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U.S. DEPARTMENT OF COMMERCE
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Midwater Trawl Comparison Study for Acoustic Surveys of Walleye Pollock (*Gadus chalcogrammus*) in Alaska

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ABSTRACT

Midwater trawling is a critical component of acoustic-trawl fisheries surveys, and it is used to determine the species and size composition of acoustically sampled fish schools. Changes in midwater trawl gear can influence the catch, and therefore potentially bias the survey data. The Alaska Fisheries Science Center conducts acoustic-trawl surveys of walleye pollock (*Gadus chalcogrammus*) in Alaska waters and recently switched to a new midwater LFS1421 trawl (LFS) from an older Aleutian Wing Trawl (AWT). A series of field trials were conducted to compare the performance of the two midwater trawls during three separate surveys in 2019-2020. For two of the surveys, both trawls were outfitted with recapture nets to assess escapement from the trawl. An analysis of the comparative pollock catch-at-length showed that the size distribution of pollock was similar between the two trawls, although the AWT had a higher catch-per-unit-effort. The escapement of pollock from the trawl was also similar, although relatively low numbers of juvenile fish in 2020 made this comparison less rigorous. The LFS trawl was more efficient at catching several smaller non-pollock fish species, as well as non-fish organisms such as euphausiids. Overall, findings in this study do not indicate substantive differences between the trawls that would constitute a dis-continuity in the acoustic-trawl survey abundance time series for pollock.

CONTENTS

INTRODUCTION

Midwater trawls are an essential tool for performing acoustic-trawl (AT) fisheries surveys. Trawl catch is used to identify the size and species composition of targeted fish aggregations, allowing for correct interpretation and scaling of acoustic backscatter into fish abundance (MacLennan and Simmonds, 2013). In Alaska, AT fisheries surveys are a primary data source for assessing the population status of walleye pollock (*Gadus chalcogrammus*, hereafter pollock), which supports the largest fishery in the United States, and one of the largest fisheries in the world (FAO, 2020). The NOAA Fisheries Alaska Fisheries Science Center regularly conducts acoustic-trawl surveys in the eastern Bering Sea (McCarthy et al., 2020), the Gulf of Alaska (Jones et al., 2022), and pollock spawning areas (McKelvey and Levine, 2023, McCarthy et al., 2022).

For surveys to accurately track populations shifts over time, standardization of methodology and gear are essential. For AT surveys, this relates to acoustic instrumentation, the survey vessel used, and trawling gear employed. However, on occasion, it becomes necessary to change one of these to replace obsolete equipment or to change survey platforms. These events require a process of inter-calibration to decouple methodological changes from the time series of survey estimates. The Alaska AT survey program changed survey vessels in 2007 (NOAA ship Miller Freeman replaced by the noise-quieted NOAA ship Oscar Dyson), and in 2019 the survey upgraded the acoustic equipment (the Simrad EK60 upgraded to the Simrad EK80 system), as well as introduced a new midwater trawl. The former two changes were investigated extensively (De Robertis et al. 2008, De Robertis et al. 2019) via inter-calibration analysis. This report represents a similar effort for examining the potential survey effects resulting from the change in trawling gear.

The role of trawling during AT surveys differs from trawl-based fisheries surveys. For example, bottom trawl surveys use bottom trawls to directly assess density of fish based on the area “swept” by the trawl (Gunderson, 1993). In Alaska, trawl-based surveys operate by sampling predetermined stations, or locations, with fixed duration tows and a high degree of attention paid to standardization of net performance, such as bottom contact and net spread/opening (e.g., Kotwicki et al. 2011). In AT surveys, the location and duration of the trawl are not standardized, but are rather determined opportunistically to allow sampling of high-density fish aggregations detected by the acoustics (Karp and Walters 1994). The critical role of trawl samples for these surveys is to accurately determine the species and size composition of acoustically sampled fish aggregations in order to correctly interpret acoustic backscatter and derive estimates of fish abundance and biomass (MacLennan and Simmonds 2013).

While many studies have been conducted on comparing survey bottom trawls (e.g., Bagley et al. 2015, Miller et al. 2010, Lewy et al. 2004), relatively few comparative studies of survey midwater trawls have been conducted (Kotwicki et al. 2017, Bethke et al. 1999), in part because the trawls are not the primary basis for abundance assessment. Thus, this study describes a unique approach to trawl comparison, utilizing both trawl catch and acoustic information to evaluate the effect of using different trawls in the context of AT surveys.

METHODS

Trawl Gear Description

From 1995 to 2019, Alaska Fisheries Science Center's (AFSC) Midwater Assessment and Conservation Engineering (MACE) program conducted pollock AT surveys using an Aleutian wing trawl (AWT, Nor'eastern trawl systems; Fig. 1) as its primary survey midwater trawl. The AWT is a commercial midwater trawl specifically designed for use in the pollock fishery, and it was modified for survey use by placing a small mesh liner (19 – 13 mm) in the codend. Having reached the end of its use period, it was replaced by the Lummi Fisheries Supply LFS1421 (hereafter LFS) trawl (Lummi Fisheries Supply; Fig. 2), which was designed as a survey trawl. In identifying the replacement trawl, it was sought to improve on certain aspects of the AWT, such as the retention of smaller pollock and other small fishes, ease of deployment, and reduced catch quantities in high-density fish aggregations. To accomplish these goals, the standard LFS trawl design was further modified by reducing mesh size in the section leading to the codend. A 3.2-mm liner was placed in the codend to aid in retaining small organisms.

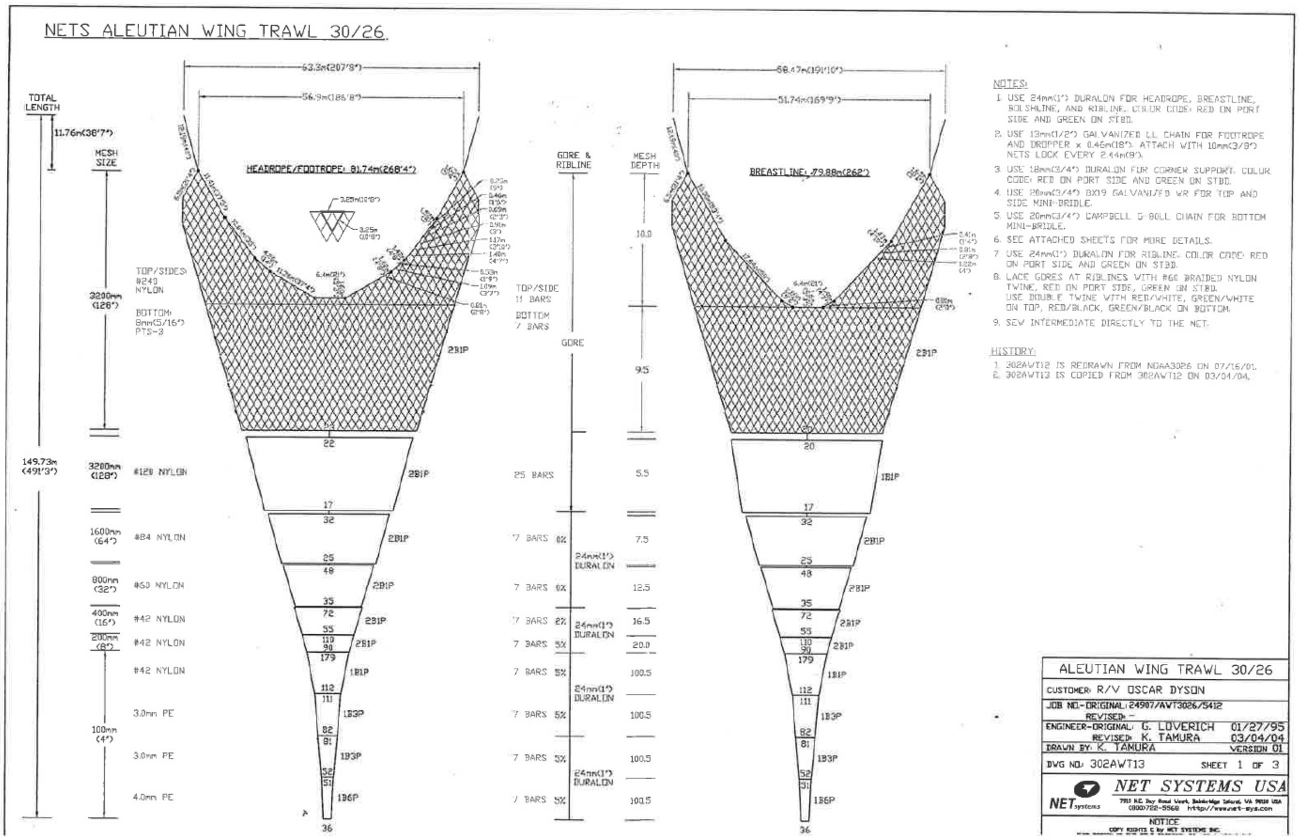


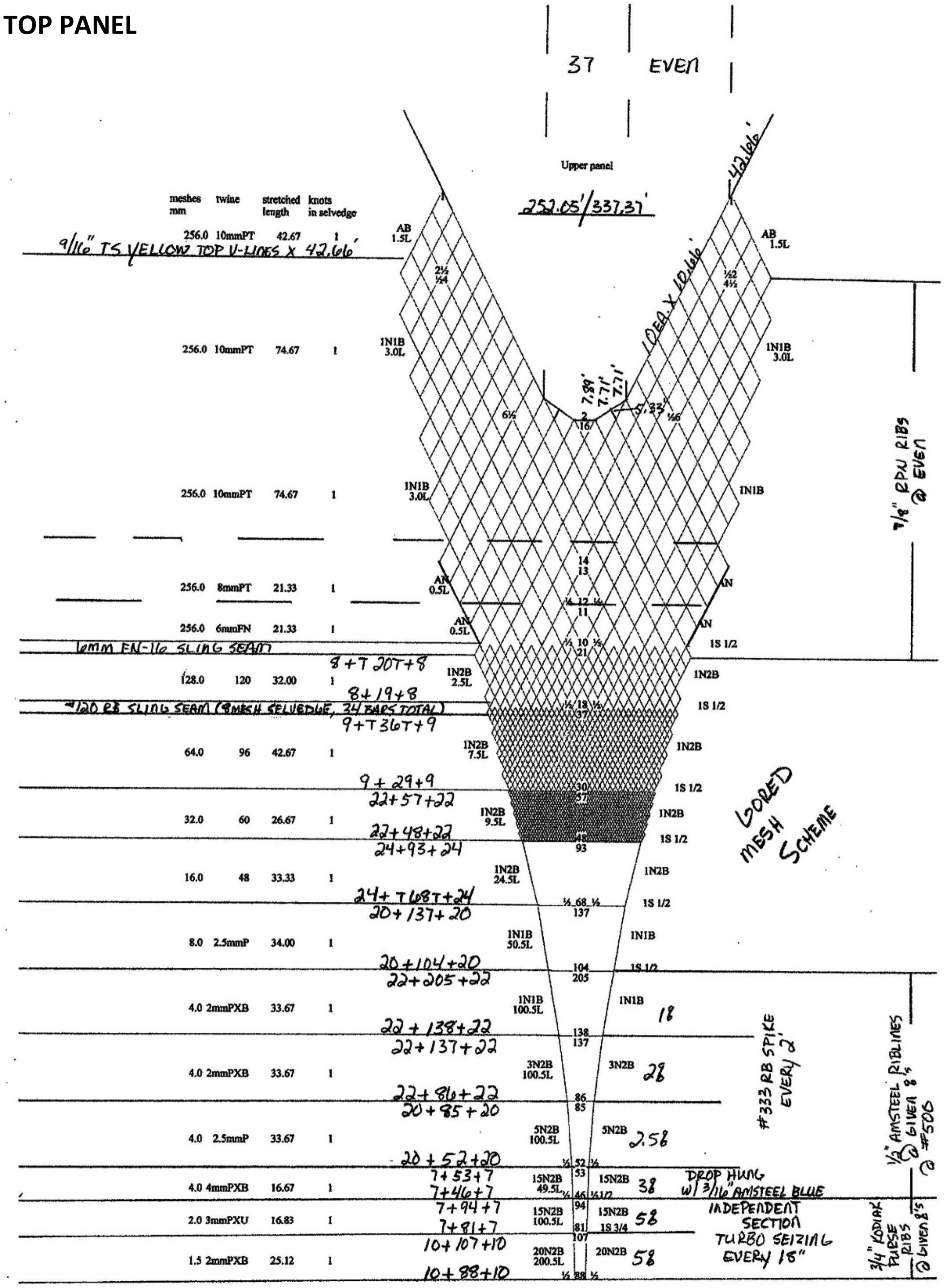
Figure 1. -- Aleutian Wing Trawl (AWT).

The LFS has a smaller headrope length, a more gradual taper, and is outfitted with synthetic rigging and weighted line for the front bottom panel (the trawl "belly"). For the AWT and LFS trawls, performance was evaluated using a Simrad FS70 netsounder, which provided measurements of headrope depth as well as estimates of the vertical and horizontal trawl opening. A comparison of trawl dimensions is provided in Table 1.

Table 1. -- Basic trawl dimensions and specified accessories for two midwater trawls.

Trawl gear	AWT	LFS
model	30/26	1421
headrope length	268' (81.7 m)	337.37' (102.8 m)
largest mesh size	128" (3.25 m)	256" (6.5 m)
smallest body mesh size	4" (100 m)	1.5" (38 mm)
codend liner size	1/2" (12 mm)	1/8" (3")
rigging	wire rope	composite
doors	Nets Fishbuster 5 m^2	Nets Fishbuster 5 m^2
tom weights for typical towing	250 - 500 lb (113 - 227 kg)	500 – 1,000 lb (227 – 554 kg

TOP PANEL

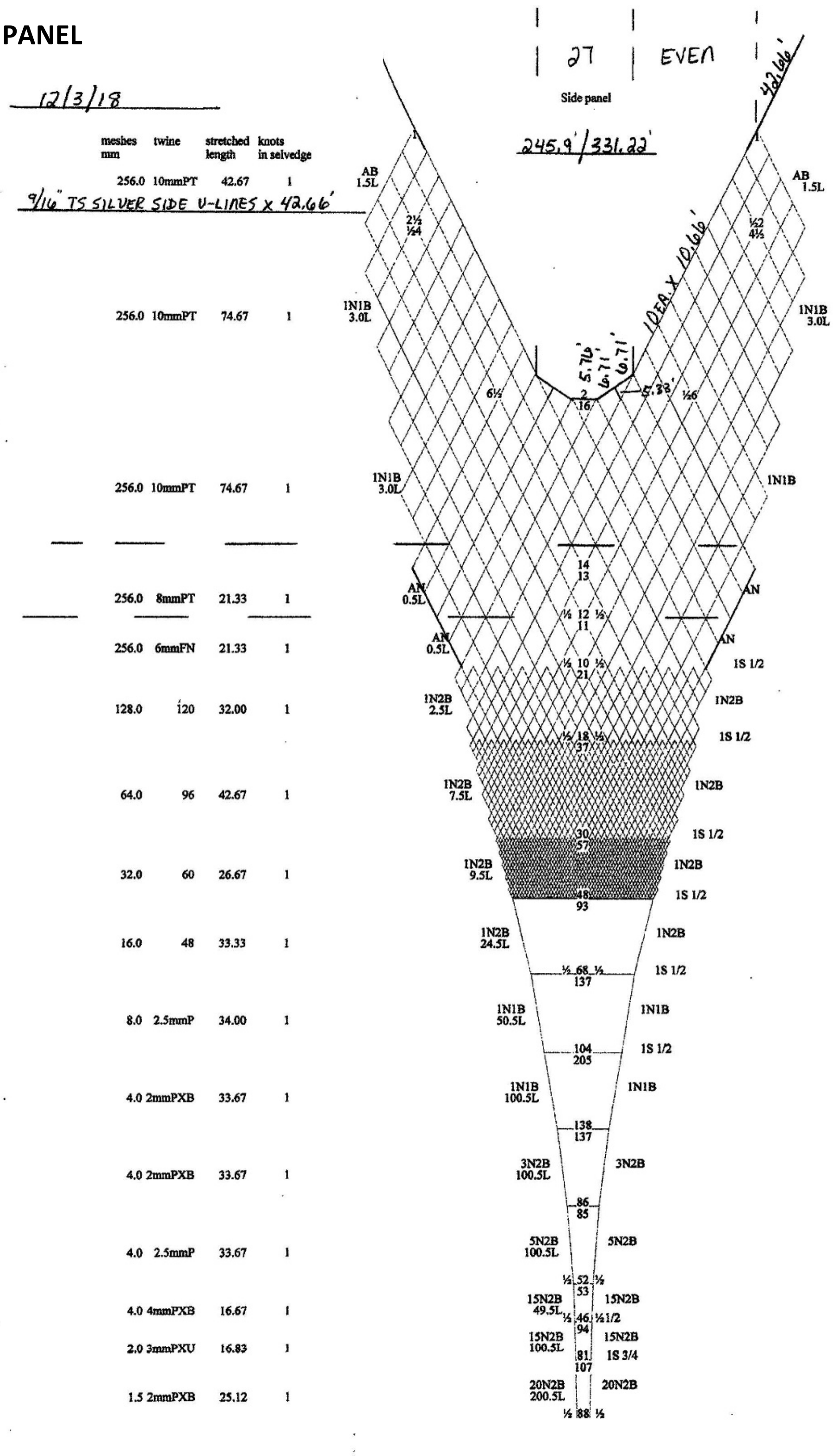


N.O.A.A., 1421 RESEARCH TRAWL

W.O. # 49147

12/3/18

SIDE PANEL



meshes mm	twine	stretched length	knots in selvedge
256.0	10mmPT	42.67	1
256.0	10mmPT	74.67	1
256.0	10mmPT	74.67	1
256.0	8mmPT	21.33	1
256.0	6mmFN	21.33	1
128.0	120	32.00	1
64.0	96	42.67	1
32.0	60	26.67	1
16.0	48	33.33	1
8.0	2.5mmP	34.00	1
4.0	2mmPXB	33.67	1
4.0	2mmPXB	33.67	1
4.0	2.5mmP	33.67	1
4.0	4mmPXB	16.67	1
2.0	3mmPXU	16.83	1
1.5	2mmPXB	25.12	1

Figure 2. -- LFS1421 midwater trawl.

Trawl Comparison Experiments

To evaluate the trawl performance and to determine how using the new trawl might impact pollock survey results, a series of comparison experiments were conducted in 2019 and 2020. Paired tows were taken concurrently with regular survey activities, with the locations and times chosen opportunistically to identify areas of observed high backscatter, with the LFS trawl catch also used for purposes of survey backscatter classification. For each pair, the first trawl to be fished was determined randomly, and the follow-up trawl was performed as soon as possible. Pairs were taken when certain conditions were present, including 1) sufficient backscatter suspected to contain pollock, 2) sufficient time available to collect both trawls during daytime hours, and 3) overall survey time availability. Pairs were conducted during the June-August 2019 summer Gulf of Alaska ATsurvey (DY1906; Jones et al., 2022), the February-March 2020 Bogoslof Island AT survey (DY2002; McKelvey and Levine, 2023), and the March 2020 Shelikof Strait AT survey (DY2003; McCarthy et al., 2022).

Trawl Selectivity

The MACE program has conducted trawl selectivity experiments with the AWT trawl since 2007 (e.g., SH1904; Lauffenburger et al. 2019, DY2002; McKelvey and Levine 2023) and the LFS trawl since 2019 (DY1906; Jones et al. 2022, DY2003; McCarthy et al. 2022; DY2102; Honkalehto et al. In review), where selectivity is defined as the species- and size-dependent probability that a fish entering the trawl opening will be retained in the codend. The MACE program has developed a method for estimating midwater trawl mesh escapement by using small recapture or "pocket" nets mounted on the outside of the trawl that sample fish as they pass through the trawl During the trawl comparison experiments, a total of nine pocket nets were used on the LFS trawl; one each on the top, bottom, and side panels of the trawl in three different sections of the trawl from the main trawl body to the codend. The AWT was outfitted with 8 nets, placed on top, bottom, port, and starboard panels of the trawl in two sections along the net. Samples from the pocket nets were used to estimate total size- and species-dependent escapement from the trawl. For the DY1906 and DY2003 surveys, pocket nets were placed on both the AWT and LFS trawls, with the AWT outfitted with 1/4-inch mesh pocket nets and the LFS outfitted with 1/8-inch mesh pocket nets, each matching the corresponding codend liners used in the trawls. The difference in mesh size between the gears, while not ideal, was necessary because the historical time-series used 1/4-inch liner with the AWT, and correct interpretation of codend selectivity requires that the same mesh size is used for the pocket nets and the codend liner to reduce any additional effects of organisms passing though the liner or pocket net.

For the DY2002 survey, pocket nets were only placed on the LFS trawl, as the AWT had not historically been outfitted with pocket nets for this survey. Pocket net catches were used to estimate selection curves for juvenile pollock escapement from both trawls in DY1906 and DY2003 surveys. Trawl selectivity curves were computed using an analysis that is based on

Williams et al. (2011), but replacing the hierarchical Bayesian approach with a general linear mixed-effects model fitted using a binomial family with a logit link function and specifying each haul event as a random effect (GLMM), fish length as the fixed effect, with the response variable being whether or not a measured fish was retained in the codend (coded as 1) or escaped from the trawl before reaching the codend (coded as 0). For this model, total escapement *Nesc* at length *l* was estimated by scaling the catch in each pocket net (*Np,l*) by the ratio of the total meshes in the trawl section represented by a pocket net to meshes covered by the pocket net itself (*Fp*) as

$$Nesc_l = \sum_p N_{p,l} * F_p \ . \qquad \text{Eq.1}$$

Due to the low abundance of age-1 fish in 2020, a separate cross-year comparison was made between the selectivity estimates for the 2021 Shelikof Strait AT survey (DY2102; Honkalehto et al. in review), which was dominated by age-1 fish, and the 2013 Shelikof Strait survey (DY1303; Jones et al. 2014) where a similar size distribution was observed. In 2021, the LFS trawl was used in the same configuration as in 2020, and in 2013, the AWT trawl was used, with pocket nets placed on the trawl in different randomly chosen locations for each trawl event, as described in Williams et al (2011).

Pollock Length Composition Comparison

During AT surveys of pollock, pollock typically comprises > 90% of the catch by weight, and the pollock length distribution is of primary importance for survey abundance estimates. For catch processing, pollock are sorted and a subsample is measured to the nearest millimeter (for details on catch processing, see Jones et al. 2022). For a comparison pair, catch data were normalized between trawl pairs by dividing the number caught by the fishing duration, resulting in a catch (in numbers)-per-unit-effort (CPUE), where the effort is minutes fished. The fishing duration was measured from the time the trawl reached target depth until haulback was initiated. To compare the CPUE at length for the two trawls, the Selectivity Ratio (*Sr*) was computed (Kotwicki et al. 2017). This metric is a relative value of catch efficiency as a function of fish length, where the absolute efficiency of either gear is not known. Several models for fitting *Sr* were described in Kotwicki et al. (2017), and for this analysis the GAM and Beta regression were compared using a ten–fold cross validation procedure to select the best model. The model fitting procedure was as follows: first, the relative ratio *p_lfs* estimated as

$$p\_lfs_l = \frac{CPUE\_lfs_l}{CPUE\_lfs_l + CPUE\_awt_l}, \qquad \text{Eq. 2}$$

where *l* is fish length (2-cm bin size). The choice of a larger bin size was made to minimize the number of size classes that did not have any observations, improving the model performance. As *p_lfs* is a continuously distributed variable on the interval [0,1], it is appropriate to use a

Beta regression to model the dependency of this variable on fish length. The Beta regression model requires that values do not exactly equal 0 or 1, therefore a transformation was employed to slightly move 0 and 1 values away from the boundaries by computing

$$ps\_lfs_l = \frac{p\_lfs_l \times (n-1) + 0.5}{n}, \qquad \text{Eq. 3}$$

where *n* equals the number of data points in length bin *l*. This situation was infrequent and only affected low abundance size classes. After fitting the model to ps_lfs_l, this value was transformed to *Sr* as

$$Sr\_lfs_l = \frac{\hat{p}\_lfs_l}{(1-\hat{p}\_lfs_l)}, \qquad \text{Eq. 4}$$

where $\hat{p}\_lfs_l$ is the model estimate of the new trawl (LFS) ratio. For fitting a GAM model, the p_lfs_l, was used instead of ps_lfs_l, as this modeling approach was not constrained to values not equaling 0 or 1. Variances for *Sr* were derived by applying a bootstrap approach where a random sampling of trawl pairs were drawn with replacement for 1,000 iterations, and the 2.5 and 97.5 percentiles of the simulated results were used as proxies for the upper and lower confidence bounds. These analyses of inter-net selectivity ratios were conducted for the catch in the trawl codends as well as for the estimated total catch, comprising the codend combined with estimated escapement from the pocket net samples.

Species Composition Comparison and Trawl Efficiency

We also compared the selectivity of the AWT and LFS trawls for a number of different species and species groups across pairs, using a similar approach to the length analysis. These species and species groups were selected based on frequency of occurrence (5% or more by number in the overall survey catch) or ecological or survey importance (e.g. forage fish species). For each species or species group, the catch by number and weight (including estimated escapement from pocket net data) were normalized by tow duration, except for the DY2002 cruise, where only codend catch was available for the AWT. The ratio of catch in the new (LFS) trawl over total catch was estimated as

$$p\_lfs_{s,i} = \frac{CPUE\_lfs_{s,i}}{CPUE\_lfs_{s,i} + CPUE\_awt_{s,i}}, \qquad \text{Eq. 5}$$

where *s* is the species or species group and *i* is the paired trawl number.

Species-specific selectivity parameters were estimated separately for each survey region. Confidence bounds for $\bar{p}\_lfs_s$ were estimated using a bootstrap across trawl pairs.

Acoustic Survey Application Comparison

The current practice for scaling acoustic backscatter is to assign acoustic measurements taken along the trackline to the nearest trawl (Jones et al. 2022). Thus, each trawl has an associated total backscatter that is then converted into abundance using standard acoustic survey methodology (De Robertis et al. 2014).

As paired trawl comparisons were taken during regular survey operations, many of the trawl samples from the LFS catches used in the comparisons were also used to scale backscatter for survey abundance estimates. To estimate the potential effect of trawl choice on acoustic backscatter scaling, backscatter associated with those LFS tows were also scaled using the paired AWT haul. Acoustic backscatter was partitioned among species using the method outlined in De Robertis et al. (2014) and Jones et al. (2022, Appendix III). Catch data included estimated escapement from expanded pocket net catches. This analysis was limited to DY1906 and DY2003 surveys, as the DY2002 had too few hauls to make a reasonable comparison. Backscatter was scaled using total catch (codend + estimated escapement) as computed for each individual haul based on catches in the pocket nets (Jones et al. 2022, Appendix IV).

RESULTS

Trawl Comparison Experiments

Overall, 43 paired trawls were collected: 26 pairs during DY1906 (Fig. 3a), 6 during DY2002, and 11 during DY2003. While the paired trawl locations, depths, and durations were replicated as closely as possible, changes in fish school location between the trawls operations often required adjustments to reach an adequate sample for comparison. An effort was made to collect paired tows throughout the survey area; however, the majority of the comparisons occurred where most of the pollock aggregations were encountered. Of the six pairs collected during the DY2002 survey (Fig. 3b), the last pair from this set occurred in Shelikof Strait during the end-of-survey transit, and thus has been included in the analysis for DY2003 (Fig. 3c), which occurred immediately after. An additional 11 pairs were collected during DY2003, bringing the total number of tows for this survey area to 12.

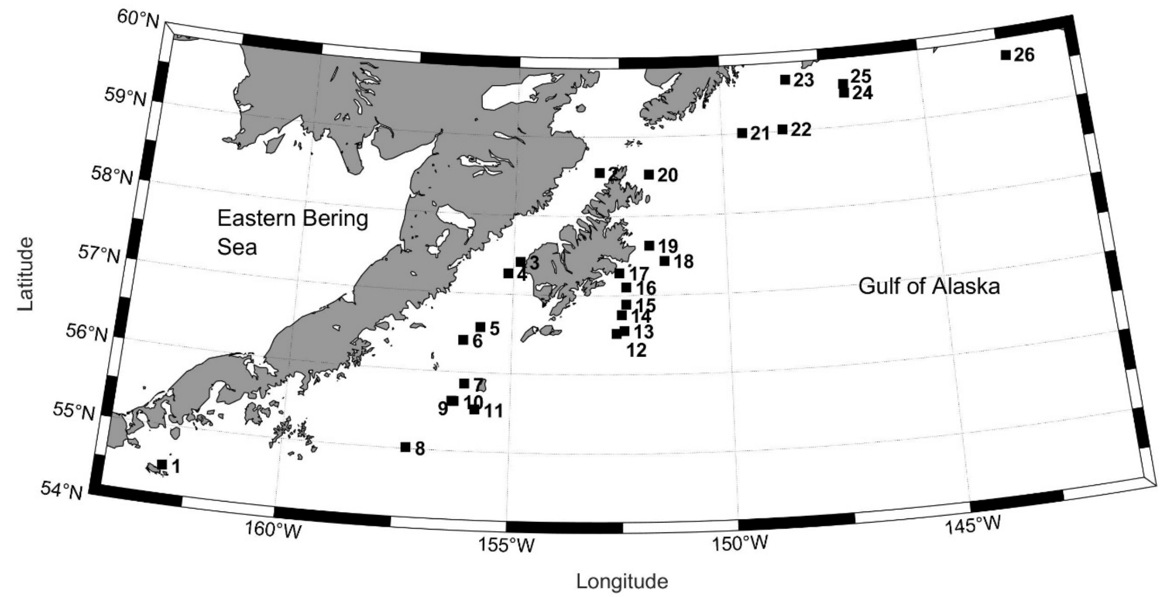


Figure 3a. -- Comparison trawl locations (numbered black squares) taken during the 2019 summer GOA survey (DY1906)

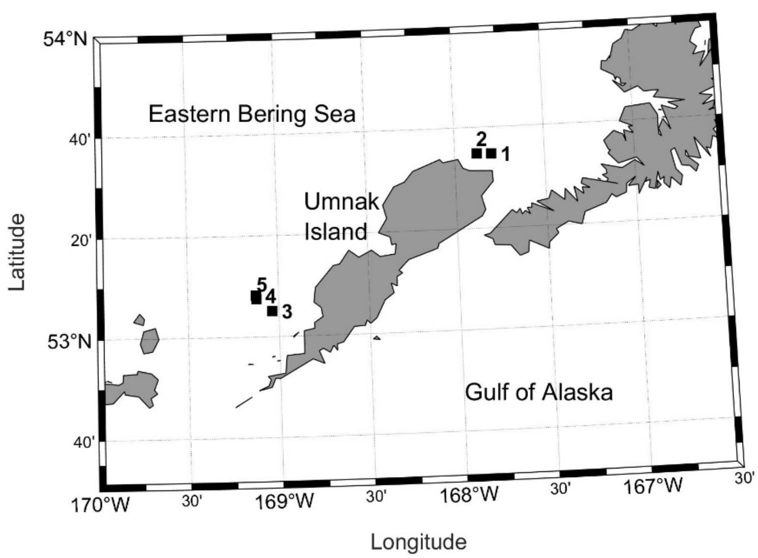


Figure 3b. -- Comparison trawl locations (numbered black squares) taken during the 2020 winter pollock pre-spawning survey of the Bogoslof Island area (DY2002)

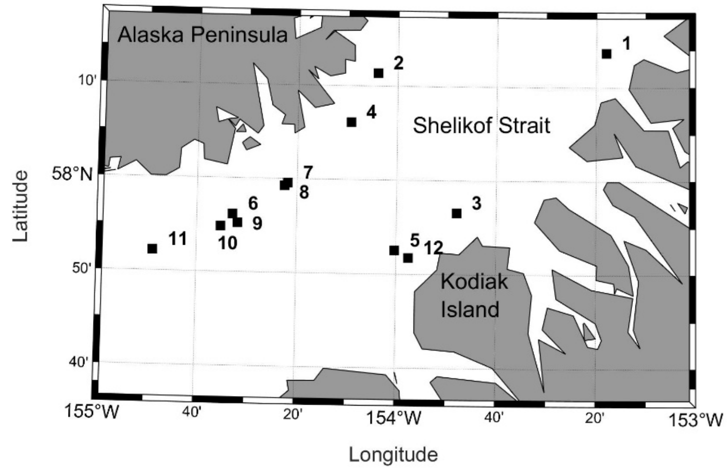


Figure 3c. -- Comparison trawl locations (numbered black squares) taken during the 2020 winter pollock pre-spawning survey of Shelikof Strait (DY2003)

The average time between trawl starts was 3.13 hours, with 90 % occurring within 4 hours (Fig. 4). The average distance between the starting locations of paired tows was 1.15 km, with 75 % occurring within 1.5 km. The depth at which fish were caught varied somewhat between pairs, likely due to diel vertical movement of fish schools. Table 2 shows the net dimensions measured during paired trawling.

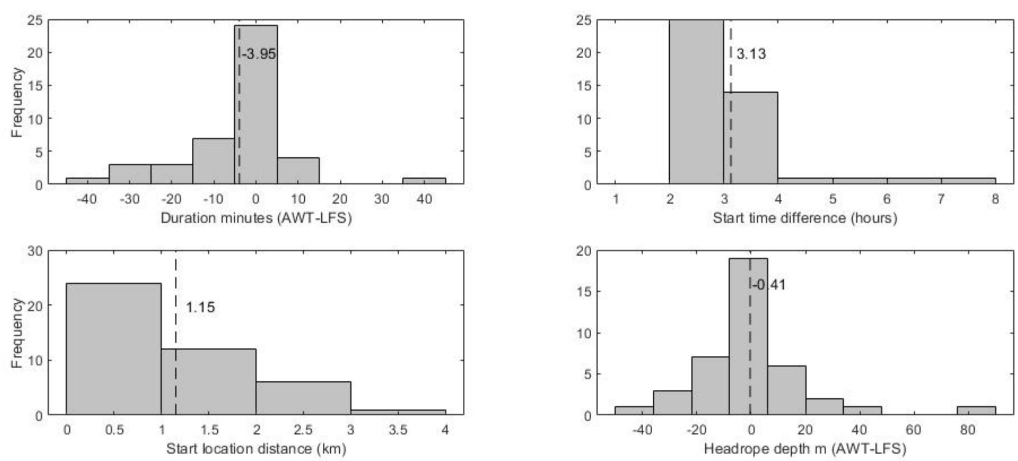


Figure 4. -- General paired trawl comparison performance and characteristics.

Table 2. -- A comparison of trawl opening and depth measurements of two midwater trawls (distances in m, area in m^2)

		net height		net width		mean	mouth
survey	gear	range	mean	range	mean	depth	area
DY1906	AWT	18.0 – 27.0	22.5	23.0 - 42.0	33.3	108.4	2451
DY1906	LFS	13.5 - 20.0	17.1	31.5 - 44.9	38.3	108.5	2409
DY2002	AWT	24.0 - 36.0	30.6	40.0 - 47.0	43.6	317.4	4329
DY2002	LFS	15.9 - 21.6	19.7	34.0 - 44.5	40.6	309.9	2860
DY2003	AWT	21.0 - 29.6	25.0	20.0 - 40.7	31.4	190.1	2504
DY2003	LFS	12.5 - 24.5	19.6	26.0 - 42.0	34.0	193.9	2258

During the DY2002 survey, pollock schools occurred in deeper water, which required more weight to be added to the trawl to assist in rapid descent to fishing depth. The LFS was fished with 500 lb tom weights for DY1906 and DY2003 surveys, for DY2002 this was increased to 750 – 1,000 lb. This change could have influenced the trawl opening (net height) estimates, as the geometry of the trawl opening was likely affected by the extra weight. The AWT tom weights were also increased from 250 lb for DY1906 and DY2003 surveys to 500 – 750 lb for DY2002, and displayed an even greater change in vertical opening than observed in the LFS trawl.

Trawl Selectivity

Trawl selectivity was estimated for pollock catches in the DY1906 and DY2003 surveys using the pocket net samples to estimate total escapement from the trawl. Overall, the catches in the pocket nets were relatively low in both surveys (4.6% and 5.7% of codend catch, respectively), and the corresponding selectivity curves indicated that the pollock of nearly all sizes were well-retained (Fig. 5). While the LFS trawl appeared less selective for pollock (e.g., retaining more) in the size range of 15 - 25 cm in DY1906, in the winter survey (DY2003) retention of the smaller sized age-1 pollock (11 – 17 cm) appeared comparable; the AWT retained 67% of this size group, while the LFS retained 66%. Overall, age-1 pollock were not very abundant in this survey, thus the data in this study are not strongly informative on their retention properties in the trawls, as seen in the overlapping selectivity curve confidence intervals in Fig. 5. The L_{50} (length at which 50% of fish are retained) estimates were also substantially higher (more escapement) in the winter survey compared with the summer.

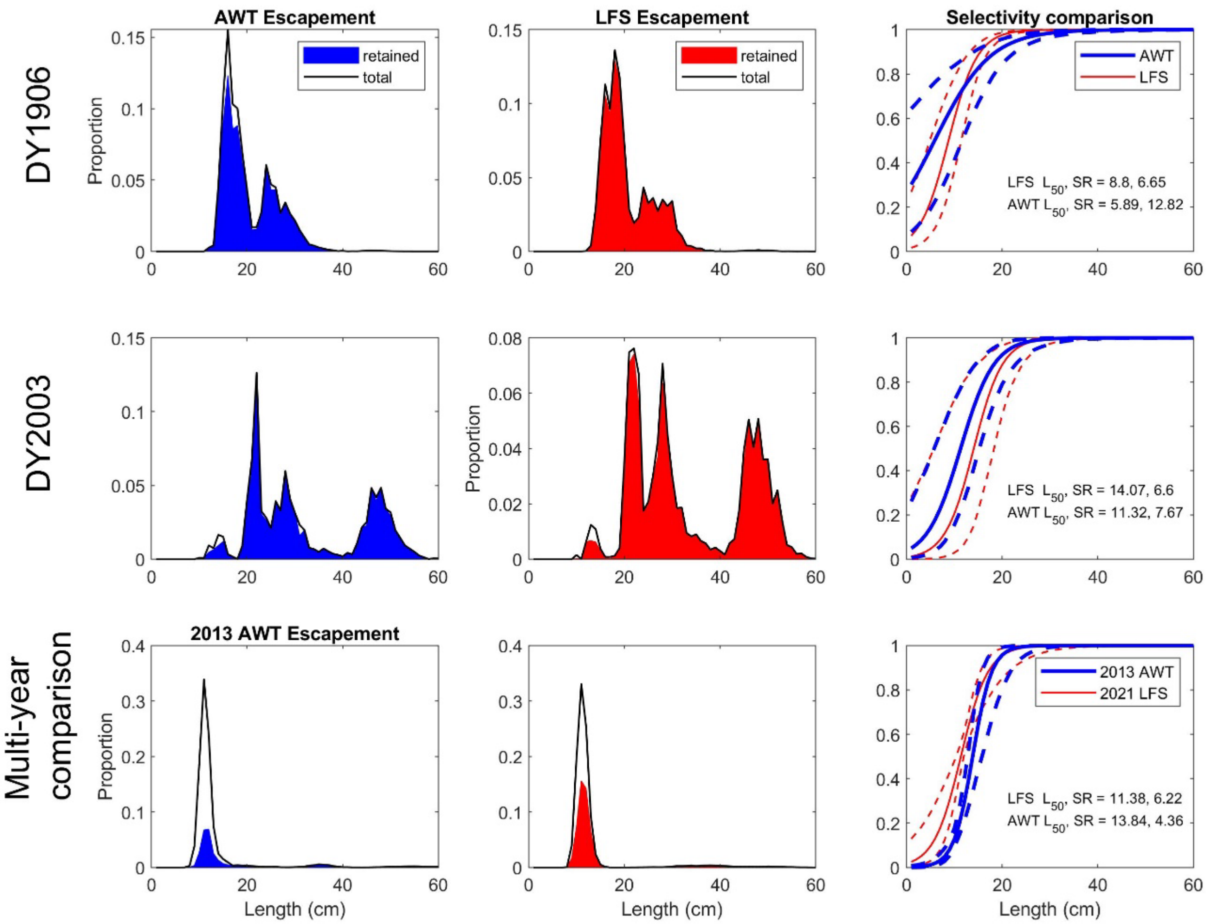


Figure 5. -- Trawl selectivity estimates for pollock for the AWT and LFS trawls. Bottom panel reflects a comparison of two past surveys with similar age structure, while the upper panels are same survey comparisons.

The multi-year comparison between 2021 (LFS) and 2013 (AWT) is more appropriate as the AWT data is based on substantially higher amounts of catch in the pocket nets, and thus may represent a better comparison for selectivity than either the 2019 or 2020 data, assuming there aren't strong annual effects on selectivity. This comparison shows that the LFS trawl is slightly less selective, retaining 96% of age-1 fish (8-16 cm), while the AWT retained 84%.

Comparison of Pollock Length Data

A comparison of relative pollock length composition for each trawl pair in general showed good agreement among the trawl samples in all surveys (Appendix Fig. 1). However, there were several substantial mismatches in targeted fish distributions; for example, the third pair from DY2002 likely encountered different fish schools as the composition differed substantially compared to the other pairs in this survey (Appendix Fig. 1). This pair was therefore excluded from further analyses. In the DY1906 survey, two AWT trawl catches were extremely low (pair 17, with 31 pollock captured and pair 26, with 4 pollock captured), and these pairs were also excluded from analysis. To facilitate comparison, the length composition was aggregated on for each survey, where each haul sample was equally weighted. For this comparison, the proportion *p* at length *l* is derived as

$$p_l = \frac{\sum_h \left(c_{h,l} / \sum_l c_h \right)}{n}, \qquad \text{Eq. 6}$$

where *c* is the catch in haul *h* at length *l* and *n* is the total number of hauls. The normalized length distributions show very minor differences between gears (Fig. 6).

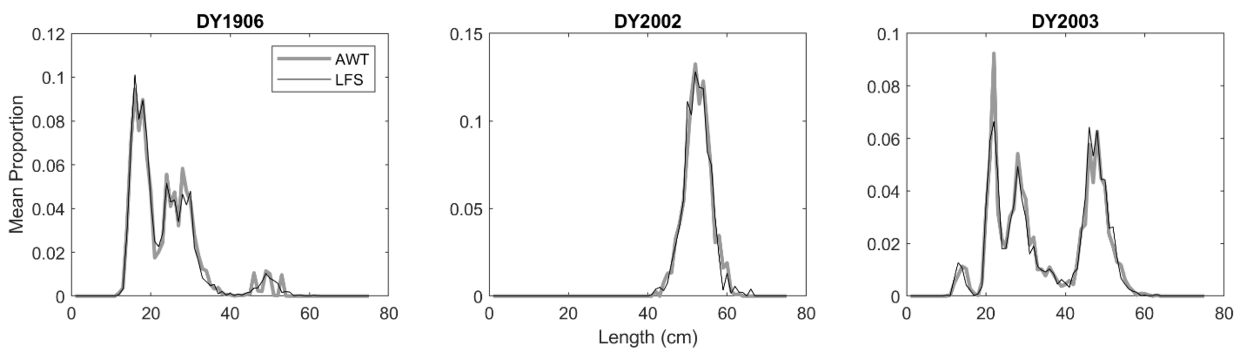
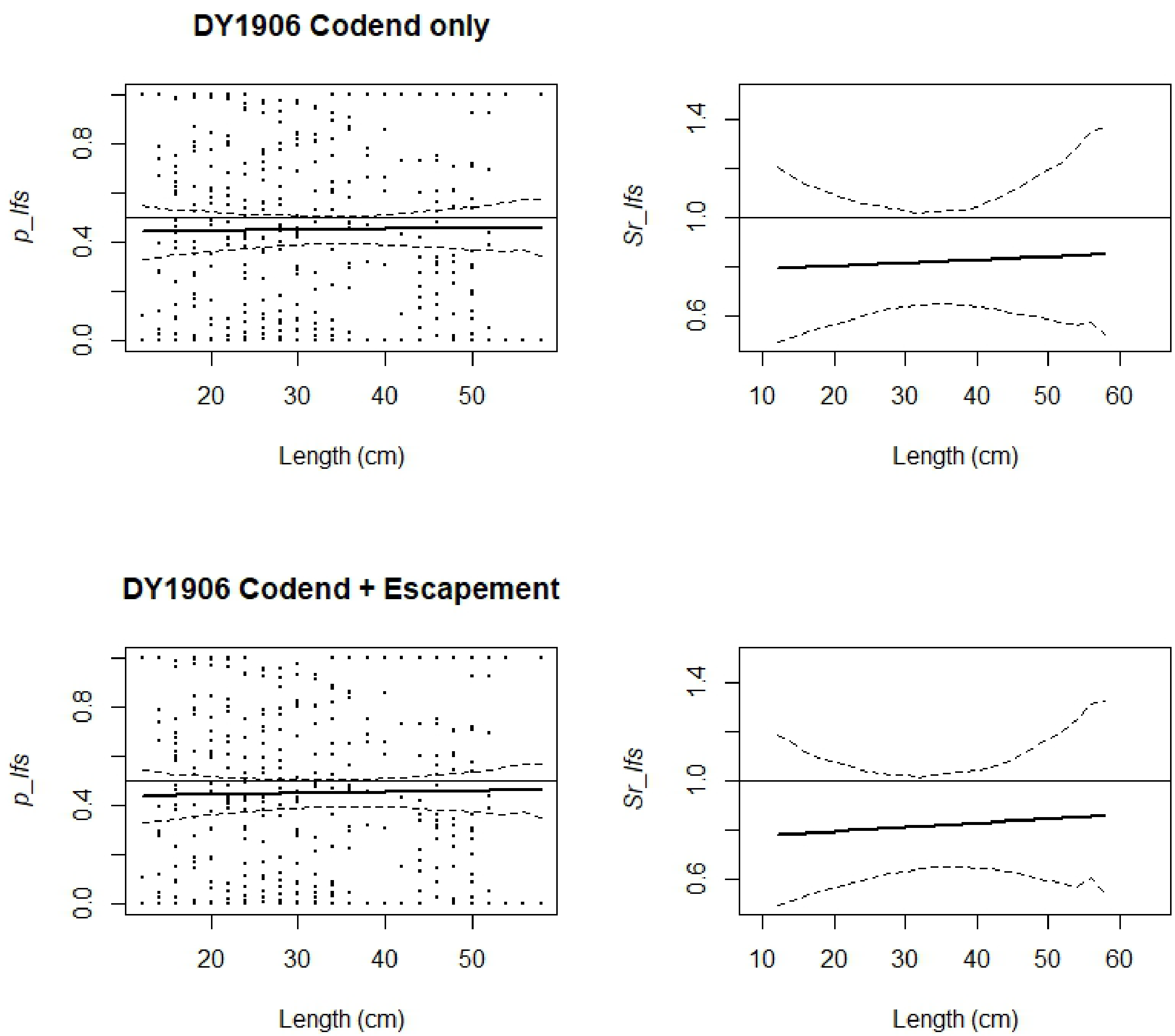


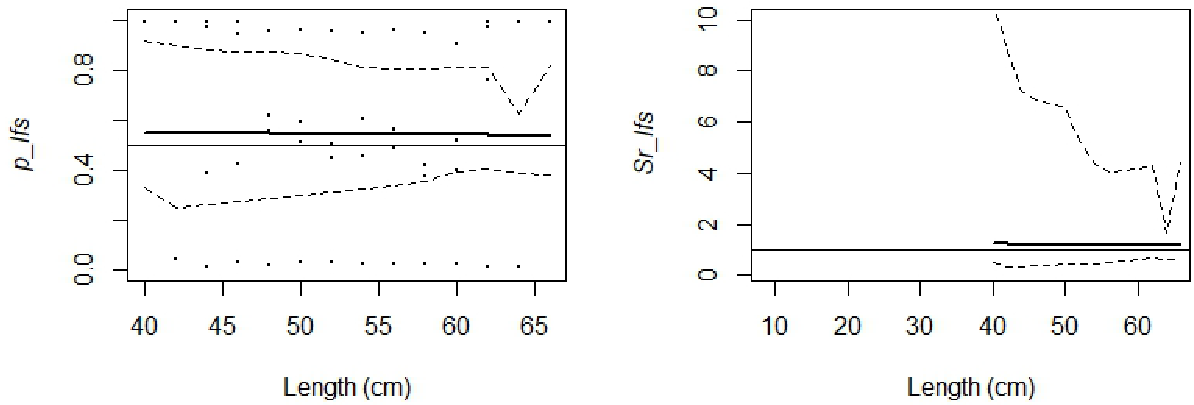
Figure 6. -- Comparison of aggregated pollock length frequencies by survey, normalized by haul.

Two models were compared in fitting ps_{new} using a cross validation procedure, a GAM model (without a beta transformed response) and a Beta regression. While the latter is similar to a binomial generalized linear model (GLM), it is fit using the *betareg* package in R statistical software (Cribari-Neto and Zeileis 2010). Both models resulted in similar RMSE values, with the Beta regression showing a slightly better fit ($RMSE_{GAM}$ = 0.339, $RMSE_{BETA}$ = 0.337). As the interest was to evaluate a simple relationship between ps_{new} and fish length, the Beta regression was chosen for further modeling.

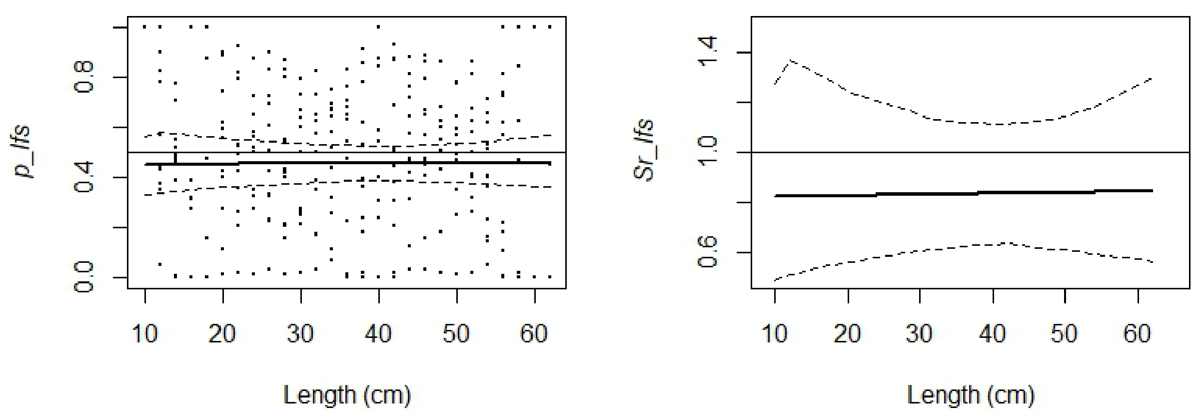
The model was fit to two datasets, the first one representing the catch in the codend only, or retained catch, and the second representing the estimate of the total fish that have entered the mouth of the trawl, e.g. retained + escaped catch (Fig. 7). The model was fit independently to each survey area, with the escaped catch unavailable for the DY2002 survey. The resulting *Sr* value was < 1 for the DY1906 and DY2003 surveys, although this value was not statistically different from 1 due to the high level of uncertainty. The DY2002 survey shows a different pattern although it was also not different than 1 statistically and was based on very few samples. Modeling full catch (retained + escaped components) did not seem to influence the outcome. In general, these models would be expected to show a stronger slope if one of the gears was more efficiently sampling a different size component of the population (see Kotwicki et al. 2017 for an example). The lack of a strong slope indicated that the length compositions associated with the two trawls are not significantly different given the data available.



DY2002 Codend only



DY2003 Codend only



DY2003 Codend + Escapement

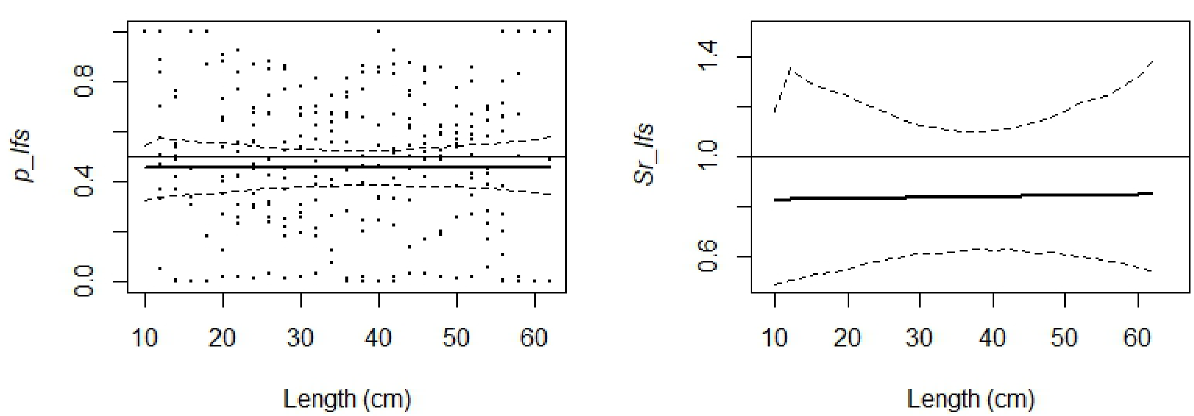


Figure 7. -- Beta regression model fits of pair-wise differences in pollock CPUE using AWT and LFS trawls. Surveys DY1906 and DY2003 were compared using codend only and selectivity corrected catch; this option was not available for the DY2002 survey. The left panels represent the relative catch ratio (LFS/(AWT+LFS)), and the right represents the selectivity ratio where 1 = equal selectivity at length.

Species Composition

Overall, the LFS trawl with the 1/8-inch codend liner retained smaller organisms (eulachon, *Thaleichthys pacificus;* herring, *Clupea pallasii*; krill, *Euphausiidae*) than the AWT (Fig. 8). The proportion of pollock in the catch was similar (Table 3). The equivalent statistics for numbers caught are different, with pollock being less represented in the catch numerically in the last two surveys.

Table 3. -- Average percent of pollock by weight and number for different trawls and including correction for escapement.

		DY1906		DY2002		DY2003	
		AWT	LFS	AWT	LFS	AWT	LFS
Codend	% pollock by weight	74.9	78.3	98.0	97.3	79.5	81.2
	% pollock by number	82.0	82.5	81.5	68.9	39.4	34.3
Codend + escaped	% pollock by weight	75.4	70.8	-	82.6	74.8	73.5
	% pollock by number	72.3	58.7	-	37.1	23.9	18.0

The current practice in MACE abundance estimation analyses is to correct for escapement from the trawl; thus, the following comparisons were based on estimates of retained and escaped catch. A comparison of only the most numerous species caught by number and weight in the summer data (DY1906) shows a higher *Sr* (> 1) for herring and eulachon, and substantially higher *Sr* for krill, which were not very effectively retained by the AWT 1/2-inch liner. This is in contrast to juvenile pollock (< 20 cm, age-1 and age-0), which indicated that pollock may have different behaviors in the trawl when compared with other forage fishes. The number of jellyfish (broadly defined as medusae and ctenophores of various species in this study), capelin (*Mallotus catervarius*), and pollock young-of-the-year (age-0) caught by the LFS appeared similar on a CPUE basis. For the DY2002 survey, values were more similar between gears across all species groups except for shrimp (*Malacostraca*). Interestingly, the average size of myctophids (*Myctophidae*) captured by the LFS was substantially smaller, which is reflected in the lower *Sr* by weight compared to the AWT. Pacific Ocean perch (POP, *Sebastes alutus*) CPUE appeared similar, but relatively few POP were encountered, with 259 individuals caught in three AWT trawls, and 262 cough tin 7 LFS trawls. The minimum fork length observed was approximately 29 cm, at which size a substantial portion of these fish are retained. No POP were encountered in pocket net catches. The winter DY2003 survey did not encounter krill, but the rest of the species groups showed higher CPUE, with the exception of capelin. As with the DY1906, LFS catch of non-pollock was proportionally higher for all categories except for capelin. The overall catch of capelin was very low in the survey, consisting of a total of 4.3 kg, compared with 70.6 kg of northern smoothtongue (*Leuroglossus schmidti*) and 2,852 kg of eulachon, which may have influenced this result.

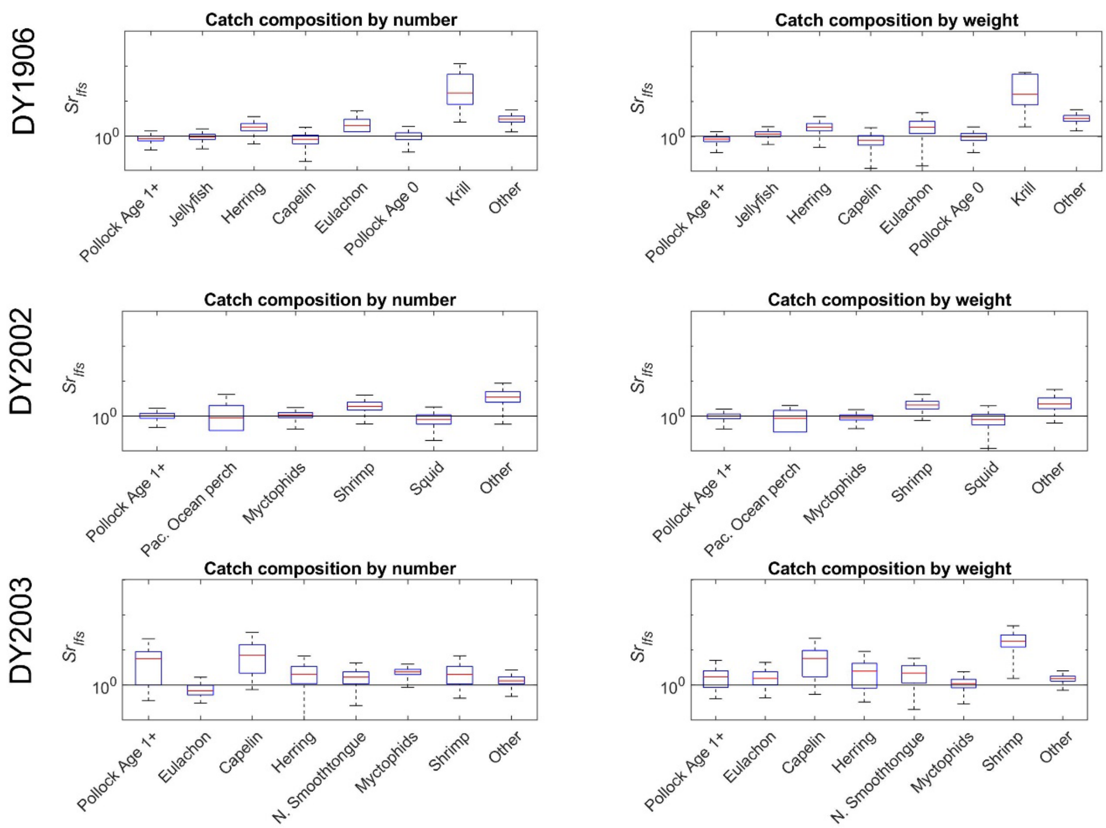


Figure 8. -- Comparison of the selectivity ratio (*Sr*) between the AWT and LFS trawls, for different species/species groups. Not the *Sr* values are plotted on a log scale. Data are presented by weight and by individual organism numbers. Data from DY2002 are based on codend catch only, while the other two surveys are based on escapement corrected data.

Acoustic Survey Application Comparison

In both surveys, the estimates of pollock numerical abundance were similar with a slight increase in numbers in the LFS analysis (Fig. 9). Biomass estimates for the LFS analysis were lower in both surveys, with the difference being a substantial 6.44% reduction for the DY2003 survey. The proportion of backscatter that was attributed to pollock was similar for the two trawls in both surveys, which indicated that while the LFS trawl retains more smaller organisms than the AWT, this greater sampling scope does not influence the attribution of backscatter to pollock. The differences in biomass estimates are therefore due to the differences in length frequency of pollock between the gears, rather than improved retention of non-pollock organisms.

While many of the LFS trawl events used for the paired comparison experiment were also used in the survey analyses, not all of them were, particularly in the winter DY2003 survey. In this survey, only six of the hauls used in the survey analysis had a paired AWT trawl, and this constituted only half of the total pairs taken (the remainder consisted of dedicated comparison trawls not used for survey). The number of pairs from the summer DY1906 survey used in the analysis was higher (all 23 paired trawl events), as expected given the larger scale of that survey, but this still represents a small share (27%) of the total number of hauls in the survey analysis. Thus, the abundance and biomass estimates derived in this component of the gear comparison analysis are a fragment of the total survey analysis and are useful only for assessing the approximate scale of variability that could be attributed to the gear.

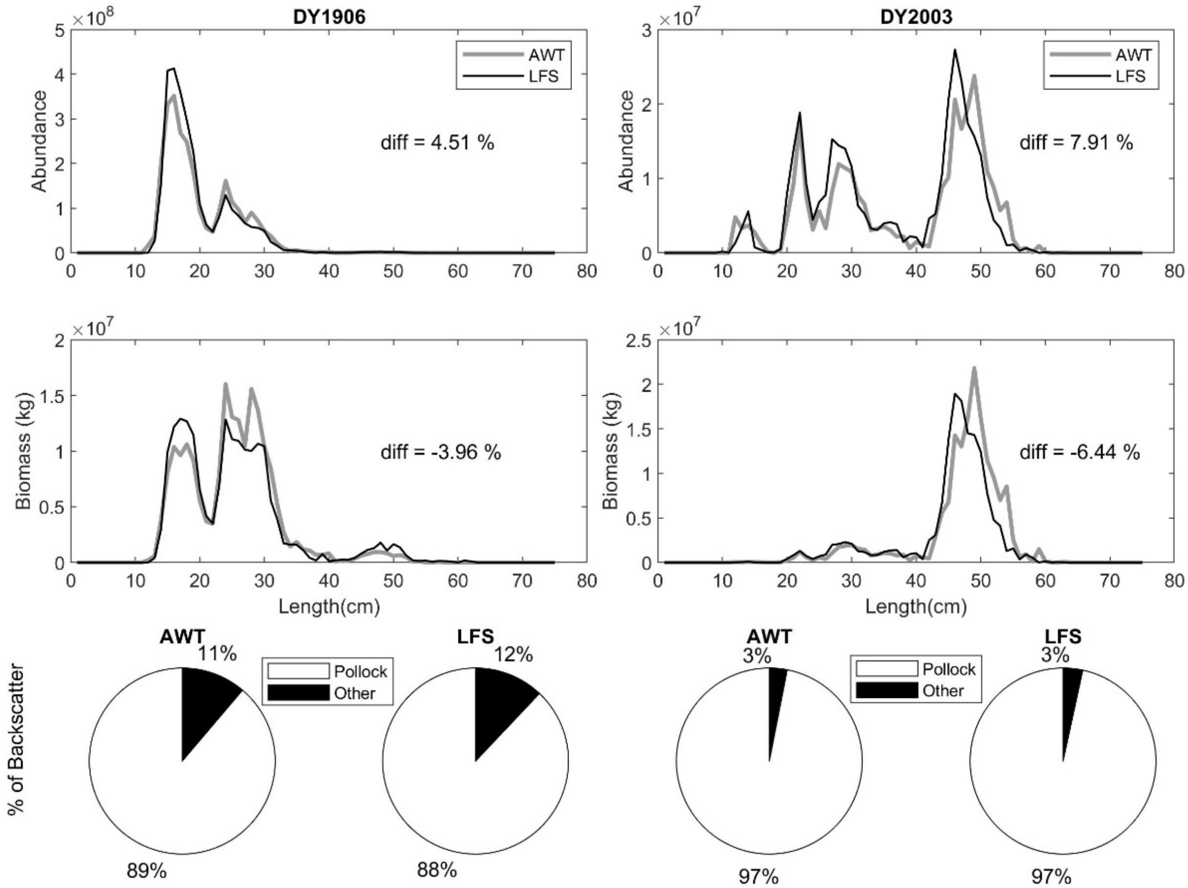


Figure 9. -- Comparison of partial acoustic-based estimates of abundance and biomass, scaled by using escapement-corrected data for two surveys. The difference refers to % change in abundance and biomass relative to the AWT. The DY1906 re-analysis is based on 26 paired trawls, while the DY2003 survey is based on six paired trawls. Lower panels show proportion of backscatter assumed to be due to non-pollock organisms.

SUMMARY

The results from this analysis present a range of comparison metrics that can be used to gauge the potential impacts of different midwater trawls on survey estimates, as well as the continuity of survey estimates of abundance if trawls are changed. The AWT was more efficient in terms of the number of pollock caught per unit time, with the exception of the DY2002 data.

Higher efficiency of the AWT would be expected given its larger mouth opening (Table 1); however, the greatest difference in mouth opening was seen in DY2002. During that survey only four haul pairs were collected (after exclusion of one pair from the analysis), which may partly explain this anomalous result. The observed efficiency patterns may also be explained by the larger mesh size in the front section of the LFS, or different propensity of pollock to avoid entering the mouth of each net (trawl avoidance, as opposed to trawl escapement through the meshes). Trawl avoidance is likely important, however, it is more difficult to measure and should be further investigated using alternative sensing equipment such as imaging sonars or underwater cameras.

Selectivity estimates for the two trawls were made using all available trawl data, and not just those hauls used for the trawl comparison. These estimates showed a lot of uncertainty due to the small number of age-1 fish in both summer and winter surveys. A comparison of the LFS from DY2102 (2021) and AWT from DY1303 (2013) Shelikof Strait surveys, although not as useful as the within-survey work, show that in independent assessments of selectivity with a large age-1 presence, the LFS performed marginally better (96% retention of age-1 fish vs 84%). For the pairwise size-dependent efficiency modeling, the differences were subtle with the selectivity ratio (*Sr*) showing only a slight inclining pattern which could be interpreted as a slightly lesser efficiency of the LFS for smaller sizes. However, uncertainty in the beta regression model was high at the edges of the size distribution. Overall, the slope of the Beta regression indicates that there is not a strong influence of fish length on *Sr*, especially relative to overall efficiency difference and the substantial uncertainty in the estimate at the extremes of the length ranges. In an overall assessment of selectivity and efficiency, we conclude there is little evidence for a consistent difference in pollock size data between the two trawls, however recognize that sample sizes were relatively small and there was substantial variability between pairs and surveys. The lack of substantial improvement in pollock selectivity was not expected, as there were several modifications made to the design of the LFS trawl to specifically improve retention of age-1 pollock.

The LFS trawl was more efficient at catching non-pollock organisms, including some forage fish species, and, most notably krill. These efficiency increases did not translate into differences in the quantity of backscatter that was attributed to pollock in the DY1906 survey. In the winter DY2003 survey, more backscatter was attributed to pollock, albeit based on a substantially smaller sample size. Improved retention of non-pollock species can be assumed to improve the overall survey results as it represents a less biased sample of the true species compositions in the survey area.

Past summer GOA surveys, most notably the 2017 survey, encountered substantial numbers of young-of-the-year (age-0) pollock, which were not well retained by the AWT equipped with an 1/2-inch codend liner. This acoustic backscatter classification of age-1+ pollock difficult due to co-occurrence of age-0 and age-1+ pollock in the water column (Jones et al. 2019). The DY1906 survey found only a modest amount of age-0 pollock, and this data showed that the relative catch efficiency of age-0 pollock with the LFS was approximately the same as that of the AWT. This result was not expected, and therefore requires more data from future surveys to understand the retention properties of the LFS trawl for age-0 pollock.

Another potential challenge for pollock assessment in the GOA summer surveys is the presence of Pacific Ocean perch (POP), which can occasionally mix with pollock in schools, making interpretation of the relative abundance of these two species dependent on their vulnerability to the trawl gear. Unfortunately, the trawl pairs in this study did not encounter POP in significant quantities (but see Figure 8, DY2002), and those that were encountered were large enough that escapement through the trawl mesh was not expected. For POP, strong diving behavior in front of the trawl has been observed during AT surveys, which may indicate a strong pre-trawl avoidance component that may make catch comparisons between the two trawls more challenging.

The application of the LFS or AWT catches from a paired trawling event to compare survey biomass estimates (Section 3.5 above) provided some useful insights. Using the AWT and LFS trawls in turn to scale the acoustic backscatter associated with each trawl pair gave a single realization of the potential differences in survey outcomes that could result from changing the trawl gear. The outcome was heavily dependent on the amount of acoustic backscatter associated with each trawl, and thus not all paired trawl sets were equally influential. In the case of the DY2003 survey, only a few paired trawl location-acoustics strata were available for this comparison. Therefore, the biomass reduction seen in the surveys using this analysis method, especially in DY2003, is likely not representative of the expected survey-level impacts of using the LFS trawl. While improved selectivity of age-1 pollock with the LFS is expected to result in higher abundance and lower biomass, the differences in this comparison are more likely related to the small sample size of trawls that could have encountered slightly different fish aggregations during the paired sampling process, with the AWT encountering larger fish than the LFS.

In conclusion, this analysis shows some expected outcomes, such as lower CPUE and increased retention of small non-pollock organisms by the LFS relative to the AWT. Length-selectivity for all sizes of pollock was similar between the two trawls. We suspect age-0 retention would be improved with the LFS trawl due to the finer codend liner, however, these data didn’t support that due to the low abundance of these fishes in the catches in 2019. The LFS was shown to retain more smaller organisms overall. These differences resulted in minimal differences in proportion of backscatter allocated to pollock when each gear was used to independently analyze a subset of the survey area, and while some difference in pollock biomass were observed in this analysis, it was probably due to a change in pollock size-distribution encountered by each trawl.

There was substantial variability in the trawl comparison data presented here, but overall there was no evidence of major differences in retention between the two trawls, especially when it comes to results for pollock. In terms of the survey time-series, it would be difficult to fully adjust historic AWT survey results to match LFS results for the differences observed here because the smallest organisms were probably not retained at all in the AWT. Based on these findings, we don't recommend making any adjustments to the acoustic-trawl survey time series for the change in gear, but the change in gear should be considered when using the data. Past survey data can be adjusted for trawl-specific selectivity depending on the application and the data available.

The LFS provides improvements in many other trawling aspects of AT survey work, including lighter, color-coded rope materials, ease of deployment and maintenance, and more appropriate catch sizes. The differences in catches between these gears does not appear to require a substantial difference in treatment of the AT survey time series for pollock.

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APPENDICES

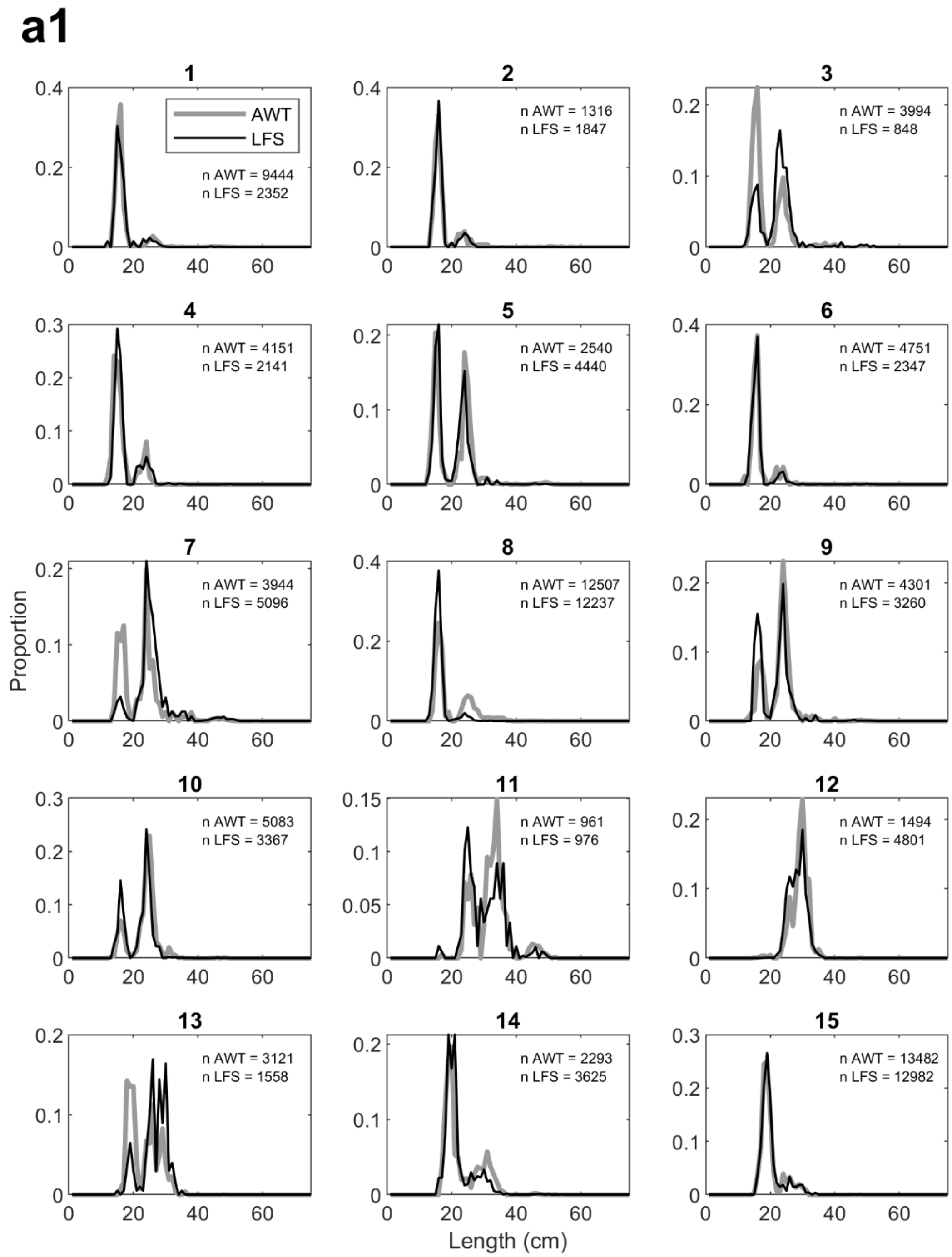
Appendix Table 1. -- Critical towing parameters for paired trawl events.

survey	haul	gear	pair number	eq time	eq latitude	eq longitude	hb time	hb latitude	hb longitude	duration (min)	headrope depth (m)	net height (m)	net width (m)	Avg wire-out	mean trawlpath S_v
DY1906	15	AWT	1	6/9/19 17:23	54.50	-162.53	6/9/19 17:33	54.50	-162.51	9.4	92.7	18.0	36.7	260.0	-57.0
DY1906	16	LFS	1	6/9/19 20:17	54.49	-162.55	6/9/19 20:58	54.50	-162.49	40.6	102.6	17.0	42.0	232.7	-68.7
DY1906	55	AWT	2	6/27/19 2:55	58.55	-152.99	6/27/19 3:28	58.52	-153.02	32.5	84.9	23.0	32.6	172.0	-75.5
DY1906	54	LFS	2	6/26/19 21:22	58.56	-152.99	6/26/19 21:48	58.54	-153.02	26.0	80.6	13.5	32.5	192.5	-66.5
DY1906	63	AWT	3	6/28/19 23:25	57.42	-154.85	6/28/19 23:45	57.40	-154.87	20.6	100.4	N/A	N/A	N/A	-67.6
DY1906	64	LFS	3	6/29/19 5:32	57.42	-154.85	6/29/19 6:10	57.39	-154.88	37.9	103.1	17.7	38.6	211.1	-73.7
DY1906	70	AWT	4	6/29/19 21:10	57.27	-155.13	6/29/19 21:35	57.26	-155.17	24.3	119.4	21.0	33.5	272.5	-67.9
DY1906	69	LFS	4	6/29/19 16:33	57.26	-155.15	6/29/19 17:00	57.26	-155.20	27.1	101.8	N/A	N/A	N/A	-70.4
DY1906	78	AWT	5	7/1/19 22:06	56.57	-155.73	7/1/19 22:16	56.57	-155.74	10.3	138.3	N/A	N/A	N/A	-70.5
DY1906	77	LFS	5	7/1/19 18:11	56.58	-155.72	7/1/19 18:36	56.58	-155.76	25.0	134.9	17.0	34.0	290.0	-61.9
DY1906	81	AWT	6	7/2/19 17:44	56.41	-156.10	7/2/19 18:28	56.39	-156.16	43.7	157.0	N/A	N/A	N/A	-73.0
DY1906	80	LFS	6	7/2/19 14:58	56.40	-156.12	7/2/19 15:05	56.40	-156.13	7.3	144.5	N/A	N/A	N/A	-67.7
DY1906	83	AWT	7	7/3/19 23:59	55.85	-156.04	7/4/19 0:02	55.85	-156.05	2.6	65.4	N/A	N/A	N/A	-58.0
DY1906	84	LFS	7	7/4/19 2:07	55.85	-156.05	7/4/19 2:10	55.84	-156.06	3.9	59.8	16.0	39.0	180.0	-65.3
DY1906	87	AWT	8	7/5/19 21:31	55.01	-157.27	7/5/19 21:48	55.00	-157.26	17.1	73.4	27.0	23.0	145.0	-70.3
DY1906	88	LFS	8	7/6/19 0:37	55.04	-157.29	7/6/19 0:52	55.03	-157.28	15.2	52.2	15.4	35.8	129.8	-60.1
DY1906	94	AWT	9	7/6/19 23:28	55.63	-156.31	7/6/19 23:29	55.63	-156.31	1.3	91.6	26.5	31.5	225.0	-83.6
DY1906	95	LFS	9	7/7/19 1:40	55.63	-156.27	7/7/19 2:04	55.62	-156.23	23.5	119.1	18.7	41.2	222.5	-71.1
DY1906	100	AWT	10	7/7/19 16:08	55.63	-156.26	7/7/19 16:08	55.63	-156.26	0.6	116.7	N/A	N/A	N/A	-87.8
DY1906	101	LFS	10	7/7/19 19:02	55.61	-156.24	7/7/19 19:28	55.58	-156.22	26.2	136.1	N/A	N/A	N/A	-69.0
DY1906	103	AWT	11	7/8/19 4:58	55.53	-155.79	7/8/19 5:18	55.52	-155.78	19.3	163.8	22.5	36.3	387.9	-69.6
DY1906	102	LFS	11	7/8/19 1:23	55.53	-155.79	7/8/19 1:48	55.51	-155.78	25.3	129.4	17.3	40.5	387.9	-72.4
DY1906	116	AWT	12	7/10/19 22:56	56.52	-152.60	7/10/19 23:04	56.52	-152.59	8.2	72.2	23.3	29.0	175.0	-65.9
DY1906	115	LFS	12	7/10/19 20:48	56.52	-152.59	7/10/19 20:52	56.52	-152.58	3.8	74.0	14.5	31.5	180.0	-64.2
DY1906	117	AWT	13	7/11/19 2:11	56.55	-152.43	7/11/19 2:18	56.55	-152.44	7.3	70.9	21.9	28.4	140.0	-68.1
DY1906	118	LFS	13	7/11/19 4:11	56.56	-152.41	7/11/19 4:14	56.56	-152.42	2.7	68.1	17.6	33.2	125.0	-67.2

DY1906	127	AWT	14	7/11/19 18:10	56.75	-152.49	7/11/19 18:25	56.74	-152.50	15.5	89.9	N/A	N/A	N/A	-63.1
DY1906	126	LFS	14	7/11/19 15:31	56.76	-152.47	7/11/19 15:44	56.75	-152.49	13.0	77.0	N/A	N/A	N/A	-65.9
DY1906	129	AWT	15	7/12/19 2:29	56.89	-152.38	7/12/19 2:39	56.88	-152.39	9.8	75.6	22.2	32.3	197.1	-65.0
DY1906	128	LFS	15	7/11/19 23:43	56.88	-152.41	7/11/19 23:50	56.88	-152.42	7.0	80.3	N/A	N/A	N/A	-58.7
DY1906	138	AWT	16	7/13/19 3:01	57.11	-152.37	7/13/19 3:09	57.10	-152.38	7.9	55.9	21.0	29.8	142.5	-66.4
DY1906	137	LFS	16	7/13/19 0:44	57.10	-152.38	7/13/19 0:44	57.10	-152.38	0.4	62.4	16.0	38.0	160.0	-83.5
DY1906	143	AWT	17	7/13/19 15:28	57.29	-152.53	7/13/19 15:39	57.29	-152.51	10.6	56.5	N/A	N/A	N/A	-62.5
DY1906	144	LFS	17	7/13/19 18:06	57.29	-152.49	7/13/19 18:16	57.29	-152.48	10.1	63.7	N/A	N/A	N/A	-52.8
DY1906	151	AWT	18	7/15/19 0:39	57.43	-151.47	7/15/19 0:44	57.43	-151.46	4.9	58.2	23.4	30.1	130.0	-65.5
DY1906	150	LFS	18	7/14/19 22:17	57.44	-151.51	7/14/19 22:31	57.44	-151.49	13.8	59.3	15.3	32.3	140.0	-74.3
DY1906	156	AWT	19	7/15/19 15:17	57.63	-151.83	7/15/19 15:28	57.64	-151.82	11.2	70.5	N/A	N/A	N/A	-63.8
DY1906	158	LFS	19	7/15/19 22:27	57.63	-151.87	7/15/19 22:31	57.62	-151.87	4.1	101.7	16.5	33.0	240.0	-57.9
DY1906	176	AWT	20	7/23/19 17:04	58.53	-151.80	7/23/19 17:08	58.52	-151.79	4.0	104.0	23.3	35.3	280.0	-50.8
DY1906	177	LFS	20	7/23/19 19:24	58.52	-151.79	7/23/19 20:04	58.48	-151.75	40.0	N/A	17.4	40.7	303.9	N/A
DY1906	201	AWT	21	7/26/19 19:21	59.01	-149.50	7/26/19 19:52	58.99	-149.54	31.2	168.4	20.1	38.5	421.3	-64.0
DY1906	200	LFS	21	7/26/19 16:09	59.02	-149.47	7/26/19 16:50	58.99	-149.52	40.7	158.5	17.1	42.0	361.9	-68.7
DY1906	206	AWT	22	7/27/19 22:11	59.02	-148.50	7/27/19 22:21	59.02	-148.51	9.9	170.9	24.1	38.6	398.3	-72.8
DY1906	205	LFS	22	7/27/19 19:16	59.03	-148.50	7/27/19 19:41	59.01	-148.51	24.9	180.0	20.0	43.2	385.9	-64.6
DY1906	225	AWT	23	7/29/19 21:59	59.65	-148.36	7/29/19 22:40	59.61	-148.38	40.7	139.7	24.0	35.0	279.5	-70.4
DY1906	224	LFS	23	7/29/19 18:48	59.66	-148.35	7/29/19 19:29	59.62	-148.37	40.7	129.1	20.0	41.0	277.4	-75.3
DY1906	232	AWT	24	7/30/19 18:22	59.42	-146.92	7/30/19 18:42	59.41	-146.92	20.5	116.3	22.9	33.5	262.5	-79.8
DY1906	233	LFS	24	7/30/19 20:42	59.43	-146.91	7/30/19 20:48	59.43	-146.91	6.0	118.8	19.0	42.0	282.7	-68.7
DY1906	236	AWT	25	7/31/19 4:32	59.53	-146.92	7/31/19 4:44	59.53	-146.94	11.3	129.7	23.7	33.7	320.0	-67.2
DY1906	235	LFS	25	7/31/19 2:07	59.54	-146.91	7/31/19 2:18	59.54	-146.93	10.8	130.8	19.0	40.4	280.0	-65.1
DY1906	262	AWT	26	8/4/19 2:25	59.65	-142.82	8/4/19 2:42	59.64	-142.85	16.4	236.7	18.0	42.0	664.1	-65.7
DY1906	261	LFS	26	8/3/19 23:00	59.66	-142.79	8/3/19 23:16	59.65	-142.82	16.4	245.7	17.3	44.9	539.4	-65.2
DY2003	1	AWT	1	3/6/20 15:38	58.23	-153.30	3/6/20 15:56	58.24	-153.28	18.0	164.7	29.6	36.0	321.8	-69.2
DY2003	2	LFS	1	3/6/20 19:24	58.22	-153.31	3/6/20 19:44	58.23	-153.28	20.0	181.0	18.5	36.7	378.0	-69.6
DY2003	3	AWT	2	3/7/20 1:30	58.19	-154.07	3/7/20 1:35	58.19	-154.06	5.1	194.4	28.0	33.5	435.0	-65.3

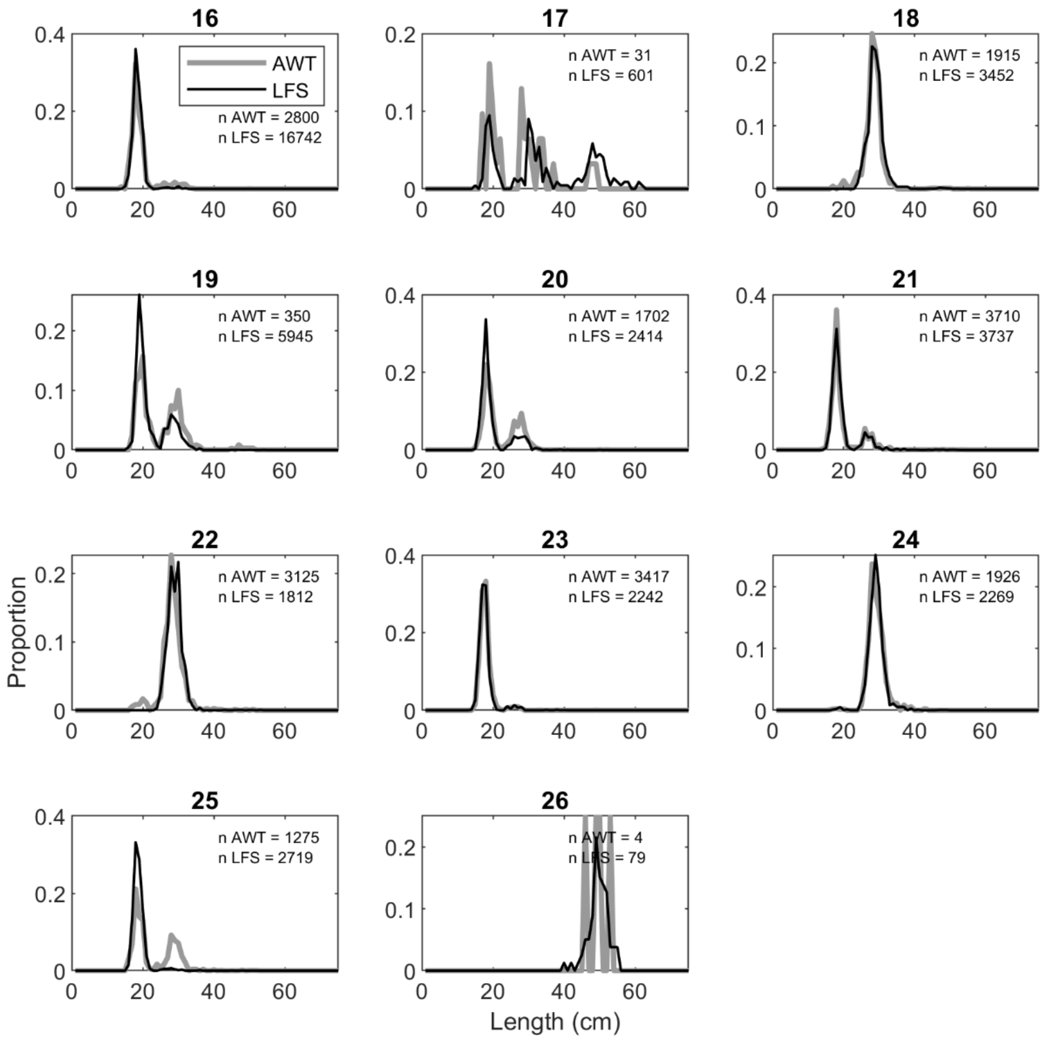
DY2003	4	LFS	2	3/7/20 3:58	58.19	-154.07	3/7/20 4:13	58.20	-154.05	15.0	214.3	16.8	31.3	405.0	-65.3
DY2003	5	AWT	3	3/7/20 9:18	57.94	-153.80	3/7/20 9:23	57.95	-153.79	5.2	145.2	26.0	32.0	285.0	-71.6
DY2003	6	LFS	3	3/7/20 12:03	57.94	-153.81	3/7/20 12:11	57.94	-153.80	7.1	151.3	19.5	30.0	255.0	-68.1
DY2003	8	AWT	4	3/7/20 19:13	58.10	-154.16	3/7/20 19:18	58.11	-154.15	5.2	211.3	25.3	40.7	535.3	-57.6
DY2003	7	LFS	4	3/7/20 15:45	58.10	-154.17	3/7/20 15:50	58.10	-154.16	4.7	225.3	20.0	38.0	510.0	-60.1
DY2003	10	AWT	5	3/8/20 3:14	57.88	-154.01	3/8/20 3:24	57.87	-154.01	9.7	159.2	26.3	26.1	362.3	-61.9
DY2003	9	LFS	5	3/8/20 0:46	57.88	-154.01	3/8/20 0:55	57.87	-154.01	9.0	160.3	20.2	39.6	318.5	-66.1
DY2003	11	AWT	6	3/8/20 7:50	57.94	-154.55	3/8/20 7:55	57.93	-154.56	5.3	175.0	29.5	33.0	400.0	-63.6
DY2003	12	LFS	6	3/8/20 10:12	57.93	-154.56	3/8/20 10:19	57.93	-154.57	6.9	164.7	19.5	31.3	355.0	-63.1
DY2003	18	AWT	7	3/11/20 5:36	57.99	-154.37	3/11/20 5:38	57.99	-154.36	2.2	223.3	N/A	N/A	N/A	-56.0
DY2003	19	LFS	7	3/11/20 8:24	57.99	-154.37	3/11/20 8:27	57.99	-154.37	3.5	230.2	24.5	32.0	410.0	-62.7
DY2003	21	AWT	8	3/11/20 13:59	57.99	-154.38	3/11/20 14:09	57.99	-154.37	10.2	228.1	21.0	30.0	463.7	-63.7
DY2003	20	LFS	8	3/11/20 11:11	57.99	-154.36	3/11/20 11:25	58.00	-154.35	14.0	222.4	23.0	32.0	399.0	-61.7
DY2003	22	AWT	9	3/11/20 19:38	57.92	-154.53	3/11/20 19:49	57.93	-154.55	11.1	219.9	21.0	30.0	489.1	-62.9
DY2003	23	LFS	9	3/11/20 22:27	57.92	-154.53	3/11/20 22:39	57.93	-154.55	11.5	225.7	17.0	38.1	530.8	-60.1
DY2003	25	AWT	10	3/12/20 3:21	57.91	-154.59	3/12/20 3:30	57.92	-154.58	9.1	N/A	23.0	25.0	450.0	-61.4
DY2003	24	LFS	10	3/12/20 0:31	57.92	-154.57	3/12/20 0:41	57.92	-154.56	10.0	N/A	19.6	31.4	428.2	-60.4
DY2003	27	AWT	11	3/12/20 9:55	57.87	-154.81	3/12/20 10:01	57.87	-154.81	6.0	207.5	24.0	20.0	395.0	-59.9
DY2003	26	LFS	11	3/12/20 6:39	57.86	-154.81	3/12/20 6:54	57.87	-154.81	15.0	N/A	24.0	26.0	420.0	-61.1
DY2003	15	AWT	12	2/27/20 17:38	57.86	-153.96	2/27/20 17:43	57.86	-153.97	5.0	162.4	21.5	39.5	430.0	-63.7
DY2003	16	LFS	12	2/27/20 20:29	57.87	-153.95	2/27/20 20:39	57.86	-153.96	9.8	163.5	12.5	42.0	495.2	-68.3
DY2002	4	AWT	1	2/21/20 4:31	53.58	-167.80	2/21/20 4:33	53.58	-167.80	1.8	347.3	28.5	47.0	660.0	-53.9
DY2002	5	LFS	1	2/21/20 7:51	53.58	-167.81	2/21/20 7:54	53.58	-167.81	2.2	261.1	15.9	43.6	625.4	-48.2
DY2002	7	AWT	2	2/21/20 14:22	53.58	-167.88	2/21/20 14:26	53.58	-167.88	4.0	259.9	24.0	45.0	540.0	-51.3
DY2002	6	LFS	2	2/21/20 11:18	53.58	-167.88	2/21/20 11:20	53.58	-167.88	1.8	256.1	20.9	44.5	539.5	-54.1
DY2002	8	AWT	3	2/22/20 9:30	53.08	-169.04	2/22/20 9:38	53.09	-169.04	8.0	266.1	30.7	44.5	481.5	-65.0
DY2002	9	LFS	3	2/22/20 12:42	53.09	-169.04	2/22/20 13:15	53.12	-169.05	33.7	308.3	21.6	41.5	562.5	-65.0
DY2002	11	AWT	4	2/22/20 23:59	53.14	-169.13	2/23/20 0:04	53.13	-169.12	5.0	367.6	36.0	40.0	710.0	-57.7
DY2002	10	LFS	4	2/22/20 20:43	53.14	-169.13	2/22/20 20:44	53.14	-169.13	0.8	345.6	20.0	34.0	800.0	-48.4

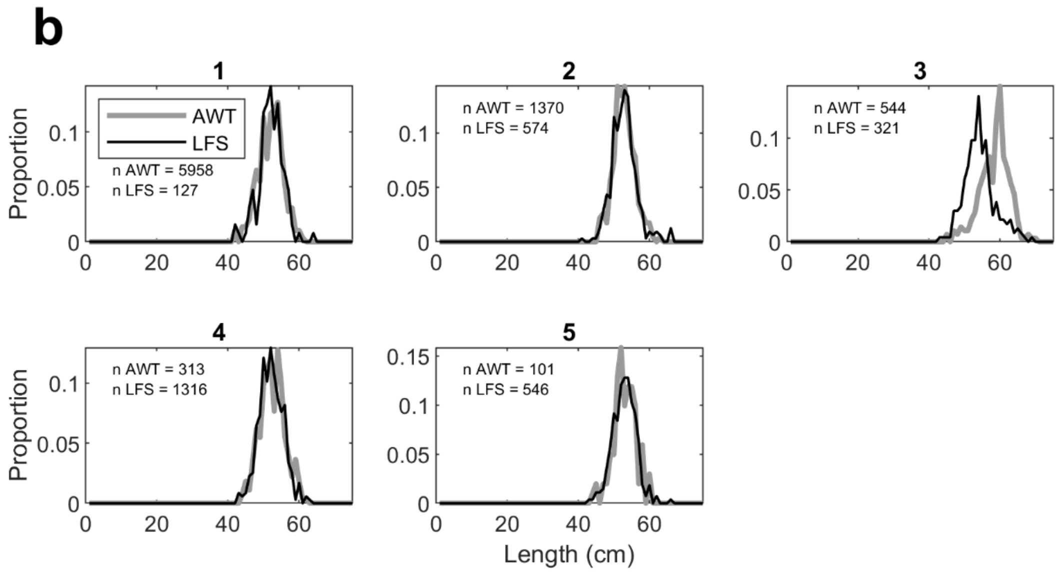
DY2002	12	AWT	5	2/23/20 3:41	53.13	-169.12	2/23/20 3:45	53.12	-169.12	4.3	346.2	34.0	41.5	740.0	-64.8
DY2002	13	LFS	5	2/23/20 7:01	53.13	-169.13	2/23/20 7:19	53.11	-169.11	18.3	378.5	20.0	39.5	743.5	N/A

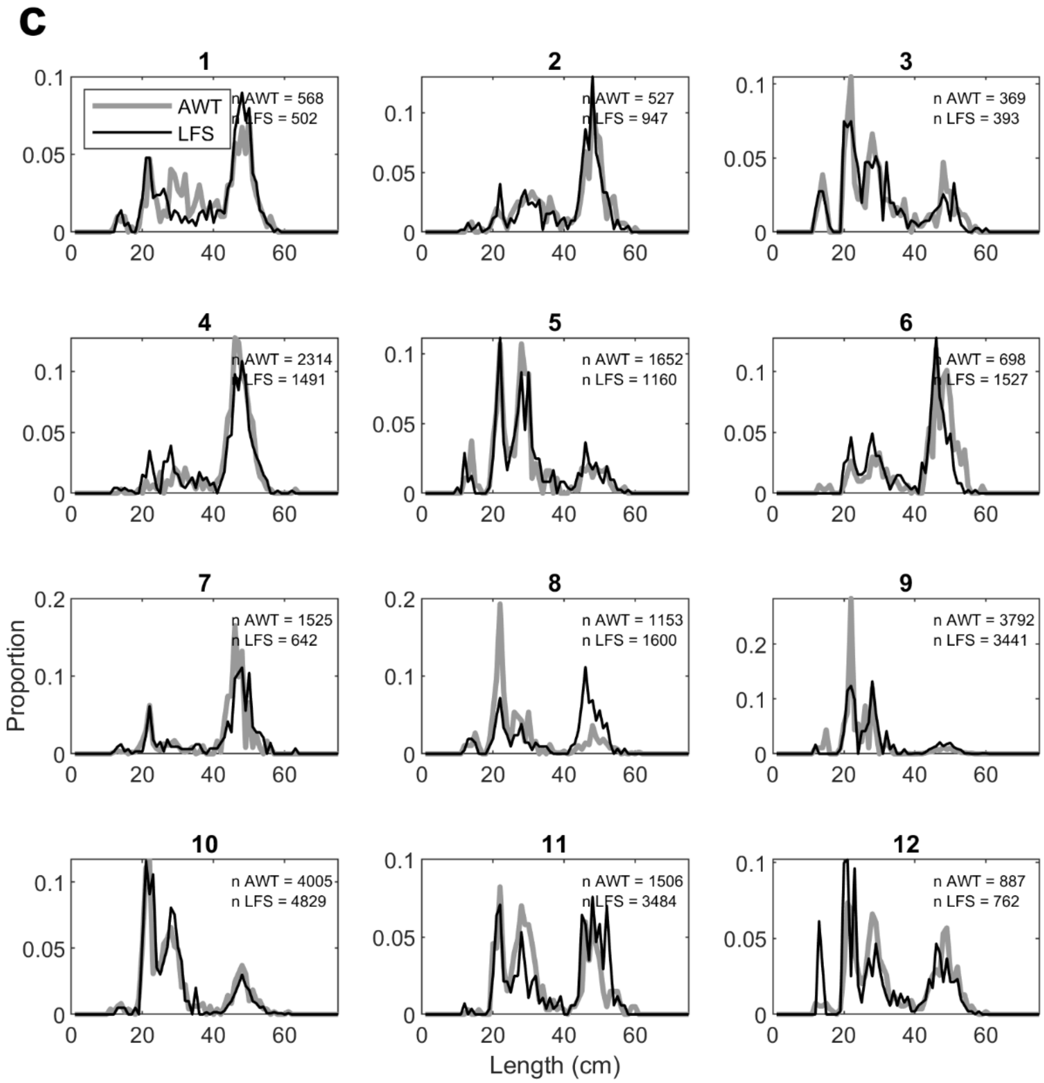


a1
1
AWT
LFS
n AWT = 9444
n LFS = 2352
2
n AWT = 1316
n LFS = 1847
3
n AWT = 3994
n LFS = 848
4
n AWT = 4151
n LFS = 2141
5
n AWT = 2540
n LFS = 4440
6
n AWT = 4751
n LFS = 2347
7
n AWT = 3944
n LFS = 5096
8
n AWT = 12507
n LFS = 12237
9
n AWT = 4301
n LFS = 3260
10
n AWT = 5083
n LFS = 3367
11
n AWT = 961
n LFS = 976
12
n AWT = 1494
n LFS = 4801
13
n AWT = 3121
n LFS = 1558
14
n AWT = 2293
n LFS = 3625
15
n AWT = 13482
n LFS = 12982
Proportion
Length (cm)

a2


16
AWT
LFS
n AWT = 2800
n LFS = 16742
17
n AWT = 31
n LFS = 601
18
n AWT = 1915
n LFS = 3452
19
n AWT = 350
n LFS = 5945
20
n AWT = 1702
n LFS = 2414
21
n AWT = 3710
n LFS = 3737
22
n AWT = 3125
n LFS = 1812
23
n AWT = 3417
n LFS = 2242
24
n AWT = 1926
n LFS = 2269
25
n AWT = 1275
n LFS = 2719
26
n AWT = 4
n LFS = 79
Proportion
Length (cm)


b
1
2
3
4
5
AWT
LFS
n AWT = 5958
n LFS = 127
n AWT = 1370
n LFS = 574
n AWT = 544
n LFS = 321
n AWT = 313
n LFS = 1316
n AWT = 101
n LFS = 546
Proportion
Length (cm)



Appendix Figure 1. -- Individual haul paired comparisons of pollock length proportions from the DY1906 summer OA survey (a1-2), the DY2002 Bogoslof Island winter survey (b), and the DY20003 Shelikof Strait winter survey (c).

U.S. Secretary of Commerce
Gina M. Raimondo

Under Secretary of Commerce for
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Dr. Richard W. Spinrad

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