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Alaska Fisheries Science Center
Resource Assessment and Conservation Engineering Division
Midwater Assessment and Conservation Engineering Program

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Acoustic Vessel-of-Opportunity (AVO) Index for Midwater Bering Sea Walleye Pollock, 2018-2019

by

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ABSTRACT

An acoustic vessel of opportunity (AVO) index for age 1+ 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 2018 and 2019 are reported here. The 2018 AVO index decreased 8% and 13.5% from the 2017 and 2016 index values, respectively. The 2019 AVO index increased slightly (1%) from 2018. Both estimates (2018, 2019) were similar to a number of previous years in the time series (2007, 2010, 2012-2013, 2016-2017) based on overlapping 95% confidence intervals. Most pollock backscatter appeared to be distributed broadly across the shelf between 50 and 200 m isobaths in 2018 and 2019. The percentage of pollock backscatter east of the Pribilof Islands (east of 170° W longitude) in the AVO index was 15% in 2018 and 24% in 2019. This is much greater than the percentage in summers 2010-2012 (range 4-9%), 2018 was less than that observed in 2016 (22%) and 2017 (19%), but 2019 was similar to that observed in 2013-2015 (ca. 25%). The relationship between the AVO index and AT survey time series was slightly reduced with the addition of 2018 results ($R^2 = 0.74$, $p = 0.003$). The presence of fish backscatter in the upper 30 m of the water column in some areas throughout the AVO regions during both 2018 and 2019 was assumed to be young-of-the-year (age-0) pollock, and it was therefore excluded from the 2018 and 2019 AVO indices. The uncertainty associated with the correct classification of this shallow backscatter was minimal in 2018 (3% of the 2018 index) but more significant in 2019 (13% of the 2019 index).

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 (Lauth et al. 2019). An acoustic-trawl (AT) survey is currently conducted biennially (intervals ranged from 1 to 3 years in the past) to assess midwater age 1+ pollock (McCarthy et al. in review). In an effort to obtain annual information for midwater pollock, Honkalehto et al. (2011) used acoustic backscatter at 38 kHz collected by BT charter 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 estimated AT survey pollock biomass (r^2 = 0.76, p = 0.015, 2006-2016; Stienessen et al. 2019). 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. 2018). This report updates and discusses AVO index results for summers 2018 and 2019.

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 2018 and 2019.

2018

Both AT and BT surveys were conducted in summer 2018. The AT survey was conducted aboard the NOAA ship *Oscar Dyson* using standard acoustic-trawl survey methods and 38 kHz backscatter data as detailed in Honkalehto et al. (2008) and McCarthy et al. (in review). The AT 2018 acoustic survey did not survey the last three transects (i.e., the western-most transects) of the survey area due to vessel mechanical problems. The biomass from this western-most area was determined with nearest haul information collected during the AT survey coupled with backscatter data collected during EBS BT charter vessel surveys that same year (McCarthy et al. 2019 in review).

The BT survey was conducted aboard the chartered vessels FV *Vesteraalen* and FV *Alaska Knight* (Lauth et al. 2019). The BT survey was extended northward on the *Alaska Knight*, but the data from this northern extension were not used in the AVO index calculation. The logistics surrounding this extension resulted in the second standard sphere calibration on the *Alaska Knight* being at the end of the survey (mid-Aug), almost 3 weeks after the portion of the BT survey that was used to calculate the 2018 AVO index. 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; however, these were not used in the AVO index. Standard sphere calibrations were conducted for both 38 and 120 kHz acoustic systems immediately before (early June) and after (early Aug. on the *Vesteraalen* and mid-Aug on the *Alaska Knight*) 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 (Demer et al. 2015). 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 (Demer et al. 2015).

2019

Only the BT survey was conducted during summer 2019. The BT survey was extended northward on both ships, as it was in 2017. 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 (late May) 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 2019 AVO index). The calibrations were conducted and processed as described for 2018, except 120 kHz data were not collected on the *Vesteraalen*. During the first leg of the cruise (end of May through mid-June), the FV *Vesteraalen* ES60 had not been recording GPS position data. GPS data were, however, being recorded by Globe navigation software (Electronic Charts Company, Inc., Seattle, USA) and written to log files. The date-time stamps from ES60 raw data were matched to the date-time stamps from Globe log files. The corresponding GPS data from the Globe files matched in time were inserted into the ES60 raw data structure for each ES60 raw file, creating new ES60 raw files containing GPS data.

Backscatter Data Classification and Processing

The 38 kHz backscatter data collected in the AVO index area during 2018-2019 were 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 was used in regions where we assumed all backscatter between 30 m from the sea surface and 3 m from the seafloor was pollock based on the concept that the eastern Bering Sea midwater fish community has historically been dominated by pollock with relatively few other acoustically important species (Honkalehto et al. 2002, De Robertis et al. 2010, Honkalehto et al. 2011). Manual classification was required in regions where the retrospective study had revealed species composition to be less certain, often due to the presence of non-fish backscatter interspersed among pollock backscatter. Backscatter data in the latter regions were first subsampled by 10% (i.e., a 50 consecutive ping subsample was taken out of every 500 pings of data; Levine and De Robertis 2019) and filtered to include data collected only during daylight hours and when the vessel speed was > 4 kts. Trained analysts then classified all subsampled 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. 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 excluded). All data were stored in an Oracle database at 10 m vertical by 926 m (0.5 nmi) horizontal resolution. Pollock backscatter data from both semi-automatic and manual classification procedures were vertically integrated to 3 m from the seafloor , 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 2018 and 2019 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.

Age-0 Pollock Backscatter in the 2018-2019 AVO Indices

In both years there appeared to be fish backscatter in the upper 30 m of the water column in some areas throughout the AVO regions. The backscatter was assumed to be young-of-the-year (age-0) pollock and therefore excluded from the analyses. This concern only applied to the hand-processed data in the AVO index because backscatter found < 30 m from the surface is never included in the semi-automatically processed data according to AVO methods.

RESULTS

Calibration

The integration (i.e., Sv) gain values used for 2018 38-kHz backscatter data for both the *Alaska Knight* and *Vesteraalen* were based on the mean of June and August calibrations. The integration gain values used for 2019 38-kHz backscatter data for both the *Alaska Knight* and *Vesteraalen* were based on the mean of May and July calibrations. The system settings were more stable on the *Vesteraalen* than on the *Alaska Knight*, both within and between years (Table 1). There was a moderate change to the 38 kHz final integration gain values used in 2019 compared to those used in 2018 for the *Alaska Knight* (17%) and a smaller change for the *Vesteraalen* (8%).

Biomass

The 2018 AVO index decreased 8% from the 2017 index value and 13.5% from the 2016 index value (Table 2, Fig. 1a). The 2019 AVO index increased slightly (1%) from 2018. Both estimates (2018, 2019) were similar to a number of previous years in the series (2007, 2010, 2012-2013, 2016-2017) based on overlapping 95% confidence intervals. That is, with the exception of higher values in 2014-2015, the estimates in the time series have remained relatively constant since 2012 (Fig. 1b). Comparison of the AVO index and AT survey time series continues to show a strong relationship ($R^2 = 0.74$, $p = 0.003$ for 2006-2018; Fig. 2a). This is reduced from its value in earlier years ($R^2 = 0.90$, $p = 0.001$ for 2006-2014; Honkalehto et al. 2017) because in 2016 the AT survey time series increased while the AVO index decreased.

Spatial Distribution

Midwater pollock backscatter from the AVO index and AT survey exhibited similar spatial patterns across the eastern Bering Sea (EBS) shelf in 2018 (Fig. 3). Most pollock backscatter appeared to be distributed evenly 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 2013-2017 and 2019 as well (Fig. 3, and see Honkalehto et al. 2014, 2017 and Stienessen et al. 2019). This even distribution is reflected in the lower relative estimation errors for 2013-2019 compared with the earlier years of the time series (Table 2).

There have been subtle changes among years in the location of the majority of the pollock backscatter over the index area within their area of distribution. Specifically, a proportion of the pollock backscatter has oscillated between the northwest and southeast of the index area over the years. Prior to 2013, the majority of the pollock backscatter had been observed in the northwest half of the index area. The percentage of pollock observed west of the Pribilof Islands ranged from 91 to 96% during 2010-2012, the center of gravity estimates were west of 173˚ W (Fig. 5), and the percentage of AT survey biomass inside the AVO index area was around 85% (Honkalehto et al. 2014). This began to change in 2013 as a larger proportion of pollock backscatter was in the southeast and outside the index area. During 2013-2015 the percentage of pollock observed west of the Pribilof Islands decreased to ca. 75%, the center of gravity estimates migrated east to almost 172˚ W (Fig. 5), and the percentage of AT survey biomass inside the AVO index decreased to 66% (Honkalehto et al. 2017). However, pollock backscatter began to shift back to the northwest in 2016 and move back into the index area by 2018. During 2016-2018 the percentage of pollock observed west of the Pribilof Islands increased to 85% and the center of gravity estimates migrated west of 173˚ W again. In 2018 the percentage of AT survey biomass inside the AVO index increased to 78% (from 65% in 2016). Finally, in 2019, pollock backscatter shifted back to the southeast: the percentage of pollock observed west of the Pribilof Islands decreased to 76% and the center of gravity estimate shifted east of 173˚ W (Fig. 5).

Age-0 Pollock Backscatter

If the backscatter classified as age-0 were included in the 2018 and 2019 indices (i.e., if we assume it is really age-1+ pollock), the index would increase by 3.5% in 2018 and by 13% in 2019.

DISCUSSION

The 2018-2019 AVO index indicated similar midwater pollock backscatter to most years since 2012, with the exception of 2014-2015 -- years that contained the highest index values in the time series. Likewise, the 2018 AT time series indicated a similar midwater pollock biomass estimate to 2012; however, both 2014 and 2016 contained the highest AT survey biomass estimates in the time series. That is, there was a significant rise in index values for both series between 2012 and 2014. The AVO index began a gradual decrease in 2016, whereas the AT index did not decline until 2018. Even so, the overall trend between the two time series is similar (Fig. 1), confirming that the AVO index is still valuable information for the stock assessment in years when an AT survey is not conducted.

During the period when the AVO index was highest, there was relatively more pollock in the southeast and outside of the AVO index area. Likely drivers of change in abundance and spatial distribution include a) movement of historically strong 2012 and 2013 year classes through the population (Honkalehto and McCarthy 2015, Honkalehto et al. 2018) and b) a small or non-existent 'cold pool' (Kotwicki and Lauth 2013, Ianelli et al. 2015).

The continued strong correlation between the AVO index pollock backscatter and the AT survey biomass time series suggests that AVO methodology correctly captures annual variation in the AT survey time series (Figs. 1, 2). The classification of age-0 pollock in some parts of the 2018 and 2019 AVO index areas likely increased the uncertainty of the AVO index for both years, but because the amount of this backscatter was small in 2018 (3.5%), the increase in uncertainty was likely very modest. However, the amount of this backscatter was larger in 2019 (13%), making the increase in uncertainty more significant for that year. This higher uncertainty may be expected to repeat in the future when there is questionable backscatter and we are uncertain whether to classify it as young-of-the-year pollock, age-1+ pollock, or 'other'.

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Table 1. -- Acoustic system descriptions and settings obtained from sphere calibrations used to process acoustic data for the summer 2018-2019 BT surveys of the Bering Sea shelf.

Year	2018						2019					
Vessel	*Alaska Knight*			*Vesteraalen*			*Alaska Knight*			*Vesteraalen*		
	June	Aug	Final	June	Aug	Final	May	July	Final	May	July	Final
Simrad Echosounder	--	--	ES60	--	--	ES60	--	--	ES60	--	--	ES60
Transducer depth (m)	--	--	3 m	--	--	4.5 m	--	--	3 m	--	--	4.5 m
Pulse length (ms)	--	--	1.024	--	--	1.024	--	--	1.024	--	--	1.024
Transmitted power (W)	--	--	2000	--	--	2000	--	--	2000	--	--	2000
2-Way beam angle (dB)	--	--	-20.69	--	--	-19.89	--	--	-20.69	--	--	-19.89
Gain (dB)	24.83	25.01	24.92	24.56	24.44	24.50	24.85	24.86	24.85	24.40	24.35	24.38
Sa correction (dB)	-0.54	-0.59	-0.56	-0.62	-0.60	-0.61	-0.58	-0.57	-0.58	-0.66	-0.65	-0.65
Integration gain (dB)	24.29	24.42	24.35	23.94	23.84	23.89	24.27	24.28	24.27	23.74	23.70	23.72
Absorption coefficient (dB/m)	0.00996	0.00907	0.00998	0.00999	0.00929	0.00998	0.00979	0.00961	0.00998	0.00987	0.00967	0.00998
Sound velocity (m/s)	1468.4	1488.5	1470.0	1468.1	1485.6	1470.0	1473.0	1480.0	1470.0	1470.9	1478.7	1470.0

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

Table 2. -- 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.

	"CV_{AT}"		"CV_{AVO}"		
	New AT survey time series				
	AT survey biomass (million metric tons)	95% CI	AVO index (scaled to mean 1999-2004)	95% CI	Relative estimation error (CV_{AVO})
2006	1.8729	0.1230	0.555	0.0555	0.0510
2007	2.2779	0.1670	0.638	0.1082	0.0865
2008	1.4056	0.1530	0.316	0.0399	0.0643
2009	1.3248	0.1780	0.285	0.0672	0.1203
2010	2.6423	0.2770	0.679	0.1142	0.0858
2011	NO SURVEY	NO SURVEY	0.543	0.0609	0.0572
2012	2.2958	0.1530	0.661	0.0809	0.0625
2013	NO SURVEY	NO SURVEY	0.694	0.0531	0.0390
2014	4.7300	0.3190	0.897	0.0752	0.0428
2015	NO SURVEY	NO SURVEY	0.953	0.0852	0.0456
2016	4.8290	0.1770	0.776	0.0555	0.0365
2017	NO SURVEY	NO SURVEY	0.730	0.0489	0.0342
2018	2.4994	0.1930	0.672	0.0442	0.0336
2019	NO SURVEY	NO SURVEY	0.680	0.0426	0.0319

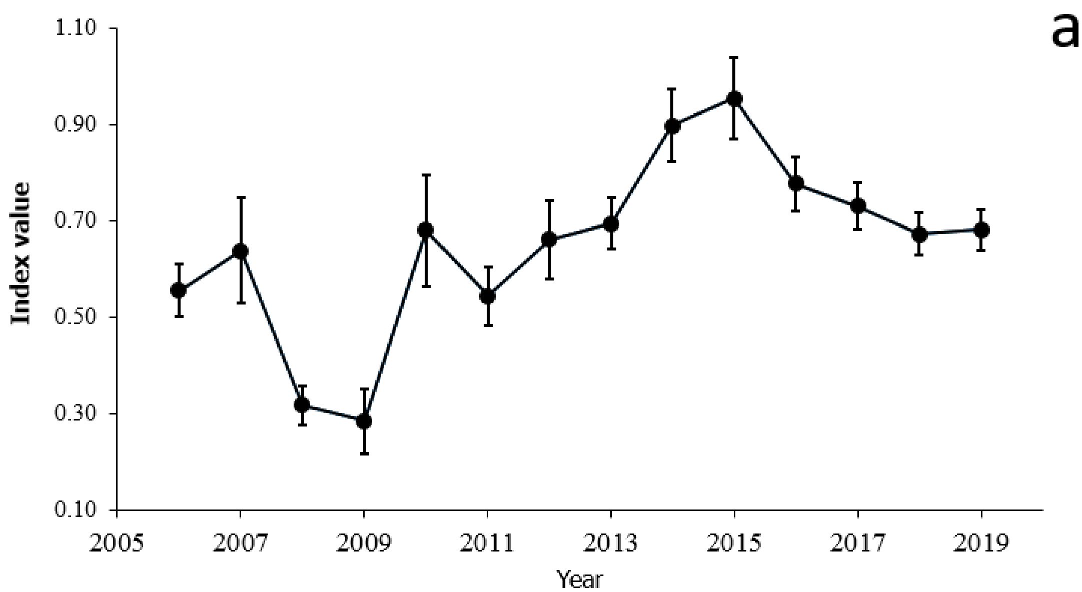

Figure 1. -- Acoustic vessel-of-opportunity (AVO) Index estimates for 2006-2019 (to 3 m off bottom) from the BT survey (a) and corresponding acoustic-trawl (AT) survey biomass estimates (to 0.5 m off bottom) in the U.S. Exclusive Economic Zone (EEZ; b). Error bars are 95% confidence intervals based on 1-D geostatistical estimates of sampling variability. The AVO index was scaled to its mean value for the period 1999-2004.

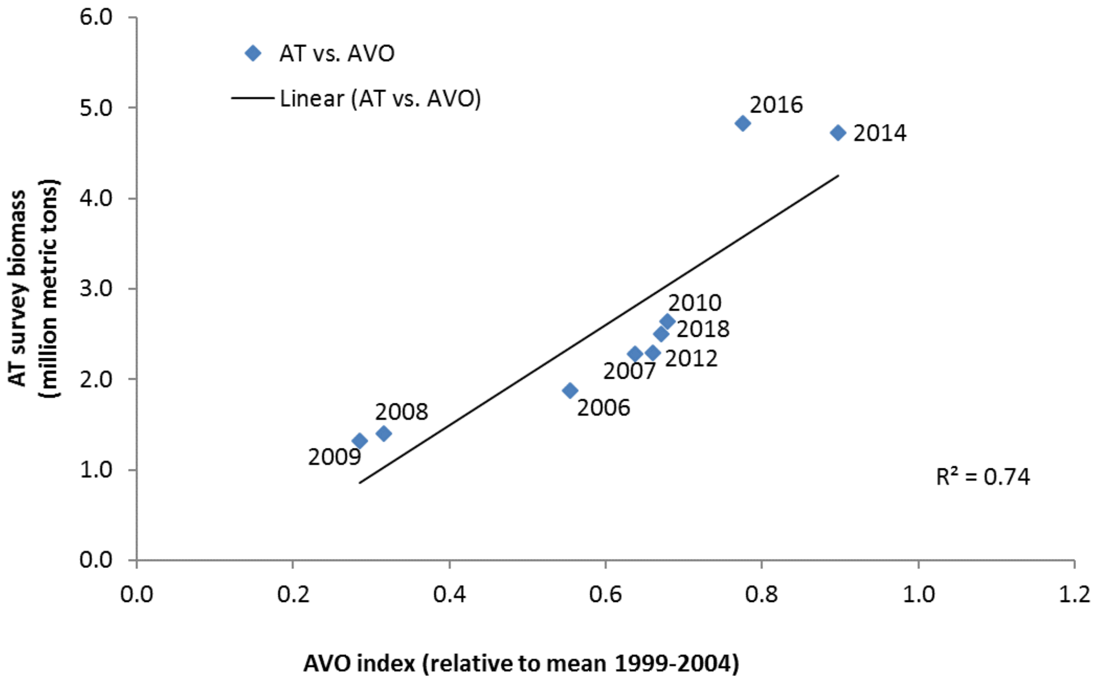

Figure 2. -- Regression of the acoustic-trawl (AT) survey biomass (million metric tons) on the acoustic vessel-of-opportunity (AVO) index value, 2006-2019.

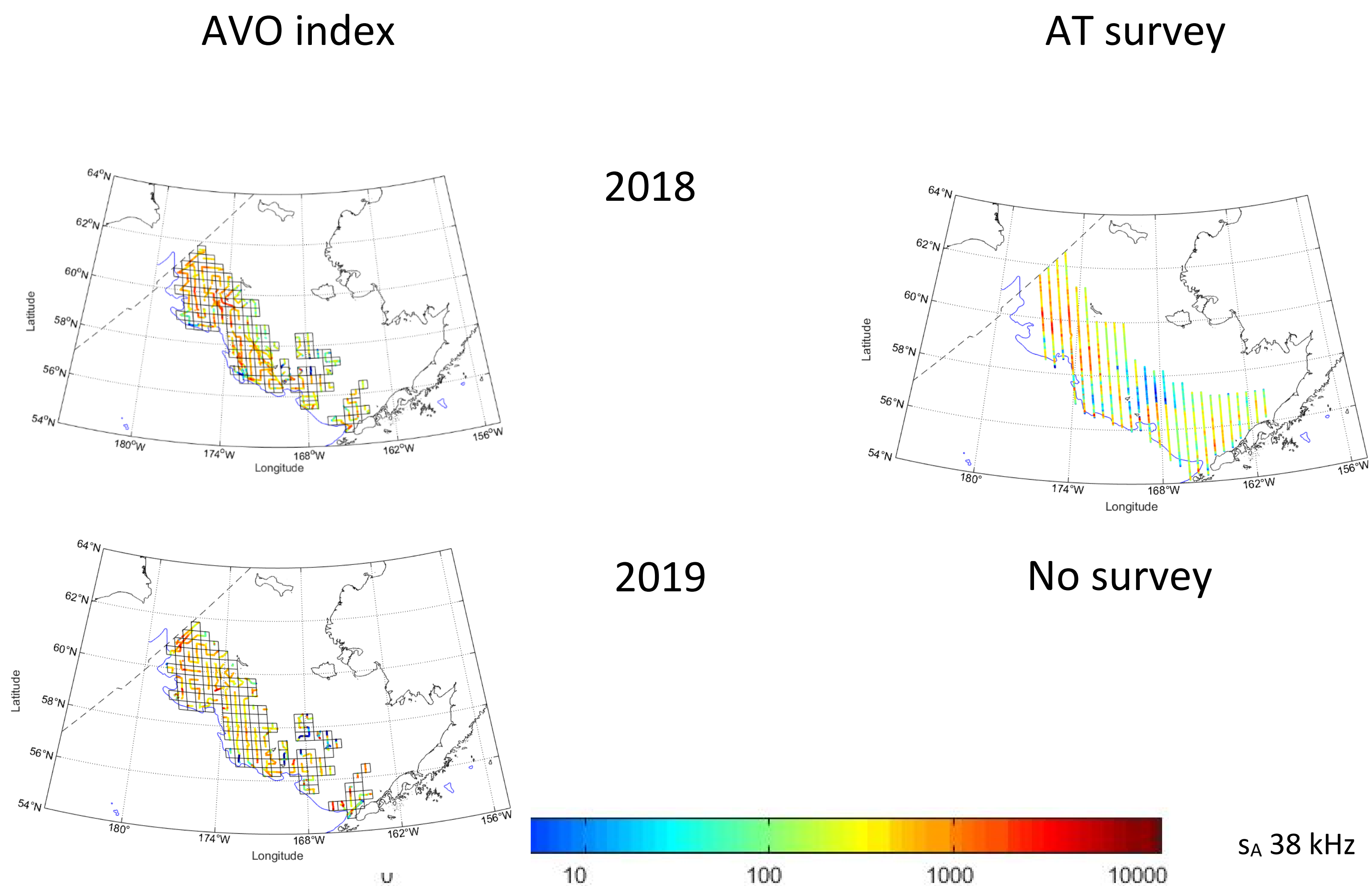

Figure 3. -- Pollock s_A (m^2 nmi^{-2}) in acoustic vessel-of-opportunity (AVO) index (left column) and acoustic-trawl (AT) survey (right column) data sets, 2018-2019. The bottom trawl (BT) survey grid cells used for the AVO index are shown in the left column. AT 2018 acoustic survey did not survey the last 3 transects (i.e., the western-most transects) of the survey area due to vessel mechanical problems, and this omission of s_A is reflected in the upper right plot. There was no AT survey in 2019. 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.

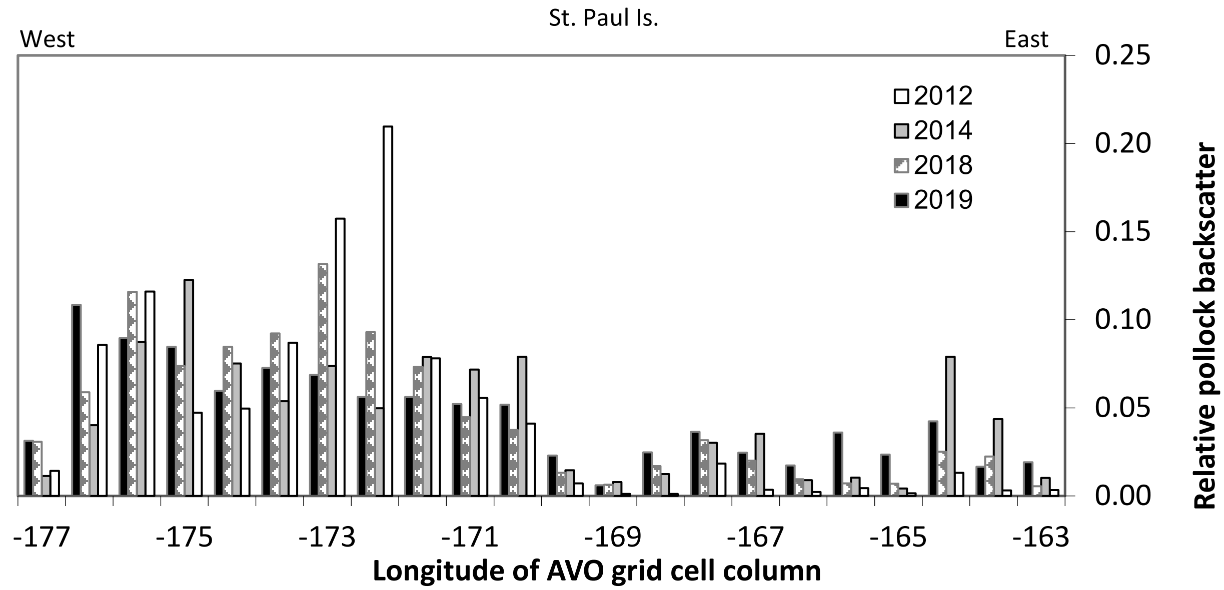

Figure 4. -- Relative pollock backscatter trends since 2012 (including 2012, 2014, 2018, and 2019) computed by summing pollock s_A (m^2 nmi^{-2}) along north-south columns of grid cells, and expressing the result as a proportion of all pollock backscatter in each year. For orientation, the location of 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.

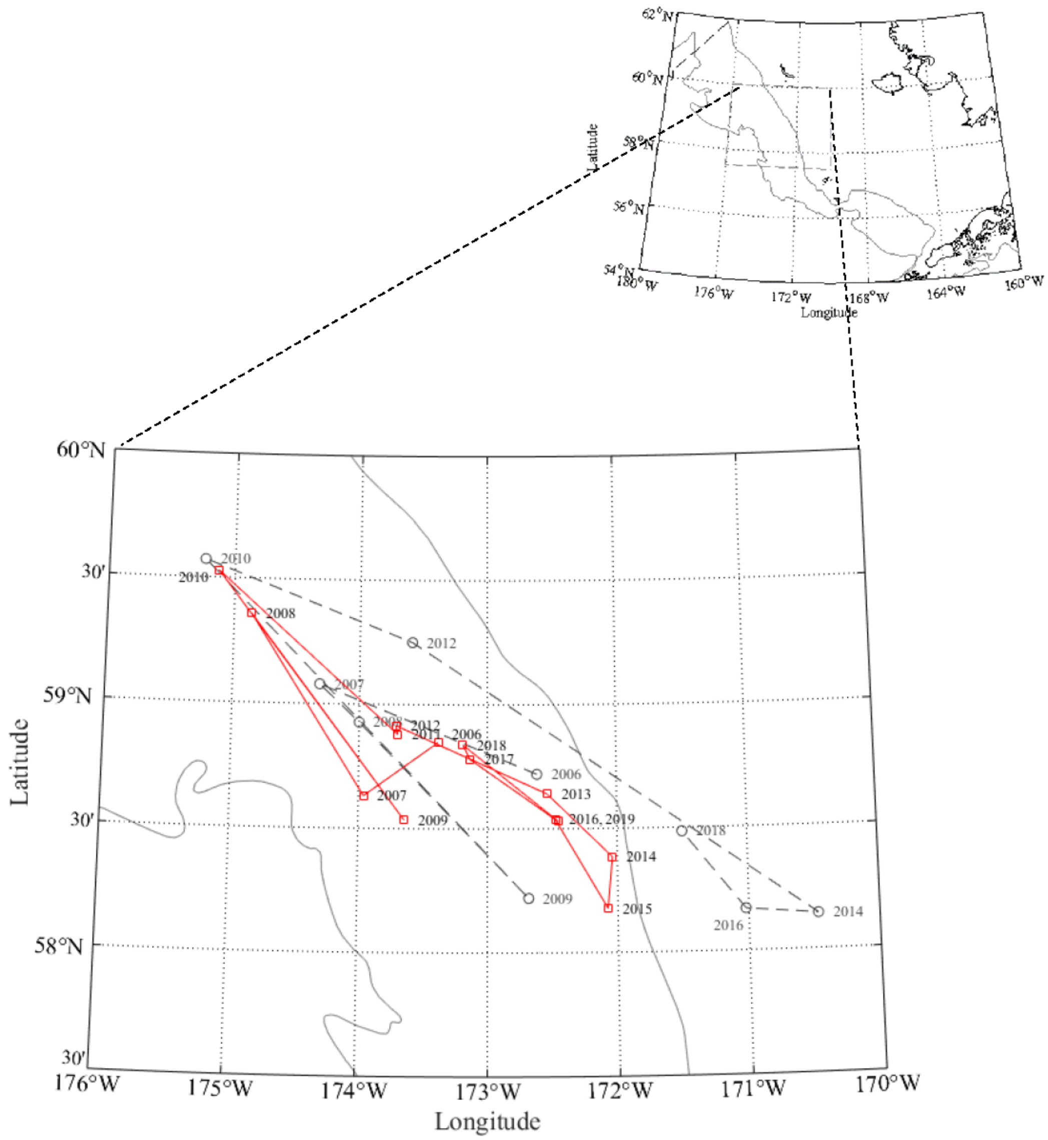

Figure 5. -- Geographic center of gravity estimates derived from pollock s_A (m^2 nmi^{-2}) from acoustic-trawl (AT) survey (gray circles) and acoustic vessel-of-opportunity index (red squares) based on the historic AT time series. The 100 and 200 m bathymetric contours are indicated in gray. AT 2018 acoustic survey did not survey the last three transects (i.e., the western-most transects) of the survey area due to vessel mechanical problems, and this omission of s_A from this area will bias the 2018 AT data point to the southeast.

U.S. Secretary of Commerce
Wilbur L. Ross, Jr.

Acting Under Secretary of Commerce
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