Corrigendum: species and size selectivity of two midwater trawls used in an acoustic survey of the Alaska Arctic

Alex De Robertis[1*], Kevin C. Taylor[2], Kresimir Williams[1], Christopher D. Wilson[1]

[1] Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA 98115, USA.

[2] The Johns Hopkins Applied Physics Laboratory, 11100 Johns Hopkins Rd, Laurel, MD 20723, USA.

[*]corresponding author: tel: +1 206 526 4789; fax: +1 206 526 6723; alex.derobertis@noaa.gov

Keywords: trawl selectivity, recapture net coverage, Chukchi Sea, midwater trawl

Here we describe a correction to estimates of the size and species selectivity of two survey trawls in De Robertis et al. (2017a). In that study, trawl selectivity was investigated by equipping a modified Marinovich survey trawl with recapture nets to estimate the degree to which organisms entering the trawl mouth escape during the capture process. On a subset of hauls, paired hauls with both the Marinovich and a larger Cantrawl trawl were conducted. The size and species selectivity of the nets was estimated by combining the catch data from both trawls in a statistical model. Escapement (E) from each section of the Marinovich was characterized as $E = \frac{c_{mar}}{f_{mar}}$

where c_{mar} is the catch in the Marinovich recapture net in a given section of the net and f_{mar} is the fraction of the trawl surface area covered by the recapture nets in that section.

In De Robertis et al. 2017a, f_{mar} of 0.022 was used in the forward portion of the trawl, and 0.055 was used in the aft portion of the trawl. We have discovered that these values were incorrectly computed. The correct value of f_{mar} in the experimental configuration is 0.065 in the forward portion of the trawl, and 0.132 in the aft portion of the trawl. Here we summarize the impacts of this inadvertent error on the selectivity estimates reported in De Robertis et al. (2017a). We also examine the effects of this error on the abundance estimates of acoustic-trawl surveys conducted in the Chukchi Sea in 2012 and 2013 as these surveys applied these selectivity relationships in an effort to correct for the selectivity of the survey trawl (De Robertis et al. 2017b).

The proportion of mesh area covered by the recapture net in De Robertis et al. (2017a) was incorrect for two reasons. First, the size of the recapture net was miscommunicated, and the number of meshes covered by the recapture net was under-estimated. Second, the codend was not included in the trawl diagram, and the area of the net covered by the fine-mesh (2 by 3 mm) codend liner was misinterpreted. We thus incorrectly assumed that the liner was placed in the aft section of the net during they survey rather than lining a separate, undocumented codend. These errors were discovered by comparing the trawl with the net diagram. These errors could have been avoided by better documentation of the trawl and recapture nets, and verifying that the recapture nets and trawl matched the net plans as part of the experiment. Corrected diagrams of the trawl and recapture nets as used in the experiment (Figs. S1.1-1.2), and a protocol to estimate recapture net coverage in this and future studies (S2) are given as supplementary material.

The primary consequence of under-estimating f_{mar} by a factor of 3 in the forward section and 2.4 in the aft section is that escapement from the Marinovich trawl was over-estimated. Escapement from the Cantrawl was also over-estimated as this depends on the estimated abundance of fish in the volume sampled which depends on the estimated selectivity of the Marinovich (De Robertis et al. 2017a, their equation 9). The reductions in estimated escapement can be visualized by comparing the revised calculations (Table 1 and Figs S1.3-S1.7) with those in the original publication (their Table 2, Figs. 4-5 and 7-9).

Although the qualitative pattern of escapement from different sectors of the net is similar to that described by De Robertis et al. (2017a), the proportion of fish escaping though the meshes is smaller (Fig. S1.4). In general, the corrected probability of retention in both nets is higher, but the slope of the curves remains similar (Figs. S1.5-7). The length at 50% retention (L_{50}), which is directly affected by the absolute value of escapement, increases when f_{mar} is corrected (compare Table 1 and De Robertis et al. (2017a), their Table 2). However, the slope of the curve defined by *SR*, which describes the difference in length at 75% and 25% retention (i.e. L_{75} - L_{25}), is less affected. For example, for Arctic cod, the most abundant species, L_{50} for the Marinovich shifts from 6.2 to 5.2 cm after correction, while *SR* is unchanged at 2.2 cm. In the case of the Cantrawl, L_{50} shifts from 5.6 to 5.3 cm, and *SR* is unchanged at 0.8 cm. Stated another way, the primary impact is that the probability of retention increased in both nets (i.e. L_{50} decreased). For example, the probability of retaining a 4 cm Arctic cod increased from 0.11 to 0.23 for the Marinovich after correction, and 0.01 to 0.02 for the Cantrawl. However, *SR* was unaffected in this case. Thus, although the corrected results indicate that the trawls are more likely to retain these small fishes than initially estimated, the relative differences between different sizes, species and trawls are less affected. We regret the error, and the corrected selectivity values and figures presented here should supersede those in the original publication.

The primary application of these selectivity relationships was to estimate selectivity-corrected species and size distributions from trawl catches for use in acoustic-trawl abundance surveys (De Robertis et al. 2017b). These survey estimates are a complex function of acoustic backscatter measurements, trawl catches, selectivity estimates, and the acoustic properties of the organisms. We re-computed the abundance estimates with the corrected selectivity estimates and find that as expected from prior sensitivity analyses (De Robertis et al. 2017b, their table 3), the effect on abundance estimates is relatively modest.

Total estimates for Arctic cod were within 0.7% of the previous estimates and those of other, less abundant species differed by at most 9.9% (Table 1). In addition, the reduced selectivity shifted size distributions towards larger sizes: mean length increased by up to 1.1% for Arctic and saffron cod, and by up to 7.9% for capelin and herring (Table 1). These differences are small because the acoustic-trawl estimates are sensitive to the relative change in escapement between species and size classes (i.e. changes in size and species composition) rather than the absolute changes in escapement. Thus, the impact of the error described above on the acoustic-trawl abundance estimates reported by De Robertis et al. (2017b) is modest, and does not appreciably alter the conclusions of that study. A revised data set with abundances computed with the corrected f_{mar} parameter is available for use in future studies (De Robertis, 2021).

Acknowledgements

This work was funded by the Alaska Fisheries Science Center, NOAA. This research builds on the Arctic EIS program and informs work relevant to the Arctic Integrated Ecosystem Research Program (IERP; http://www.nprb.org/arctic-program/). This manuscript is NPRB Publication ArcticIERP-37.

References

De Robertis, A. (2021), “De Robertis et al, 2017 - Chukchi shelf acoustic-trawl survey (corrected)”, Mendeley Data, V1, doi: 10.17632/py3859yhnf.1 https://data.mendeley.com/datasets/py3859yhnf/1

De Robertis, A., Taylor, K., Williams, K., and Wilson, C. D. 2017a. Species and size selectivity of two midwater trawls used in an acoustic survey of the Alaska Arctic. Deep-Sea Research II, 135: 40-50. https://doi.org/10.1016/j.dsr2.2015.11.014

De Robertis, A., Taylor, K., Wilson, C., and Farley, E. 2017b. Abundance and Distribution of Arctic cod (*Boreogadus saida*) and other pelagic fishes over the U.S. continental shelf of the Northern Bering and Chukchi seas Deep-Sea Research II, 135: 51-65. https://doi.org/10.1016/j.dsr2.2015.11.014

Orr, J. W., Wildes, S., Kai, Y., Raring, N., Katugin, O., and Guyon, J. 2015. Systematics of North Pacific sand lances of the genus *Ammodytes* based on molecular and morphological evidence, with the description of a new species from Japan. Fishery Bulletin, 113: 129-156.

Table 1. Revised logistic selection curve parameters with bootstrapped confidence intervals. Methods are equivalent to those in De Robertis et al. (2017a) but with a correction for the degree of coverage of the recapture nets. L_{50} is the length in cm at 50% retention, and SR is the length in cm between 75 and 25% retention. Scientific names are follows: Arctic cod (*Boreogadus saida*), saffron cod (*Eleginus gracilis*), Arctic sand lance (*Ammodytes hexapterus*), Pacific capelin (*Mallotus villosus*). In the case of Arctic sand lance and capelin, some of the point estimates of L_{50} and SR fall outside of the 90% bootstrap confidence interval, which suggests that these values are affected by a small number of trawl hauls. Large values of SR imply little size selectivity across the observed size range. Note that *A. hexapterus* is referred to as Arctic sand lance (Orr et al., 2015), while this species was referred to as Pacific sand lance in De Robertis et al., 2017a,b.

Species Group	Marin. L_{50} (cm) (90% CI)	Marin. SR (cm) (90% CI)	Can. L_{50} (cm) (90% CI)	Can. SR (cm) (90% CI)
Arctic cod	5.2 (4.7,5.9)	2.2 (1.6, 3.1)	5.3 (4.1, 5.8)	0.8 (0.7, 1.0)
saffron cod	10.3 (8.3, 19.7)	6.1 (4.2, 14.2)	6.3 (-15.5, 24.4)	1.1 (-1.3, 3.3)
Arctic sand lance	11.1 (6.5, 18.9)	5.9 (2.1, 15.6)	257.2 (-64.3, 94.4)	77.5 (-19.7, 24.9)
capelin	-48.2 (-31.7, 45.7)	-88.8 (-56.3, 59.4)	6.2 (-4.3, 18.5)	1.0 (-12.2, 7.5)
other fishes	9.3 (8.2, 24.5)	5.2 (4.3, 15.7)	13.0 (9.1, 34.0)	2.9 (1.8, 9.0)
jellyfish	3.2 (-0.8, 3.8)	1.3 (0.1, 1.5)	89.4 (-437.6, 557.7)	52.6 (-283.8, 342.4)

Table 2. Revised abundance of fishes by year and area estimated with acoustic-trawl methods in the 2012 and 2013 Arctic Eis surveys of the northern Bering and Chukchi continental shelf. The abundance in various survey sub-regions is given for comparison with the previously published results (De Robertis et al, 2017a; their table 3). A summary of the percent changes in abundance $\left[\left(1-\frac{N_{corr}}{N_{orig}}\right)*100\right]$and mean length $\left[\left(1-\frac{\bar{L}_{corr}}{\bar{L}_{orig}}\right)*100\right]$ comparing the original estimates of De Robertis et al. (2017b) (*orig*) and the corrected estimates (*corr*) is provided.

Species	**Year**	**N. Bering** (No. fish)	**S. Chukchi** (No. fish)	**N. Chukchi** (No. fish)	**Entire area** (No. fish)	**Common area** (No. fish)	**Change in abundance** (% in entire area)	**Change in length** (% of mean length)
Arctic cod	2012	$6.5 \cdot 10^{9}$	$2.0 \cdot 10^{8}$	$8.0 \cdot 10^{10}$	$8.6 \cdot 10^{10}$	$8.6 \cdot 10^{10}$	0.2	0.5
	2013	$2.8 \cdot 10^{2}$	$2.3 \cdot 10^{9}$	$2.5 \cdot 10^{11}$	$2.5 \cdot 10^{11}$	$2.4 \cdot 10^{11}$	-0.7	1.0
Saffron cod	2012	$5.8 \cdot 10^{7}$	$6.9 \cdot 10^{8}$	$6.6 \cdot 10^{8}$	$1.4 \cdot 10^{9}$	$1.4 \cdot 10^{9}$	7.5	1.1
	2013	$1.3 \cdot 10^{7}$	$4.4 \cdot 10^{9}$	$1.5 \cdot 10^{9}$	$5.9 \cdot 10^{9}$	$5.9 \cdot 10^{9}$	2.3	0.3
Capelin	2012	$3.3 \cdot 10^{8}$	$2.9 \cdot 10^{8}$	$7.5 \cdot 10^{8}$	$1.4 \cdot 10^{9}$	$1.1 \cdot 10^{9}$	5.2	7.9
	2013	$6.2 \cdot 10^{8}$	$3.3 \cdot 10^{7}$	$1.1 \cdot 10^{9}$	$1.8 \cdot 10^{9}$	$1.7 \cdot 10^{9}$	9.9	3.9
Herring	2012	$1.3 \cdot 10^{9}$	$1.7 \cdot 10^{8}$	$1.3 \cdot 10^{7}$	$1.5 \cdot 10^{9}$	$1.5 \cdot 10^{9}$	-1.1	2.0
	2013	$7.5 \cdot 10^{9}$	$4.2 \cdot 10^{7}$	$1.5 \cdot 10^{5}$	$7.6 \cdot 10^{9}$	$6.6 \cdot 10^{9}$	0.1	0.8

Supplementary Material – Corrigendum to: "Species and size selectivity of two midwater trawls used in an acoustic survey of the Alaska Arctic" (Deep-Sea Res. II 135 (2017) 40–50)

S1. Supplementary figures

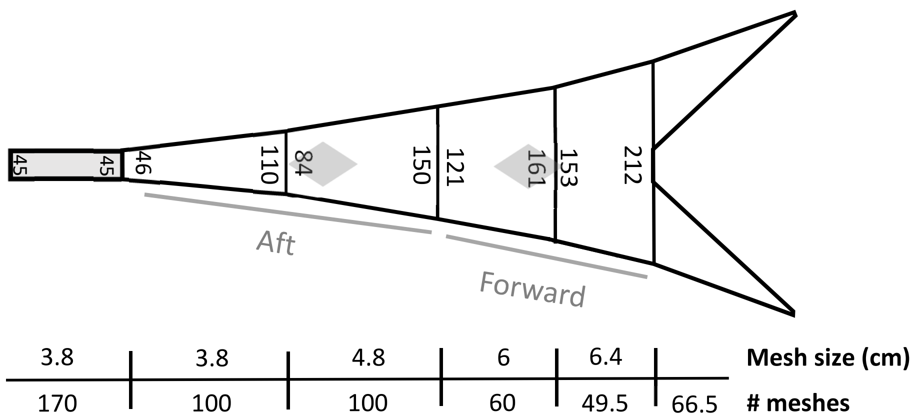

Fig. S1.1 Diagram of the modified Marinovich trawl used in De Robertis et al., 2017a. The size and number of meshes is annotated at the bottom. Mesh size refers to the length of meshes when stretched. The trawl is symmetrical with an equivalent top, side and bottom. Only one view is depicted. For the purposes of analysis, the trawl was divided into forward and aft sections of similar mesh size. The approximate location of the recapture nets in the center of each section is given by the gray diamonds, and the 2 by 3 mm codend liner is indicated by gray shading.

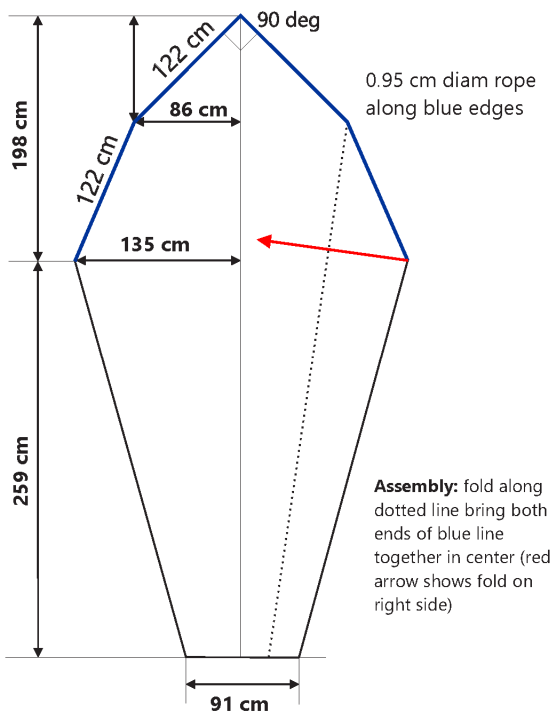

Fig. S1.2 Schematic of recapture nets. The net is made of the same 2 by 3 mm oval mesh used for the codend liner. The net is assembled by folding both sides of the leading edge (blue lines) towards the mid-line forming a diamond, and sewing the two sides together. The dotted line shows the fold location on the right side, and the red line shows the direction of the fold.

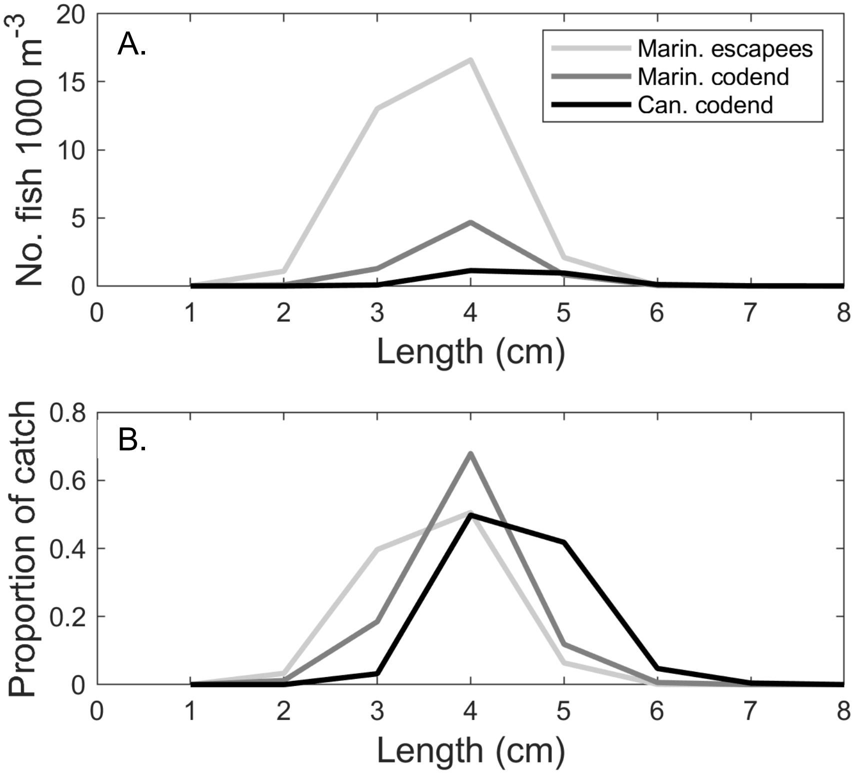

Fig. S1.3 Corrected abundance and size distribution of Arctic cod escaping from the mod-Marinovich trawl, and those captured in the Marinovich and Cantrawl codends. The figures depict the catch in the 7 hauls where both the Marinovich with recapture nets and Cantrawl net were deployed and Arctic cod were caught. A) Abundance of fish as a function of length estimated to escape from the Marinovich based on the recapture net catches and abundance of those captured in the codends of the Marinovich and Cantrawl trawls. The abundance of escapees was computed by extrapolating the recapture net escapement over the body of the net. B) Size distribution of juvenile Arctic cod in recapture nets, and the codends of the Marinovich and Cantrawl trawls. Replaces Fig. 4 in De Robertis et al. (2017a).

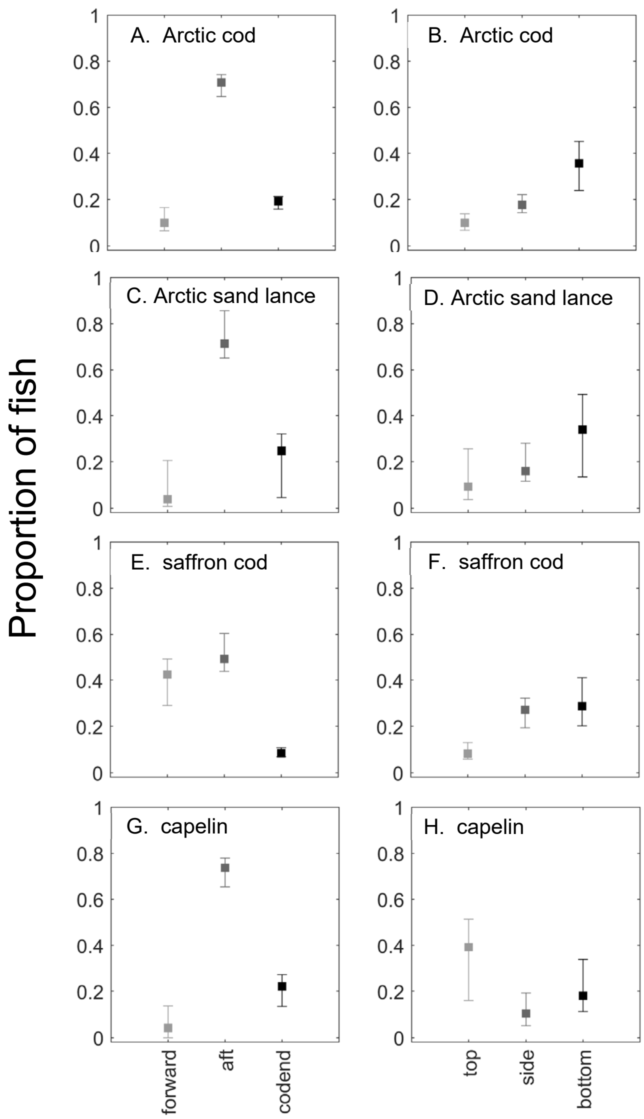

Fig. S1.4 Corrected escapement pattern of abundant fish species in the Marinovich trawl estimated from recapture net catches. A-B) Arctic cod, C-D) Arctic sand lance, E-F) saffron cod, G-H) capelin. Panels to the left indicate the proportion of fish entering the trawl mouth estimated to escape through the forward and aft net sections or retained in the codend. Panels to the right depict the proportion of individuals expected to exit the net through the meshes in the top, either side (i.e. total escapement from both sides divided by 2), and bottom of the trawl. The points represent the observed means, and error bars represent a 95% bootstrapped confidence interval. Replaces Fig. 5 in De Robertis et al. (2017a).

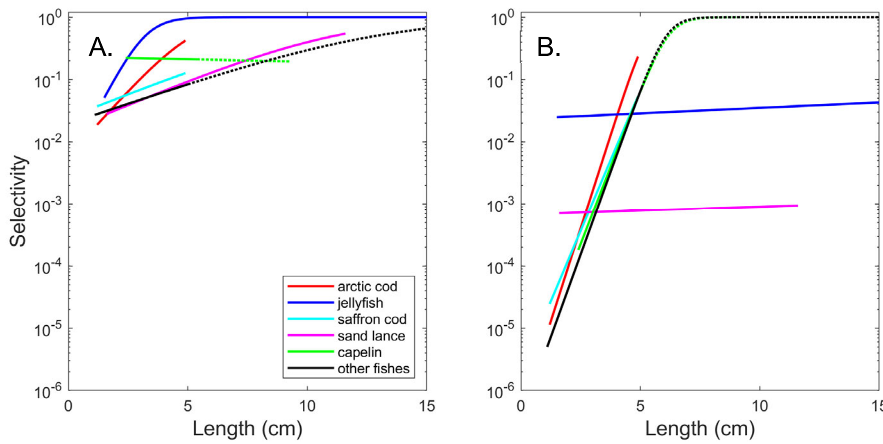

Fig. S1.5 Corrected estimates of size-specific selectivity by species group for A) Marinovich and B) Cantrawl trawls derived from joint analysis of catches in the Marinovich recapture nets and codend catches in both trawls. The logistic selectivity curves fitted in the model are depicted on semi-log plots as the probabilities of retention are low for small individuals. The predicted selectivity at a given size was higher for the Marinovich than the Cantrawl except for the case of larger capelin and other fishes where the dotted line indicates that the calculated selectivity is higher for the Cantrawl. Average capelin selectivity decreased with length for the Marinovich trawl because it was estimated to retain few large capelin compared to the densities captured in the Cantrawl. This indicates larger capelin may be avoiding the Marinovich prior to entering the trawl mouth, however the associated uncertainties are high (see Table 1, Fig S1.7D). The curves extend over the size range encompassing 99% of the fish in the environment (as estimated by combining the Marinovich codend catch with the recapture nets, see De Robertis et al., 2017a, their equation 13). Replaces Fig. 7 in De Robertis et al. (2017a).

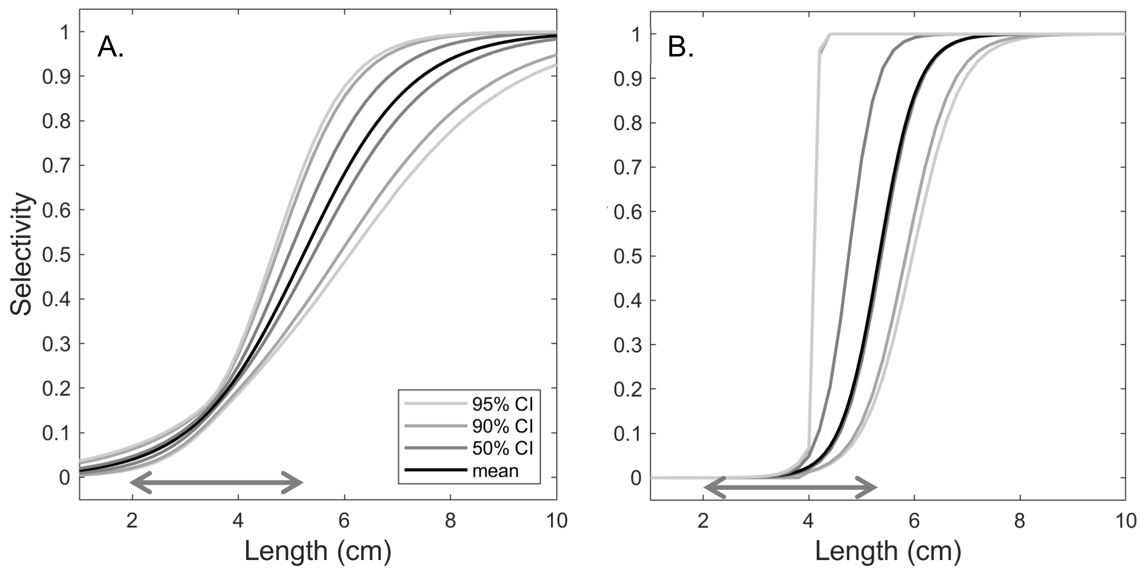

Fig. S1.6 Corrected confidence intervals (CI) of selectivity of A) Marinovich and B) Cantrawl trawls on Arctic cod generated by taking the 95^{th}, 90^{th} and 50^{th} percentiles of 10000 bootstrap estimates. The lower 50% CI in panel B is very close to the black line representing the mean value and is difficult to visualize. The arrows indicate the size range of 99% of Arctic cod individuals as estimated from the Marinovich catches. Replaces Fig. 8 in De Robertis et al. (2017a).

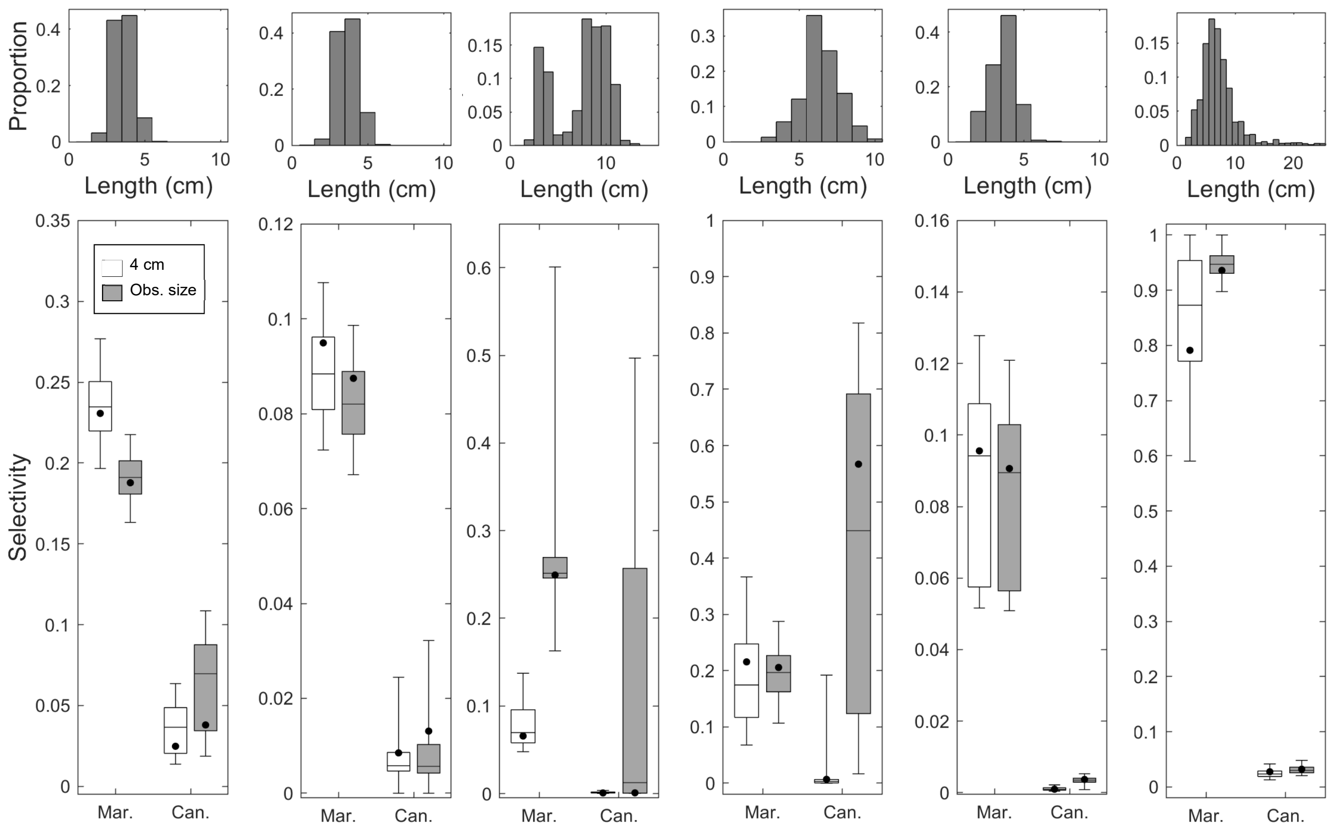

Fig. S1.7 Corrected bootstrap analysis of the variability in estimates of Marinovich and Cantrawl selectivity for different species groups: A) Arctic cod, B) saffron cod, C) Arctic sand lance, D) capelin, E) other fishes, F) jellyfish. The top panel shows the size distribution estimated to be present in environment based on 30 hauls with the Marinovich equipped with recapture nets. The histograms extend over the size range encompassing at least 99% of the fish in the environment. The bottom panel shows box plots of bootstrapped probabilities of retention of a 4 cm individual (white), and the average probability of capturing animals with the size distribution observed in the experiment as depicted in the upper plot (gray). The boxplots represent the 5th, 25th, 50th, 75th and 95th percentiles of the selectivity estimate. Estimates of selectivity using parameters derived from all available data (Table 1) are shown as a black dot. Replaces Fig. 9 in De Robertis et al. (2017a).

S2. Quantifying of the proportion of meshes covered by recapture nets

After the recapture nets were sewn onto the outside of the trawl in a diamond pattern (Fig. S1.1), the number of meshes covered by the recapture net was counted. The forward recapture net, which was installed over 6 cm meshes, extended 35 meshes in the fore-aft direction, and 35 in the right-left direction. The aft recapture net, which was installed on 3.8 cm meshes, extended 47 meshes in the fore-aft direction, and 47 in the right-left direction. The number of meshes covered by a recapture net is the product of the fore-aft and left-right coverage. Thus, the forward recapture net covered 1225 (35^2) 6 cm meshes, and the aft net covered 2209 (47^2) 3.8 cm meshes.

The number of meshes in each panel, was treated as a trapezoid:

$$m_p = \left(0.5\left(w_{f,p} + w_{a,p}\right) \cdot l_p\right), \qquad (1)$$

where $w_{f,p}$ represents the width of panel p in meshes towards the front of the trawl, $w_{a,p}$ represents the width of the panel towards the aft part of the trawl, and l_p represents the length in meshes (see Fig. S1.1 for these quantities).

The fraction of the surface area covered by the recapture nets (f) in a given section was estimated by normalizing the number of meshes covered by the recapture net (c) to the total number of meshes m_p in the two panels p making up the section covered by the pocket net. Because the mesh size varies in different parts of the trawl, mesh sizes are expressed as the of number 1 cm mesh equivalents in each section:

$$f = \frac{c \cdot \left(\frac{s_k}{s_r}\right)^2}{\sum_p \left(m_p \cdot \left(\frac{s_p}{s_r}\right)^2\right)}, \qquad (2)$$

Where c represents the number of meshes covered by the recapture net, s_k represents the size of the meshes covered by the recapture net, s_r represents a reference mesh size (1 cm), and s_p

represents the mesh size in panel *p*. Given that the trawl is made up of identical top, bottom, right, and left sides, the fraction covered is the same on all sides. For trawls where this is not the case, *f* would differ for each side of the trawl.

Thus, the fraction of surface area covered in the forward section (i.e. 2 forward panels) in the Mod-1 Marinovich trawl can be expressed as

$$f_{fwd} = \frac{1225 \cdot \left(\frac{6}{1}\right)^2}{\left(9033.75 \cdot \left(\frac{6.4}{1}\right)^2\right) + \left(8460 \cdot \left(\frac{6}{1}\right)^2\right)}, \text{ or } 0.065. \quad (3)$$

Likewise, the fraction of surface area covered by recapture nets in the aft section (i.e. 2 aft panels) can be expressed as

$$f_{aft} = \frac{2209 \cdot \left(\frac{4.8}{1}\right)^2}{\left(11700 \cdot \left(\frac{4.8}{1}\right)^2\right) + \left(7800 \cdot \left(\frac{3.8}{1}\right)^2\right)}, \text{ or } 0.132. \quad (4)$$