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

Acoustic Vessel-of-Opportunity (AVO) Index for Midwater Bering Sea Walleye Pollock, 2021

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Acoustic Vessel-of-Opportunity (AVO) Index for

Midwater Bering Sea Walleye Pollock, 2021

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. Typically AVO index estimates for two consecutive summers are reported. However, the annual bottom trawl survey was canceled in 2020 due to the COVID-19 pandemic. Only the 2021 AVO index estimate is reported here. The 2021 AVO index increased 37.6% from the 2019 index value. This estimate is the second highest value on record, only 1.8% less than the value recorded in 2015. Most pollock backscatter appeared to be distributed broadly across the shelf between 50 and 200 m isobaths, and the percentage of pollock backscatter east of the Pribilof Islands (east of 170° W longitude) in the AVO index was 16% in in 2021. This is on the low end of the range observed during the more recent summers between 2013 and 2019 (ca. 15% to 25%). Although the AT survey was completed in 2020, the canceled bottom trawl surveys prevented further tracking of the relationship between the AVO index and AT survey ($R^2 = 0.74$, $p = 0.003$, 2006-2018). A strong non-pollock backscatter layer extended deeper than 30 m depth in the northwest part of the auto-processed index area in 2021, invalidating the AVO index semi-automatic processing assumption that all backscatter deeper than 30 m depth in this area is pollock. To address this, the overall mean pollock backscatter in the index area was assigned to the six bottom trawl survey grid cells that were most heavily influenced by this problem for computation of the 2021 AVO index.

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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 (De Robertis et al. 2021, McCarthy et al. 2020). 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 strongly correlates with the total estimated AT survey pollock biomass ($R^2 = 0.74$, $p = 0.003$, 2006-2018; Stienessen et al. 2020). Typically, this acoustic 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. 2020). However, the BT surveys were canceled in 2020 due to the COVID_19 pandemic. Therefore, this report updates and discusses AVO index results for summer 2021 only.

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 2020 and 2021.

2020

Both the BT and AT surveys were canceled in 2020 because of the COVID-19 pandemic. To help mitigate the loss of AT survey information, three uncrewed surface vehicles (USVs) with mounted echosounders were deployed to cover the historic AT survey area. Trawling was not possible from the USVs, so a conversion from backscatter to biomass using a historical relationship was applied (De Robertis et al. 2021).

2021

Only the BT survey was conducted during summer 2021. The BT survey was conducted aboard the chartered vessels FV *Vesteraalen* and FV *Alaska Knight* (Lauth et al. 2019). 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 on the FV *Alaska Knight;* however, these data were not used in computing the AVO index. The BT survey was extended northward from the area usually covered on both ships, as it was in 2017 and 2019. 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 (early July) the BT survey on both vessels (the latter calibration occurred two-thirds of the way though the portion of the BT survey that was used to calculate the 2021 AVO index). The two calibrations on the FV *Vesteraalen* yielded poor results, so a third calibration was conducted at the end of the survey (mid-August) on that ship. For these calibrations, split-beam target-strength (TS) and echo integration measurements of a tungsten carbide (38.1 mm diameter) sphere were made for the 38 kHz on the *Vesteraalen* and the 38 and 120 kHz on the *Alaska Knight* (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 available in the Simrad EK60 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).

During the first three legs (end of May through end of July), the FV *Alaska Knight* ES60 had not been recording GPS position data into acoustic data files (Simrad .raw files). Location data are necessary for data analysis. GPS data were, however, 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 that could be then be used in data analysis. At the end of the second (early July) and throughout the third leg (July) there were intermittent issues with the FV *Vesteraalen*'s GPT. This caused the ES60 to stop collecting data for ca. 10-30 seconds at a time, after which the ES60 began receiving data again. This lead to some gaps in the data collected by this vessel.

Backscatter Data Classification and Processing

The 38 kHz backscatter data collected in the AVO index area during 2021 were either classified semi-automatically using custom software written in Python (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, which assumed all backscatter between 30 m from the sea surface and 3 m from the seafloor was pollock, was used in regions where a retrospective analysis by Honkalehto et al. 2011 determined backscatter at 38 kHz was mostly from pollock. The eastern Bering Sea midwater fish community encountered in AT surveys 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 in Honkalehto et al. (2011) had determined 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 > 2.1 m/s (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 averaged into 926 m (0.5 nmi) along-track elementary distance sampling units (EDSUs) and were stored in an Oracle database at 10 m vertical by 926 m (0.5 nmi) horizontal resolution. Semi-automatic processed EDSUs with backscatter > 1,500 nautical area scattering coefficient (s_A) were examined, and those EDSUs that were not dominated by pollock backscatter (i.e., EDSUs in which > 50% of all backscatter between 30 m depth and 3 m off the bottom was not attributed to pollock), were marked as "invalid" and removed from the analysis. 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) grid cells 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 the 2021 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.

Low Sample Sizes in the 2021 AVO Index

The AVO index area contains 138 grid cells. The backscatter data in 68 of these are semi-automatically classified. In 2021, an abnormally large number of these semi-automatically classified grid cells (n = 22) contained a low number of valid EDSUs (i.e., < 15 EDSUs; it is typical for grid cells to have ca. 55 valid EDSUs). Therefore average pollock s_A was computed with a relatively low sample size in a large number of grid cells.

We were able to attribute the low sample sizes in a large number of grid cells to a strong non-pollock backscatter layer that extended deeper into the water column this year (i.e., deeper than 30 m) in the semi-automatically classified grid cells primarily found in the northwest part of the index area. The pervasive presence of this non-pollock backscatter below 30 m depth in 2021 caused many semi-automatically classified EDSUs to be marked “invalid” in this area and removed from the dataset (n = 680 of 1,120 EDSUs in the northwestern part of the index area). The 2021 AVO index was very sensitive to the inclusion of these sparsely sampled grid cells, so we elected to treat the 6-grid cells most heavily affected by this problem (i.e., those auto-processed grid cells with < 15 EDSUs, a mean backscatter > 2,500 s_A, and non-pollock contamination) as missing data, and assign the mean pollock s_A from the entire Index area to them (rather than using the mean computed from the few EDSUs they contained). This is how empty or unsampled grid cells have been treated when they occurred in past AVO data sets (Honkalehto et al. 2011).

RESULTS

Calibration

The integration (i.e., S_v) gain value used for 2021 38-kHz backscatter data for the *Alaska Knight* was based on the mean of June and July 2021 calibrations. The integration gain value used for 2021 38-kHz backscatter data for the *Vesteraalen* was based solely on the August 2021 calibration (Table 1). There was almost no change in integration gain values between May and July for the *Alaska Knight* (0.4%). There was a moderate change to the 38 kHz final integration gain values used in 2021 compared to those used in 2019 for the *Alaska Knight* (-13%) and a smaller change for the *Vesteraalen* (7%).

Backscatter

The 2021 AVO index increased 37.6% from the 2019 index value (Table 2, Fig. 1a). It was similar to the two highest values on record (2014, 2015) based on overlapping 95% confidence intervals, and it is the second highest value on record, only 1.8% less than the value recorded in 2015. If sparsely sampled grid cells with non-pollock backscatter were not treated as missing data (see 'Low Sample Sizes in the 2021 AVO Index', above), the 2021 AVO index would have been even higher. Similarly, the 2020 AT biomass increased from the previous value in the AT time series (2018; Fig. 1b). The canceled 2020 bottom trawl surveys prevented adding another datum to the regression between the AVO index and AT survey ($R^2 = 0.74$, $p = 0.003$, 2006-2018; Fig. 2).

Spatial Distribution

Midwater pollock backscatter from the AVO index appeared to be distributed evenly throughout the center of the AVO survey areas between the 50 and 200 m isobaths (Fig. 3). AVO pollock backscatter data show this relatively widespread distribution pattern in 2013-2017 and 2019 as well (see Honkalehto et al. 2014, 2017 and Stienessen et al. 2019, 2020). This even distribution is reflected in the lower relative estimation errors for 2013-2021 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. Prior to 2013, the majority of the pollock backscatter had been observed in the northwest half of the index area. The center of gravity estimates were west of 173˚ W (Fig. 4) during these years, the percentage of AT survey biomass inside the AVO index area was around 85% (Honkalehto et al. 2014), and the percentage of pollock observed west of the Pribilof Islands ranged from 91% to 96% during 2010-2012 (Fig. 5). After 2012, the center of gravity estimates were east of

174˚ W (Fig. 4), the percentage of AT survey biomass inside the AVO index area ranged from 65% to 78% (Honkalehto et al. 2017, Stienessen 2019, 2020), and the percentage of pollock observed west of the Pribilof Islands ranged from 75% to 85% (Fig. 5). Specifically in 2021, the center of gravity estimate was just west of 173˚ W, the westernmost this value has been since 2012 (Fig. 4), and the percentage of pollock observed west of the Pribilof Islands was 84%, an increase from 76% in 2019 (Fig. 5).

DISCUSSION

The 2021 AVO index indicated similar midwater pollock backscatter to 2014 and 2015 -- years that contained the highest index values in the AVO time series. Although the 2020 AT time series was not as high as it was in 2014 and 2016 (the highest values in the AT time series), it was the third highest value, indicating both time series follow a similar relative trend in 2021. There was a significant rise in 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. Both series began to increase after 2019.

During 2014 and 2015 when the AVO index was highest, there was relatively more pollock in the southeast and outside of the AVO index area compared to other years of the AVO survey. However, in 2021 when the AVO index was also high, there was comparatively less pollock in the southeast of the index area. Possible 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 presence of a non-pollock backscatter layer that extended into deeper waters (i.e., deeper than 30 m) in the auto-processed cells found in the northwest part of the index area in 2021 was inconsistent with the assumption that the backscatter deeper than 30 m depth can be attributed to pollock without manual classification. If the presence and amount of this backscatter in this area becomes a recurring trend, instead of an isolated incident, extending the subsampling and hand processing methodology to this area would provide a more accurate calculation of the index value moving forward.

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CITATIONS

Bez, N., J. Rivoirard, and P. H. Guiblin. 1997. Covariogram and related tools for structural analyses of fish survey data, p. 1,316-1,317. *In* Geostatistics Wollongong '96. E.Y. Baafi, and N. A. Schofield (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands. Volume 2.

De Robertis, A., M. Levine, N. Lauffenburger, T. Honkalehto, J. Ianelli, C. Monnahan, R. Towler, D. Jones, S. Stienessen, and D. McKelvey. 2021. Uncrewed surface vehicle (USV) survey of walleye pollock, *Gadus chalcogrammus*, in response to the cancellation of ship-based surveys. ICES J. Mar. Sci. https://doi.org/10.1093/icesjms/fsab155

De Robertis, A., D. R. McKelvey, and P. H. Ressler. 2010. Development and application of an empirical multifrequency method for backscatter classification. Can. J. Fish. Aquat. Sci. 67:1459-1474.

Honkalehto, T., and A. L. McCarthy. 2015. Results of the acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) on the U.S. Bering Sea Shelf in June-August 2014 (DY1407). AFSC Processed Rep. 2015-07, 62 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Honkalehto, T., A. L. McCarthy, and N. Lauffenburger. 2018. Results of the acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) on the U.S. Being Sea Shelf in June-August 2016 (DY1608). AFSC Processed Rep. 2018-03, 84 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Honkalehto, T., P. H. Ressler, S. C. Stienessen, Z. Berkowitz, R. H. Towler, A. L. McCarthy, and R. R. Lauth. 2014. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2012-2013. AFSC Processed Rep. 2014-04, 19 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Honkalehto, T., P. H. Ressler, R. H. Towler , N. E. Lauffenburger, S. C. Stienessen, E. T. Collins, A. L. McCarthy, and R. R. Lauth. 2017. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2014-2015. AFSC Processed Rep. 2014-04, 32 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Honkalehto, T., P. H. Ressler, R. H. Towler, and C. D. Wilson, 2011. Using acoustic data from fishing vessels to estimate walleye pollock (*Theragra chalcogramma*) abundance in the eastern Bering Sea. Can. J. Fish. Aquat. Sci. 68: 1231–1242.

Honkalehto, T., N. Williamson, S. de Blois, and W. Patton. 2002. Echo integration-trawl survey results for walleye pollock (*Theragra chalcogramma*) on the Bering Sea shelf and slope during summer 1999. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-125, 77 p.

Ianelli, J. N., T. Honkalehto, S. Barbeaux, and S. Kotwicki. 2015. Chapter 1: Assessment of the walleye pollock stock in the eastern Bering Sea, p. 53-152. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pacific Fishery Management Council, Anchorage, 605 West 4th, Suite 306, Anchorage, Alaska 99501-2252. Available from https://www.afsc.noaa.gov/REFM/Docs/2015/EBSpollock.pdf.

Ianelli, J. N., B. Fissel , K. Holsman, A. De Robertis, T. Honkalehto, S. Kotwicki, C. Monnahan, E. Siddon, and J. Thorson. 2020. Chapter 1: Assessment of the walleye pollock stock in the eastern Bering Sea, p. 1-173. *In* 2020 Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands regions. North Pacific Fishery Management Council, Anchorage, 605 West 4th, Suite 306, Anchorage, Alaska 99501-2252. Available from https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/EBSPollock.pdf

Kotwicki, S., and R. R. Lauth. 2013. Detecting temporal trends and environmentally-driven changes in the spatial distribution of bottom fishes and crabs on the eastern Bering Sea shelf. Deep Sea Res. Pt. II 94: 231-243.

Lauth, R.R., E.J. Dawson, and J. Conner. 2019. Results of the 2017 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-396, 260 p.

Levine, M. and A. De Robertis. 2019. Don't work too hard: Subsampling leads to efficient analysis of large acoustic datasets. Fisheries Research 219. Early Online 10.1016/j.fishres.2019.105323.

MacLennan, D. N., P. G. Fernandes, and J. Dalen, 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES J. Mar. Sci. 59: 365-369.

McCarthy, A., T. Honkalehto, N. Lauffenburger, and A. De Robertis. 2020. Results of the acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) on the U. S. Bering Sea shelf in June – August 2018 (DY1807). AFSC Processed Rep. 2020-07, 83 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle, WA 98115.

Petitgas, P. 1993. Geostatistics for fish stock assessments: a Review and an acoustic application. ICES J. Mar. Sci. 50(3): 285–298. doi:10.1006/jmsc.1993.1031.

Simrad. 2008. Simrad ER60 scientific echo sounder manual. Version Rev. C. Simrad Subsea A/S, Strandpromenaden 50, Box 111, N-3191 Horten, Norway.

Stienessen, S. C., T. Honkalehto, N. E. Lauffenburger, P. H. Ressler, and R. R. Lauth. 2020. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2018-2019. AFSC Processed Rep. 2020-01, 31 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Stienessen, S. C., T. Honkalehto, N. E. Lauffenburger, P. H. Ressler, and R. R. Lauth. 2019. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2016-2017. AFSC Processed Rep. 2019-01, 24 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Woillez, M., J-C. Poulard, J. Rivoirard, P. Petitgas, and N. Bez. 2007. Indices for capturing spatial patterns and their evolution in time, with application to European hake (*Merluccius merluccius*) in the Bay of Biscay. ICES J. Mar. Sci. 64: 537-550.

Woillez, M., J. Rivoirard, and P. Petitgas. 2009. Notes on survey-based spatial indicators for monitoring fish populations. Aquat. Living Res. 22: 155-164.

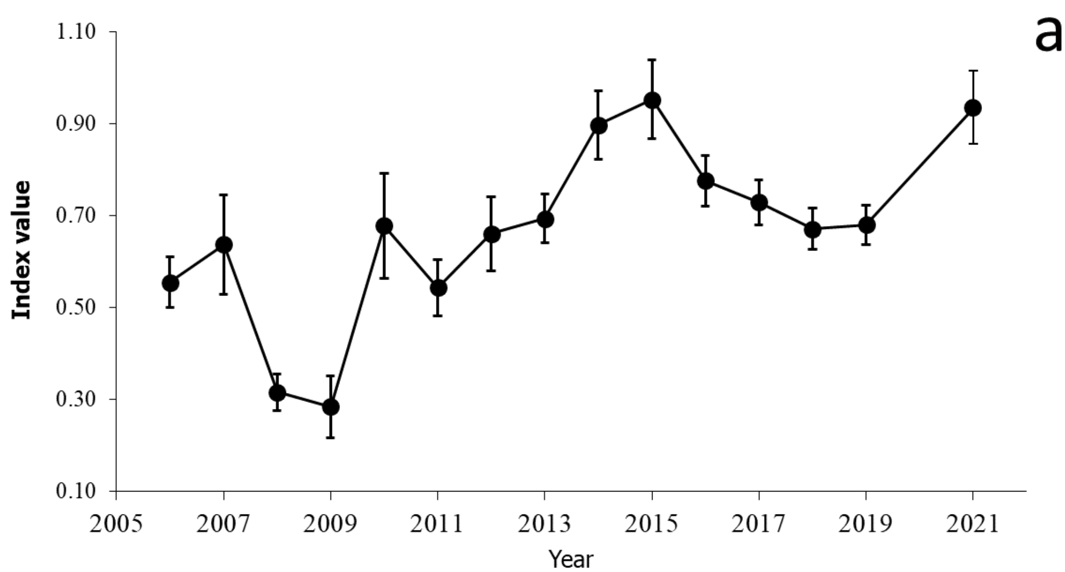
Table 1. --Acoustic system descriptions and settings obtained from sphere calibrations used to process acoustic data for the summer 2021 BT surveys of the Bering Sea shelf.

	2021				
	Alaska Knight			*Vesteraalen*	
	June	July	Final	Aug.	Final
Simrad echosounder	--	--	ES60	--	ES60
Transducer depth (m)	--	--	3 m	--	4.5 m
Pulse length (ms)	--	--	1.024	--	1.024
Transmitted power (W)	--	--	2000	--	2000
2-way beam angle (dB)	--	--	-20.69	--	-19.89
Gain (dB)	24.68	24.55	24.61	--	24.41
s_A correction (dB)	-0.66	-0.53	-0.60	--	-0.54
Integration gain (dB)	24.01	24.02	24.02	--	23.87
Absorption coefficient (dB/m)	0.00980	0.00957	0.00998	0.00914	0.00998
Sound velocity (m/s)	1472.9	1480.8	1470.0	1487.0	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 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}"		
	AT survey time series				
	AT survey biomass to 0.5 m off bottom (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
2020	3.62	0.681	NO SURVEY	NO SURVEY	NO SURVEY
2021	NO SURVEY	NO SURVEY	0.9359	0.0793	0.0432



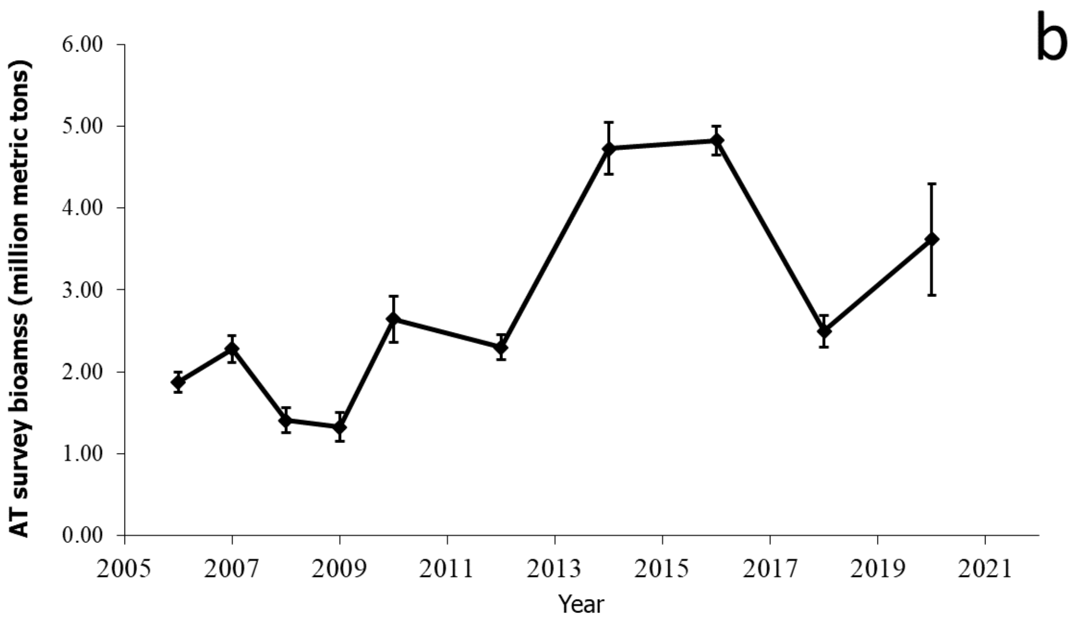


Figure 1. -- Acoustic vessel-of-opportunity (AVO) Index estimates for 2006-2021 from the BT survey (a) and corresponding acoustic-trawl (AT) survey biomass estimates in the U.S. Exclusive Economic Zone (EEZ; b). Error bars are 95% confidence intervals based on 1-D geostatistical estimates of sampling variability. The AVO index was scaled to its mean value for the period 1999-2004.

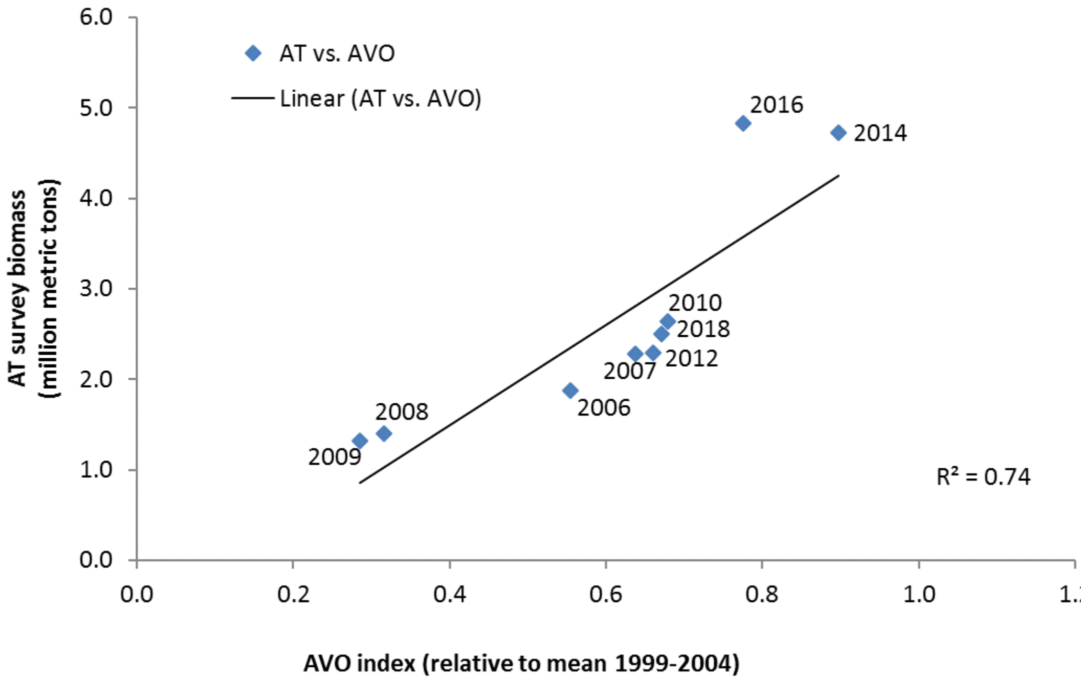


Figure 2. -- Regression of the acoustic-trawl (AT) survey biomass (million metric tons) on the acoustic vessel-of-opportunity (AVO) index value, 2006-2018. There was no bottom trawl (BT) survey conducted in 2020 (when the most recent AT survey took place).

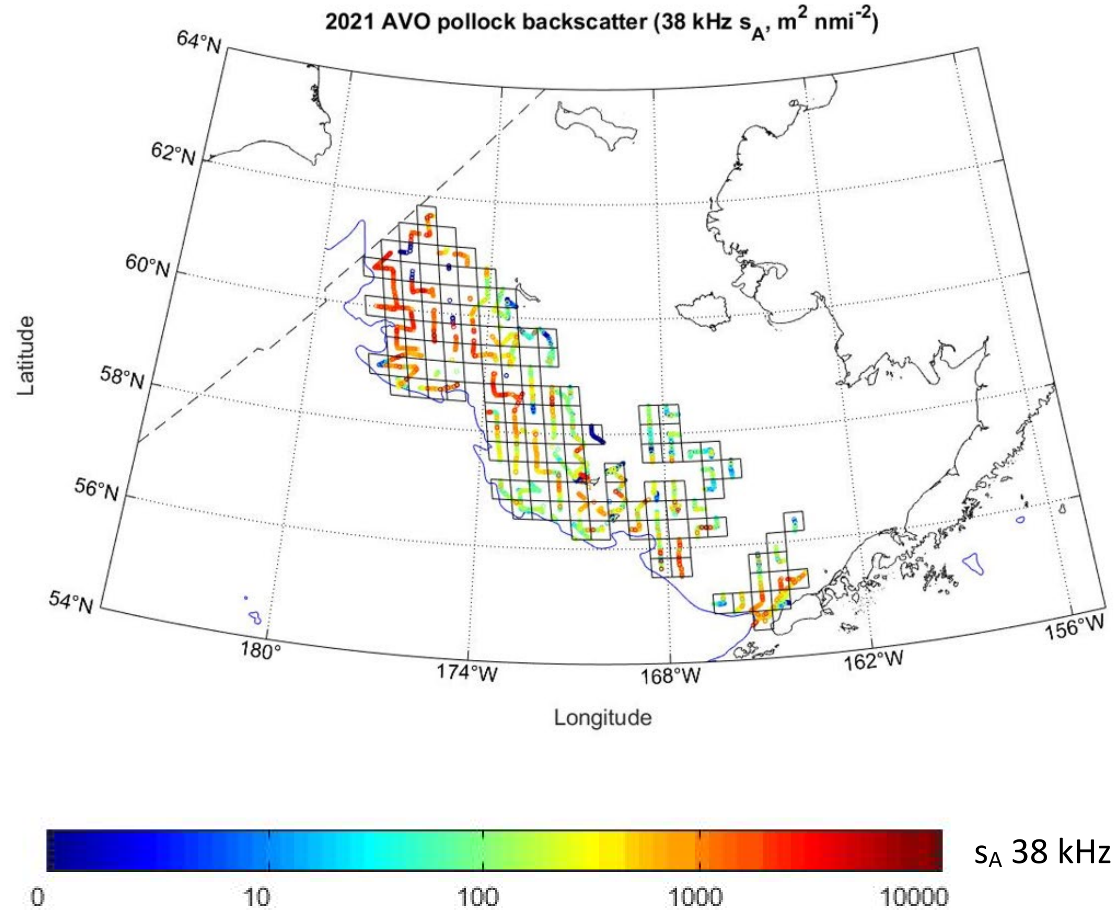


Figure 3. -- Pollock s_A (m^2 nmi^{-2}) in acoustic vessel-of-opportunity (AVO) index 2021 data set. The bottom trawl (BT) survey grid cells used for the AVO index are shown. The 200 m bathymetric contour is indicated in blue, and the boundary between the U.S. and Russian Exclusive Economic Zones is denoted by a black line across the upper left corner of the plot. Note color scale is logarithmic.

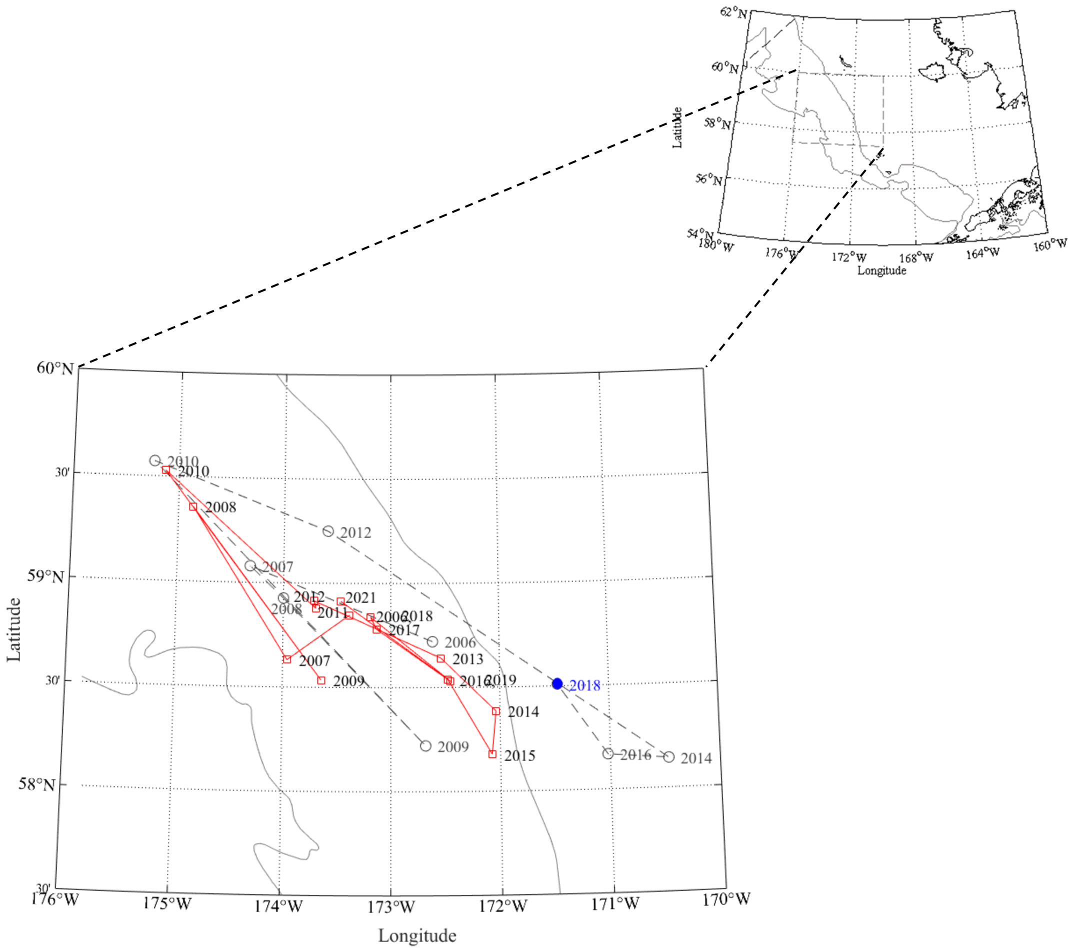


Figure 4. -- Geographic center of gravity estimates derived from pollock s_A (m^2 nmi^{-2}) from acoustic vessel-of-opportunity index (red squares) and from the acoustic-trawl (AT) survey (gray circles; based on the historic AT time series). The 100 and 200 m bathymetric contours are indicated in gray. AT 2018 acoustic survey (blue filled circle) 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. AT 2020 data were collected with saildrones, with no trawling, and the center of gravity is not included on this plot.

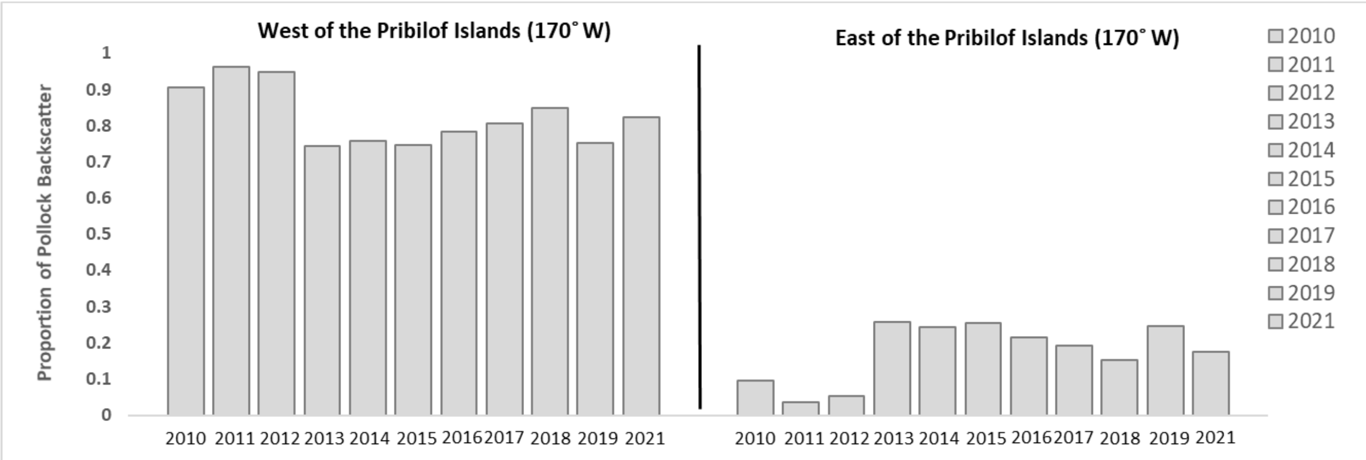


Figure 5. -- Relative pollock backscatter trends separated into the east and west side of the U.S. Exclusive Economic Zone boundary (i.e., the approximate longitude of St. Paul Island, ca. 170° W.), computed by summing pollock s_A (m^2 nmi^{-2}) along north-south columns of grid cells, and expressing the result as a proportion of all pollock backscatter in each year.

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