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Results of the March 2016 Acoustic-Trawl Survey
of Walleye Pollock (*Gadus chalcogrammus*)
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by Denise McKelvey and Nathan Lauffenburger

August 2017

ABSTRACT

Scientists from the Alaska Fisheries Science Center conducted an acoustic-trawl survey in early March 2016 to estimate the abundance of pre-spawning walleye pollock (*Gadus chalcogrammus*) in the southeastern Aleutian Basin near Bogoslof Island. This report summarizes the observed pollock distribution and biological information, and provides an abundance estimate used for stock assessment. The estimated abundance for pollock in 2016 was 866 million fish weighing 507 thousand tons, which is a 665% increase in abundance and a 352% increase in biomass from the 2014 survey estimates. The pollock population was dominated by younger fish; 91% were less than 51 cm and 97% were less than 9 years of age. Most of the fish were from the 2009 year class, which was not a strong year class in the eastern Bering Sea or the Gulf of Alaska. Second in importance were fish from the 2012 year class, which was a strong year class in the eastern Bering Sea and the Gulf of Alaska.

CONTENTS

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 for the Aleutian Basin pollock stock[1]. This report summarizes observed pollock distribution and biological information from the winter 2016 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 4 and 8 March 2016 (Cruise DY2016-03) 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).

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[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 a Simrad EK60 scientific echosounding system (Simrad 2008, Bodholt and Solli 1992). Five, split-beam transducers (18-, 38-, 70-, 120-, and 200-kHz) were mounted on the bottom of the vessel's retractable centerboard, which 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.

Two standard sphere acoustic system calibrations were conducted to measure acoustic system performance. The first calibration was conducted prior to the start of cruise DY2016-02 and the second occurred 37 days later, during the middle of cruise DY2016-04. The vessel dynamic positioning system was used to maintain the vessel location during calibrations. A tungsten carbide sphere (38.1 mm diameter) suspended below the centerboard-mounted transducers was used to calibrate the 38-, 70-, 120-, and 200-kHz systems. The tungsten carbide sphere was then replaced with a 64 mm diameter copper sphere to calibrate the 18-kHz system. A two-stage calibration approach was followed for each frequency. On-axis sensitivity (i.e., transducer gain and 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 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]. 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 targeting backscatter shallower than 500 m depth 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 for individual fish length measurements following procedures described in Williams et al. (2010b).

Midwater backscatter was also sampled with a poly Nor'eastern (PNE) bottom trawl, which is a 4-panel high-opening trawl 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.

Both trawls were monitored during fishing for trawl depth and vertical mouth openings. The AWT was monitored using a Simrad FS70 third-wire net netsonde or a Furuno CN24 acoustic-link netsonde attached to the trawl headrope. The vertical net opening ranged from 21.5 to 40 m and averaged 28.1 m while fishing. The PNE was monitored using the Furuno (CN-24) attached to the headrope. The PNE vertical net opening was 6 m for the single deployment.

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. Surface temperature (± 0.2°C) was measured continuously using a Furuno T-2000 external probe attached to the hull, located mid-ship, approximately 1.4 m below the surface of the water. Other environmental measurements (e.g., surface salinity) were also recorded using the ship's sensors interfaced with the ship's Scientific Computing System (SCS). Surface temperatures were averaged to 0.5 nautical mile (nmi) intervals for analysis.

Survey Design

The original survey was designed with 35 north-south parallel transects that were spaced 3 nmi apart spanning from Unalaska Island at about 167°W longitude to the Islands of Four Mountains near 170°W. 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 $\leq$ 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 transect 1 start location 1.2 nmi west of the 2003 start location. Because of extensive fish sign in the western survey area, an additional transect was added to the original survey trackline for a total of 36 transects. Survey operations were conducted from east to west 24 hours/day. The survey covered 1,400 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 fish 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. Gonad maturity was determined by visual inspection and categorized as immature, developing, pre-spawning, spawning, or post-spawning[3]. Gonado-somatic-indices (GSI) were computed as ovary-weight/body-weight for

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

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). Stomachs were sampled from all fish species in support of a winter-fish predator-prey study (Troy.Buckley@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. 6.1.70.28466). 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 trawl 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 (Honkalehto and Williamson 1995). During these historical analyses, separate 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 2016 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. Weight-at-length measurements from individual pollock were used to estimate mean weight-at-length for each 1-cm length interval when there were five or more pollock for that 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 $fish^{-1}$). 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 in centimeters. Further details on how numbers and biomass were estimated are described in Honkalehto et al. (2008b).

Pollock otoliths were collected from all areas for age determination by the AFSC Age and Growth Program researchers. An age-length key was applied to the population numbers at length to estimated numbers at age as detailed in (Jones et al. 2017, Appendix 1). For lengths where no otolith specimens were collected, the proportion-at-age was derived using a Gaussian model approach fitting the likely age to length from historical data.

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.

<u>Sensitivity Analysis</u>

A sensitivity analysis examined the effect of three specific changes to the primary analysis of pollock 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) Backscatter in the primary analysis was converted to estimates of fish abundance using the average length-composition derived from hauls grouped into geographical strata. The alternative analysis converted backscatter in each 0.5 nmi interval using length-composition data from the nearest haul.

3) 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

Calibration

Pre- and post-survey calibration measurements of gain and transducer beam pattern were similar. That is, the difference in integration gain (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 2016 survey were warmer than temperatures measured in 2014. In 2016, mean surface-temperatures ranged from 4.7 º to 5.6 ºC (Fig. 1), whereas in 2014, mean surface-temperatures ranged from 3.5 º to 5.0 ºC. The coolest surface-temperatures measured in 2016 were observed in the easternmost transects, which was consistent with 2014. Water temperatures at trawl sites were warmer throughout the water column compared to 2014, especially in the upper 200 m (Fig. 2). Temperatures between 300 and 600 m, where most of the pollock were distributed in the Bogoslof area in 2016, averaged between 3.6 º and 4.5 ºC compared to 3.5 º and 3.9 °C in 2014 (Fig. 2). When compared to temperature profiles observed from previous Bogoslof surveys, the profile in 2016 was the warmest in the time series between 2000 and 2016.

Acoustic Backscatter

Acoustic backscatter at 38 kHz was observed along all 36 transect lines within the Central Bering Sea Specific Area (Fig. 3). Overall, the densest backscatter was distributed farther north as compared to backscatter observed during the 2014 survey. The survey area was divided into two regions, Umnak (transects 1-15) and Samalga (transects 16-36). Trawl hauls were conducted to sample acoustic backscatter throughout the survey area (Fig. 3).

Trawl Samples

Biological data and specimens were collected from 11 trawl sites in the survey region (Tables 2-4, Fig. 3). By weight, pollock dominated the trawl catches and represented 98% of the total catch for the 10 AWT hauls and 97% of the catch for the single PNE haul (Table 3). By number, pollock accounted for 59% of the total catch from the AWT hauls and was followed next by myctophids (i.e., lanternfishes; 30%). Pollock also dominated the PNE catch by number (33%) and was followed by jellyfish (25%; Table 3).

Pollock length measurements (3,144, Table 4) collected from hauls 1-11 were used to convert the acoustic data to estimates of biomass and numbers at length. Historical surveys have shown that pollock length compositions can vary across the survey area. For example, in 2014, the length compositions from the Umnak area were more similar to each other than the length compositions from the Samalga area so each area had a length stratum (McKelvey and Stienessen 2015). For the 2016 survey, all hauls were reviewed for regional differences, particularly between the Umnak region (hauls 1-5) and the Samalga region (6-11). Because the length compositions from both regions were similar in 2016, lengths from all hauls were grouped into one length stratum (Fig. 4). Lengths ranged from 34 to 69 cm FL, with similar modes at 45 and 47 cm, and a smaller mode at 39 cm.

The female pollock maturity-compositions were similar in the Umnak and the Samalga regions, where 7% of the females were in the pre-spawning stage and > 60% were already post-spawning (Fig. 5a). The low percentage of pre-spawning females in the Samalga area was a marked change from the 2014 survey when 89% of the female fish were in pre-spawning condition.

The average gonado-somatic-index (GSI) for pre-spawning mature female pollock was computed for each area and for both areas combined. The average GSI was 0.10 for Umnak and 0.08 for Samalga (see Fig. 5b for individual measurements). The GSI estimated for combined strata was 0.09, which was lower than the 0.14 observed in 2014.

Pollock mean weight-at-length were computed for most of the pollock lengths encountered (Fig. 5c). Because of the small sample size for the smallest and largest pollock encountered, mean weight-at-length for the 1-cm length-intervals at 34 cm, and 55-69 cm were estimated by using weight (g) = $0.000069 \times \mathrm{FL\ (cm)}^{2.36}$.

Distribution and Abundance

Pollock biomass was distributed on all transects with localized concentrations in the Umnak and Samalga areas (Fig. 6). The densest concentrations were located on transects 6-11, within the Umnak area, which represented 34% of the estimated pollock biomass, and transects 26-28 in the Samalga area, representing 40% of the estimated biomass. The most extensive pollock layer was measured on transect 27. This layer extended horizontally for about 10 nmi with a vertical extent from 350 m down to 800 m below the surface (Fig. 7). The pollock biomass-weighted depth estimate for this transect was 531 m. Pollock biomass-weighted depth estimates ranged from about 200 and 650 m for the entire surveyed area (Fig. 8). Fish generally stayed close to the bottom until bottom depths reached about 500 m. Pollock formed pelagic layers around 450-600 m over deeper bottom depths (> 600 m). The pollock mean biomass-weighted depth estimate was 425 m for the Umnak area and 403 m for the Samalga area.

The pollock abundance estimate in 2016 was 866 million fish weighing 507 thousand metric tons (t) for the entire surveyed area (Tables 5-7; Fig. 9). The estimates represent an increase of 665% in abundance and 352% in biomass from the 2014 survey estimates (McKelvey and Stienessen 2015). Based on the 1D geostatistical analysis, the relative estimation error for the biomass estimate was 11.0% (Table 5).

The overall size composition for pollock was essentially unimodal at 45-48 cm FL (Figs. 10-11), with a minor mode at 39 cm. Ninety-one percent of the 2016 population was 50 cm or smaller. Fish less than 50 cm were observed in both the Umnak and Samalga areas (Fig.5).

The estimated age composition ranged from 3 to 12 years of age in 2016 (Tables 8-9; Fig. 12). Forty-two percent of the overall pollock abundance were 7-year-old fish (2009 year classes), 19%

were 6-year-old fish (2010 year class), and nearly 20% were 4-year-old fish (2012 year class). The relatively large numbers of 4-year-old fish and the minor appearance of older fish were unusual features for the Bogoslof time series (Tables 8-9; Fig. 12).

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 weighting by the sex ratio (1st sensitivity analysis). A slight reduction (2%) was observed between abundance estimates and a negligible effect (< 1%) was observed between biomass estimates, when converting backscatter using the nearest haul's length-composition (2nd sensitivity analysis). The largest positive effect (6%) occurred between biomass estimates from the 3rd sensitivity analysis, which excluded fish in post-spawning condition from the length-weight relationship. The effect was most apparent in fish 47-50 cm FL (Fig. 13).

DISCUSSION

The estimated abundance of 866 million pollock in the Bogoslof region from the 2016 acoustic-trawl survey was greater than estimates observed over the last 14 surveys (i.e., 1996; Table 6). The size composition for pollock observed during the 2016 survey was primarily composed of fish less than 50 cm, with few larger fish (Fig. 11). This resulted in an overall average-length of 45.7 cm, which is the smallest mean length ever computed for the Bogoslof time series (Table 6). The 7-year-old pollock (2009 year class) dominated the 2016 survey estimate (42% by number), and was the largest abundance estimate for 7-year-old pollock historically observed (Table 8). The 2009 year class was also a strong component of the 2014 Bogoslof survey abundance as 5-year-old fish. It continues to be notable that the 2009 year class was not an above average year class in the eastern Bering Sea (EBS) or the Gulf of Alaska (GOA) pollock stock (Dorn et al. 2016, Ianelli et al. 2016b). Second in importance (20% by number) in 2016 were 4-year-old fish. The abundance estimate for the 2012 year class was the largest abundance estimate for 4-year-old pollock historically observed (Table 8, Fig. 12). These younger fish ranged from 36 to 47 cm in the Bogoslof region, which was nearly the same size group observed in the EBS and GOA during the 2016 summer and winter AT surveys (Honkalehto et al. in prep., Stienessen et al. 2017). Unlike the 2009 year class, the 2012 year class has been historically strong in both the EBS and GOA (Dorn et al. 2016, Ianelli et al. 2016b).

As in historical Bogoslof stock assessments, the 2016 pollock population length composition was computed for the primary analysis by assuming that the population's sex ratio was 50:50. However, during the 2016 survey, haul 8 (410 m depth; Table 2) and haul 11 (720 m) sampled a multi-layered aggregation yielding > 90% males in both length samples, which was contrary to the expectation of female fish dominating at shallow depths and males dominating at deeper depths. Unfortunately, there were no other opportunities during the 2016 survey to conduct paired hauls at a single location to make such comparisons. More extensive paired trawl-samples in multi-layered aggregations in the future would help determine whether vertical stratification of pollock by sex persists. The sensitivity analysis results indicate negligible differences if the 50:50 sex-ratio assumption was dropped (Table 10, Fig. 13). This is likely due to the prevalence of a single length mode in all areas and little difference in the length distribution between male and female pollock.

The percentage of fish in spawning and post-spawning condition in the Umnak and the Samalga areas was high (>70%), but not unprecedented in this survey time series (Table 11). Since 1988, the Bogoslof survey has generally occurred in late February – early March to survey the pre-spawning pollock aggregations in the southeast Aleutian region. A large percentage of fish in these late-stage spawning conditions have been observed in some areas and years during the survey time series. This can potentially confound interpretation of the 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. For example, the sensitivity analysis results indicated an increase in biomass (6%) 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).

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Itinerary

Alaska Standard Time

1 March	Embark scientists in Kodiak, AK
3-4 March	Transit towards southeast Aleutian Basin, Alaska
4-8 March	Acoustic-trawl survey of the Bogoslof Island area
13 March	Disembark scientists in Kodiak, Alaska

Scientific Personnel

Name	Position	Organization
Denise McKelvey	Chief Scientist	AFSC
Darin Jones	Fishery Biologist	AFSC
Scott Furnish	Info. Tech. Specialist	AFSC
Nathan Lauffenburger	Fishery Biologist	AFSC
Chris Bassett	Oc. Acoustics Eng.	AFSC
Sandi Neidetcher	Fishery Biologist	AFSC
Mathew Phillips	Fishery Biologist	AFSC-AIS
Kimberly Sawyer	Fishery Biologist	AFSC-UW

AFSC	Alaska Fisheries Science Center, Seattle WA
AIS	AIS Scientific and Environmental Services, Inc., Marion, MA
UW	University of Washington

Table 1. -- Simrad ER60 38 kHz acoustic system description and settings used during the winter 2016 acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. Also presented are results from standard sphere acoustic system calibrations conducted in association with the survey, and final values used to calculate biomass and abundance data.

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

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

Table 2.-- Trawl station and catch data summary from the winter 2016 acoustic-trawl survey of walleye pollock in the Bogoslof Island area. The Aleutian Wing trawl was used for all samples except for haul 2, when the poly Nor' eastern trawl was used.

Haul number	Stratum	Date (GMT)	Time (GMT)	Duration (minutes)	Start position Latitude (N)	Start position Longitude (W)	Depth (m) Footrope	Depth (m) Bottom	Water temp. (^oC) Headrope	Water temp. (^oC) Surface	Catch Pollock (kg)	Catch Pollock Number	Catch Other (kg)	Camtrawl deployment
1	Umnak	5-Mar-16	6:09	5	53° 58.59'	167° 3.31'	442	589	4.3	4.9	299	512	8.6	Y
2	Umnak	5-Mar-16	14:35	24	53° 49.61'	167° 17.62'	344	473	4.4	5.0	10	17	0.4	
3	Umnak	5-Mar-16	20:13	3	53° 42.97'	167° 28.53'	442	481	4.3	5.1	1,284	2,258	5.7	Y
4	Umnak	6-Mar-16	3:44	2	53° 36.41'	167° 38.21'	456	655	4.2	5.1	2,979	4,809	20.6	
5	Umnak	6-Mar-16	13:34	7	53° 37.34'	168° 8.84'	367	714	4.3	5.2	84	160	11	Y
6	Samalga	6-Mar-16	23:48	4	53° 29.81'	168° 38.99'	492	795	4.2	5.3	352	591	13.6	Y
7	Samalga	7-Mar-16	8:07	15	53° 16.75'	168° 49.04'	365	451	4.4	5.3	104	180	8.3	Y
8	Samalga	7-Mar-16	19:36	4	53° 10.42'	169° 14.11'	410	--	4.1	5.2	612	1,112	8.4	Y
9	Samalga	8-Mar-16	8:23	80	53° 9.49'	169° 23.72'	665	1262	3.4	5.1	83	123	65.7	
10	Samalga	8-Mar-16	21:15	35	53° 8.29'	169° 59.09'	434	553	3.9	5.4	42	68	15.8	Y
11	Samalga	11-Mar-16	4:50	15	53° 8.91'	169° 14.59'	720	1178	3.4	5.4	1,905	2,933	15.5	

Table 3.--Catch by species, including numbers of length and weight measurements, taken from individuals captured in 11 trawl hauls during the winter 2016 acoustic-trawl survey of walleye pollock in the Bogoslof Island area. Data are separated into catch from 10 Aleutian wing trawl samples (A) and one poly Nor'eastern trawl sample (B).

A. Aleutian Wing Trawl

Species name	Scientific name	Catch				Individual measurements	
		Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	7745.9	97.9	12745	58.7	3469	1135
lanternfish	Myctophidae (family)	53.1	0.7	5327	24.5	295	94
sea nettle	*Chrysaora melanaster*	22.2	0.3	30	0.1	21	18
northern smoothtongue	*Leuroglossus schmidti*	17.7	0.2	1409	6.5	100	57
smooth lumpsucker	*Aptocyclus ventricosus*	16.0	0.2	8	<0.1	8	5
hydromedusa	Aequoreidae (family)	9.5	0.1	49	0.2	1	1
lanternfish	*Stenobrachius* (genus)	7.0	0.1	311	1.4	45	17
northern lampfish	*Stenobrachius leucopsarus*	6.6	0.1	605	2.8	35	10
chinook salmon	*Oncorhynchus tshawytscha*	5.8	0.1	4	0.0	4	4
squid	*Gonatopsis* (genus)	3.9	<0.1	149	0.7	63	15
grenadier	Macrouridae (family)	2.8	<0.1	1	<0.1	1	1
robust blacksmelt	*Bathylagus milleri*	2.3	<0.1	129	0.6	18	11
brokenline lampfish	*Lampanyctus jordani*	2.2	<0.1	89	0.4	12	12
Pacific ocean perch	*Sebastes alutus*	2.0	<0.1	3	<0.1	1	1
lamprey	Petromyzontidae (family)	2.0	<0.1	5	<0.1	3	2
lumpsucker	Cyclopteridae (family)	1.6	<0.1	1	<0.1	1	1
viperfish	Chauliodontidae (family)	1.2	<0.1	25	0.1	6	6
shrimp	Decapoda (order)	1.2	<0.1	136	0.6	70	23
northern rock sole	*Lepidopsetta polyxystra*	1.1	<0.1	1	<0.1	1	1
magistrate armhook squid	*Berryteuthis magister*	1.0	<0.1	11	<0.1	9	9
moon jelly	*Aurelia labiata*	1.0	<0.1	6	<0.1	4	4
blackmouth eelpout	*Lycodapus fierasfer*	0.9	<0.1	283	1.3	90	24
Gonatus squid	Gonatidae (family)	0.8	<0.1	29	0.1	10	10
Atolla jellyfish	*Atolla* (genus)	0.6	<0.1	43	0.2	17	17
arrowtooth flounder	*Atheresthes stomias*	0.5	<0.1	5	<0.1	2	1
berry armhook squid	*Gonatus berryi*	0.4	<0.1	2	<0.1	2	2
barracudina	Paralepididae (family)	0.3	<0.1	9	<0.1	3	3
dreamer	Oneirodidae (family)	0.2	<0.1	1	<0.1	1	1
Boreopacific armhook squid	*Gonatopsis borealis*	0.2	<0.1	3	<0.1	3	3
giant grenadier	*Albatrossia pectoralis*	0.2	<0.1	1	<0.1	1	1
lanternfish	*Diaphus* (genus)	0.2	<0.1	14	0.1	2	2
helmet jellyfish	*Periphylla periphylla*	0.1	<0.1	106	0.5	38	20
Pacific glass shrimp	*Pasiphaea pacifica*	0.1	<0.1	67	0.3	21	4
eulachon	*Thaleichthys pacificus*	0.1	<0.1	8	<0.1	2	1
giant red mysid	*Gnathophausia ingens*	0.1	<0.1	68	0.3	17	6
prowfish	*Zaprora silenus*	0.1	<0.1	1	<0.1	1	1
shrimp	Pasiphaeidae (family)	0.1	<0.1	5	<0.1	5	5
California headlightfish	*Diaphus theta*	0.1	<0.1	7	<0.1	1	1
fried egg jellyfish	*Phacellophora camtschatica*	0.1	<0.1	1	<0.1	1	1
shrimp	*Notostomus* (genus)	<0.1	<0.1	1	<0.1	1	1
Pacific viperfish	*Chauliodus macouni*	<0.1	<0.1	1	<0.1	1	1
prickleback	Stichaeidae (family)	<0.1	<0.1	1	<0.1	1	-
snailfish	Liparidae (family)	<0.1	<0.1	4	<0.1	1	-
fish	Teleostei (infraclass)	<0.1	<0.1	1	<0.1	1	-
Total		7911.1		21704		4389	1532

B. poly Nor 'eastern trawl

Species name	Scientific name	Catch				Individual measurements	
		Weight (kg)	%	Number	%	Length	Weight
walleye pollock	*Gadus chalcogrammus*	10.0	96.6	17	33.3	17	17
moon jelly	*Aurelia labiata*	0.4	3.4	1	2.0	1	1
lanternfish	Myctophidae (family)	<0.1	0.2	8	15.7	3	3
jellyfish	Scyphozoa (class)	<0.1	0.2	12	23.5	12	1
blackmouth eelpout	*Lycodapus fierasfer*	<0.1	0.1	2	3.9	2	2
shrimp	Decapoda (order)	<0.1	0.1	6	11.8	6	4
smooth lumpsucker	*Aptocyclus ventricosus*	<0.1	0.1	1	2.0	1	1
flatfish larvae	Pleuronectiformes (family)	<0.1	<0.1	1	2.0	1	1
northern smoothtongue	*Leuroglossus schmidti*	<0.1	<0.1	3	5.9	3	3
Total		10.4		51		46	33

Table 4.--Numbers of walleye pollock measured and biological samples collected during the winter 2016 acoustic-trawl survey in the Bogoslof Island area.

				Walleye pollock					
Haul number	Random lengths	Lengths and weights	Maturities	Otoliths	Ovary weights*	Ovary preserved	Stomach preserved	Non-random**	Camtrawl lengths
1	258	126	126	63	1	6	2		52
2	-	17	17	17	1	9	9		-
3	277	110	110	70	1	8	10		105
4	387	118	34	34	1	5	9	6	-
5	-	160	160	41	14	13	10		29
6	357	97	97	30	-	4	5		36
7	80	100	100	41	1	5	5		12
8	338	107	107	24	2	7	11	16	59
9	-	122	122	70	1	6	16		-
10	-	68	68	67	5	11	10		11
11	333	89	89	21	5	9	10	16	-
Totals	2030	1114	1030	516	32	83	97	38	304

* From prespawning pollock

** Non-random length, weight, maturity, 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 2016.

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	0.507	1,400	11.0	0.507	11.0

*The relative error for 2012 was computed for the primary survey area represented by transects 1-35 (1,455 nmi^2).

Table 6.--Numbers-at-length estimates (millions), and average fork length (cm) 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, or 2015. The 1999 survey was conducted by the Japan Fisheries Agency.

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

Table 6. -- Continued.

Length (cm)	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007	2009	2012	2014	2016
42	48	23	23	7	7	9	40	14	3	11	8	1	1	2	<1	12	10	2	<1	<1	8	43
43	118	33	31	14	6	14	40	17	4	11	13	3	1	5	1	11	16	4	<1	<1	9	56
44	179	54	36	18	7	21	41	21	5	10	13	3	2	5	2	11	20	8	<1	<1	8	61
45	329	159	46	28	8	21	50	23	7	9	17	4	3	7	3	13	23	11	<1	1	9	89
46	488	177	55	32	13	21	53	31	10	11	19	5	4	5	5	11	23	17	<1	2	7	74
47	547	389	79	42	22	18	40	36	14	9	14	6	5	9	5	11	18	17	1	2	7	99
48	476	434	130	68	28	17	55	36	15	12	11	6	5	7	7	10	17	20	1	2	6	88
49	389	431	168	102	46	16	47	37	18	15	10	5	6	6	6	8	14	14	2	2	5	59
50	248	366	205	129	69	39	52	40	21	20	16	6	6	5	7	8	9	18	2	3	7	59
51	162	279	189	144	76	46	58	45	24	23	11	8	6	5	4	9	9	15	5	3	2	26
52	80	168	160	118	73	52	78	52	26	28	20	10	7	4	4	7	7	13	5	2	2	19
53	48	85	122	106	73	49	81	52	26	35	17	13	8	6	4	7	5	12	6	2	4	8
54	19	50	63	67	66	43	88	53	31	41	21	16	9	7	3	7	5	10	8	2	2	7
55	12	13	40	41	50	37	81	48	28	38	33	21	13	9	5	8	3	9	8	2	2	3
56	4	5	17	27	29	26	69	40	24	35	38	20	13	12	7	6	6	8	8	2	3	3
57	3	8	8	13	14	17	58	37	22	30	33	24	16	13	7	7	5	6	6	3	4	3
58	1	1	4	6	9	10	47	28	17	27	36	23	14	14	10	6	7	7	6	3	4	1
59	0	0	1	5	3	6	31	19	13	18	23	16	12	12	9	8	5	7	5	3	4	<1
60	0	0	1	1	1	3	17	12	12	13	15	13	12	12	13	7	7	6	2	4	3	2
61	2	0	1	<1	1	2	7	6	6	8	18	10	10	8	9	9	5	8	2	2	3	6
62	0	0	<1	<1	<1	1	4	2	3	5	13	7	6	6	7	7	5	7	1	2	2	<1
63	0	0	0	0	0	<1	2	1	1	3	4	4	4	4	5	7	4	4	2	3	2	<1
64	0	0	0	1	<1	0	1	<1	1	1	3	2	3	3	5	5	2	4	1	2	1	<1
65	0	0	<1	0	0	0	<1	<1	<1	1	1	1	1	1	3	4	2	3	<1	<1	<1	0
66	0	0	0	0	0	0	<1	0	<1	1	<1	<1	<1	1	1	2	2	3	<1	1	<1	0
67	0	0	0	0	0	0	0	0	0	0	1	<1	<1	<1	1	2	1	2	<1	1	<1	0
68	0	0	0	0	0	0	1	0	0	<1	0	<1	<1	<1	<1	1	1	1	<1	<1	<1	0
69	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1	<1	<1	1	<1	0	<1	<1
70	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	<1	<1	<1	<1	0	<1	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	<1	<1	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
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	0	<1	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	866
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

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, or 2015. 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
10	0	0	0	0	0	0	<1	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
12	0	0	0	0	0	0	<1	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
14	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0
15	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
17	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
19	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
21	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
23	0	0	<1	0	0	0	0	0	0	0	0	0	0	<1	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
25	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
27	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
29	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
31	0	0	0	<1	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
33	0	0	0	<1	0	0	0	0	0	0	0	0	0	<1	<1	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
35	0	0	0	0	0	0	<1	0	<1	0	0	0	0	<1	0	0	0	0	0	0	0	<1
36	0	0	0	<1	0	0	<1	<1	<1	<1	0	0	0	<1	0	0	0	0	0	0	0	2
37	3	1	<1	0	0	0	<1	<1	<1	<1	0	0	0	<1	<1	<1	0	0	0	0	<1	4
38	2	0	1	<1	<1	0	<1	<1	<1	<1	0	0	<1	1	<1	<1	<1	0	0	0	<1	11
39	6	1	2	0	1	<1	2	1	1	1	<1	<1	<1	1	<1	1	<1	<1	0	0	<1	17
40	11	1	3	<1	2	1	6	2	1	3	1	<1	<1	2	<1	3	1	0	0	0	1	14
41	13	2	8	1	2	3	10	4	1	4	6	1	<1	2	<1	5	2	<1	<1	<1	2	18

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
42	24	11	11	3	4	5	21	7	1	6	7	1	<1	1	<1	6	5	1	<1	<1	4	21
43	64	17	16	7	3	8	22	9	2	6	12	2	1	3	<1	6	9	2	<1	<1	5	28
44	105	30	20	10	4	13	25	13	3	6	12	2	2	4	1	6	12	5	<1	<1	5	32
45	207	94	28	16	5	14	33	15	5	6	16	3	2	5	2	8	15	7	<1	1	6	49
46	329	113	36	21	9	15	37	22	7	8	18	3	3	4	4	8	17	12	<1	1	5	43
47	395	268	57	29	17	14	30	26	11	7	14	5	4	7	4	9	14	13	1	1	5	59
48	367	323	101	52	22	14	45	29	12	10	11	5	4	6	6	8	15	17	1	2	5	56
49	321	346	141	84	40	14	40	32	16	13	11	5	5	6	6	7	13	13	2	2	4	40
50	218	315	187	116	64	36	48	36	20	19	18	5	6	5	7	7	9	18	2	3	6	42
51	152	258	186	140	76	46	57	43	24	23	12	8	6	5	4	9	10	16	5	3	2	19
52	80	166	171	124	78	56	82	54	29	29	23	11	8	4	5	8	7	15	6	2	2	15
53	51	90	140	120	83	55	90	57	30	39	20	15	9	6	5	8	6	15	8	3	4	7
54	21	57	78	82	79	52	104	62	38	49	25	19	11	8	4	9	6	13	11	2	2	6
55	14	16	53	53	64	48	102	59	36	47	39	27	17	12	6	11	5	13	13	2	3	3
56	6	6	24	39	40	35	92	53	33	48	47	27	17	16	11	9	10	13	12	2	5	3
57	4	11	12	20	21	24	82	52	32	43	41	35	24	19	11	10	7	10	9	4	6	3
58	1	1	7	9	14	16	71	41	26	41	45	34	22	22	16	10	11	11	10	5	7	1
59	0	0	1	8	4	10	49	29	21	28	28	26	20	19	15	14	9	10	9	5	7	<1
60	0	0	3	3	2	5	28	20	21	22	18	22	20	21	23	13	11	13	5	6	4	2
61	3	0	2	1	2	4	12	11	11	14	23	19	18	15	17	17	8	14	5	4	5	7
62	0	0	1	1	<1	2	8	4	6	10	15	13	12	12	15	13	10	15	2	4	4	<1
63	0	0	0	0	0	<1	4	3	3	6	5	7	8	8	11	14	8	9	4	6	4	<1
64	0	0	0	1	<1	0	1	1	1	2	3	4	6	6	11	10	6	9	2	4	3	<1
65	0	0	1	0	0	0	<1	1	1	1	2	2	3	2	7	9	4	7	1	<1	2	0
66	0	0	0	0	0	0	<1	0	<1	1	<1	1	1	2	4	5	5	6	1	2	2	0
67	0	0	0	0	0	0	0	0	0	0	1	1	<1	1	2	5	3	5	<1	2	1	0
68	0	0	0	0	0	0	3	0	0	<1	0	<1	<1	1	1	2	2	3	<1	<1	<1	0
69	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1	1	1	3	<1	0	<1	1
70	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	<1	<1	1	<1	0	<1	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<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	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
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	507

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, or 2015. 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
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	1	0	0	0	0	0	0	0	0	--	0	0	0	--	0	--	--	0	--	<1	--	0
2	0	0	--	4	0	0	0	0	0	0	0	0	0	0	<1	0	--	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
6	327	58	--	46	54	44	26	278	96	16	61	29	4	12	41	7	--	31	104	92	--	1	--	--	15	--	31	--	161
7	247	363	--	213	97	46	38	105	187	55	34	77	14	10	11	25	--	13	18	70	--	7	--	--	10	--	11	--	365
8	164	147	--	93	74	48	36	68	85	88	70	34	30	10	8	11	--	11	6	17	--	23	--	--	2	--	14	--	99
9	350	194	--	160	71	42	36	80	40	38	77	50	16	14	6	4	--	22	6	3	--	26	--	--	1	--	7	--	18
10	1,201	91	--	44	55	28	17	53	37	28	32	75	28	12	7	5	--	7	9	3	--	8	--	--	2	--	3	--	8
11	288	1,105	--	92	57	51	27	54	24	16	25	29	45	18	8	4	--	3	3	8	--	1	--	--	7	--	<1	--	0
12	287	222	--	60	33	25	23	19	24	16	21	27	21	31	14	10	--	5	2	4	--	1	--	--	8	--	1	--	2
13	202	223	--	373	34	27	13	59	12	13	19	25	16	13	30	8	--	4	4	1	--	1	--	--	1	--	5	--	0
14	89	82	--	119	142	42	9	32	36	7	18	16	11	7	9	26	--	5	5	5	--	<1	--	--	<1	--	4	--	0
15	27	90	--	41	164	92	45	12	18	13	9	12	11	9	7	6	--	11	8	5	--	<1	--	--	<1	--	2	--	0
16	17	30	--	38	59	47	36	31	4	5	15	10	9	8	9	5	--	12	5	3	--	1	--	--	<1	--	0	--	0
17	7	60	--	29	8	25	28	103	16	4	5	8	3	5	5	3	--	6	7	6	--	1	--	--	<1	--	<1	--	0
18	3	0	--	32	15	11	16	60	35	12	8	6	6	1	4	5	--	4	2	4	--	<1	--	--	<1	--	<1	--	0
19	0	0	--	56	22	11	4	18	26	12	10	3	3	3	2	1	--	3	1	3	--	1	--	--	<1	--	0	--	0
20	0	0	--	4	42	11	4	5	12	7	15	4	2	1	2	<1	--	1	2	1	--	<1	--	--	0	--	0	--	0
21	0	0	--	2	13	10	8	5	3	2	4	3	1	0	0	1	--	<1	<1	<1	--	<1	--	--	0	--	0	--	0
22	0	0	--	0	3	1	2	6	2	1	1	2	1	0	0	0	--	0	0	1	--	0	--	--	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	--	0
24	0	0	--	0	0	0	1	2	0	1	0	0	<1	<1	<1	0	--	<1	0	1	--	0	--	--	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	--	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	--	866

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, or 2015. 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
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	<1	0	0	0	0	0	0	0	0	--	0	0	0	--	0	--	--	0	--	<1	--	0
2	0	0	--	<1	0	0	0	0	0	0	0	0	0	0	<1	0	--	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
6	192	41	--	25	38	39	22	208	69	11	38	28	3	11	34	6	--	25	85	80	--	1	--	--	15	--	23	--	92
7	156	241	--	143	67	43	40	83	165	50	30	78	12	10	10	26	--	14	19	86	--	9	--	--	11	--	10	--	226
8	115	111	--	75	59	47	39	72	76	95	74	37	30	12	9	12	--	15	7	25	--	33	--	--	3	--	19	--	66
9	251	149	--	149	67	44	40	96	46	44	94	60	18	18	8	6	--	29	8	4	--	39	--	--	1	--	12	--	14
10	910	68	--	44	57	31	21	64	45	38	40	90	40	16	9	8	--	10	15	6	--	13	--	--	4	--	5	--	9
11	226	895	--	94	61	59	32	71	31	23	36	35	63	26	12	7	--	6	4	14	--	2	--	--	12	--	<1	--	0
12	233	187	--	59	36	27	28	26	33	22	29	33	32	50	23	18	--	9	3	7	--	2	--	--	14	--	1	--	2
13	167	194	--	378	37	30	17	77	17	18	27	30	25	20	48	14	--	8	6	1	--	2	--	--	2	--	10	--	0
14	82	72	--	116	150	47	11	42	49	11	26	19	18	11	15	47	--	10	9	11	--	1	--	--	<1	--	8	--	0
15	23	81	--	39	169	107	53	17	24	20	13	14	16	14	12	11	--	21	15	12	--	1	--	--	1	--	3	--	0
16	16	24	--	38	63	54	43	38	6	7	22	13	15	14	15	8	--	25	9	6	--	2	--	--	<1	--	<1	--	0
17	7	52	--	31	9	28	32	131	21	5	8	10	6	7	8	5	--	11	13	12	--	2	--	--	1	--	<1	--	0
18	3	0	--	32	15	11	18	74	43	17	10	7	8	2	6	10	--	8	3	8	--	1	--	--	<1	--	1	--	0
19	0	0	--	55	23	14	5	22	32	17	13	3	5	5	3	2	--	5	2	6	--	1	--	--	<1	--	0	--	0
20	0	0	--	4	44	12	5	6	14	9	19	4	3	2	3	1	--	1	3	2	--	<1	--	--	0	--	0	--	0
21	0	0	--	1	15	10	9	5	4	2	5	4	2	0	0	2	--	<1	1	1	--	<1	--	--	0	--	0	--	0
22	0	0	--	0	3	1	2	8	2	1	1	3	2	0	0	0	--	0	0	2	--	0	--	--	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	--	0
24	0	0	--	0	0	0	1	3	0	1	0	0	1	<1	1	0	--	<1	0	1	--	0	--	--	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	--	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	--	507

Table 10. -- Effect of changing post-processing parameters on estimated walleye pollock abundance and biomass observed during the winter 2016 acoustic-trawl survey in the Bogoslof Island area.

		% Change relative to the primary analysis	
Alternative analysis		Abundance	Biomass
1)	Did not assume 50:50 sex ratio	-0.10	0.35
2)	Scaled backscatter using the nearest haul's length composition	-2.33	0.15
3)	Excluded fish in post-spawning condition from length-weight computations	-	5.74

Table 11. --Percent walleye pollock females in spawning and post-spawning maturity condition by regions during Bogoslof survey years 1988-2016. Percentages greater than 50% are outlined.

Bogoslof

		% 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	48.0	60.4	71.7	530		
1989	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		71.4			

*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.

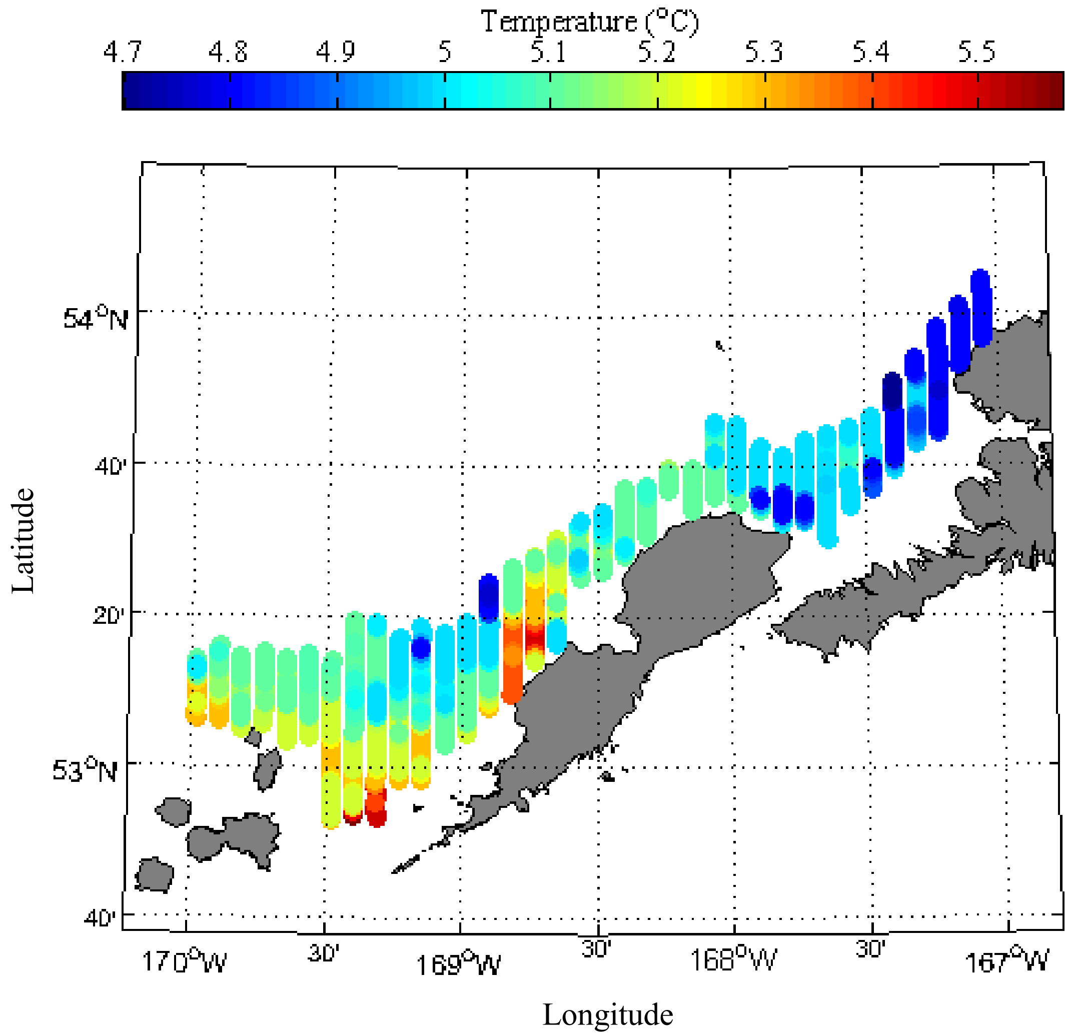


Figure 1. -- Averaged sea-surface temperatures observed along transects during the winter 2016 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island.

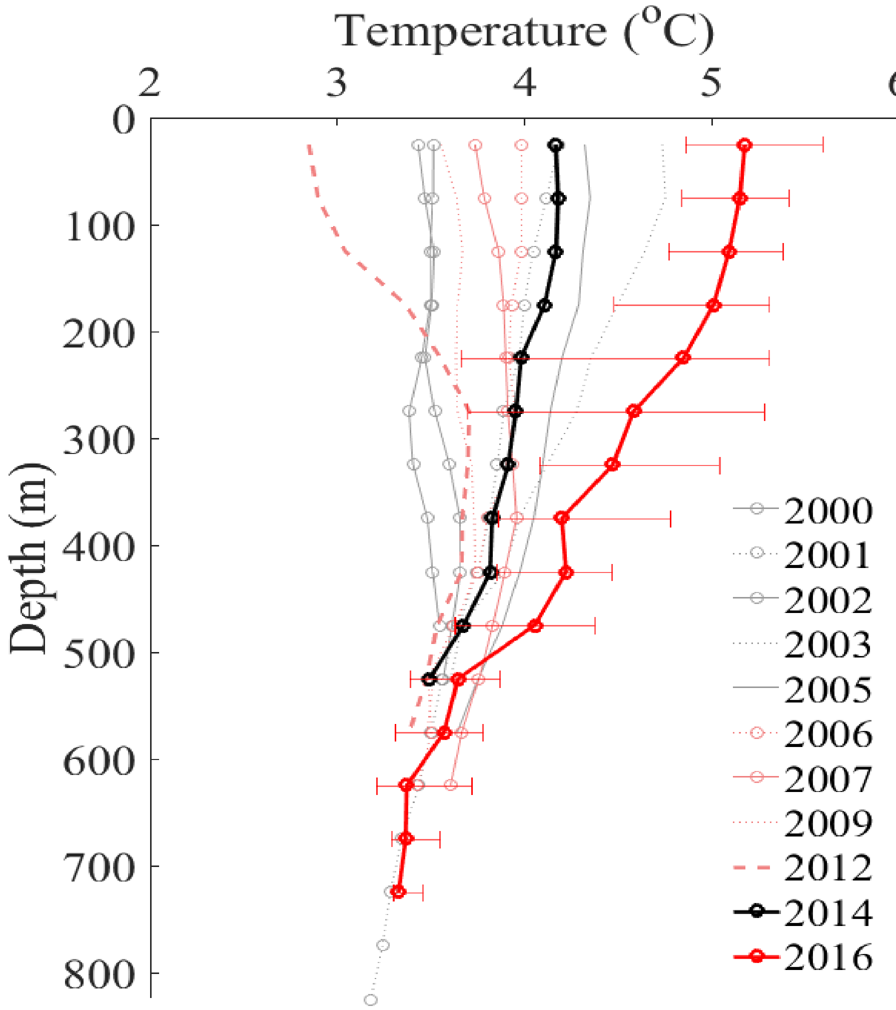


Figure 2. -- Average temperature (ºC) by 50-m depth intervals observed during hauls from the winter 2000-2003, 2005-2007, 2009, 2012, 2014, and 2016 acoustic-trawl surveys of walleye pollock in the Bogoslof Island area. The horizontal bars represent temperature ranges observed during the 2016 survey.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

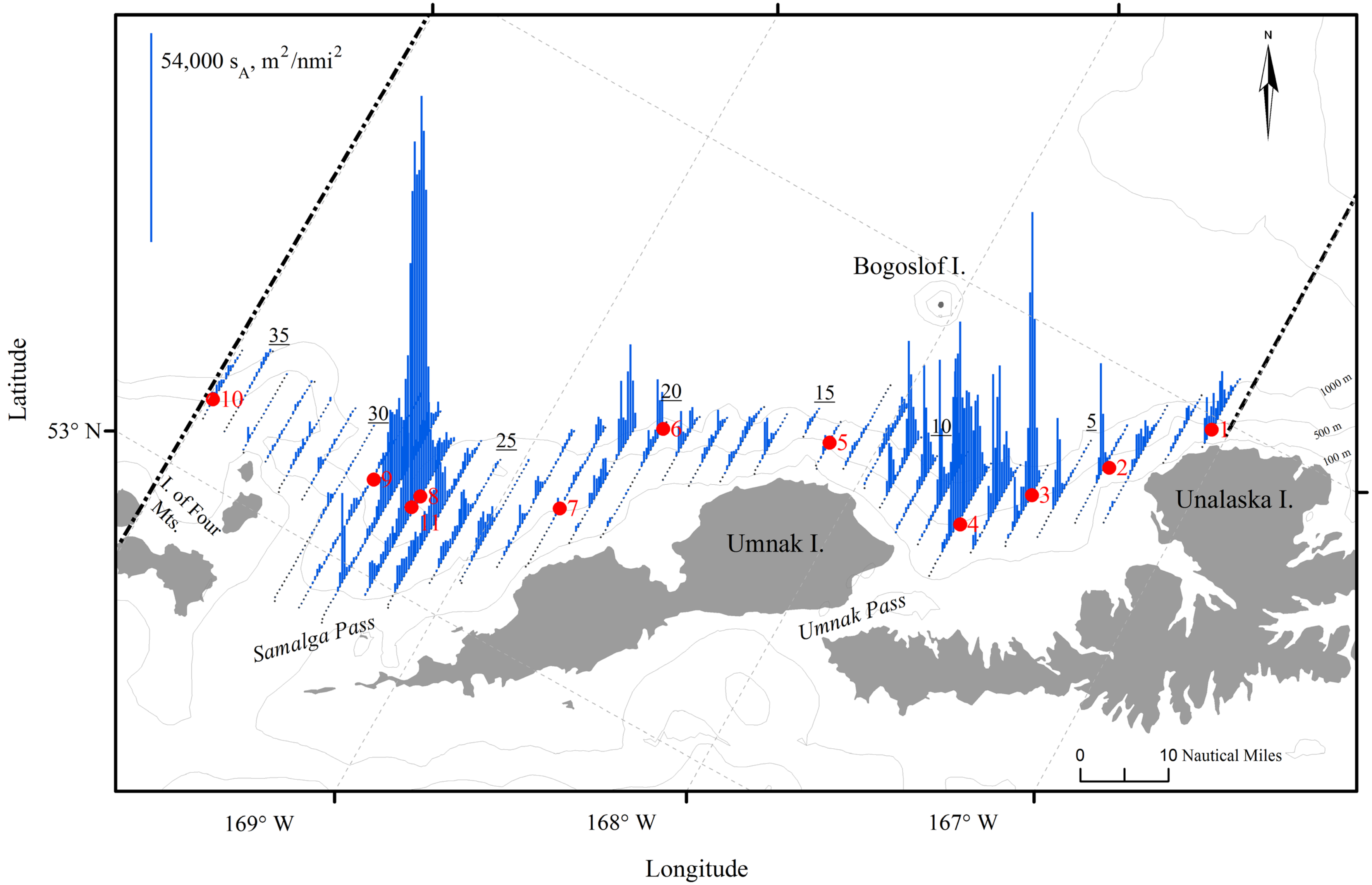


Figure 3. -- Undifferentiated 38 kHz backscatter (vertical bars, s_A, m^2/nmi^2) measured along transects during the winter 2016 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island. Transect numbers are underlined, trawl haul locations are indicated by red dots, and the Central Bering Sea Specific Area is indicated between the two dash-dotted lines.

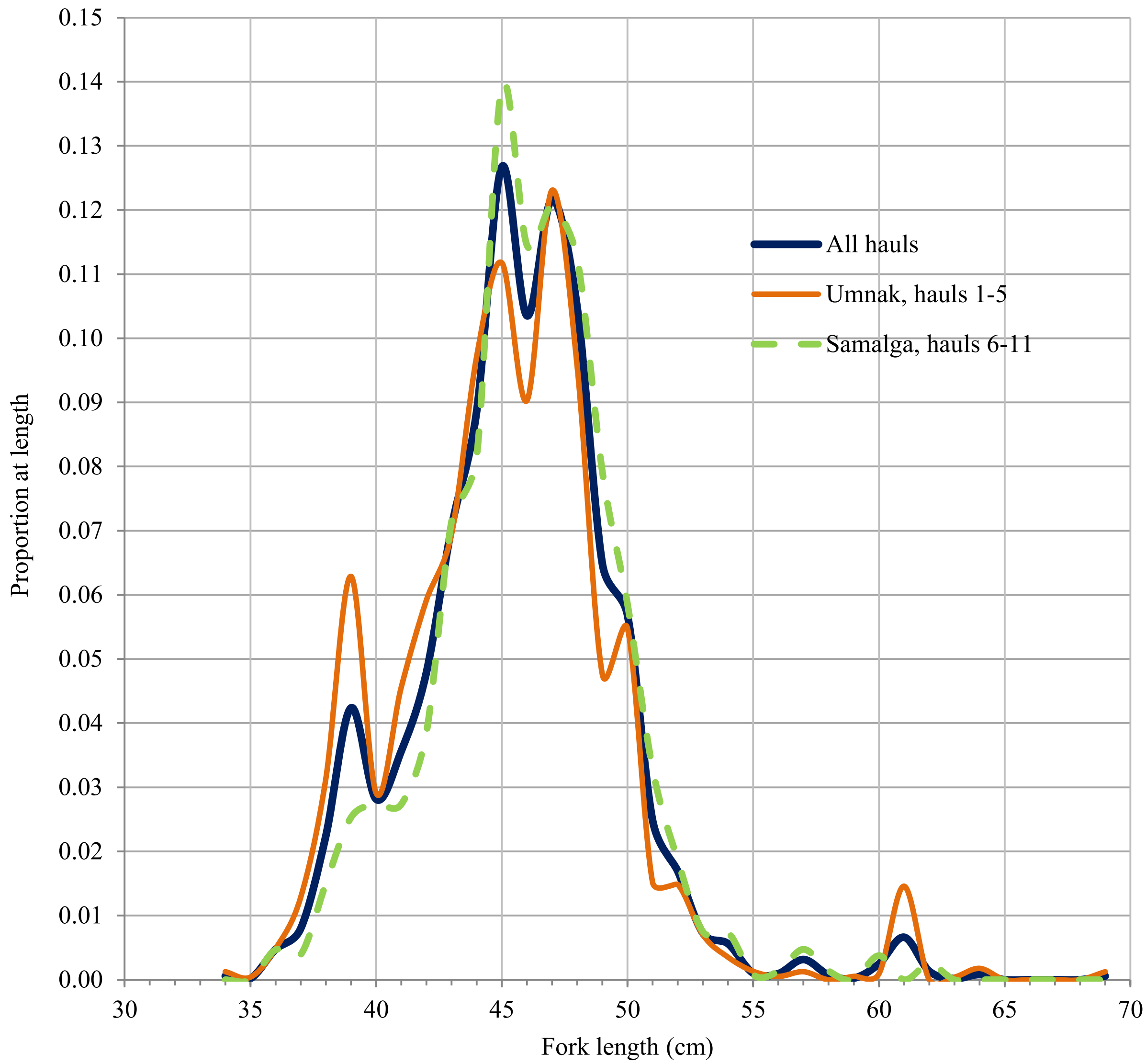


Figure 4. -- Average proportion at length for pollock measured in the Umnak region (hauls 1-5), Samalga region (hauls 6-11), and across all hauls during the winter 2016 acoustic-trawl survey of the Bogoslof Island area.

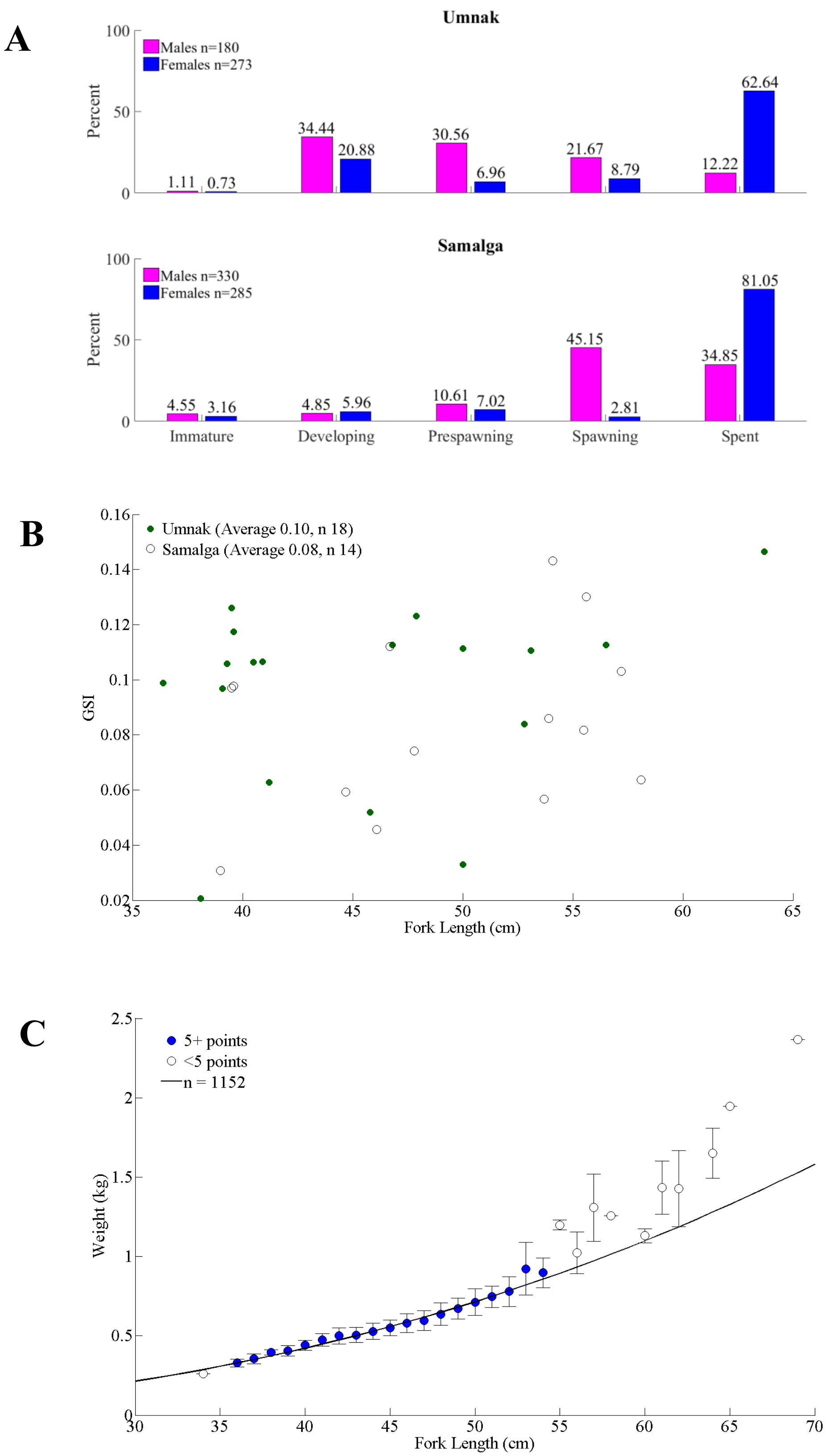


Figure 5. --Walleye pollock maturity stages by region and sex, with percentages annotated for female and male maturity stages (A), gonado-somatic index (GSI) by region for pre-spawning females as a function of fork length (B), and observed mean weight-at-length for adult fish, with fitted regression line for combined regions and sexes (C), observed during the winter 2016 acoustic-trawl survey of the Bogoslof Island area. In panel C, hollow circles indicate fewer than five fish were measured and vertical bars indicate +/- one standard deviation.

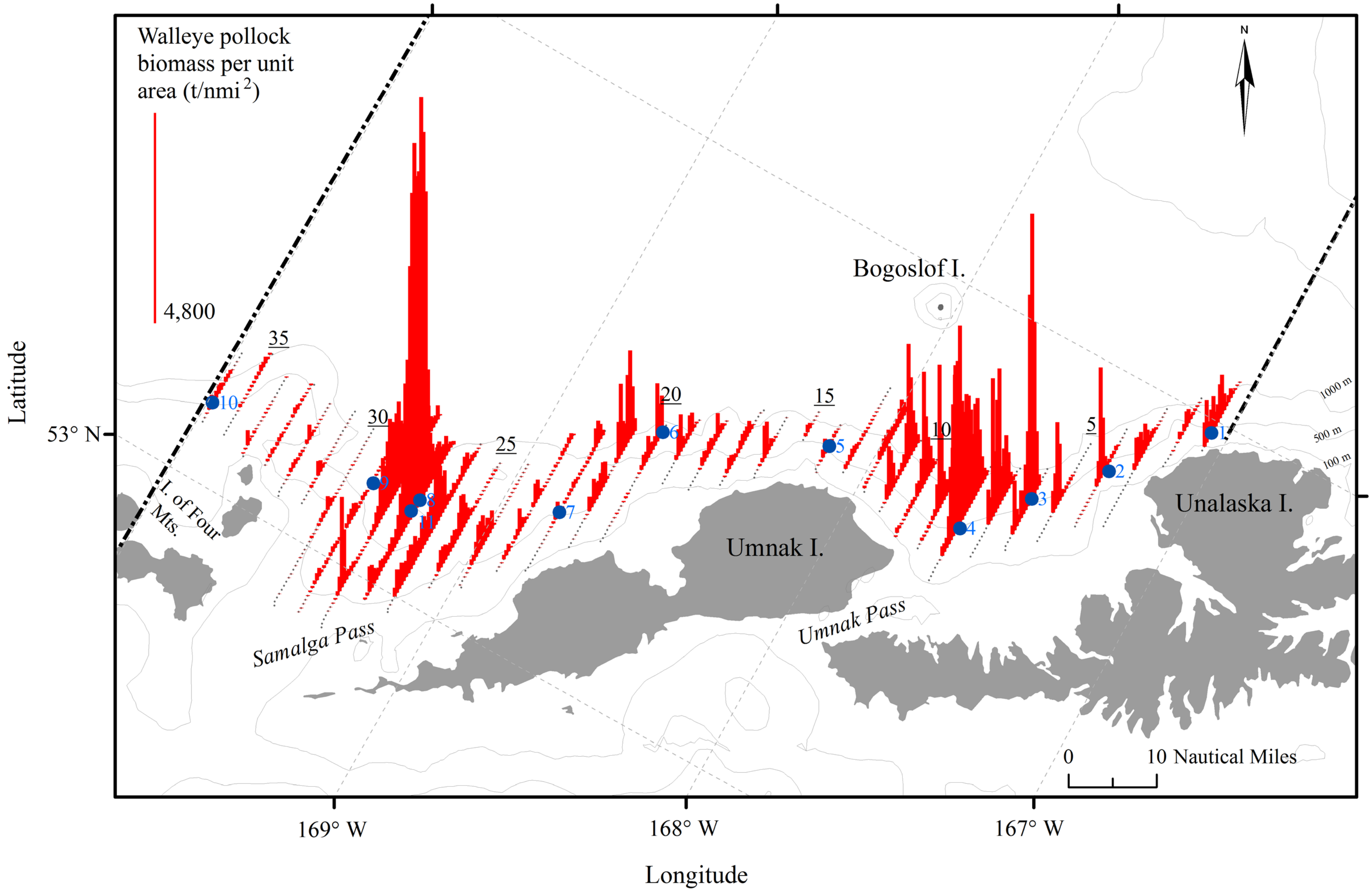


Figure 6. --Transects, haul locations, and walleye pollock biomass per unit area (t/nmi^2) observed along transects during the winter 2016 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island. Transect numbers are underlined, trawl haul locations are indicated by 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.

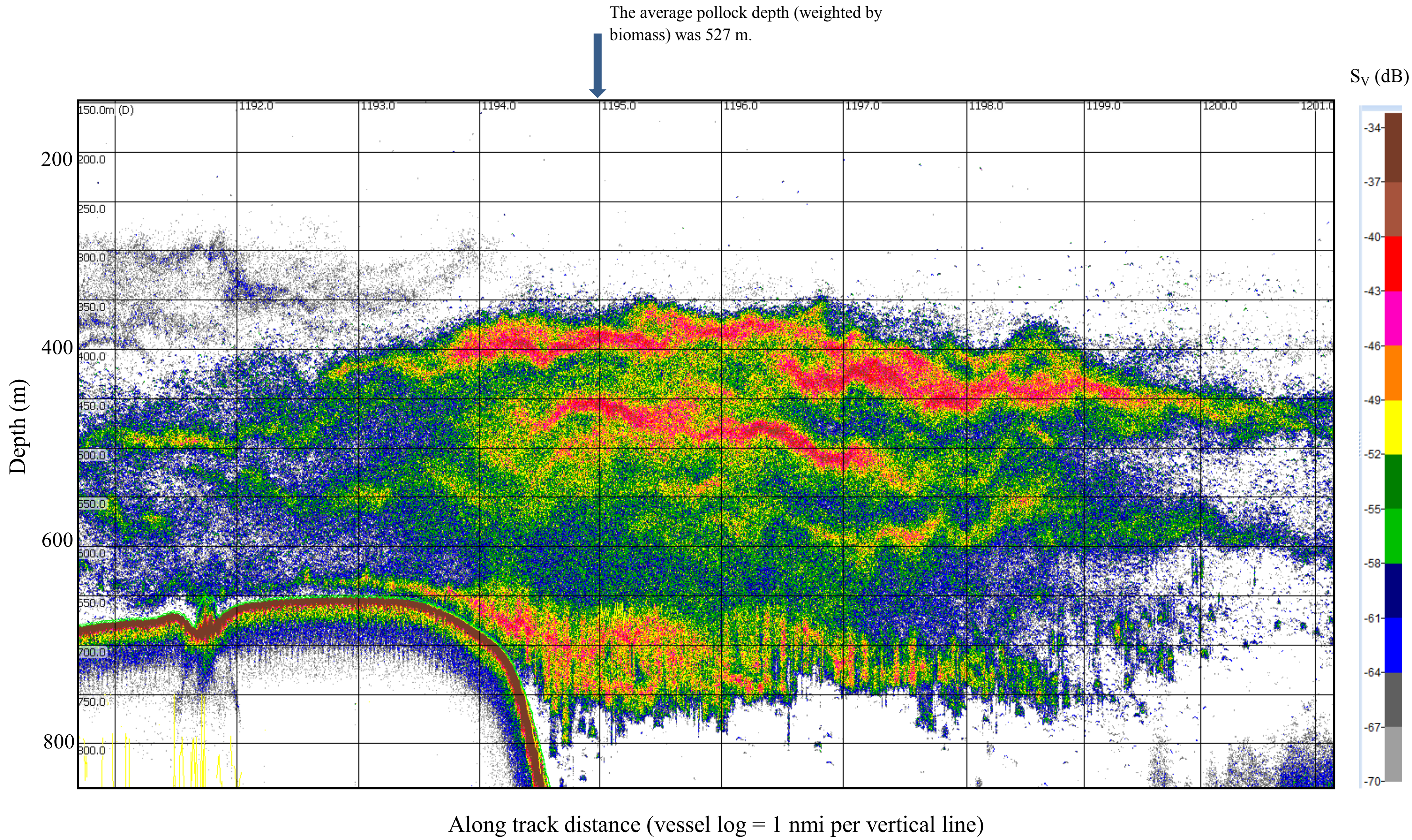


Figure 7. -- Echogram depicting pollock backscatter measured along Transect 27 during the winter 2016 acoustic-trawl survey of walleye pollock in the southeast Aleutian Basin near Bogoslof Island.

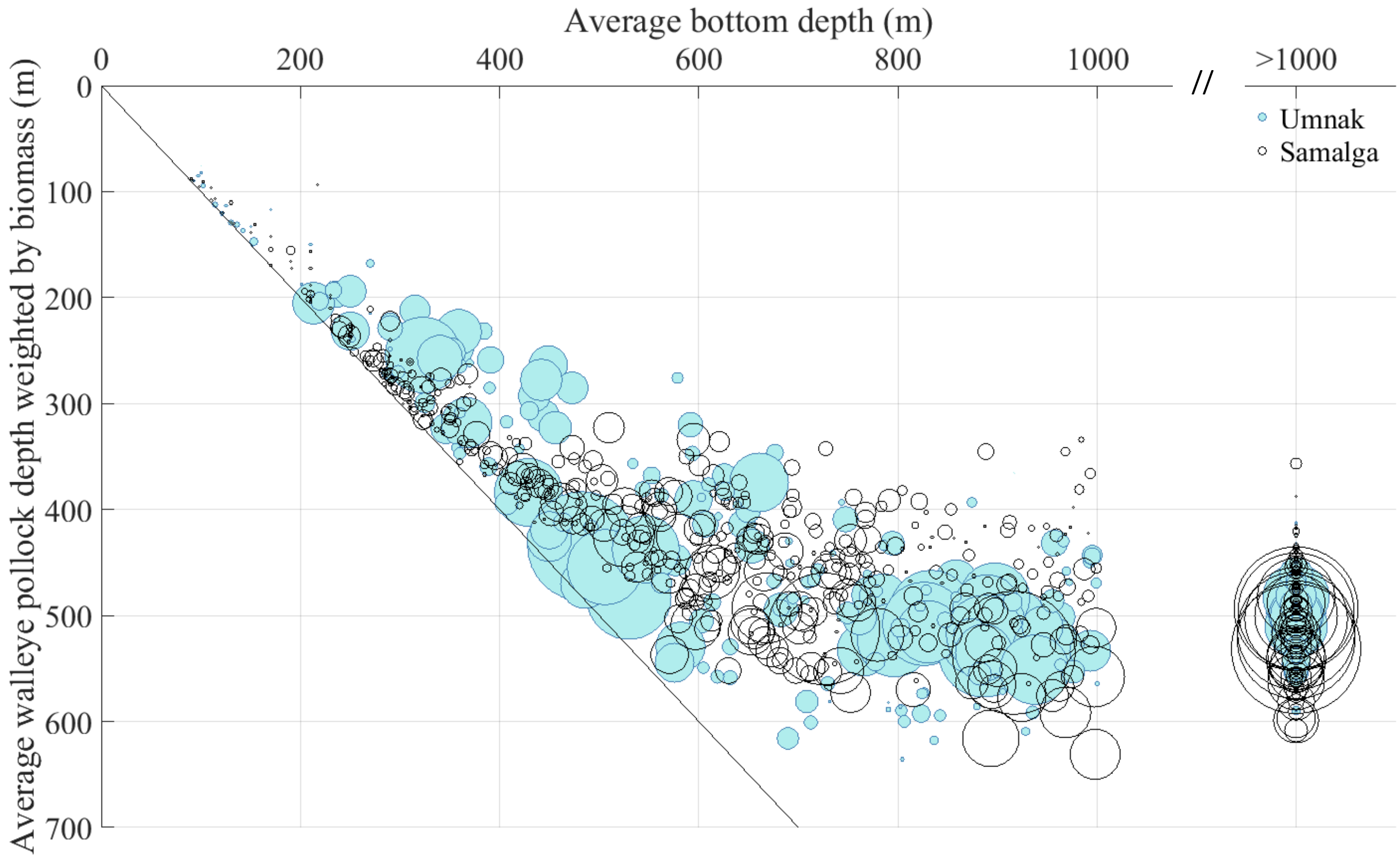


Figure 8. -- Average walleye pollock depth (weighted by biomass) versus bottom depth (m), per 0.5 nmi sailed distance for the Umnak and Samalga strata during the winter 2016 acoustic-trawl survey of walleye pollock in the Bogoslof Island area. Bubble size was scaled to the maximum biomass/0.5 nmi interval (Samalga region 14.3 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.

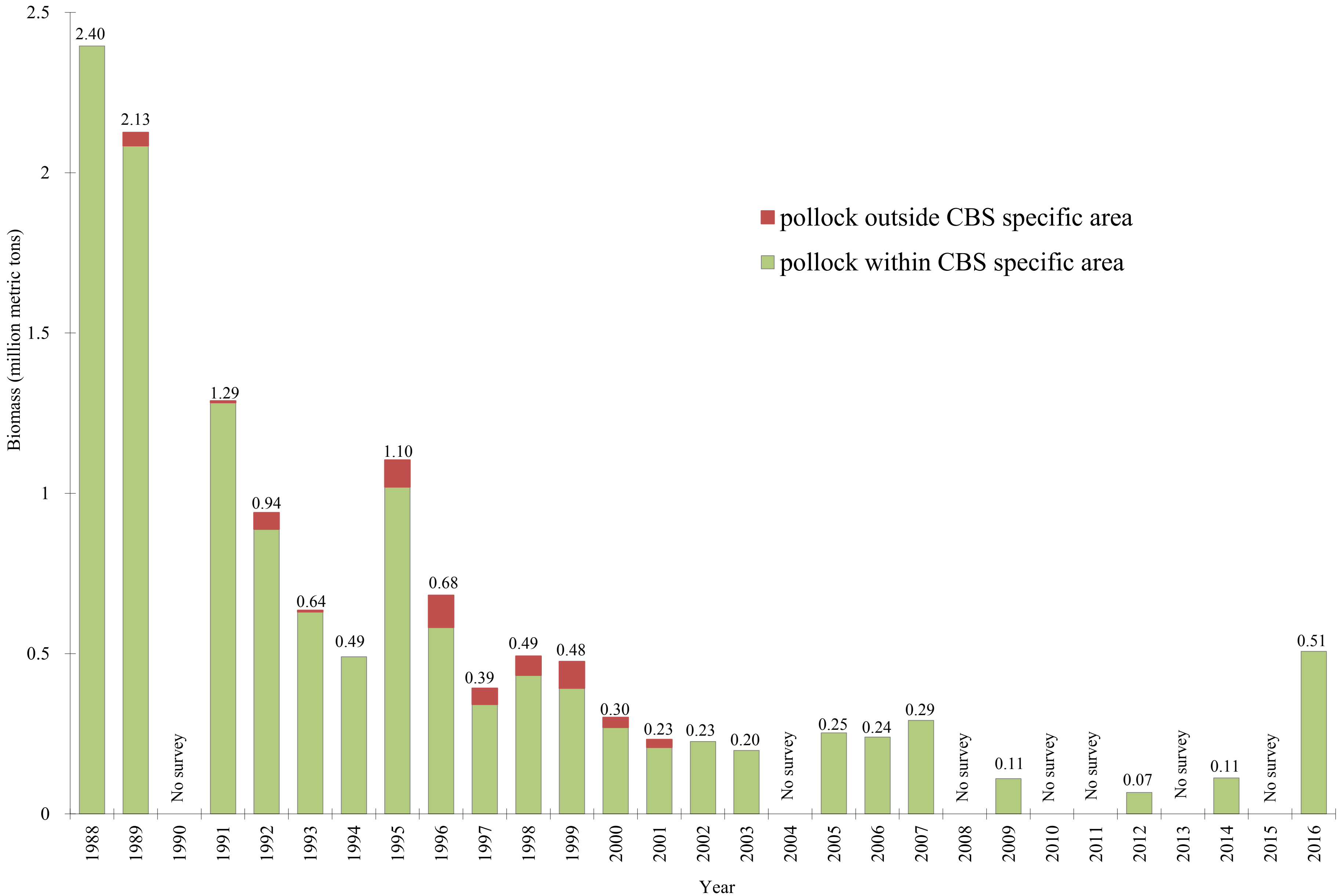


Figure 9. -- Biomass estimates for the winter acoustic-trawl surveys for walleye pollock in the Bogoslof Island area, within and outside the Central Bering Sea (CBS) specific area, 1988-2016. The United States conducted all but the 1999 survey, which was conducted by Japan. There were no surveys in 1990, 2004, 2008, 2010-2011, 2013, or 2015. Total pollock biomass (million metric tons) for each survey year is indicated on top of each bar.

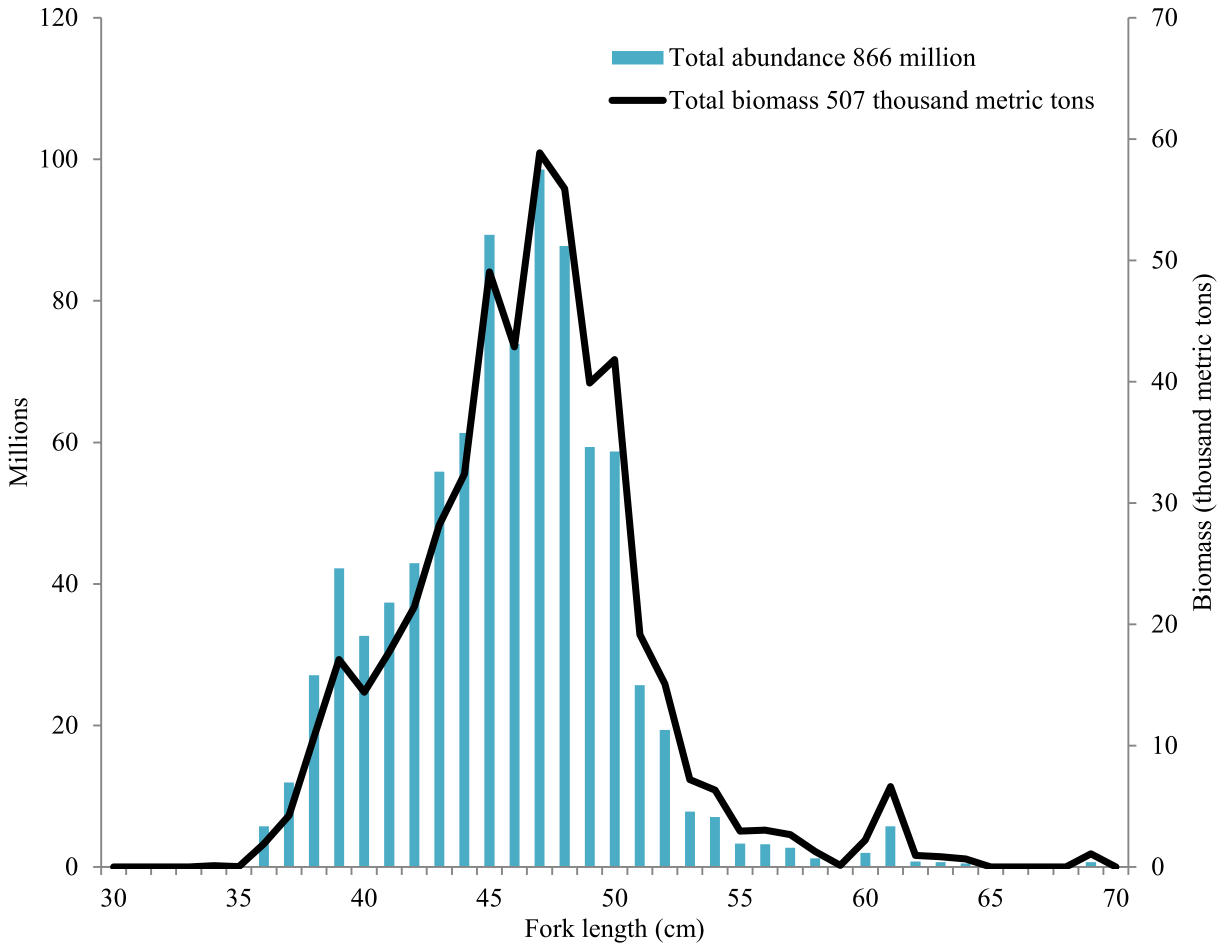
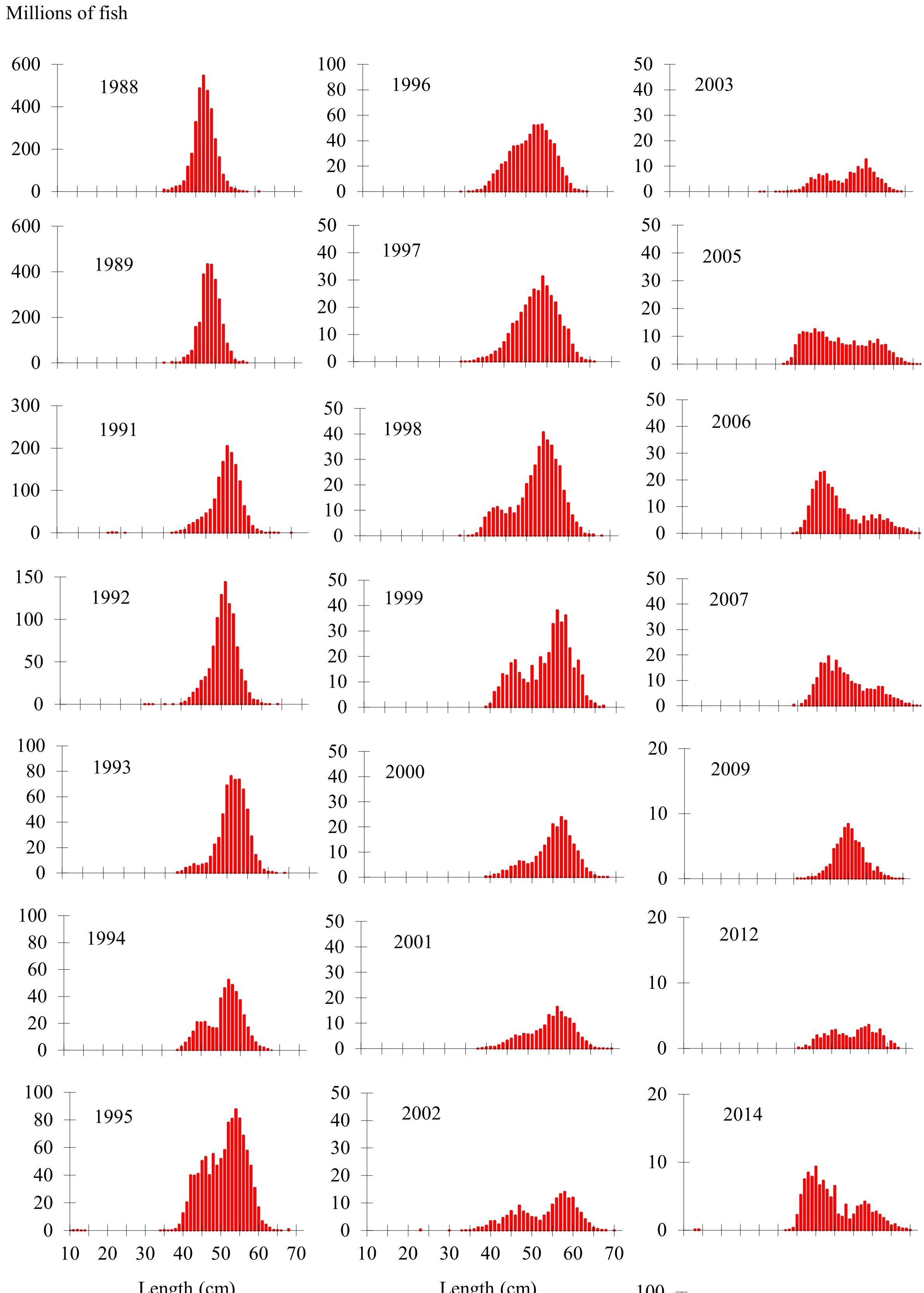


Figure 10. -- Numbers-at-length and biomass at length estimates from the winter 2016 acoustic-trawl survey of walleye pollock in the Bogoslof Island area.



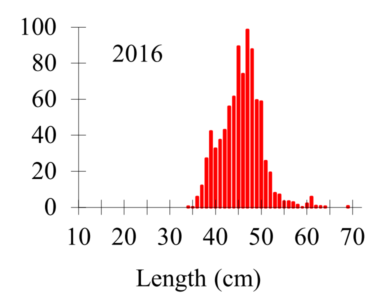


Figure 11. -- Numbers-at-length estimates (millions) from winter acoustic-trawl surveys of spawning pollock near Bogoslof Island. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, or 2015. The 1999 survey was conducted by Japan. Note: Y-axis scales differ.

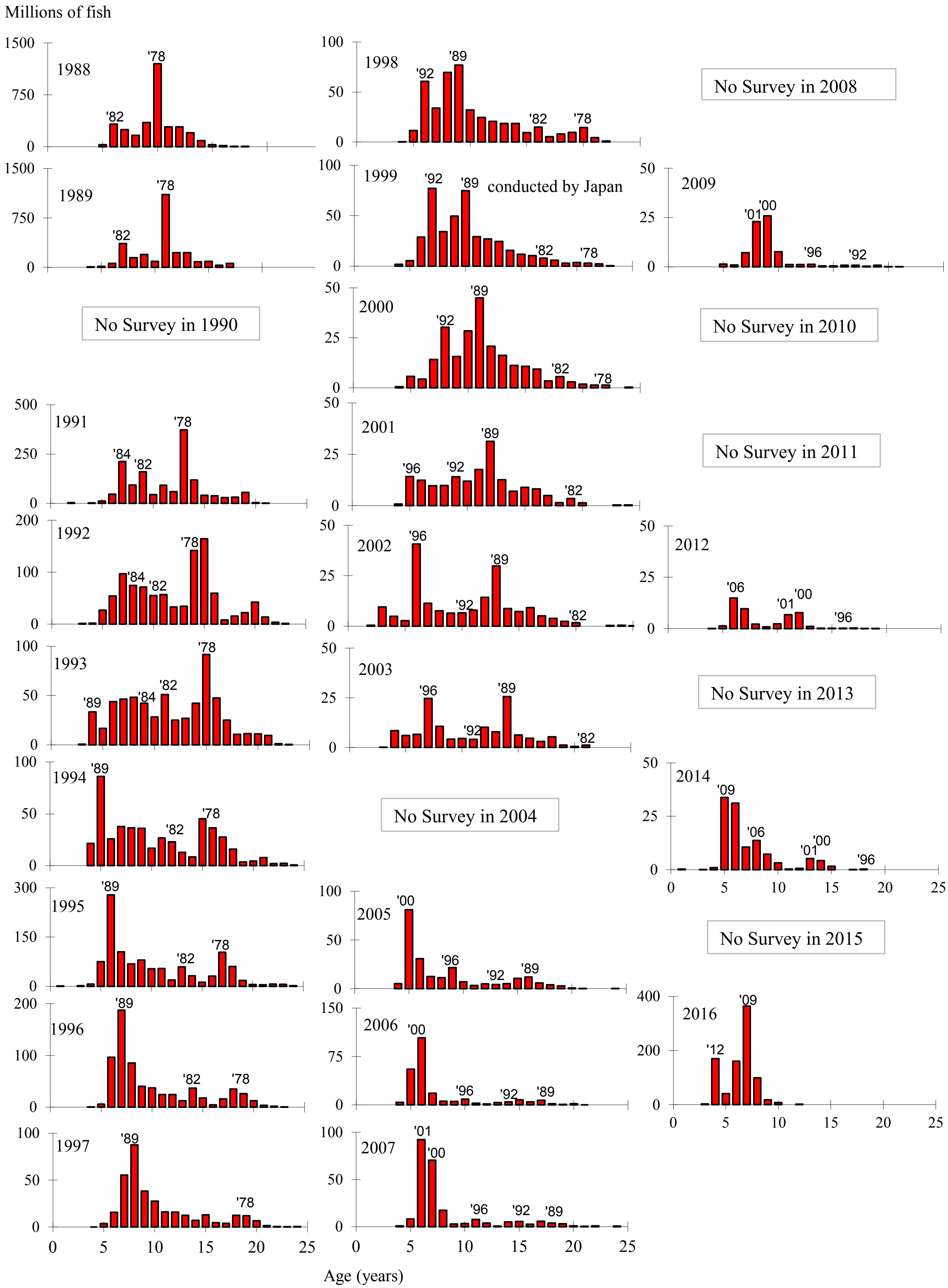


Figure 12.--Numbers-at-age estimates (millions) from acoustic-trawl surveys of pollock near Bogoslof Island. Major year classes on the Bering Sea shelf are indicated at the top. No surveys were conducted in 1990, 2004, 2008, 2010-2011, 2013, or 2015.

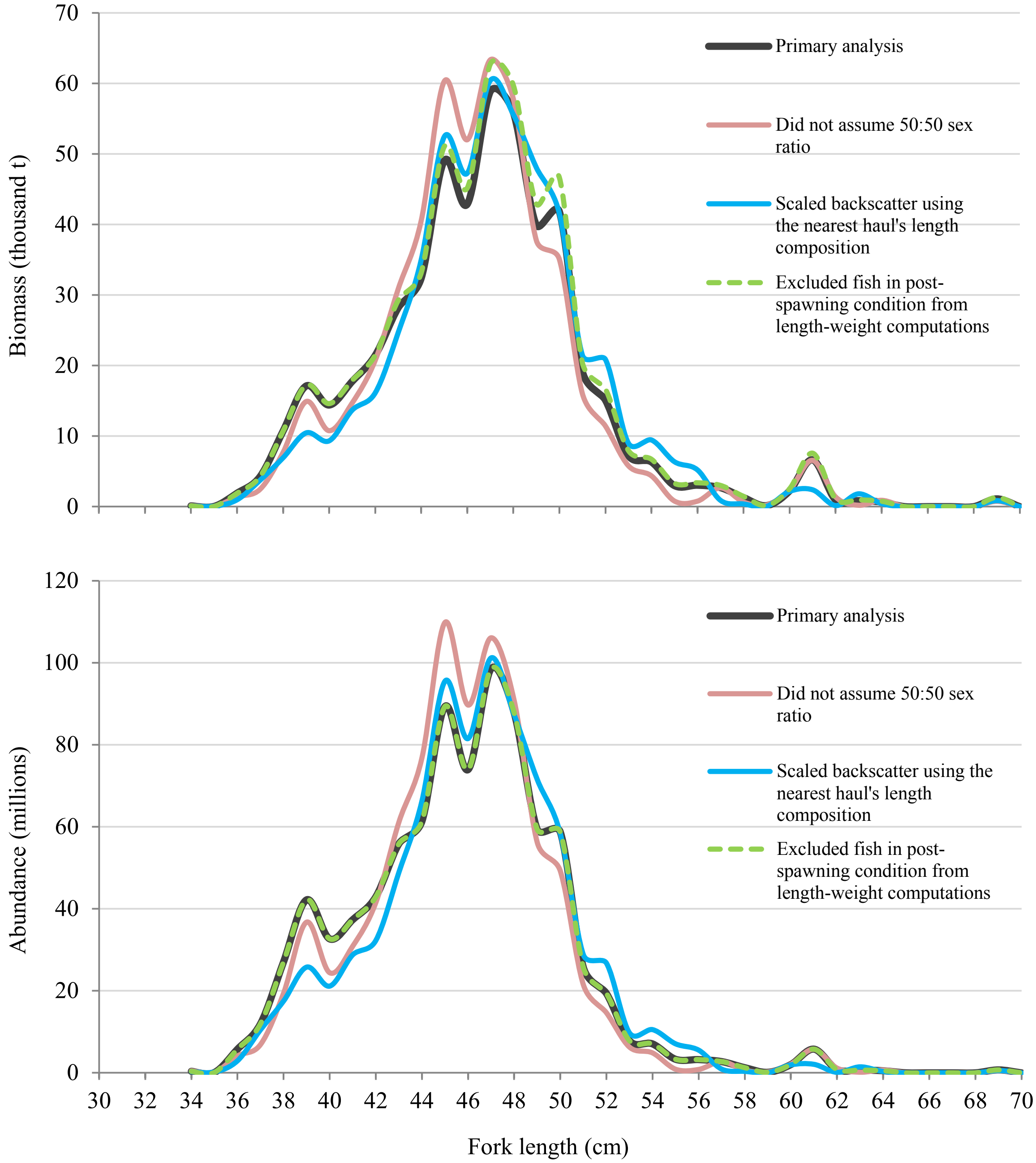


Figure 13. -- Estimated pollock biomass (thousand t) and numbers (millions) at length comparing results from the primary analysis with results from the sensitivity analysis.