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Acoustic Vessel-of-Opportunity (AVO) Index for Midwater Bering Sea Walleye Pollock, 2016-2017

by

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ABSTRACT

An acoustic vessel of opportunity (AVO) index for midwater walleye pollock (*Gadus chalcogrammus*) in the eastern Bering Sea has been estimated since 2006 using backscatter information collected during the annual Alaska Fisheries Science Center bottom trawl (BT) survey. AVO index estimates for summer 2016 and 2017 are reported here. The 2016 AVO index decreased 19% and 14% from the 2015 and 2014 index values, respectively. The 2017 AVO index decreased slightly (6%) from 2016. Both estimates (2016, 2017) were similar to a number of previous years in the time series (2006, 2010, 2012-2013) based on overlapping 95% confidence intervals. Most pollock backscatter appeared to be distributed broadly across the shelf between 50 and 200 m isobaths in 2016 and 2017. The percentage of pollock backscatter east of the Pribilof Islands (east of 170° W longitude) in the AVO index was 22% in 2016 and 19% in 2017. This is much greater than the percentage in summers 2010-2012 (range 4-9%), but slightly less than that observed in 2013 (26%) and 2015 (25%), and much less than that observed in 2014 (33%). After a sharp increase in 2013-2014, the percentage of biomass of midwater pollock east of the Pribilof Islands is slowly declining. The correlation between the AVO index and AT survey time series was reduced with the addition of 2016 results ($r^2 = 0.76$, $p = 0.015$) because the AVO index did not increase in 2016 as did the AT survey biomass. Classification of AVO backscatter was more difficult than usual in summer 2017 in some parts of the AVO index area, increasing the uncertainty in the 2017 AVO index. Finally, the AT survey time series has historically measured the presence of walleye pollock found in midwater down to 3 m off bottom (“historic” AT time series; Honkalehto et al. in press). In 2016, this time series was altered to include pollock found down to 0.5 m off bottom (“new” AT time series). The AVO index was also compared to the new AT survey time series. It was equally well correlated ($r^2 = 0.76$, $p = 0.015$),

which suggests that AVO methodology correctly captures annual variation in both AT survey time series.

CONTENTS

INTRODUCTION

Walleye pollock (*Gadus chalcogrammus*, hereafter pollock) is a commercially important gadid fish species and the target of a major trawl fishery on the eastern Bering Sea shelf. The fishery-independent time series used to manage this valuable stock include data from two summer surveys conducted by the Alaska Fisheries Science Center. A bottom trawl (BT) survey is conducted annually to assess demersal pollock, as well as other commercially important groundfish and crab species (Conner et al. 2017). An acoustic-trawl (AT) survey is currently conducted biennially (intervals ranged from 1 to 3 years in the past) to assess midwater pollock (Honkalehto et al. in press). In an effort to obtain annual information for midwater pollock, Honkalehto et al. (2011) used acoustic backscatter at 38 kHz collected by BT survey vessels for a portion of the eastern Bering Sea shelf, from near surface to 3 m off bottom, to develop an abundance index that was strongly correlated with the total biennially estimated AT survey pollock biomass ($r^2 = 0.90$, $p = 0.001$, 2006-2014; Honkalehto et al. 2017). This abundance index from vessels of opportunity (AVO) is estimated annually. It is an important component of the Bering Sea pollock stock assessment because it provides information on midwater pollock in years when the AT survey is not conducted (Ianelli et al. 2016). This report updates and discusses AVO index results for summers 2016 and 2017.

METHODS

Methods for estimating the AVO index are based on Honkalehto et al. (2011), who used a retrospective analysis to determine that summed 38 kHz backscatter from roughly half of the AT survey area (‘AVO index area’) was strongly correlated with total AT survey pollock biomass. These methods are briefly described here, emphasizing what pertains to index years 2016 and 2017.

2016

Both AT and BT surveys were conducted in summer 2016. The AT survey was conducted aboard the NOAA ship *Oscar Dyson* using standard acoustic-trawl survey methods as detailed in Honkalehto et al. (2008, 2017). The BT survey was conducted aboard the chartered vessels FV *Vesteraalen* and FV *Alaska Knight* (Conner et al. 2017). 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 nautical miles (nmi) intervals along the vessel track. Backscatter data were also collected at 120 kHz, but these were not used in the AVO index. Standard sphere calibrations were conducted for both 38 and 120 kHz acoustic systems immediately before (late May) and after (late July) the survey. First, split-beam target-strength (TS) and echo integration measurements of a tungsten carbide (38.1 mm diameter) sphere were made for each frequency once the sphere was centered on the respective beam axis (stationary sphere method; Foote et al. 1987). Next, on-axis sensitivity and beam characteristics such as along and athwart beam angles and angle offsets were estimated using the post-processing software bundled with the echosounder (calibration.exe; Simrad 2008), based on data collected from the sphere, which was moved throughout the four quadrants of each beam (moving sphere method; Foote et al. 1987).

2017

Only the BT survey was conducted during summer 2017. During 2017, the BT survey was extended northward. The data from this northern extension were not used in the AVO index calculation, but logistics surrounding this extension resulted in standard sphere calibrations being conducted before (early June) and halfway through (mid-July) the BT survey (the latter calibration occurred two-thirds of the way though the portion of the BT survey that was used to calculate the 2017 AVO index). The calibrations were conducted and processed as described for 2016. On 11 June 2017, it was discovered that the FV *Vesteraalen* ES60 had not been recording GPS position data since the third day of the cruise on 4 June. GPS data were, however, being recorded by Globe navigation software (Electronic Charts Company, Inc., Seattle, USA) and written to log files. The times from ES60 raw data were compared to the times from Globe log files. Based on the times of interest, the corresponding GPS data from the Globe files were inserted into the ES60 raw data structure for each ES60 raw file, creating a new ES60 raw file containing GPS data.

Backscatter Data Classification and Processing

The 38 kHz backscatter collected in the AVO 'index area' during 2016-2017 was either classified semi-automatically using custom software (Python Software Foundation, https://www.python.org), or classified manually by trained analysts using Echoview software (Echoview Software Pty Ltd, Hobart, Australia). Semi-automatic classification assumed all backscatter between 30 m from the sea surface and 3 m from the sea floor was pollock. Manual classification was required in regions where the retrospective study had revealed species composition to be less certain. Experts classified all backscatter in these regions from 16 m below the surface to within 0.5 m of the bottom into approximately half a dozen taxonomic categories based on the concept that the eastern Bering Sea midwater fish community is dominated by pollock and relatively few other acoustically important species (Honkalehto et al. 2002, De Robertis et al. 2010). Generally, a line was drawn in Echoview below a near-surface layer attributed to a variable mixture of plankton and unidentified fishes. Nearly all midwater fish aggregations between that line and a line 0.5 m off bottom were attributed to age-1+ pollock, with a few exceptions (e.g., backscatter attributed to jellyfish, other fish, age-0 pollock, or dense euphausiid layers were also excluded). All data were stored in an Oracle database at 10 m vertical by 926 m (0.5 nmi) horizontal resolution. Pollock backscatter from both semi-automatic and manual classification procedures was vertically integrated, averaged into 37 × 37 km (20 nmi × 20 nmi) blocks surrounding BT survey bottom trawl stations, and summed across the index area to compute the AVO index.

Relative Estimation Error and Spatial Distribution

The 1-D geostatistical relative estimation errors (Petitgas 1993) and approximate 95% confidence intervals describing sampling variability were calculated for 2016 and 2017 AVO index values following methods described by Honkalehto et al. (2011). Maps of acoustic backscatter and center of gravity estimates (Bez et al. 1997; Woillez et al. 2007, 2009) were used to compare pollock distribution patterns from the AVO index and the AT survey.

A New Time Series for the AT Survey

The AT survey time series has historically measured the presence of walleye pollock found in midwater down to 3 m off bottom (“historic” AT time series; Honkalehto et al. in press). In 2016, this time series was altered to include pollock found down to 0.5 m off bottom (“new” AT time series; see Fig. 19 in Honkalehto et al. in press). Both the historic and new AT survey time series were compared with the AVO index to determine whether it was reasonable to continue to use the AVO index produced by current methods. Unless stated otherwise, the remainder of this report references the historic AT survey time series.

Questionable Backscatter in the 2017 AVO Index

In 2017 there appeared to be a relatively large amount of questionable backscatter (QBS) in the water column. The backscatter was deemed 'questionable' because it was difficult to classify and did not have the same appearance as typical pollock or plankton backscatter that has been observed in the past (Honkalehto et al. in press). The QBS looked like fish backscatter, but it was unclear whether it was age-1+ pollock, age-0 pollock, or something else. Typically, this backscatter was in the upper 30-40 m of the water column, but it was not uncommon for it to extend down deeper, sometimes all the way to the seafloor. To exclude this backscatter from the AVO index and quantify how prevalent it was in 2017, manually processed backscatter data containing QBS was classified as a separate non-pollock category and not included in the AVO index computation. Additionally, during routine quality checks of semi-automatically processed data (i.e., the visual inspection of all 0.5 nmi intervals where total backscatter was ≤ 1,200 s_A ($m^2 nmi^{-2}$), 0.5 nmi intervals containing QBS were flagged and not included in the AVO index.

RESULTS

Calibration

The integration gain used for 2016 38-kHz backscatter data for FV *Alaska Knight* was based on the mean of May and July 2016 calibrations (results of the two calibrations differed by about 9%). The gain used for FV *Vesteraalen* in 2016 was based on the May calibration, whose results were deemed more reliable since conditions were poor for the July calibration. The integration gains used for 2017 38-kHz backscatter data for both the *Alaska Knight* and *Vesteraalen* were based on the mean of June and July calibrations (results of the two calibrations differed by about 10% and 22%, respectively). There were small to moderate changes to the 38 kHz final integration gain values used in 2017 compared to those used in 2016 (6% for *Alaska Knight*, 16% for *Vesteraalen*).

Biomass

The 2016 AVO index decreased 19% from the 2015 index value and 14% from the 2014 index value (Table 1, Fig. 1a). The 2017 AVO index decreased slightly (6%) from 2016. Both estimates (2016, 2017) were similar to a number of previous years in the series (2006, 2010, 2012-2013) based on overlapping 95% confidence intervals. The 2016 and 2017 confidence intervals overlapped with each other, but not with the two prior years (2014, 2015) in the time series. For comparison, the summer 2016 AT survey estimate of midwater pollock biomass increased 18% over that from the previous AT survey conducted in 2014 (Fig. 1b). Because the AT survey time series increased in 2016 while the AVO index decreased, comparison of the AVO index and AT survey time series shows a reduced, but still strong, correlation ($r^2 = 0.76$, $p = 0.015$, Fig. 2a).

Spatial Distribution

Midwater pollock backscatter from the AVO index and AT survey exhibited similar spatial patterns across the eastern Bering Sea (EBS) shelf in 2016 (Fig. 3). Most pollock backscatter appeared to be distributed in a broad band throughout the center of the AT and AVO survey areas between the 50 and 200 m isobaths. AVO pollock backscatter data show this relatively widespread distribution pattern in 2013-2015 and 2017 as well (Fig. 3, and see Honkalehto et al. 2014 and Honkalehto et al. 2017). This even distribution is reflected in the lower relative estimation errors for 2013-2017 compared with the earlier years of the time series (Table 1).

The percentage of pollock backscatter east of the Pribilof Islands (east of 170° W longitude) in the AVO index was 22% in 2016 and 19% in 2017 (Figs. 3, 4). Both values are much greater than the percentage in summers 2010-2012 (range 4-9%), slightly less than that observed in 2013 (26%) and 2015 (25%), and much less than that observed in 2014 (33%). Also, the pollock center of gravity estimates from both the AVO index and the AT survey for 2013-2017 were east of those for most other years in the time series, though 2016 and 2017 data indicate that the center of gravity has begun to shift back towards the north and west (Fig. 5). Finally, the percentage of AT survey biomass inside the AVO index area was 65% in 2016. This is very similar to the percentage in 2014 (66%) but lower than in earlier years of the time series (ca. 85% was typical), reflecting the relatively substantial (though slowly declining) amount of midwater pollock biomass in the index area along the southeast shelf east of the Pribilofs in 2016 and 2017, an area where there are fewer AVO index grid cells (Fig. 5).

New AT Survey Time Series

Historic (down to 3 m above the seafloor) and new (down to 0.5 m above the seafloor) AT survey time series generally show the same trends over time (Fig. 1b), though there are differences in some years. For example, the new AT survey time series showed only a 2% increase in biomass from 2014 to 2016, compared to an 18% increase in the historic AT survey time series between these two years (Table 1). Overall, the AVO index shows the same strong correlation to the new AT survey time series ($r^2 = 0.76$, $p = 0.015$, Fig. 2b) as it does to the historic AT survey time series.

Questionable Backscatter

There were 49 AVO index grid cells (35.5% of the total number of AVO grid cells) that contained QBS in 2017 (Fig. 6). These cells were located predominately in the eastern half of the AVO index area. Of these 49 cells, 38 were cells that were manually classified. The grid cells that contained QBS also contained 8% of the pollock s_A within the index area.

DISCUSSION

The AVO index indicated less midwater pollock biomass in 2016-2017 than it had in the two previous years (2014-2015), but similar midwater pollock biomass to several previous years in the time series (2010-2013). Also, the AVO index indicated that the relative proportion of midwater pollock east of 170° W decreased in 2016-2017 relative to 2013-15 (Figs. 3-4), though this proportion was still substantial compared to prior years in the time series, and secondly that the progression of pollock center of gravity estimates had shifted back to the northwest (Fig. 5). Both of these spatial changes suggest a gradual return to spatial patterns in midwater pollock seen prior to 2013.

The AT survey time series indicated a moderate increase in midwater pollock biomass between 2014 and 2016, while the AVO index time series did not. There are fewer AVO index area cells east than west of 170° W, and less of the AT survey pollock biomass occurred in the AVO index area in 2014-2016 than in prior years. Thus, it is possible that the biomass increase on the eastern shelf detected by the AT survey in 2016 was underrepresented by the AVO index. Such changes in pollock distribution reinforce the value of continuing to monitor the correlation between the AVO index and AT survey biomass.

The continued strong correlation between the AVO index pollock backscatter and both the historic and new AT survey biomass time series suggests that AVO methodology correctly captures annual variation in both AT survey time series (Figs. 1, 2). The presence of QBS in some parts of the 2017 AVO index area likely increased the uncertainty of the 2017 AVO index, but since the contribution of pollock backscatter from grid cells with QBS to AVO index backscatter was small (8.0%), the increase in uncertainty was likely very modest.

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

	Historic AT survey time series				New AT survey time series				
	AT survey biomass (million metric tons)	AT survey biomass (scaled to mean 1999-2004)	95% CI	Relative estimation error (CV_{AT})	AT survey biomass (million metric tons)	[a]95% CI	AVO index (scaled to mean 1999-2004)	95% CI	Relative estimation error (CV_{AVO})
2006	1.560	0.470	0.0362	0.0393	1.8729	0.1872	0.555	0.0555	0.0510
2007	1.769	0.534	0.0469	0.0449	2.2779	0.3864	0.638	0.1082	0.0865
2008	0.997	0.301	0.0450	0.0764	1.4056	0.1772	0.316	0.0399	0.0643
2009	0.924	0.279	0.0481	0.0881	1.3248	0.3125	0.285	0.0672	0.1203
2010	2.323	0.701	0.0831	0.0605	2.6423	0.4445	0.679	0.1142	0.0858
2011	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	0.543	0.0609	0.0572
2012	1.843	0.556	0.0458	0.0421	2.2958	0.2572	0.661	0.0809	0.0625
2013	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	0.694	0.0531	0.0390
2014	3.439	1.037	0.0944	0.0464	4.7300	0.5790	0.897	0.0752	0.0428
2015	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	0.953	0.0852	0.0456
2016	4.063	1.225	0.0505	0.0210	4.8290	0.3695	0.776	0.0555	0.0365
2017	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	NO SURVEY	0.730	0.0489	0.0342

[a]The 95% confidence interval for the new AT survey time series was calculated using the relative estimation error for the historic AT survey time series of that same year.

Figure Captions

Figure 1. -- Acoustic vessel-of-opportunity (AVO) Index estimates for 2006-2017 from the BT survey (a) and corresponding historic and new acoustic-trawl (AT) survey biomass estimates in the U.S. Exclusive Economic Zone (EEZ; b). Error bars are 95% confidence intervals based on 1-D geostatistical estimates of sampling variability. For a given year, the 95% confidence interval for the new AT survey time series was calculated using the relative estimation error for the historic AT survey time series of that same year. The AVO index was scaled to its mean value for the period 1999-2004.

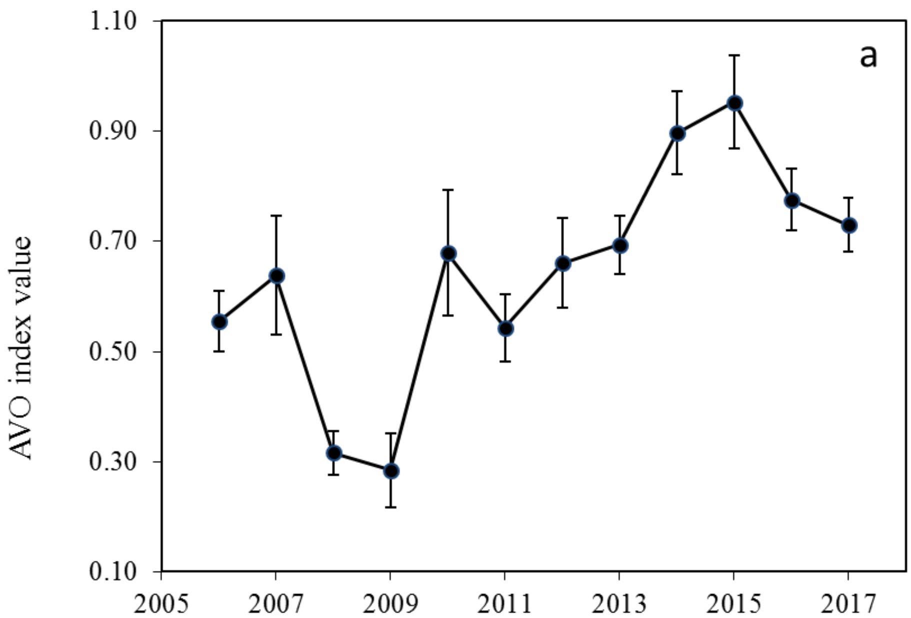
Figure 2. – Regression of the historic (a) and new (b) acoustic-trawl (AT) survey biomass (million metric tons) on the acoustic vessel-of-opportunity (AVO) index value, 2006-2017.

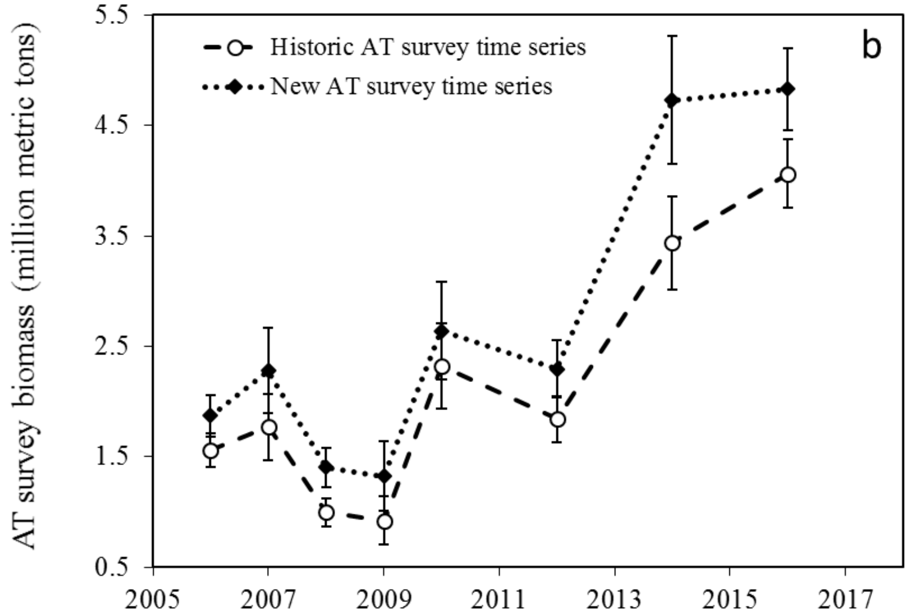
Figure 3. -- Pollock s_A (m^2 nmi^{-2}) in acoustic vessel-of-opportunity (AVO) index (left column) and acoustic-trawl (AT) survey (right column) data sets, 2016-2017. The bottom trawl (BT) survey grid cells used for the AVO index are shown in the left column. The AT survey in 2016 is reflective of the new survey time series (includes biomass down to 0.5 m off bottom). There was no AT survey in 2017. 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 color scale is logarithmic.

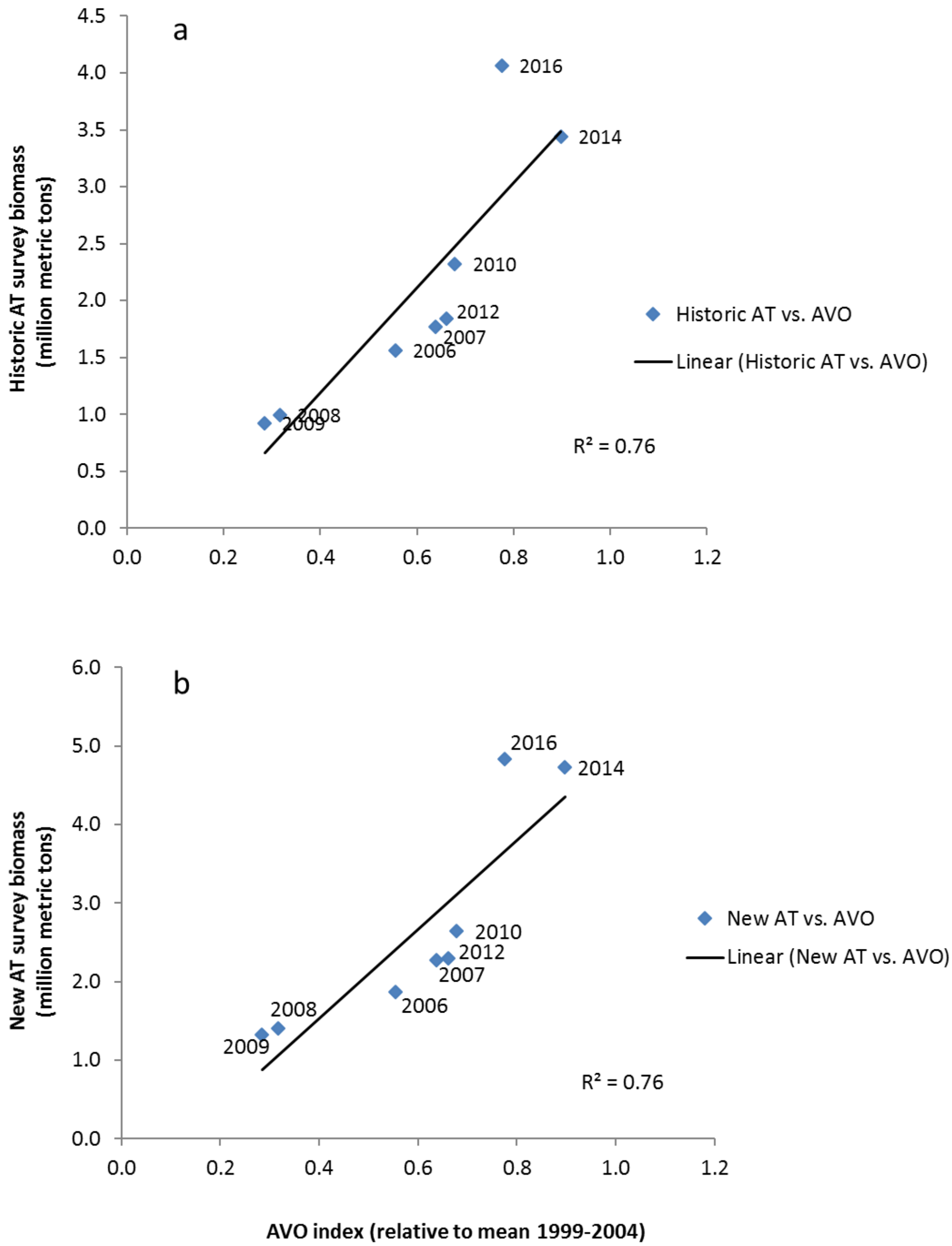
Figure 4. -- Relative pollock backscatter trends since 2012 (including 2012, 2014, 2016, and 2017) computed by summing pollock s_A (m^2 nmi^{-2}) along north-south columns of grid cells, and expressing the result as a proportion of all pollock backscatter in each year. For orientation, the location of the east and west boundaries of the U.S. Exclusive Economic Zone and the approximate longitude of St. Paul Island are indicated at the top of the plot.

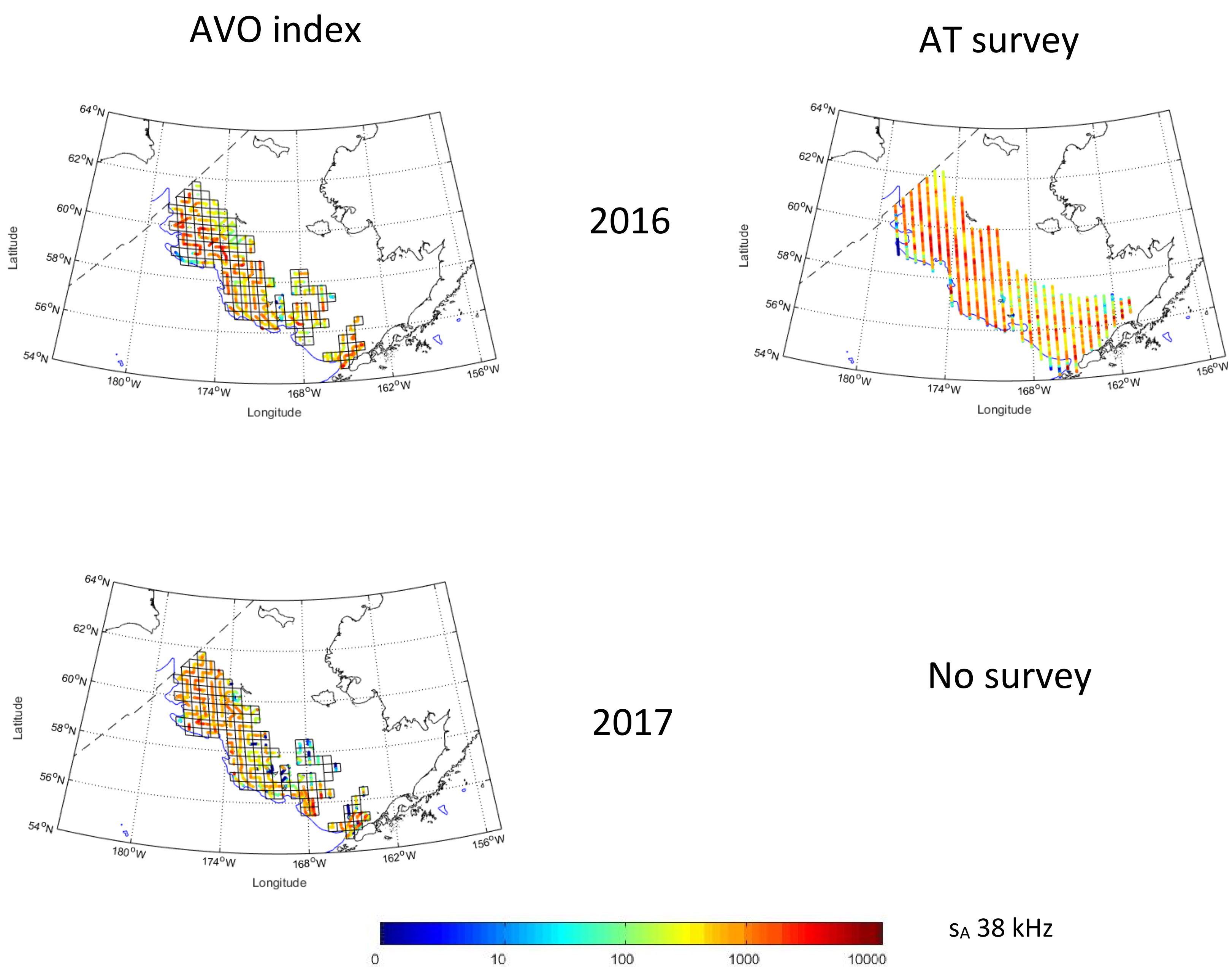
Figure 5. -- Geographic center of gravity estimates derived from pollock s_A (m^2 nmi^{-2}) from acoustic-trawl (AT) survey (black circles) and acoustic vessel-of-opportunity index (red squares) based on the historic AT time series. The 100 and 200 m bathymetric contours are indicated in gray.

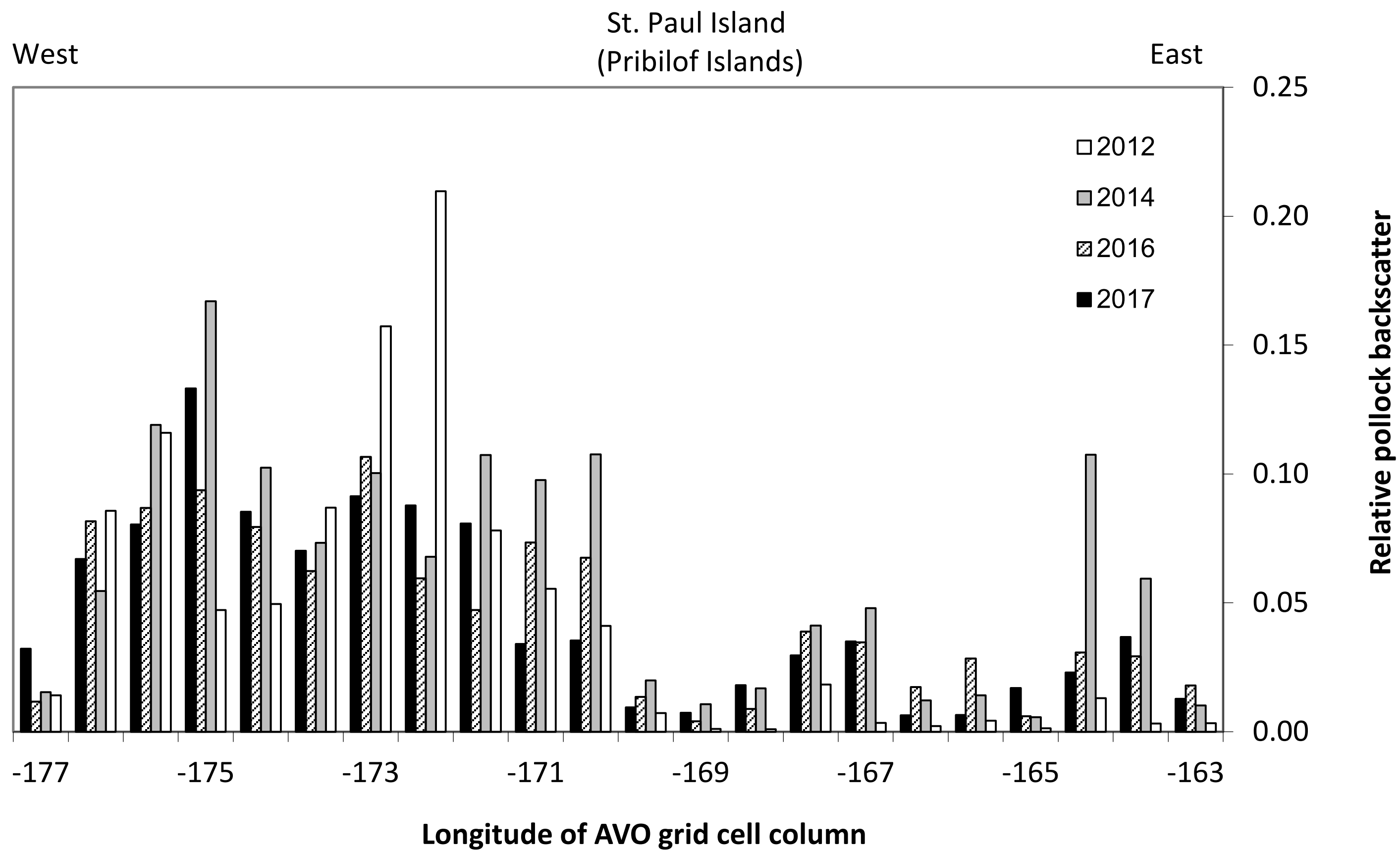
Figure 6. -- Pollock s_A (m^2 nmi^{-2}) in the 2017 acoustic vessel-of-opportunity (AVO) data set. Grid cells containing questionable backscatter (QBS) are outlined in pink.


a
AVO index value
1.10
0.90
0.70
0.50
0.30
0.10
2005
2007
2009
2011
2013
2015
2017

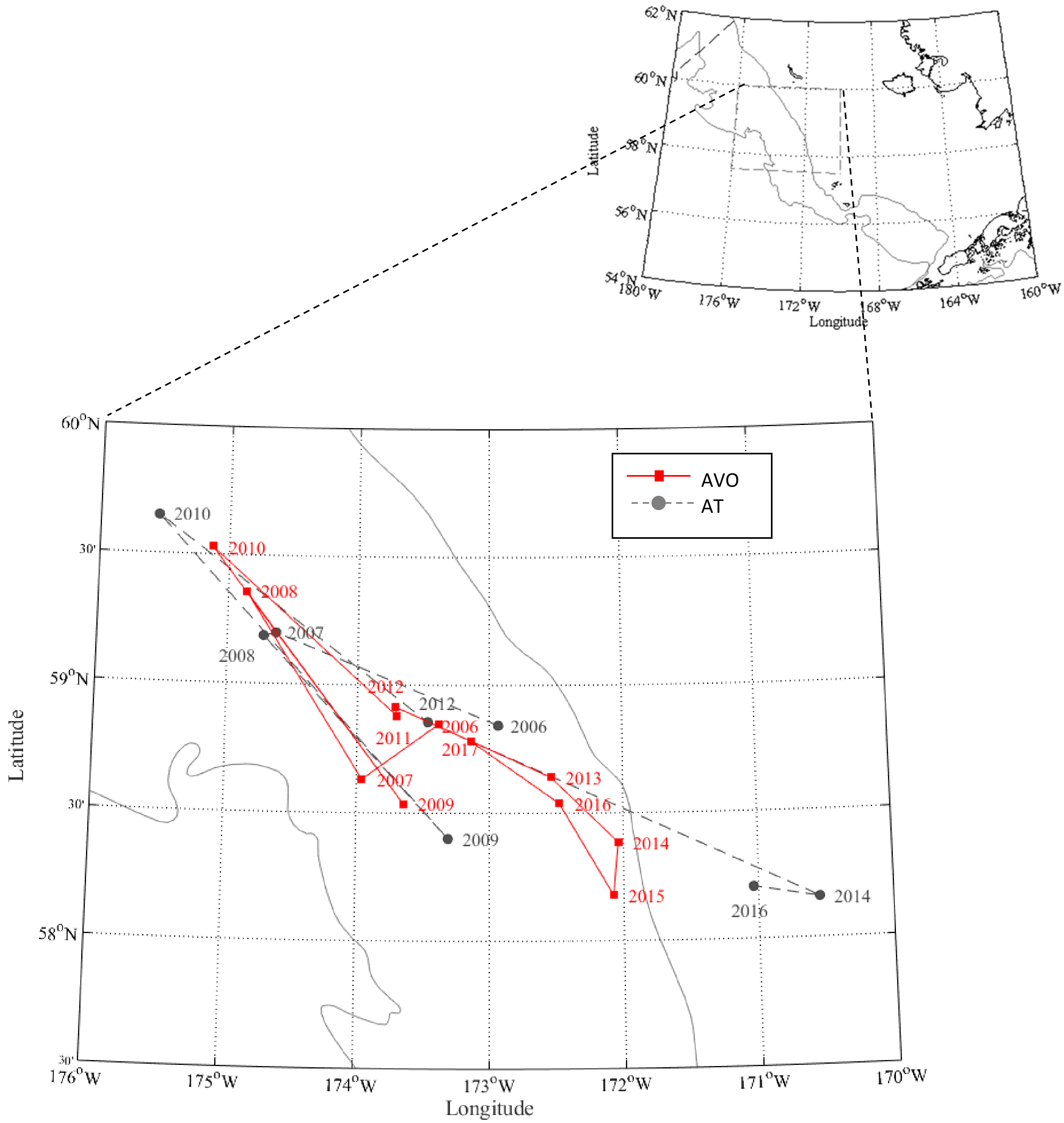

b
Historic AT survey time series
New AT survey time series
AT survey biomass (million metric tons)
5.5
4.5
3.5
2.5
1.5
0.5
2005
2007
2009
2011
2013
2015
2017

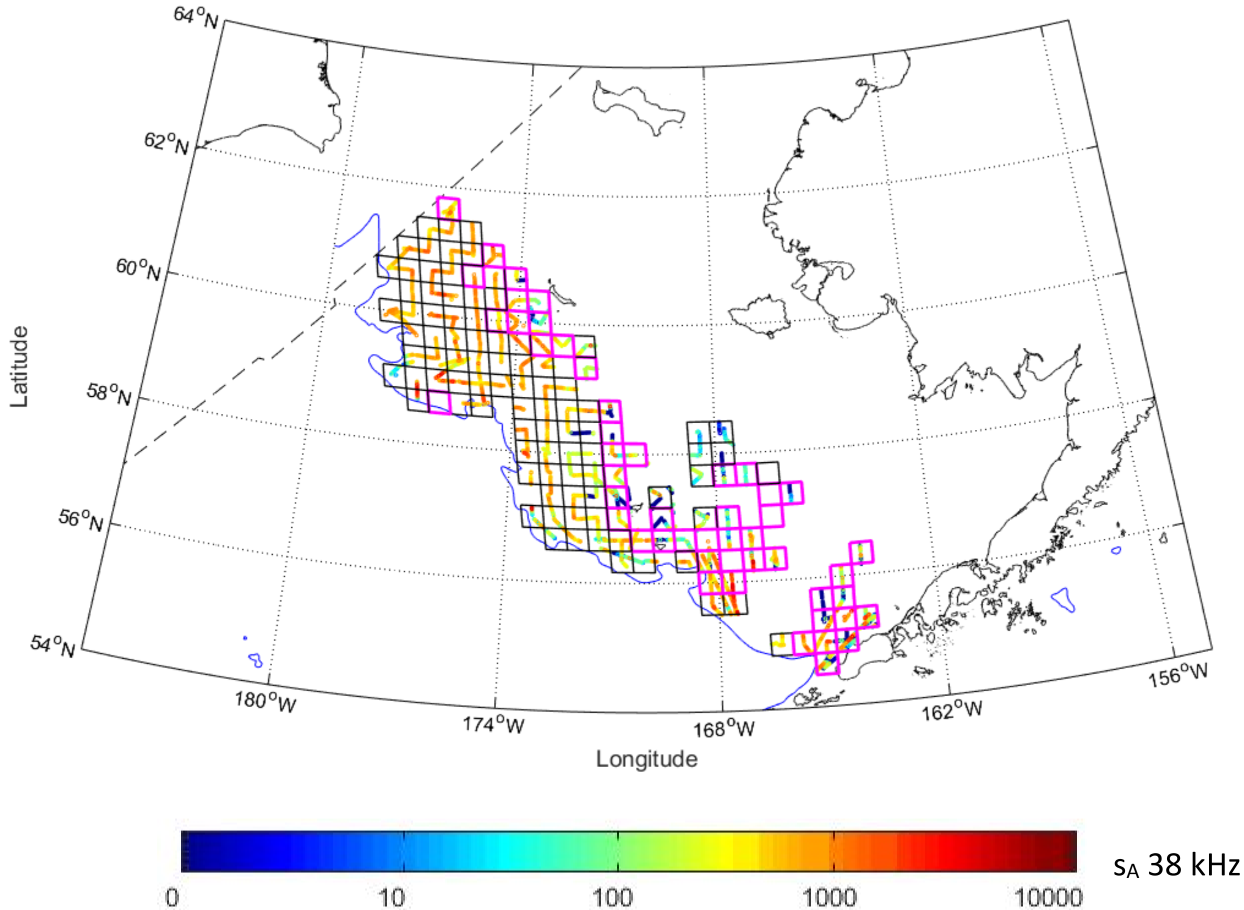

a
Historic AT survey biomass (million metric tons)
2016
2014
2010
2012
2007
2006
2008
2009
Historic AT vs. AVO
Linear (Historic AT vs. AVO)
R² = 0.76
b
New AT survey biomass (million metric tons)
2016
2014
2010
2012
2007
2006
2008
2009
New AT vs. AVO
Linear (New AT vs. AVO)
R² = 0.76
AVO index (relative to mean 1999-2004)


AVO index
AT survey
2016
2017
No survey
64°N
62°N
60°N
58°N
56°N
54°N
180°W
174°W
168°W
162°W
156°W
Latitude
Longitude
0
10
100
1000
10000
s_A 38 kHz



West
St. Paul Island
(Pribilof Islands)
East
2012
2014
2016
2017
0.25
0.20
0.15
0.10
0.05
0.00
Relative pollock backscatter
-177
-175
-173
-171
-169
-167
-165
-163
Longitude of AVO grid cell column


AVO
AT
2010
2008
2007
2012
2011
2006
2017
2013
2016
2009
2014
2015
Latitude
Longitude
60°N
59°N
58°N
176°W
175°W
174°W
173°W
172°W
171°W
170°W
62°N
56°N
54°N
180°W
168°W
164°W
160°W


64°N
62°N
60°N
58°N
56°N
54°N
Latitude
180°W
174°W
168°W
162°W
156°W
Longitude
0
10
100
1000
10000
sA 38 kHz