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Acoustic Vessel-of-Opportunity (AVO) Index for Midwater Bering Sea Walleye Pollock, 2012-2013

by

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ABSTRACT

Surveys of the semi-demersal gadoid walleye pollock (*Gadus chalcogrammus*) are conducted in summer on the eastern Bering Sea shelf by the Alaska Fisheries Science Center (AFSC). The demersal portion of the stock is surveyed annually as part of a multispecies bottom trawl (BT) survey of groundfish and crab, while the midwater portion of the stock is assessed biennially with an acoustic-trawl (AT) survey. The acoustic vessel-of-opportunity (AVO) index of midwater walleye pollock biomass uses acoustic data collected by BT survey vessels to provide information on the biomass of midwater walleye pollock during years in which AT survey data are not available. The AVO index time series began in 2006, and this information has been used in the Bering Sea walleye pollock stock assessment since 2010 as an additional fishery-independent index of walleye pollock abundance. Index estimates for summers 2012 and 2013 are reported here. Differences were not detectable between the 2012 and 2013 estimates or among them and most other estimates in the time series based on overlapping confidence bounds. Exceptions were that 2012 and 2013 were different from the relatively low 2008 and 2009 values, and 2013 was different from 2006 and 2011. Most walleye pollock were distributed north and west of the Pribilofs in both years, although in 2013 the center of gravity of the population shifted to the south and east. The 2012 AVO index compared well with the 2012 AT survey walleye pollock biomass estimate to confirm that the index remains a good proxy for midwater walleye pollock abundance and distribution. Several sources of uncertainty affecting the AVO index and its relationship to the AT survey biomass estimate are discussed, including presence of larger than usual amounts of non-pollock backscatter in the index area, potential inclusion of small amounts of suspected age-0 walleye pollock, and different potential ways of scaling the index.

CONTENTS

INTRODUCTION

Summer surveys of the semi-demersal gadoid walleye pollock (*Gadus chalcogrammus*, hereafter referred to as pollock) are conducted over the eastern Bering Sea shelf by the Alaska Fisheries Science Center. The demersal portion of the stock is surveyed annually as part of a multispecies bottom trawl (BT) survey of groundfish and crab (Lauth and Nichol 2013) while the midwater portion of the stock is surveyed biennially using acoustics and targeted trawling on acoustic backscatter (acoustic-trawl (AT) survey; Honkalehto et al. 2013). Honkalehto et al. (2011) reported that acoustic data collected using BT survey vessels between 2006-2009 could provide an index of midwater pollock biomass during years in which AT survey data were not available. This acoustic vessel-of-opportunity (AVO) index of midwater pollock biomass has been updated annually, and has been used in the Bering Sea walleye pollock stock assessment each year since 2010 (Ianelli et al. 2010, 2011, 2012). Previous AVO index results from 2006 through 2010 (years when concomitant AT surveys were also conducted) indicated that the AT survey biomass time series was highly correlated with the AVO index ($r^2 = 0.913$, $n = 5$, $p = 0.011$). Both the AT survey and the AVO index of midwater pollock abundance declined between 2006 and 2009. In 2010, both indices roughly doubled from 2009, whereas in 2011 (with no AT survey), the AVO index suggested that midwater pollock biomass decreased by about 20% from 2010 (Ressler et al. 2012). This document updates and discusses AVO index results for summers 2012 and 2013.

METHODS

Methods for generating the AVO index are described in Honkalehto et al. (2011) and are only briefly presented here. Honkalehto et al. (2011) used results of AT surveys conducted between 1999 and 2004 to define an index area of the shelf where acoustic backscatter (s_A, $m^2\ nmi^{-2}$, MacLennan et al. 2002) at 38 kHz attributed to midwater pollock was consistently detected and strongly correlated with the AT survey estimate for the entire eastern Bering Sea. These strong patterns have continued in subsequent years, justifying continued use of the index area to facilitate post-cruise analysis by reducing the data volume. As in prior years, pollock backscatter collected by BT survey chartered commercial fishing vessels during 2012, 2013 from the index area was classified through either 1) manual processing of some data by trained analysts using Myriax Echoview software, or 2) semi-automated processing of other data with custom software routines in which all water column backscatter between 30 m from the surface and 3 m off bottom was assumed to be pollock.

In 2012, customized software for semi-automated processing and quality control, originally in Matlab (The Mathworks, Natick, Massachusetts, USA), was upgraded and rewritten in Python (www.python.org, v. 2.75, The Python Software Foundation). The Oracle SQL database used to store AVO data was updated and improved in 2012. AVO index results were created using 2011 data and running the old and new processing software and databases in parallel to verify accuracy of the new process. The AVO index results from the new processing software and database were in close agreement to estimates obtained with the original software (within 1.9 % of previously obtained results). Thus, the 2012 and 2013 index results were processed and analyzed using the new Python processor and database.

2012

Both AT and BT surveys were conducted in summer 2012. Honkalehto et al. (2013) describe details of the 2012 AT survey conducted aboard the NOAA ship *Oscar Dyson*. The BT survey was conducted aboard the chartered vessels FV *Aldebaran* and FV *Alaska Knight* (Lauth and Nichol 2013). Both BT survey vessels collected 38 kHz acoustic backscatter data with Simrad ES38B split beam transducers and ES60 echosounding systems. These data were averaged into 0.5 nmi intervals along the vessel track. Backscatter data were also collected at 120 kHz but were not used in the AVO index. Standard sphere calibrations were conducted immediately before and after the survey. Tungsten carbide (38.1 mm diameter) spheres were centered on axis for each frequency (38 kHz and 120 kHz) and split beam target strength (TS) and echo integration measurements were made (stationary sphere method; Foote et al. 1987).

2013

Only the BT survey was conducted during summer 2013. The survey vessels were the FV *Aldebaran* and FV *Alaska Knight.* Both vessels collected 38 and 120 kHz data averaged into 0.5 nmi intervals. Standard sphere calibrations were conducted before and after the survey. In addition to the collection of on-axis calibration measurements, spheres were moved systematically through all four quadrants of each beam (moving sphere method; Foote et al. 1987) for post-processing with software provided by the manufacturer (calibration.exe; Simrad 2008) to estimate both on-axis sensitivity and beam characteristics.

Estimates of AVO indices, 1-D geostatistical relative estimation errors (Petitgas 1993), and approximate 95% confidence intervals describing sampling variability were calculated for 2012 and 2013 following methods described by Honkalehto et al. (2011).

RESULTS

Calibration

The integration gains used in processing the 2012 data were based on the mean of June and August on-axis measurements. Integration gains used for the 2013 data were based on the mean of June and July moving sphere method measurements for *Alaska Knight*, and on July moving sphere method measurements for *Aldebaran* (conditions for the June *Aldebaran* calibration were poor). No notable changes to the 38 kHz integration gain values were observed between years for either vessel.

Biomass

The AVO index increased in 2012, relative to the previous year, and again in 2013 (Table 1, Fig. 1). Confidence bounds based on geostatistical sampling error overlapped between adjacent years in the period 2010-2013, but 2011 and 2013 error bars did not overlap, suggesting that biomass was significantly higher in 2013 than in 2011. The AVO index remained highly correlated with AT survey biomass within the U.S. EEZ in years when both AT and BT surveys were conducted ($r^2 = 0.904$, $n = 6$, $p = 0.004$, 2006-2012; Fig. 2). Both AT survey biomass and the AVO index declined between 2010 and 2012, and both time series indicated greater biomass in 2010-2012 than the series' low points in 2008-2009 (Fig. 1).

Spatial Distribution

About 74% of the AVO index pollock s_A was found west of the Pribilof Islands (west of 170° W) in 2013 compared to 95% in 2012 (Figs. 3 and 4). In 2013, AVO index pollock s_A was 17% lower west of the Pribilofs and 4 times higher east of the Pribilofs than in 2012 (Fig. 4). AVO index pollock s_A appeared to be quite evenly distributed in 2013 compared with other years as evidenced by the lowest relative estimation error of the time series (Table 1). The spatial patterns observed between AT survey backscatter and AVO index backscatter showed broad agreement in 2012 (Figs. 3 and 4). That is, most of the AT survey pollock biomass (85%) was found west of the Pribilof Islands and most (85%) was inside the index area, as has been the case since 2006 in years when the two surveys co-occurred. A plot of the center of gravity estimates of the AVO index and AT surveys over the time series suggests relatively little change in values between 2012 and 2011 (Fig. 5). Center of gravity estimates from both surveys were very closely located in 2012. In 2013, a relatively large shift in the center of gravity of walleye pollock to the south and east (the second largest eastward shift in the time series, after 2009) was detected (Fig. 5).

Uncertainty in the AVO Index

Three sources of uncertainty in the AVO index were investigated. The first two involved potential classification error in 2012 and 2013. The third, present in all years, involved uncertainty in the size composition of midwater pollock biomass measured by the AVO index.

AVO backscatter data that are subjected to semi-automated processing are also visually examined to detect large problems such as invalid bottom detections, acoustic interference, and non-walleye pollock backscatter (Honkalehto et al. 2011). In 2012 and 2013, these visual audits revealed some 0.5 nmi intervals with a large amount of non-pollock backscatter below 30 m depth as compared to previous surveys in the AVO time series. This non-pollock backscatter was not (and should not) be included in the AVO index. We computed the 2012 and 2013 AVO indices both with (2012 n = 6,826, 2013 n=6,728) and without (2012 n = 6,446, 2013 n = 6,453) these intervals to assess their influence on the resultant AVO index estimates of pollock had they remained undetected. Results showed that if intervals with large amounts of non-pollock backscatter had not been excluded, the AVO index results presented here (Fig. 1, Table 1) would have been about 12% higher in 2012 and 5% higher in 2013, implying a larger increase in pollock biomass from 2011 to 2012 and little change from 2012 to 2013.

There was also an increased amount of pollock backscatter between the surface and 30 m depth in certain areas in 2013 which had not been observed in prior years of the AVO time series. Some of this backscatter was likely attributable to age-1 or older pollock, which should be included in the AVO index. However, some portion may have also been age-0 pollock, which should not be included in the index. The final 2013 AVO index estimate excluded some shallow backscatter suspected to be from age-0 pollock (Fig. 1, Table 1). The suspected age-0 pollock backscatter was concentrated primarily northwest of St. Paul near the 90 m isobath, with much smaller amounts observed northeast of Pribilof Canyon and on the northwest edge of Zhemchug Canyon. To investigate the uncertainty in the AVO index due to the classification of this shallow backscatter (with no available trawl sampling for validation), we computed the AVO index both with and without all shallow (< 30 m depth) suspected pollock backscatter. Compared to the 2013 AVO index (Table 1), including the suspected age-0 pollock backscatter would have increased the AVO index by less than 1%, whereas excluding all suspected pollock backscatter found shallower than 30 m would have decreased the 2013 AVO index by about 4%.

If the ratio of pollock backscatter to pollock biomass is assumed to be constant regardless of fish size, biomass will be overestimated when most fish are small and underestimated when most fish are large, due to the fact that weight-specific target strength (i.e., target strength per kilogram) decreases in proportion to fish length (e.g., Traynor 1996, Honkalehto et al. 2013). The AVO index of midwater pollock currently has no midwater trawls to provide size composition. Assuming the average AT survey pollock length composition applies to pollock in the AVO index area, we evaluated the importance of pollock size composition to the relationship between the AVO index and AT survey biomass in three ways:

1) Average length composition and average fish weight from the AT survey (see Tables 8 and 9 Honkalehto et al. 2013) and the target strength to length relationship for walleye pollock (Traynor 1996) were used to scale AVO backscatter into units of biomass in years when both the AT survey and AVO index of pollock were available from 2006 to 2012. AVO index biomass estimated in this way was more weakly correlated with AT survey biomass (r^2 = 0.763, n = 6, p = 0.023) than was AVO backscatter (r^2 = 0.904, n = 6, p = 0.004), although the difference between these correlations was not statistically significant (n = 6, p = 0.08 using the method of Steiger (1980) as implemented by Revelle 2014).

2) AT survey biomass in those same years was modeled as a function of the AVO index and mean fish length in the AT survey using a multivariate additive regression model (GAM). Inclusion of mean fish length did not significantly improve the model's predictive power, based on comparison of AIC (Akiake Information Criterion) scores among models with and without mean fish length as a covariate. Similar results were obtained when the related quantities mean fish weight or mean backscattering cross-section were included as covariates in place of mean fish length.

3) AVO backscatter was examined as a predictor of AT survey pollock *backscatter* (i.e., not scaled by fish length or weight), rather than *biomass.* The AVO index was more weakly associated with AT survey backscatter ($r^2 = 0.757$, $n = 6$, $p = 0.024$) than it was with the AT survey pollock biomass ($r^2 = 0.904$, $n = 6$, $p = 0.004$). The difference between these correlations was statistically significant ($n = 6$, $p = 0.04$).

DISCUSSION

The AVO index indicated that midwater pollock biomass increased slightly in 2012 and again in 2013 compared to the 2011 value reported by Ressler et al. (2012). Most pollock backscatter was observed west of the Pribilof Islands in both years. Proportionately more pollock backscatter was detected east of the Pribilofs in 2013 than in 2012, and the estimated center of gravity for the 2013 backscatter distribution was the farthest east in the time series (Fig. 5). This appeared counter to both time series' trends observed 2006-2012, where, on average, 93% of AVO backscatter and 86% of AT survey biomass has been west of the Pribilofs (see Honkalehto et al. 2013, Table 7). Pollock also appeared to be more evenly distributed geographically in 2013 than in 2012 as evidenced by the lower sampling estimation error.

The 2013 AVO index is particularly important because it is the only source of fishery-independent information on the status of midwater pollock that year as the AT survey is typically only conducted during even years. The slight increase in the 2013 AVO index corresponded well with other indicators of the eastern Bering Sea pollock population, such as the roughly 30% increase in the demersal pollock biomass estimate from the BT survey between 2012 and 2013 (B. Lauth, NMFS-AFSC, personal communication). Summer CPUE estimates from the pollock fishing industry also increased from 2012 to 2013 (Ianelli et al. 2013).

Comparison of 2012 AVO and AT survey results confirmed the AVO index is highly correlated with the AT survey results and remains a good proxy for the abundance and distribution of midwater walleye pollock biomass in the eastern Bering Sea. Both the AVO index and the AT survey estimates exhibited a slight decline from 2010 to 2012, though the AT survey decline was slightly larger. The degree of association between the AVO index and AT survey biomass likely depends on several factors including sampling variability, classification uncertainty, conversion of backscatter to biomass based on having fish length and weight information, and possibly timing offsets between AT and BT coverage of particular locations.

Two specific sources of uncertainty in backscatter classification were present in the 2012 and 2013 data sets: large densities of non-pollock backscatter below 30 m in the semi-automatically processed portion of the index area for both years, and an increase in shallow (< 30 m depth) pollock backscatter that was attributed to both age-0 and age-1+ pollock in 2013. Incorrect classification of backscatter could potentially change the interpretation of relative year-to-year changes in the AVO index value. However, we found that the backscatter in question was generally restricted in geographical distribution and constituted a small part of the total backscatter in the AVO index area, so that contributions from these sources to the 2012 and 2013 AVO index estimates were minimal.

Findings from the analysis to examine the influence of inclusion of length data in generating an AVO index of abundance were insightful. Generally, inclusion of pollock length data from an AT survey conducted in the same year did not improve the ability of the AVO index to predict AT survey pollock biomass. We interpret these results to indicate that converting the AVO backscatter to biomass using the average AT survey pollock length composition merely added noise to a comparison of two somewhat noisy time series estimates. The coefficient of variation (CV) of the AT survey biomass and AVO index time series are probably on the order of 20-30% (Ianelli et al. 2012, Woillez et al. submitted), and other sources of variability in each index are also significant when one is used to predict the other. However, it is possible that scaling the AVO index backscatter using length data collected concurrent to the backscatter data collection (i.e., during the BT survey) would improve this comparison and this should be investigated.

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Table 1. -- Acoustic vessel-of-opportunity (AVO) index values and acoustic-trawl (AT) survey biomass within the U.S. Exclusive Economic Zone since 2006. Relative estimation errors are one-dimensional geostatistical estimates of sampling variability.

	AT survey biomass (million t)	AT survey biomass*	Relative estimation error	AVO index*	Relative estimation error
2006	1.560	0.470	0.039	0.555	0.051
2007	1.769	0.534	0.045	0.638	0.087
2008	0.997	0.301	0.076	0.316	0.064
2009	0.924	0.279	0.088	0.285	0.120
2010	2.323	0.701	0.060	0.679	0.086
2011	NO SURVEY	NO SURVEY	NO SURVEY	0.543	0.057
2012	1.843	0.556	0.042	0.661	0.063
2013	NO SURVEY	NO SURVEY	NO SURVEY	0.696	0.039

*Scaled to average value 1999-2004 (cf. Honkalehto et al. 2011).

Figure 1. -- Acoustic vessel-of-opportunity (AVO) index 2006-2013 (a), acoustic-trawl (AT) survey biomass in the U.S. Exclusive Economic Zone (b), and 95% confidence intervals based on 1-D geostatistical estimates of sampling variability. The AVO index has been scaled to its mean value for the period 1999-2004 (not shown).

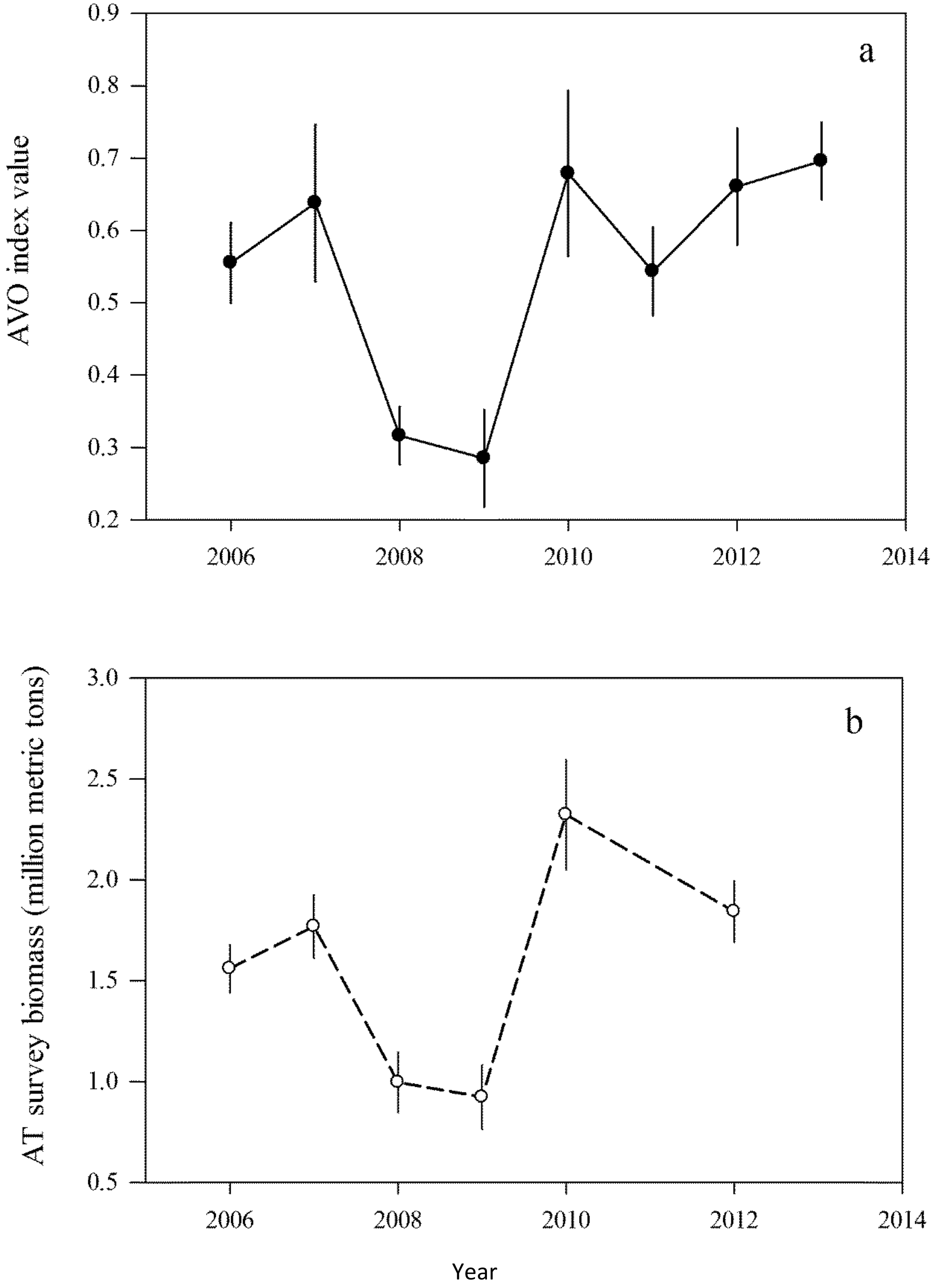

Figure 2. –Regression of the AT survey biomass (million metric tons) on the AVO index value, 2006-2012.

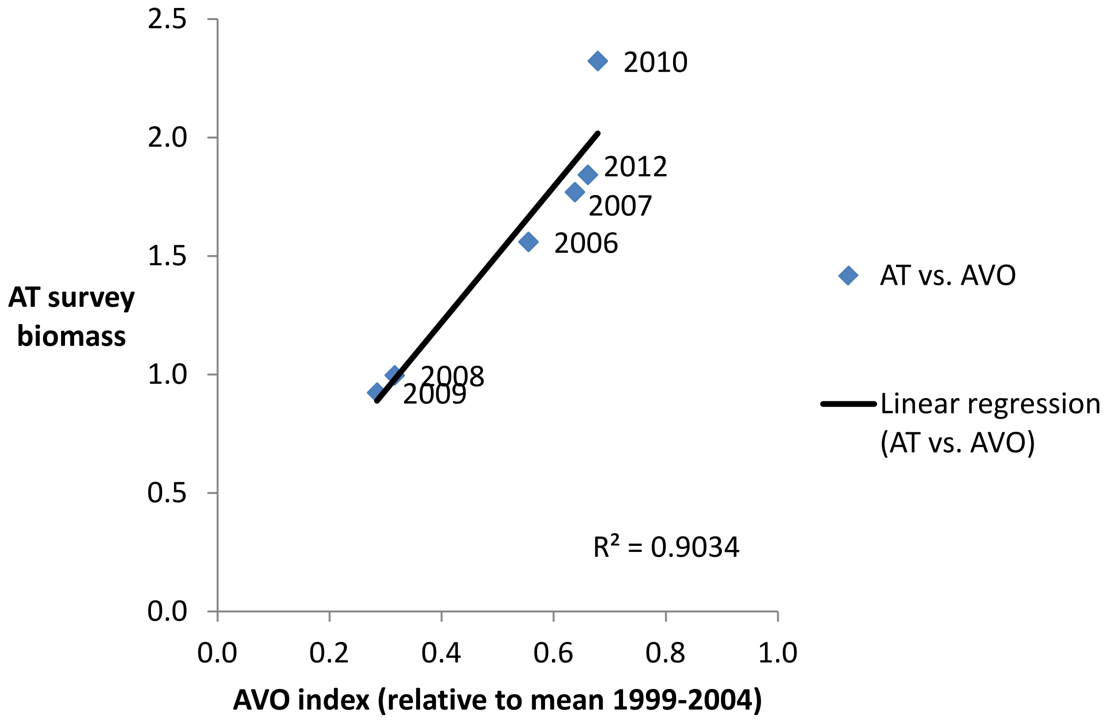

Figure 3. -- Pollock s_A (m^2 nmi^{-2}) in acoustic vessel-of-opportunity (AVO) index (left column) and acoustic-trawl (AT) survey (right column) data sets, 2012-2013. The bottom trawl (BT) survey grid cells used for the AVO index are shown in the left column. There was no AT survey in 2013. The 200 m bathymetric contour is indicated in blue, and the boundary between the U.S. and Russian Exclusive Economic Zones is denoted by a black line across the upper left corner of the plot. Note that the color scale is logarithmic.

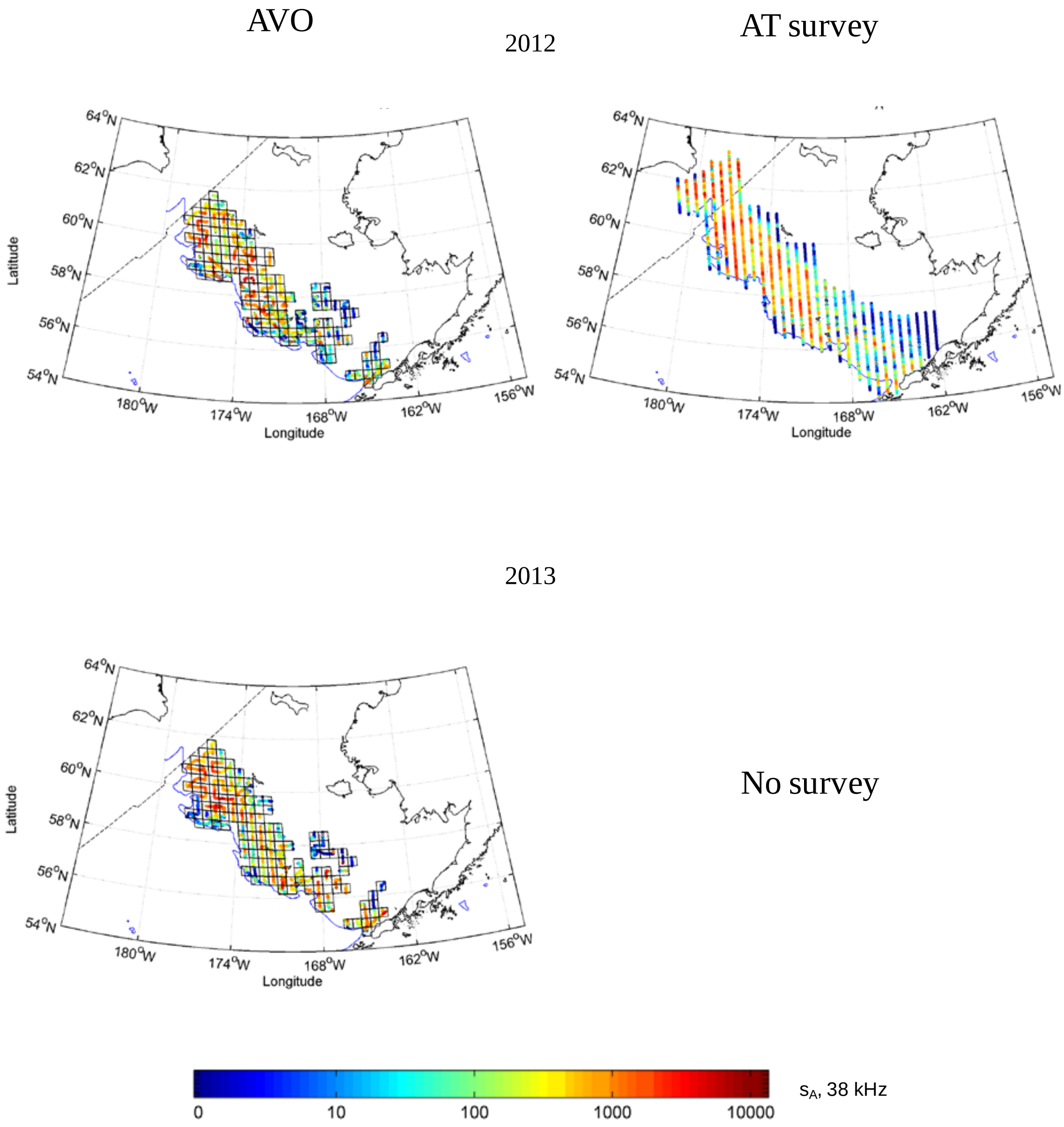

Figure 4. -- Relative pollock backscatter in 2012 and 2013, computed by multiplying pollock s_A (m^2 nmi^{-2}) in each acoustic vessel-of-opportunity (AVO) index grid cell (see Fig. 2) by grid cell area (400 nmi^2), summing along north-south columns of grid cells, and expressing the result as a proportion of all pollock backscatter in each year. For orientation, the location of the east and west boundaries of the U.S. Exclusive Economic Zone and the approximate longitude of St. Paul Island are indicated by text at the top of the plot.

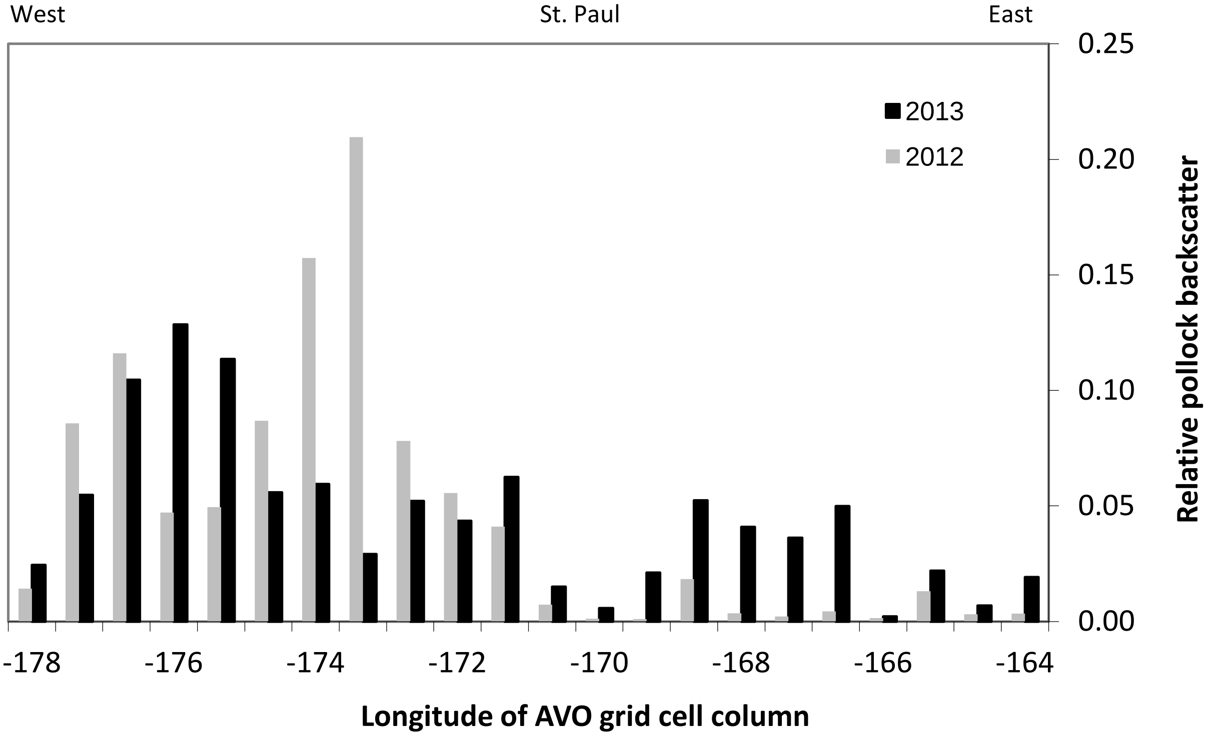

Figure 5. -- Spatial center of gravity estimates derived from pollock s_A from acoustic-trawl (AT) survey (open symbols) and acoustic vessel-of-opportunity index (filled symbols). The 100 and 200 m bathymetric contours are indicated in gray.