Alaska
Fisheries Science
Center

National Marine
Fisheries Service

U.S DEPARTMENT OF COMMERCE

AFSC PROCESSED REPORT 2018-07

Results of the March 2018 Acoustic-Trawl Survey of Walleye Pollock (*Gadus chalcogrammus*) Conducted in the Southeastern Aleutian Basin Near Bogoslof Island, Cruise DY2018-02

December 2018

This document should be cited as follows:

McKelvey, D., and M. Levine. 2018. Results of the March 2018 acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) conducted in the Southeastern Aleutian Basin near Bogoslof Island, Cruise DY2018-027. AFSC Processed Rep. 2018-07, 44 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Available at http://www.afsc.noaa.gov/Publications/ProcRpt/PR2018-07.pdf.

Results of the March 2018 Acoustic-Trawl Survey of Walleye Pollock (*Gadus chalcogrammus*) Conducted in the Southeastern Aleutian Basin Near Bogoslof Island, Cruise DY2018-02

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December 2018

ABSTRACT

Scientists from the Alaska Fisheries Science Center conducted an acoustic-trawl survey in early March 2018 to estimate the abundance of pre-spawning walleye pollock (*Gadus chalcogrammus*) in the southeastern Aleutian Basin near Bogoslof Island. Thirty-five transect lines were surveyed, and 5 trawl hauls were conducted for biological measurements in the eastern Umnak region. Mechanical problems with the trawl-winch system prevented any trawling in the western Samalga region. This report summarizes the observed pollock distribution and biological information, and provides an abundance estimate used for stock assessment. The estimated numbers of pollock in 2018 were 964 million fish with a biomass of 663 thousand metric tons (t). This was a 31% increase in biomass from the 2016 estimate (507 thousand t). Most pollock were 60 cm or smaller with a mode at 49 cm fork length. Sixty-eight percent of the pollock biomass were from the 2009-2010 year classes.

INTRODUCTION

Scientists from the Midwater Assessment and Conservation Engineering (MACE) Program of the Alaska Fisheries Science Center (AFSC) regularly conduct acoustic-trawl (AT) surveys in late February and early March to estimate the abundance of pre-spawning walleye pollock (*Gadus chalcogrammus*; hereafter referred to as "pollock") in the southeastern Aleutian Basin near Bogoslof Island (Honkalehto et al. 2008a). These surveys were conducted annually between 1988 and 2007 (with the exception of 1990 and 2004), and biennially starting in 2009 (with the exception of 2011). The biomass estimate for pollock within the Central Bering Sea (CBS) Convention Specific Area obtained during these AT surveys provides an index of abundance representing 60% of the Aleutian Basin pollock stock[1]. Therefore, when the pollock biomass estimate from this survey surpasses 1-million metric tons, the Aleutian Basin pollock stock surpasses a 1.67-million metric ton threshold above which targeted pollock fishing in the Aleutian Basin can be negotiated. This report summarizes observed pollock distribution and biological information from the winter 2018 AT survey, provides an abundance estimate used for stock assessment (Ianelli et al. 2016a), and summarizes water temperature observations and acoustic system calibration results.

METHODS

MACE scientists conducted the acoustic-trawl survey between 3 and 7 March 2018 (Cruise DY2018-02) aboard the NOAA ship *Oscar Dyson*, a 64-m stern trawler equipped for fisheries and oceanographic research. Surveys followed established AT methods as specified in NOAA protocols for fisheries acoustics surveys and related sampling[2]. The acoustic units used here are defined in MacLennan et al. (2002).

[1] Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea, Annex (Part 1), Treaty Doc. 103-27. 1994. Hearing before the Committee on Foreign Relations U.S. Senate, 103rd Congress, 2nd Session. Washington: U.S. Government Printing Office.

[2] 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

Acoustic Equipment, Calibration, and Data Collection

Acoustic measurements were collected with Simrad EK60 and EK80 scientific echosounding systems (Simrad 2008, Bodholt and Solli 1992, Demer et al. 2017). The EK60 transceivers were synchronized to ping alternately with the Simrad EK80 transceivers, nominally once every 6 seconds, to test the functionality of the new wideband EK80 while collecting survey data. Both transceivers were connected to the five, split-beam transducers (18-, 38-, 70-, 120-, and 200-kHz) mounted on the bottom of the vessel's retractable centerboard. The centerboard was extended to a nominal depth of 9 m during the survey. System electronics were housed inside the vessel in a permanent laboratory space dedicated to acoustics. This report concerns the data collected by the EK60.

Five standard sphere acoustic system calibrations were conducted in Alaska to measure acoustic system performance (Table 1). The vessel dynamic positioning system was used to maintain the vessel location during calibrations. A tungsten carbide sphere (38.1 mm diameter) suspended below the centerboard-mounted transducers was used to calibrate the 38-, 70-, 120-, and 200-kHz systems. The tungsten carbide sphere was then replaced with a 64 mm diameter copper sphere to calibrate the 18-kHz system. A two-stage calibration approach was followed for each frequency. On-axis sensitivity (i.e., transducer gain and Sa correction) was estimated from measurements with the sphere placed in the center of the beam following the procedure described in Foote et al. (1987). Transducer beam characteristics (i.e., beam angles and angle offsets) were estimated by moving the sphere in a horizontal plane through the beam and fitting these data to a second order polynomial model of the beam pattern using the ER60's calibration utility (Simrad 2008, Jech et al. 2005). The equivalent beam angle is used to characterize the volume sampled by the beam, but it was not estimated using this calibration approach because the absolute position of the sphere was unknown (Demer et al. 2015). Thus, the transducer-specific, equivalent beam angle measured by the echosounder manufacturer was corrected for the local sound speed (see Bodholt 2002) and used in data processing.

Acoustic data were collected between 16 m from the ocean surface to 1,000 m depth, 24 hours/day. Raw acoustic data (EK60) from the five frequencies were logged using ER60 software (v. 2.4.3) and acoustic telegram data were logged using EchoLog 500 (v. 5.22). The average sounder-detected bottom line was calculated using 3 to 5 frequencies, depending on the depth (Jones et al. 2011).

Trawl Gear and Oceanographic Equipment

Organisms responsible for midwater backscatter were sampled with an Aleutian wing 30/26 trawl (AWT). This trawl was constructed with full-mesh nylon wings, and polyethylene mesh in the codend and aft section of the body. The headrope and footrope each measured 81.7 m (268 ft). Mesh sizes tapered from 325.1 cm (128 in) in the forward section of the net to 8.9 cm (3.5 in) in the codend, which was fitted with a single 12 mm (0.5 in) codend liner. The AWT was fished with four 82.3 m (270 ft) non-rotational wire rope (1.9 cm (0.75 in) dia. 8H19) bridles, 226.8 kg (500 lb) or 340.2 kg (750 lb) tom weights on each side, and 5 m^2 Fishbuster trawl doors [1,247 kg (2,750 lb) each]. The AWT was monitored for trawl depth and vertical mouth openings using a Simrad FS70 third-wire net netsounde attached to the trawl headrope; the vertical net opening ranged from 21.3 to 26.0 m, averaging 23.5 m. To gauge escapement of smaller fishes from the net, 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 (Williams et al. 2011). Stereo-camera images of fishes passing into the AWT codend were recorded during hauls using a stereo-camera system attached to the net, forward of the codend (i.e., CamTrawl; Williams et al. 2010a). Camera images were used to identify species, and to estimate individual fish lengths following procedures described in Williams et al. (2010b).

Physical oceanographic measurements were collected throughout the cruise. Temperature-depth profiles were obtained at trawl sites with a Sea-Bird Electronics temperature-depth probe (SBE-39) attached to the trawl headrope. Sea surface temperature data were measured using the ship's calibrated Sea-Bird Electronics sea surface temperature system (SBE 38, accuracy $\pm$ 0.002°C). At times when the SBE 38 was not operating, sea surface temperatures were taken from the mid-ship Furuno T-2000 temperature probe (accuracy $\pm$ 0.2°C) located 1.4 m below the surface. Because the Furuno sensor was not calibrated, a temperature correction was applied based on the observed difference between the calibrated SBE 38 and the Furuno, when both systems were recording. During this survey, the SBE 38 was used 67.5% of the time and the Furuno was used

32.5% of the time. Surface temperatures were averaged to 0.5 nautical mile (nmi) intervals for analysis. Other environmental measurements (e.g., surface salinity) were also recorded using the ship's sensors interfaced with the ship's Scientific Computing System (SCS).

Survey Design

The survey was designed with 35 north-south parallel transects that were spaced 3 nmi apart between about 167°W (Unalaska Island) and 170°W (Islands of Four Mountains). The first transect's start location (longitude) was randomly generated with constraints, to add an element of randomness to an otherwise systematic transect design (Rivoirard et al. 2000). That is, the randomly assigned longitude for the first transect was constrained to be within ≤ 3 nmi (transect spacing) of the start location used in 2003, the last year that start locations were not randomized. This resulted in a new start location for the first transect 0.4 nmi west of the 2003 start location. For comparison purposes, the survey was divided into two regions, Umnak (transects 1-15), and Samalga (transects 16-35) according to differing pollock length distribution in these two areas during prior surveys. Survey operations were conducted from east to west 24 hours/day. The survey covered 1,500 nmi^2 of the CBS Convention Specific Area.

Trawl hauls were conducted to identify the species composition of observed acoustic scattering layers, and to provide biological samples. Trawling speed averaged 3.0 knots. Organism lengths were measured to the nearest 1 millimeter (mm) using an electronic measuring board (Towler and Williams 2010). Pollock were sampled to determine sex, fork length (FL), body weight, age, gonad maturity, and ovary weights. Smaller forage fishes such as lanternfishes (family Myctophidae) were measured to the nearest 1 mm standard length. An electronic motion-compensating scale (Marel M60) was used to weigh individual specimens to the nearest 2 g. Pollock otoliths were collected and stored in 50% glycerin/thymol-water solution for age determination by the AFSC Age and Growth Program researchers. Gonad maturity was determined by visual inspection and categorized as immature, developing, mature (hereafter, "pre-spawning"), spawning, or spent (hereafter, "post-spawning")[3]. Gonado-somatic-indices

3 ADP Codebook. 2016. Unpublished document. RACE Division, AFSC, NMFS, NOAA; 7600 Sand Point Way NE, Seattle, WA 98115. Available online http://www.afsc.noaa.gov/RACE/groundfish/Groundfish_Survey_Codes.pdf

(GSI) were computed as ovary-weight/body-weight for pre-spawning mature pollock. Trawl station and biological measurements were electronically recorded and stored using the Catch Logger for Acoustic Midwater Surveys (CLAMS) customized software program and relational database developed by MACE scientists.

Additional biological samples were collected for special projects. Pollock ovaries were collected from pre-spawning walleye pollock to investigate interannual variation in fecundity of mature females (Sandi.Neidetcher@noaa.gov), and from female walleye pollock of all maturity stages for a histological study (Martin.Dorn@noaa.gov). Fin clips were taken from spawning male and female pollock to investigate the genetic population structure within spawning stocks (Ingrid.Spies@noaa.gov). Results from these special projects will be reported elsewhere.

Data Analysis

Pollock abundance was estimated by combining acoustic backscatter at 38 kHz with trawl information. Acoustic backscatter was classified as near-surface unidentified, deep unidentified, pollock, rockfishes, fishes, or macrozooplankton based on trawl catch information from trawl hauls, and by the backscatter appearance using Echoview software (v. 8.0.104.32739). Pollock backscatter at 38 kHz was integrated at 0.5 nmi horizontal by 20 m vertical resolution, exported to a database, and converted to abundance and biomass using pollock length and weight information. A minimum S_v threshold of -70 decibels (dB) re 1 m^{-1} was used for both echogram display and echo integration.

In the Bogoslof Island area, pre-spawning pollock aggregations are often densely packed and sometimes vertically stratified by sex, with males dominating the deeper pollock scattering layers and the females dominating the shallower layers (Honkalehto and Williamson 1995, Schabetsberger et al. 1999). The vertically stratified layers make it difficult to sample the deeper layers without over-sampling the shallower layer. Because female pollock > 5 years of age tend to be longer than males, over-sampling the shallower layer can lead to biased estimates of population length. Since 1994, the Bogoslof survey population-at-length estimates have been derived assuming that the true population's sex ratio was 50:50, rather than the sex ratio observed in the specimens collected in the trawl hauls (Honkalehto and Williamson 1995). For these survey estimates since 1994, male-female proportions-at-length were derived for each haul, then the separate male-female proportions-at-length were averaged across multiple hauls to represent a region, and finally, the male proportion-at-length for the region was averaged with the female proportion-at-length for the region to represent the region's final, sexes-combined length vector (Honkalehto and Williamson 1996). For the primary 2018 survey analysis and final abundance estimates, proportion-at-length was computed using this historical approach.

Pollock mean weight-at-length was estimated using data from all trawl catches. Because of the potential for biased sampling of males (or females) mentioned above, additional male fish (or females) in the catch were selected from the catch (nonrandom specimens) and used to supplement the length-weight and length-age samples. Thus, weight-at-length measurements from individual random, and non-randomly selected pollock specimens were used to estimate mean weight-at-length for each 1-cm length interval. When < 5 pollock occurred per interval, weight at a given length interval was estimated from a linear regression of the natural logs of the length and weight data and corrected for a small bias due to back-transformation (Miller 1984, De Robertis and Williams 2008).

Briefly, pollock abundance was estimated by dividing the acoustic measurements of nautical area backscattering coefficient (s_A, m^2 nmi^{-2}) by the mean backscattering cross section (σ_{bs}, m^2). Pollock σ_{bs} is a linear representation of target strength (TS, dB re 1 m^2; TS = 10 log10 (σ_{bs})), and was estimated using a target strength to length relationship of TS = 20 $\log_{10}$ (FL) – 66 (Traynor 1996), where FL is observed fork length (cm) in the haul data from each length stratum. Further details on how numbers and biomass were estimated are described in Honkalehto et al. (2008b).

An age-length key, and a subsequent proportion-at-age matrix was applied to the population numbers-at-length to estimate numbers at age (Jones, et al. 2017, Appendix 1). For population estimates at lengths where no otolith specimens were collected, the proportion-at-age was estimated using a Gaussian-model approach based on historical age-at-length data (1988-2018).

Relative estimation errors associated with spatial structure observed in the acoustic data were derived using a one-dimensional (1D) geostatistical method (Petitgas 1993, Williamson and

Traynor 1996, Rivoirard et al. 2000, Walline 2007). The relative estimation error is defined as the ratio of the square root of the estimation variance to the biomass estimate. The error quantifies only transect sampling variability. Other sources of error (e.g., target strength, trawl sampling) are not included in the estimate.

Estimates of average pollock depth (weighted by biomass) were compared to the average bottom depth for each 0.5 nmi distance interval. Average pollock depth for each 0.5 nmi interval was computed as

$$average\ pollock\ depth = \frac{\sum_D D*B}{\sum_D B},$$

where D is the midpoint depth (m) of each 20 m depth layer, and B is biomass in the 20 m depth layer. Average bottom depth was the average sounder-detected bottom depth in each interval. The average pollock depth was sometimes deeper than the average sounder-detected bottom depth in areas of extreme slope. In these cases, the maximum-depth of the pollock backscatter was used as the average bottom depth.

Sensitivity Analysis

A sensitivity analysis examined the effect of two specific changes to the primary analysis of pollock biomass and abundance estimates in the Bogoslof region.

1) The primary analysis assumed a 50:50 sex ratio in the pollock population. This alternative analysis did not assume an equal sex ratio. Rather, the length-composition was computed without regard to sex for each haul.
2) Pollock mean weight-at-length in the primary analysis was estimated using data from all maturity stages. This alternative analysis investigated the effect of excluding post-spawning fish from the length-weight relationship.

RESULTS AND DISCUSSION

Calibration

Pre- and post-survey calibration measurements of gain and transducer beam pattern were similar. That is, the difference in integration gains (i.e., gain + Sa correction) measured before and after the survey was < 0.1 dB, and transducer beam pattern measurements were similar. These measurements confirmed that the ER60 38-kHz acoustic system was stable throughout the survey, so the calibration results were averaged in the linear domain and used for the final analysis (Table 1).

Water Temperature

Water temperatures measured during the 2018 survey were cooler than temperatures measured in 2016. Mean surface-temperatures ranged from 4.1 º to 4.7 ºC in 2018 (Fig. 1), whereas mean surface-temperatures ranged from 4.7 º to 5.6 ºC in 2016. The coolest surface-temperatures measured in 2018 were observed in the easternmost transects, which was consistent with 2016. Water temperatures at trawl sites were cooler throughout the water column compared to 2016, especially in the upper 250 m (Fig. 2). Temperatures between 250 and 500 m, where most of the pollock were distributed in the Bogoslof area in 2018, averaged between 4.5 º and 3.7 ºC compared to 4.8º and 3.6°C in 2016 (Fig. 2). When compared to temperature profiles observed from previous Bogoslof surveys, the profile in 2018 was cooler than 2016 (the warmest year in the time series between 2000 and 2018) but was warmer than nearly all other surveyed years.

Acoustic Backscatter

Acoustic backscatter at 38 kHz was observed along all 35 transect lines within the Central Bering Sea Specific Area (Fig. 3). Backscatter in the Umnak region was sampled with trawl hauls, but mechanical problems with the trawl-winch system prevented any trawling in the Samalga region, where the densest backscatter was distributed (Fig. 3).

Trawl Samples

Biological data and specimens were collected from 5 trawl sites in the Umnak region

(Tables 2-4, Fig. 3). Pollock dominated the trawl catches by weight, and represented 98.5% of the total catch for the 5 AWT hauls (Table 3). Northern smoothtongue dominated the catch by number, (48.6%), with pollock second most numerous at 37.5% of the total catch (Table 3).

Pollock length measurements collected from the 5 hauls were used to convert the acoustic data to numbers-at-length and biomass-at-length estimates. Fish lengths ranged from 37 to 63 cm FL, with a primary mode at 49 cm. Random length measurements (n = 1,286, Table 4) were used to compute the number at length estimates; 41% of the length specimens were male and 59% were female.

Pollock specimens from the Umnak region were examined for maturity stages. Of the 183 males, 7% were in the pre-spawning stage, 56% were spawning, and 37% were in the post-spawning stage (Fig. 4a). Of the 223 females, 18% were in the pre-spawning stage, 3% were spawning, and 79% were in the post-spawning stage (Fig. 4a). The average gonado-somatic-index (GSI) for pre-spawning mature (i.e., FL$\geq$ 39.9) female pollock in the Umnak region was 0.17 (see Fig. 4b for individual measurements), which was greater than the 0.10 observed in 2016 for the Umnak region.

Pollock mean weight-at-length estimates were computed for most of the pollock lengths encountered in the specimen collection (Fig. 4c). To estimate mean weight-at-length for biomass-at- length estimates, both random and non-random lengths were used (Table 4). Because of the small sample size for the smallest and largest pollock encountered, mean weight-at-length for the 1-cm length-intervals were estimated by using, weight (g) = $0.000025 \times \text{FL (cm)}^{2.63}$. A single length-weight relationship was used for the entire surveyed area.

<u>Distribution and Abundance</u>

Pollock biomass was distributed on all transects with minor concentrations in the Umnak region and the bulk of the biomass located in a relatively small area of the Samalga region. The densest concentration was located on transect 26, within the Samalga region, which represented 66% of the estimated pollock biomass. This layer extended horizontally for about 9 nmi with a vertical extent from 150 m down to 650 m below the surface (Fig. 5). Pollock biomass-weighted depth estimates ranged from about 50 to 500 m for the entire surveyed area (Fig. 6). Fish generally stayed close to the bottom until bottom depths reached about 300 - 350 m. Pollock formed pelagic layers around 300-600 m over deeper bottom depths (> 600 m), except along transects 26 and 27, where pollock formed pelagic layers extending from 150 m. The pollock mean biomass-weighted depth estimate was 338 m for the Umnak area and 307 m for the Samalga area. The pollock biomass-weighted depth estimate for the dense aggregation on transect 26 was 274 m.

The pollock abundance estimate in 2018 was 964 million fish weighing 663 thousand metric tons (t) for the entire surveyed area (Tables 5-7; Fig. 7). The overall size-composition for the pollock was unimodal at 49 cm FL (Fig. 8-9), with an average length at 48.2 cm (Table 6). The estimates represent an increase of 11% in abundance and 31% in biomass from the 2016 survey estimates of 866 million fish weighing 507 thousand metric tons (McKelvey and Lauffenburger 2017). Based on the 1D geostatistical analysis, the relative estimation error for the biomass estimate was 42.5% (Table 5). This error rate was the largest estimated to date and likely reflects the high-density biomass estimate on transect 26 (Fig. 5).

The estimated age-composition for pollock ranged from 5 to 12 years of age (Tables 8-9; Fig. 10). Sixty-eight percent of the estimated biomass were 8-9-year old fish (2010-2009 year classes), and another 14% were 6-year-old fish (2012 year class).

Sensitivity Analysis

The sensitivity analysis showed variable effects relative to pollock abundance estimates from the primary analysis (Table 10). Negligible effects (< 1%) were observed between abundance or biomass estimates when the length-compositions were constructed without assuming a 50:50 sex ratio in sensitivity analysis 1. Abundance was slightly lower and biomass was slightly higher when the observed length composition was used. The largest positive effect (8%) occurred between biomass estimates in sensitivity analysis 2, where biomass was greater when fish in post-spawning condition were excluded from the length-weight relationship. The effect was most apparent in fish greater than 48 cm FL (Fig. 11).

Survey Time Series and 2018 Point Estimate

Pollock abundance estimates from the Bogoslof AT surveys provide a relative abundance index for the Aleutian Basin pollock stock, where it is assumed that 60% of the Aleutian Basin pollock spawn in the Bogoslof region. That is, the Bogoslof AT survey estimate represents 60% of the Aleutian Basin pollock stock. When the biomass estimate for this survey surpasses 1-million metric tons, the assumption is that the Aleutian Basin pollock stock surpasses a 1.67-million metric ton threshold, which would mean that targeted pollock fishing in the Aleutian Basin would be considered. Although the 2018 estimated biomass of 0.663 million metric tons in the Central Bering Sea (CBS) Specific Area was greater than estimates observed over the last 14 surveys (i.e., since 1996; Table 5), the estimate was still below the 1-million metric ton threshold (Fig. 7)

Caveats and Future Directions

A major assumption underlying the survey results for 2018 was that the backscatter observed in the Samalga region was primarily from pollock (Fig. 3). Backscatter observed on transect 26 in this region was particularly important because it contributed 66% of the estimated pollock biomass in 2018. Because no trawl samples occurred in the Samalga region, we relied on prior pollock surveys to support this assumption. Similar backscatter confirmed by trawling was observed in this region during the 2014 and 2016 surveys (transect 27: Fig. 4 in McKelvey and Stienessen 2015; transect 27: Fig. 6 in McKelvey and Lauffenburger 2017).

The length composition of the "Samalga-pollock" was assumed the same as that from hauls in the Umnak region. Prior surveys have shown that pollock lengths can vary across the survey area in some years but not in others. For example, fish larger than 50 cm were primarily observed in the Samalga region in 2012 and 2014 (McKelvey and Stienessen 2012, McKelvey and Stienessen 2015), whereas similar length compositions existed in both regions in 2016 (McKelvey and Lauffenburger 2017).

The 2018 pollock population length composition was computed by assuming that the population's sex ratio was 50:50, as has been done since 1994. The sensitivity analysis results indicated negligible differences if this 50:50 sex ratio assumption was dropped (Table 10, Fig. 10). Although the relatively equal proportion of males to females captured across all hauls likely contributed to this result, the proportion of males to females was variable and sometimes skewed (e.g., 86% females in haul 2). Extensive paired trawl-samples in multi-layered aggregations in the future would help determine whether vertical stratification of pollock by sex persists.

The percentage of fish in spawning and post-spawning maturity stages have exceeded 50% in a number of past surveys (Table 11). This high percentage of fish in late stages potentially confounds interpretation of the Bogoslof survey time-series estimates in two ways. If pollock move out of the survey area after spawning, a negative bias in survey abundance estimates could result (Wilson 1994), but this needs to be confirmed for the Bogoslof survey. Secondly, when a large percentage of the fish observed by a survey are in post-spawning condition, the average fish weight-at-length is reduced, which can also negatively bias survey results (e.g., biomass). For example, the sensitivity analysis results indicated an 8% increase in biomass relative to the primary analysis when post-spawning fish were not used in determining mean weight-at-length (Table 10). Further analyses of the Bogoslof survey time-series is warranted to determine whether the percent of fish in spawning and post-spawning condition can be predicted based on factors such as calendar date, population size, average fish length, location, or environmental conditions (Lawson and Rose 2000).

ACKNOWLEDGMENTS

The authors would like to thank the officers and crew of the NOAA ship *Oscar Dyson*, and all of the scientists who prepared for and participated in this survey for their contributions to the successful completion of this work.

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Itinerary

Alaska Standard Time

27 February	Embark scientists in Kodiak, AK
1-3 March	Transit towards southeast Aleutian Basin, Alaska
3-7 March	Acoustic-trawl survey of the Bogoslof Island area
7 March	Transit towards Dutch Harbor
7-10 March	Diagnose and repair winches for the trawl system and for the third-wire netsounde system
10 March	Disembark scientists in Dutch Harbor, Alaska

Scientific Personnel

Name	Position	Organization
Denise McKelvey	Chief Scientist	AFSC
Abigail McCarthy	Fishery Biologist	AFSC
Nathan Lauffenburger	Info. Tech. Specialist	AFSC
Chris Wilson	Fishery Biologist	AFSC
Chris Bassett	Oc. Acoustics Eng.	AFSC
Mike Levine	Fishery Biologist	AFSC
Mathew Phillips	Fishery Biologist	AFSC-AIS

AFSC Alaska Fisheries Science Center, Seattle WA

AIS AIS Scientific and Environmental Services, Inc., Marion, MA

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.

	Winter 2018 system settings	6 Feb Kalsin Bay Alaska	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
Sa 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	--	--	--	--	--	-70
Standard sphere TS (dB re 1 m^2)	--	-42.13	-42.13	-42.15	-42.16	-42.15	--
Sphere range from transducer (m)	--	20.63	21.06	19.85	20.51	19.61	--
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)	--	3.1	3.6	3.6	4.0	4.0	--
Number of replicates	--	2	2	2	1	5	--

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

Table 2.--Trawl station and catch data summary from the winter 2018 acoustic-trawl survey of walleye pollock in the Bogoslof Island area. The Aleutian Wing Trawl was used for all samples.

										Catch			
Haul	Date	Time	Duration	Start position		Depth (m)		Water temp. (°C)		Pollock		Other	Camtrawl
number	(GMT)	(GMT)	(minutes)	Latitude (N)	Longitude (W)	Footrope	Bottom	Headrope	Surface	(kg)	Number	(kg)	deployment
1	4-Mar-18	2:11	6	53.98	-167.06	451	516	3.9	4.6	1,287.68	1,839	13.7	Y
2	4-Mar-18	11:13	36	53.79	-167.33	347	473	4.1	4.6	1,290.76	1,860	10.9	Y
3	4-Mar-18	17:45	15	53.68	-167.52	327	368	4.2	4.6	24.13	36	1.4	Y
4	5-Mar-18	0:32	14	53.62	-167.71	464	936	3.9	4.7	1,377.45	1,959	54.0	Y
5	5-Mar-18	7:27	18	53.65	-167.88	427	888	4.0	4.6	2,026.79	2,766	13.5	Y

Table 3.--Catch by species, including numbers of length and weight measurements, taken from individuals captured in 5 Aleutian Wing Trawl hauls during the winter 2018 acoustic-trawl survey of walleye pollock in the Bogoslof Island area.

		Catch				Individual measurements	
Species name	Scientific name	Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	6,006.8	98.5	8,459	37.5	1,335	406
northern smoothtongue	*Leuroglossus schmidti*	38.2	0.6	10,973	48.6	82	44
lanternfish	*Stenobrachius* (genus)	23.6	0.4	2,112	9.4	54	36
Pacific ocean perch	*Sebastes alutus*	6.5	0.1	9	<0.1	9	9
smooth lumpsucker	*Aptocyclus ventricosus*	6.3	0.1	3	<0.1	3	3
sea nettle	*Chrysaora melanaster*	4.2	0.1	35	0.2	-	18
squid	*Gonatopsis* (genus)	3.4	0.1	25	0.1	20	20
jellyfish	*Aequorea* (genus)	3.4	0.1	18	0.1	-	-
chinook salmon	*Oncorhynchus tshawytscha*	1.7	<0.1	1	<0.1	1	1
magistrate armhook squid	*Berryteuthis magister*	1.3	<0.1	13	0.1	9	9
eelpout	Zoarcidae (family)	1.3	<0.1	398	1.8	30	11
arrowtooth flounder	*Atheresthes stomias*	0.8	<0.1	1	<0.1	1	1
Pacific lamprey	*Lampetra tridentata*	0.6	<0.1	2	<0.1	2	2
squid	Cephalopoda (class)	0.5	<0.1	113	0.5	1	1
lanternfish	*Diaphus* (genus)	0.5	<0.1	35	0.2	2	2
shrimp	*Sergestes* (genus)	0.4	<0.1	293	1.3	-	-
comb jelly	Ctenophora (phylum)	0.4	<0.1	18	0.1	1	1
Pacific glass shrimp	*Pasiphaea pacifica*	0.1	<0.1	53	0.2	-	-
viperfish	Stomiidae (family)	<0.1	<0.1	1	<0.1	1	1
jellyfish	Scyphozoa (class)	<0.1	<0.1	4	<0.1	-	4
shrimp	*Notostomus* (genus)	<0.1	<0.1	1	<0.1	1	1
shrimp	Malacostraca (class)	<0.1	<0.1	1	<0.1	-	-
Total		6,100.2		22,568		1,552	570

Table 4. -- Numbers of walleye pollock measured and biological samples collected during the winter 2018 acoustic-trawl survey in the Bogoslof Island area.

Walleye pollock							
Haul number	Random lengths	Lengths and weights	Maturities	Otoliths	Ovary weights*	Ovary preserved	Non-random**
1	330	80	80	62	17	20	18
2	319	81	81	61	1	7	19
3	36	36	36	36	-	1	-
4	300	80	80	48	6	8	12
5	301	80	80	60	10	4	-
Total	1,286	357	357	267	34	40	49

* From pre-spawning pollock
** Non-random length, weight, maturity, and otolith

Table 5.--Walleye pollock biomass (metric tons (t)) estimated by survey area and management area from February-March acoustic-trawl surveys in the Bogoslof Island area between 1988 and 2018.

Bogoslof Survey Area				**Central Bering Sea Specific Area**	
Year	**Biomass (million t)**	**Area (nmi^2)**	**Relative estimation error (%)**	**Biomass (million t)**	**Relative estimation error (%)**
1988	2.396	--	--	2.396	--
1989	2.126	--	--	2.084	--
1990	--	No survey	--	--	--
1991	1.289	8,411	11.7	1.283	--
1992	0.940	8,794	20.4	0.888	--
1993	0.635	7,743	9.2	0.631	--
1994	0.490	6,412	11.6	0.490	--
1995	1.104	7,781	10.7	1.020	--
1996	0.682	7,898	19.6	0.582	--
1997	0.392	8,321	14.0	0.342	--
1998	0.492	8,796	19.0	0.432	19.0
1999	0.475	Conducted by Japan Fisheries Agency		0.393	--
2000	0.301	7,863	14.3	0.270	12.7
2001	0.232	5,573	10.2	0.208	11.8
2002	0.226	2,903	12.2	0.226	12.2
2003	0.198	2,993	21.5	0.198	21.5
2004	--	No survey	--	--	--
2005	0.253	3,112	16.7	0.253	16.7
2006	0.240	1,803	11.8	0.240	11.8
2007	0.292	1,871	11.5	0.292	11.5
2008	--	No survey	--	--	--
2009	0.110	1,803	19.2	0.110	19.2
2010	--	No survey	--	--	--
2011	--	No survey	--	--	--
2012	0.067	3,656	--	0.067	9.8*
2013	--	No survey	--	--	--
2014	0.112	1,150	11.8	0.112	11.8
2015	--	No survey	--	--	--
2016	0.508	1,400	11.0	0.508	11.0
2018	0.663	1,500	42.5	0.663	42.5

*The relative error for 2012 was computed for the primary survey area represented by transects 1-35 (1,455 nı

Table 6.--Numbers-at-length estimates (millions), and average fork length from February-March acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017. The 1999 survey was conducted by the Japan Fisheries Agency. Lengths are in centimeters.

Length	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007	2009	2012	2014	2016	2018
10	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0
14	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	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
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	2	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0
24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0
31	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	<1	0	0	0	0	0	0	0	0	0	<1	<1	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	<1	<1	0	<1	0	0	0	<1	<1	0	0	0	0	0	0	<1	0
35	0	0	0	0	0	0	<1	0	<1	0	0	0	0	<1	0	0	0	0	0	0	0	<1	0
36	0	0	0	<1	0	0	<1	<1	<1	<1	0	0	0	1	0	0	0	0	0	0	0	6	0
37	9	3	<1	0	0	0	<1	<1	<1	<1	0	0	0	1	<1	<1	0	0	0	0	<1	12	1
38	6	0	2	<1	1	0	1	1	<1	1	0	0	<1	1	<1	1	<1	0	0	0	<1	27	0
39	16	4	5	0	2	<1	4	1	1	3	<1	<1	<1	2	<1	2	<1	<1	0	0	<1	42	1
40	24	3	7	1	4	3	12	4	1	7	1	<1	1	3	<1	7	2	0	0	0	2	33	4
41	27	4	19	3	5	6	20	8	2	9	6	1	1	4	<1	11	5	1	<1	<1	5	37	8

Table 6.--Continued.

Length	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007	2009	2012	2014	2016	2018
42	48	23	23	7	7	9	40	14	3	11	8	1	1	2	<1	12	10	2	<1	<1	8	43	9
43	118	33	31	14	6	14	40	17	4	11	13	3	1	5	1	11	16	4	<1	<1	9	56	30
44	179	54	36	18	7	21	41	21	5	10	13	3	2	5	2	11	20	8	<1	<1	8	61	38
45	329	159	46	28	8	21	50	23	7	9	17	4	3	7	3	13	23	11	<1	1	9	90	87
46	488	177	55	32	13	21	53	31	10	11	19	5	4	5	5	11	23	17	<1	2	7	74	79
47	547	389	79	42	22	18	40	36	14	9	14	6	5	9	5	11	18	17	1	2	7	98	143
48	476	434	130	68	28	17	55	36	15	12	11	6	5	7	7	10	17	20	1	2	6	88	108
49	389	431	168	102	46	16	47	37	18	15	10	5	6	6	6	8	14	14	2	2	5	60	158
50	248	366	205	129	69	39	52	40	21	20	16	6	6	5	7	8	9	18	2	3	7	59	94
51	162	279	189	144	76	46	58	45	24	23	11	8	6	5	4	9	9	15	5	3	2	26	57
52	80	168	160	118	73	52	78	52	26	28	20	10	7	4	4	7	7	13	5	2	2	19	59
53	48	85	122	106	73	49	81	52	26	35	17	13	8	6	4	7	5	12	6	2	4	8	41
54	19	50	63	67	66	43	88	53	31	41	21	16	9	7	3	7	5	10	8	2	2	7	27
55	12	13	40	41	50	37	81	48	28	38	33	21	13	9	5	8	3	9	8	2	2	3	9
56	4	5	17	27	29	26	69	40	24	35	38	20	13	12	7	6	6	8	8	2	3	3	5
57	3	8	8	13	14	17	58	37	22	30	33	24	16	13	7	7	5	6	6	3	4	3	5
58	1	1	4	6	9	10	47	28	17	27	36	23	14	14	10	6	7	7	6	3	4	1	<1
59	0	0	1	5	3	6	31	19	13	18	23	16	12	12	9	8	5	7	5	3	4	<1	0
60	0	0	1	1	1	3	17	12	12	13	15	13	12	12	13	7	7	6	2	4	3	2	1
61	2	0	1	<1	1	2	7	6	6	8	18	10	10	8	9	9	5	8	2	2	3	6	0
62	0	0	<1	<1	<1	1	4	2	3	5	13	7	6	6	7	7	5	7	1	2	2	1	0
63	0	0	0	0	0	<1	2	1	1	3	4	4	4	4	5	7	4	4	2	3	2	1	0
64	0	0	0	1	<1	0	1	<1	1	1	3	2	3	3	5	5	2	4	1	2	1	1	0
65	0	0	<1	0	0	0	<1	<1	<1	1	1	1	1	1	3	4	2	3	<1	<1	<1	0	0
66	0	0	0	0	0	0	<1	0	<1	1	<1	<1	<1	1	1	2	2	3	<1	1	<1	0	0
67	0	0	0	0	0	0	0	0	0	0	1	<1	<1	<1	1	2	1	2	<1	1	<1	0	0
68	0	0	0	0	0	0	1	0	0	<1	0	<1	<1	<1	<1	1	1	1	<1	<1	<1	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1	<1	<1	1	<1	0	<1	1	0
70	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	<1	<1	<1	<1	0	<1	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	<1	<1	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1	<1	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	<1	0	0	0	0
Total	3,236	2,687	1,419	975	613	478	1,081	666	337	435	416	229	170	181	134	225	239	236	73	49	113	868	964
Average length	47.2	48.7	49.6	50.6	51.4	51.0	50.9	51.4	52.8	52.5	53.4	55.0	55.1	53.1	55.7	51.2	49.7	52.3	55.3	55.5	49.6	45.7	48.2

Table 7.--Biomass-at-length estimates (1,000 t) from February-March acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017. The 1999 survey was conducted by the Japan Fisheries Agency. Lengths are in centimeters.

Length	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007	2009	2012	2014	2016	2018
10	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0
14	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	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
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	<1	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0
24	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
31	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	<1	0	0	0	0	0	0	0	0	0	<1	<1	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	<1	<1	0	<1	0	0	0	<1	<1	0	0	0	0	0	0	<1	0
35	0	0	0	0	0	0	<1	0	<1	0	0	0	0	<1	0	0	0	0	0	0	0	<1	0
36	0	0	0	<1	0	0	<1	<1	<1	<1	0	0	0	<1	0	0	0	0	0	0	0	2	0
37	3	1	<1	0	0	0	<1	<1	<1	<1	0	0	0	<1	<1	<1	0	0	0	0	<1	4	<1
38	2	0	1	<1	<1	0	<1	<1	<1	<1	0	0	<1	1	<1	<1	<1	0	0	0	<1	11	0
39	6	1	2	0	1	<1	2	1	1	1	<1	<1	<1	1	<1	1	<1	<1	0	0	<1	17	<1
40	11	1	3	<1	2	1	6	2	1	3	1	<1	<1	2	<1	3	1	0	0	0	1	14	2
41	13	2	8	1	2	3	10	4	1	4	6	1	<1	2	<1	5	2	<1	<1	<1	2	18	4

Table 7.--Continued.

Length	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007	2009	2012	2014	2016	2018
42	24	11	11	3	4	5	21	7	1	6	7	1	<1	1	<1	6	5	1	<1	<1	4	21	4
43	64	17	16	7	3	8	22	9	2	6	12	2	1	3	<1	6	9	2	<1	<1	5	28	15
44	105	30	20	10	4	13	25	13	3	6	12	2	2	4	1	6	12	5	<1	<1	5	32	21
45	207	94	28	16	5	14	33	15	5	6	16	3	2	5	2	8	15	7	<1	1	6	49	51
46	329	113	36	21	9	15	37	22	7	8	18	3	3	4	4	8	17	12	<1	1	5	43	48
47	395	268	57	29	17	14	30	26	11	7	14	5	4	7	4	9	14	13	1	1	5	59	90
48	367	323	101	52	22	14	45	29	12	10	11	5	4	6	6	8	15	17	1	2	5	56	72
49	321	346	141	84	40	14	40	32	16	13	11	5	5	6	6	7	13	13	2	2	4	40	109
50	218	315	187	116	64	36	48	36	20	19	18	5	6	5	7	7	9	18	2	3	6	42	72
51	152	258	186	140	76	46	57	43	24	23	12	8	6	5	4	9	10	16	5	3	2	19	46
52	80	166	171	124	78	56	82	54	29	29	23	11	8	4	5	8	7	15	6	2	2	15	48
53	51	90	140	120	83	55	90	57	30	39	20	15	9	6	5	8	6	15	8	3	4	7	35
54	21	57	78	82	79	52	104	62	38	49	25	19	11	8	4	9	6	13	11	2	2	6	26
55	14	16	53	53	64	48	102	59	36	47	39	27	17	12	6	11	5	13	13	2	3	3	8
56	6	6	24	39	40	35	92	53	33	48	47	27	17	16	11	9	10	13	12	2	5	3	6
57	4	11	12	20	21	24	82	52	32	43	41	35	24	19	11	10	7	10	9	4	6	3	5
58	1	1	7	9	14	16	71	41	26	41	45	34	22	22	16	10	11	11	10	5	7	1	<1
59	0	0	1	8	4	10	49	29	21	28	28	26	20	19	15	14	9	10	9	5	7	<1	0
60	0	0	3	3	2	5	28	20	21	22	18	22	20	21	23	13	11	13	5	6	4	2	1
61	3	0	2	1	2	4	12	11	11	14	23	19	18	15	17	17	8	14	5	4	5	7	0
62	0	0	1	1	<1	2	8	4	6	10	15	13	12	12	15	13	10	15	2	4	4	1	0
63	0	0	0	0	0	<1	4	3	3	6	5	7	8	8	11	14	8	9	4	6	4	1	0
64	0	0	0	1	<1	0	1	1	1	2	3	4	6	6	11	10	6	9	2	4	3	1	0
65	0	0	1	0	0	0	<1	1	1	1	2	2	3	2	7	9	4	7	1	<1	2	0	0
66	0	0	0	0	0	0	<1	0	<1	1	<1	1	1	2	4	5	5	6	1	2	2	0	0
67	0	0	0	0	0	0	0	0	0	0	1	1	<1	1	2	5	3	5	<1	2	1	0	0
68	0	0	0	0	0	0	3	0	0	<1	0	<1	<1	1	1	2	2	3	<1	<1	<1	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1	1	1	3	<1	0	<1	1	0
70	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	<1	<1	1	<1	0	<1	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	1	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0
Total	2,396	2,126	1,289	940	635	490	1,104	682	392	492	475	301	232	226	198	253	240	292	110	67	112	508	663

Table 8.--Numbers-at-age estimates (millions) from February-March acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017. The 1999 survey was conducted by the Japan Fisheries Agency. Ages are in years.

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	1	0	0	0	0	0	0	0	0	--	0	0	0	--	0	--	--	0	--	<1	--	--	--	--
2	0	0	--	4	0	0	0	0	0	0	0	0	0	0	<1	0	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--
3	0	0	--	0	1	1	0	2	0	0	0	0	0	0	9	<1	--	0	0	0	--	0	--	--	0	--	<1	--	3	--	--
4	0	6	--	2	2	33	21	6	<1	<1	<1	2	1	1	5	8	--	5	4	1	--	0	--	--	<1	--	1	--	170	--	--
5	28	15	--	12	27	17	86	75	6	4	11	5	6	14	3	6	--	81	55	8	--	1	--	--	1	--	34	--	41	--	59
6	327	58	--	46	54	44	26	278	96	16	61	29	4	12	41	7	--	31	104	92	--	1	--	--	15	--	31	--	161	--	152
7	247	363	--	213	97	46	38	105	187	55	34	77	14	10	11	25	--	13	18	70	--	7	--	--	10	--	11	--	367	--	81
8	164	147	--	93	74	48	36	68	85	88	70	34	30	10	8	11	--	11	6	17	--	23	--	--	2	--	14	--	99	--	381
9	350	194	--	160	71	42	36	80	40	38	77	50	16	14	6	4	--	22	6	3	--	26	--	--	1	--	7	--	17	--	247
10	1,201	91	--	44	55	28	17	53	37	28	32	75	28	12	7	5	--	7	9	3	--	8	--	--	2	--	3	--	9	--	27
11	288	1,105	--	92	57	51	27	54	24	16	25	29	45	18	8	4	--	3	3	8	--	1	--	--	7	--	<1	--	--	--	14
12	287	222	--	60	33	25	23	19	24	16	21	27	21	31	14	10	--	5	2	4	--	1	--	--	8	--	1	--	1	--	3
13	202	223	--	373	34	27	13	59	12	13	19	25	16	13	30	8	--	4	4	1	--	1	--	--	1	--	5	--	--	--	--
14	89	82	--	119	142	42	9	32	36	7	18	16	11	7	9	26	--	5	5	5	--	<1	--	--	<1	--	4	--	--	--	--
15	27	90	--	41	164	92	45	12	18	13	9	12	11	9	7	6	--	11	8	5	--	<1	--	--	<1	--	2	--	--	--	--
16	17	30	--	38	59	47	36	31	4	5	15	10	9	8	9	5	--	12	5	3	--	1	--	--	<1	--	0	--	--	--	--
17	7	60	--	29	8	25	28	103	16	4	5	8	3	5	5	3	--	6	7	6	--	1	--	--	<1	--	<1	--	--	--	--
18	3	0	--	32	15	11	16	60	35	12	8	6	6	1	4	5	--	4	2	4	--	<1	--	--	<1	--	<1	--	--	--	--
19	0	0	--	56	22	11	4	18	26	12	10	3	3	3	2	1	--	3	1	3	--	1	--	--	<1	--	0	--	--	--	--
20	0	0	--	4	42	11	4	5	12	7	15	4	2	1	2	<1	--	1	2	1	--	<1	--	--	0	--	0	--	--	--	--
21	0	0	--	2	13	10	8	5	3	2	4	3	1	0	0	1	--	<1	<1	<1	--	<1	--	--	0	--	0	--	--	--	--
22	0	0	--	0	3	1	2	6	2	1	1	2	1	0	0	0	--	0	0	1	--	0	--	--	0	--	0	--	--	--	--
23	0	0	--	0	1	1	2	6	1	<1	0	<1	0	<1	<1	0	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--
24	0	0	--	0	0	0	1	2	0	1	0	0	<1	<1	<1	0	--	<1	0	1	--	0	--	--	0	--	0	--	--	--	--
25	0	0	--	0	0	0	0	0	0	0	0	0	0	0	<1	0	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--
Total	3,236	2,687	--	1,419	975	613	478	1,081	666	336	435	416	229	170	181	134	--	225	239	236	--	73	--	--	49	--	113	--	868	--	964

Table 9.--Biomass-at-age estimates (1,000 t) from February-March acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017. The 1999 survey was conducted by the Japan Fisheries Agency. Ages are in years.

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	<1	0	0	0	0	0	0	0	0	--	0	0	0	--	0	--	--	0	--	<1	--	--	--	--
2	0	0	--	<1	0	0	0	0	0	0	0	0	0	0	<1	0	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--
3	0	0	--	0	<1	<1	0	1	0	0	0	0	0	0	5	<1	--	0	0	0	--	0	--	--	0	--	<1	--	1	--	--
4	0	2	--	1	1	19	13	3	<1	<1	<1	2	<1	<1	3	7	--	3	2	1	--	0	--	--	<1	--	1	--	76	--	--
5	15	7	--	6	21	12	60	49	4	2	7	6	4	12	2	5	--	52	36	6	--	1	--	--	1	--	19	--	20	--	31
6	192	41	--	25	38	39	22	208	69	11	38	28	3	11	34	6	--	25	85	80	--	1	--	--	15	--	23	--	92	--	93
7	156	241	--	143	67	43	40	83	165	50	30	78	12	10	10	26	--	14	19	86	--	9	--	--	11	--	10	--	228	--	56
8	115	111	--	75	59	47	39	72	76	95	74	37	30	12	9	12	--	15	7	25	--	33	--	--	3	--	19	--	66	--	264
9	251	149	--	149	67	44	40	96	46	44	94	60	18	18	8	6	--	29	8	4	--	39	--	--	1	--	12	--	13	--	185
10	910	68	--	44	57	31	21	64	45	38	40	90	40	16	9	8	--	10	15	6	--	13	--	--	4	--	5	--	11	--	20
11	226	895	--	94	61	59	32	71	31	23	36	35	63	26	12	7	--	6	4	14	--	2	--	--	12	--	<1	--	--	--	11
12	233	187	--	59	36	27	28	26	33	22	29	33	32	50	23	18	--	9	3	7	--	2	--	--	14	--	1	--	1	--	3
13	167	194	--	378	37	30	17	77	17	18	27	30	25	20	48	14	--	8	6	1	--	2	--	--	2	--	10	--	--	--	--
14	82	72	--	116	150	47	11	42	49	11	26	19	18	11	15	47	--	10	9	11	--	1	--	--	<1	--	8	--	--	--	--
15	23	81	--	39	169	107	53	17	24	20	13	14	16	14	12	11	--	21	15	12	--	1	--	--	1	--	3	--	--	--	--
16	16	24	--	38	63	54	43	38	6	7	22	13	15	14	15	8	--	25	9	6	--	2	--	--	<1	--	<1	--	--	--	--
17	7	52	--	31	9	28	32	131	21	5	8	10	6	7	8	5	--	11	13	12	--	2	--	--	1	--	<1	--	--	--	--
18	3	0	--	32	15	11	18	74	43	17	10	7	8	2	6	10	--	8	3	8	--	1	--	--	<1	--	1	--	--	--	--
19	0	0	--	55	23	14	5	22	32	17	13	3	5	5	3	2	--	5	2	6	--	1	--	--	<1	--	0	--	--	--	--
20	0	0	--	4	44	12	5	6	14	9	19	4	3	2	3	1	--	1	3	2	--	<1	--	--	0	--	0	--	--	--	--
21	0	0	--	1	15	10	9	5	4	2	5	4	2	0	0	2	--	<1	1	1	--	<1	--	--	0	--	0	--	--	--	--
22	0	0	--	0	3	1	2	8	2	1	1	3	2	0	0	0	--	0	0	2	--	0	--	--	0	--	0	--	--	--	--
23	0	0	--	0	1	1	2	7	1	<1	0	1	0	<1	<1	0	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--
24	0	0	--	0	0	0	1	3	0	1	0	0	1	<1	1	0	--	<1	0	1	--	0	--	--	0	--	0	--	--	--	--
25	0	0	--	0	0	0	0	0	0	0	0	0	0	0	<1	0	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--
Total	2,396	2,126	--	1,289	940	635	490	1,104	682	392	492	475	301	232	226	198	--	253	240	292	--	110	--	--	67	--	112	--	508	--	663

Table 10. -- Effect of changing post-processing parameters on estimated walleye pollock abundance and biomass observed during the winter 2018 acoustic-trawl survey in the Bogoslof Island area.

Alternative Analysis		% Change relative to the primary analysis	
		Abundance	Biomass
1)	Did not assume 50:50 sex ratio	-0.08	0.26
2)	Excluded fish in post-spawning condition from length-weight computations	-	8.22

Table 11.--Percent female walleye pollock in spawning and post-spawning maturity condition by regions during Bogoslof survey years 1988-2018. Percentages greater than 50% are outlined, and n = total number of female pollock

		% pollock females spawning and post-spawning by region*					
		Samalga		Umnak		Unalaska	
Year	Date	%	n	%	n	%	n
1988	12-26 Feb	26.8	183	20.0	744	10.7	326
	27 Feb - 1 Mar	56.7	1440				
	2-3 Mar	60.4	48	71.7	530		
1989	6-7 Feb	0.5	200	0.0	50		
	23-25 Feb	29.4	51	7.3	55		
	1-7 Mar	86.5	133	88.7	97	10.0	50
1991	24-27 Feb	9.2	163	7.5	212		
	1-3 Mar	36.4	118	20.9	67		
	8-10 Mar	59.1	127	71.2	59		
	15 Mar					97.7	44
1992	29 Feb - 8 Mar	1.0	101	0.8	491	2.4	41
1993	27 Feb - 5 Mar	5.0	160	2.6	470	0.0	98
	12 Mar			67.0	97		
1994	27 Feb - 9 Mar	14.7	170	6.3	816	0.0	64
1995	26 Feb - 4 Mar	24.4	127	12.1	141	12.0	117
	5-8 Mar	6.5	169	24.5	94		
1996	27 Feb - 8 Mar	3.0	368	1.8	220	0.0	100
1997	1-8 Mar	14.7	224	4.0	125	4.3	69
	9-10 Mar	30.0	30	37.0	100	18.2	99
1998	2-9 Mar	4.8	294	13.6	199	2.4	85
2000	2-12 Mar	0.9	218	1.7	118	4.2	24
2001	5-11 Mar	2.3	350	0.9	110		
2002	5-8 Mar	2.0	358	23.0	148		
2003	9-13 Mar	8.7	69	15.3	111		
2005	7-13 Mar	3.6	225	39.0	349		
2006	4-9 Mar	6.7	357	59.8	214		
2007	1-10 Mar	21.4	313	26.5	215		
2009	7-13 Mar	0.8	119	4.8	105		
2012	7-15 Mar	5.2	115	9.6	94		
2014	7-11 Mar	7.7	91	60.5	76		
2016	4-8 Mar	83.9	285	71.4	273		
2018	3-7 Mar			81.6	223		

*Regions defined:
Samalga: west of 168° 30' W, and south of 55° N.
Umnak: between 168° 30' W and 167° W, and south of 55° N.
Unalaska: between 167° W and 166° W, and south of 55° N.

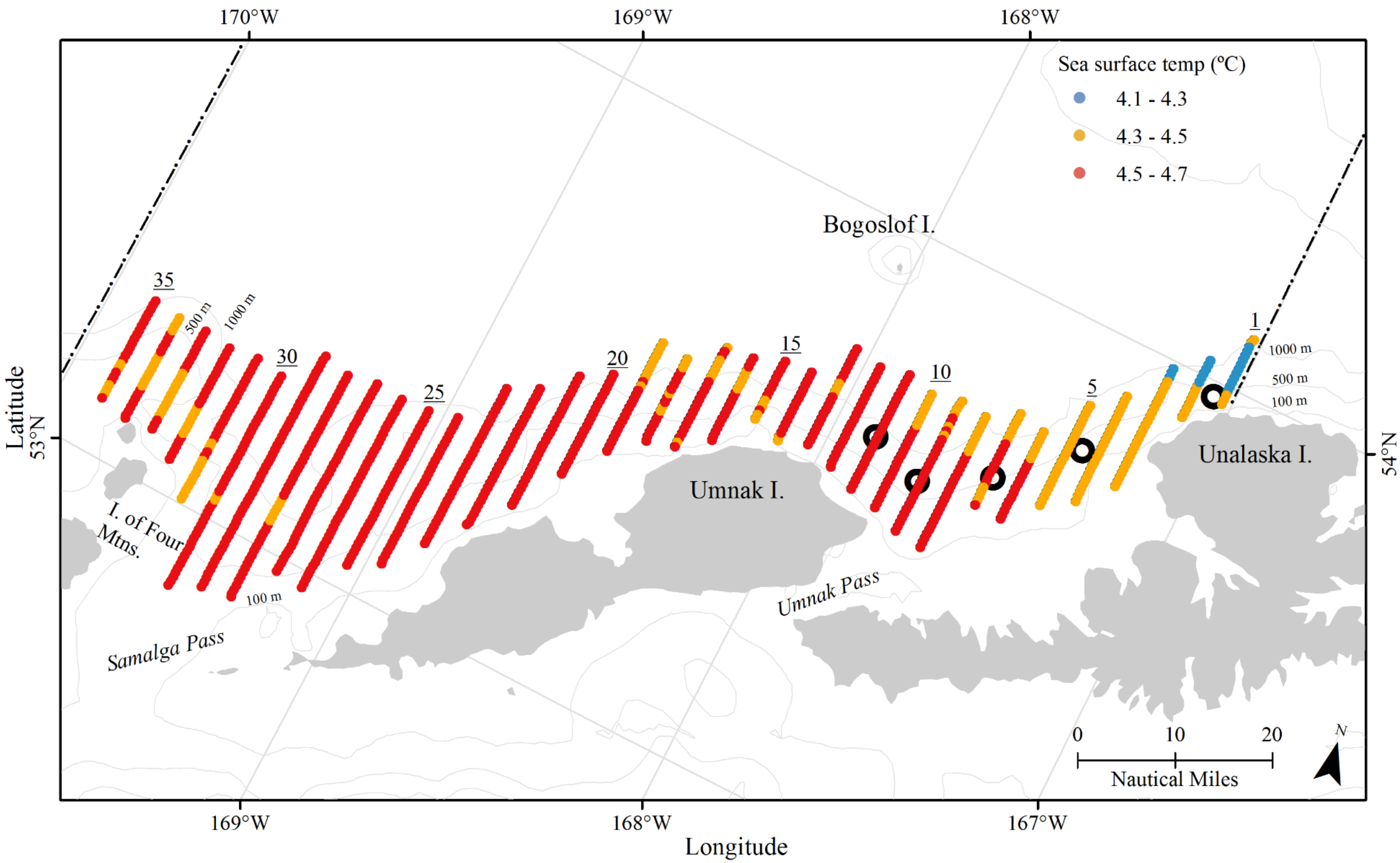

Figure 1.-- Surface water temperatures (°C) during the winter 2018 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island. Temperatures were recorded at 5-second intervals and averaged within 0.5-nmi intervals. Transect numbers are underlined, trawl haul locations are indicated by circles, and the Central Bering Sea Specific area is indicated by dotted lines.

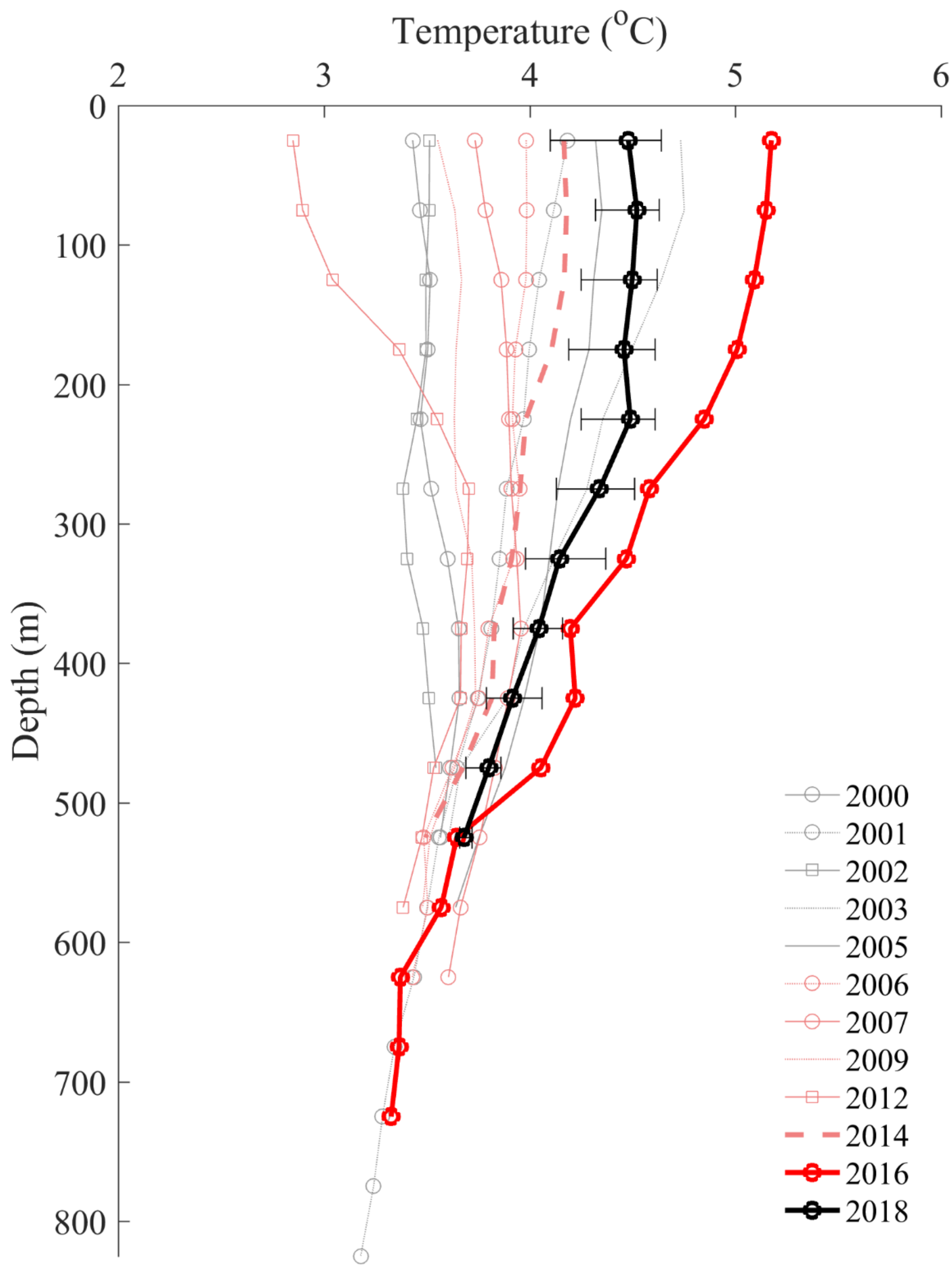

Figure 2. -- Average temperature (ºC) by 50-m depth intervals observed during hauls from the winter 2000-2003, 2005-2007, 2009, 2012, 2014, 2016, and 2018 acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. The horizontal bars represent temperature ranges observed during the 2018 survey. Note: Temperature data from the 2003 survey were collected from only three locations and temperature data from the 2018 survey were collected from only five locations.

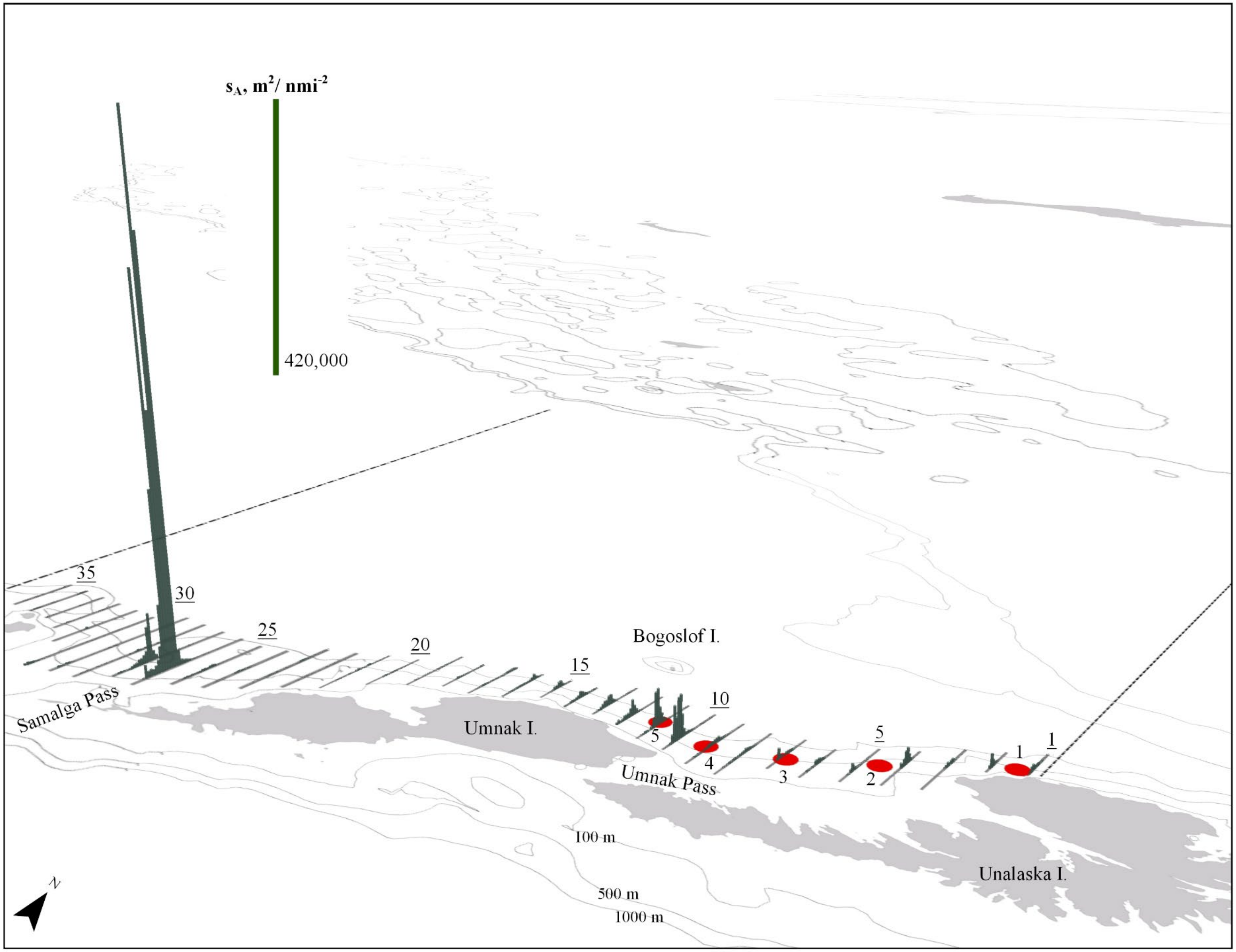

Figure 3. -- Undifferentiated 38 kHz backscatter (vertical bars, s_A, m^2/nmi^2) measured along transects during the winter 2018 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island. Transect numbers are underlined, trawl haul locations are indicated by red dots, and the Central Bering Sea Specific Area is indicated between the two dash-dotted lines.

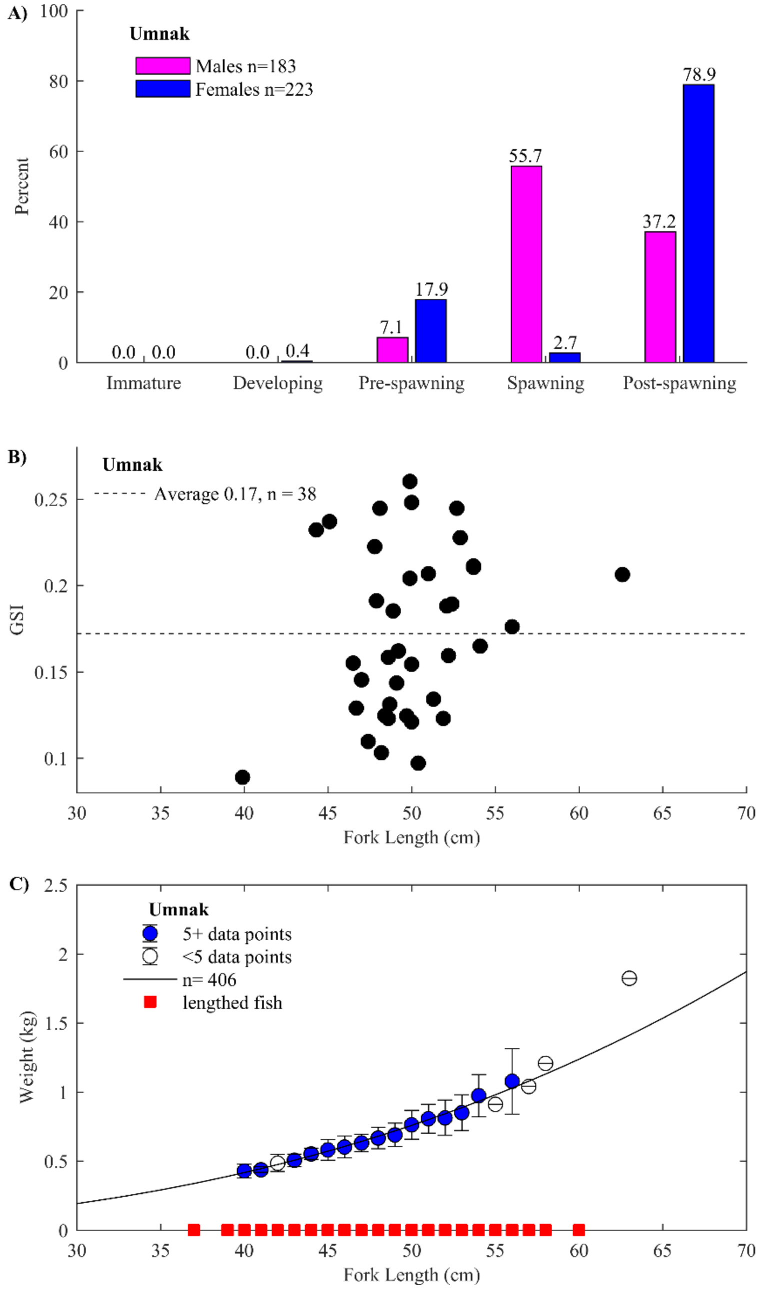

Figure 4. -- A) Walleye pollock maturity stages by sex, with percentages annotated for male and female maturity stages (random and non-random fish), B) gonado-somatic index (GSI) for pre-spawning females as a function of fork length, with mean GSI indicated by dashed horizontal line, and C) observed mean weight-at-length for random and non-random fish, with fitted regression line for combined sexes. Black hollow circles indicate cases where fewer than five fish were measured and filled circles indicate cases where more than 5 fish were measured; vertical bars indicate +/- one standard deviation. Red squares indicate random fish lengths. Note that samples are exclusively from the Umnak region (no trawling was conducted in the Samalga region).

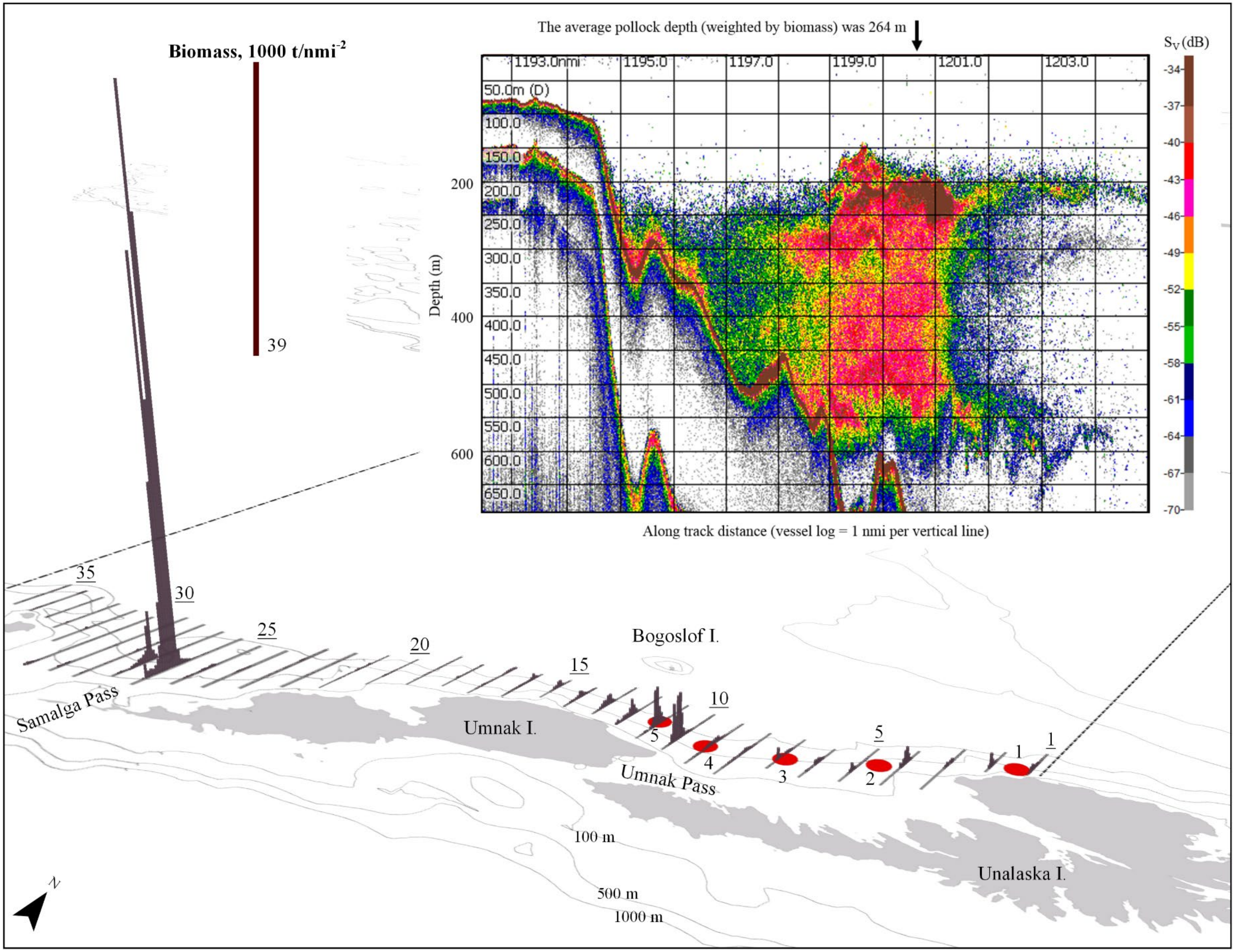

Figure 5. -- Transects, haul locations, and walleye pollock biomass per unit area (1000 t/nmi^2) observed along transects during the winter 2018 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island. Transect numbers are underlined, trawl haul locations are indicated by red circles, and the Central Bering Sea Specific area is indicated between the two dash-dotted lines. The Umnak stratum includes transects 1-15, and the Samalga stratum includes transects 16-36. Inset echogram depicts pollock backscatter measured along Transect 26.

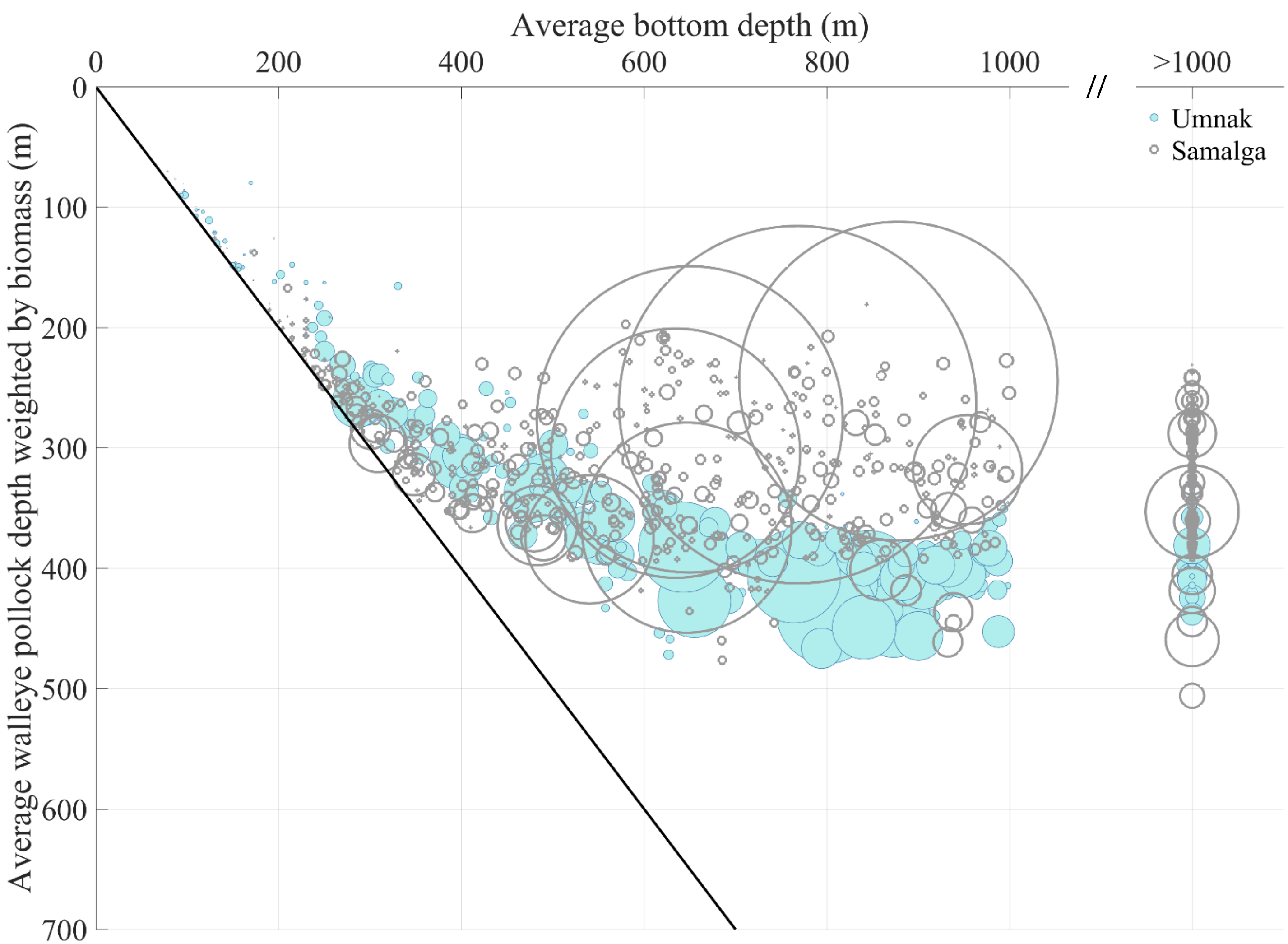

Figure 6. -- Average walleye pollock depth (weighted by biomass) versus bottom depth (m), per 0.5 nmi interval for the Umnak and Samalga strata during the winter 2018 acoustic-trawl survey of walleye pollock in the Bogoslof Island area. Bubble size was scaled to the maximum biomass/0.5 nmi interval (Samalga region 117.4 thousand t/0.5 nmi). The diagonal line indicates where the average pollock depth equals bottom depth. Note that bottom depth measurements were limited to 1,000 m.

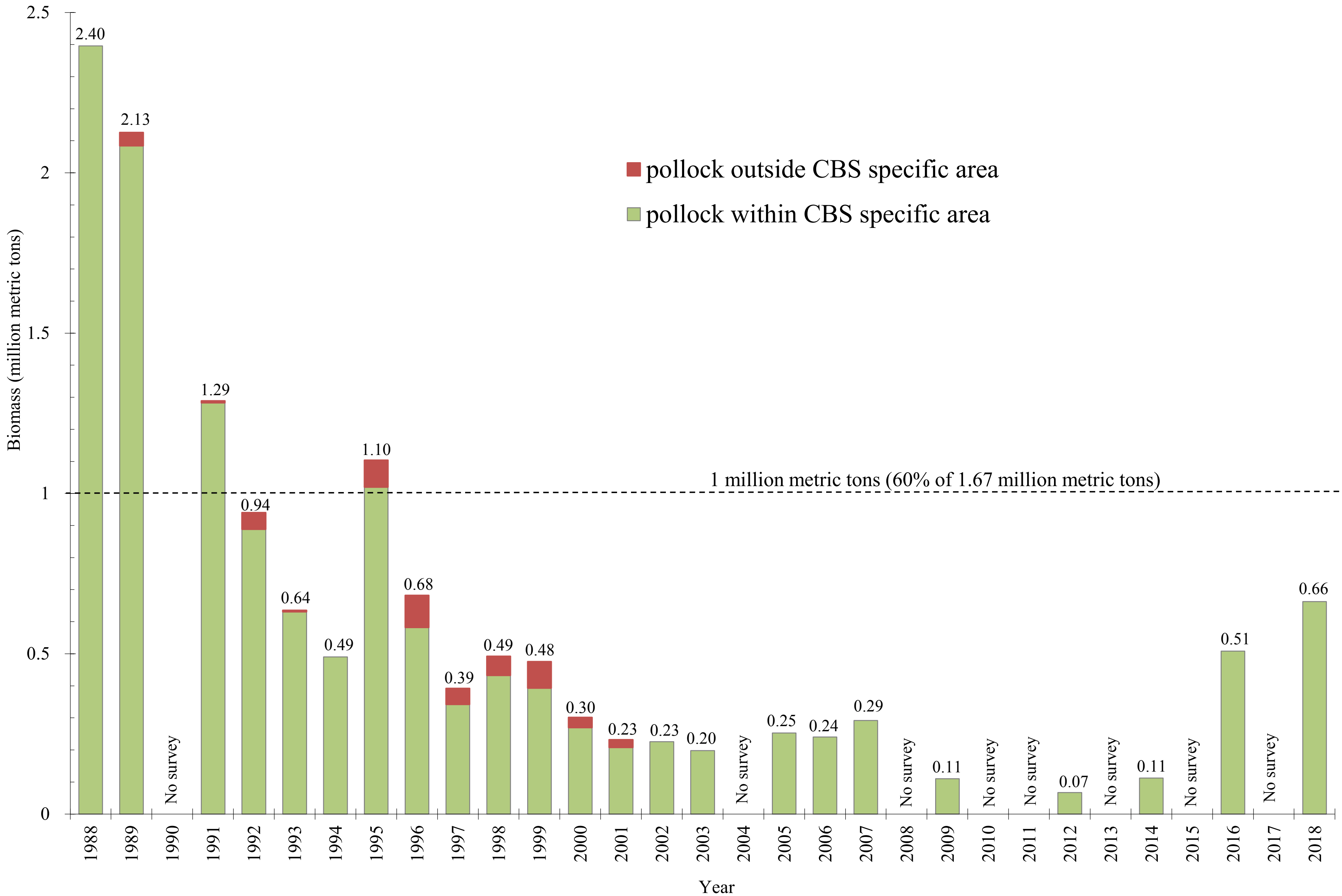

Figure 7.--Biomass estimates for the winter acoustic-trawl surveys for walleye pollock in the Bogoslof Island area, within and outside the Central Bering Sea (CBS) specific area, 1988-2018. The United States conducted all but the 1999 survey, which was conducted by Japan. There were no surveys in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017. Total pollock biomass (million metric tons) for each survey year is indicated on top of each bar. Pollock within the CBS specific area must reach 1 million metric tons before targeted pollock fishing can reconsidered in the Aleutian Basin.

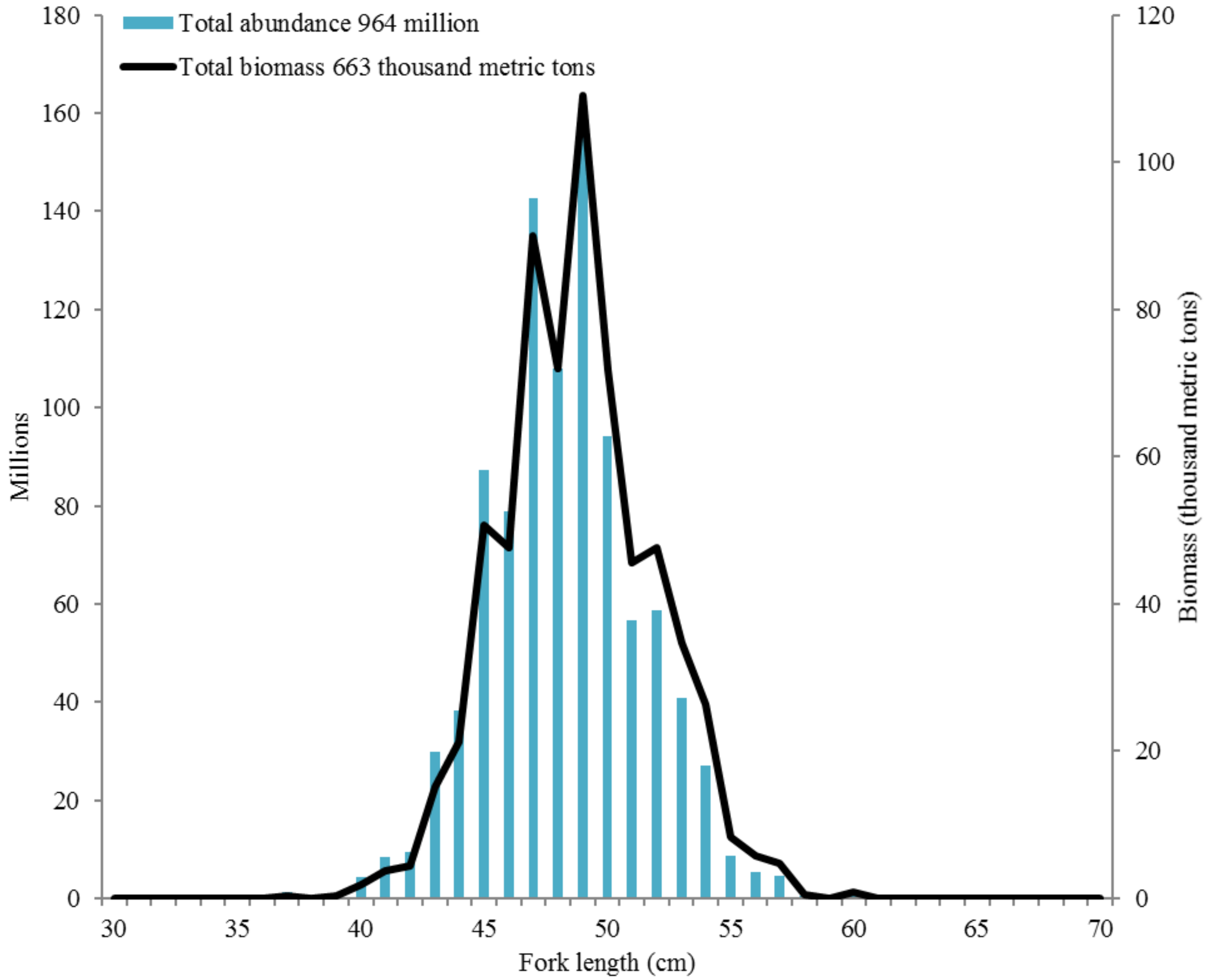

Figure 8. -- Numbers-at-length and biomass at length estimates from the winter 2018 acoustic-trawl survey of walleye pollock in the Bogoslof Island area.

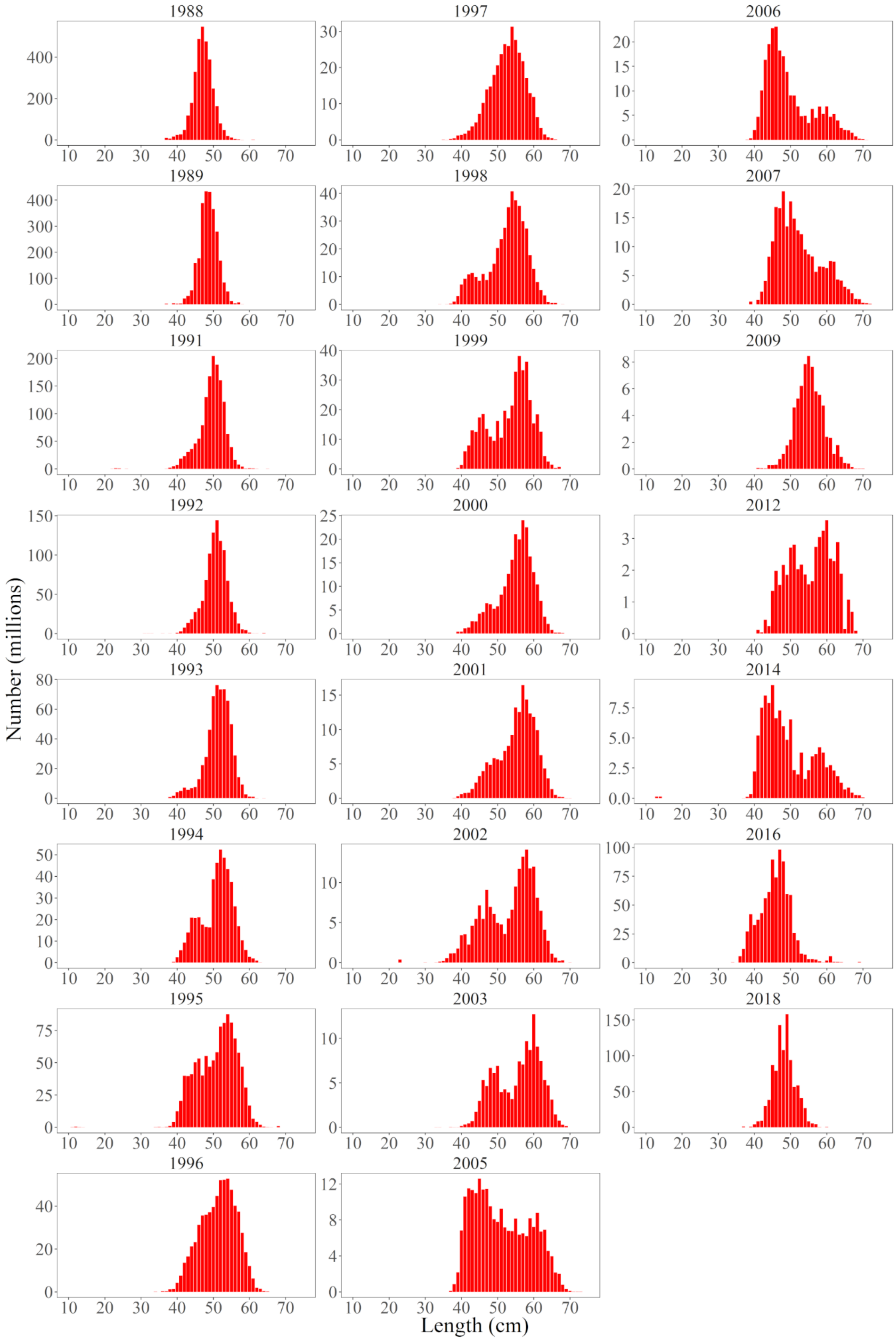

Figure 9. -- Numbers-at-length estimates (millions) from winter acoustic-trawl surveys of spawning pollock near Bogoslof Island. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017. The 1999 survey was conducted by Japan. Note: Y-axis scales differ.

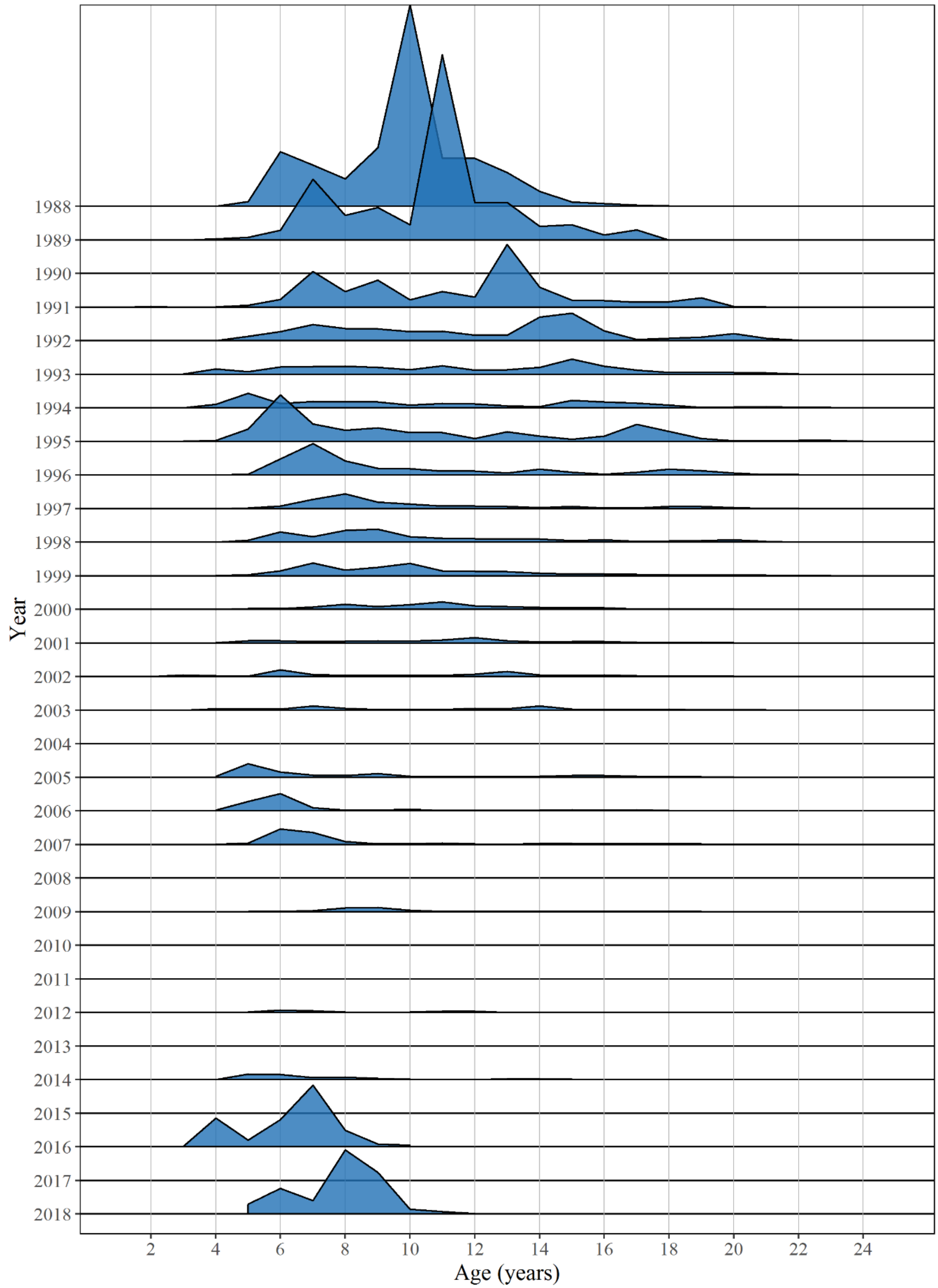

Figure 10. -- Numbers-at-age estimates (millions) from acoustic-trawl surveys of pollock near Bogoslof Island. Ages were scaled to the maximum number-at-age observed (1988 survey: 1,200 million fish at age 10). No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, 2015, or 2017.

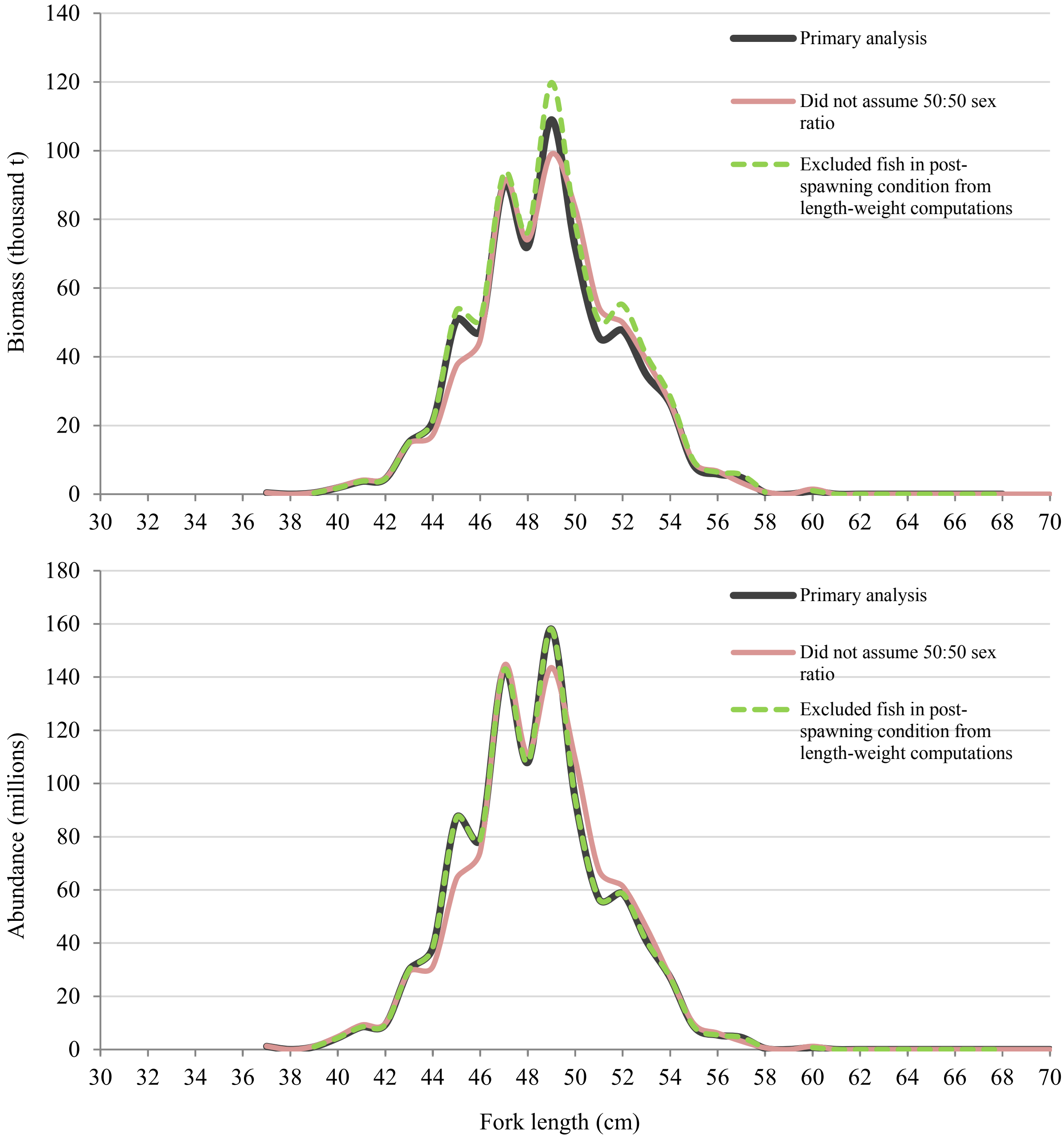

Figure 11. -- Estimated pollock biomass (thousand t) and numbers (millions) at length comparing results from the 2018 primary analysis with results from the sensitivity analysis.