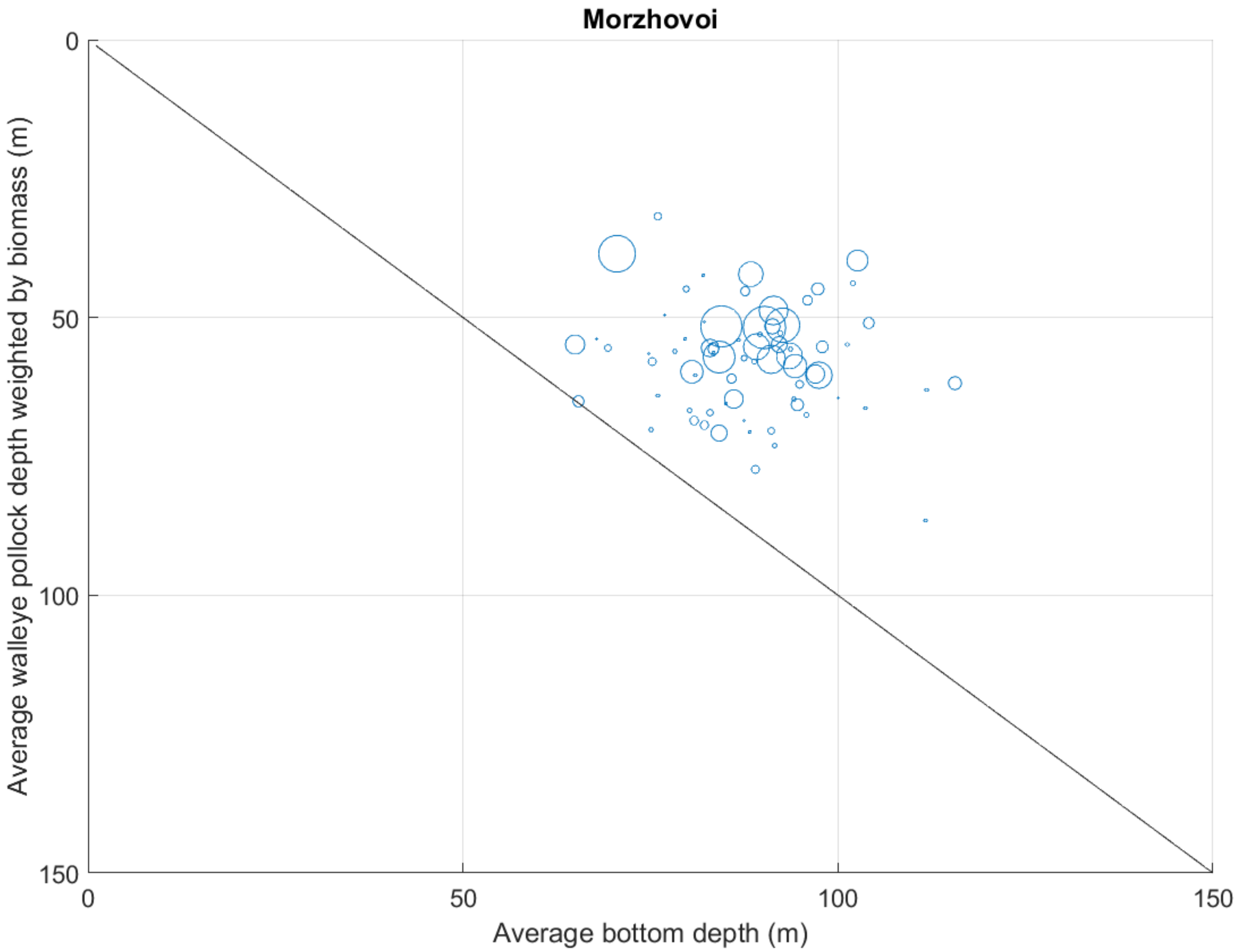


Figure 16. -- Average walleye pollock depth (weighted by biomass) versus bottom depth (m) during the winter 2016 acoustic-trawl survey of Morzhovoi Bay. Circle size is scaled to the maximum biomass per 0.5 nautical mile survey track interval. The diagonal line indicates where the average pollock depth equals bottom depth.

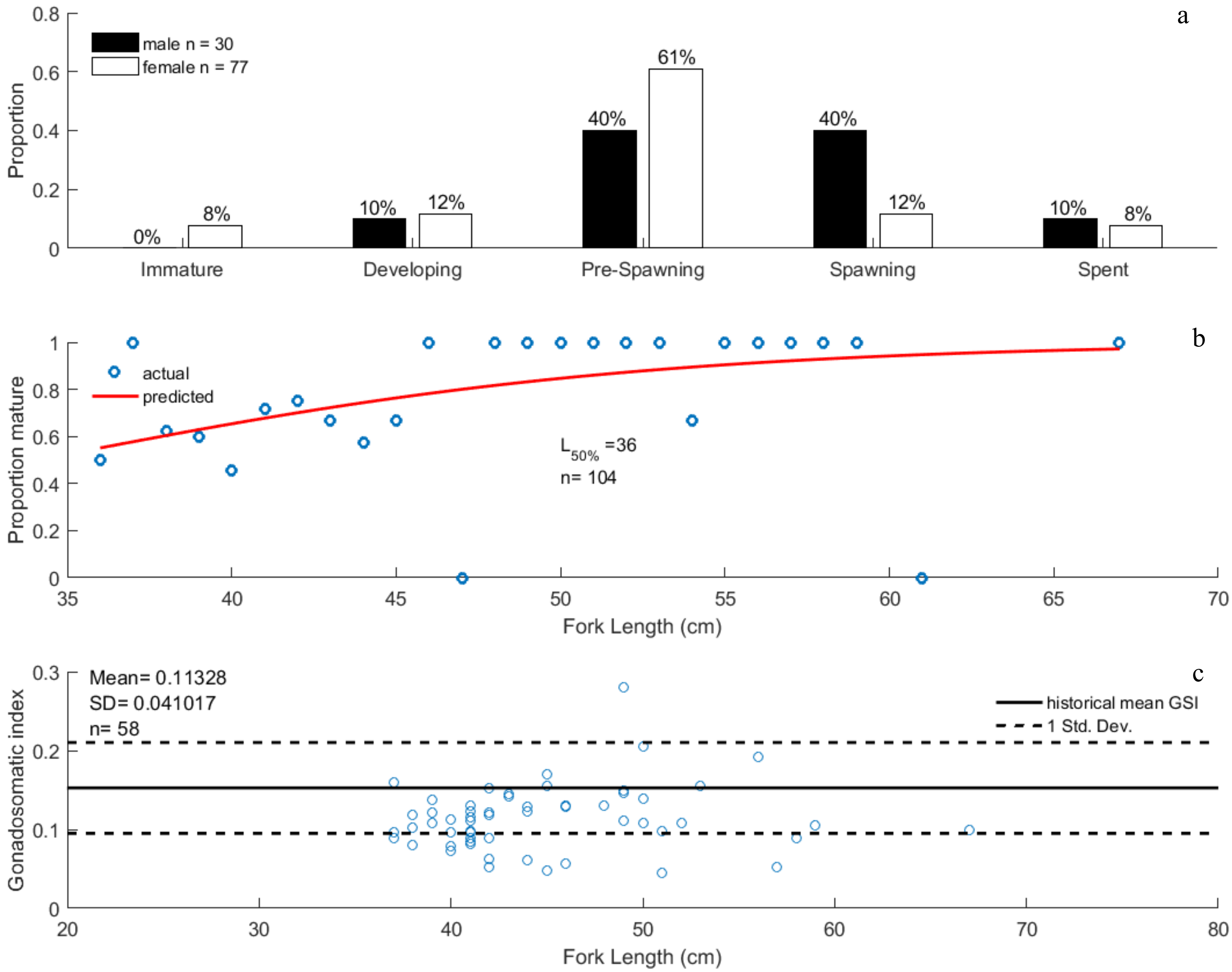


Figure 17. -- (a) Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage; (b) proportion mature (i.e., pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; and (c) gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2016 acoustic-trawl survey of Pavlof Bay. Note: these graphs do not include data from age-1 fish.

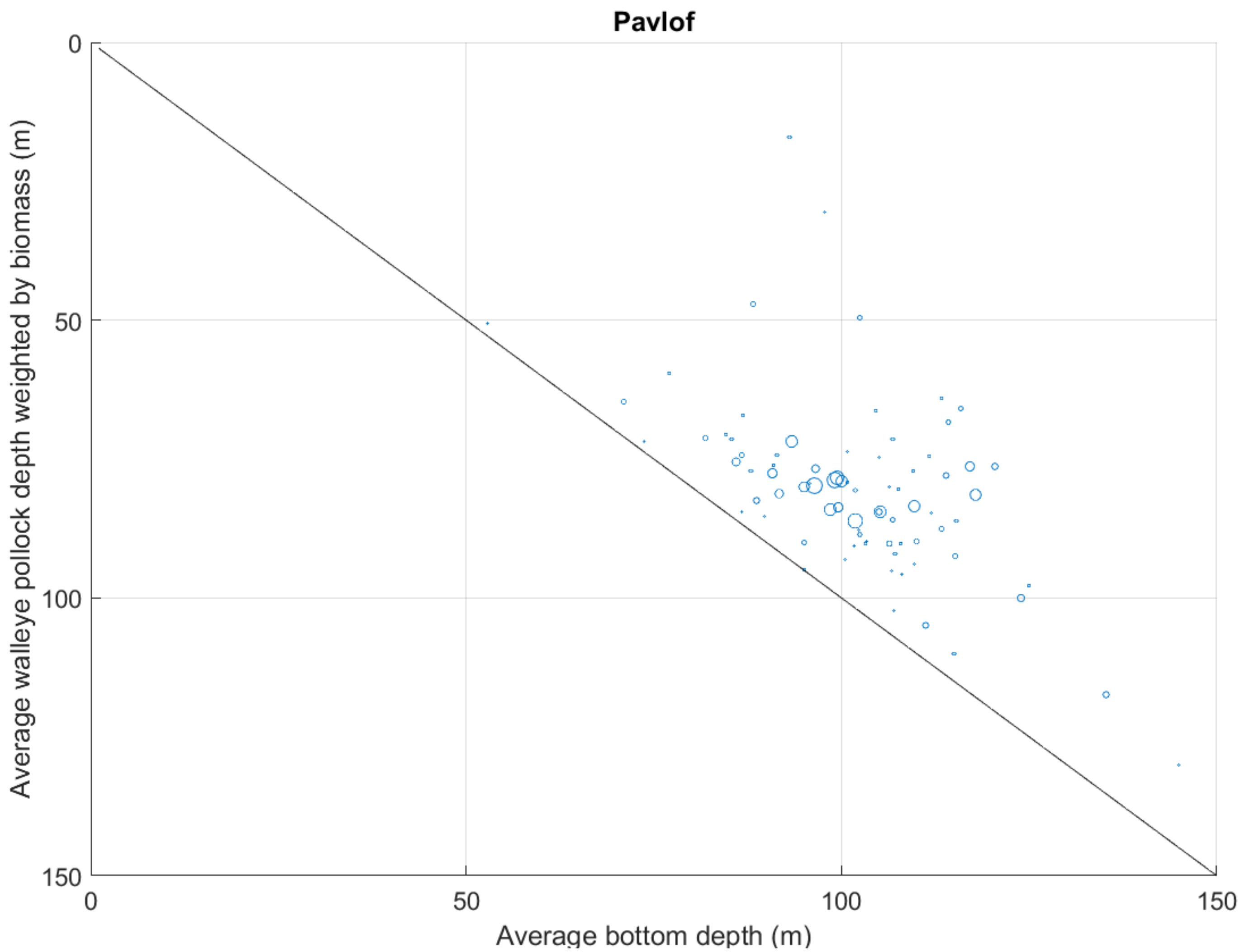


Figure 18. -- Average walleye pollock depth (weighted by biomass) versus bottom depth (m) during the winter 2016 acoustic-trawl survey of Pavlof Bay. Circle size is scaled to the maximum biomass per 0.5 nautical mile survey track interval. The diagonal line indicates where the average pollock depth equals bottom depth.

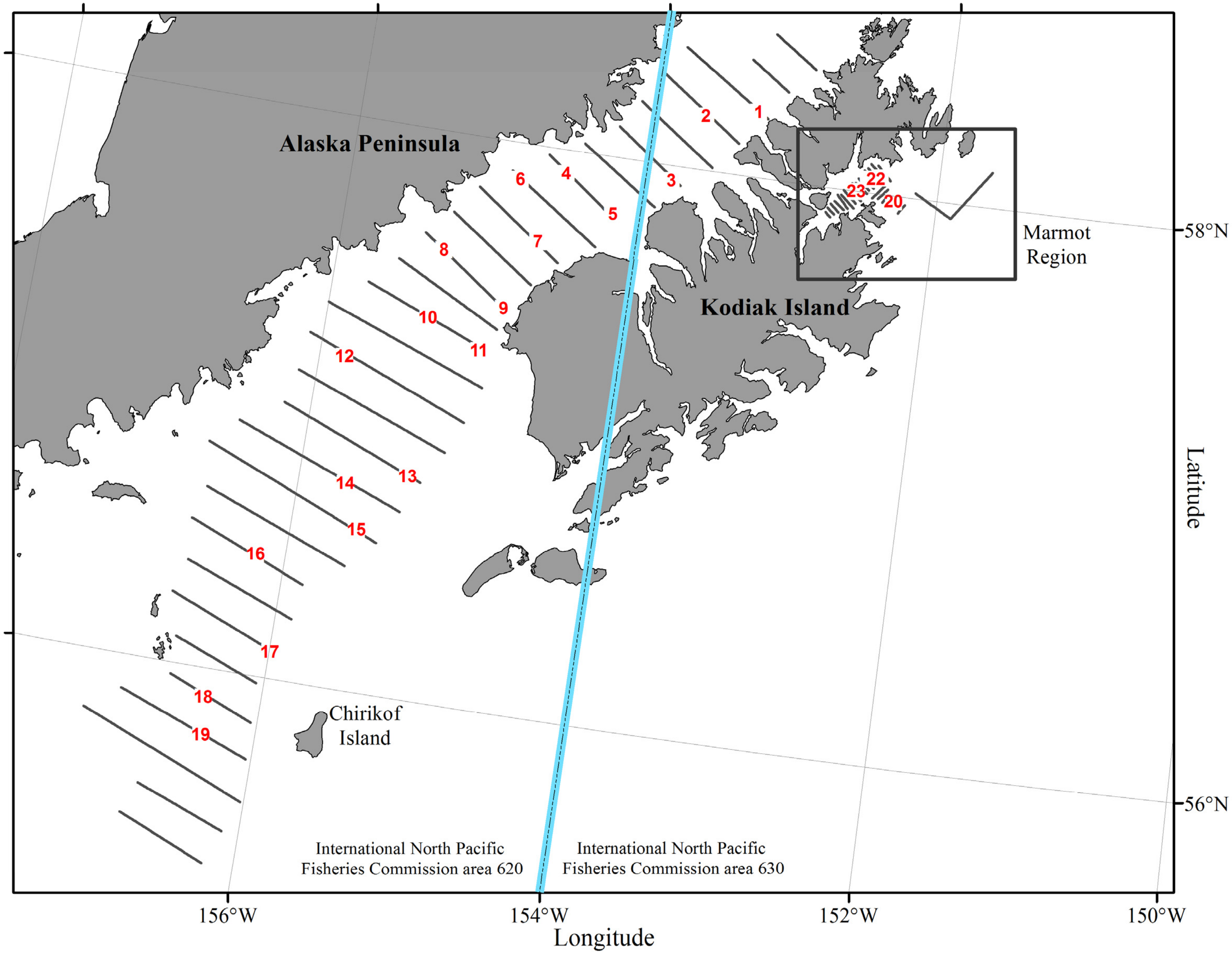


Figure 19. -- Transect lines and locations of Aleutian wing trawl (AWT) hauls (denoted by red numbers) during the winter 2016 acoustic-trawl survey of walleye pollock in Shelikof Strait and Marmot Bay. Haul numbers are on top of haul symbols. Box indicates area enlarged in Figure 29.

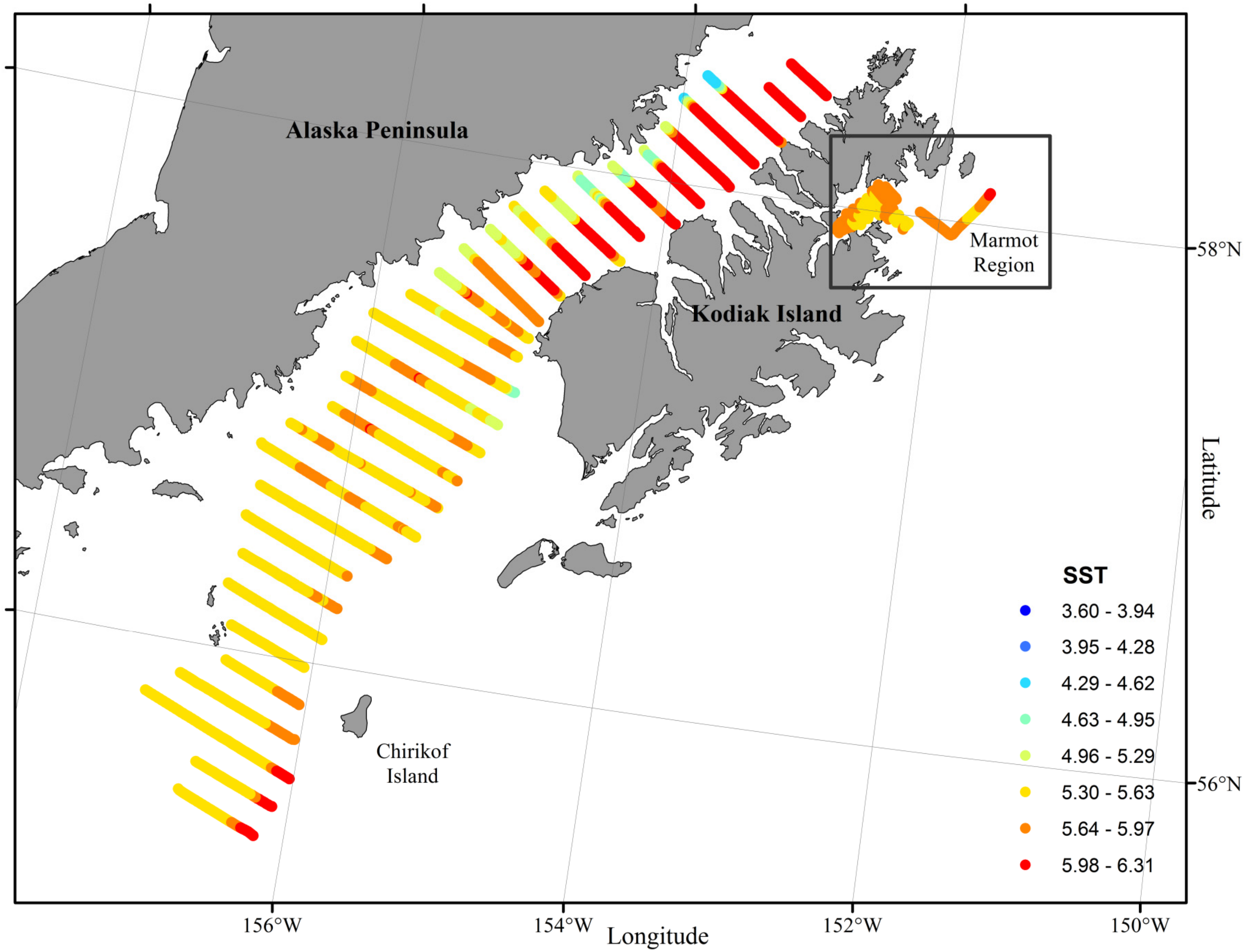


Figure 20. -- Surface water temperatures (°C) during the 2016 acoustic-trawl survey of Shelikof Strait and Marmot Bay. Box indicates area enlarged in Figure 30.

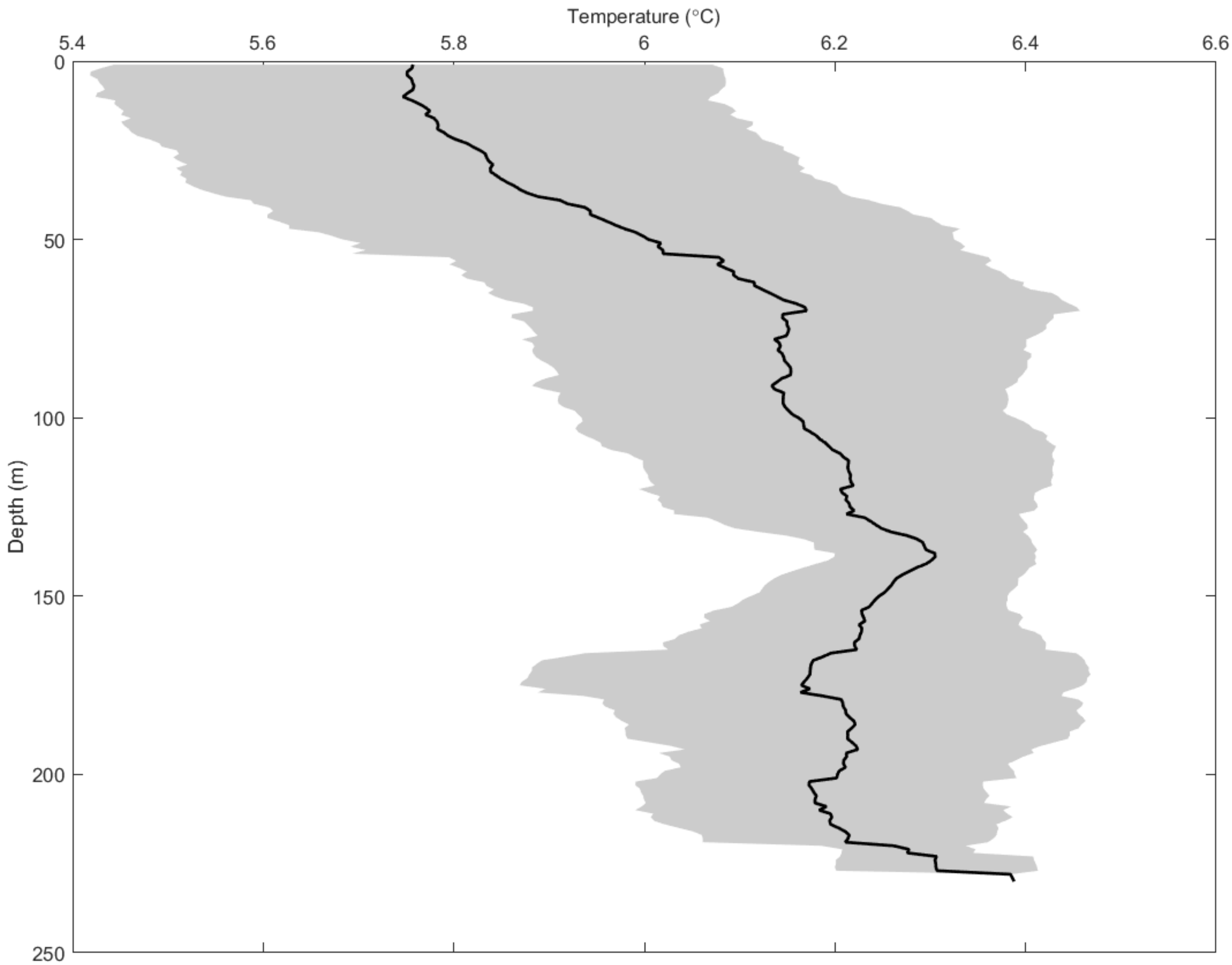


Figure 21. -- Mean water temperature (°C; solid line) by 1-m depth intervals for the 19 trawl haul locations observed during the winter 2016 acoustic-trawl survey of walleye pollock in Shelikof Strait. The shaded area represents one standard deviation.

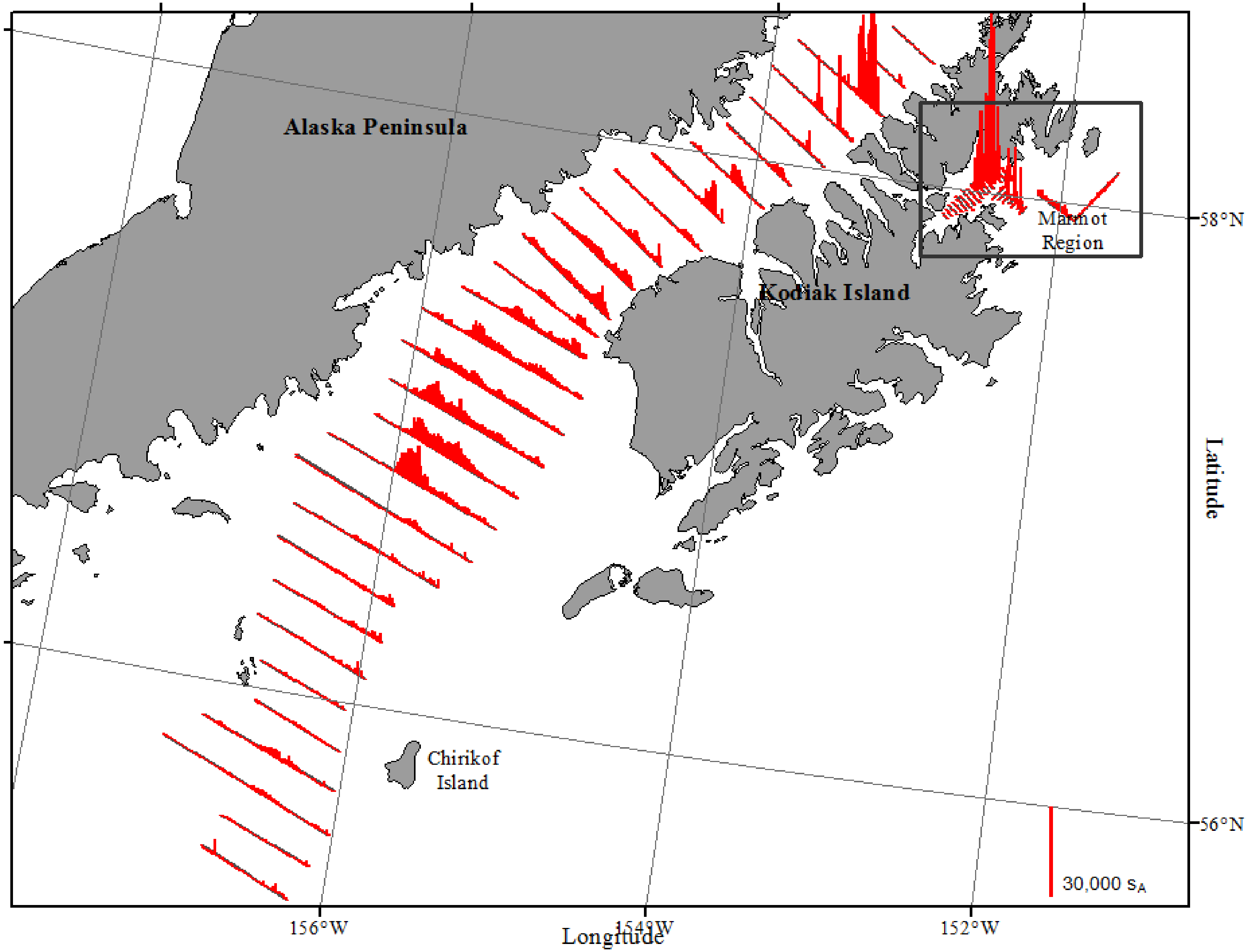


Figure 22. -- Backscatter (s_A) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2016 acoustic-trawl survey of the Shelikof Strait and Marmot Bay. The Marmot Bay region is shown in Figure 33.

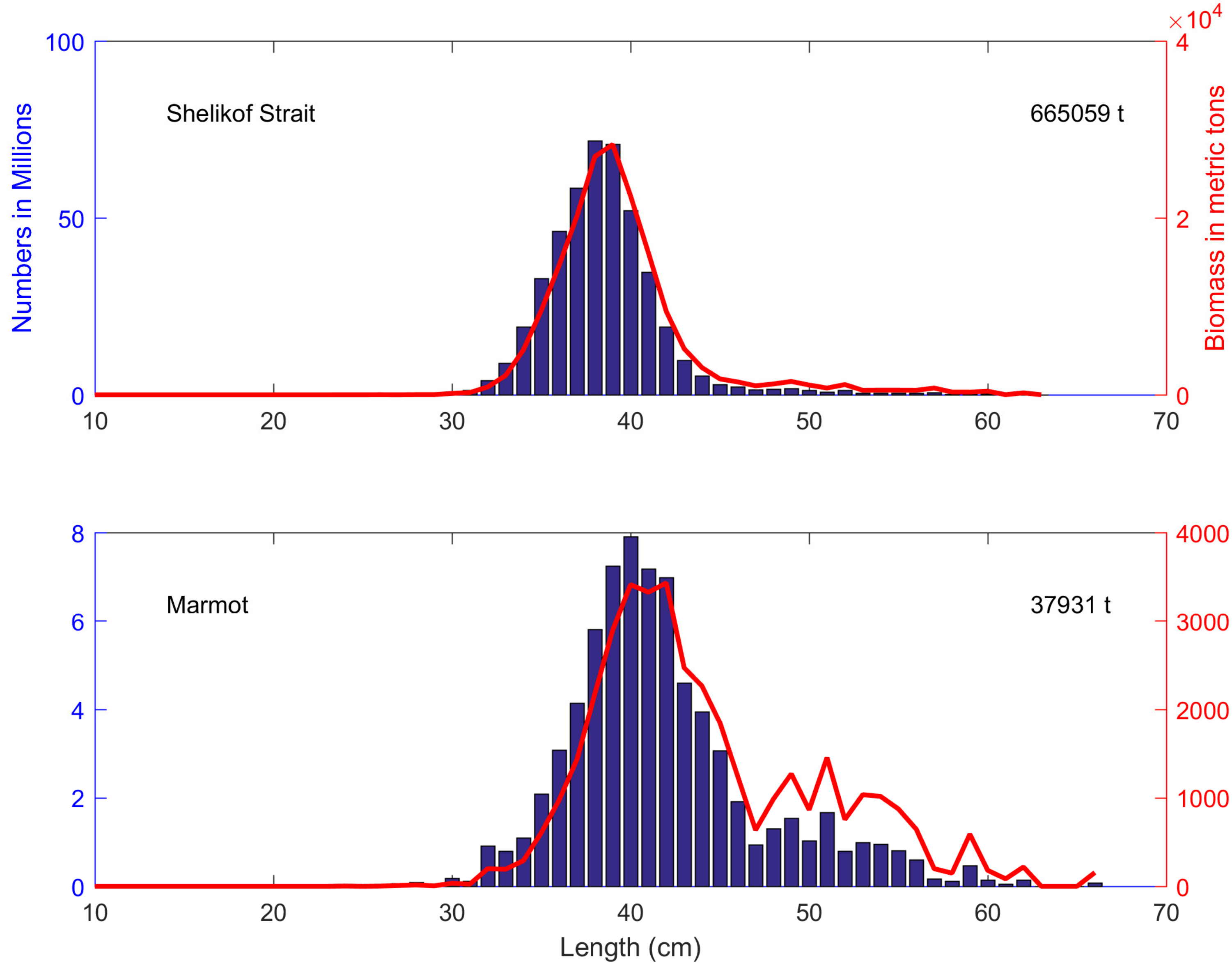


Figure 23. -- Length distribution of walleye pollock shown with blue bars (numbers) and biomass estimate in red line (metric tons, t) for the 2016 acoustic-trawl survey of the Shelikof Strait and Marmot Bay.

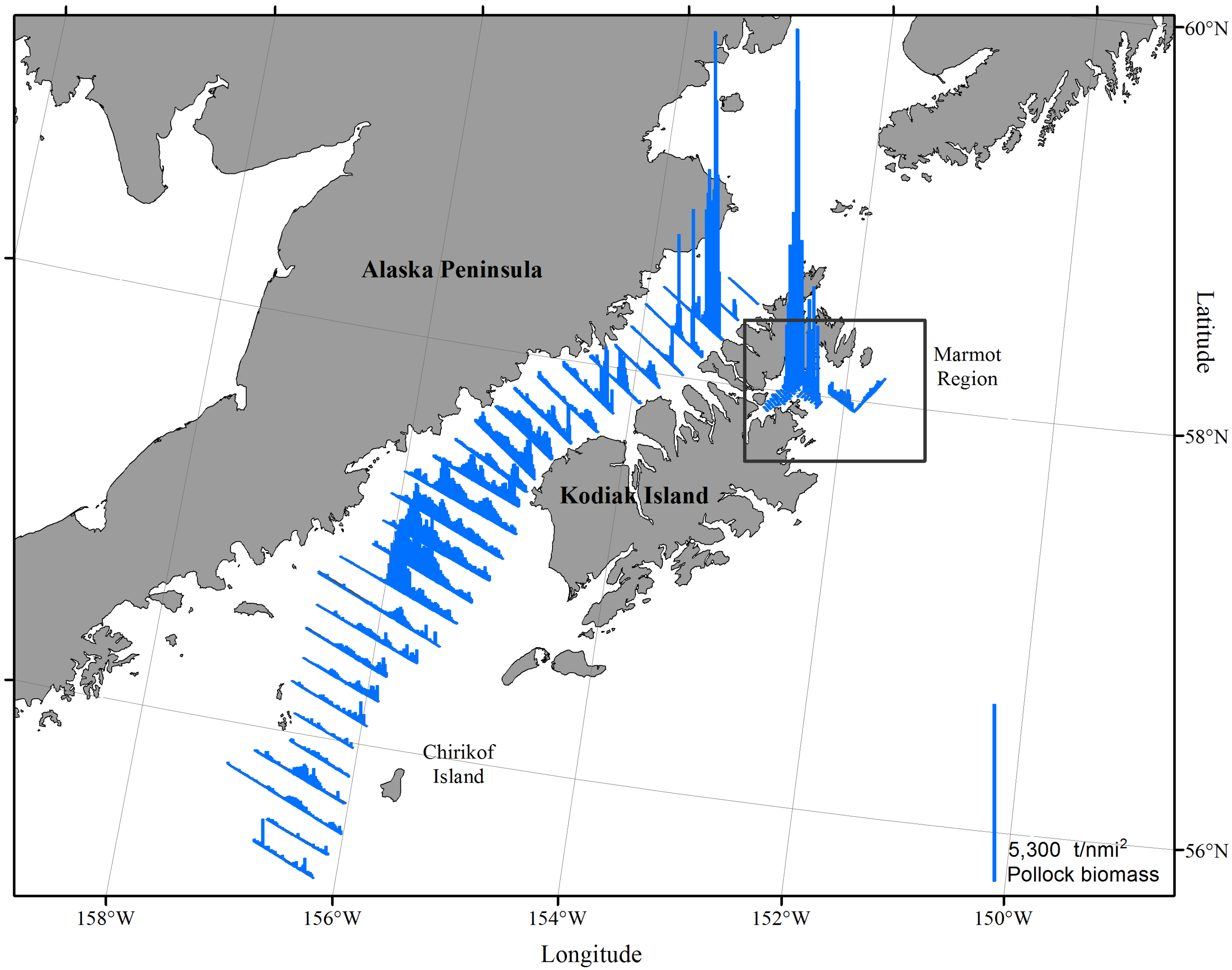


Figure 24. -- Biomass (t/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2016 acoustic-trawl survey of Shelikof Strait and Marmot Bay. Box indicates area enlarged in Figure 35.

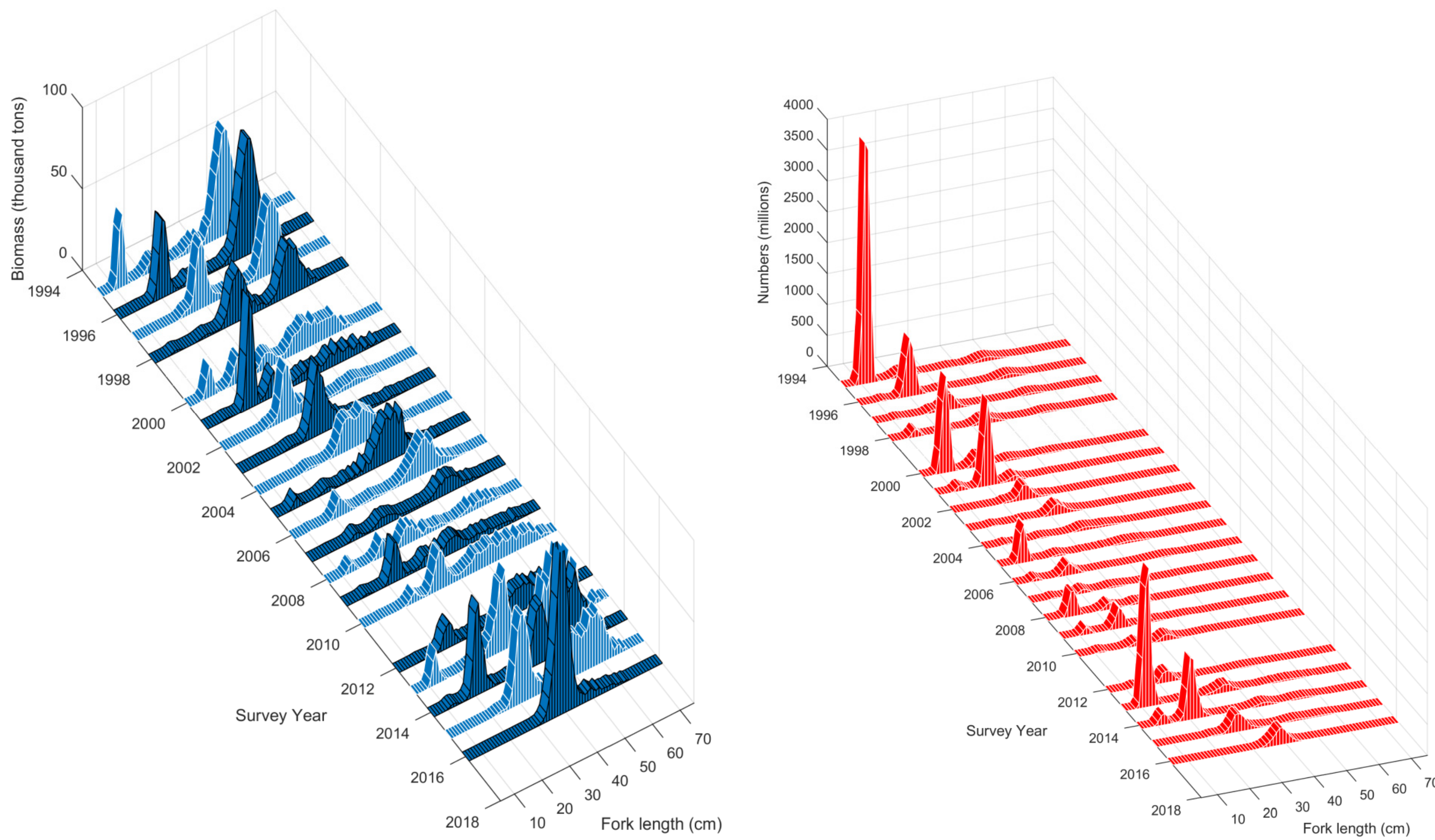


Figure 25. -- Walleye pollock biomass in thousands of metric tons (left) and numbers (right) at length from the Shelikof Strait acoustic-trawl surveys since 1995. No surveys were conducted in 1999 or 2011.

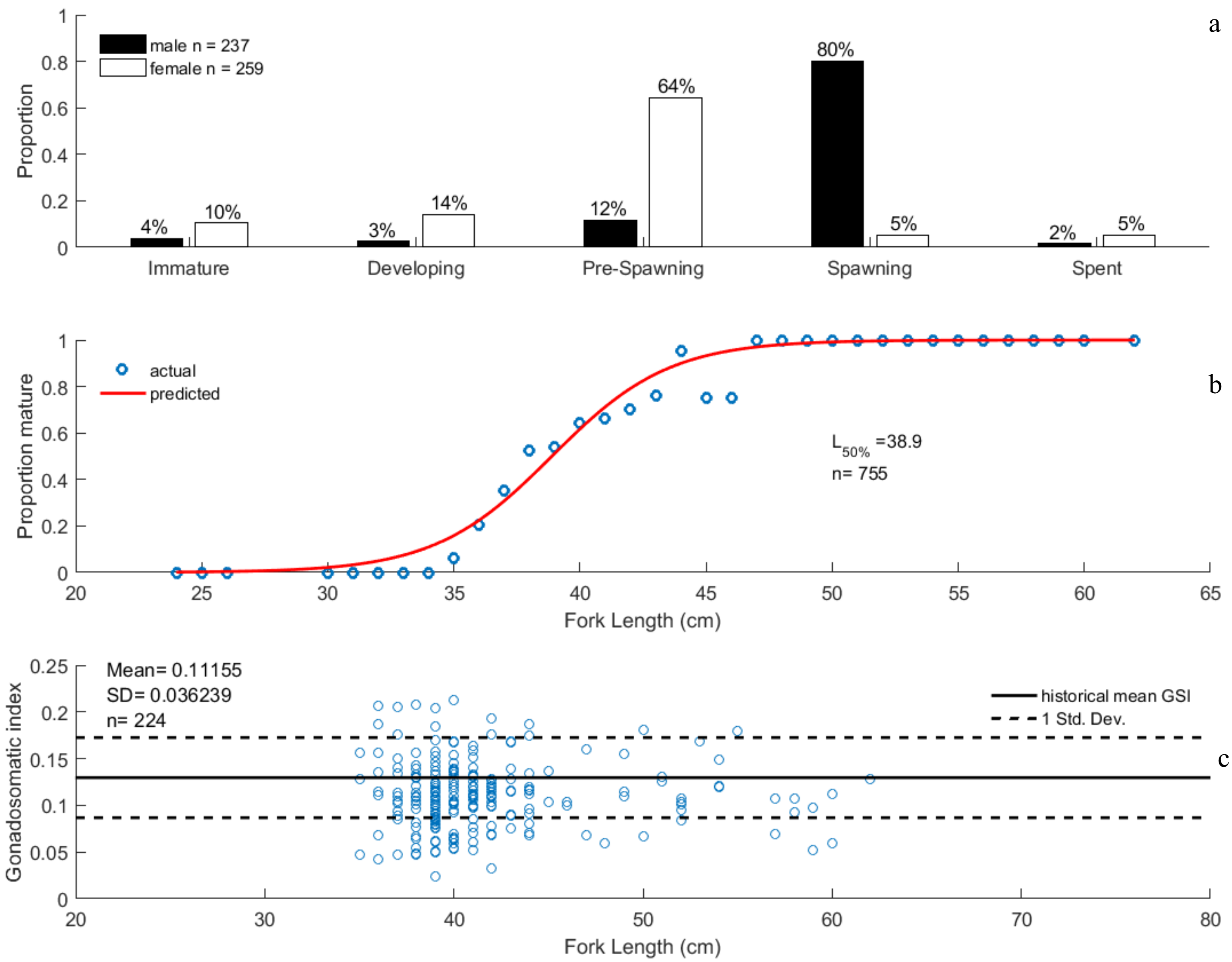


Figure 26. -- (a) Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage; (b) proportion mature (i.e., pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; and (c) gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2016 acoustic-trawl survey of the Shelikof Strait region. Note: these graphs do not include data from age-1 fish.

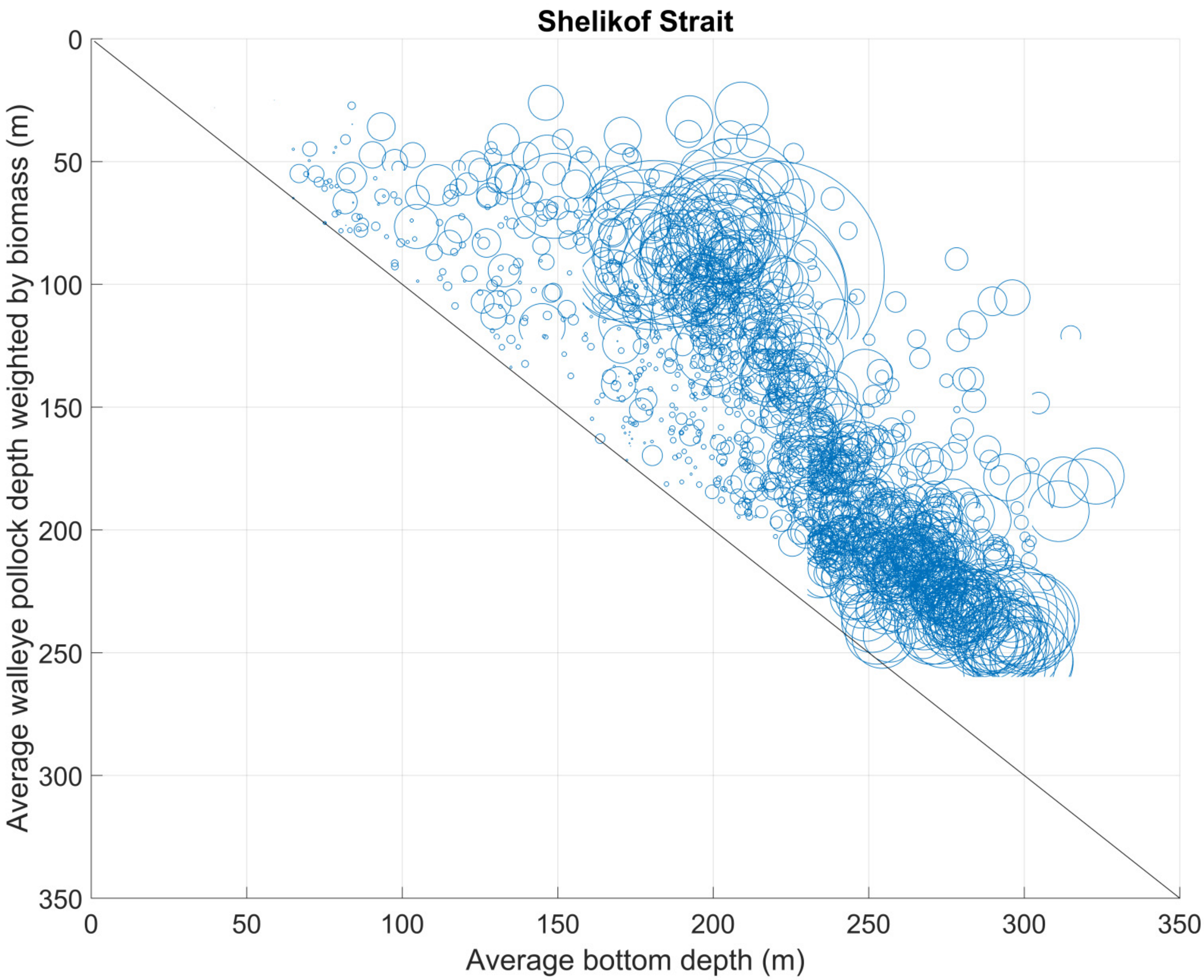


Figure 27. -- Average pollock depth (weighted by biomass) versus bottom depth (m) for walleye pollock observed during the winter 2016 acoustic-trawl survey of Shelikof Strait area. Circle size is scaled to the maximum biomass per 0.5 nautical mile survey track interval. The diagonal line indicates where the average fish depth equals bottom depth.

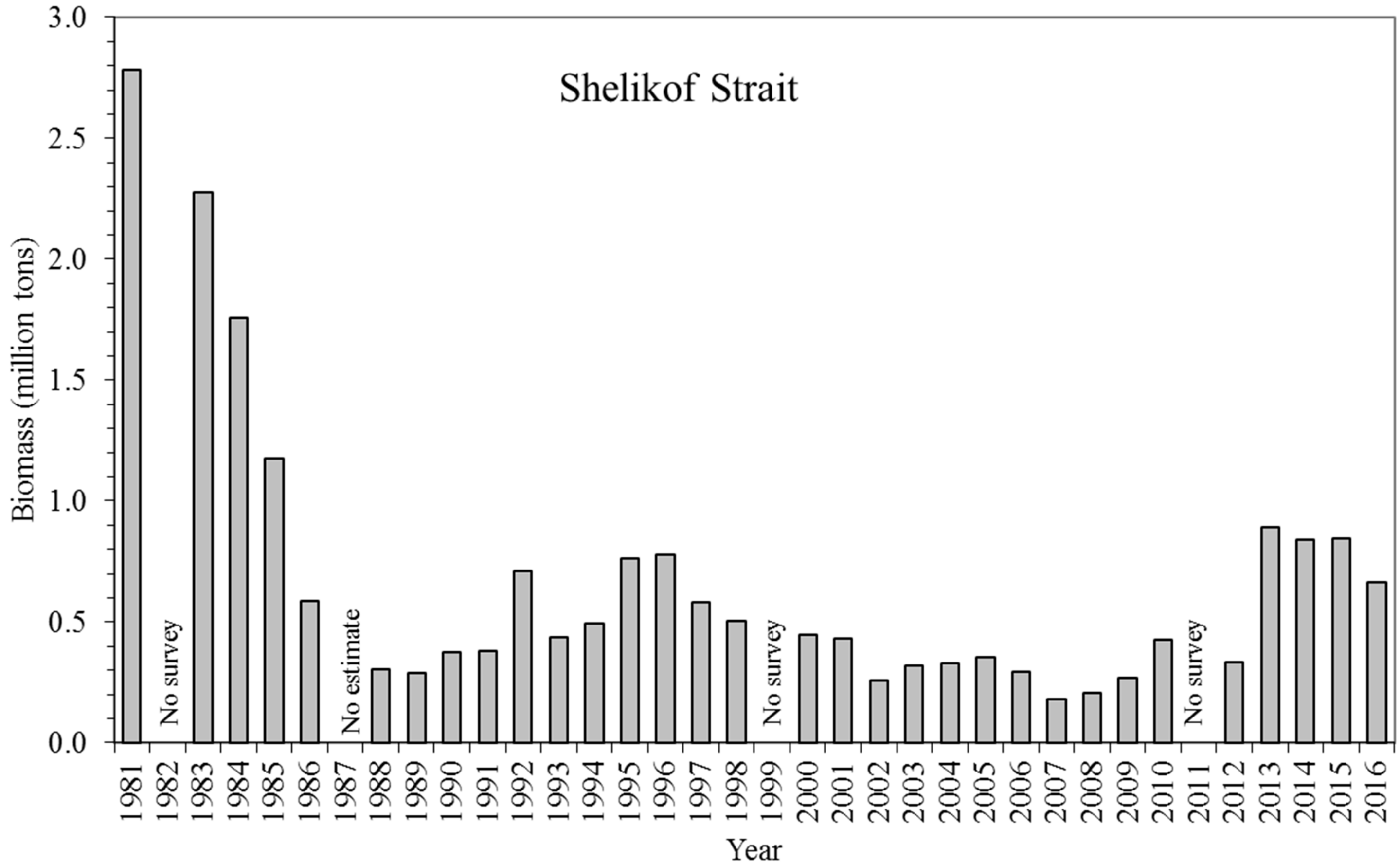


Figure 28. -- Summary of walleye pollock biomass estimates (million metric tons) based on acoustic-trawl surveys of the Shelikof Strait area.

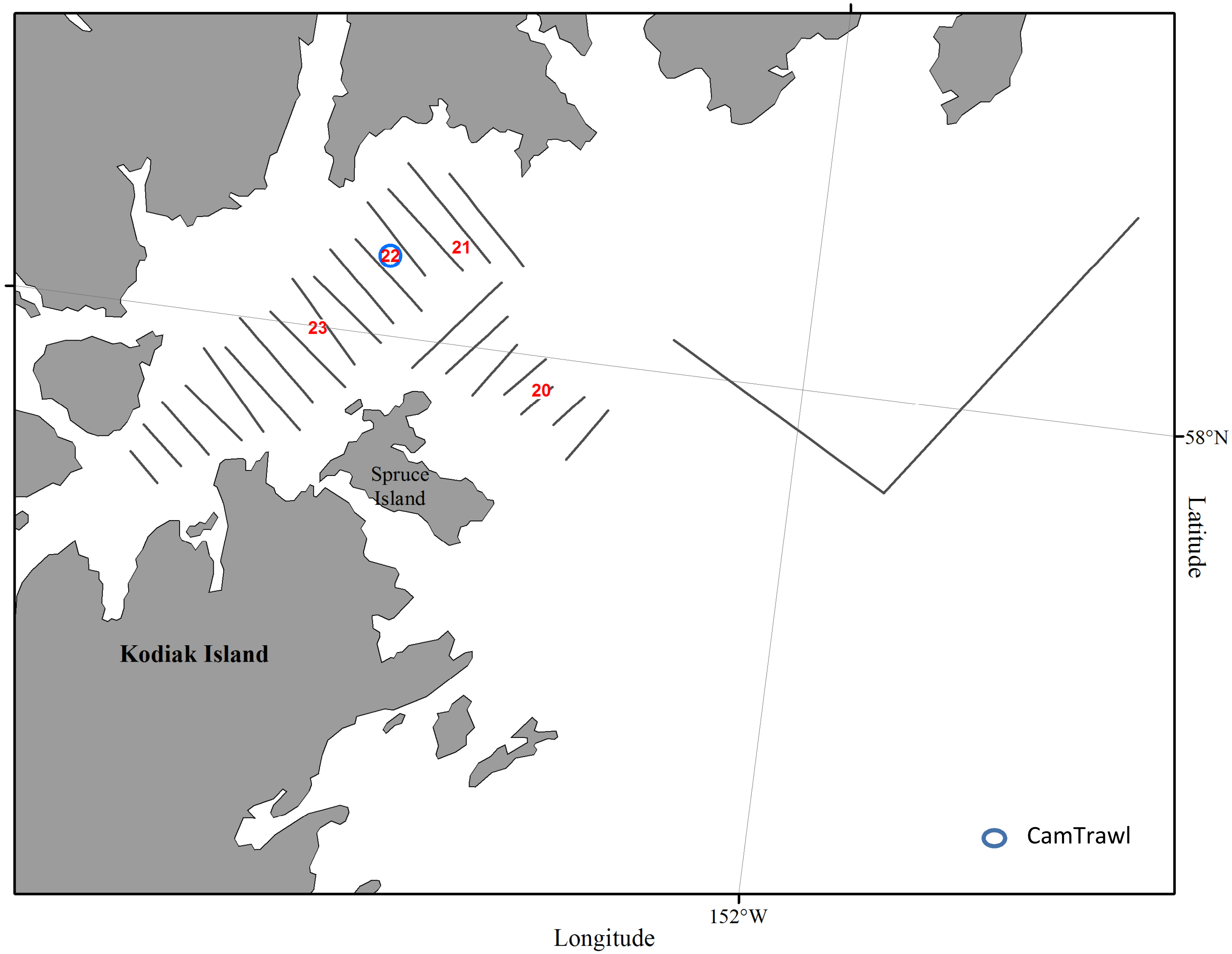


Figure 29. -- Transect lines and locations of Aleutian wing trawl (AWT) and CamTrawl hauls (hauls denoted by red numbers) during the winter 2016 acoustic-trawl survey of walleye pollock in Marmot Bay.

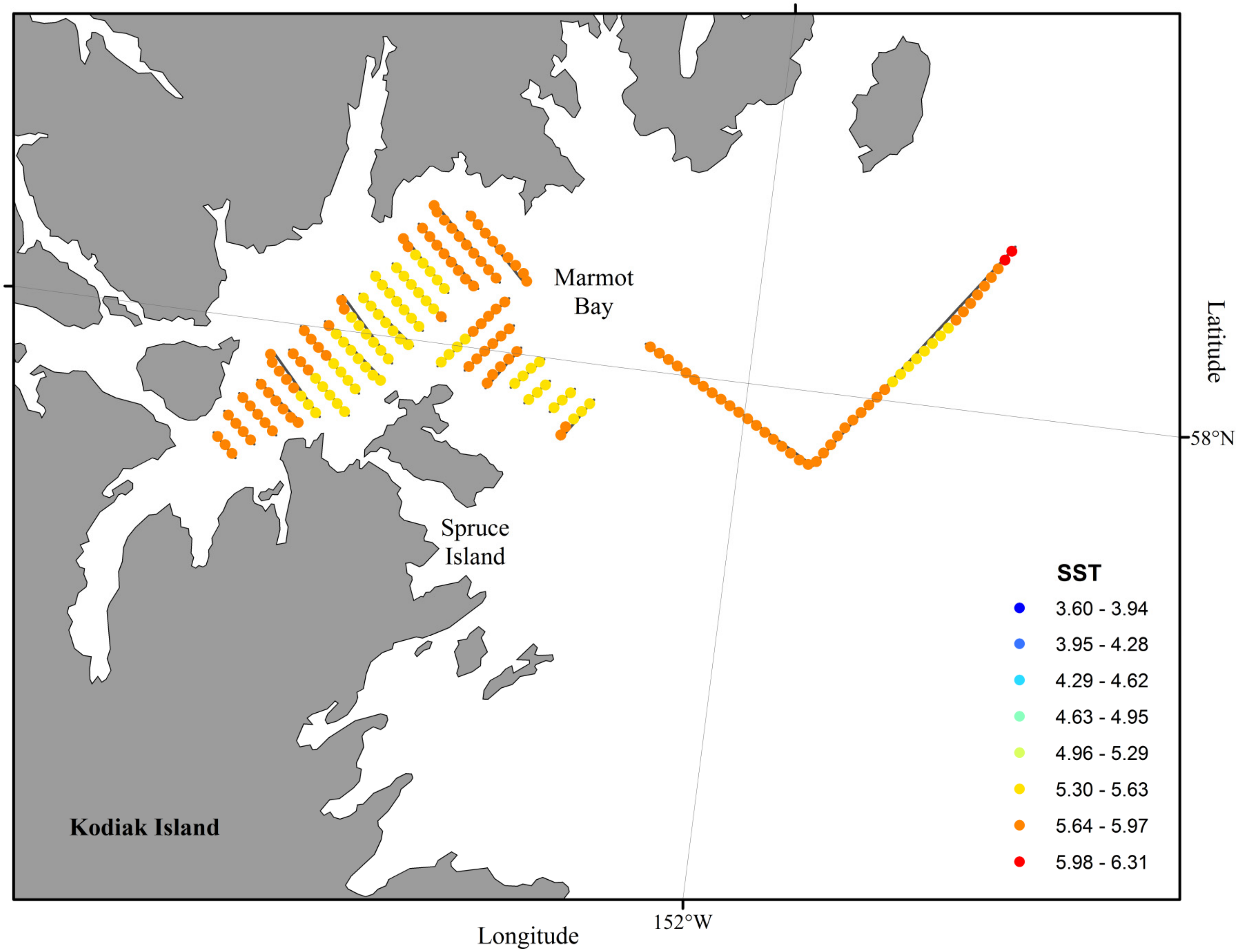


Figure 30. -- Surface water temperatures (°C) during the 2016 acoustic-trawl survey of Marmot Bay.

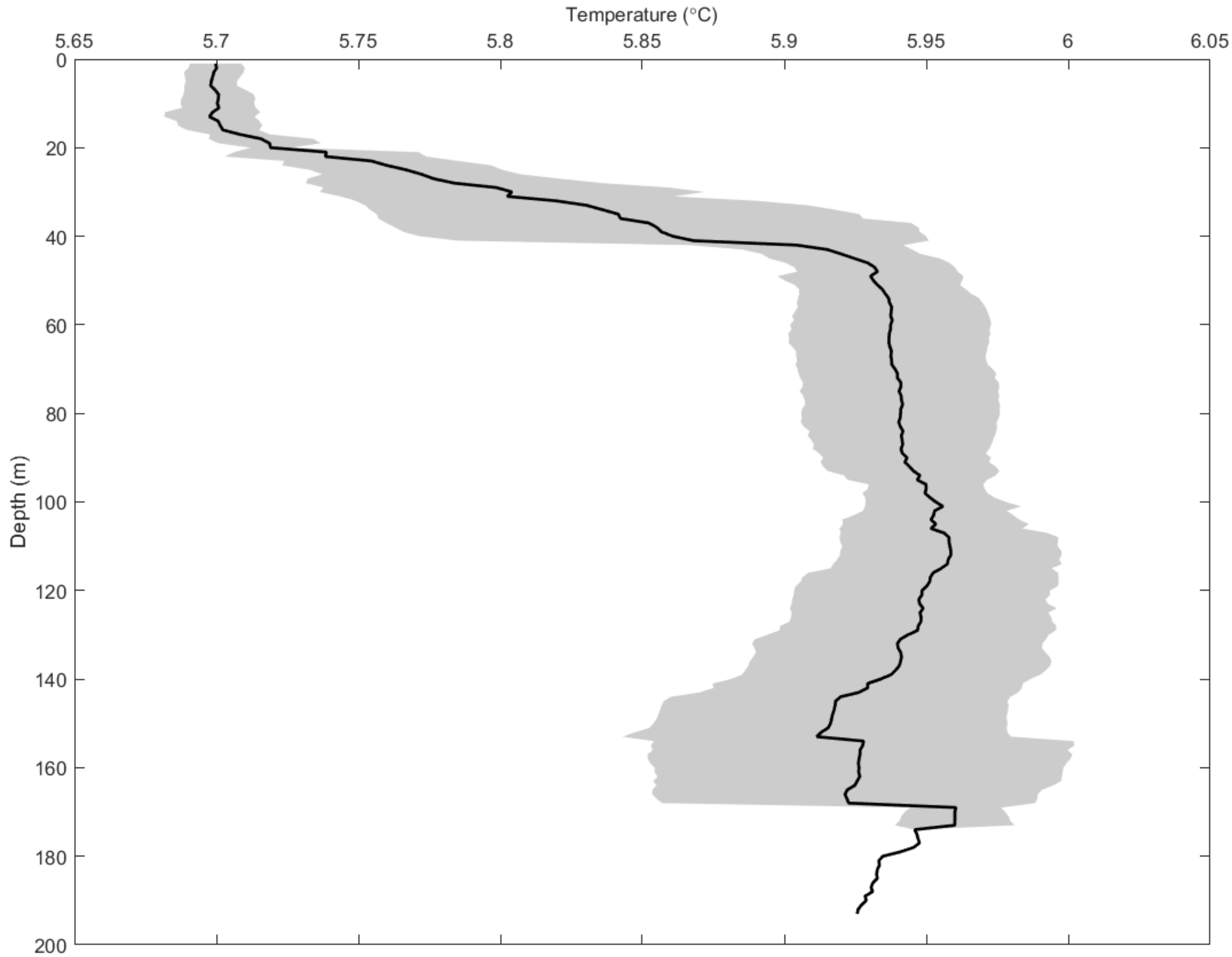


Figure 31. -- Mean water temperature (°C; solid line) by 1-m depth intervals for the four trawl haul locations observed during the winter 2016 acoustic-trawl survey of walleye pollock in Marmot Bay, shaded area represents one standard deviation.

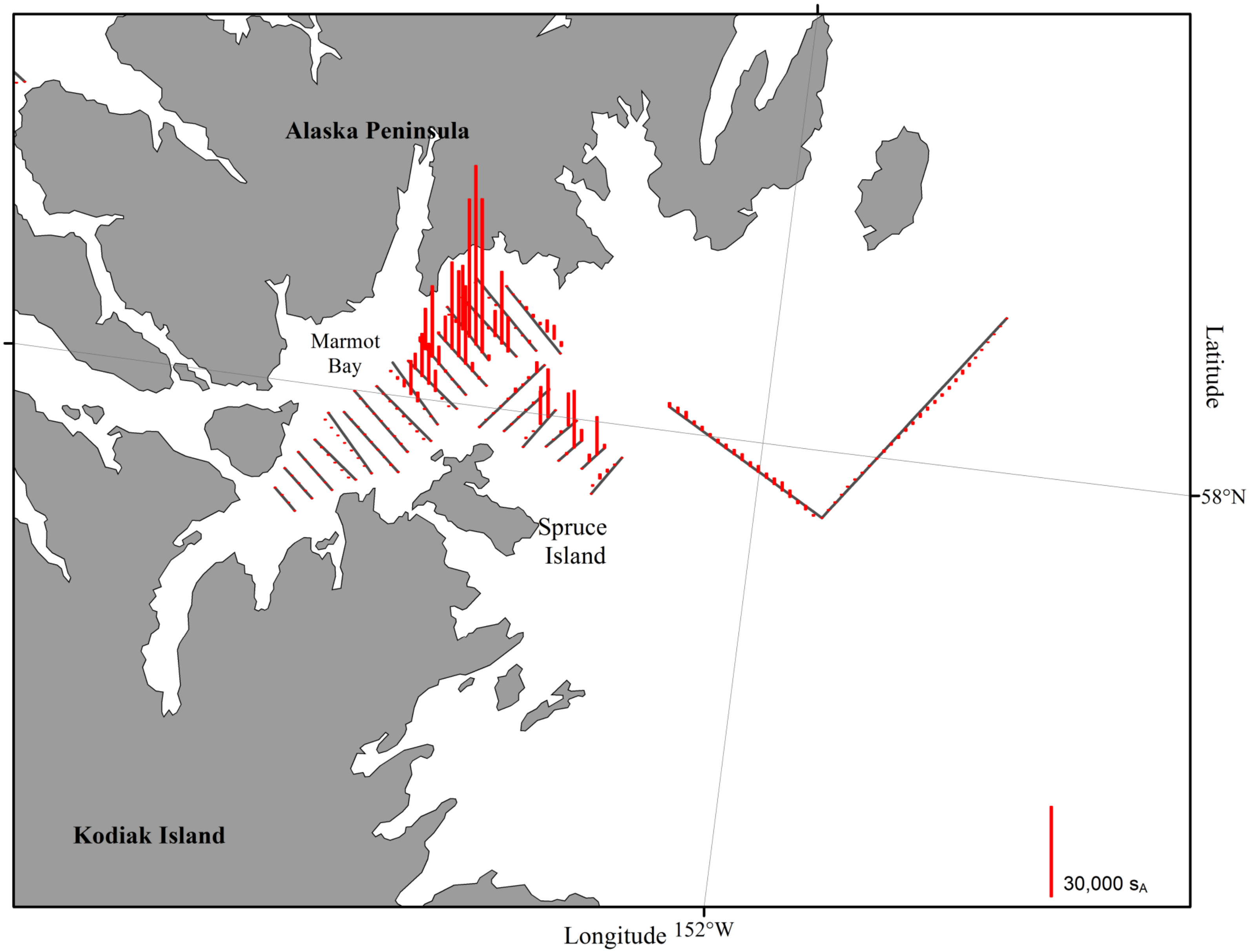


Figure 32. -- Backscatter (s_A) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2016 acoustic-trawl survey of Marmot Bay.

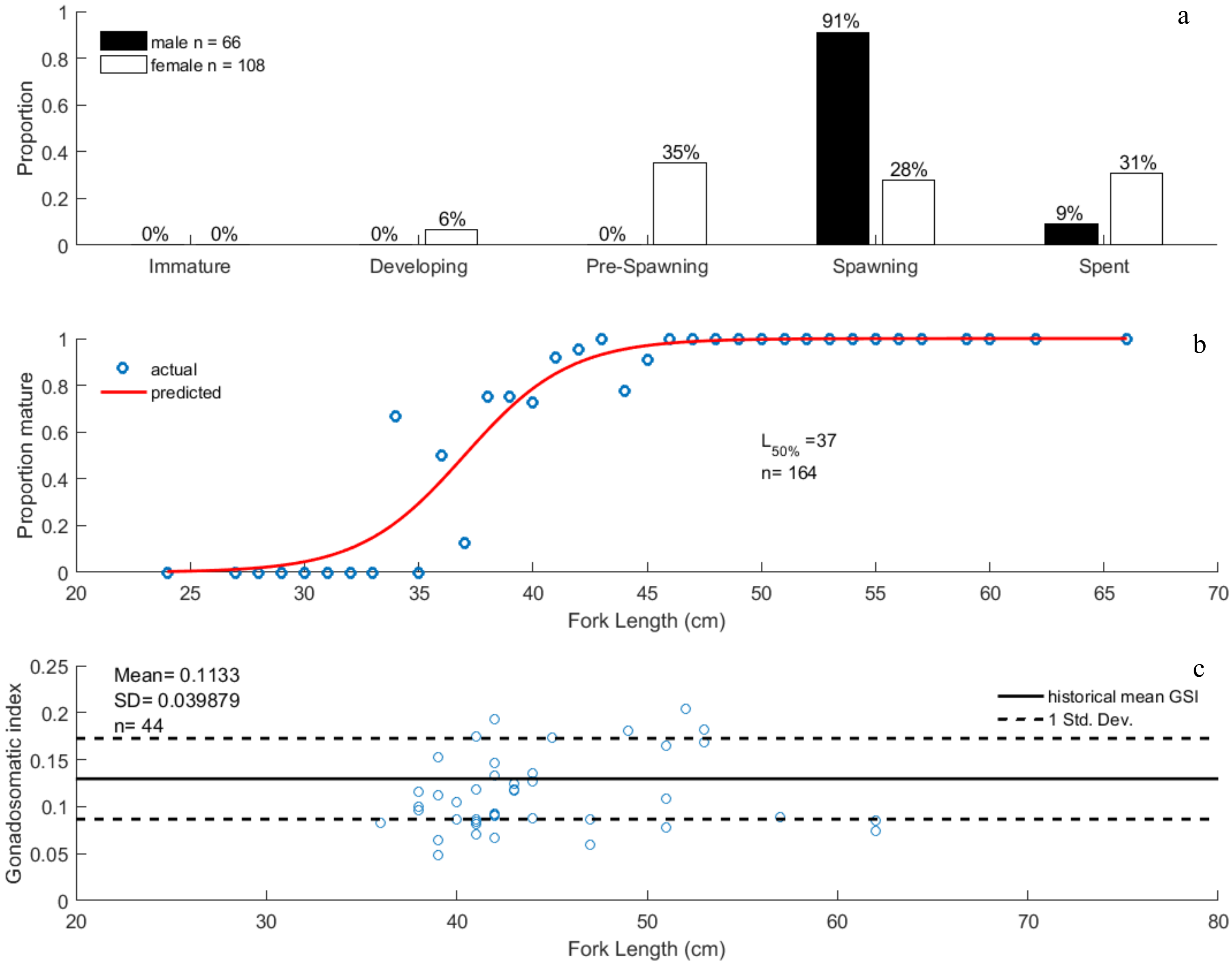


Figure 33. -- (a) Maturity stages and percentage of fish greater than 40 cm FL within each stage for male and female walleye pollock; (b) proportion mature (i.e., pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; and (c) gonadosomatic index (with historic survey mean, and minimum and maximum of historic survey means) for pre- spawning females examined during the 2016 acoustic-trawl survey of the Marmot Bay area. Note: these graphs do not include data from age-1 fish.

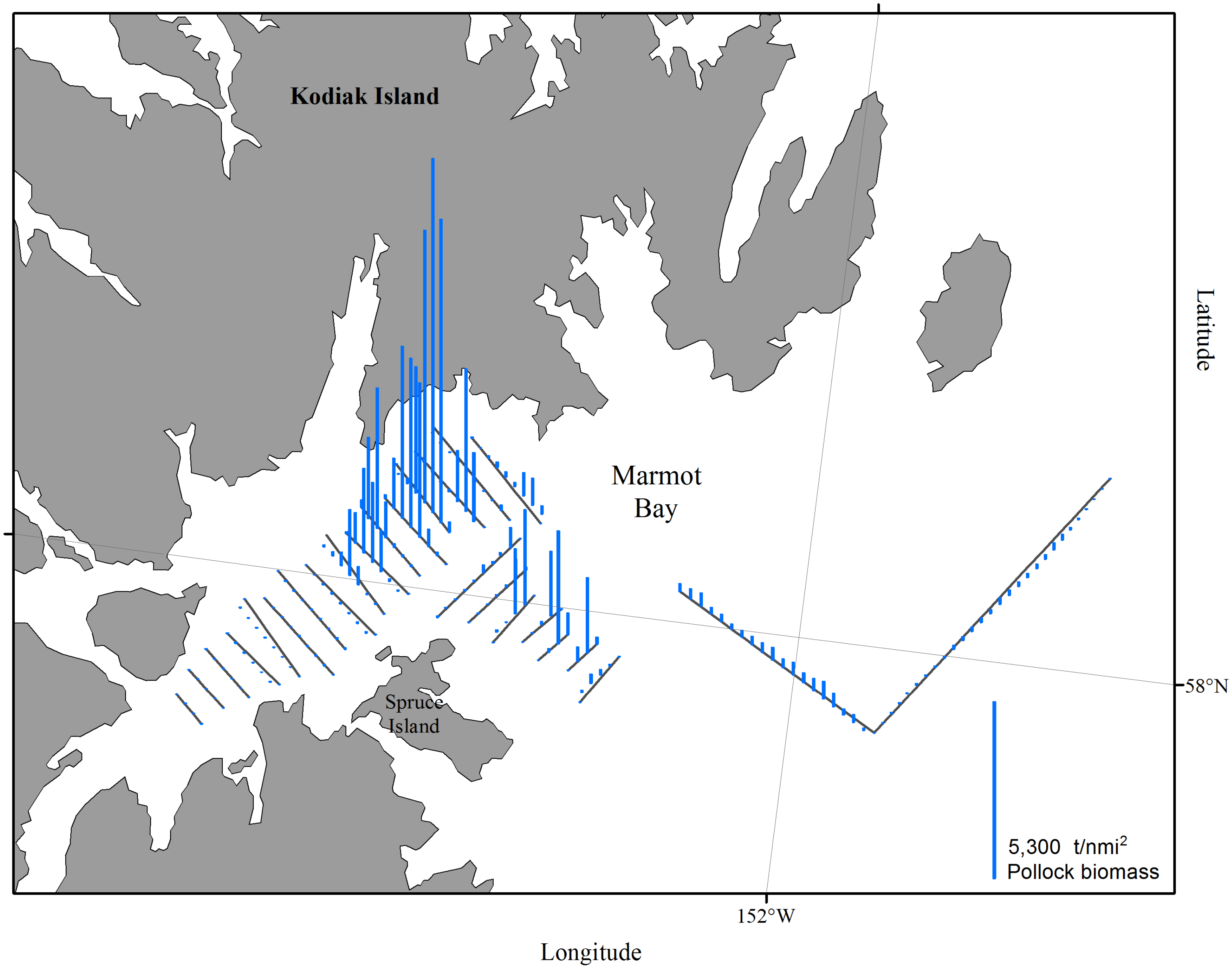


Figure 34. -- Biomass (t/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2016 acoustic-trawl survey of Marmot Bay.

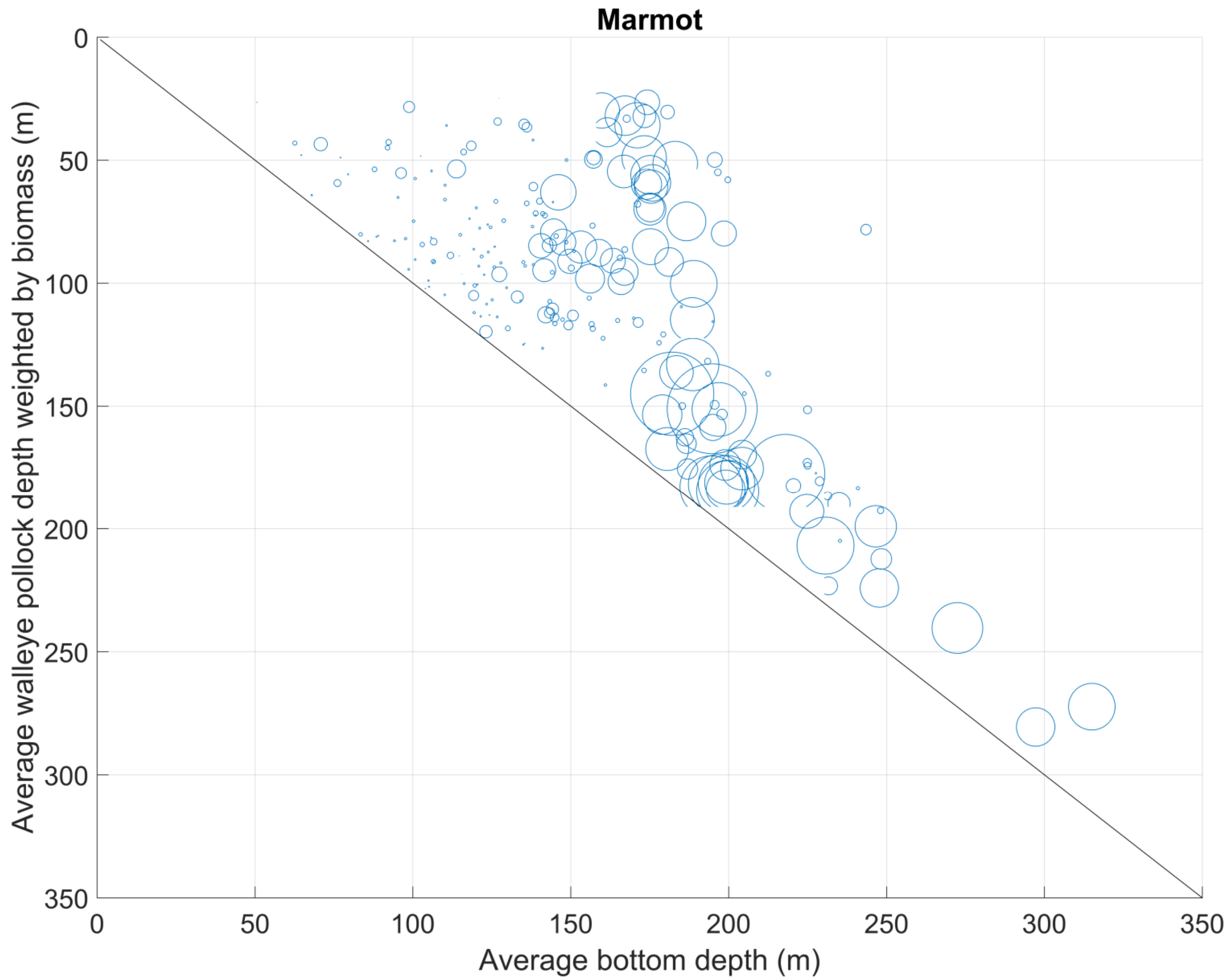


Figure 35. -- Average pollock depth (weighted by biomass) versus bottom depth (m) for walleye pollock observed during the winter 2016 acoustic-trawl survey of Marmot Bay. Circle size is scaled to the maximum biomass per 0.5 nautical mile survey track interval. The diagonal line indicates where the average fish depth equals bottom depth.

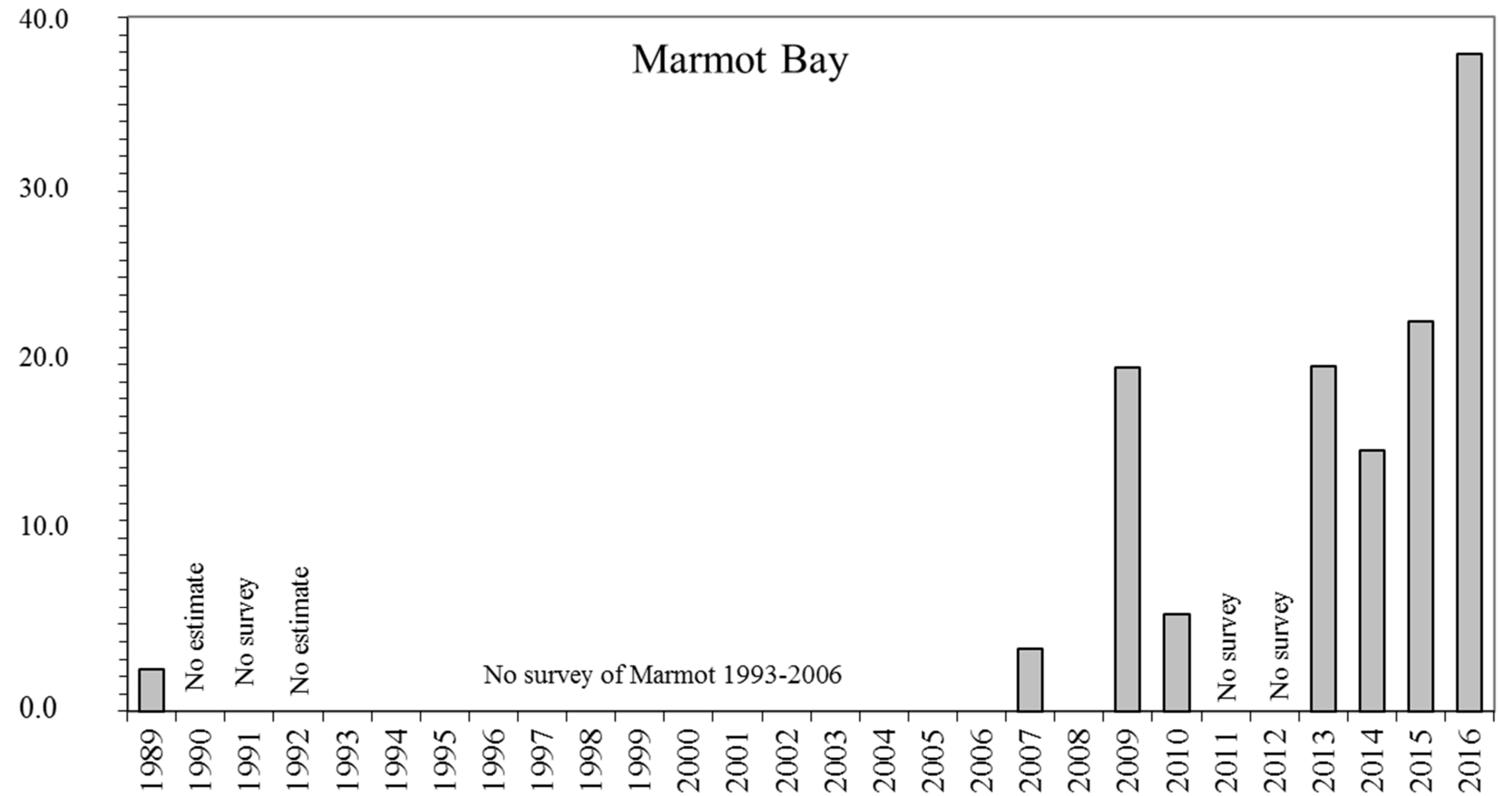
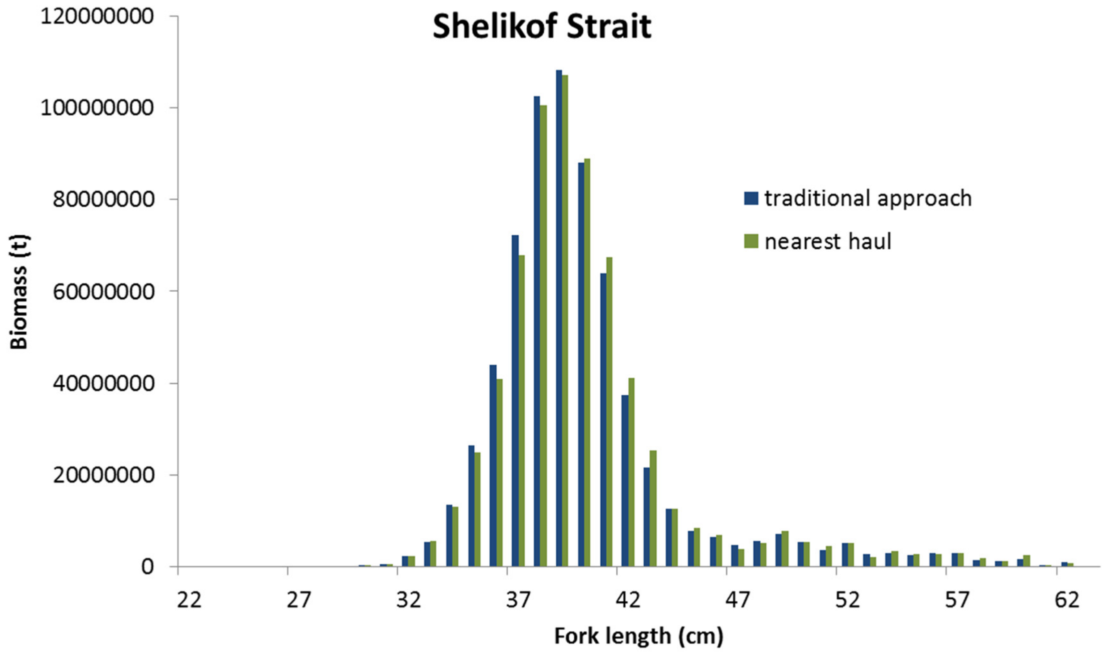


Figure 36. -- Summary of walleye pollock biomass estimates (million metric tons) based on acoustic-trawl surveys of Marmot Bay.



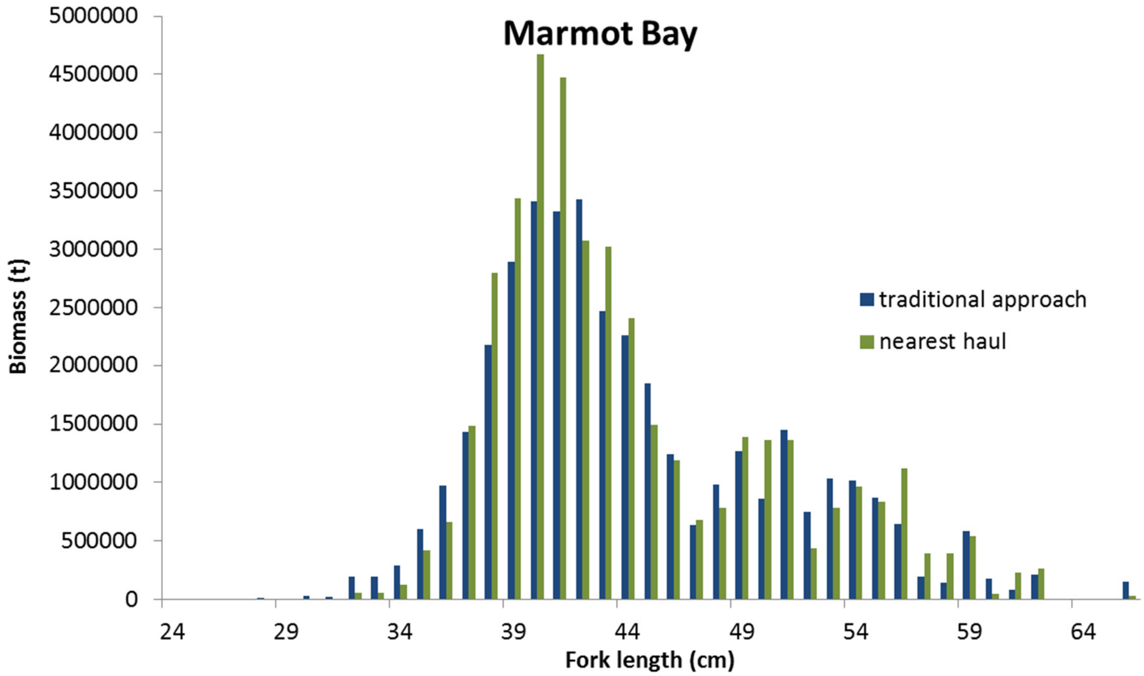


Figure 37. -- Walleye pollock biomass (t) by length (cm) calculated using the traditional approach (blue bars) versus the nearest haul sensitivity (green bars) in Shelikof Strait and Marmot Bay in winter 2016.

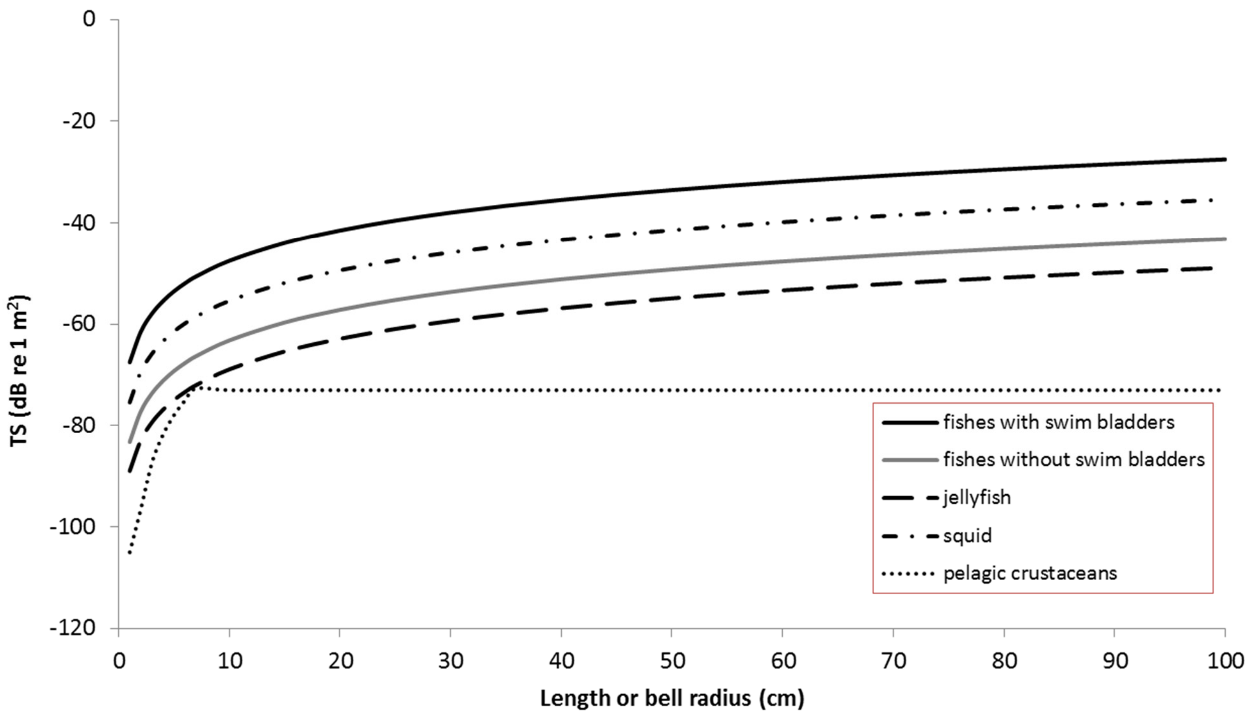


Figure 38. -- The five TS-to-length relationships used to estimate acoustic scattering from the trawl catches in the GOA winter 2016 surveys.

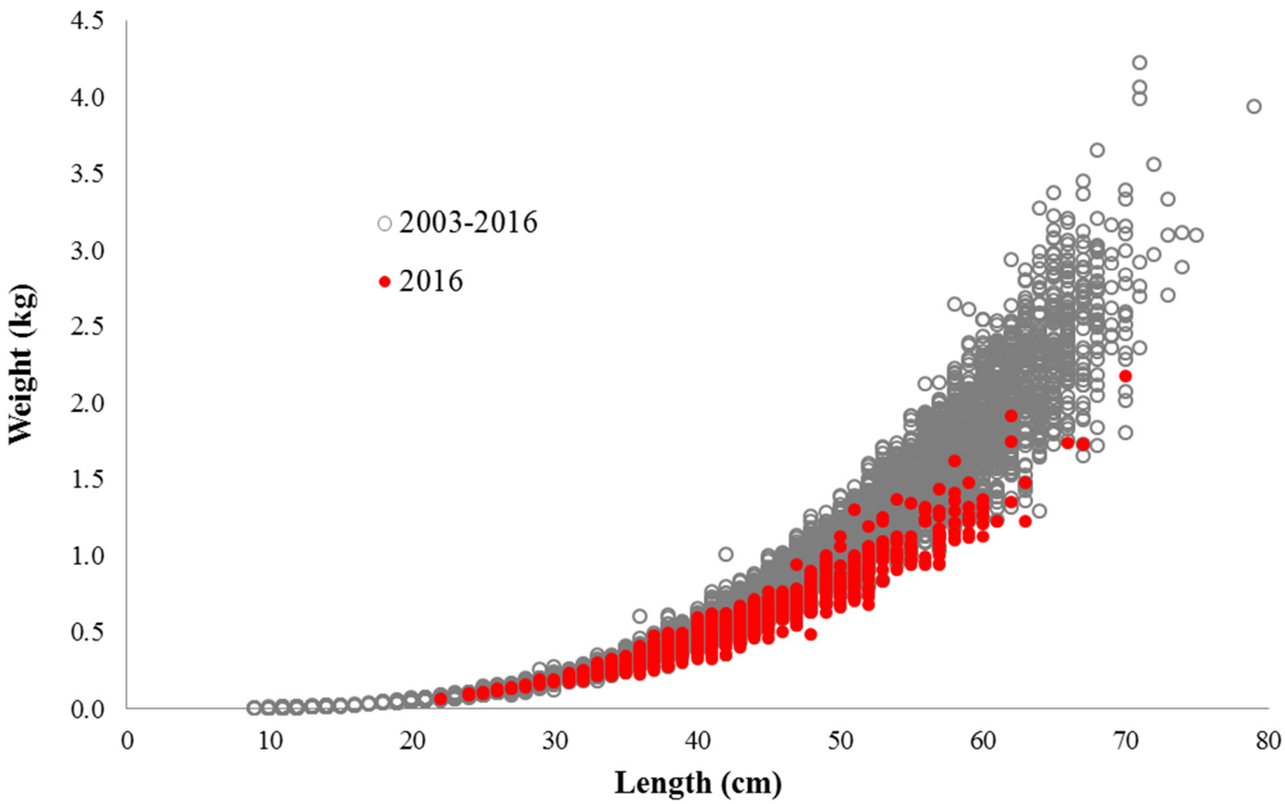


Figure 39. --Weight at length of walleye pollock caught in the Gulf of Alaska during winter acoustic trawl surveys since 2003.