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Results of the Acoustic-Trawl Surveys of Walleye Pollock (*Gadus chalcogrammus*) in the Gulf of Alaska, February-March 2018 (DY2018-01 and DY2018-03)

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 2018 to estimate the distribution and abundance of walleye pollock (*Gadus chalcogrammus*) at several of their main spawning grounds. These pre-spawning pollock surveys covered the Shumagin Islands, Sanak Trough, Morzhovoi and Pavlof bays (DY2018-01; 5-15 February), and Shelikof Strait and Marmot Bay (DY2018-03; 12-23 March). The Shumagin Islands area has been surveyed annually in winter since 2001 (except in 2004 and 2011), as well as in 1994, 1995, and 1996. This survey has also frequently included Sanak Trough, Morzhovoi Bay, and Pavlof Bay since 2002. The Shelikof Strait area has been surveyed annually in winter since 1981 (except in 1982, 1999, and 2011), and since 1989 this survey has often included Marmot Bay.

The abundance of walleye pollock for the winter 2018 Shumagin Islands survey was estimated to be 1,247 million pollock weighing 17,390 metric tons (t), with an additional 35 million pollock weighing 9,708 t in the Sanak, Morzhovoi, and Pavlof areas combined. The estimated abundance of walleye pollock for the winter 2018 Shelikof Strait survey was 4,077 million pollock weighing 1,320,867 t, with an additional 111 million pollock weighing 13,521 t in the Marmot area. Pollock between 40 and 53 cm fork length (FL), dominated by the 2012 year class, contributed the majority of the biomass in all areas. These estimates are based on a ‘primary analysis’, which allowed backscatter to be attributed to both pollock and other species, used the biological data from nearest haul locations to assign length-frequency distributions of various species to the backscatter, and included a selectivity correction for escapement of smaller pollock (primarily age-1 fish) from the midwater net. These results were compared to alternate analyses considering the effects of not incorporating net selectivity (‘no-selectivity analysis’) as well as applying the historical methods used for earlier surveys (‘historic analysis’). In general, the no-selectivity analysis estimated slightly more biomass (up to 9%, depending on area) compared to the primary analysis. The historic analysis, which corresponds to the methodology used in previous surveys and does not use a selectivity correction, produced biomass estimates between

100.6% and 121.6% of the primary estimates (and 99.3% and 112% of the no-selectivity estimates), depending on area.

CONTENTS

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. The goal of these surveys is to estimate the distribution and abundance of pre-spawning walleye pollock (*Gadus chalcogrammus*) at several of their main spawning grounds (i.e., pre-spawning surveys). The Shumagin Islands area has been surveyed annually since 2001 (except in 2004 and 2011) with prior surveys in 1994, 1995 and 1996, and Sanak Trough has been surveyed annually since 2002 (except in 2004 and 2011). Morzhovoi Bay has been surveyed intermittently since 2006, and Pavlof Bay was surveyed in 2002, 2010, 2016, and 2017. The Shelikof Strait area has been surveyed annually since 1981 except in 1982, 1999, and 2011. Marmot Bay has been surveyed in 1989, 1990, 1992, and annually since 2007 (except for 2008, 2011, and 2012). This report presents the results from AT surveys conducted in the aforementioned areas of the GOA during February and March 2018.

METHODS

Two cruises were conducted to survey several GOA pollock spawning areas. The first cruise (DY2018-01) surveyed the Shumagin Islands area (i.e., Shumagin Trough, Stepovak Bay, Renshaw Point, Unga Strait, and West Nagai Strait; 7-10 February), Sanak Trough (11 February), Morzhovoi Bay (11 February), and Pavlof Bay (12 February). The second cruise (DY2018-03) covered Shelikof Strait (15-21 March) and Marmot Bay (21-22 March). The surveys were conducted with 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 backscatter was measured with a Simrad EK60 and EK80 scientific echosounding systems (Simrad 2008, Bodholt and Solli 1992). Two echosounder systems were to allow for a project comparing these two instruments (De Robertis et al. 2019). The EK60 transceivers were synchronized to alternate pings with the EK80 transceivers on a common transducer. The echosounders transmitted once every 1.7 seconds during DY2018-01 and once every 2.5 seconds during DY2018-03 to test the narrowband performance of the new EK80. Both transceivers were connected to five split-beam transducers (18-, 38-, 70-, 120-, and 200-kHz) mounted on the bottom of the vessel's retractable centerboard. During the survey, the centerboard was extended to a nominal depth of 9.1 m. System electronics were housed inside the vessel in a permanent laboratory space dedicated to acoustics.

Five standard sphere acoustic system calibrations were conducted to measure acoustic system performance during the winter cruises (Table 1). The vessel's 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

[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

and fitting these data to a second order polynomial model of the beam pattern using the EK60'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 because knowledge is required of the absolute position of the sphere (see Demer et al. 2015). Thus, the transducer-specific equivalent beam angle measured by the echosounder manufacturer, corrected for the local sound speed (see Bodholt 2002), was used in data processing.

Raw acoustic data were recorded at five split-beam frequencies using ER60 software (v. 2.4.3). Processed telegram data were logged with Echoview EchoLog 500 (v. 5.22) 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. The raw acoustic data were analyzed using Echoview post-processing software (v. 8.0.91.31697).

Trawl Gear and Oceanographic Equipment

General trawl gear specifications for the sampling of acoustic scatters are described below. Midwater sound scatterers were sampled with an Aleutian wing 30/26 trawl (AWT). This trawl is constructed with full-mesh nylon wings and polyethylene mesh in the codend and aft section of the body. The headrope and footrope each measure 81.7 m (268 ft). Mesh sizes taper 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 AWT was fished with four 82.3 m (270 ft) non-rotational wire rope bridles (1.9 cm (0.75 in) dia. 8H19), 113.4 kg (250 lb) or 340.2 kg (500 lb) tom weights on each wingtip, and 5 m^2 Fishbuster trawl doors [1,247 kg (2,750 lb) each]. To gauge escapement of smaller fishes from the net, eight removable small-mesh (12 mm) pocket nets were placed at various locations of the middle and aft sections of the AWT (Williams et al. 2011). Additionally, a small-mesh (12 mm) recapture net was permanently attached to the bottom panel of the AWT approximately 26 m (85 ft) forward of the codend. Stereo camera images of fishes passing into the AWT codend were recorded during hauls fished shallower than 500 m depth using a stereo camera system attached to the net, forward of the codend (i.e., CamTrawl; Williams et al. 2010b). Camera images were used to identify species and to measure fish length following the procedures described in Williams et al. (2010a).

Near-bottom acoustic scatterers were also sampled with a poly Nor'eastern (PNE) bottom trawl. The trawl is a 4-panel high-opening net equipped with roller gear and constructed with stretch mesh sizes that range from 13 cm (5 in) in the forward portion of the net to 8.9 cm (3.5 in) in the codend. The PNE codend was fitted with a single 12 mm (0.5 in) codend liner and was fished with the same 5 m^2 Fishbuster trawl doors. In two instances when the AWT was temporarily unavailable, the PNE net was used to sample acoustic scatterers in the midwater.

The depth and vertical mouth openings of both trawls were monitored during fishing. The AWT was monitored using a Simrad FS70 third-wire net trawl sonar attached to the trawl headrope. The AWT's net vertical opening ranged from 12 to 29 m (39-95 ft) and averaged 20 m (66 ft) while fishing. The AWT was fished at an approximate trawling speed of 1.7 m/sec (3.3 knots). The PNE was monitored using a Furuno CN-24 trawl sonar attached to the headrope. The PNE's vertical net opening averaged 6.5 m while fishing in midwater and 8 m while fishing near-bottom. Oceanographic data were collected during the cruises. Temperature profiles were obtained with a Sea-Bird Electronics temperature-depth probe (SBE-39) attached to the trawl headrope, and conductivity-temperature-depth (CTD) observations were collected with a Sea-Bird CTD (SBE 911 plus) system at calibration sites. Near-surface temperature was measured using the ship's Sea-Bird Electronics sea surface temperature system (SBE 38, accuracy $\pm$ 0.002° C) located near the ship's bow, approximately 1.4 m below the surface. At times when the SBE-38 was not operating, near-surface temperatures were taken from a Furuno T-2000 temperature probe (accuracy $\pm$ 0.2° C) located amidships 1.4 m below the surface. During this winter season, the SBE 38 was used 93% of the time and the Furuno was used 7% of the time. 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 parallel transects in each survey area, except in areas where it was necessary to reorient transects to maintain a perpendicular alignment to the isobaths or navigate around landmasses. Spatial 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). The surveys 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 and weighed. When large numbers of juvenile and adult walleye pollock were encountered, the predominant size groups were sampled separately (e.g., age-1 vs. large adults). Sex, length, body weight, maturity, age (otoliths), 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 standard length (SL) for small specimens, with an electronic measuring board (Towler and Williams 2010). All lengths are reported as FLs in this report: lengths were converted to FL using FL to SL regressions if necessary. Gonadosomatic index [GSI: ovary weight/(ovary weight + body weight)] was calculated for pre-spawning females. Gonad maturity was determined by visual inspection and categorized as immature, developing, mature (hereafter, "pre-spawning"), spawning, or spent[2]. The length at 50% maturity (L50) was estimated for female pollock using a logistic regression following Williams 2007. The ovary weight was determined for 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 using the MACE Program's custom Catch Logger for Acoustic Midwater Surveys (CLAMS) software. Pocket net catches were logged in a manner similar to, but separate from, the codend catches.

For each trawl haul in cruise DY2018-01, length measurements from an average of 249 randomly selected walleye pollock were collected, with an average of 50 individuals more extensively sampled for body weight, maturity, and age (Table 2). For each haul in cruise DY2018-03, length measurements from an average of 306 randomly selected walleye pollock

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[2] 2016. RACE Division, AFSC, NMFS, NOAA; 7600 Sand Point Way NE, Seattle, WA 98115. Available online: https://www.afsc.noaa.gov/RACE/groundfish/Groundfish_Survey_Codes.pdf.

were collected, with an average of 56 individuals more extensively sampled for body weight, maturity, and age (Table 3). Only pollock > 20 cm FL were used in maturity calculations.

Otoliths were used to estimate walleye pollock ages, and were collected from the Shumagin Islands (n = 217), Sanak Trough (n = 35), Morzhovoi Bay (n= 35), Pavlof Bay (n = 81), Shelikof Strait (n = 727), and Marmot Bay (n = 120) areas (Tables 2-3). 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 at the time of this report.

Data Analysis

Processing of acoustic data

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. The sounder-detected bottom was calculated by averaging the bottom detections for all five frequencies (Jones et al. 2011). A minimum S_v threshold of –70 dB re 1 m^{-1} was applied to the 38 kHz acoustic data, which were then echo-integrated from 16 m below the surface to 0.5 m above the sounder-detected bottom. Data were averaged at 0.5 nautical miles (nmi) horizontal by 10 m vertical resolution intervals (*i*) and exported to a database. In one small portion of the DY2018-01 survey area (Stepovak Bay), a two-part data filter was applied due to the difficulty of separating pollock backscatter from co-occurring non-pollock targets which exhibited near-resonant scattering at 18 kHz but were not retained in our trawls. This filter consisted of a frequency-response criterion, such that anything that was more than one standard deviation above the expected pollock response for 18-120 kHz was removed by the filter (4.8 dB higher at 18 than 38 kHz**;** De Robertis et al. 2010). In addition, the integration threshold was changed from -70 to -60 dB re 1 m^{-1}, which excluded pervasive low-intensity backscatter unlikely to be from pollock.

Associating size and species composition with acoustic backscatter

Walleye pollock abundance was estimated by combining acoustic and trawl information. The analysis method employed here (i.e., the ‘primary analysis’) had three principal features. First, backscatter was attributed to scatterers of a given species and size based on trawl catches.

Second, a correction estimate was made for escapement of age-1+ pollock from the midwater net (based on data collected by the eight removable pocket nets; Williams et al. 2011) Third, catch data from nearest geographic haul locations within a stratum were used to convert the backscatter to estimates of abundance.

More specifically, acoustic backscatter was assigned to strata based on the appearance and vertical distribution of the aggregations. Strata containing backscatter not believed to be from pollock (e.g., the near-surface mixture of undifferentiated backscatter that is often present) were excluded from further analyses. Each trawl was associated with a stratum, and the backscatter at a given location was associated with the species and size composition of the geographically nearest haul within that stratum (see De Robertis et al. 2017 for details). For example, if juvenile pollock were consistently found only at shallow depths in a given area, and adult pollock layers were consistently found at deeper depths in that same area, the backscatter dominated by aggregations of juveniles would be assigned to a shallow stratum (A) and the backscatter dominated by adult layers would be assigned to a deep stratum (B). Hauls that sampled the juvenile aggregations would be assigned to stratum A, and hauls that sampled the adult layer would be assigned to stratum B. Within a stratum backscatter would be converted to abundance by species and size using the species and size composition from the geographically nearest trawl in that stratum as described below.

<u>Selectivity correction</u>

Previous research has found that juvenile pollock are less likely to be retained by the survey trawl than adults (Williams et al. 2011). To account for this bias, the pollock length composition was adjusted to that which would be expected from an unselective sampler. Trawl selectivity S_l for each centimeter pollock length class (l) was estimated by analyzing the catch of the codend and that of eight small recapture nets permanently mounted on the outside of the trawl during DY2018-03 using methods similar to those presented in Williams et al. (2011). A generalized linear mixed effects model was fit with a logistic link function and binomial error where variation between tows in selectivity was modeled with random effects. S_l was then computed as

$$S_l = \left(1 + e^{2\log 3(LR_{50}-l)/SR}\right)^{-1} , \qquad \text{Eqn. (1)}$$

where LR_{50} is the length at which 50% of individuals we be retained and SR = selection range (i.e., range in length between 25% and 75% retention values). Eight of the AWT trawls conducted during DY2018-03 were fitted with the full complement of resample nets and also caught juvenile pollock in the codend of the net. Analysis of these eight ATW hauls resulted in estimates of LR_{50} of 11.52 cm and SR of 3.53. These estimates were used to calculate selectivity curves for both DY2018-01 and DY2018-03.

This trawl selection estimate was then applied to the pollock codend catch length composition to correct the sample for trawl escapement as

$$N_{pk\_corr,l} = \frac{N_{pk}}{S_l}, \qquad \text{Eqn. (2)}$$

where $N_{pk\_corr,l}$ is the number of pollock that would be captured by an unselective net in the sampled population and $N_{pk,l}$ is the number of pollock in the 1 cm length class l in the trawl catch. In analyses with a selectivity correction applied, $N_{pk\_corr,l}$ was used in place of $N_{pk,l}$ in the abundance calculations (see Eqn. 7) No selectivity correction was applied for other species.

Abundance calculations

Fish abundance was calculated by combining species and size compositions from the hauls with acoustic backscatter data following the approach described (De Robertis et al. (2017). A series of target strength (TS) to length relationships from the literature were used along with size and species distributions from trawl catches to estimate the proportion of the observed acoustic scattering attributable to each of the organisms captured in the trawls. For abundant species, (those contributing > 5% of the numbers or weight to the total catch during the course of a specific survey (e.g., > 5% of the numbers or weight of the total catch in DY2018-01), the most appropriate TS to length relationship for that species available in the literature was used. Other, less abundant taxa, were assigned to one of five generic categories: fishes with swim bladders, fishes without swim bladders, jellyfish, squid, and pelagic crustaceans (Table 4).
Pollock, capelin, eulachon, and *Pandalus* sp. contributed more than 5% of the catch in DY2018-01 by weight or numbers. Therefore, a more specific TS relationship was used for pollock,

capelin, and eulachon (see below) in the DY2018-01 analysis. However, a more specific one is not available for *Pandalus* sp.*,* so the generic pelagic crustacean TS relationship was used (Table 4). Pollock and eulachon also contributed more than 5% of the catch in DY2018-03 by numbers, and a specific TS relationship was used for these two species (see below) in the DY2018-03 analysis.

Pollock abundance was estimated using the following approach. 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 backscatter from an individual fish is referred to as its backscattering cross-section, σ σ_{bs} (m^2), or in logarithmic terms as its target strength, TS (dB re 1 m^2), where,

$$TS = 10 \log_{10} \sigma_{bs}. \quad \text{Eqn. (3)}$$

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

$$TS = 20 \log_{10} L - 66, \quad \text{Eqn. (4)}$$

where L = FL in centimeters.

The TS relationship developed by Guttormsen and Wilson (2009) was used for capelin in DY2018-01:

$$TS = 20 \log_{10} L - 70.3, \quad \text{Eqn. (5)}$$

where L = total length (TL) in centimeters.

The TS-to-length relationship developed by Gauthier and Horne (2004) with a fixed slope of 20 was used for eulachon in both DY2018-01 and DY2018-03:

$$TS = 20 \log_{10} L - 84.5, \quad \text{Eqn. (6)}$$

where L = TL in centimeters.

The numbers of fish of species s and of length l ($N_{s,l}$) captured in each haul h were used to compute the proportion of acoustic backscatter associated with each species and length. First, the sample numbers were converted to a proportion ($P_{s.l,h}$)

$$P_{s,l,h} = \frac{N_{s,l,h}}{\sum_{s,l,h} N_{s,l,h}} \quad ,$$

where $\sum_{s,l,h} P_{s,l,h} = 1$. Eqn. (7)

In analyses where pollock trawl selectivity was considered, the selectivity-corrected pollock numbers $N_{pk\_corr,l}$ were used in place of $N_{s,l}$ in Eqn. 7.

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

$$\sigma_{bs_{s,l}} = 10^{(0.1 \cdot TS_{s,l})} \ , \qquad \text{Eqn. (8)}$$

where TS is the target strength (dB re m^2) computed using the relationships in Table 4 and in equations 4-6.

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

$$PB_{s,l,h} = \frac{P_{s,l,h} \cdot \sigma_{bs_{s,l}}}{\sum_{s,l,h} (P_{s,l,h} \cdot \sigma_{bs_{s,l}})} \ . \qquad \text{Eqn. (9)}$$

The measured nautical area backscattering coefficient (s_A) at interval i was allocated to species and length as follows:

$$s_{A_{s,l,i}} = s_{A_i} \cdot PB_{s,l,h} \ , \qquad \text{Eqn. (10)}$$

where haul h is the nearest haul within a stratum assigned to represent the species composition in a given 0.5 nmi along-track interval i . The nearest geographic haul was determined by using great-circle distance to find the nearest trawl location (defined as the location where the net is at depth and begins to catch fish) out of the pool of hauls assigned to the same stratum (see above for details) closest to the start of interval i.

The abundance of pollock of a given length in a given interval i was estimated from the area represented by that interval (A_i, nmi^2), the mean areal backscatter attributed to pollock (i.e., $s = pk$) in given length/size class l ($s_{A_{pk,l,i}}$, m^2 nmi^{-2}), and mean backscattering cross-section of pollock at that size ($\sigma_{bs_{pk,l}}$ m^2):

$$\text{Numbers at length : } N_{pk,l} = \sum_i \left(\frac{s_{A,pk,l,i}}{4\pi\sigma_{bs_{pk,l,i}}} \cdot A_i \right) \qquad \text{Eqn. (11)}$$

$$\text{Biomass at length } l\text{: } B_{pk,l} = \Sigma_i \left(W_{pk,l} \times N_{pk,l,i} \right), \qquad \text{Eqn. (12)}$$

where $W_{pk,l}$ is the mean pollock weight-at-length in each 1 cm length interval. $W_{pk,l}$ was estimated from the trawl information when five or more walleye pollock were measured within a length interval. Otherwise, weight-at-length was estimated using a linear regression of the natural log-transformed length-weight data (De Robertis and Williams 2008).

The abundance at age was computed from $Q_{pk,l,,j}$, the proportion of j-aged pollock of length l as follows:

$$\text{Numbers at age } j\text{: } N_{pk,j} = \Sigma_i \left(Q_{pk\ l,,j} \times N_{pk,l} \right) \qquad \text{Eqn. (13)}$$

$$\text{Biomass at age } j\text{: } \mathrm{B}_{\mathrm{pk},j} = \Sigma_i \left(Q_{pk,l,,j} \times B_{pk,l} \right). \qquad \text{Eqn. (14)}$$

The abundance in each survey area was estimated by adding the estimates for all length or age classes.

Relative estimation error

In areas where transects were parallel, relative estimation errors for the acoustic-based estimates were derived using a one-dimensional (1-D) geostatistical method (Petitgas 1993, Williamson and Traynor 1996, Walline 2007). "Relative estimation error" is defined as the ratio of the square root of the 1-D estimation variance ($variance_{sum}$) to the biomass estimate (i.e., the sum of biomass over all transects, $biomass_{sum}$, kg):

$$Relative\ estimation\ error_{1\text{-}D} = \frac{\sqrt{variance_{sum}}}{biomass_{sum}} \quad . \qquad \text{(Eq. 15)}$$

Because sampling resolution affects the variance estimate, and the 1-D method assumes equal transect spacing, estimation variance was determined separately in each area with unique transect spacing. Relative estimation error for an entire survey area (among *n* survey areas with different transect spacings) was computed by summing the estimation variance for each area *j*, taking the square root, 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):

$$Relative\ estimation\ error_{1\text{-}D\ survey} = \frac{\sqrt{\sum_{j=1}^{n} variance_{sum\ j}}}{\sum_{j=1}^{n} biomass_{sum_j}} \quad . \qquad \text{(Eq. 16)}$$

A two-dimensional (2-D) geostatistical method (Petigas 1993, Rivoirard et al. 2000) was used to derive relative estimation errors in outer Marmot Bay where a zig-zag transect pattern was used. The 2-D method differs from the 1-D method in that it computes a variance ($variance_{mean}$) for the mean biomass density ($biomass_{mean}$, kg nmi^{-2}) rather than the biomass sum (kg) in each area. Mean biomass density is multiplied by the surveyed area (nmi^2) to obtain the biomass estimate for that area (kg); likewise, 2-D relative estimation error is obtained as follows:

$$Relative\ estimation\ error_{2\text{-}D} = \frac{variance_{mean_j} * area_j^2}{biomass_{mean_j} * area_j} \qquad \text{(Eq. 17)}$$

and over several zig-zag survey areas as:

$$\textit{Relative estimation error}_{\textit{2-D survey}} = \frac{\sqrt{\sum_{j=1}^{n} variance_{mean_j} * area_j^2}}{\sum_{j=1}^{n} biomass_{mean_j} * area_j^2} \quad . \qquad \text{(Eq. 18)}$$

Equations 17 and 18 are analogous to Equations 15 and 16 after accounting for unit conversions.

The biomass estimate for Marmot Bay was obtained by summing biomass estimates derived for both inner and outer Marmot. Although the 1-D and 2-D relative estimation errors may not be strictly comparable (Patigas 1993), the total relative estimation error for Marmot Bay was determined by combining the estimation of error for biomass within the inner bay (1-D) and outer bay (2-D) following Equation 16.

Geostatistical methods were used to compute estimation error as a means to account for estimation uncertainty arising from the observed spatial structure in the fish distribution. These errors, however, quantify only transect sampling variability of the acoustic data (Rivoirard et al. 2000). Other sources of error (e.g., target strength, trawl sampling) were not evaluated.

Alternative analyses

Two alternative analyses were conducted to estimate numbers and biomass of walleye pollock. The primary analysis described above relies on the fewest assumptions to generate abundance estimates, and is thus considered the most appropriate approach. A no-selectivity analysis was conducted to evaluate the impact of incorporating the trawl escapement correction on pollock estimates. The no-selectivity analysis was the same as the primary analysis except that it did not include a correction for age-1+ pollock escapement. That is, the selectivity ($S_{s,l}$) was set to 1 (see Eqn. 2) for all species and size classes. A historic analysis was conducted, which describes the analytical approach used through 2017 (see Honkalehto et al. 2018 for details). The historic analysis: 1) did not incorporate with species mixtures: in general all backscatter in a stratum assigned to pollock was assumed to be exclusively pollock (e.g., some pollock rockfish mixtures were apportioned by catch weight, 2) the historical analysis used length strata based on post-hoc groupings of hauls with similar length distributions (rather than nearest haul) to assign length-frequency distributions of pollock to the backscatter, and 3) the historical analysis did not include a correction for age 1+ pollock trawl escapement (see McCarthy et al. 2018). Unless stated otherwise, estimates presented in this report for 2018 are based on the primary analysis. Estimates for surveys prior to 2018 are based on the historic analysis.

RESULTS and DISCUSSION

Calibration

Pre-, mid-, 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 1). At 38 kHz the integration gain differed by < 0.1 dB across the five measurements, and the average of all results (averages calculated in the linear domain for dB quantities) were used in the final analysis (Table 1).

Shumagin Islands

Acoustic backscatter was measured along 872 km (471 nmi) of transects (Fig. 1). The survey transects were spaced 1.9 km (1.0 nmi) apart southeast 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. Bottom depths did not exceed 220 m and transects generally did not extend into waters less than 55 m depth.

Water temperature

Surface water temperatures averaged 4.2° C throughout the Shumagin Islands survey area (Fig. 2), which was about 0.4 degrees lower than last year's average of 4.6° C. Mean water temperature ranged 0.5° C between the surface and 160 m across all hauls (Fig. 3).

Trawl samples

Biological data and specimens were collected in the Shumagin Islands from seven midwater AWT hauls (Tables 2, 5; Fig. 1) targeting backscatter attributed to walleye pollock (Fig. 4). Walleye pollock was the most abundant species caught by weight and numbers, contributing

97.6% and 74.0% to the total catch, respectively (Table 6). Capelin and eulachon were the next abundant species by numbers, contributing 11.7% and 8.9%, respectively, to the total catch.

The majority of walleye pollock in the Shumagin Islands in 2018 were between 9 and 14 cm fork length (FL; Fig. 5). This size range is characteristic of age-1 pollock. This size range accounted for 99.1% of the numbers and 55.7% of the biomass. Larger pollock between 40 and 60 cm FL accounted for 43.8% of the biomass of all pollock observed in this area (Fig. 5). This larger size range is dominated by age-6 walleye pollock, and suggests the continued success of the 2012 year class (Fig. 6). A few pollock were observed between 20 and 39 cm FL (~ 2-3 year-olds), contributing less than 1% to the total biomass. Large adults (≥ 60 cm) were not observed (Fig. 5).

The maturity composition of males > 40 cm FL (n = 100) was 0% immature, 4% developing, 93% pre-spawning, 3% spawning, and 0% spent (Fig. 7a). The maturity composition of females > 40 cm FL (n = 128) was 3% immature, 9% developing, 88% pre-spawning, 0% spawning, and 0% spent (Fig. 7a). In AT surveys from this area in other years, most females were also in the pre-spawning stage of maturity and relatively few were spawning or spent. This suggests that the timing of the 2018 Shumagin Islands area survey relative to the spawning period was similar to other survey years. The few pollock under 41 cm FL were all immature, and all pollock > 41 cm FL were mature (i.e., the vast majority of pollock in a given 1-cm size group were in pre-spawning, spawning, or spent condition; Fig. 7b). The length at which 50% females were mature (L_{50}) could not be accurately calculated because of the lack of contrast in length and maturity status in the data set. The average GSI of pre-spawning females, based on 100 samples, was 0.11 ± 0.03 (mean ± SD; Fig. 7c), similar to the average GSI from the 2017 survey (0.09 ± 0.04). Most 2018 GSI estimates were within ± 1 SD of the historical mean GSI of all surveys between 1994 and 2017 (0.12 ± 0.05).

Distribution and abundance

Walleye pollock between 9 and 14 cm FL were present mainly in Shumagin Trough (Fig. 8). Pollock between 40 and 60 cm FL were present mainly off Renshaw Point, where they have historically been detected (but were absent in 2017), and near the mouth of Stepovak Bay (Fig. 8). The majority of the pollock were scattered throughout the water column between 50 and

200 m depth, within approximately 50 m of the bottom (Fig. 9), and occasionally formed small, very dense (i.e., “cherry ball”) schools.

The estimated amounts of pollock for the Shumagin area were 1,247 million pollock weighing 17,390 t, which is 42% lower than last year’s estimate (29,621 t) and 24% of the historical mean of 73,330 t for this survey (Table 7; Fig. 10). The relative estimation error of the biomass based on the 1-D geostatistical analysis was 8.3%.

Sanak Trough

Acoustic backscatter in Sanak Trough was measured along 165 km (89 nmi) of transects spaced 3.7 km (2 nmi) apart (Fig. 1). Bottom depths ranged from 50 m at the transect end points to 165 m along the deepest part of the southernmost transects.

<u>Water temperature</u>
Surface water temperatures in the Sanak Trough survey area averaged 4.1 °C (Fig. 2) which was similar to the 4.0° C average for 2017. Water temperature ranged 0.1° C between the surface and 90 m (the maximum trawl depth) in Sanak (Fig. 11).

<u>Trawl samples</u>
Biological data and specimens were collected in Sanak Trough from a single AWT haul (Tables 2, 5; Fig. 1) targeting backscatter attributed to walleye pollock (Fig. 4). Walleye pollock was the most abundant species, contributing 95.4% and 72.3% of the catch weight and numbers, respectively (Table 8). *Pandalus* spp. shrimp contributed 24.2% by numbers. A few walleye pollock with FL between 11 and 12 cm FL were present (2% by numbers), but the size distribution was dominated by pollock were between 37 and 56 cm FL (Fig. 5). This mode accounted for 99.9% of the biomass of all pollock observed in Sanak Trough and likely represents mostly age-6 fish.

The maturity composition of males > 40 cm FL (n = 18) was 0% immature, 0% developing, 89% pre-spawning, 11% spawning, and 0% spent (Fig. 12a). The maturity composition of females > 40 cm FL (n = 31) was 0% immature, 10% developing, 90% pre-spawning, 0% spawning, and

0% spent (Fig. 12a). The relatively high percentage of pre-spawning females and the absence of spawning and spent females in the 2018 Sanak area suggests that survey timing may have been somewhat earlier in the spawning season compared to results from earlier survey years. Nearly all of the female pollock observed in this survey were > 36 cm FL and were reproductively mature (i.e., the vast majority of pollock in a given 1-cm size group were in pre-spawning, spawning, or spent condition; Fig. 12b). Thus, the L_{50} could not be accurately estimated because of the lack of contrast in length and maturity status in the data set (Fig. 12b). The average GSI of pre-spawning females was 0.11 $\pm$ 0.04 (Fig. 12c), slightly higher than last year (0.08 $\pm$ 0.04), but lower than the historic mean of 0.14 $\pm$ 0.05 for the time series from 2003 to 2017.

Distribution and abundance

The majority of walleye pollock biomass was located in the middle of the surveyed trough (Fig. 8) and distributed throughout the water column below 50 m, concentrated around 140 m (Fig. 13).

The estimated amount of pollock in Sanak Trough was 1.9 million pollock weighing 1,317 t. This biomass estimate is 38% higher than last year's estimate of 957 t, and represents only 3.5% of the historic mean of 36,823 t for this survey (Table 7; Fig. 14). The relative estimation error of the biomass based on the 1-D geostatistical analysis was 12.2%.

Morzhovoi Bay

Acoustic backscatter was measured along 37 km (68.5 nmi) of transects in Morzhovoi Bay (Fig. 1). The transects were spaced 3.7 km (2 nmi) apart (Fig. 1). Bottom depths ranged from about 45 to 120 m.

Water temperature

Surface water temperatures in the Morzhovoi Bay survey area averaged 3.3 °C overall (Fig. 2). The value was 0.2 degrees warmer than the average 3.1° C temperatures recorded in 2017 and warmer than the 2.6° C average for surveys in this area since 2006. Mean water temperature ranged 0.4° C between the surface and 75 m (deepest trawl depth) at one haul location (Table 5, Fig. 15).

Trawl samples

Biological data and specimens were collected in Morzhovoi Bay from one AWT haul (Tables 2, 5; Fig. 1). Walleye pollock was the most abundant species caught by weight and numbers, contributing 87.5% and 65.3% to the total catch, respectively (Table 9). Rock sole was the next most abundant species by weight, contributing 6.6% to the total catch weight (Table 9). Walleye pollock between 10 and 14 cm FL, indicative of age-1 pollock, accounted for 24% of the numbers but only 0.4% of the biomass of all pollock observed in this area (Fig. 5). Larger pollock between 39 and 59 cm FL accounted for 75% and 99.6% of the numbers and biomass, respectively.

The maturity composition of males > 40 cm FL (n = 9) was 0% immature, 0% developing, 56% pre-spawning, 44% spawning, and 0% spent (Fig. 16a). The maturity composition of females longer than 40 cm FL (n = 21) was 0% immature, 19% developing, 67% pre-spawning, 14% spawning, and 0% spent (Fig. 16a). In AT surveys from this area in other years, most females were also in the pre-spawning maturity stage with fewer classified as spawning or spent compared to prespawning. This suggests that the timing of the 2018 Morzhovoi Bay survey relative to the spawning period was likely similar to most other survey years. Nearly all of the female pollock observed in this survey were > 38 cm FL and reproductively mature (i.e., the vast majority of pollock in a given 1-cm size group were in pre-spawning, spawning, or spent condition; Fig. 16b). Thus, the L_{50} could not be accurately estimated because of the lack of contrast in length and maturity status in the data (Fig. 16b). The average GSI of pre-spawning females was 0.15 $\pm$ 0.04 (Fig. 16c), which is greater than that measured in 2017 (0.10 $\pm$ 0.05), and equal to the historical average of 0.15 $\pm$ 0.06.

Distribution and abundance

The walleye pollock biomass in Morzhovoi Bay were located throughout the surveyed area (Fig. 8) and were concentrated between 50 and 100 m depth from the surface (Fig. 17).

The estimated amounts of pollock in Morzhovoi Bay were 6.2 million pollock weighing 3,772 t. This biomass estimate is comparable to the biomass estimates generated between 2007 and 2013 and in 2017 (mean = 2,677 t; standard deviation = 897 t), and approximately a third of the estimate from either 2006 (11,700 t) or 2016 (11,412 t, Table 7, Fig. 14). The relative estimation error of the biomass estimate based on the 1-D geostatistical analysis was 23.0%.

Pavlof Bay

Acoustic backscatter was measured along 75 km (40.5 nmi) of transects in Pavlof Bay. The transects were spaced 3.7 km (2 nmi) apart (Fig. 1), and the depths ranged from about 45-135 m.

Water temperature

Surface water temperatures in the Pavlof Bay survey area averaged 3.4 °C overall (Fig. 2), 0.5 degrees warmer than last year's mean temperature of 2.9 °C. Mean water temperature ranged 0.6 °C between the surface and deepest trawl depth (90 m) at the two haul locations (Fig. 18).

Trawl samples

Biological data and specimens were collected in Pavlof Bay from two AWT hauls (Tables 2, 5; Fig. 1). Walleye pollock was the most abundant species caught, contributing 99.6% by weight and 95.4% by numbers (Table 10). Walleye pollock between 10-14 cm fork length (FL), indicative of age-1 pollock, accounted for 77% of the numbers but only 4.7% of the biomass of all pollock observed in this area (Fig. 5). Larger pollock between 25 and 60 cm FL accounted for 23% and 95.3% of the numbers and biomass, respectively.

The maturity composition of males > 40 cm FL (n = 29) was 0% immature, 24% developing, 41% pre-spawning, 34% spawning, and 0% spent (Fig. 19a). The maturity composition of females > 40 cm FL (n = 38) was 0% immature, 11% developing, 87% pre-spawning, 3% spawning, and 0% spent (Fig. 19a). In AT surveys from this area in other years (n = 2), most females were also in the pre-spawning stage of maturity, which suggests that the timing of the 2018 Pavlof Bay survey relative to spawning was likely similar to other survey years. Fifty percent of female pollock > 20 cm FL were reproductively mature at 41 cm FL (n = 46; Fig. 19b). The average GSI of pre-spawning females was 0.13 ± 0.04 (Fig. 19c), higher than that observed in 2017 (0.10 + 0.03) and 2016 (0.11 + 0.04). No biological data were collected in Pavlof Bay in 2002 or 2010.

Distribution and abundance

The majority of walleye pollock biomass in Pavlof Bay was generally located in the NW portion of the surveyed area, where pollock were also abundant in 2017 (Fig. 8). The pollock were scattered throughout the water column between 25 and 150 m from the surface but were concentrated around 95 m (Fig. 20). Higher backscatter attributed to pollock was observed farther north in the bay in 2002, and relatively low backscatter was measured throughout Pavlof Bay in 2010.

The estimated amounts of pollock in in Pavlof Bay were 27 million pollock weighing 4,619 t. The 2018 biomass estimate is roughly double either the 2016 or 2017 estimates of 2,130 t and 2,228 t, respectively (Table 7, Fig. 14). The relative estimation error of the biomass based on the 1-D geostatistical analysis was 19.9%. Surveys of Pavlof Bay was also conducted in 2002 and 2010, but biomass could not be estimated due to an equipment malfunction in 2002 and inclement weather which prevented trawling in 2010.

Shelikof Strait

Acoustic backscatter was measured along 1,613 km (871 nmi) of transects spaced 13.9 km (7.5 nmi) apart (Fig. 21). Bottom depths in the survey area ranged from 40 to 325 m.

Water temperature

Surface water temperatures in Shelikof Strait averaged 3.8 °C overall (Fig. 22), and ranged from 2.4 °C to 4.6 °C. This was 0.5 degrees warmer than the average of 3.3 °C observed during 2017 and 0.2 °C higher than the historic mean of the prior 35 surveys conducted in this area since 1981 (3.6 °C.) Mean water temperature at fishing depths was 5.4 °C (Table 11). Mean estimates at haul locations varied around 2 °C between the surface and deepest trawl depth across all hauls (Fig. 23).

Trawl samples

Biological data and specimens were collected in the Shelikof Strait area from 14 AWT hauls and 3 PNE hauls (Tables 3 and 11, Fig. 21) targeted on backscatter attributed to walleye pollock (Fig. 24). Walleye pollock and eulachon were the most abundant species by weight and numbers in AWT hauls, contributing 97.6% and 2.1% by weight, and 60.0% and 37.1% by numbers, respectively (Table 12). Compared to the years when eulachon were most abundant, the contribution of eulachon to total catch by weight in 2018 was small (i.e., in 2008 when eulachon contributed 47% of the total catch by weight). Walleye pollock was the most abundant species in the three PNE hauls conducted in the Shelikof Strait this year, contributing 99.4% of the total weight and 90.1% of the total numbers. Eulachon were the next-most abundant species by numbers, contributing 7.2% to the total catch (Table 13). Walleye pollock between 10 and 14 cm FL, indicative of age-1 pollock, accounted for 53% of the numbers but only 1.6% of the biomass of all pollock observed in this area (Fig. 25). Larger pollock between 39 and 62 cm FL accounted for 44% and 97.5% of the numbers and biomass, respectively.

The maturity composition in the Shelikof Strait area of males > 40 cm FL (n = 324) was 0% immature, 2% developing, 5% pre-spawning, 69% spawning, and 24% spent (Fig. 26a). The maturity composition of females > 40 cm FL (n = 383) was 0% immature, 2% developing, 30% pre-spawning, 24% spawning, and 44% spent (Fig. 26a). In AT surveys from this area in other years, most females were in the pre-spawning stage of maturity and substantially less were spawning or spent, which suggests that the timing of the 2018 Shelikof survey relative to spawning was late compared to other survey years. The only other years since 1982 when spawning/spent females was > 20% was in 1995 (53%) and 1996 (23%). Fifty percent of female pollock > 20 cm FL were reproductively mature at 35.8 cm FL (n = 415; Fig. 26b). The average GSI from 111 pre-spawning females was 0.14 $\pm$ 0.05 (Fig. 26c), which was virtually identical to the 2017 estimate and the historical mean (0.14 $\pm$ 0.04).

Distribution and abundance

Walleye pollock were observed throughout the surveyed area and were most abundant in the central part of the surveyed area (Fig. 27). Pollock of all lengths were detected as a thick, uniform midwater layer between 150 m to 300 m from the surface (Fig. 28). Dense midwater aggregations of pollock ≥ 39 cm FL were encountered higher in the water column, generally above 100 m. Spawning aggregations historically observed in the northwestern part of the Strait were not observed in 2018 (or in 2016-2017), which contrasts with previous years.

The estimated amounts of pollock in Shelikof Strait were 4.1 billion pollock weighing 1,320,867 t. The 2018 biomass was 88% of that observed in 2017 (1,489,723 t) and almost twice the historic mean of 690,451 t (Table 14; Fig. 29). Survey biomass estimates in 2017 and 2018 are the largest since the mid-1980s (Table 14; Fig. 29). The relative estimation error of the 2018 biomass estimate based on the 1-D geostatistical analysis was 3.9%.

The 2018 survey likely occurred later in the spawning period relative to other survey years (i.e., an unusually large estimate (68%) of the sampled female pollock were classified as spawning or spent), which can potentially negatively bias the survey estimate compared to other time series estimates in at least two ways. First, pollock move into and out of Shelikof Strait over the course of the spawning season (De Robertis et al. 2018). Wilson (1994) showed that the numbers of pollock in Shelikof Strait decreased by 16%, resulting in a 24% reduction in biomass, between pre- and post-peak spawning (i.e., over a 2-week window) in 1994. Secondly, spent pollock will weigh less at a given length than those in earlier stages of gonad maturity. De Robertis and Williams (2008) showed that spent pollock in Shelikof Strait are 15% lighter than spawning pollock and 10% lighter than pre-spawning pollock. If spent pollock are removed from the length-weight key to allow the length-weight key to better approximate what it would have been if the survey encountered only pre-spawning and spawning pollock, the total biomass is projected to be 1,362,107 t. That is, the bias associated with the presence of relatively lower weight spent pollock would cause an estimated 3% reduction in biomass.

The progression of the strong 2012 year class is clearly visible in the time series of both biomass and numbers of pollock in the survey area beginning in 2013 (Fig. 30). Although there are more pollock in the 10-14 cm FL range compared to larger pollock (Table 15), the larger pollock (ca. 40 cm FL to 55 cm FL, mostly age-6) account for the majority of the biomass (97.3%, Table 16). Also noteworthy is that no pollock older than 8 years of age were caught during this survey (Fig. 31; Tables 17, 18), and pollock of most ages were smaller when compared to the same age group from previous winter acoustic-trawl surveys of Shelikof Strait and Marmot Bay (Fig. 32).

McKelvey (1996) showed that there was a strong relationship between the estimated number of age-1 pollock from the Shelikof Strait AT survey and year-class strength for GOA pollock. The McKelvey index is based on data that does not include a correction for escapement of age-1 pollock. Thus, the 2018 non-selectivity based estimate must be used to properly classify the strength of the 2017 year class (age-1 pollock observed in 2018). The no-selectivity estimate of 937 million age-1 pollock would be considered a medium sized-year class based on the McKelvey index.

Marmot Bay

Acoustic backscatter was measured along 137.5 km (74 nmi) of transects spaced 1.75 km (1.0 nmi) apart in inner Marmot Bay, and 43.5 km (23.5 nmi) of a zig-zag transect in outer Marmot Bay (Figs. 21, 33). Bottom depths ranged from 68 to 275 m in inner Marmot Bay and from 108 to 190 m in outer Marmot Bay.

Water temperature

Surface water temperatures averaged 4.2 °C throughout the Marmot Bay survey area (Figs. 34, 34), 0.4 degrees warmer than last year's mean of 3.8 °C. Mean water temperature ranged 0.35 °C between the surface and deepest trawl depth across all hauls (Fig. 35) and averaged 4.2 °C at fishing depths (Table 11).

Trawl samples

Biological data and specimens were collected in Marmot Bay from 3 AWT hauls throughout the survey area (Table 3 and 19; Fig. 33). Walleye pollock and eulachon were the most abundant species by weight and numbers in AWT hauls, contributing 96.8% and 3.1% by weight, and 58.7% and 31.5% by numbers, respectively (Table 19). Historically, eulachon are more numerous in the catch than pollock in the Marmot area. Walleye pollock between 10 and 14 cm FL, indicative of age-1 pollock, accounted for 74% of the numbers but only 4% of the biomass of all pollock observed in this area (Fig. 25). Walleye pollock ranging from 39 to 56 cm FL with a mode centered at 45 cm accounted for 94.6% of the biomass. There were no pollock > 56 cm captured in Marmot Bay in 2018 (Fig. 25).

The maturity composition in Marmot Bay of males > 40 cm FL (n = 60) was 0% immature, 2% developing, 8% pre-spawning, 58% spawning, and 32% spent (Fig. 36a). The maturity composition of females > 40 cm FL (n = 40) was 0% immature, 10% developing, 25% pre-spawning, 3% spawning, and 63% spent (Fig. 36a). In AT surveys from this area in other years, most females were in the pre-spawning stage of maturity and a substantially smaller proportion were spawning or spent, which suggests that the timing of the 2018 Marmot survey relative to spawning was late compared to other survey years. Fifty percent of female pollock > 20 cm FL were reproductively mature at 39.4 cm FL (n = 45; Fig. 36b). The average GSI for pre-spawning females was 0.15 + 0.05 (Fig. 36c), which was higher than the past 3 years (0.11 + 0.03) and the historical mean (0.13 + 0.04).

Distribution and abundance

A diffuse acoustic scattering layer present near the seafloor in the inner Bay was composed of age-1 pollock. Most pollock biomass occurred in aggregations in Spruce Gully, just NE of Spruce Island (Fig. 37). These aggregations were typically within 100 m of the seafloor (Fig. 38).

The estimated amounts of pollock for Marmot Bay were 111 million pollock weighing 13,521 t, which was slightly less than both last year's estimate of 14,259 t and the historic mean of 15,576 t (Table 14; Fig. 39). Sixty-seven percent of the total Marmot biomass was observed in inner Marmot, and 33% of the total Marmot biomass was observed in outer Marmot. The relative estimation error of the biomass in Marmot Bay, determined by combining the results of the 1-D and 2-D geostatistical analyses (following Eqn. 16), was 7.5%.

Other Analyses

No-selectivity analysis

Without the trawl escapement correction, the acoustic estimates of abundance are biased toward larger pollock. Specifically, without the escapement correction, the estimated number of primarily age-1 pollock decreased, most notably in areas where larger numbers of age-1 pollock were found mixed with adult pollock. For example, in Shelikof Strait, where age-1 pollock were frequently observed to co-occur with adults, the number of age-1 pollock was 937 million without the escapement correction and the estimate approximately doubled (1,932 million) when the correction was applied. However, in the Shumagin Islands area, where age-1 pollock were mostly observed in areas without adult pollock, the number of age-1 pollock was 1,115 million without the escapement correction versus 1,249 million fish when the correction was applied. When the escapement correction was not applied (Table 20), it reduced the total (i.e., age 1+) abundance of pollock by up to 20% - 27% (i.e., Shelikof Strait, Pavlof Bay). Changes in total biomass were smaller (Table 20), ranging between < 1% (i.e., Sanak Trough, Morzhovoi Bay) and 9% (i.e., Shumagin Islands;). Total biomass in Shelikof increased by 2% when the escapement correction was applied.

Historic analysis

The historic analysis represents the method used to generate estimates for the winter GOA MACE surveys prior to 2018. When the historic analysis approach was compared with the non-selectivity approach (i.e., to evaluate effect of nearest haul versus the use of post-hoc length strata) for the 2018 survey, the historic analysis estimates resulted in increased biomass between 0.4% (i.e., Shelikof Strait) and 12% (i.e., Shumagin Islands) in most areas although it decreased the biomass by 1% in Marmot Bay (Table 20). The large discrepancy in the Shumagin Islands area was because there was a high-density aggregation of scatters in the NE portion of Shumagin Trough (Fig. 4) that was not sampled (Fig. 1), and the survey results are sensitive to the pollock size distribution assigned to that high-density area. The estimate in Marmot Bay is a result of a size-frequency distribution with more of the smaller pollock being applied to a higher proportion of the backscatter in the historic analysis than the primary analysis. Review of this assignment of size composition in the historic analysis indicates that the decision was relatively arbitrary. Thus, a different analyst could reasonably have made a different decision, which would have produced results more similar to those of the primary analysis.

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 Sandi Neidetcher for more information: Sandi.Neidetcher@noaa.gov). Pacific ocean perch (POP) ovaries and otoliths were collected to study reproductive trends in POP (contact Christina Conrath for more information: Christina.Conrath@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). Several specimens were processed at-sea by scientific guests. The visual field of various fish species were examined to characterize the spectral sensitivity range (contact Lyle Britt: Lyle.Britt@noaa.gov), and pollock stomachs were scanned to determine diets of, and predation on, the large 2017 year class of walleye pollock in the Gulf of Alaska (contact Troy Buckley: Troy.Buckley@noaa.gov). Finally, next-generation EK80 echosounder transceivers were multiplexed with the Dyson EK60 transceivers to collect narrowband acoustic data throughout the 2018 winter surveys to evaluate EK80 performance compared with EK60s (contact Alex De Robertis: Alex.DeRobertis@noaa.gov). The results of these special projects will be reported elsewhere.

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TABLES AND FIGURES

Table 1. -- Simrad ER60 38 kHz acoustic system description and settings used during the winter 2018 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. Data presented from each calibration event are the average of multiple replicate measurements on that date, which is shown in the final row.

	Winter 2018 system settings	5 Feb Kalsin Bay Alaska	12-13 Feb Volcano Bay Alaska	14 Feb Kalsin Bay Alaska	12 Mar Captain's Bay Alaska	23 Mar Kalsin 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)	22.63	22.63	22.64	22.63	22.54	22.58	22.60
s_A correction (dB)	-0.67	-0.65	-0.64	-0.65	-0.62	-0.62	-0.64
Integration gain (dB)	21.96	21.98	22.00	21.98	21.91	21.96	21.97
3 dB beamwidth along	6.69	6.69	6.71	6.68	6.70	6.71	6.70
3 dB beamwidth athwart	7.12	7.12	7.14	7.12	7.13	7.12	7.13
Angle offset along	-0.10	-0.10	-0.08	-0.08	-0.08	-0.08	-0.09
Angle offset athwart	-0.08	-0.08	-0.04	-0.08	-0.08	-0.08	-0.07
Post-processing S_v threshold (dB re 1 m^{-1})	-70	NA	NA	NA	NA	NA	-70
Standard sphere TS (dB re 1 m^2)	NA	-42.13	-42.13	-42.15	-42.16	-42.15	NA
Sphere range from transducer (m)	NA	20.63	21.06	19.85	20.51	19.61	NA
Absorption coefficient (dB/m)	0.0099	0.0100	0.0097	0.0100	0.0099	0.0099	0.0099
Sound velocity (m/s)	1466	1460.2	1460.7	1462.8	1463.3	1463.4	1466
Water temp at transducer (°C)	NA	3.1	3.6	3.6	4.0	4.0	NA
Number of replicates	NA	2	2	2	1	5	NA

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.

-- symbol indicates the same values for the system steeings and final analysis are also applicable for the various calibrations

Table 2.-- Numbers of walleye pollock measured and biological samples collected during the winter 2018 acoustic-trawl surveys of Shumagin Islands (hauls 1-7), Sanak Trough (hauls 8), Morzhovoi Bay (haul 9), and Pavlof Bay (haul 10-11).

	Walleye pollock				
Haul no.	Catch Lengths	Weights	Maturities	Otoliths	Ovary weights
1	121	42	27	32	12
2	143	25	-	5	-
3	74	36	16	22	6
4	72	72	48	53	9
5	223	55	50	35	21
6	550	60	50	35	26
7	490	65	50	35	26
8	339	55	51	35	28
9	241	45	30	35	7
10	141	60	55	45	12
11	345	36	32	36	18
Totals	2,739	551	409	368	165

Table 3. -- Numbers of walleye pollock measured and biological samples collected during the winter 2018 acoustic-trawl surveys of Shelikof Strait (hauls 1-18) and Marmot Bay (hauls 19-21).

	Walleye pollock				
Haul no.	Catch Lengths	Weights	Maturities	Otoliths	Ovary weights
1	468	44	41	44	20
2	465	66	50	46	15
3	446	66	49	55	7
4[a]	18	18	17	-	2
5	387	65	50	45	9
6	349	65	50	55	14
7	296	50	50	40	7
8	416	62	50	45	9
9	356	65	50	45	-
10	365	64	49	45	2
11	394	49	49	39	2
12	318	65	50	45	6
13[b]	300	-	-	-	-
14	387	63	48	43	1
15	337	50	50	40	6
16	260	55	50	45	1
17	102	60	45	50	8
18	175	65	49	45	4
19	70	25	10	15	1
20	369	65	50	55	-
21	141	50	50	50	8
Totals	6,419	1,112	907	847	122

[a] Aborted haul

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

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

*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.

+If L < 15 mm, TS = -105 dB; and if L > 65 mm, TS = -73 dB.

#k = 2πfc, where f = 38,000 (frequency in Hz) and c = 1470 (sound speed in m/s).

Table 5. -- Trawl station and catch data summary from the winter 2018 acoustic-trawl survey of walleye pollock in Shumagin Islands, Sanak Trough, Morzhovoi Bay, and Pavlof Bay.

Haul No.	Area	Gear type[1]	Date (GMT)	Time (GMT)	Duration (minutes)	Start position Latitude (N)	Start position Longitude (W)	Depth (m) Footrope	Depth (m) Bottom	Water temp. (°C) Headrope	Water temp. (°C) Surface[2]	Catch Pollock (kg)	Catch Pollock Number	Catch Eulachon (kg)	Catch Other (kg)
1	Shumagins	AWT	7-Feb-18	13:10:42	15.23	55.2469	-158.4561	175.73	196	4.78	4.33	36.7	2668	2.4	3.7
2	Shumagins	AWT	7-Feb-18	22:02:15	5.13	55.3231	-158.8793	157	185	4.5	4.2	38.2	4494	-	0.1
3	Shumagins	AWT	8-Feb-18	8:31:57	20.4	55.3675	-159.329	140	161	4.5	4.1	12.2	388	2.5	5.7
4	Shumagins	AWT	10-Feb-18	5:24:31	30.57	55.2105	-160.1951	207	222	4.4	4.5	40.7	93	1.7	14.9
5	Shumagins	AWT	10-Feb-18	14:49:28	26.97	55.5396	-159.8966	115	179	4.1	4.3	149.2	223	3.2	1.1
6	Shumagins	AWT	10-Feb-18	17:56:18	15.28	55.5867	-160.1813	155	183	4.3	4.3	810.6	1174	1.6	1.6
7	Shumagins	AWT	10-Feb-18	20:33:07	7.15	55.5653	-160.3523	139	168	4.3	4.3	734.9	1088	4.3	2.1
8	Sanak	AWT	11-Feb-18	13:27:28	30.68	54.5312	-162.4465	103	149	4.2	4.3	268.7	401	0.2	12.8
9	Morzhovoi	AWT	12-Feb-18	5:02:48	30.48	54.9382	-162.9964	86	99	3.4	3.3	150.8	241	-	21.5
10	Pavlof	AWT	12-Feb-18	20:33:39	7.22	55.3534	-161.6717	123	141	4.0	3.4	33.7	297	-	3.5
11	Pavlof	AWT	13-Feb-18	0:03:31	13.6	55.2201	-161.7887	107	115	4.0	3.5	808.4	997	-	0.1

[1]Gear type: AWT = Aleutian wing trawl

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

Table 6. -- Catch by species, and numbers of length and weight measurements taken from individuals, during the seven Aleutian Wing midwater trawl hauls during the winter 2018 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*	1822.5	97.6	10128	74.0	1673	355
eulachon	*Thaleichthys pacificus*	15.7	0.8	1224	8.9	202	80
chinook salmon	*Oncorhynchus tshawytscha*	7.2	0.4	3	0.0	3	3
capelin	*Mallotus villosus*	6.3	0.3	1605	11.7	55	55
Pacific cod	*Gadus macrocephalus*	5.7	0.3	2	0.0	2	2
arrowtooth flounder	*Atheresthes stomias*	3.1	0.2	4	0.0	4	4
flathead sole	*Hippoglossoides elassodon*	2.6	0.1	15	0.1	15	15
smooth lumpsucker	*Aptocyclus ventricosus*	2.1	0.1	1	0.0	1	1
Pandalus sp.	*Pandalus* sp.	1.2	0.1	580	4.2	59	
southern rock sole	*Lepidopsetta bilineata*	0.5	< 0.1	1	0.0	1	1
sidestripe shrimp	*Pandalopsis dispar*	0.2	< 01	22	0.2	2	
Pacific herring	*Clupea pallasii*	0.1	< 0.1	4	0.0	3	3
Aequorea sp.	*Aequorea* sp.	0.1	< 0.1	11	0.1	-	-
Pandalus borealiseous	*Pandalus borealis*	0.1	< 0.1	33	0.2	3	-
smelt unid.	Osmeridae (family)	< 0.1	< 01	39	0.3	12	12
jellyfish unid.	Scyphozoa (class)	< 0.1	< 0.1	9	0.1	-	-
isopod unid.	Isopoda(class)	< 0.1	< 0.1	11	0.1	-	-
squid unid.	Cephalopoda (class)	< 0.1	< 0.1	1	< 0.1	1	-
polychaete worm unid.	Polychata (class)	< 0.1	< 0.1	1	< 0.1	-	-
Total		1867.5		13693		2036	531

Table 7. -- Estimates of walleye pollock biomass (in metric tons) and relative estimation error for the Shumagin Islands, Sanak Trough, Morzhovoi Bay, and Pavlof Bay.

Year	Shumagin Islands		Sanak Trough		Morzhovoi Bay		Pavlof Bay	
	Biomass	Est. error	Biomass	Est. error	Biomass	Est. error	Biomass	Est. error
1994	112,000 [1]							
1995	290,100							
1996	117,700 [2]							
1997	no survey							
1998	no survey							
1999	no survey							
2000	no survey							
2001	119,600							
2002	135,600	27.1%					no est.	no est.
2003	67,700	17.2%	80,500	21.6%			no survey	--
2004	no survey	--	no survey	--			no survey	--
2005	52,000	11.4%	65,500	7.4%			no survey	--
2006	37,300	10.1%	127,200	10.4%	11,700	15.1%	no survey	--
2007	20,000	8.6%	60,300	5.7%	2,500	15.1%	no survey	--
2008	30,600	9.8%	19,800	6.7%	no survey	--	no survey	--
2009	63,300	10.8%	31,400	17.4%	no survey	--	no survey	--
2010	18,200	11.6%	26,700	11.6%	1,800	no est.	no est.	no est.
2011	no survey	--	no survey	--	no survey	--	no survey	--
2012	15,500	5.2%	24,300	15.6%	no survey	--	no survey	--
2013	91,300	17.3%	13,300	5.1%	2,476	11.6%	no survey	--
2014	37,346	18.2%	7,319	9.0%	no survey	--	no survey	--
2015	61,369	17.1%	17,863	10.0%	no survey	--	no survey	--
2016	20,706	7.2%	3,556	6.9%	11,412	12.0%.	2,130	14.7%
2017	29,621	9.8%	957	19.6%	3,932	6.5%	2,228	9.5%
2018	**17,390**	**8.3%**	**1,317**	**12.2%**	**3,772**	**23.0%**	**4,619**	**19.9%**

[1]Survey conducted after peak spawning had occurred.

[2]Partial survey.

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 2018 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*	268.7	95.4	401	72.3	339	55
Pacific cod	*Gadus macrocephalus*	10.6	3.7	2	0.4	2	2
northern rock sole	*Lepidopsetta polyxystra*	1.1	0.4	3	0.5	3	3
flathead sole	*Hippoglossoides elassodon*	1.0	0.3	6	1.1	6	6
Pandalus sp.	*Pandalus* sp. *Thaleichthys*	0.3	0.1	134	24.2	15	-
eulachon	*pacificus*	0.2	0.1	8	1.4	6	6
Total		281.7		555		371	72

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 2018 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*	150.8	87.5	241	65.3	241	45
Aurelia labiata	Lepidopsetta (genus)	11.4	6.6	34	9.2	15	15
Pacific cod	*Gadus macrocephalus*	6.3	3.7	2	0.5	2	2
starry flounder	*Platichthys stellatus*	3.0	1.7	1	0.3	1	1
flathead sole	*Hippoglossoides elassodon*	0.3	0.2	2	0.5	2	2
sturgeon poacher	*Podothecus accipenserinus*	0.3	0.2	6	1.6	6	6
Pandalus sp.	*Pandalus* sp.	0.1	< 0.1	64	17.3	7	-
capelin	*Mallotus villosus*	0.1	< 0.1	12	3.3	12	12
arrowtooth flounder	*Atheresthes stomias*	< 0.1	< 0.1	1	0.3	1	1
Pacific herring	*Clupea pallasii*	< 0.1	< 0.1	4	1.1	4	4
snailfish unid.	Liparidae (family)	< 0.1	< 0.1	1	0.3	1	1
Crangon sp.	*Crangon* sp.	< 0.1	< 0.1	1	0.3	-	-
Total		172.2		369		292	89

Table 10. -- Catch by species and numbers of length and weight measurements taken from individuals, during the two Aleutian Wing midwater trawl haul during the winter 2018 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*	842.1	99.6	1294	95.4	486	96
Aurelia labiata	*Aurelia labiata*	1.9	0.2	12	0.9	2	2
Pacific herring	*Clupea pallasii*	1.5	0.2	30	2.2	30	12
capelin	*Mallotus villosus*	0.1	< 0.1	16	1.2	16	11
sturgeon poacher	*Podothecus accipenserinus*	< 0.1	< 0.1	2	0.1	2	2
isopod unid.	Isopoda (order)	< 0.1	< 0.1	2	0.1	-	-
Total		845.7		1356		536	123

Table 11. -- Trawl station and catch data summary from the winter 2018 acoustic-trawl survey of walleye pollock in Shelikof Strait and Marmot Bay.

Haul			Date	Time	Duration	Start position		Depth (m)		Water temp. (^oC)		Catch			
												Pollock		Eulachon	Other
No.	Area	Gear type[a]	(GMT)	(GMT)	(minutes)	Latitude (N)	Longitude (W)	Footrope[b]	Bottom	Headrope	Surface[c]	(kg)	Number	(kg)	(kg)
1	Shelikof	AWT	16-Mar	9:51:45	49	56.28	-156.13	167	251	5.6	4.0	276.3	468	0.9	0.8
2	Shelikof	AWT	16-Mar	22:00:27	26	56.49	-155.93	188	238	5.5	4.1	235.9	1,194	23.3	1.5
3	Shelikof	AWT	17-Mar	11:44:34	9	56.76	-155.81	244	288	5.6	4.1	1,015.9	2,533	12.3	4.3
4[d]	Shelikof	PNE	18-Mar	4:56:00	9	57.00	-155.53	-	279	9.4	4.0	9.3	18	-	-
5	Shelikof	PNE	18-Mar	10:08:12	20	57.02	-155.48	235	272	5.6	3.2	504.1	891	0.4	1.1
6	Shelikof	PNE	18-Mar	16:55:00	4	56.99	-155.88	257	305	5.5	3.8	213.9	349	0.0	1.6
7	Shelikof	AWT	18-Mar	23:37:50	43	57.18	-155.31	104	252	4.5	3.1	348.6	621	-	1.0
8	Shelikof	AWT	19-Mar	3:56:25	14	57.24	-155.65	249	273	5.6	3.0	1,711.3	5,108	12.1	2.6
9	Shelikof	AWT	19-Mar	10:20:53	5	57.34	-155.41	-	263	5.5	3.5	1,208.9	3,321	31.7	6.4
10	Shelikof	AWT	19-Mar	19:07:28	2	57.60	-155.31	227	304	5.5	3.3	1,978.8	4,252	80.9	0.3
11	Shelikof	AWT	20-Mar	2:50:11	6	57.57	-154.83	99	238	4.4	3.8	1,447.2	2,405	-	2.8
12	Shelikof	AWT	20-Mar	8:45:57	5	57.64	-154.57	-	208	5.5	3.7	645.2	2,701	116.4	4.8
13[e]	Shelikof	AWT	20-Mar	14:38:52	17	57.86	-154.77	223	280	4.8	3.7	-	-	-	-
14	Shelikof	AWT	20-Mar	22:01:02	3	58.00	-154.34	233	268	5.3	3.9	856.7	1,543	6.5	0.2
15	Shelikof	AWT	21-Mar	2:01:18	3	57.95	-153.78	114	193	4.4	4.3	2,744.1	4,525	-	5.9
16	Shelikof	AWT	21-Mar	7:43:50	2	58.30	-153.91	219	248	4.9	3.8	1,847.1	3,078	17.3	0.6
17	Shelikof	PNE	21-Mar	17:39:48	7	58.35	-153.20	182	192	5.5	4.1	25.2	543	1.6	0.0
18	Shelikof	AWT	21-Mar	23:14:29	4	58.54	-152.90	172	203	4.9	4.4	79.0	2,877	7.3	12.3
19	Marmot	AWT	22-Mar	12:35:37	9	57.99	-152.54	153	188	4.2	4.1	17.1	2,116	19.5	1.1
20	Marmot	AWT	22-Mar	18:25:26	5	58.00	-152.35	215	282	4.2	4.3	1,228.5	2,944	22.6	0.3
21	Marmot	AWT	22-Mar	22:40:03	7	57.97	-152.20	99	182	4.2	4.4	84.5	141	-	-

[a] Gear type: AWT = Aleutian wing trawl, PNE = poly Nor'eastern bottom trawl

[b] Footrope depths not collected for some trawls

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

[d] Aborted haul

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

Table 12. -- Catch by species and numbers of length and weight measurements taken from individuals found in the codend, during the 13 Aleutian Wing midwater trawl hauls that fished with a closed codend (i.e., excludes haul 13) during the winter 2018 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*	14395.1	97.6	34626	59.9	4,701	782
eulachon	*Thaleichthys pacificus*	308.6	2.1	21435	37.1	401	107
chinook salmon	*Oncorhynchus tshawytscha*	27.8	0.2	23	< 0.1	16	15
smooth lumpsucker	*Aptocyclus ventricosus*	7.2	< 0.1	7	< 0.1	5	5
pandalid shrimp unid.	Pandalidae (family)	2.6	< 0.1	1121	1.9	55	-
Pacific herring	*Clupea pallasii*	1.9	< 0.1	47	0.1	18	18
flathead sole	*Hippoglossoides elassodon*	0.8	< 0.1	5	< 0.1	3	3
lanternfish unid.	Myctophidae (family)	0.8	< 0.1	230	0.4	45	37
northern smoothtongue	*Leuroglossus schmidti*	0.7	< 0.1	88	0.2	17	17
chum salmon	*Oncorhynchus keta*	0.5	< 0.1	2	< 0.1	2	2
arrowtooth flounder	*Atheresthes stomias*	0.4	< 0.1	3	< 0.1	1	1
Pacific glass shrimp	*Pasiphaea pacifica*	0.2	< 0.1	-	-	-	-
Stenobrachius sp.	*Stenobrachius* sp.	0.2	< 0.1	40	< 0.1	-	-
pasiphaeid shrimp unid.	Pasiphaeidae (family)	0.1	< 0.1	71	< 0.1	10	-
shrimp unid.	Malacostraca (class)	0.1	< 0.1	26	< 0.1	7	-
squid unid.	Cephalopoda (class)	< 0.1	< 0.1	5	< 0.1	3	3
capelin	*Mallotus villosus*	< 0.1	< 0.1	13	< 0.1	11	1
jellyfish unid.	Scyphozoa (class)	< 0.1	< 0.1	3	< 0.1	2	2
isopod unid.	Isopoda (order)	< 0.1	< 0.1	12	< 0.1	-	-
smelt unid.	Osmeridae (family)	< 0.1	< 0.1	5	< 0.1	3	1
sculpin unid.	Cottidae (family)	< 0.1	< 0.1	3	< 0.1	1	1
Crangon sp.	*Crangon* sp.	< 0.1	< 0.1	1	< 0.1	-	-
Total		14,747.2		57,761		5,301	995

Table 13. -- Catch by species, and numbers of length and weight measurements taken from individuals found in the codend of the three poly Nor'eastern bottom trawl hauls during the winter 2018 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*	752.5	99.4	1,801	90.1	838	190
eulachon	*Thaleichthys pacificus*	2.1	0.3	143	7.2	72	23
rougheye rockfish	*Sebastes aleutianus*	1.6	0.2	1	0.1	1	1
chinook salmon	*Oncorhynchus tshawytscha*	1.1	0.1	1	0.1	1	-
pandalid shrimp unid.	Pandalidae (family)	< 0.1	< 0.1	24	1.2	24	-
Stenobrachius sp.	*Stenobrachius* sp.	< 0.1	< 0.1	5	0.3	3	3
Pacific glass shrimp	*Pasiphaea pacifica*	< 0.1	< 0.1	12	0.6	8	-
pasiphaeid shrimp unid.	Pasiphaeidae (family)	< 0.1	< 0.1	4	0.2	4	1
lanternfish unid.	Myctophidae (family)	< 0.1	< 0.1	6	0.3	6	6
northern smoothtongue	*Leuroglossus schmidti*	< 0.1	< 0.1	1	0.1	1	1
isopod unid.	Isopoda (order)	< 0.1	< 0.1	1	0.1	-	-
Total		757.4		1,999		958	225

Table 14. -- Estimates of walleye pollock biomass (in metric tons) and relative estimation error for the Shelikof Region.

Year	Shelikof Strait		Chirikof shelf break		Marmot Bay	
	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%			no survey	--
1995	763,600	4.5%			no survey	--
1996	777,200	3.7%			no survey	--
1997	583,000	3.7%			no survey	--
1998	504,800	3.8%			no survey	--
1999	no survey	--			no survey	--
2000	448,600	4.6%			no survey	--
2001	432,800	4.5%			no survey	--
2002	256,700	6.9%	82,100	12.2%	no survey	--
2003	316,500	5.2%	30,900	20.7%	no survey	--
2004	326,800	9.2%	30,400	20.4%	no survey	--
2005	356,100	4.1%	77,000	20.7%	no survey	--
2006	293,600	4.0%	69,000	11.0%	no survey	--
2007	180,900	5.8%	36,600	6.7%	3,600	5.0%
2008	208,000	5.6%	22,100	9.6%	no survey	--
2009	266,000	5.9%	400	32.3%	19,800	no est.
2010	429,700	2.6%	9,300	15.0%	5,600	no est.
2011	no survey	--	no survey	--	no survey	--
2012	335,800	7.9%	21,200	16.4%	no survey	--
2013	891,261	5.3%	63,000	31.4%	19,900	4.1%
2014	842,138	4.7%	no survey	--	14,992	9.4%
2015	845,306	4.3%	12,685	14.2%	22,470	3.1%
2016	665,059	6.5%	no survey	--	37,161	8.8% [2]
2017	1,489,723	4.3%	4,007	24.0%	14,259	7.9%
2018	**1,320,867**	**3.9%**	**no survey**	**--**	**13,521**	**7.5%** [2]

[1]Shelikof Strait surveyed in 1987, but no estimate was made due to mechanical problems.

[2]During these years, outer Marmot was surveyed in a zig-zag pattern, rather than parallel transects. Inner Marmot was surveyed with parallel transects. Relative estimation error was determined by combining estimation of error for biomass within the inner bay (1-D) and outer bay (2-D) following Equation 16.

Table 15. -- 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	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018
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	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	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	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	2.0	0.0	0.0	0.0	<1	0.0	0.0	0.0	<1	0.0	0.0	0.0	0.0	0.0	<1	0.0	0.0	1.0	<1	0.0	0.0	0.0
9	<1	<1	4.0	163.0	0.0	3.0	4.0	29.0	4.0	0.0	0.0	<1	6.0	3.5	<1	6.6	1.2	1.3	<1	81.9	6.0	0.0	0.0	0.8	61.5
10	4.0	3.0	32.0	1120.0	3.0	3.0	16.0	372.0	33.0	0.0	1.0	10.0	106.0	36.3	3.7	25.0	16.1	9.6	1.5	800.6	65.0	0.8	0.0	13.3	529.3
11	27.0	16.0	51.0	3906.0	12.0	20.0	70.0	1162.0	87.0	0.0	8.0	15.0	476.0	61.5	14.0	161.4	73.5	20.3	7.7	1934.9	152.0	1.0	0.0	54.1	822.0
12	74.0	26.0	60.0	3779.0	20.0	21.0	140.0	1565.0	87.0	5.0	14.0	24.0	621.0	39.1	20.5	407.3	134.0	27.9	22.4	2239.6	185.0	1.6	0.0	114.7	454.1
13	79.0	13.0	33.0	1538.0	18.0	15.0	104.0	999.0	52.0	2.0	20.0	3.0	296.0	12.8	10.5	411.7	73.8	21.4	34.0	800.1	122.0	2.1	0.0	83.6	51.8
14	36.0	3.0	6.0	157.0	4.0	7.0	49.0	320.0	24.0	1.0	8.0	1.0	98.0	5.3	3.8	265.4	30.5	7.4	18.3	320.6	32.0	1.5	0.0	25.6	10.1
15	6.0	1.0	<1	25.0	<1	1.0	10.0	30.0	2.0	1.0	1.0	<1	19.0	2.3	0.7	77.3	1.8	1.1	8.8	103.7	9.0	0.3	0.0	10.7	2.4
16	1.0	0.0	<1	1.0	5.0	<1	2.0	7.0	2.0	0.0	<1	<1	4.0	0.9	0.1	11.1	1.1	<1	2.3	34.0	3.0	0.2	0.0	3.3	1.2
17	0.0	0.0	0.0	1.0	51.0	<1	<1	1.0	20.0	0.0	<1	<1	<1	6.5	1.6	2.2	0.0	<1	0.0	8.4	35.0	0.0	0.0	0.0	0.0
18	0.0	<1	1.0	4.0	249.0	1.0	<1	10.0	185.0	<1	0.0	<1	1.0	23.4	7.6	0.1	5.6	<1	0.0	<1	114.0	0.1	0.0	0.0	0.4
19	<1	<1	<1	16.0	634.0	1.0	1.0	32.0	808.0	3.0	1.0	1.0	2.0	75.4	24.3	4.7	6.6	9.1	10.8	0.6	492.0	0.7	0.0	0.0	3.6
20	1.0	4.0	2.0	39.0	945.0	8.0	3.0	81.0	1407.0	15.0	3.0	4.0	8.0	140.6	54.5	4.5	76.7	15.7	55.3	1.7	1014.0	1.3	0.0	0.0	5.9
21	2.0	8.0	5.0	68.0	772.0	23.0	10.0	147.0	1043.0	36.0	11.0	10.0	20.0	203.1	60.2	19.9	179.0	36.2	155.6	3.9	967.0	9.1	0.0	0.0	16.9
22	5.0	17.0	7.0	92.0	441.0	50.0	16.0	196.0	460.0	29.0	15.0	20.0	29.0	161.3	41.6	38.1	347.2	63.5	183.9	12.7	488.0	16.6	<1	0.0	27.0
23	8.0	20.0	6.0	93.0	131.0	48.0	20.0	176.0	107.0	43.0	17.0	23.0	38.0	107.4	19.6	83.4	293.4	88.8	189.4	10.8	326.0	20.8	0.0	<1	28.3
24	10.0	14.0	5.0	73.0	54.0	48.0	21.0	68.0	20.0	56.0	16.0	18.0	30.0	66.2	9.0	117.0	181.4	49.9	142.3	15.4	102.0	17.2	<1	<1	23.4
25	6.0	7.0	4.0	53.0	18.0	89.0	10.0	30.0	22.0	128.0	11.0	12.0	16.0	27.4	6.1	75.9	79.7	26.9	64.6	19.1	58.0	16.8	<1	<1	19.1
26	5.0	5.0	2.0	36.0	9.0	208.0	8.0	11.0	31.0	239.0	8.0	9.0	7.0	13.7	7.4	35.6	19.6	16.3	33.5	28.7	29.0	38.9	<1	0.0	7.8
27	3.0	1.0	3.0	27.0	9.0	275.0	6.0	6.0	60.0	250.0	9.0	4.0	2.0	6.2	10.9	30.1	9.5	7.7	8.5	11.6	6.0	84.6	<1	0.0	7.9
28	3.0	1.0	1.0	17.0	11.0	268.0	5.0	10.0	85.0	210.0	23.0	2.0	3.0	3.1	15.1	19.4	13.6	9.2	10.2	11.0	8.0	167.6	<1	<1	4.1
29	8.0	1.0	1.0	5.0	22.0	205.0	10.0	13.0	91.0	124.0	52.0	3.0	1.0	5.4	23.1	13.3	5.6	27.7	1.5	9.2	1.0	280.6	<1	0.0	0.0
30	19.0	1.0	3.0	2.0	23.0	104.0	25.0	18.0	50.0	74.0	107.0	4.0	8.0	5.6	29.5	10.6	6.3	55.3	5.7	28.8	1.0	299.9	<1	0.0	1.2
31	25.0	2.0	6.0	6.0	15.0	59.0	42.0	32.0	37.0	42.0	153.0	7.0	8.0	5.6	23.2	27.1	8.9	90.5	1.9	45.9	1.0	270.6	1.9	0.0	0.3
32	37.0	3.0	7.0	4.0	15.0	31.0	78.0	37.0	15.0	25.0	185.0	16.0	2.0	5.6	23.1	38.1	13.1	107.7	4.8	48.6	2.0	208.9	3.2	0.9	0.3
33	48.0	5.0	11.0	8.0	13.0	21.0	102.0	34.0	14.0	29.0	145.0	25.0	10.0	6.5	18.7	42.3	24.3	91.3	6.1	79.7	4.0	142.4	10.6	0.0	0.4
34	67.0	6.0	6.0	6.0	6.0	16.0	99.0	28.0	7.0	20.0	122.0	41.0	3.0	8.0	15.6	31.4	23.7	66.1	6.1	89.2	3.0	66.1	21.9	1.2	0.0
35	85.0	10.0	7.0	11.0	4.0	11.0	103.0	22.0	6.0	17.0	77.0	56.0	10.0	4.8	12.4	31.5	18.7	31.6	5.8	133.0	4.0	49.0	50.6	<1	0.0
36	83.0	9.0	6.0	15.0	4.0	10.0	84.0	13.0	8.0	7.0	57.0	59.0	4.0	3.8	7.7	16.6	17.0	25.3	5.6	124.0	4.0	28.1	90.8	5.1	0.0
37	84.0	17.0	3.0	14.0	3.0	10.0	66.0	9.0	9.0	5.0	38.0	54.0	18.0	2.7	4.8	18.8	8.1	14.1	4.6	126.9	6.0	23.8	138.9	14.5	1.2
38	65.0	26.0	3.0	20.0	2.0	9.0	45.0	8.0	9.0	6.0	28.0	47.0	10.0	2.3	4.3	7.1	12.3	10.5	3.7	68.1	8.0	15.7	209.0	58.1	1.7
39	36.0	40.0	2.0	9.0	2.0	5.0	26.0	7.0	11.0	6.0	23.0	39.0	11.0	1.3	3.5	3.3	16.4	7.5	3.3	49.0	15.0	15.4	273.6	130.7	10.2

Table 15. – Continued.

Length	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018
40	30.0	53.0	3.0	15.0	2.0	8.0	15.0	11.0	9.0	2.0	14.0	35.0	23.0	2.2	3.7	7.7	9.9	8.5	4.5	27.5	28.0	7.0	270.8	315.2	45.1
41	22.0	57.0	5.0	5.0	2.0	4.0	16.0	13.0	12.0	2.0	13.0	35.0	22.0	2.1	3.0	6.7	14.0	8.5	6.1	15.8	42.0	7.0	204.4	505.8	102.1
42	15.0	57.0	9.0	7.0	2.0	5.0	6.0	19.0	8.0	3.0	7.0	38.0	32.0	2.5	2.4	4.1	15.9	10.2	9.2	13.2	59.0	7.4	137.8	561.6	201.3
43	14.0	48.0	16.0	17.0	4.0	4.0	7.0	19.0	7.0	2.0	6.0	32.0	33.0	3.8	2.6	3.9	14.6	10.6	12.5	10.8	59.0	8.7	76.1	501.3	304.0
44	14.0	37.0	23.0	18.0	6.0	5.0	5.0	18.0	7.0	2.0	5.0	27.0	41.0	5.3	2.3	3.0	14.5	11.1	13.0	12.7	57.0	13.4	40.1	344.4	368.1
45	17.0	33.0	36.0	35.0	7.0	3.0	2.0	19.0	8.0	3.0	3.0	24.0	39.0	7.1	2.9	3.8	11.9	14.5	16.7	5.2	42.0	18.2	22.1	196.0	349.9
46	22.0	23.0	39.0	53.0	13.0	4.0	2.0	22.0	5.0	2.0	3.0	18.0	33.0	9.1	2.1	3.0	8.9	13.8	16.6	6.5	27.0	23.6	12.9	97.3	261.5
47	21.0	19.0	46.0	62.0	25.0	4.0	3.0	19.0	5.0	3.0	3.0	17.0	37.0	10.9	2.9	1.4	5.6	11.4	18.8	9.5	17.0	26.4	10.1	59.2	188.2
48	32.0	17.0	37.0	74.0	37.0	6.0	4.0	17.0	6.0	4.0	2.0	11.0	33.0	13.6	2.9	0.6	4.7	12.0	17.9	13.8	13.0	32.6	6.9	28.7	116.0
49	38.0	16.0	33.0	73.0	53.0	13.0	6.0	13.0	9.0	3.0	2.0	8.0	22.0	15.4	4.3	1.2	2.8	10.4	15.8	15.0	11.0	30.1	7.4	17.8	62.4
50	46.0	17.0	29.0	66.0	64.0	20.0	13.0	16.0	8.0	3.0	2.0	7.0	28.0	17.6	6.1	<1	2.9	12.3	16.6	15.0	14.0	24.9	8.8	13.1	30.6
51	40.0	15.0	24.0	51.0	69.0	30.0	18.0	10.0	5.0	4.0	2.0	5.0	14.0	19.5	7.7	<1	2.6	10.8	13.3	26.8	15.0	23.0	6.4	5.8	29.2
52	38.0	14.0	21.0	40.0	64.0	36.0	24.0	11.0	9.0	4.0	2.0	4.0	7.0	19.0	5.9	1.2	3.5	9.5	13.3	19.4	27.0	19.1	4.3	9.2	9.8
53	35.0	14.0	24.0	30.0	53.0	37.0	26.0	10.0	6.0	3.0	2.0	2.0	6.0	15.6	8.9	1.1	2.2	6.4	11.0	22.9	27.0	20.4	5.4	5.6	9.5
54	35.0	13.0	18.0	22.0	39.0	34.0	23.0	9.0	4.0	3.0	1.0	3.0	4.0	11.7	7.4	2.0	2.5	7.4	9.0	30.6	28.0	18.9	2.6	3.9	3.7
55	30.0	11.0	18.0	16.0	29.0	28.0	20.0	9.0	5.0	2.0	1.0	3.0	3.0	12.8	7.9	1.8	1.6	8.4	10.2	23.5	28.0	24.8	2.8	4.1	6.7
56	15.0	9.0	18.0	14.0	19.0	24.0	19.0	8.0	5.0	1.0	<1	2.0	2.0	6.5	5.8	3.5	2.6	6.1	8.1	30.5	32.0	21.3	2.3	2.2	1.8
57	18.0	7.0	13.0	7.0	13.0	12.0	12.0	9.0	3.0	1.0	<1	1.0	1.0	4.5	4.9	1.0	1.7	5.2	8.2	21.7	24.0	20.9	2.7	1.1	0.3
58	14.0	7.0	11.0	6.0	10.0	8.0	9.0	6.0	2.0	1.0	<1	1.0	1.0	3.1	4.4	2.3	1.3	6.3	8.3	19.1	19.0	21.2	2.6	1.5	0.0
59	4.0	4.0	9.0	3.0	6.0	5.0	8.0	5.0	3.0	1.0	1.0	1.0	1.0	3.1	2.7	2.7	1.3	5.8	4.9	18.8	14.0	15.9	1.2	0.7	0.0
60	2.0	3.0	7.0	2.0	5.0	3.0	4.0	2.0	3.0	<1	1.0	<1	1.0	1.8	1.9	1.8	1.3	3.6	4.6	21.9	13.0	15.3	0.9	1.6	0.2
61	2.0	2.0	5.0	1.0	3.0	2.0	2.0	1.0	1.0	<1	1.0	<1	<1	1.6	1.6	2.6	1.3	5.5	2.4	9.7	9.0	9.0	1.3	0.1	0.0
62	3.0	1.0	2.0	2.0	2.0	1.0	2.0	2.0	<1	<1	<1	<1	0.0	1.0	1.0	1.1	1.0	4.1	1.4	9.8	7.0	8.2	<1	0.1	0.4
63	1.0	1.0	1.0	<1	1.0	1.0	2.0	1.0	1.0	<1	<1	<1	1.0	0.9	0.9	1.1	1.1	3.5	1.5	14.0	3.0	4.5	0.7	0.5	0.0
64	<1	<1	1.0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.4	0.7	4.0	1.0	3.2	4.0	1.8	0.0	0.0	0.0
65	0.0	<1	1.0	<1	<1	<1	<1	<1	<1	<1	0.0	<1	<1	<1	<1	<1	<1	3.5	1.0	2.3	2.0	2.8	0.0	0.0	0.0
66	<1	<1	<1	0.0	<1	<1	<1	<1	1.0	0.0	0.0	0.0	<1	<1	<1	0.6	1.1	2.5	<1	2.8	2.0	2.5	0.0	0.0	0.0
67	<1	<1	<1	0.0	<1	<1	0.0	<1	0.0	<1	<1	0.0	0.0	<1	<1	<1	0.6	2.7	<1	<1	1.0	0.6	0.0	0.0	0.0
68	0.0	<1	0.0	0.0	<1	<1	<1	0.0	<1	<1	0.0	<1	0.0	<1	<1	<1	<1	1.4	<1	0.8	1.0	1.1	0.0	0.0	0.0
69	0.0	<1	<1	0.0	<1	<1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<1	<1	<1	<1	0.0	0.0	<1	<1	0.0	0.0	0.0
70	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	<1	<1	<1	1.0	<1	0.0	0.0	0.0	0.0
71	0.0	0.0	<1	0.0	0.0	0.0	0.0	0.0	0.0	<1	0.0	0.0	0.0	0.0	<1	0.0	<1	<1	0.0	1.1	<1	0.0	0.0	0.0	0.0
72	0.0	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	<1	0.0	0.0	<1	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	<1	<1	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	<1	<1	0.0	0.0	0.0	0.0
75	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	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	<1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1339.0	740.0	729.0	11931.0	4024.0	1866.0	1425.0	5742.0	4931.0	1424.0	1224.0	780.0	2252.0	1239.6	575.0	2100.0	1832.0	1165.3	1244.8	7668.0	4885.0	2212.0	1633.0	3194.0	4182.6

Table 16. -- Biomass-at-length estimates (thousands of metric tons) from acoustic-trawl surveys of walleye pollock in the Shelikof Strait area.

Length	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018
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	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	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	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	< 1	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	<1	0.0	0.0	<1	<1	0.0	0.0	0.0
9	< 1	< 1	< 1	1.0	0.0	< 1	< 1	< 1	< 1	0.0	0.0	< 1	< 1	< 1	< 1	<1	<1	<1	<1	<1	<1	0.0	0.0	<1	0.3
10	< 1	< 1	< 1	7.0	< 1	< 1	< 1	3.0	< 1	0.0	< 1	< 1	1.0	< 1	< 1	<1	<1	<1	<1	4.7	<1	<1	0.0	0.1	3.4
11	< 1	< 1	< 1	35.0	< 1	< 1	1.0	11.0	1.0	0.0	< 1	< 1	4.0	< 1	< 1	1.5	0.6	<1	<1	14.9	1.0	<1	0.0	0.4	6.7
12	1.0	< 1	1.0	44.0	< 1	< 1	1.0	20.0	1.0	< 1	< 1	< 1	7.0	< 1	< 1	4.5	1.4	<1	<1	21.3	2.0	<1	0.0	1.1	4.7
13	1.0	< 1	< 1	23.0	< 1	< 1	1.0	16.0	1.0	< 1	< 1	< 1	4.0	< 1	< 1	6.2	1.0	<1	<1	9.6	2.0	<1	0.0	1.1	0.7
14	1.0	< 1	< 1	3.0	< 1	< 1	1.0	7.0	< 1	< 1	< 1	< 1	2.0	< 1	< 1	4.6	0.5	<1	<1	4.8	1.0	<1	0.0	0.4	0.2
15	< 1	< 1	< 1	1.0	< 1	< 1	< 1	1.0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1.7	<1	<1	<1	1.9	<1	<1	0.0	0.2	0.1
16	< 1	0.0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0.0	< 1	< 1	< 1	< 1	< 1	<1	<1	<1	<1	0.8	<1	<1	0.0	0.1	<1
17	0.0	0.0	0.0	< 1	2.0	< 1	< 1	< 1	1.0	0.0	< 1	< 1	< 1	< 1	< 1	<1	0.0	<1	0.0	<1	1.0	<1	0.0	0.0	0.0
18	0.0	< 1	< 1	< 1	9.0	< 1	< 1	< 1	6.0	< 1	0.0	< 1	< 1	< 1	< 1	<1	<1	<1	0.0	<1	4.0	<1	0.0	0.0	<1
19	< 1	< 1	< 1	1.0	27.0	< 1	< 1	2.0	33.0	< 1	< 1	< 1	< 1	3.3	1.1	<1	<1	<1	<1	<1	22.0	<1	0.0	0.0	0.2
20	< 1	< 1	< 1	2.0	48.0	< 1	< 1	5.0	68.0	1.0	< 1	< 1	< 1	7.1	2.8	<1	4.2	<1	3.1	<1	50.0	<1	0.0	0.0	0.3
21	< 1	< 1	< 1	4.0	46.0	1.0	1.0	10.0	59.0	2.0	1.0	1.0	1.0	12.0	3.6	1.3	11.2	2.2	9.6	<1	56.0	0.6	0.0	0.0	1.1
22	< 1	1.0	1.0	7.0	30.0	4.0	1.0	16.0	31.0	2.0	1.0	1.0	2.0	10.8	2.8	3.0	24.7	4.3	13.1	0.9	33.0	1.1	<1	0.0	1.9
23	1.0	2.0	1.0	8.0	10.0	4.0	2.0	17.0	8.0	4.0	1.0	2.0	3.0	8.4	1.6	6.9	23.3	7.0	15.5	0.9	25.0	1.6	0.0	<1	2.4
24	1.0	1.0	1.0	7.0	5.0	5.0	2.0	7.0	2.0	5.0	2.0	2.0	3.0	5.9	0.9	11.2	16.4	4.7	12.9	1.4	9.0	1.5	<1	<1	2.1
25	1.0	1.0	< 1	6.0	2.0	10.0	1.0	4.0	2.0	14.0	1.0	1.0	2.0	3.0	0.6	8.4	7.9	2.7	6.4	1.9	6.0	1.8	<1	<1	2.0
26	1.0	1.0	< 1	5.0	1.0	25.0	1.0	1.0	4.0	29.0	1.0	1.0	1.0	1.7	0.9	4.6	2.4	1.9	4.1	3.3	4.0	4.6	<1	0.0	0.9
27	< 1	< 1	< 1	4.0	1.0	38.0	1.0	1.0	8.0	35.0	1.0	< 1	< 1	< 1	1.5	4.2	1.3	1.0	1.2	1.5	1.0	11.1	<1	0.0	1.1
28	< 1	< 1	< 1	3.0	2.0	42.0	1.0	2.0	13.0	33.0	3.0	< 1	< 1	< 1	2.3	3.2	2.2	1.4	1.6	1.7	1.0	24.7	<1	<1	0.6
29	1.0	< 1	< 1	1.0	4.0	36.0	2.0	2.0	15.0	22.0	9.0	1.0	< 1	< 1	3.9	2.4	1.0	4.7	<1	1.6	<1	45.2	<1	0.0	0.0
30	4.0	< 1	1.0	< 1	4.0	20.0	5.0	4.0	9.0	15.0	20.0	1.0	2.0	1.1	5.5	2.1	1.3	10.6	1.1	5.6	<1	54.2	<1	0.0	0.2
31	5.0	< 1	1.0	1.0	3.0	13.0	9.0	8.0	8.0	9.0	32.0	1.0	2.0	1.2	4.8	6.2	1.9	18.9	<1	9.9	<1	54.7	<1	0.0	0.1
32	9.0	1.0	2.0	1.0	3.0	7.0	19.0	10.0	3.0	6.0	43.0	4.0	1.0	1.3	5.4	9.7	3.0	24.5	1.1	11.6	1.0	46.6	0.6	0.2	0.1
33	12.0	1.0	3.0	2.0	3.0	5.0	26.0	10.0	4.0	8.0	37.0	7.0	3.0	1.7	4.9	12.1	6.0	23.0	1.6	21.0	1.0	35.8	2.3	0.0	0.1
34	19.0	2.0	2.0	2.0	2.0	5.0	28.0	9.0	2.0	6.0	34.0	12.0	1.0	2.4	4.5	9.8	6.5	18.3	1.7	25.9	1.0	17.9	5.3	0.3	0.0
35	27.0	3.0	2.0	4.0	1.0	4.0	33.0	8.0	2.0	6.0	24.0	18.0	3.0	1.5	3.9	10.8	5.7	9.5	1.8	43.2	1.0	14.6	13.4	<1	0.0
36	29.0	3.0	2.0	5.0	1.0	3.0	29.0	5.0	3.0	2.0	19.0	20.0	1.0	1.3	2.7	6.2	5.6	8.6	1.9	42.7	1.0	9.4	26.4	1.6	0.0
37	32.0	6.0	1.0	5.0	1.0	4.0	25.0	4.0	3.0	2.0	14.0	21.0	7.0	1.0	1.8	7.7	3.1	5.2	1.7	49.4	2.0	8.6	44.1	5.0	0.4
38	26.0	11.0	1.0	8.0	1.0	4.0	19.0	4.0	4.0	2.0	11.0	20.0	4.0	< 1	1.8	3.2	5.0	4.2	1.5	28.9	3.0	6.5	72.3	21.4	0.6
39	16.0	18.0	1.0	4.0	1.0	2.0	12.0	3.0	5.0	3.0	10.0	18.0	5.0	< 1	1.6	1.6	7.4	3.5	1.4	21.9	7.0	6.8	102.5	51.5	4.1

Table 16. – Continued.

Length	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018
40	15.0	26.0	2.0	7.0	1.0	4.0	7.0	6.0	4.0	1.0	7.0	17.0	12.0	1.2	1.9	4.5	4.8	4.2	2.1	16.7	13.0	3.5	108.3	134.8	19.9
41	11.0	30.0	3.0	3.0	1.0	2.0	8.0	7.0	6.0	1.0	7.0	19.0	13.0	1.2	1.7	4.2	7.6	4.7	3.2	8.7	21.0	3.7	88.1	233.6	47.9
42	9.0	32.0	5.0	4.0	1.0	3.0	3.0	11.0	5.0	2.0	4.0	22.0	19.0	1.5	1.4	2.6	9.1	6.0	5.1	7.7	32.0	4.2	63.9	276.7	99.2
43	9.0	29.0	10.0	10.0	2.0	2.0	4.0	13.0	5.0	1.0	4.0	20.0	21.0	2.5	1.6	2.8	9.1	6.8	7.6	6.8	35.0	5.2	37.4	260.1	163.6
44	9.0	24.0	16.0	12.0	4.0	3.0	3.0	13.0	5.0	1.0	3.0	19.0	27.0	3.7	1.6	2.3	10.0	7.6	8.3	8.6	36.0	8.7	21.5	192.0	213.6
45	12.0	23.0	26.0	24.0	5.0	2.0	2.0	15.0	6.0	2.0	2.0	17.0	27.0	5.2	2.3	3.2	8.9	11.1	11.7	3.8	29.0	13.0	12.7	116.2	213.3
46	17.0	18.0	31.0	39.0	10.0	3.0	1.0	17.0	4.0	2.0	3.0	15.0	24.0	7.3	1.6	2.2	7.0	11.3	12.5	5.2	20.0	18.1	7.8	63.2	170.4
47	17.0	16.0	39.0	49.0	20.0	3.0	3.0	16.0	4.0	2.0	3.0	14.0	29.0	9.7	2.6	1.3	4.9	9.9	15.0	8.0	13.0	21.6	6.5	41.4	130.0
48	29.0	15.0	34.0	63.0	32.0	6.0	4.0	15.0	6.0	3.0	2.0	10.0	28.0	12.2	2.7	0.6	4.4	11.1	15.0	12.5	11.0	28.5	4.7	21.6	87.9
49	36.0	15.0	32.0	66.0	48.0	13.0	6.0	13.0	8.0	3.0	2.0	8.0	19.0	15.2	4.2	1.3	2.9	10.6	14.9	14.6	10.0	28.2	5.6	15.4	49.6
50	47.0	17.0	30.0	63.0	62.0	20.0	13.0	16.0	8.0	3.0	2.0	8.0	28.0	18.4	6.3	<1	3.3	13.1	16.9	16.2	14.0	25.4	7.2	11.9	24.8
51	43.0	16.0	26.0	52.0	71.0	32.0	20.0	12.0	6.0	4.0	2.0	5.0	14.0	21.9	8.6	<1	2.9	12.5	14.4	30.0	16.0	24.6	5.3	5.3	28.3
52	44.0	15.0	24.0	43.0	70.0	41.0	27.0	13.0	10.0	5.0	2.0	5.0	8.0	23.0	7.1	1.6	4.6	11.8	15.4	23.6	32.0	21.4	3.7	9.2	9.4
53	43.0	17.0	29.0	34.0	62.0	45.0	32.0	12.0	8.0	4.0	2.0	3.0	7.0	20.2	11.3	1.5	3.1	8.7	13.0	29.9	34.0	24.8	5.1	5.7	9.7
54	45.0	17.0	23.0	26.0	48.0	44.0	30.0	13.0	6.0	4.0	1.0	4.0	5.0	16.3	9.9	2.9	3.7	10.1	11.3	42.5	36.0	24.1	2.7	4.2	4.0
55	41.0	15.0	24.0	20.0	38.0	38.0	27.0	12.0	7.0	3.0	2.0	4.0	4.0	19.2	11.5	2.8	2.7	12.6	14.1	32.6	38.0	32.7	3.0	4.6	7.7
56	22.0	13.0	27.0	19.0	27.0	35.0	28.0	12.0	8.0	2.0	< 1	3.0	3.0	10.4	8.8	5.7	4.3	9.7	12.2	46.4	47.0	30.6	2.5	2.7	2.1
57	28.0	11.0	21.0	10.0	20.0	19.0	18.0	13.0	5.0	2.0	< 1	1.0	1.0	7.7	8.5	1.7	2.9	9.1	12.0	34.3	36.0	31.1	2.9	1.2	0.4
58	24.0	12.0	19.0	10.0	15.0	13.0	15.0	11.0	4.0	2.0	1.0	2.0	2.0	5.5	7.7	4.3	2.4	11.2	14.4	32.9	30.0	33.9	3.0	2.0	0.0
59	8.0	7.0	16.0	4.0	11.0	8.0	13.0	8.0	6.0	2.0	2.0	1.0	1.0	5.8	4.8	4.9	2.7	10.6	8.5	33.2	24.0	26.1	1.5	0.9	0.0
60	4.0	5.0	13.0	3.0	9.0	5.0	8.0	4.0	6.0	1.0	1.0	< 1	1.0	3.8	3.6	3.7	2.5	7.0	8.2	41.9	25.0	26.8	1.1	2.4	0.2
61	4.0	3.0	9.0	3.0	5.0	4.0	4.0	2.0	3.0	1.0	1.0	< 1	< 1	3.6	3.2	5.6	2.7	11.2	4.3	19.3	16.0	16.7	1.6	0.2	0.0
62	5.0	2.0	4.0	3.0	3.0	2.0	3.0	3.0	1.0	1.0	< 1	< 1	0.0	2.2	2.2	2.5	2.2	8.5	2.8	20.5	13.0	15.6	<1	0.2	0.7
63	3.0	1.0	3.0	< 1	2.0	2.0	4.0	1.0	3.0	< 1	< 1	1.0	1.0	2.2	2.2	3.0	2.4	8.0	3.2	30.9	6.0	8.5	1.0	0.8	0.0
64	1.0	< 1	2.0	1.0	1.0	< 1	1.0	1.0	1.0	< 1	1.0	< 1	< 1	1.0	1.0	3.5	1.7	9.3	2.2	7.4	8.0	3.9	0.0	0.0	0.0
65	0.0	< 1	2.0	< 1	1.0	< 1	1.0	< 1	< 1	< 1	0.0	< 1	< 1	< 1	0.8	1.3	0.8	8.7	2.2	5.6	4.0	6.2	0.0	0.0	0.0
66	1.0	< 1	< 1	0.0	< 1	< 1	1.0	< 1	3.0	0.0	0.0	0.0	1.0	< 1	< 1	1.8	2.9	6.4	<1	7.1	4.0	5.5	0.0	0.0	0.0
67	1.0	< 1	1.0	0.0	< 1	< 1	0.0	< 1	0.0	< 1	< 1	0.0	0.0	< 1	< 1	1.2	1.6	7.5	1.0	1.1	1.0	1.5	0.0	0.0	0.0
68	0.0	< 1	0.0	0.0	< 1	1.0	< 1	0.0	1.0	< 1	0.0	< 1	0.0	< 1	< 1	<1	1.4	4.0	<1	2.3	1.0	2.9	0.0	0.0	0.0
69	0.0	< 1	< 1	0.0	< 1	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 1	<1	0.8	1.6	0.0	0.0	<1	<1	0.0	0.0	0.0
70	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	<1	3.0	<1	3.0	<1	0.0	0.0	0.0	0.0
71	0.0	0.0	< 1	0.0	0.0	0.0	0.0	0.0	0.0	< 1	0.0	0.0	0.0	0.0	< 1	0.0	0.8	2.1	0.0	3.5	<1	0.0	0.0	0.0	0.0
72	0.0	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	1.8	0.0	0.0	<1	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	1.4	<1	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.6	<1	0.0	0.0	0.0	0.0
75	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	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	<1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	713.0	436.0	493.0	764.0	777.0	583.0	505.0	449.0	433.0	257.0	317.0	331.0	356.0	294.0	181.0	208.0	266.0	429.7	335.8	891.3	842.0	845.0	665.0	1489.7	1301.1

Table 17. -- 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	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018	Mean
1	228.0	63.0	186.0	10,690.0	56.0	70.0	395.0	4,484.0	289.0	8.0	48.0	53.0	1,626.1	161.7	53.5	1,368.0	331.9	90.0	94.9	6,324.3	575.7	7.4	0.0	306.1	1,932.3	1,177.7
2	34.0	76.0	36.0	510.0	3,307.0	183.0	89.0	755.0	4,104.0	163.0	94.0	94.0	157.5	836.0	231.7	391.2	1,204.5	305.6	851.5	149.4	3,640.2	103.9	2.0	0.0	145.0	698.5
3	74.0	37.0	49.0	79.0	119.0	1,247.0	126.0	217.0	352.0	1,107.0	205.0	58.0	55.5	40.7	174.9	249.6	110.2	531.6	43.5	803.3	19.1	1,635.8	79.0	9.9	1.6	297.0
4	188.0	72.0	32.0	78.0	25.0	80.0	474.0	16.0	61.0	97.0	800.0	159.0	34.6	11.5	29.7	53.2	98.7	84.5	76.9	60.9	295.3	72.2	1,446.9	124.3	9.9	179.2
5	368.0	233.0	155.0	103.0	54.0	18.0	136.0	67.0	42.0	16.0	56.0	357.0	172.7	17.4	10.1	12.0	60.2	78.9	95.8	68.8	86.9	152.5	43.4	2559.3	165.7	205.2
6	84.0	126.0	84.0	245.0	71.0	44.0	14.0	132.0	23.0	16.0	8.0	48.0	162.4	56.0	17.3	2.2	9.9	28.5	46.2	114.2	58.5	62.2	33.7	131.1	1,796.0	136.5
7	85.0	27.0	42.0	122.0	201.0	52.0	32.0	17.0	35.0	8.0	4.0	3.0	36.0	75.0	34.4	4.1	2.9	11.8	29.2	65.2	99.5	56.5	15.2	46.8	85.8	47.6
8	171.0	36.0	27.0	54.0	119.0	98.0	36.0	13.0	13.0	7.0	2.0	3.0	3.6	32.2	20.9	10.7	0.9	5.5	4.5	49.1	54.9	67.8	4.4	14.5	46.4	35.8
9	33.0	39.0	44.0	17.0	40.0	53.0	74.0	10.0	6.0	1.0	1.0	3.0	2.4	6.9	1.5	6.7	5.1	5.3	1.1	11.9	25.8	29.9	6.1	0.5	0.0	17.0
10	56.0	16.0	48.0	11.0	13.0	14.0	26.0	8.0	3.0	1.0	< 1	< 1	0.0	< 1	1.0	2.0	6.1	10.8	< 1	5.4	17.7	10.9	2.1	1.4	0.0	12.1
11	2.0	8.0	15.0	15.0	11.0	2.0	14.0	14.0	1.0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1.4	9.4	< 1	5.7	7.4	5.6	0.0	0.0	0.0	6.6
12	15.0	3.0	7.0	6.0	5.0	3.0	7.0	7.0	2.0	< 1	0.0	0.0	0.0	< 1	0.0	0.0	< 1	3.5	0.5	0.6	0.7	3.6	0.0	0.0	0.0	2.9
13	1.0	2.0	1.0	2.0	3.0	1.0	< 1	2.0	1.0	< 1	< 1	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	2.3	0.9	0.0	0.0	0.0	0.9
14	< 1	< 1	2.0	< 1	< 1	< 1	1.0	1.0	< 1	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.6	0.0	0.0	0.0	0.5
15	0.0	1.0	< 1	0.0	0.0	0.0	1.0	0.0	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.7	1.5	0.0	0.0	0.0	0.3
16	0.0	1.0	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	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.1
17	0.0	< 1	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 1
18	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1,339.0	740.0	728.0	11,932.0	4,024.0	1,865.0	1,425.0	5,743.0	4,932.0	1,424.0	1,220.0	777.0	2,251.7	1,240.0	576.0	2,099.6	1,831.8	1,165.3	1,244.6	7,668.0	4,884.7	2,212.0	1,633.0	3,194.0	4,182.6	2,813.3

Table 18. -- Biomass-at-age estimates (thousands of metric tons) from acoustic-trawl surveys of walleye pollock in the Shelikof Strait area since 1992. No surveys were conducted in 1999 or 2011 due to mechanical problems with the survey vessel.

Age	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018	Mean
1	3.0	1.0	2.0	114.0	1.0	1.0	4.0	57.0	2.0	< 1	< 1	< 1	18.1	1.5	< 1	19.2	3.7	0.9	1.3	58.7	7.0	0.1	0.0	3.4	16.0	15.0
2	3.0	6.0	3.0	46.0	180.0	15.0	8.0	63.0	214.0	13.0	8.0	8.0	13.2	54.9	14.6	38.6	94.0	24.1	67.6	18.9	210.9	9.8	<1	0.0	12.8	46.9
3	16.0	11.0	14.0	23.0	24.0	195.0	28.0	60.0	60.0	164.0	42.0	14.0	17.0	10.7	38.9	66.7	28.8	127.3	11.8	278.9	5.8	326.8	23.4	3.4	0.3	63.6
4	60.0	34.0	20.0	41.0	12.0	28.0	153.0	9.0	25.0	29.0	222.0	77.0	19.0	5.0	13.2	25.8	51.5	56.8	50.2	38.1	175.4	39.1	564.3	56.1	5.1	72.4
5	144.0	136.0	127.0	83.0	50.0	13.0	53.0	54.0	27.0	12.0	25.0	179.0	132.5	14.4	8.5	9.6	44.2	86.3	88.9	79.6	61.8	134.1	24.1	1292.1	89.3	118.7
6	68.0	90.0	75.0	220.0	73.0	53.0	12.0	107.0	24.0	16.0	7.0	35.0	119.2	62.9	21.6	3.0	10.6	36.7	61.7	156.6	75.6	65.7	25.1	75.8	1,093.7	103.5
7	92.0	28.0	48.0	116.0	212.0	61.0	39.0	17.0	40.0	9.0	5.0	4.0	28.8	87.2	47.4	7.7	4.8	21.5	43.4	104.2	133.0	80.8	13.3	42.6	58.2	53.8
8	194.0	43.0	34.0	55.0	132.0	120.0	47.0	17.0	18.0	8.0	2.0	3.0	4.2	42.8	30.0	19.9	1.7	11.4	7.0	87.1	84.1	101.5	4.0	13.8	41.4	44.9
9	36.0	46.0	64.0	19.0	48.0	67.0	95.0	15.0	8.0	2.0	2.0	4.0	2.9	10.3	2.8	12.6	10.7	12.0	2.2	22.0	40.5	47.6	8.1	0.7	0.0	23.1
10	71.0	21.0	68.0	15.0	17.0	20.0	33.0	11.0	5.0	1.0	1.0	< 1	0.0	1.0	1.9	4.1	12.8	22.1	0.7	11.5	29.1	17.5	1.9	1.9	0.0	15.3
11	3.0	10.0	21.0	20.0	16.0	3.0	21.0	22.0	2.0	1.0	< 1	< 1	1.4	1.6	1.4	< 1	2.8	21.6	< 1	12.6	11.4	8.9	0.0	0.0	0.0	8.6
12	21.0	4.0	10.0	7.0	7.0	5.0	10.0	11.0	3.0	1.0	0.0	0.0	0.0	1.3	0.0	0.0	< 1	8.9	< 1	2.0	1.4	6.4	0.0	0.0	0.0	4.3
13	1.0	3.0	2.0	3.0	4.0	1.0	< 1	4.0	1.0	< 1	< 1	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.7	1.5	0.0	0.0	0.0	1.4
14	1.0	1.0	4.0	1.0	< 1	1.0	1.0	2.0	1.0	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	1.4	0.0	0.0	0.0	1.0
15	0.0	1.0	< 1	0.0	0.0	0.0	1.0	0.0	< 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	1.3	2.5	0.0	0.0	0.0	0.5
16	0.0	1.0	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	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.1
17	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	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
18	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	713.0	436.0	493.0	764.0	777.0	583.0	505.0	449.0	433.0	257.0	316.0	327.0	356.1	293.6	180.9	208.0	266.0	429.7	335.8	891.3	842.0	845.0	665.0	1,489.7	1,316.8	566.9

Table 19. -- Catch by species, and numbers of length and weight measurements taken from individuals found in the codend, during the three Aleutian Wing midwater trawl hauls during the winter 2018 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*	1,330.1	96.8	5,201	58.7	580	140
eulachon	*Thaleichthys pacificus*	42.1	3.1	2,794	31.5	73	21
pandalid shrimp unid.	Pandalidae (family)	0.5	< 0.1	694	7.8	11	-
capelin	*Mallotus villosus*	0.3	< 0.1	47	0.5	5	5
Pacific herring	*Clupea pallasii*	0.3	< 0.1	8	0.1	2	2
flathead sole	*Hippoglossoides elassodon*	0.3	< 0.1	1	< 0.1	1	1
Mysidae	Mysidae (family)	< 0.1	< 0.1	75	0.8	-	-
pasiphaeid shrimp unid.	Pasiphaeidae (family)	< 0.1	< 0.1	30	0.3	1	-
smelt unid.	Osmeridae (family)	< 0.1	< 0.1	9	0.1	-	-
Total		1,373.6		8,859		673	169

Table 20. -- Estimates of walleye pollock numbers and biomass for six areas of the Gulf of Alaska observed during winter 2018 based on three different analyses (primary analysis, non-selectivity analysis, and historic analysis).

	Shumagin Islands	Sanak Trough	Morzhovoi Bay	Pavlof Bay	Shelikof Strait	Marmot Bay
			Numbers (millions)			
Primary	1,247.2	1.9	6.2	27.0	4,076.5	111.4
Non-selectivity	1,129.4	1.9	5.5	19.8	3,247.1	96.6
Historic	1,125.6	1.9	5.6	17.9	3,269.1	101.4
			Biomass (mt)			
Primary	17,389.7	1,316.7	3,772.0	4,618.6	1,320,867	13,520.8
Non-selectivity	18,872.1	1,317.3	3,797.4	4,842.8	1,343,449	13,719.4
Historic	21,137.8	1,330.3	3,859.7	5,112.9	1,348,247	13,614.0

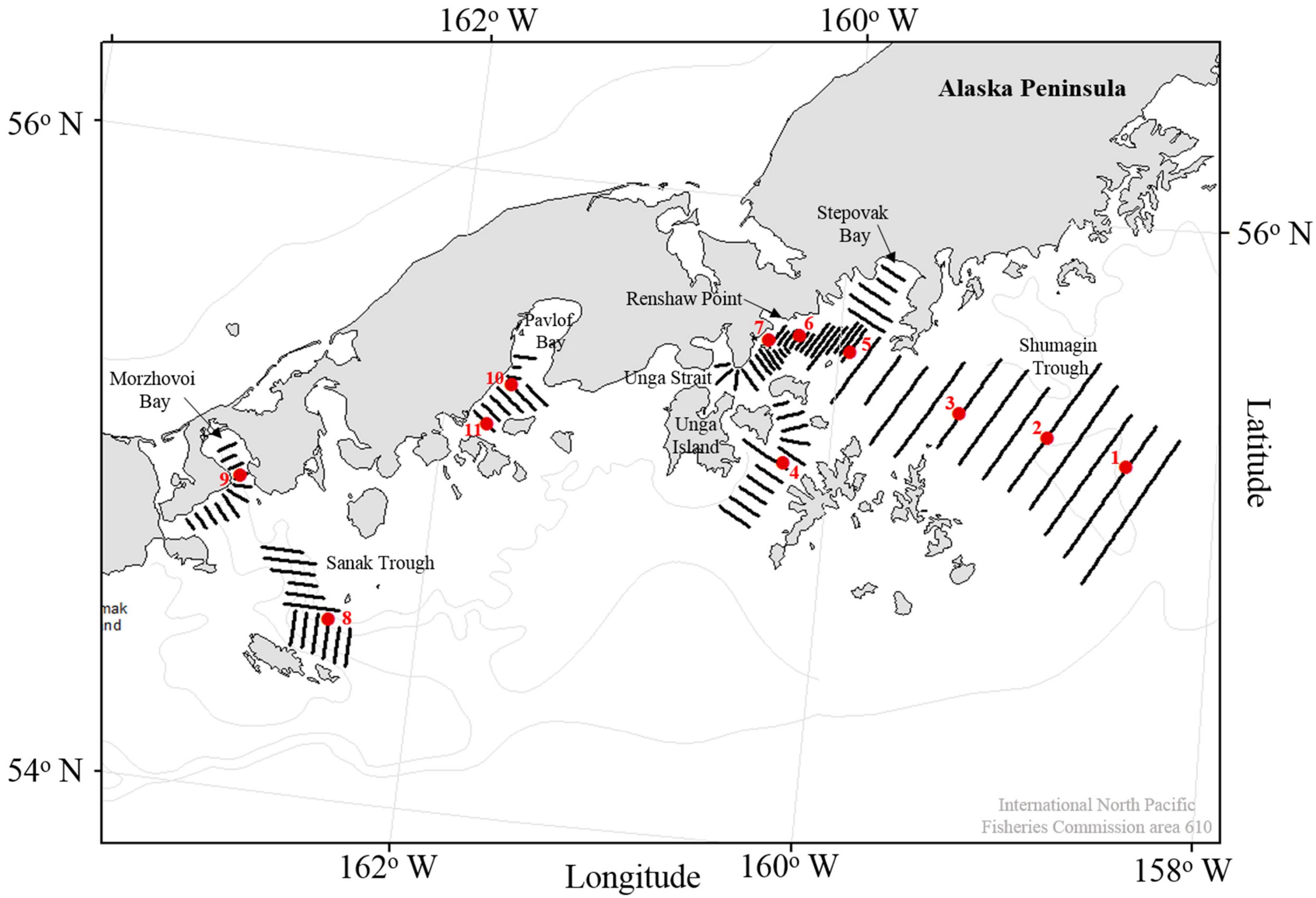

Figure 1. -- Transect lines and locations of Aleutian-wing trawl (AWT) hauls during the winter 2018 acoustic-trawl survey of walleye pollock in the Shumagin Islands, Sanak Trough, Morzhovoi Bay and Pavlof Bay.

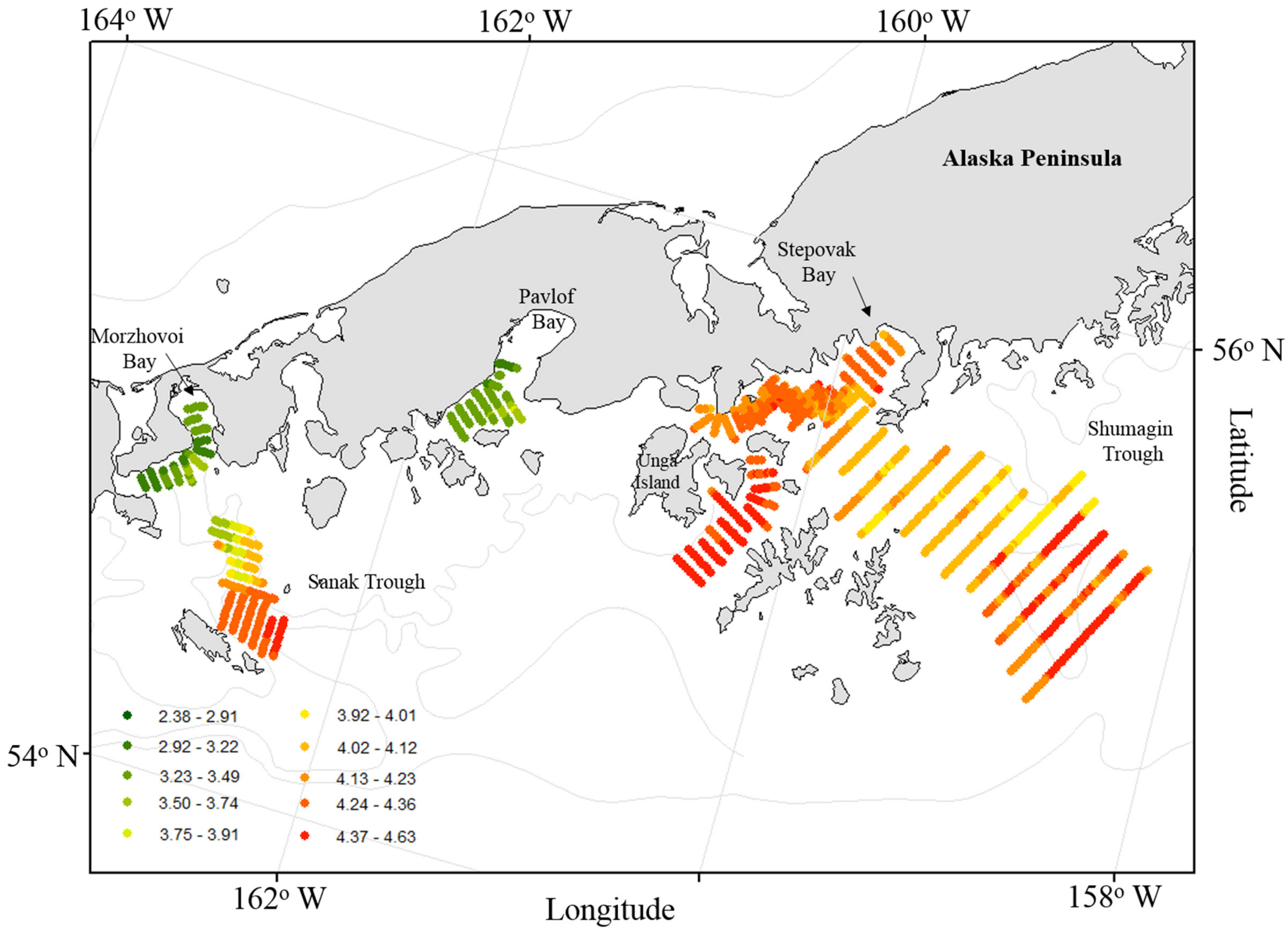

Figure 2. -- Surface water temperatures (°C) recorded at 5-second intervals during the 2018 acoustic-trawl survey of the Shumagin Islands. Temperatures were primarily from the ship's bow-mounted Seabird SBE-38 temperature sensor. At times when the SBE-38 was not operating, temperatures were from the mid-ship Furuno T-2000 temperature probe located 1.4 m below the surface.

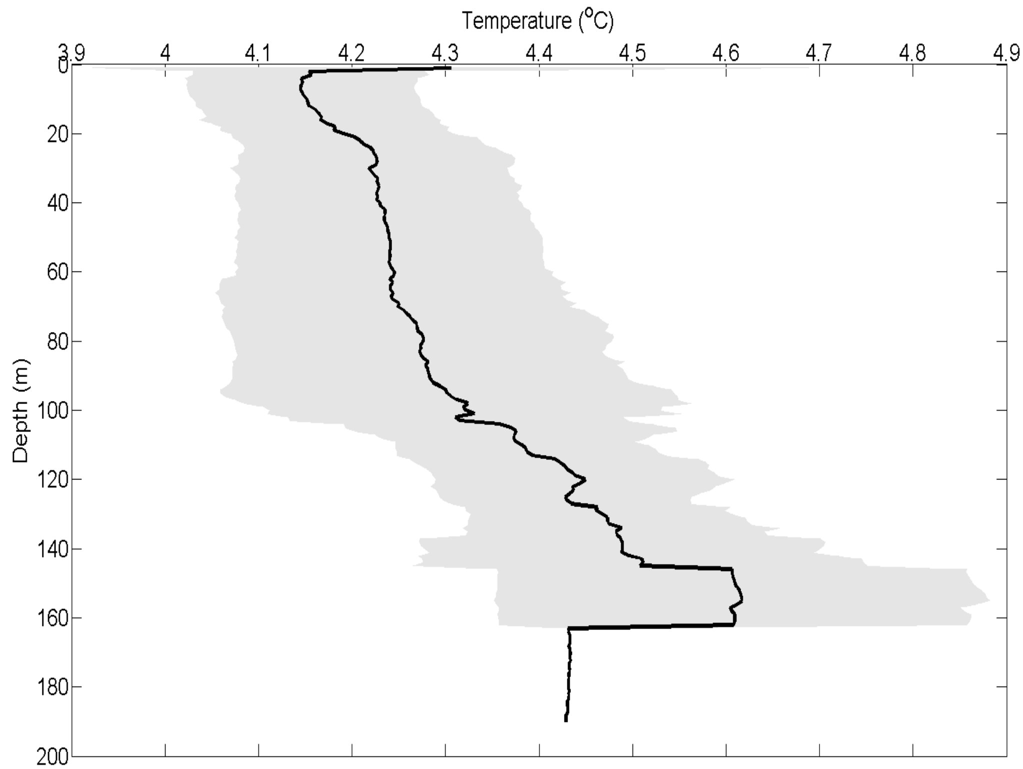

Figure 3. -- Mean water temperature (°C; solid line) by 1-m depth intervals for the 7 trawl haul locations observed during the winter 2018 acoustic-trawl survey of walleye pollock in the Shumagin Trough region. The shaded area represents one standard deviation.

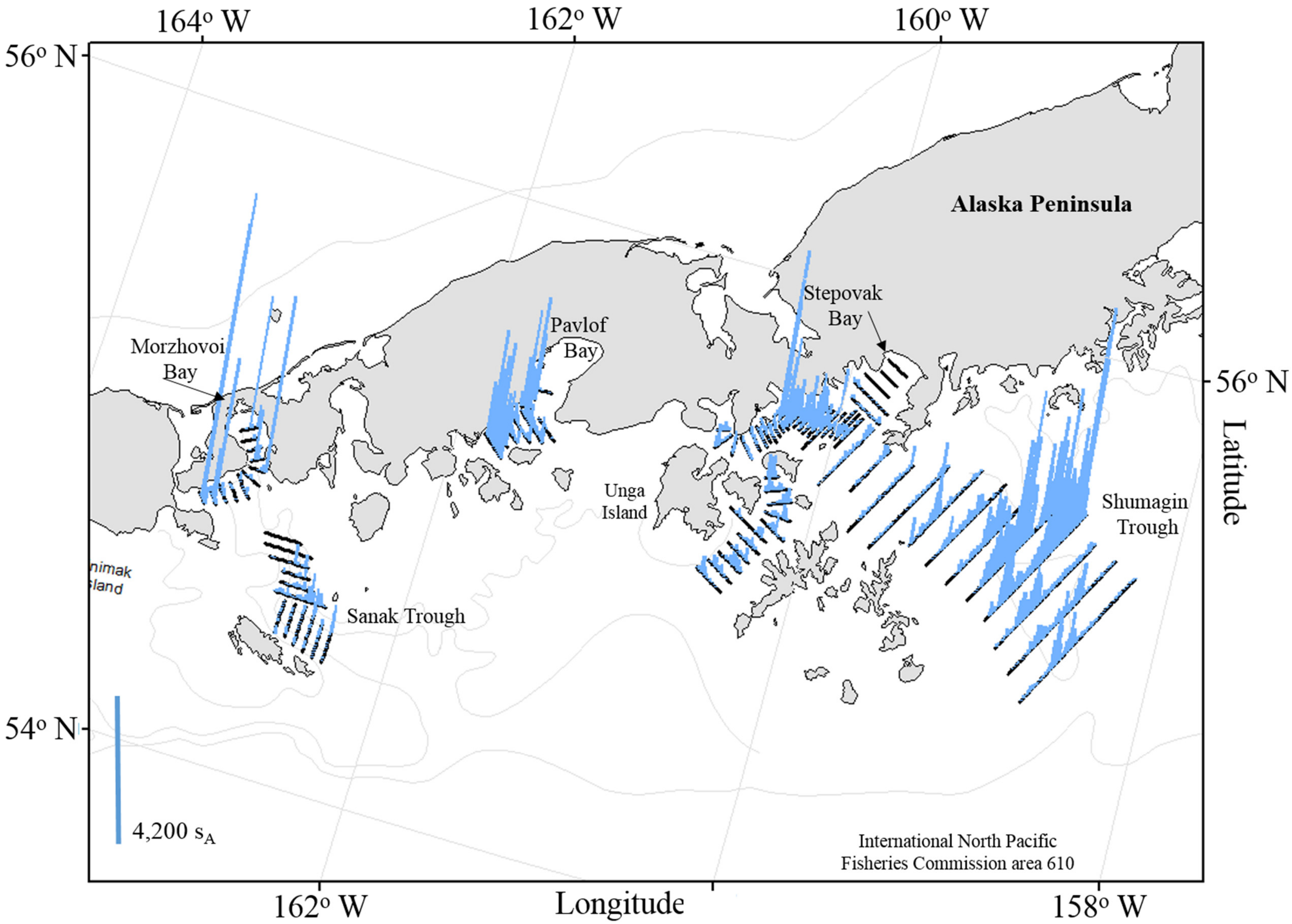

Figure 4. -- Backscatter (s_A, m^2/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2018 acoustic-trawl survey of the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof bays.

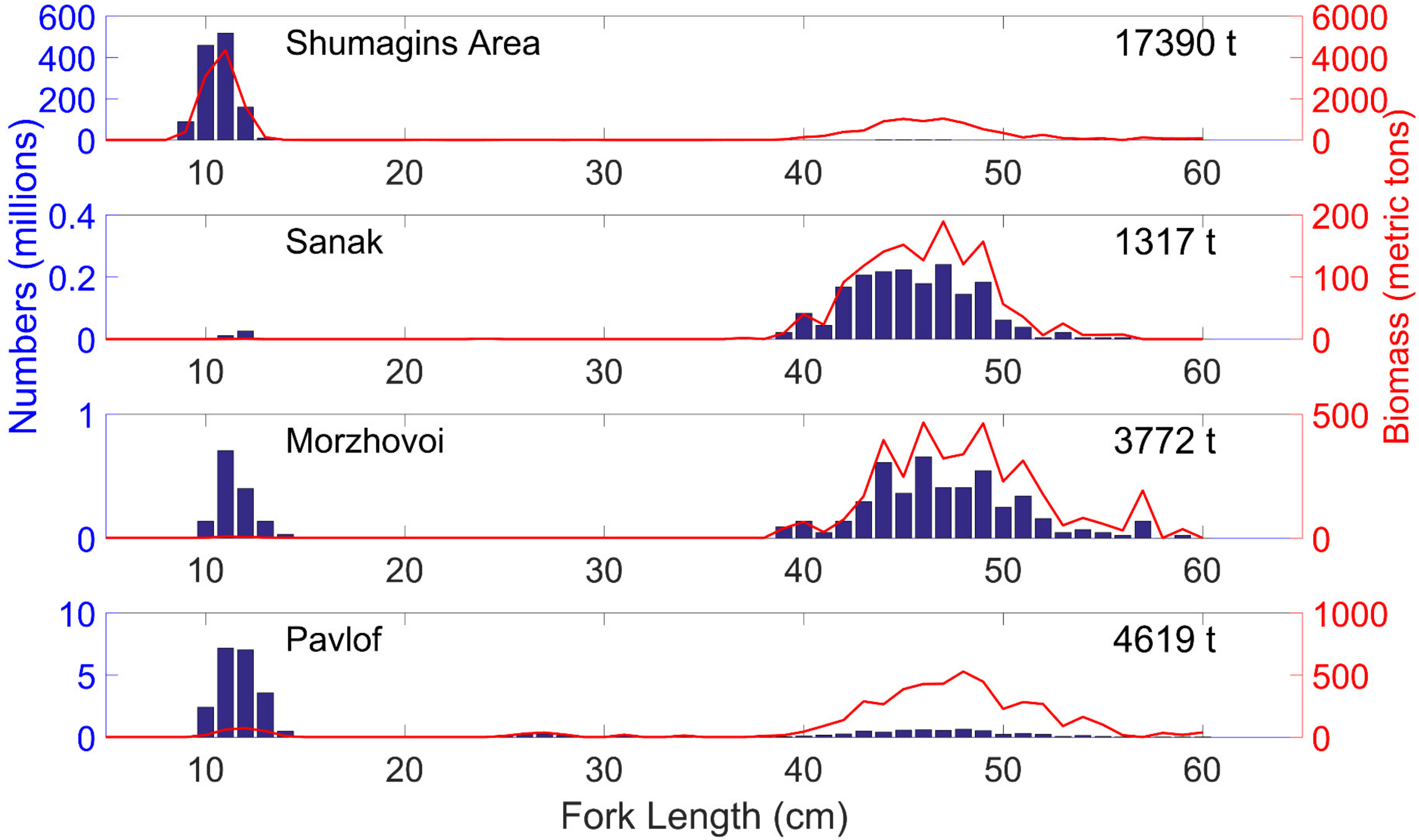

Figure 5. -- Length distributions of walleye pollock are shown with bars (numbers) and biomass estimates are shown with a solid red line (metric tons, t) for the 2018 acoustic-trawl survey of Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlov bays.

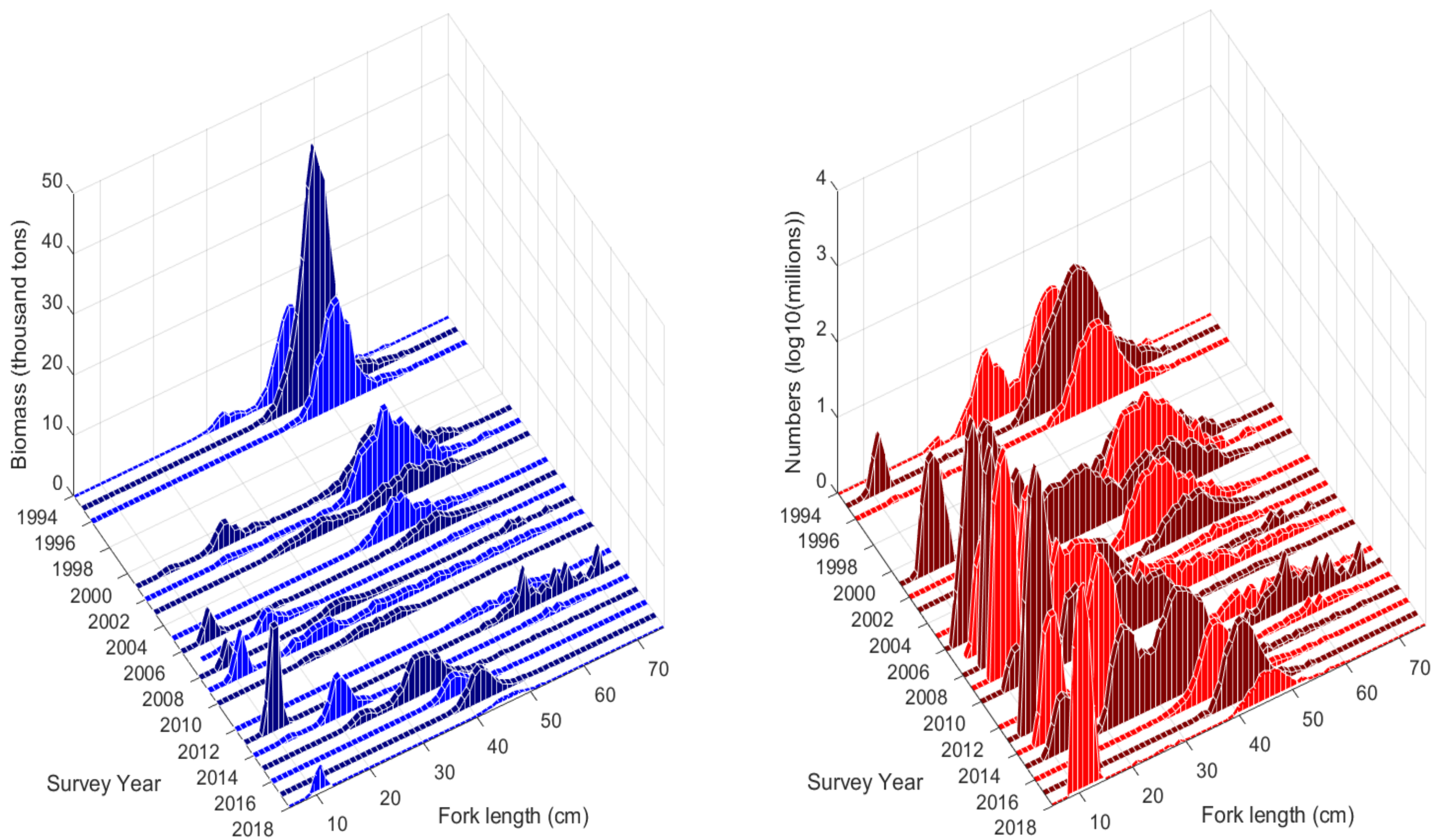

Figure 6. -- Walleye pollock biomass in thousands of metric tons (left) and numbers in $\log_{10}$(millions) (right) at length from the Shumagin Islands acoustic-trawl surveys since 1994. No surveys were conducted in 1997-2000, 2004, or 2011.

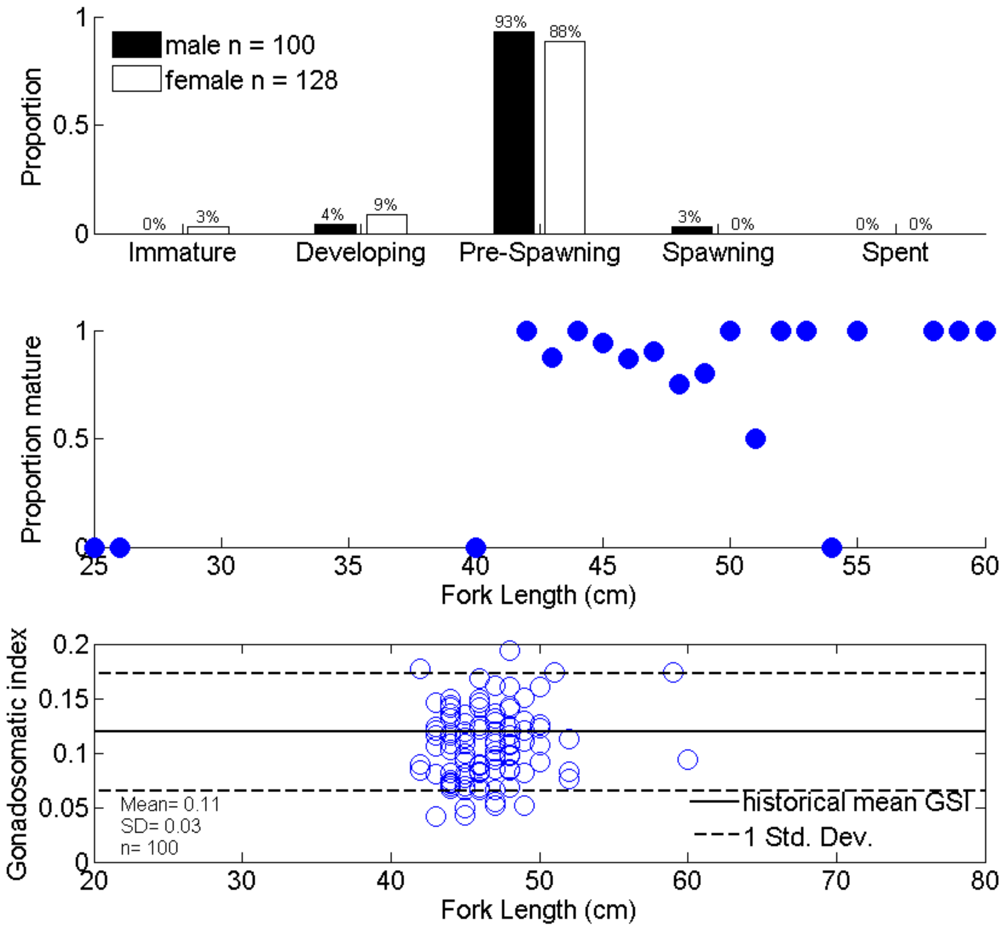

Figure 7. -- Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage (a); proportion mature (i.e. pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock (b); gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2018 acoustic-trawl survey of the Shumagin Islands (c). Note: these graphs do not include data from age-1 fish.

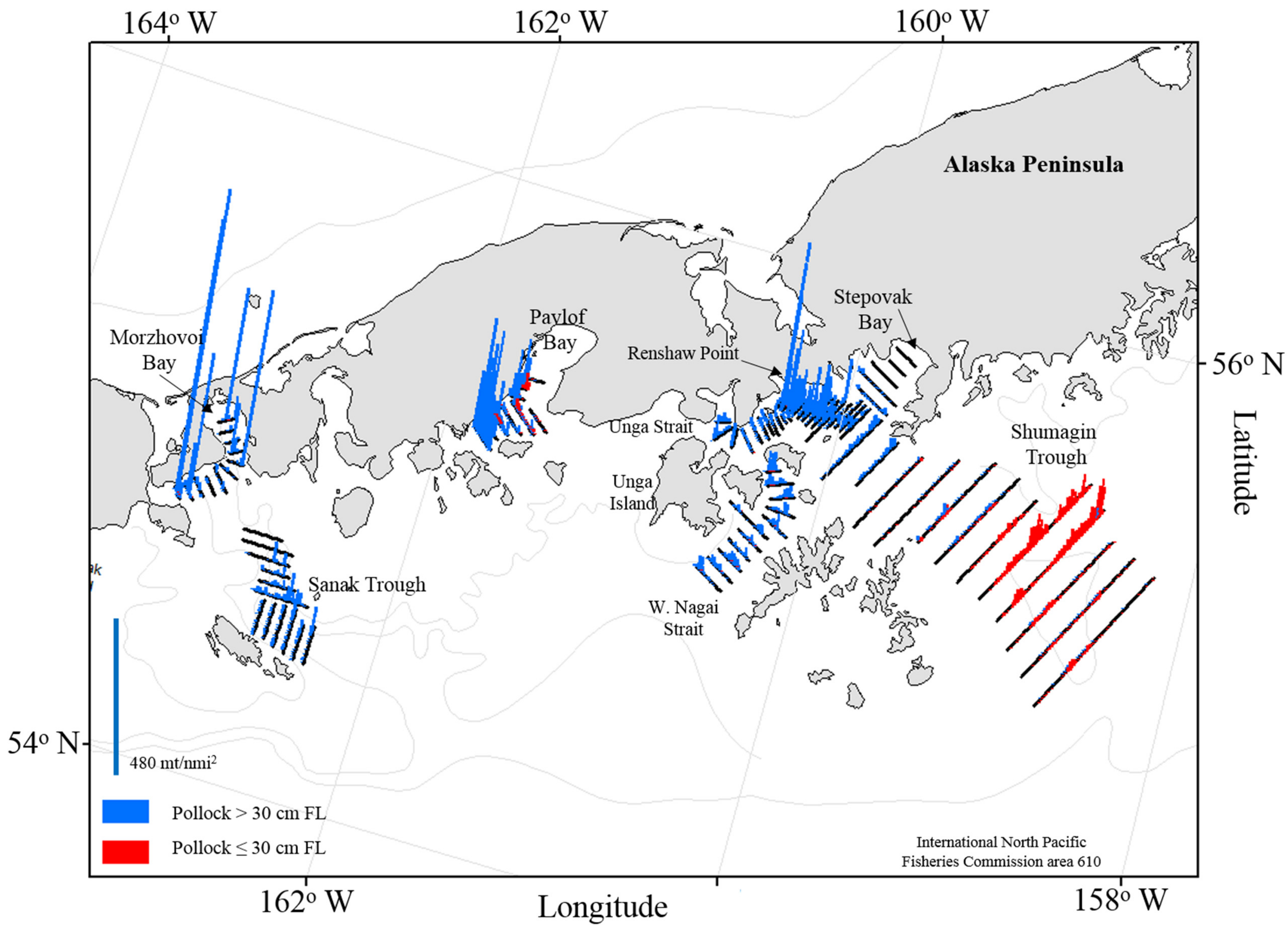

Figure 8. -- Biomass (t/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2018 acoustic-trawl survey of the Shumagin Islands, Sanak Trough, and Morzhovoi and Pavlof bays.

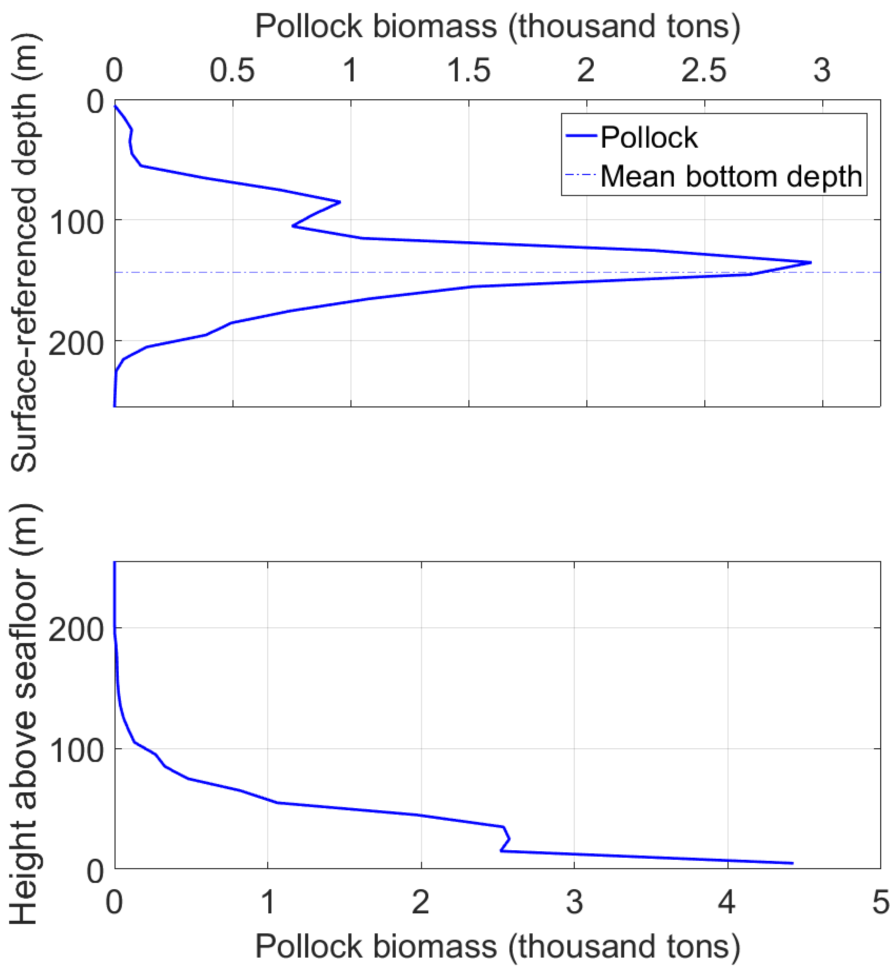

Figure 9. -- Depth distribution (m) of walleye pollock biomass in thousands of tons (t) observed in the Shumagin Islands during the winter 2018 acoustic-trawl survey. Depth is referenced to the surface and to the bottom and is averaged in 10 m depth bins.

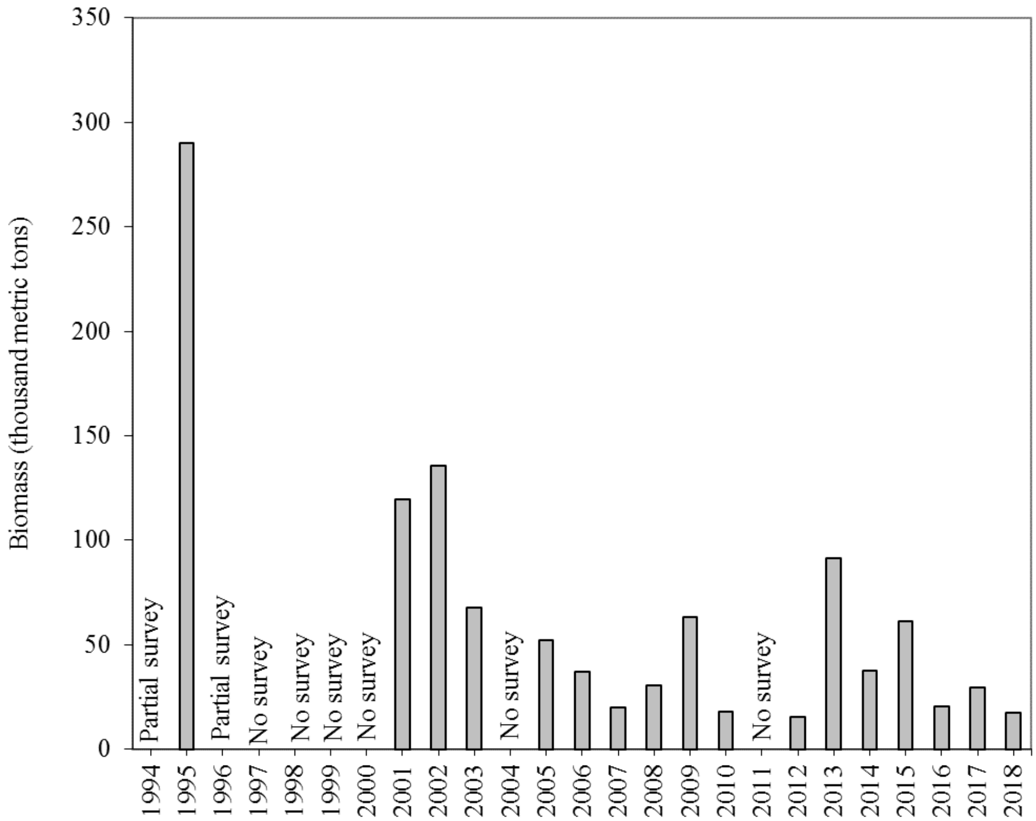

Figure 10. -- Summary of walleye pollock biomass estimates (thousand metric tons) based on acoustic-trawl surveys of the Shumagin Islands area.

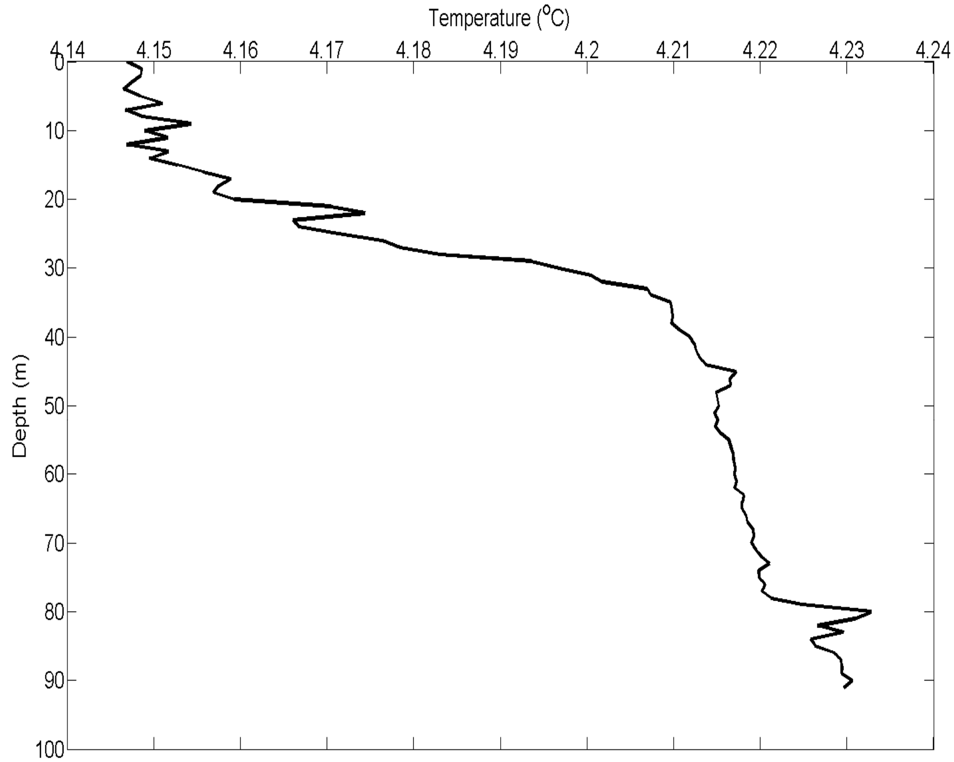

Figure 11. -- Water temperature (°C; solid line) by 1-m depth intervals for the 1 trawl haul location observed during the winter 2018 acoustic-trawl survey of walleye pollock in Sanak Trough.

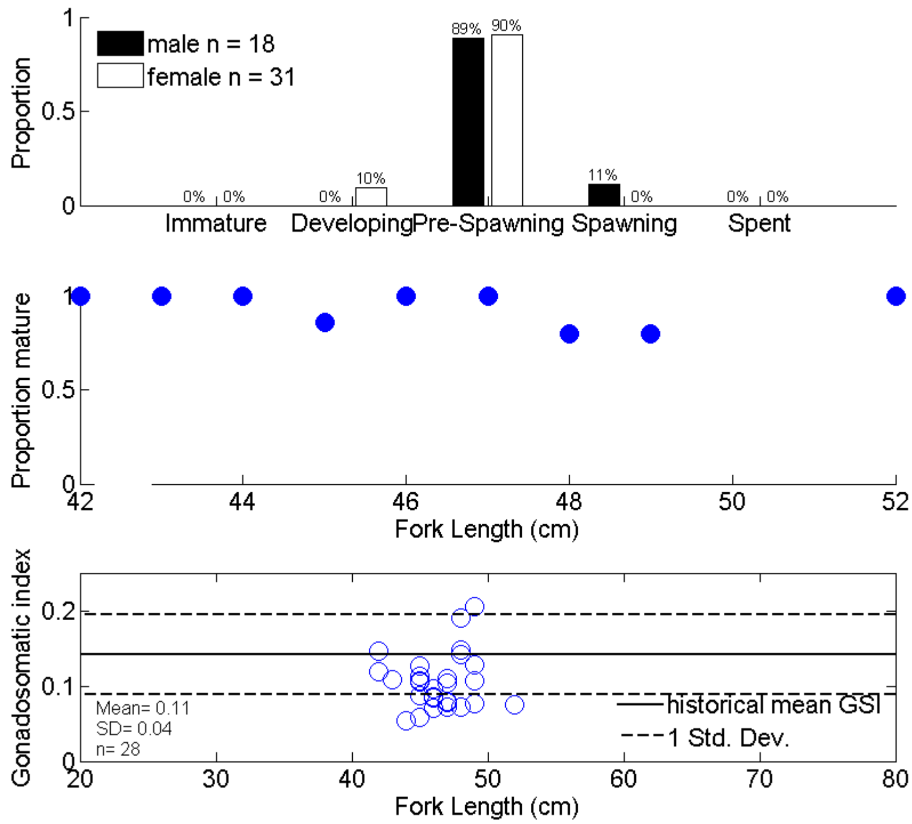

Figure 12. -- Maturity composition for male and female walleye pollock > 40 cm FL within each stage (a); proportion mature (i.e. pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock (b); gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2018 acoustic-trawl survey of the Sanak Trough (c). Note: these graphs do not include data from age-1 fish.

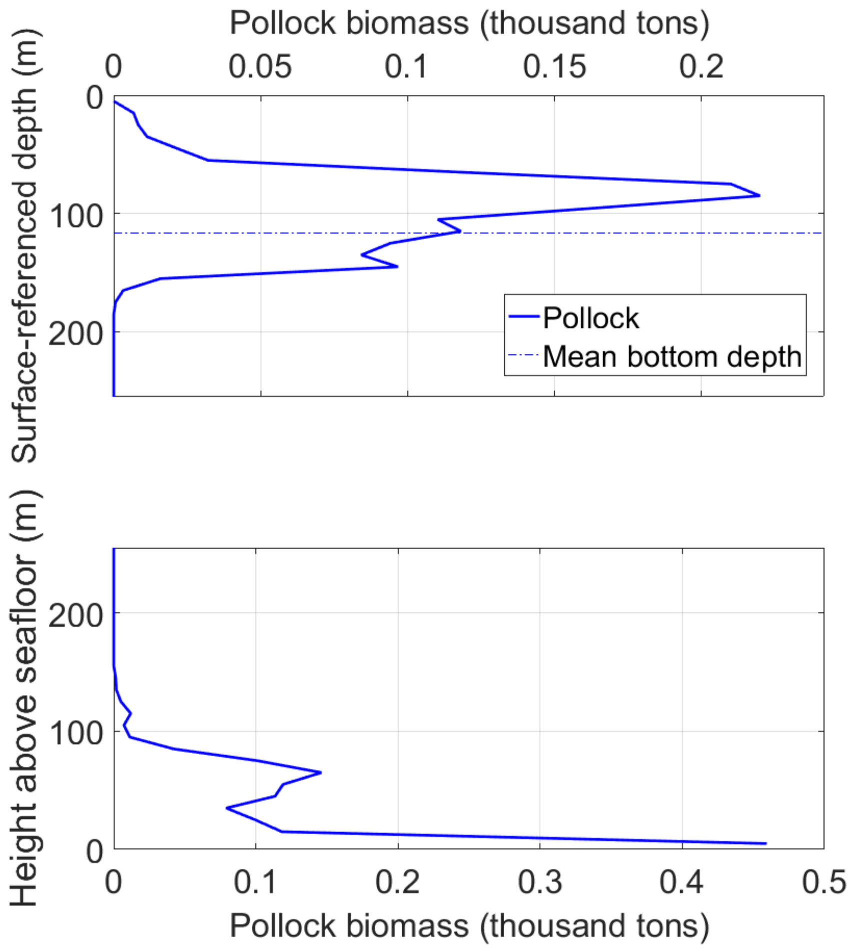

Figure 13. -- Depth distribution (m) of walleye pollock biomass in thousands of tons (t) observed in the Sanak Trough during the winter 2018 acoustic-trawl survey. Depth is referenced to the surface and to the bottom and is averaged in 10 m depth bins.

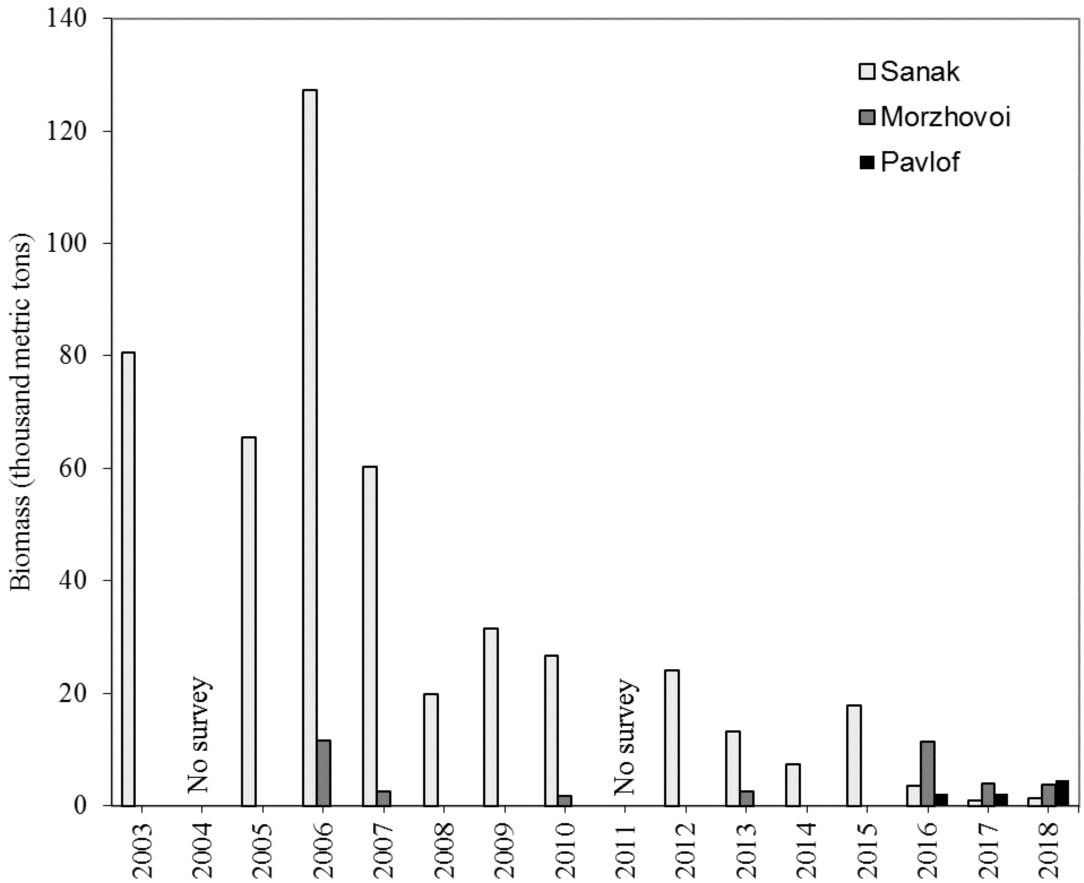

Figure 14. -- Summary of walleye pollock biomass estimates (thousand metric tons) based on acoustic-trawl surveys of Sanak Trough, Morzhovoi Bay, and Pavlof Bay.

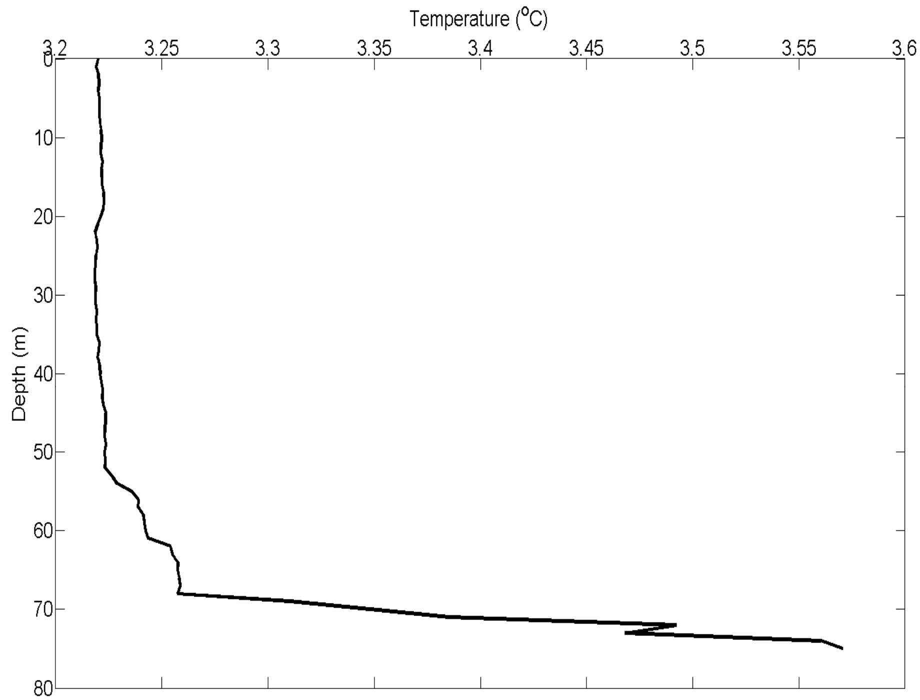

Figure 15. -- Mean water temperature (°C; solid line) by 1-m depth intervals for the 1 trawl haul locations observed during the winter 2018 acoustic-trawl survey of walleye pollock in Morzhovoi Bay. The shaded area represents one standard deviation.

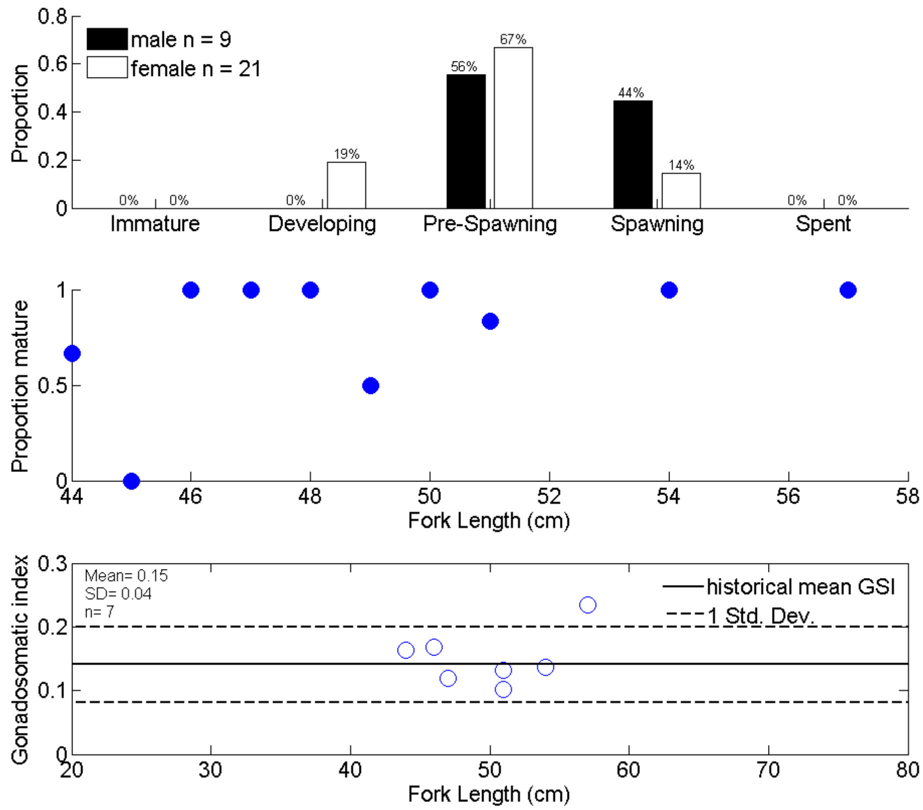

Figure 16. -- Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage (a); proportion mature (i.e. pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock (b); gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2018 acoustic-trawl survey of Morzhovoi Bay (c). Note: these graphs do not include data from age-1 fish.

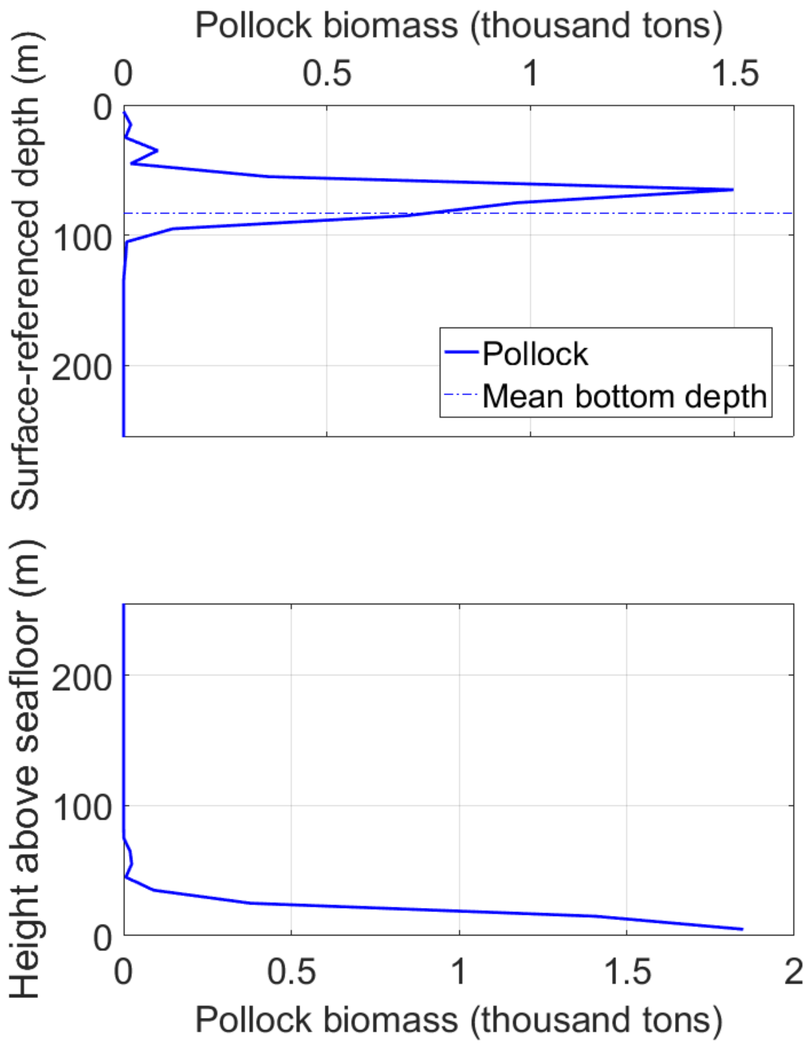

Figure 17. -- Depth distribution (m) of walleye pollock biomass in thousands of tons (t) observed in Morzhovoi Bay during the winter 2018 acoustic-trawl survey. Depth is referenced to the surface and from the bottom and is averaged in 10 m depth bins.

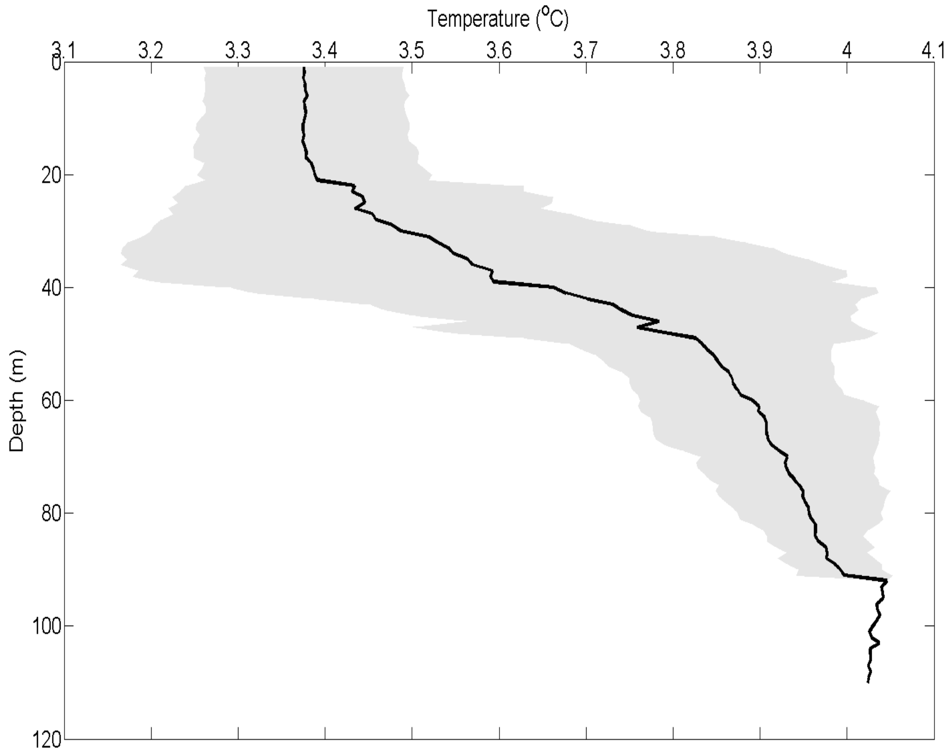

Figure 18. -- Mean water temperature (°C; solid line) by 1-m depth intervals for the 2 trawl haul locations observed during the winter 2017 acoustic-trawl survey of walleye pollock in Pavlov Bay. The shaded area represents one standard deviation.

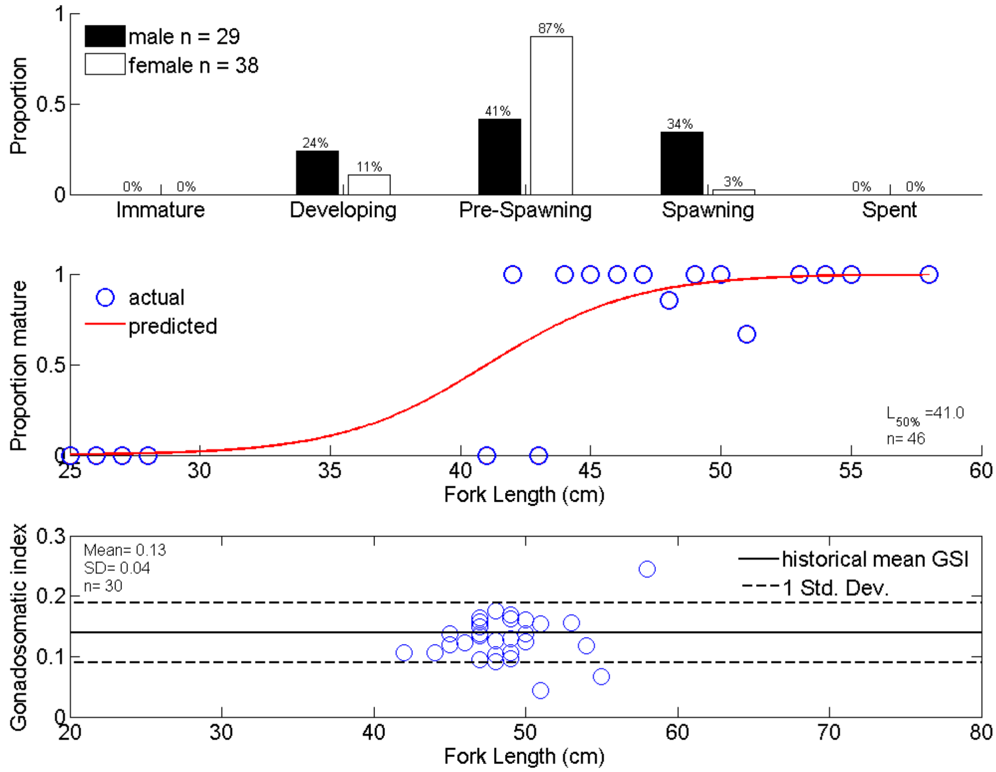

Figure 19. -- Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage (a); proportion mature (i.e. pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock (b); gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2018 acoustic-trawl survey of Pavlov Bay (c). Note: these graphs do not include data from age-1 fish.

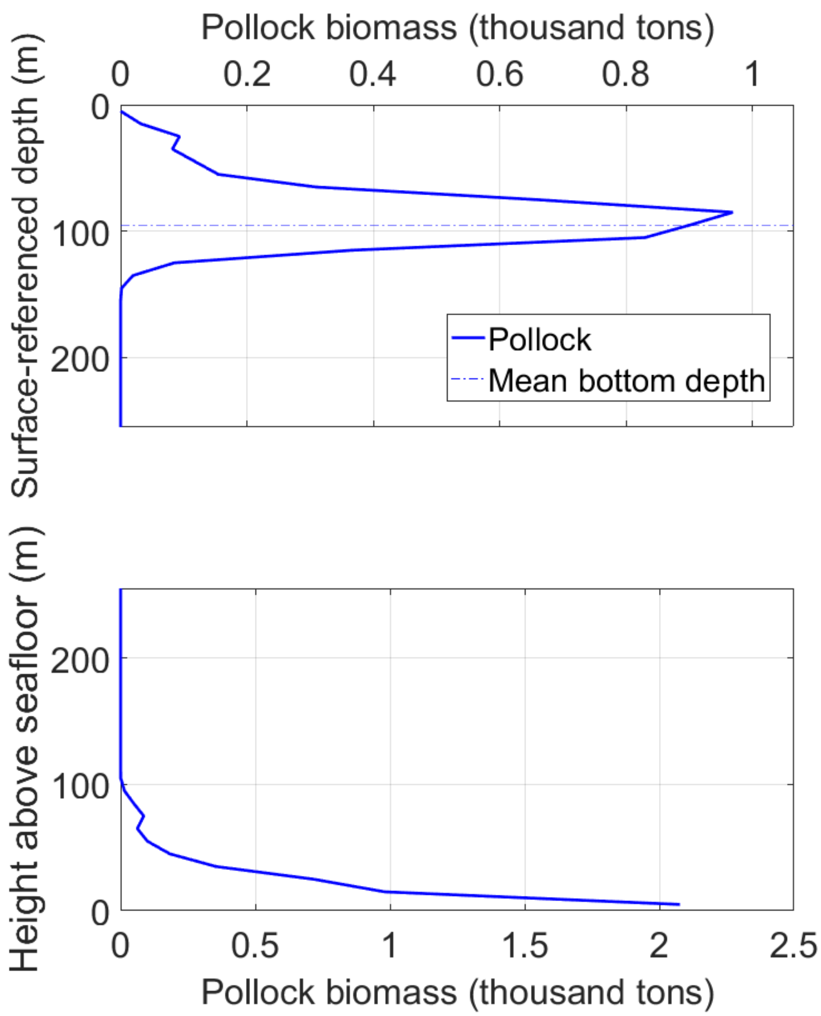

Figure 20. -- Depth distribution (m) of walleye pollock biomass in thousands of tons (t) observed in Pavlov Bay during the winter 2018 acoustic-trawl survey. Depth is referenced to the surface and to the bottom and is averaged in 10 m depth bins.

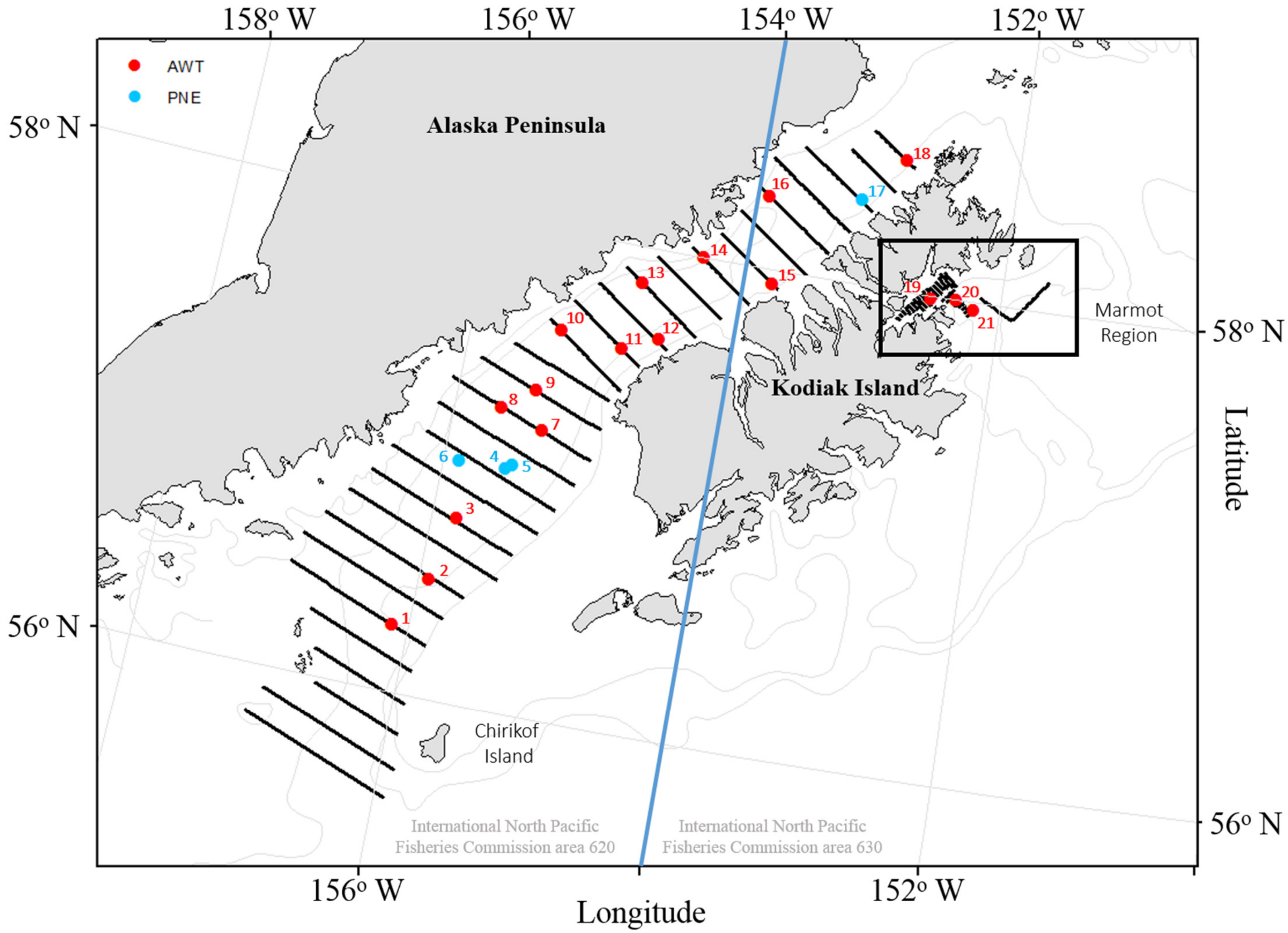

Figure 21. -- Transect lines and locations of Aleutian-wing trawl (AWT; red circle) and poly-Nor'eastern trawl (PNE; blue circle) hauls during the winter 2018 acoustic-trawl survey of walleye pollock in Marmot Bay, Shelikof Strait, and the Chirikof shelf break. International North Pacific Fisheries Commission areas 620 and 630 are shown on map. Haul numbers are on top of haul symbols. Box indicates area enlarged in Figure 33.

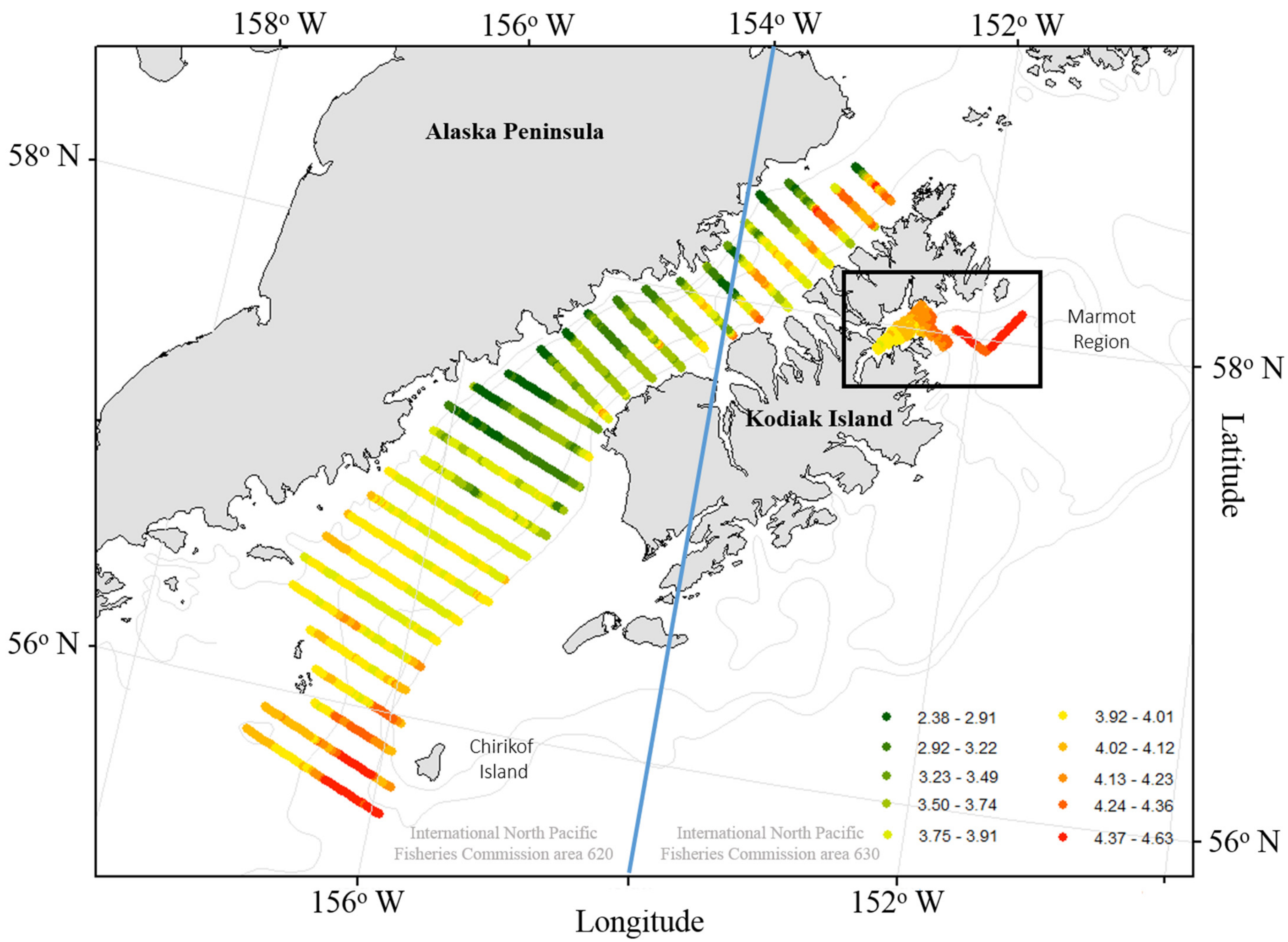

Figure 22. -- Surface water temperatures (°C) recorded at 5-second intervals during the 2018 acoustic-trawl survey of Shelikof Strait and Marmot Bay. Temperatures are primarily from the ship's bow-mounted Seabird SBE-38 temperature sensor. At times when the SBE-38 was not operating, temperatures are from the mid-ship Furuno T-2000 temperature probe located 1.4 m below the surface. Box indicates area enlarged in Figure 50.

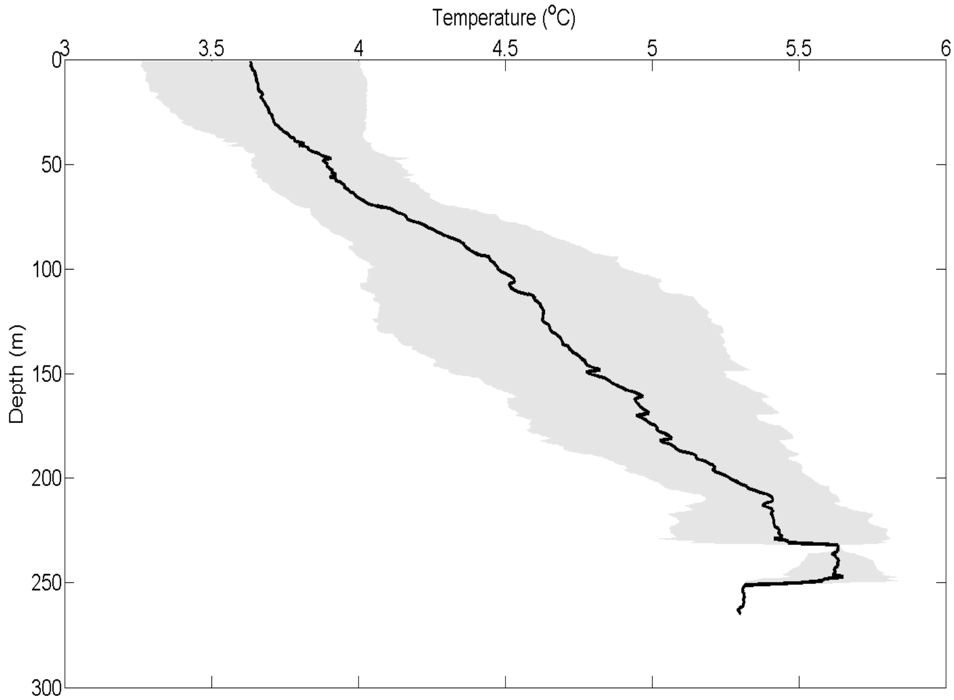

Figure 23. -- Mean water temperature (°C; solid line) by 1-m depth intervals for 18 of the trawl haul locations observed during the winter 2018 acoustic-trawl survey of walleye pollock in Shelikof Strait. The shaded area represents one standard deviation.

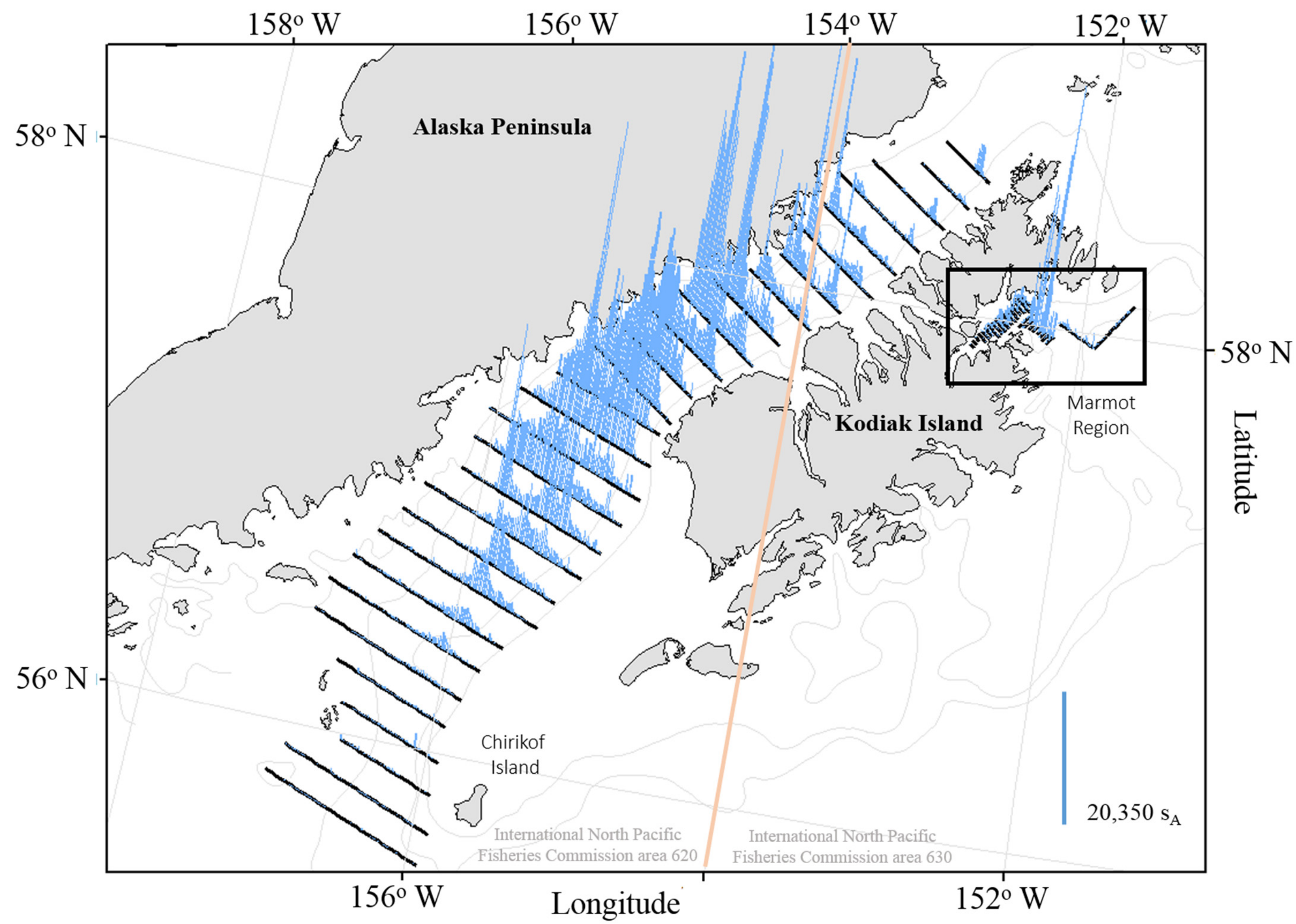

Figure 24. -- Backscatter (s_A, m^2/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2018 acoustic-trawl survey of the Shelikof Strait and Marmot Bay.

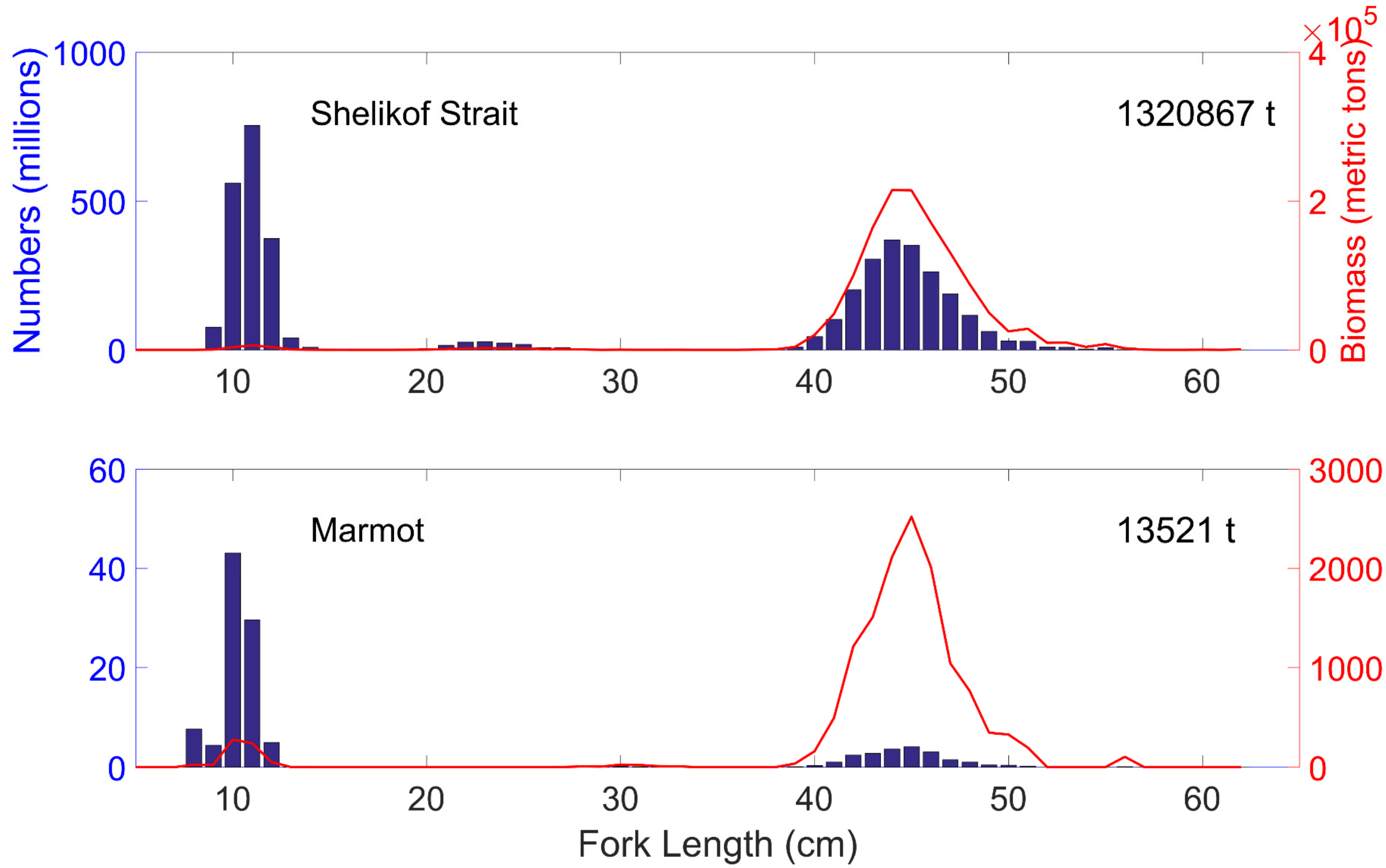

Figure 25. -- Length distribution of walleye pollock shown with blue bars (numbers) and biomass estimate in red line (metric tons, t) for the 2018 acoustic-trawl survey of the Shelikof Strait and Marmot Bay.

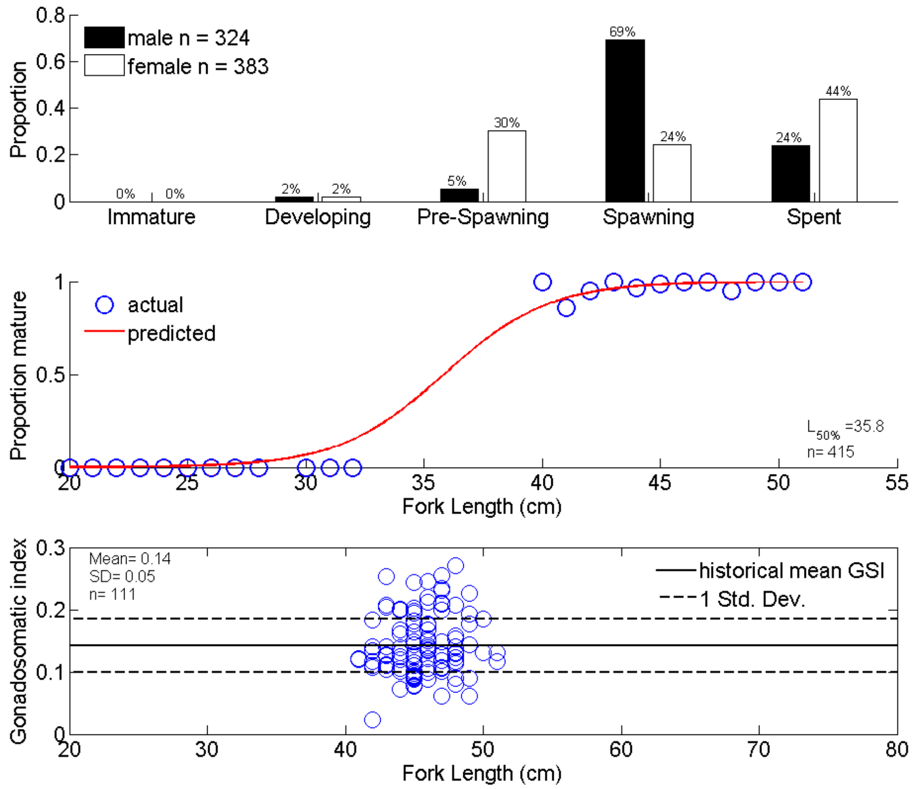

Figure 26. -- Maturity composition for male and female walleye pollock greater than 40 cm FL within each stage (a); proportion mature (i.e. pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock (b); gonadosomatic index (with historic survey mean ± 1 std. dev.) for pre-spawning females examined during the 2018 acoustic-trawl survey of the Shelikof region (c). Note: these graphs do not include data from age-1 fish.

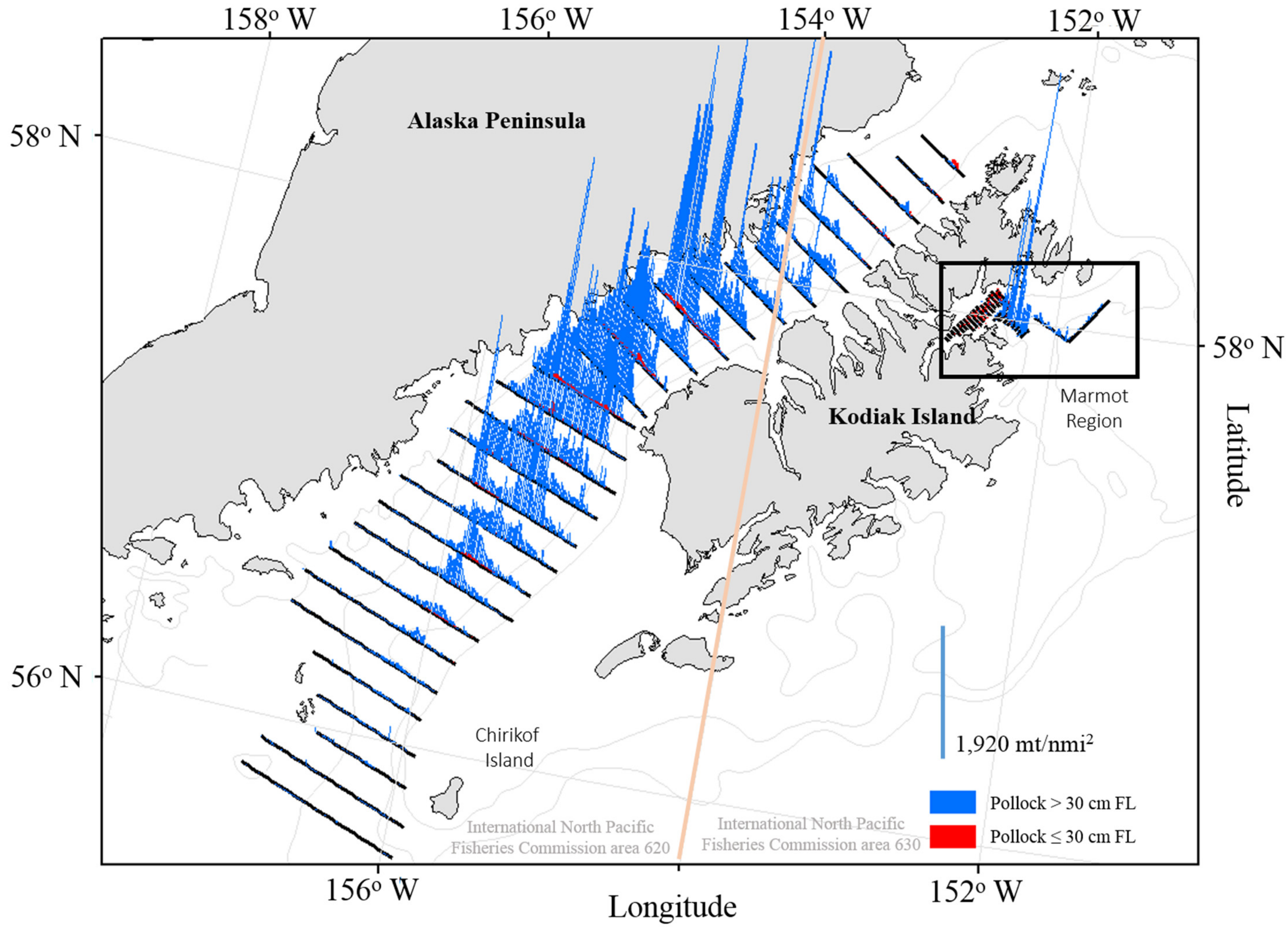

Figure 27. -- Biomass (t/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2018 acoustic-trawl survey of Shelikof Strait and Marmot Bay. Box indicates area enlarged in Figure 35.

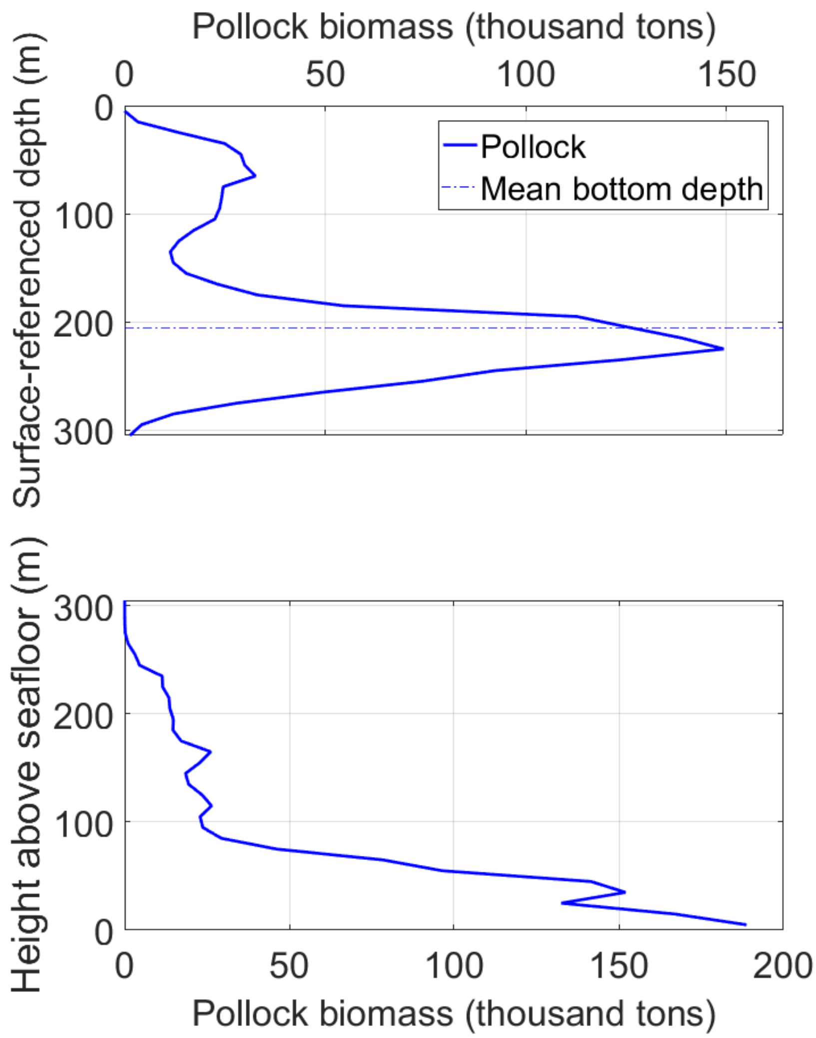

Figure 28. -- Depth distribution (m) of walleye pollock biomass in thousands of tons (t) observed in the Shelikof Strait during the winter 2018 acoustic-trawl survey. Depth is referenced to the surface and to the bottom and is averaged in 10 m depth bins.

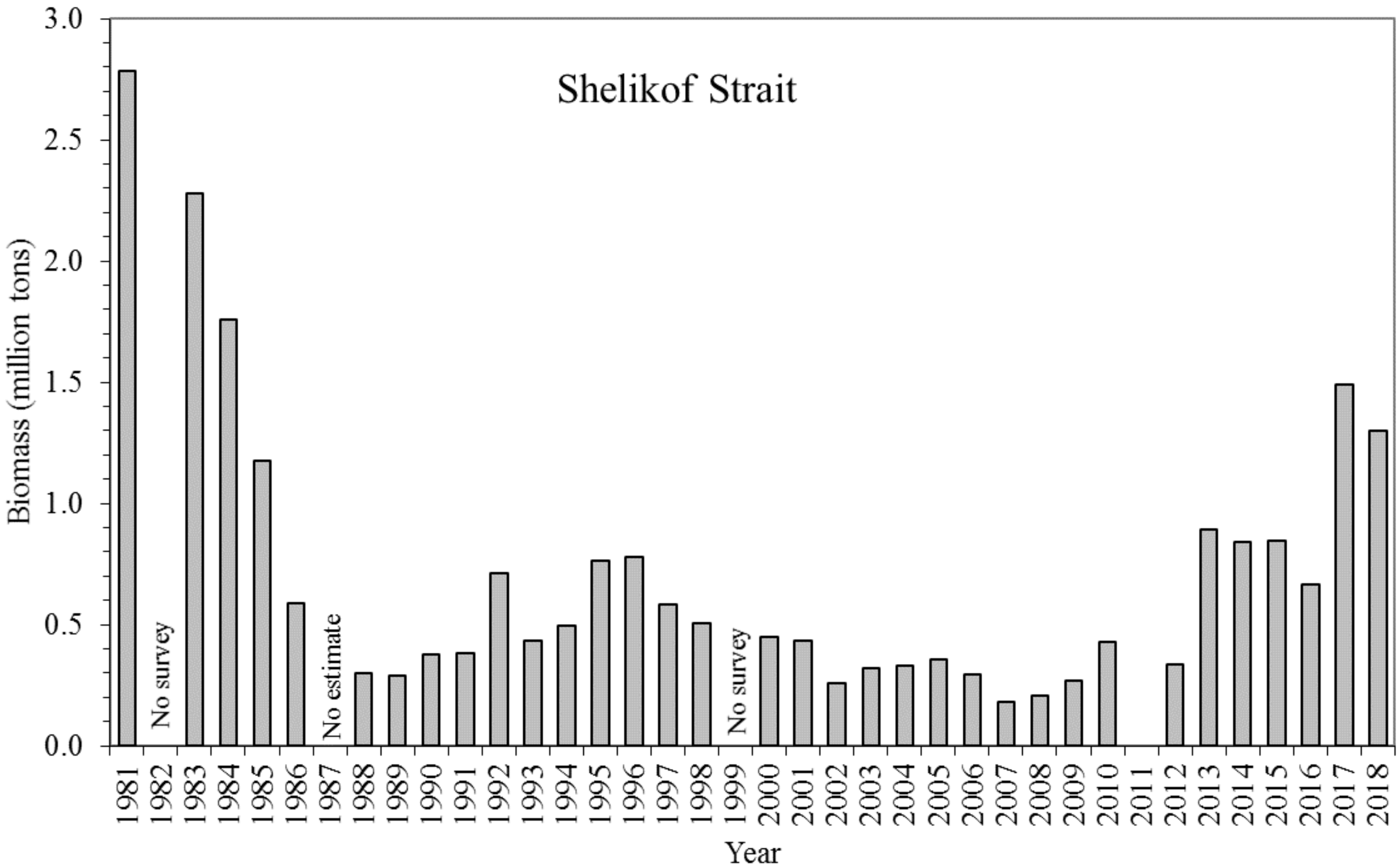

Figure 29. -- Summary of walleye pollock biomass estimates (million metric tons) based on acoustic-trawl surveys of the Shelikof Strait area.

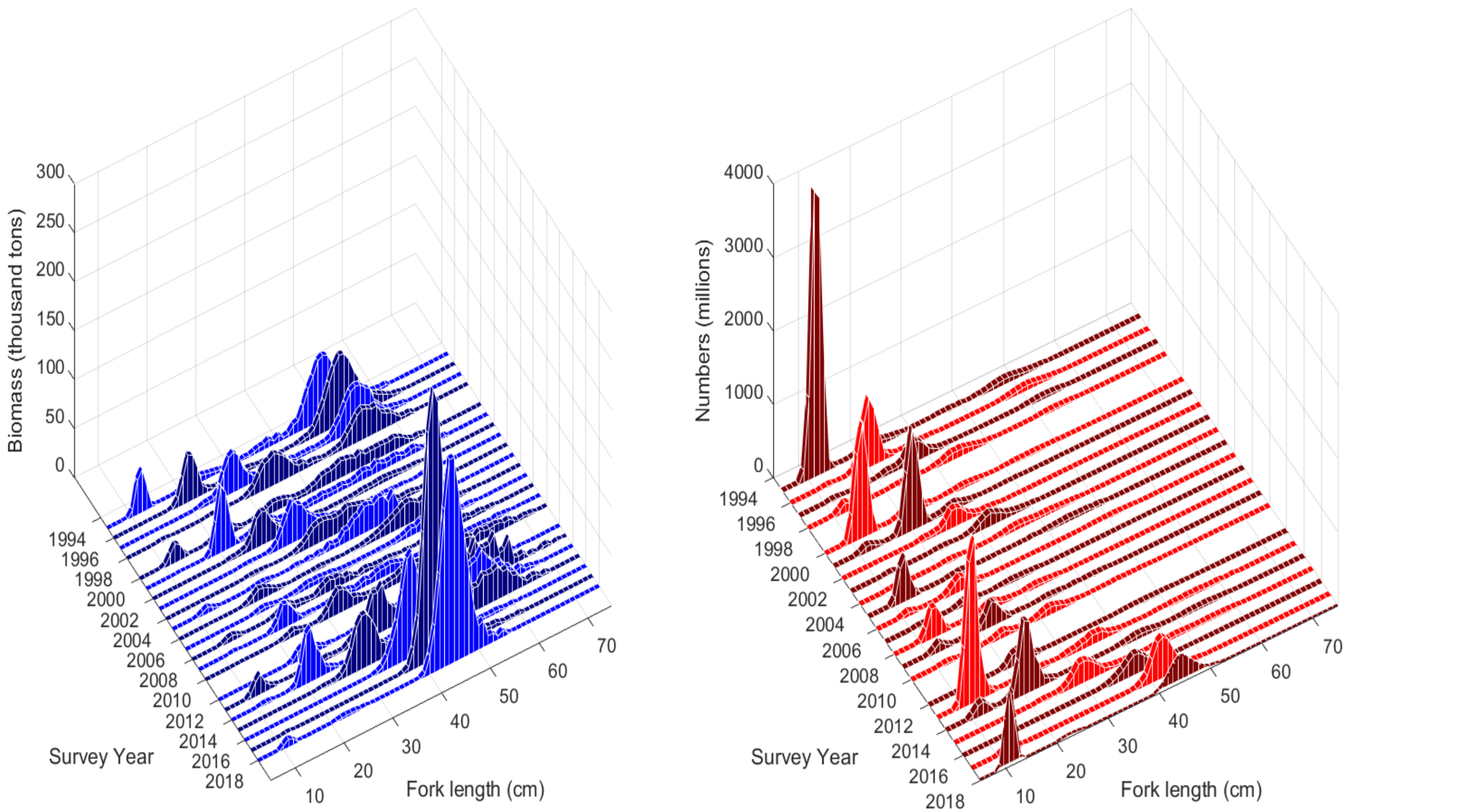

Figure 30. -- Walleye pollock biomass in thousands of metric tons (left) and numbers in millions (right) at length from Shelikof Strait acoustic-trawl surveys since 1994. No surveys were conducted in 1998 or 2011.

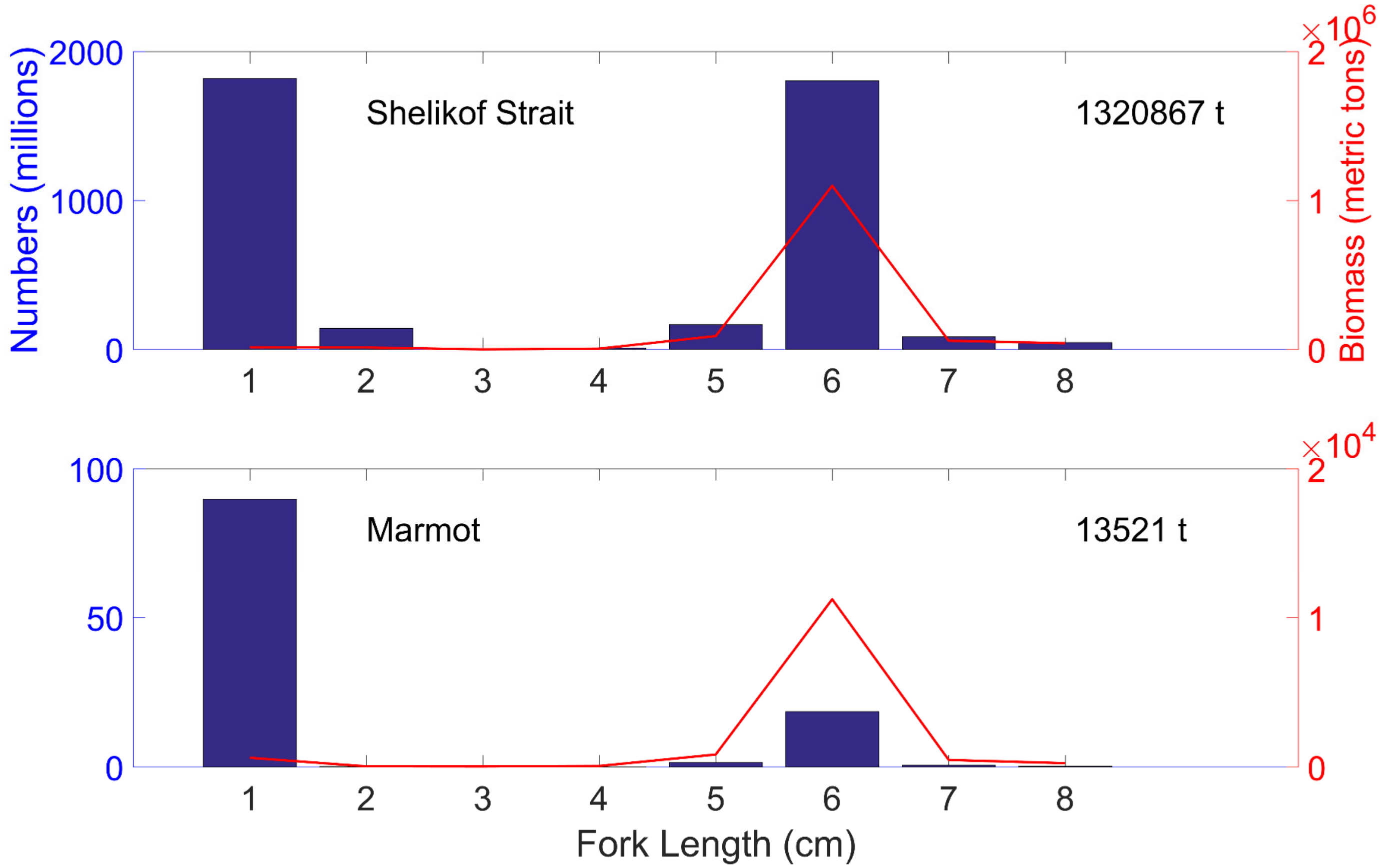

Figure 31. -- Age distribution of walleye pollock shown with blue bars (numbers) and biomass estimate in red line (metric tons, t) for the 2018 acoustic-trawl survey of the Shelikof Strait and Marmot Bay.

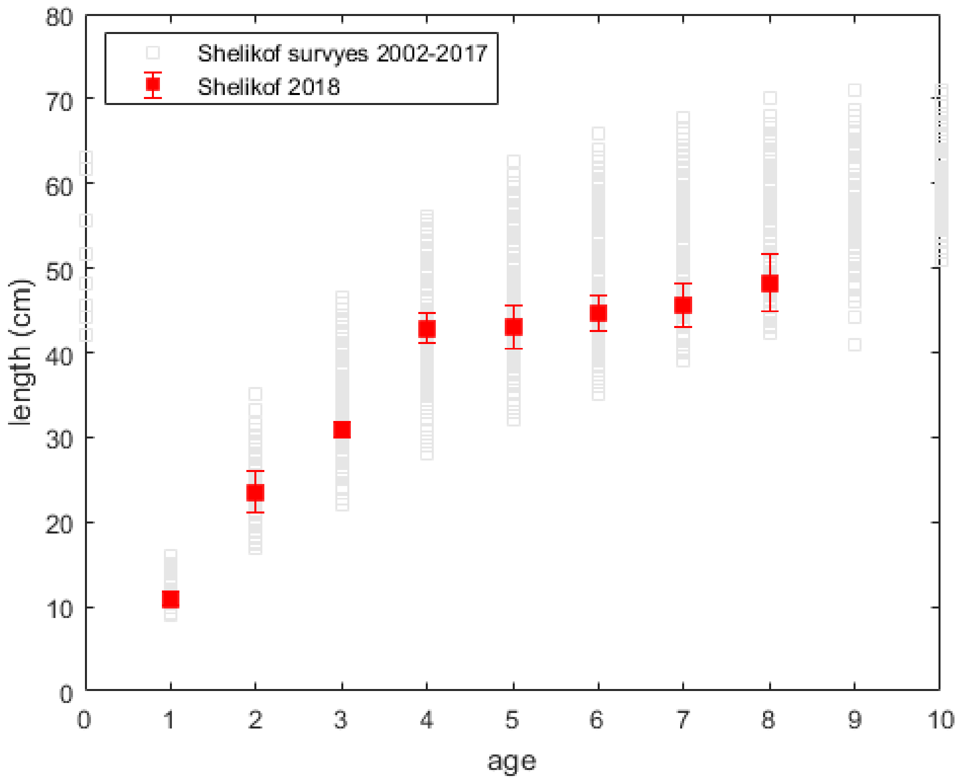

Figure 32. -- Walleye pollock average length at age from historic winter Shelikof (2002-2010, 2012-2017) and Marmot (2007, 2009-2010, 2013-2017) acoustic-trawl surveys compared with walleye pollock average length at age for winter 2018. Bars show +/- 1 standard deviation for the historic data.

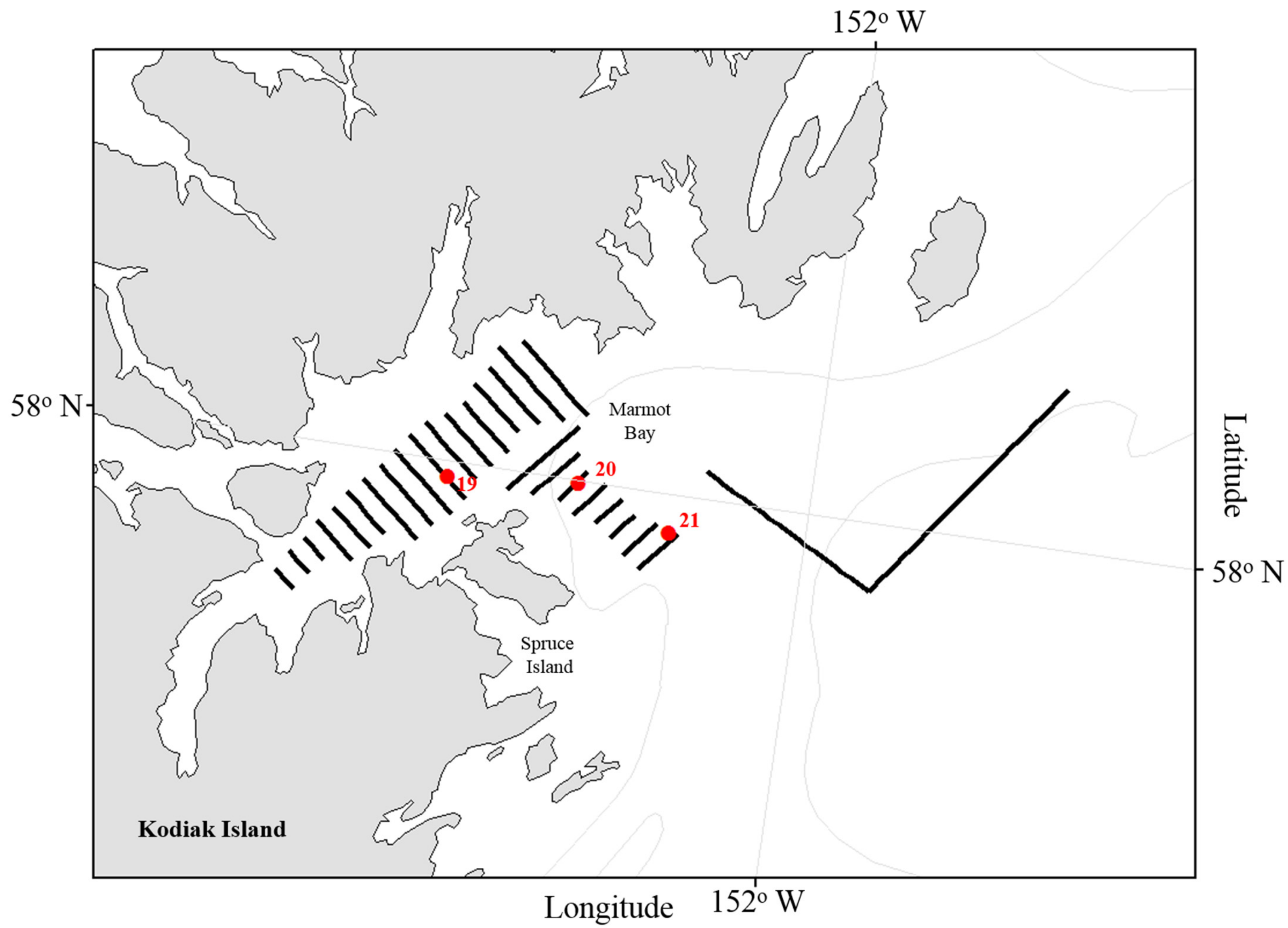

Figure 33. -- Transect lines and locations of Aleutian-wing trawl (AWT) hauls during the winter 2018 acoustic-trawl survey of walleye pollock in Marmot Bay. Figure represents area enlarged from Figure 21.

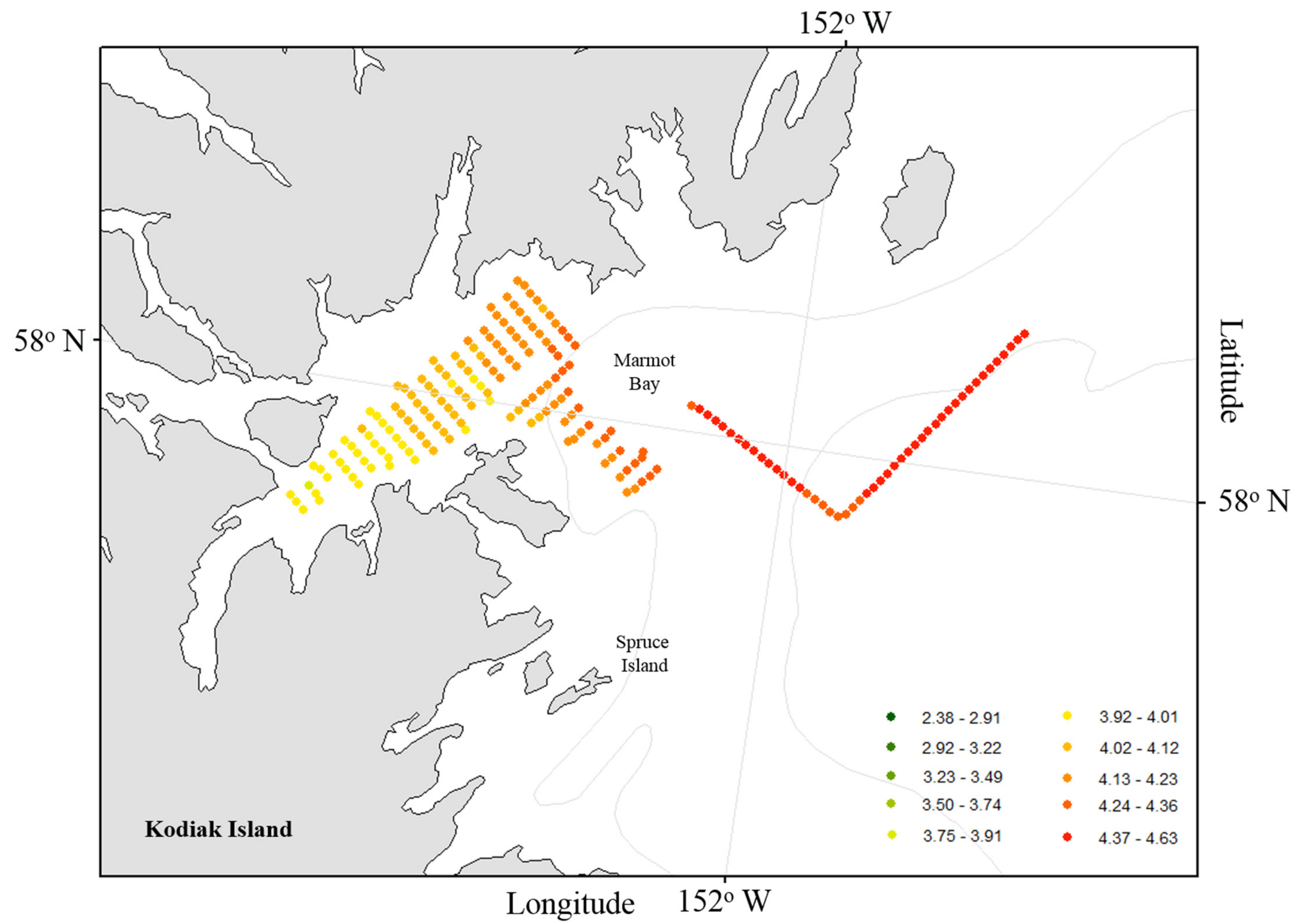

Figure 34. -- Surface water temperatures (°C) recorded at 5-second intervals during the 2018 acoustic-trawl survey of Marmot Bay. Temperatures are primarily from the ship's bow-mounted Seabird SBE-38 temperature sensor. At times when the SBE-38 was not operating, temperatures are from the mid-ship Furuno T-2000 temperature probe located 1.4 m below the surface.

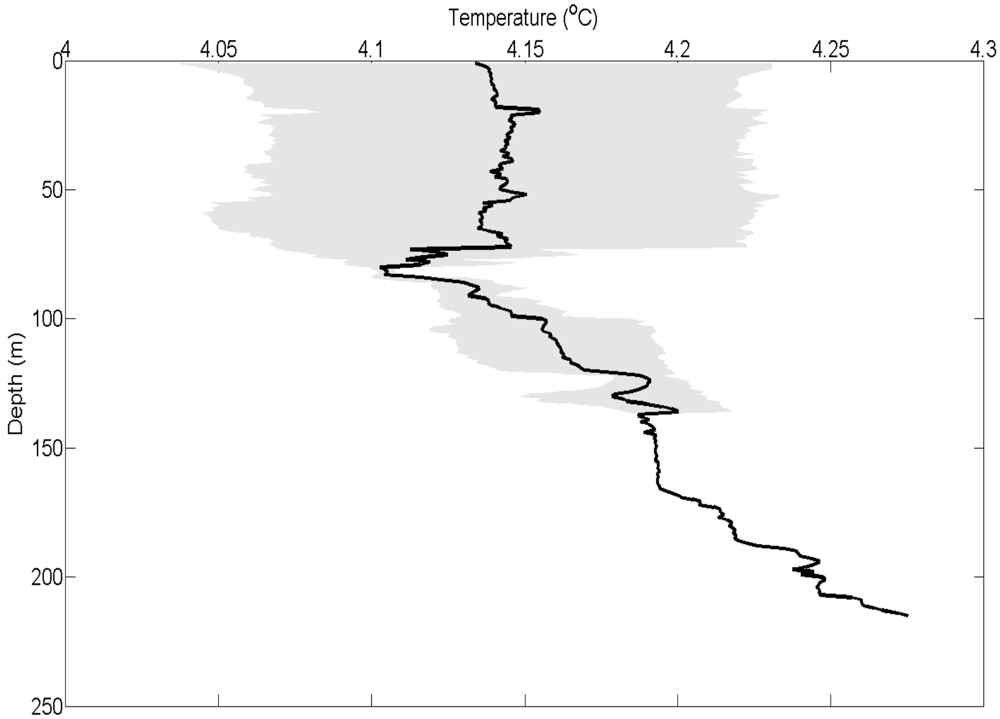

Figure 35. -- Mean water temperature (°C; solid line) by 1-m depth intervals for the 3 trawl haul locations observed during the winter 2018 acoustic-trawl survey of walleye pollock in Marmot Bay. Shaded area represents one standard deviation.

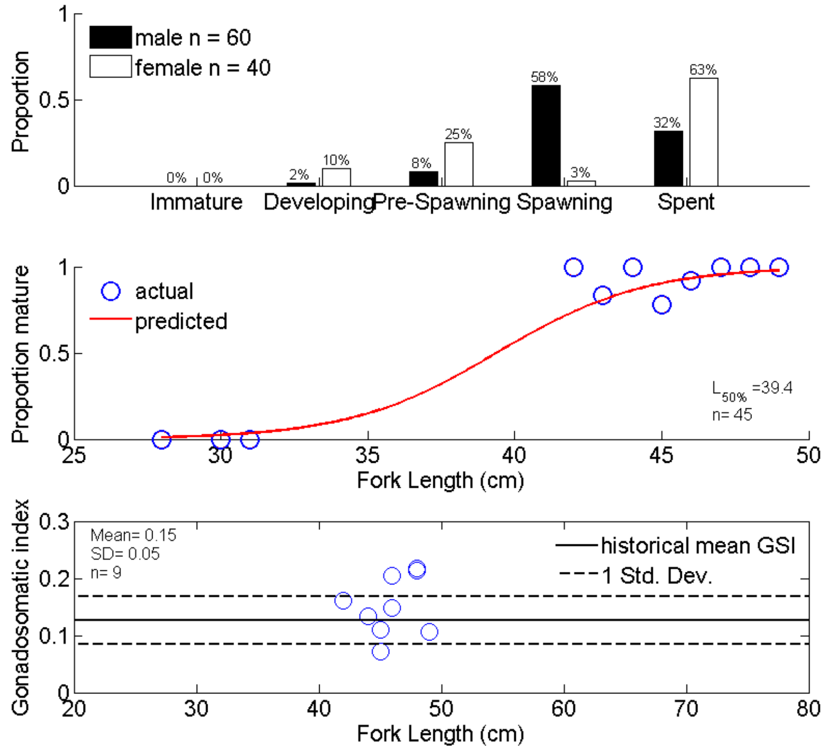

Figure 36. -- Maturity stages and percentage of fish > 40 cm FL within each stage for (a) male and female walleye pollock; (b) proportion mature (i.e. pre-spawning, spawning, or spent) by 1-cm size group for female walleye pollock; (c) gonadosomatic index (with historic survey mean, and minimum and maximum of historic survey means) for pre- spawning females examined during the 2018 acoustic-trawl survey of the Marmot region. Note: these graphs do not include data from age-1 fish.

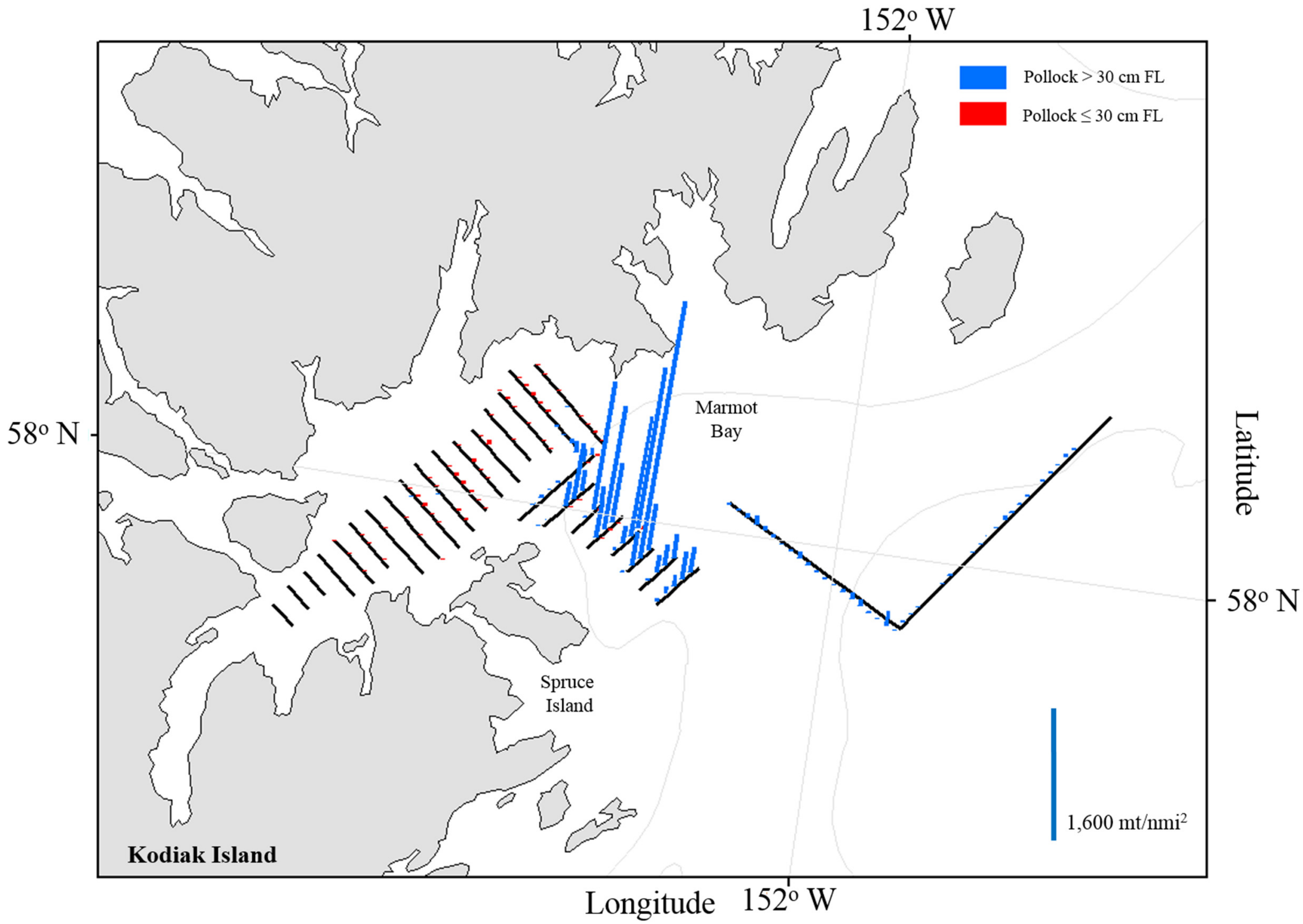

Figure 37. -- Biomass (t/nmi^2) attributed to walleye pollock (vertical lines) along tracklines surveyed during the winter 2018 acoustic-trawl survey of Marmot Bay.

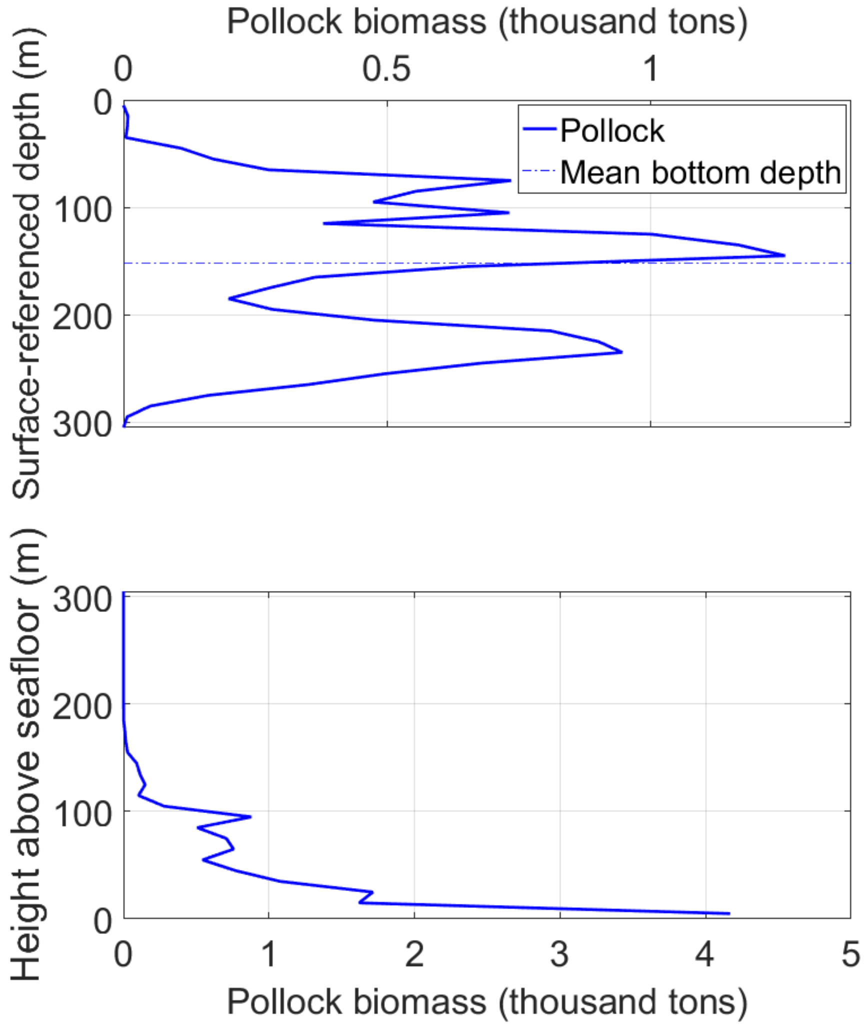

Figure 38. -- Depth distribution (m) of walleye pollock biomass in thousands of tons (t) observed in Marmot Bay during the winter 2018 acoustic-trawl survey. Depth is referenced to the surface and to the bottom and is averaged in 10 m depth bins.

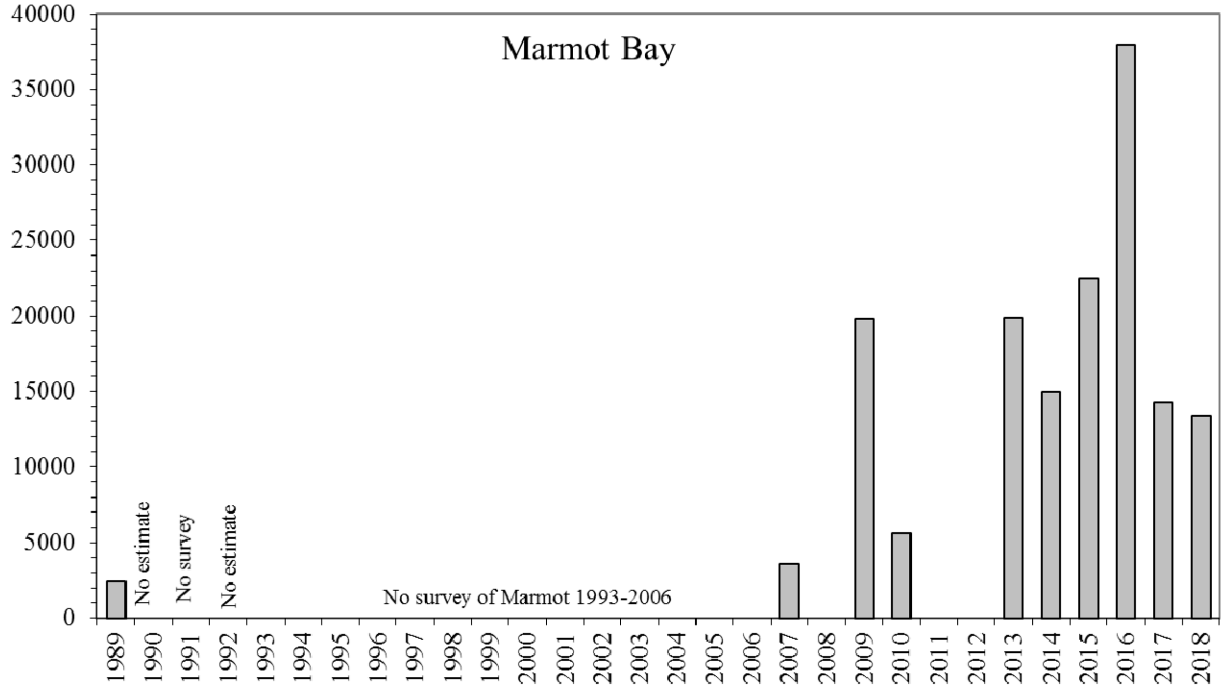

Figure 39. -- Summary of walleye pollock biomass estimates (metric tons) based on acoustic-trawl surveys of Marmot Bay.

APPENDIX I. ITINERARY

DY2018-01

Shumagin Islands\Sanak Trough\Morzhovoi Bay\Pavlof Bay

5 Feb.	Depart Kodiak, AK.
5 Feb.	Acoustic sphere calibration in Kalsin Bay, AK.
7-10 Feb.	Acoustic-trawl survey of Shumagin Islands.
11 Feb.	Acoustic-trawl survey of Sanak Trough.
11 Feb.	Acoustic-trawl survey of Morzhovoi Bay.
12 Feb.	Acoustic-trawl survey of Pavlof Bay.
12-13 Feb.	Acoustic sphere calibration in Volcano Bay, AK
14 Feb.	Acoustic sphere calibration in Kalsin Bay, AK.
15 Feb.	Arrive Kodiak, AK. End cruise.

DY2018-03

Shelikof Strait\Marmot Bay

12 Mar.	Depart Dutch Harbor, AK. Acoustic sphere calibration in Captains Bay, AK. Return Dutch Harbor, AK.
13 Mar.	Depart Dutch Harbor, AK.
15-21 Mar.	Acoustic trawl survey of Shelikof Strait.
21-22 Mar.	Acoustic-trawl survey of outer Marmot Bay.
23 Mar.	Acoustic sphere calibration in Kalsin Bay, AK.
23 Mar.	Arrive Kodiak, AK. End cruise.

APPENDIX II. SCIENTIFIC PERSONNEL

DY2017-01

Shumagin Islands\Sanak Trough\Morzhovoi Bay\Pavlof Bay

Name	Position	Organization
Taina Honkalehto	Chief Scientist	AFSC-RACE
Alex DeRobertis	Fishery Biologist	AFSC-RACE
Darin Jones	Fishery Biologist	AFSC-RACE
Scott Furnish	IT Spec.	AFSC-RACE
Troy Buckley	Fishery Biologist	AFSC-RACE
Nathan Lauffenburger	Fishery Biologist	AFSC-RACE
Matthew Phillips	Fishery Biologist	AIS

DY2017-03

Shelikof Strait\Marmot Bay

Name	Position	Organization
Darin Jones	Chief Scientist	AFSC-RACE
Sarah Stienessen	Fishery Biologist	AFSC-RACE
Scott Furnish	IT Spec.	AFSC-RACE
Matthew Phillips	Fishery Biologist	AIS
Mike Levine	Fishery Biologist	AFSC-RACE
Kresimir Williams	Fishery Biologist	AFSC-RACE
Annette Dougherty	Fishery Biologist	AFSC-RACE
Troy Buckley	Fishery Biologist	AFSC-RACE
Lyle Britt	Fishery Biologist	AFSC-RACE
Rebecca Haehn	Fishery Biologist	AFSC-RACE

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

RACE – Resource Assessment and Conservation Engineering Division

AIS – AIS Scientific and Environmental Services, Inc.