Determining Selectivity and Optimum Mesh Size to Harvest Three Commercially Important Mid-Atlantic Species

A Report to the Mid-Atlantic Fishery Management Council and the Atlantic States Marine Fisheries Commission

FINAL REPORT

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ABSTRACT

In order to update selectivity parameters for three important Mid-Atlantic species, a collaborative at-sea research project was conducted. The selectivity for *Paralichthys dentatus* (summer flounder) and *Centropristis striata* (black sea bass) and *Stenotomus chrysops* (scup) was determined for a range of mesh sizes, shapes, and configurations. This study compared the catch composition, retention efficiency, and size selectivity parameters of five different codends in the commercial bottom trawl fishery within the Mid-Atlantic region. This project evaluated the selectivity of *P. dentatus, C. striata*, and *S. chrysops* using a trouser trawl outfitted with removable codends configured with 4.5" diamond, 5" diamond, 5.5" diamond, 6" diamond, 6" square mesh, and a 2.125" mesh control codend. A SELECT model was employed for determination of selectivity parameters. All tested codend mesh sizes are effective at releasing at least 75% of scup at or below the length at 50% maturity, and at least 50% of scup which are 100% mature. For scup, the 5" diamond regulation mesh is very effective in releasing fish that are at or less than the minimum size. All codends release at least 75% of black sea bass that are at or below the length at 50% maturity, and the 5.5" diamond, 6" diamond, and 6" square meshes were effective at releasing at least 50% of black sea bass which are 100% mature. For black sea bass, the 4.5" diamond regulation mesh is effective at releasing fish that are at or less than the minimum size. Either a 4.5" or 5" diamond codend could be considered as a common regulation mesh codend for both scup and black sea bass. Input would be needed from industry to determine how this might affect catch, market and market price for these species. The 5" diamond, 5.5" diamond, 6" diamond and 6" square mesh are effective in releasing at least 75% of summer flounder that are at the length of 50% maturity. None of the tested codends are effective at releasing summer flounder that are 100% mature. For summer flounder, the 5.5" diamond regulation codend is effective at releasing fish that are at or less than the commercial minimum size. The 6" square regulation mesh codend is less effective at releasing fish that are at minimum size.

INTRODUCTION

The Cornell University Cooperative Extension Marine Program (CCE), in collaboration with the Cornell University Department of Natural Resources, Jonathan Knight of Superior Trawl and members of the commercial fishing industry of the Mid-Atlantic region, conducted an at-sea research project aboard a commercial fishing vessel involved in the directed summer flounder (*Paralichthys dentatus*), black sea bass (*Centropristis striata*), and scup (*Stenotomus chrysops*) fisheries of the Mid-Atlantic to determine the selectivity of five different codends for three commercially important species. The project was conducted pursuant to the Mid-Atlantic Fishery Management Council (MAFMC) request for proposals for Mid-Atlantic Collaborative Fisheries Research, specifically Priority 5: to determine mesh selectivity for summer flounder and/or black sea bass and to quantify selectivity at a range of mesh sizes, shapes, and configurations. CCE included an additional species, scup, in our assessment since it is also a commercially important species to the MAFMC and managed under the same Fishery Management Plan (FMP) with summer flounder and black sea bass. All three of these species are managed with different minimum mesh sizes.

This priority was selected by CCE based on feedback received from the commercial fishing industry and our own review of the history that formed the basis of the minimum mesh size requirements for these species. Upon review it was found that there were few selectivity studies leading to the formation of the mesh size requirements for these valuable commercial species. Those selectivity studies that were conducted for these species are more than 20 years old and utilized various gears and methods. Through the many years of amendments to the FMP, the correlation between the species' minimum size and corresponding mesh size requirements are no longer clear. (See Appendix A for a detailed review of these studies and the development of mesh size and minimum fish size management measures.) Consequently, the goal of this project was to determine the selectivity of multiple codend mesh sizes, and configurations, relative to summer flounder, black sea bass, and scup retention. This goal is associated with six objectives:

- Effectively determine the selectivity of 4.5" diamond, 5" diamond, 5.5" diamond, 6" diamond and 6" square mesh codends for all 3 species
- To determine if one or more of these mesh sizes effectively reduces the catch of juvenile summer flounder, black sea bass and scup
- To evaluate the current mesh size regulations relative to current minimum retention size of each of these 3 species
- To demonstrate what the potential is for a possible successful common mesh size to reduce discards in the Mid-Atlantic fisheries
- To complete an applied experiment across a wide range of strata and conditions including: areas, depths and bottom types, which are reflective of the summer flounder, black sea bass and scup fisheries
- Validate these results for fishery managers and fishermen

The study described below fully addressed the stated project goal and objectives. All objectives were met as described in the Data Analysis, Results and Conclusions sections of this report.

Summer flounder, black sea bass, and scup are managed under the same Fishery Management Plan. The original FMP was developed in 1988 and focused on summer flounder. Scup and black sea bass were added in 1996. A significant component to fisheries management is the designation of a minimum mesh size. Currently the minimum fish size for summer flounder, black sea bass, and scup are 14", 11", and 9" respectively. The minimum codend mesh size requirements for trawls are: 5.5" diamond or 6" square mesh for summer flounder; 4.5" diamond mesh for black sea bass; and 5" diamond mesh for scup. As mentioned above, the selectivity research used to inform regulatory mesh size was inconsistent and performed many years ago. A current study was needed and requested to comprehensively re-examine mesh selectivity for these three species. Additionally, the results of such a study could supply a basis for one or two common mesh sizes that would provide the required size selectivity for these species rather than requiring four different mesh sizes. Standardizing the mesh size for these three species has been suggested but it has never been researched.

The study that was used to determine the summer flounder selectivity, (Anderson et al., 1983) was performed over 20 years ago and the mesh sizes of the experimental codends were different per vessel due to material type. The mesh selectivity studies used to inform scup management were conducted by DeAlteris and Riefsteck (1992) and were simulations of commercial fishing activity in flume tanks using rod and reel caught fish. The net in the tank was attached to a towing sled and was constructed with a covered codend which may have affected the simulated results. In developing the black sea bass mesh regulations there was a lack of mesh selectivity information, so data was used from a lobster trap study that determined a mesh size estimate based on a relationship between body depth and length (Weber and Briggs, 1983). The studies that have quantified the codend selectivity for these three species are further described in much greater detail in Appendix A.

MATERIALS AND METHODS

Vessel

The project was conducted onboard a commercial fishing vessel targeting summer flounder, black sea bass, and scup. The vessel to be used in this project was originally scheduled to be the F/V Caitlin & Mairead, a trawl vessel homeported in Montauk, New York. Shortly after the funding for this project was received it was realized that the use of this vessel as a research platform would not be possible. The project design was amended and the F/V Prevail based out of Point Judith, RI was recruited as the project's industry partner. The F/V Prevail is a 77.9 foot, 140 gross tonnage, steel stern trawler built in 1980. The vessel has 755 H.P., two hydraulic net reels, and an ITI Trawl Monitoring System (door mounted sensors that report net spread). The ITI system allowed for real time monitoring of the net geometry ensuring consistency throughout the duration of research fishing.

Gear

This study compared the catch composition, retention efficiency and size selectivity parameters of five different codends in the commercial, bottom trawl fishery in the Mid-Atlantic region. These methods were used to evaluate the selectivity of summer flounder, black sea bass, and scup with the following codends: 4.5" diamond, 5" diamond, 5.5" diamond, 6" diamond, and 6" square mesh. All codends were tested against a $2^1/_8$ inch control codend. All experimental codend measurements are inside-stretched mesh between the knots. The small mesh codend was designed to retain all fish of all sizes for our three target species.

Tows were conducted using a trouser trawl adapted for use in this study. The trouser trawl design is a single trawl net with two separate trouser leg sections and two individual codends. The configuration of this type of trawl net allows a control codend to be compared with an experimental codend on the exact same course during each tow and interacting with the same assemblage of fish. Therefore, each individual tow made by one vessel will be, in of itself, a replicate tow due to the inherent nature of the trouser trawl net design. Using a single net capable of delivering replicate tows provided this study with a comparison of sequentially exact tows using the control and experimental gear effectively.

The net used for this project was a 420 X 16 cm, 4 seam trawl with a bottom hanging line of 38 meters. 92-inch Type 4 Tyberon doors were used. This trawl is typical of a trawl used along the East Coast of the U.S. The sweep of the trawl consisted of 2 3/8" and 3" rubber discs on wire rope. The sweep was 124 feet long. It was mounted to the bottom hanging line with the use of a traveler. The sweep hung to the traveler by 3 links of chain (approx. 5" long). To construct the trouser trawl, a standard 420 X 16cm, 4 seam trawl was cut off 2.5 meshes behind the fishing circle for the entire circle of the trawl. The removed back end was replaced with a two-legged back end creating a trouser. The trouser itself was constructed from 16 cm, 12 cm, and 6 cm webbing. The legs of the trouser were then completed with a control codend constructed using 3mm polyethylene twine 60 meshes around of 6.5" diamond mesh with a 6cm liner. The control cod end was 32' long. The other side or leg of the trouser was outfitted with the experimental codends that this study evaluated;

- 6.0" diamond mesh - 60 meshes around of double 6mm polyethylene twine, 32 feet long
- 6.0" square mesh - 60 bars of double 6mm polyethylene twine, 32 feet long
- 5.5" diamond mesh - 65 meshes around of double 5mm polyethylene twine, 32 feet long
- 5.0" diamond mesh - 72 meshes around of double 4mm polyethylene twine, 32 feet long
- 4.5" diamond mesh - 80 meshes around of double 4mm polyethylene twine. 32 feet long

All codends were outfitted with a 6.5" double 6mm polyethylene chaffing mat attached along the bottom of the codend for 25 feet. The forward end of the experimental codends, as well as the control codend, are ringed as is each of the singular leg portions of the trawl. This method of incorporating strong, plastic rings into the separable parts of the net is done to facilitate the process of switching the codends between the legs and switching experimental codends. Appendix B details the schematic of the net used during this project. Project partner Jon Knight (Superior Trawl) made the trouser trawl and donated it for use in this project. Jon Knight constructed all codends used in this project.

This net design has proven to be functional and effective in the scientific realm of at-sea research. Since the trouser - split occurs in the front end of the net, fish that are herded into the fishing circle or mouth of the net are separated there and cannot move from one leg to the other in response to different back pressures that may be caused by different codend mesh sizes. CCE in coordination with the Commercial Fisheries Research Foundation (CFRF), Sea Freeze Ltd., and the Northeast Cooperative Research Program (NCRP) have previously used this trouser trawl to successfully complete a study that evaluated butterfish codend selectivity (Hasbrouck et al., 2015a).

Experimental Design

To assist in project development and implementation CCE established a Program Advisory Committee (PAC). The PAC was formed to define the specific and final methods for the design of the at-sea research project. The PAC had input on tow locations, monitored project activities and results, and provided real-time adaptive recommendations. PAC members included: Henry Milliken (NOAA-NEFSC); Kiley Dancy (MAFMC); Kirby Rootes-Murdy (ASMFC); Pat Sullivan (Cornell University); Mark Terceiro (NOAA-NEFSC); Rich Seagraves (MAFMC); Jon Knight (Superior Trawl Inc.); John Maniscalco (NYSDEC); Dave Aripotch (F/V Caitlin Mairead) and Bonnie Brady (LICFA); Phil Ruhle (F/V Prevail). See Appendix C for PAC meeting summary.

The evaluation of the five different meshes was to occur when conditions were optimal in the field, allowing us to locate co-occurrences of summer flounder, black sea bass, and scup. The specific time frame for this occurrence was left to be decided by our project partners in the commercial fishing industry. Research trips were therefore planned depending on reported concentrations of the three species of concern gathered by our commercial fishing partner. Trip dates and times as well as sampling stations were selected by the captain with the goal of simultaneously catching scup, black sea bass and summer flounder during each tow.

Depths, locations, and gear deployment methodologies were standard for the fishery. Starting and hauling depths, positions, times, and tow warp lengths were recorded for each tow. Tow speeds, tow cable scope, and tow cable length were maintained consistently across all tows. Net spread was recorded for each tow and remained consistent among tows. Experimental codend mesh size measurements were taken during each day of research fishing. The mesh of each experimental codend was measured prior to and after its use. Ten consecutive meshes beginning no fewer than five meshes from the terminus of the codend were measured using stainless steel Vernier calipers. The meshes were measured inside stretch knot-to-knot in the direction they were hung. This procedure follows the Northeast Fisheries Science Center (NEFSC) Observer Operations Manual protocol. This was done to monitor and ensure the integrity and consistency of the mesh sizes being evaluated. Mesh measurements can be found in Appendix D.

The project design alternated the trawl leg on which the control and experimental codends were placed as well as switching experimental codends every two tows. This randomized any possible "side" effect (port and starboard leg) that might have occurred if the control and experimental codends had remained on the same leg for the entirety of the project. This was achieved through the creation of a net switching plan. A five-variable random number generator was used to assign codend sequence and leg of the trawl. This served to randomize across the entire project the use of each experimental codend as well as leg of the trawl containing the experimental codend. The codends were further randomized in blocks of 5 with two consecutive tows for each codend before the next randomly assigned pair was swapped in. See Appendix E for details and sequence of the net switching plan. This random net switching plan insured that each mesh size received equal treatment while reducing any bias that can be associated with the numerous variables that exist when attempting this type of research. Utilizing this net switching plan we were able to complete a total of 118 tows. Each experimental codend except for 6" square was fished for 24 tows. The 6" square codend was fished for 22 tows. See Table 1 for a summary of codend use.

After the 45-minute research tow duration the net was hauled back. Codends were hauled in as quickly as possible with minimal time in water to avoid sifting. The catch of each codend (experimental vs. control) was kept separated during haul-back and release on-deck. The experimental codend was always brought aboard the vessel first and released in the forward checker on deck. The control codend was brought in immediately following and released in the aft checker on deck. The onboard catch processing followed standard NMFS survey methods. Random samples of summer flounder, scup and black sea bass were removed from each codend and kept separated. To quantify differences in retention and size distribution between the control and the experimental codends, the total catch by species of summer flounder, black sea bass, and scup for each tow and each codend was accurately weighed. Summer flounder, black sea bass, and scup were also sampled for length frequency. The goal was minimally 200 random length measurements of each species per tow per codend. If fewer than 200 individuals were caught, all were measured. The total weight of all species combined, the total catch weight for each tow and from each codend, was also obtained. Total catch weight was determined either by directly weighing the total catch, or for large catches, the entire catch was placed in baskets and a sub-sample of the baskets weighed. Sub-sampling procedures for catch estimations based on basket or tote counts followed the NMFS At Sea Monitoring Program and the Observer Program Biological Sampling protocols as outlined in the NEFSC sampling manuals. Please see Sampling Day Procedure included as Appendix F.

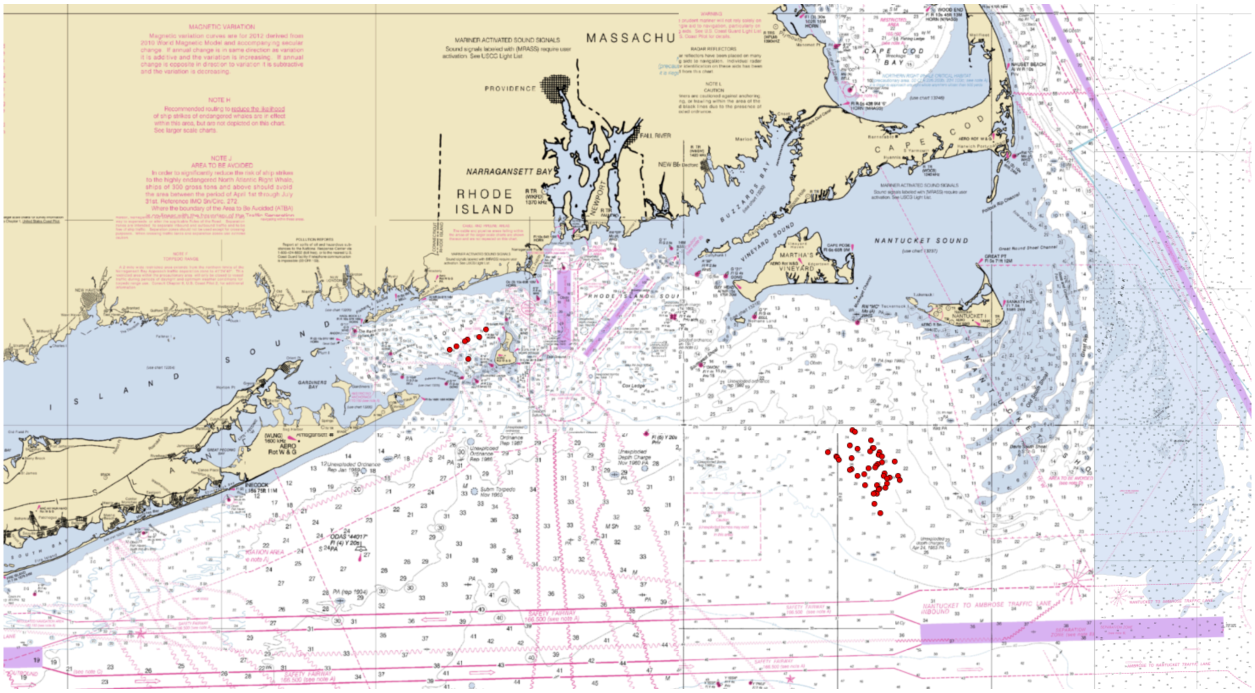
A total of four research trips were completed over the course of this project for a total of 118 research tows successfully completed during 15 total days at sea. CCE exceeded the proposed goal of 100 experimental tows by 18 tows. CCE accomplished the project goal of completing an applied experiment across a wide range of strata and conditions. Experimental fishing was completed in a range of depths and in different locations. It was determined that CCE would set in/haul back within 10-15 minutes of either side of sun up or sun down.

Table 1. Number of Tows Per Treatment

	Treatment (118 tows)					
Treatment	4.5" Diamond	5" Diamond	5.5" Diamond	6" Diamond	6" Square	Control
# on Port	12	12	12	12	12	58
# on Starboard	12	12	12	12	10	60
Total Tows	24	24	24	24	22	118

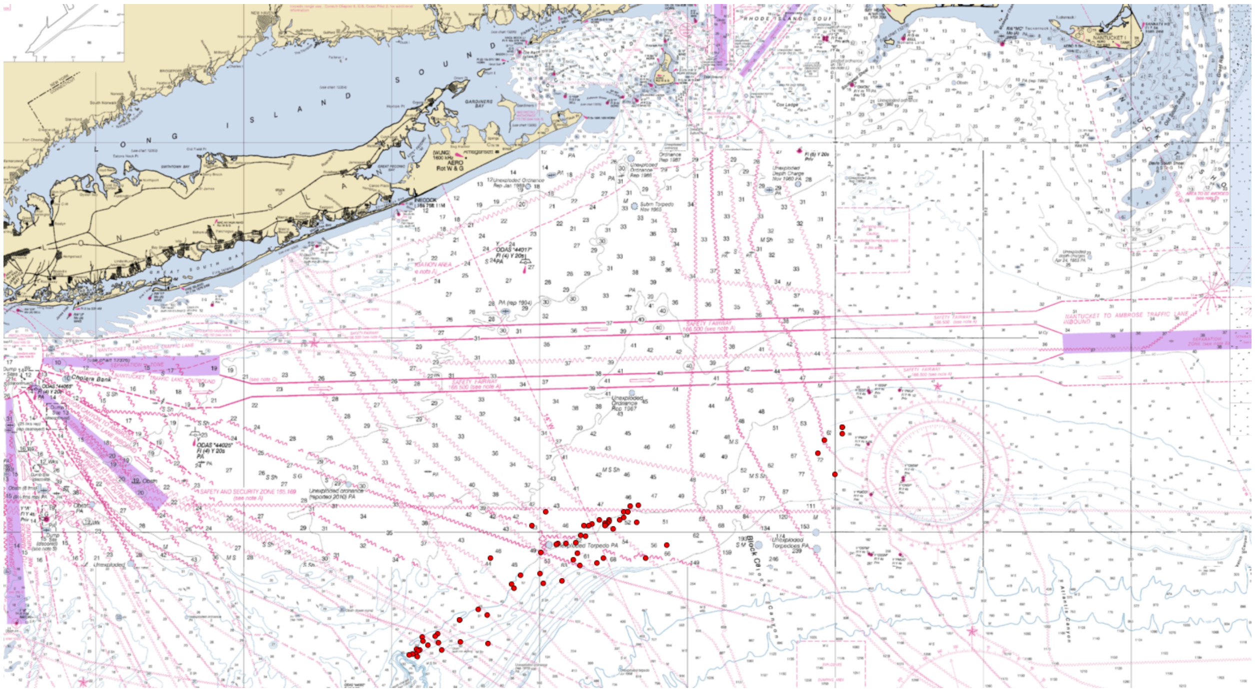
Trip 1 was completed between October 2nd and October 4th during which we conducted 24 tows. Beginning on October 2nd, two days were spent fishing approximately 30 miles south of Martha's Vineyard at an average depth of 21 fathoms. Seventeen research tows were completed during this two-day period. On the third day, in order to escape high winds, the fishing effort moved west to the protected Block Island Sound where seven additional tows were completed at an average depth of 18 fathoms. Trip 2 was completed between October 6th and October 8th. Beginning on October 6th, three days were spent fishing approximately 30 miles south of Martha's Vineyard at an average depth of 24 fathoms. Twenty-six research tows were completed during this three-day period. Each of the five experimental codends were deployed ten times over the course of the 50 totals tows for trips 1 and 2. See Figure 1 for a map of the fall research areas.

Figure 1. Fall 2016 Research Tows



Research fishing during trip 3 was completed between April 9th and April 12th, 2017. The first day, April 9th, was spent fishing approximately 60 miles south-southeast of Block Island, RI. Six research tows were completed at an average depth of 65 fathoms. A rather significant move to the west was initiated after the first day in order to find a better mix of scup, black sea bass and summer flounder and the remaining three days of trip 3 were conducted in an area between approximately 60 miles due south of Montauk, NY and the east side of Hudson Canyon. Twenty-two additional tows were completed in this area over the three-day period at an average depth of 56 fathoms. Trip 3 concluded with a total of 28 research tows over four days. Trip 4 was completed between April 18th and April 22nd, 2017. Beginning on April 18th, five days were spent fishing between approximately 60 miles due south of Montauk, NY and the east side of Hudson Canyon. Forty tows were completed at an average depth of 50 fathoms over the course of five days during trip 4. Each of the five experimental codends were deployed 14 times, except for the 6" square mesh. The 6" square mesh was deployed 12 times. See Figure 2 for a map of the spring research areas.

Figure 2. Spring 2017 Research Tows



DATA ANALYSIS

Expanding and Converting Catch Data

Prior to data analysis and in order to get an accurate estimation of the species-specific catch numbers at length for each tow/codend, subsample length frequency data was "scaled up" to determine the number of fish at each length following the protocol used by Hendrickson (2011). For each tow and codend combination, the number of fish (by species) caught at each length interval was calculated as the number of fish (by species) at each length in the subsample multiplied by the ratio of total catch weight by species to subsample catch weight by species. This was computed separately for the control codend and each experimental codend.

It is important to note that the scup lengths that were collected for this project were fork lengths as per basic scientific protocol for this species. However, the commercial legal minimum size for scup is 9 inches (22.86 cm) measured in total length. Therefore, the following conversion was used to convert all of our lengths in fork length (FL) to total length (TL) so that the selectivity parameters can be used to evaluate codend mesh sizes by total length for scup. All scup lengths were converted to total length prior to statistical analysis. The Hamer (1979) conversion is consistent with FL/TL conversions used in the scup assessment. (Terceiro, NEFSC, personal communication)

Total Length (cm) = 1.14 x Fork length (cm) – 0.44 (Hamer, 1979)

SELECT Model

We followed the statistical methods recommended in the ICES Manual of Methods of Measuring the Selectivity of Towed Fishing Gears (ICES, 1996). To estimate the selectivity parameters of the experimental codends, the SELECT model (Share Each LEngth's Catch Total) was used. SELECT was developed by Millar (1992), Millar and Walsh (1992), Millar and Fryer (1999) and is further defined in ICES (1996). SELECT is also described by Hendrickson (2011) where the model was recently used to estimate selectivity parameters in the small mesh longfin squid fishery. As described in these references, the model uses a logistic approach to produce a maximum likelihood fit of selectivity and associated selectivity parameters. SELECT also calculates a relative fishing intensity or fishing power factor (also called the "split" parameter) to account for the fact that fish of each size may not separate into each leg of the trouser trawl on a .5 basis (ICES, 1996; Millar, 1992; Millar and Walsh, 1992).

As defined in Millar (1992), Millar and Walsh (1992), ICES (1996) and Hendrickson (2011), the SELECT model uses a maximum likelihood estimation approach where the expected proportion of the total catch (in both codends), for length class *l*, that was caught in the experimental codend, $\phi(l)$, is modeled as a function of the parameters (calculated by the model) *a, b, δ*, and the relative fishing efficiency (*p*) of the gear such that:

$$\phi(l) = [\frac{\mathrm{p}\exp(a+bl)}{(1-p)+\exp(a+bl)}]$$

Selectivity parameter estimates were obtained by fitting the SELECT model to the combined codends (control and experimental) catch-at-length data binned by each centimeter interval, for each of five experimental codends. The model was fit using the "ttfit" and "Rep.ttfit" functions in the "Trawlfunctions" programs for R (developed by Millar, 1998). As suggested by ICES (1996) model fits were assessed using model deviances, degrees of freedom and examination of the deviance residuals plotted by length class. The Rep.ttfit p-value, generated from the deviance and degrees of freedom, is used to determine the statistical significance of the model fit. The Rep.ttfit function uses a combined hauls approach to account for between haul variability and to account for any estimated overdispersion. The function estimates the standard errors of the selectivity parameters corrected for any between haul variability and overdispersion (Millar et al., 2004).

SELECT logistic model runs provided the best fits to the data. The model was run in most instances using length classes with expected catches greater than three individuals in each codend. However, as described below, this created some issues in determining selectivity parameters for lengths containing few individuals. After discussion with Millar (University of Auckland, personal communication.) for some model runs we lowered the expected catch in SELECT to less than 3.

RESULTS

We ran the SELECT model for each experimental codend for scup, black sea bass and summer flounder. Model output is presented in several formats for each species. First we provide a table of the maximum likelihood fits of the logistic selectivity curve parameters and model goodness-of-fit measures. We have also included the model-output (with standard error) for fishing efficiency (p), L_{25}, L_{50}, L_{75} and Selection Range. We have also calculated the coefficient of variation for L_{25}, L_{50} and L_{75}. Note that there are two p factors in the table. One is the fishing efficiency or split-factor calculated by the model. The other is the "Rep.ttfit" generated p-value as described above. Selection factor was calculated as the length at 50% retention (L_{50}) divided by the mean codend mesh size (in inches).

We then plot for each codend: the observed and expected proportions of the catch in the experimental codend; the deviance residuals from the fit; the corresponding logistic selection curve with L_{25}, L_{50} and L_{75} indicated; the number of fish at each length interval for the control codend and for the experimental codend. We also provide length frequency plots for the control and experimental codends for each codend/species combination. For each species we generate a combined plot of the five logistic selectivity curves fitted for each experimental codend. Then for each experimental codend we generate a combined plot for each species by codend.

As mentioned above, the model runs using length classes with expected catches greater than three individuals in each codend. However, with the 6.0" diamond and 6.0" square for black sea bass there were often tows with three or fewer individuals in either the control or experimental codends. Likewise with summer flounder across all experimental mesh sizes there were often tows with three or fewer individuals in either the control or experimental codends. Thus the model was not using several length bins/tows. We discussed this issue with Millar (pers. comm., 2017). He mentioned that the variable that sets the minimum number of individuals per length bin that the model will use can be user-defined and was set at 3 in the "Trawlfunctions" code. He suggested that we set this variable to a value less than 3. So for the above-stated codends for black sea bass and summer flounder the model was run with the variable set to 1 to utilize more of the data.

SCUP

Table 2. Maximum likelihood fit of logistic selectivity curve parameters for 5 codend mesh sizes and SELECT model goodness-of-fit measures for scup
Standard error is shown in parentheses. Coefficient of variation is shown in double parentheses. All scup lengths are total lengths. 5" Diamond is the current regulation minimum mesh.

	4.5" Diamond	5" Diamond	5.5" Diamond	6" Diamond	6" Square
N tows (paired)	24	24	24	24	22
N length classes	40	35	34	36	36
Length class range (cm)	6.4-50.86	6.4-45.16	7.54-45.16	6.4-46.3	8.68-48.58
a	-8.64	-9.14	-10.04	-10.99	-16.12
b	0.31	0.32	0.32	0.31	0.50
p - relative fishing efficiency	0.60 (0.02)	0.58 (0.03)	0.46 (0.03)	0.50 (0.07)	0.45 (0.04)
L_{25} (total length in cm)	24.48 (0.54) ((0.022))	25.50 (0.58) ((0.023))	27.9 (0.69) ((0.025))	31.93 (1.22) ((0.038))	29.79 (0.54) ((0.018))
L_{50} (total length in cm)	28.05 (0.73) ((0.026))	28.99 (0.75) ((0.026))	31.33 (0.86) ((0.027))	35.48 (1.39) ((0.039))	31.97 (0.64) ((0.020))
L_{75} (total length in cm)	31.61 (0.95) ((0.030))	32.47 (0.93) ((0.029))	34.75 (1.04) ((0.030))	39.02 (1.57) ((0.040))	34.14 (0.74) ((0.022))
Selection range	7.13 (0.50)	6.97 (0.43)	6.85 (0.41)	7.09 (0.42)	4.36 (0.25)
Selection factor	6.24	5.77	5.7	5.91	5.33
Model deviance	6882.426	3542.094	2786.878	1033.891	889.506
df	331	255	251	176	136
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Figure 3. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for scup in the 4.5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}. All scup lengths are total lengths.

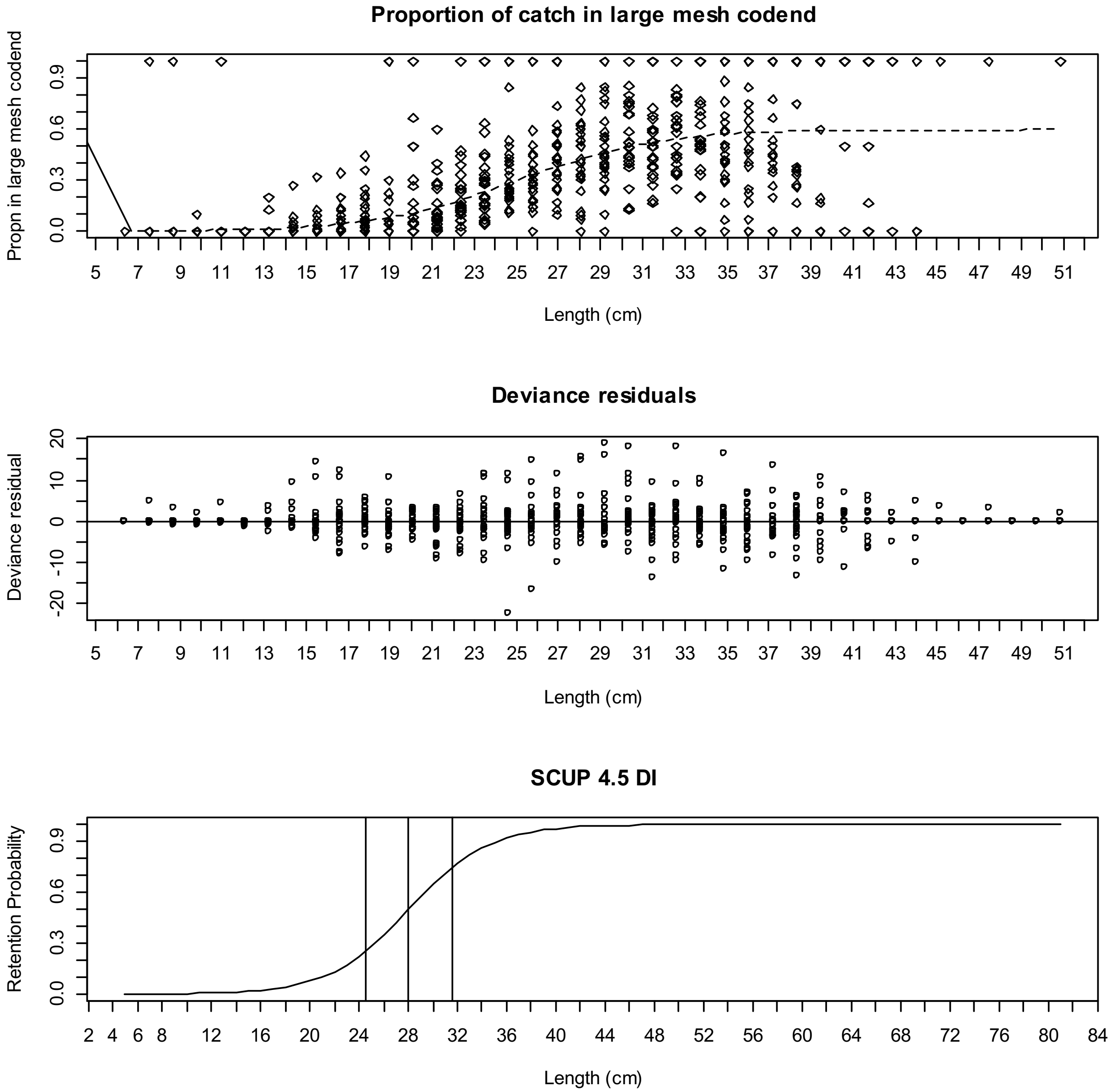


Figure 4. Length frequency distributions in the treatment (4.5" Diamond) and control codends for scup. (All scup lengths are total lengths.)

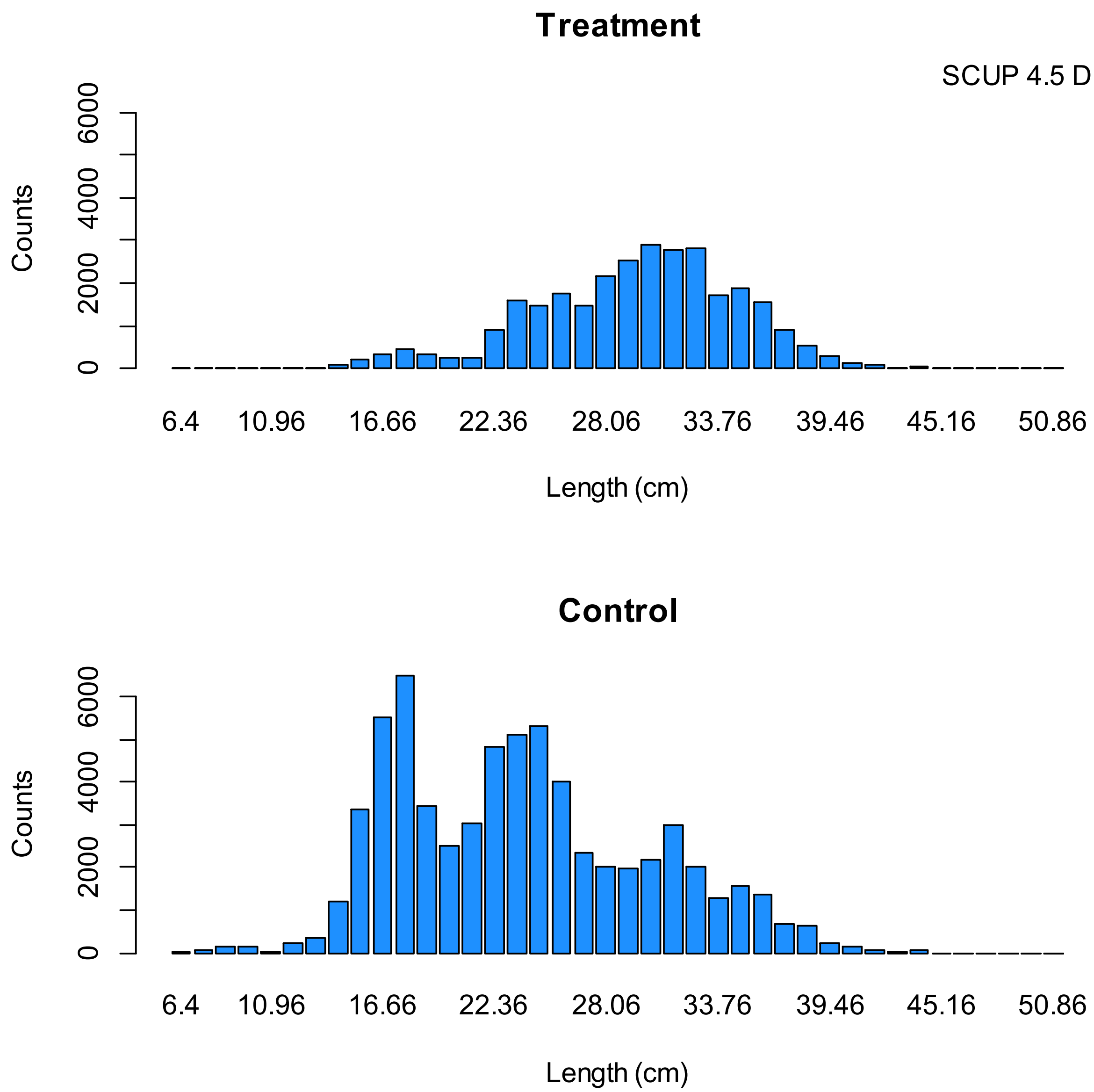


Figure 5. Length frequency distribution of scup in the 4.5” diamond codend.
(All scup lengths are total lengths.)

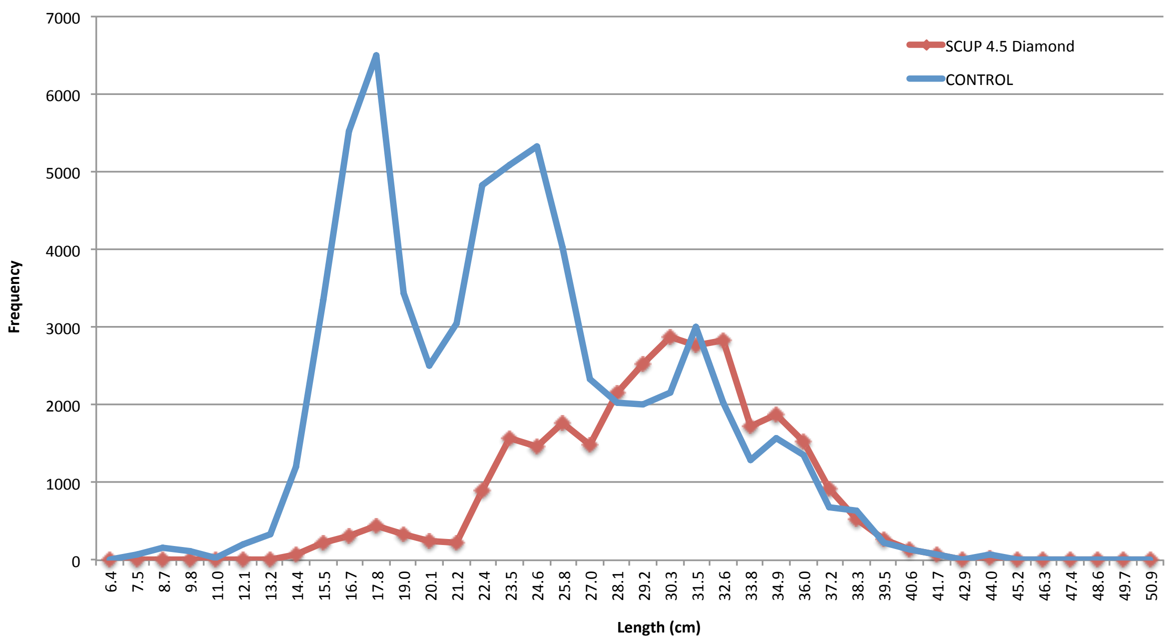


Figure 6. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for scup in the 5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}. (All scup lengths are total lengths.)

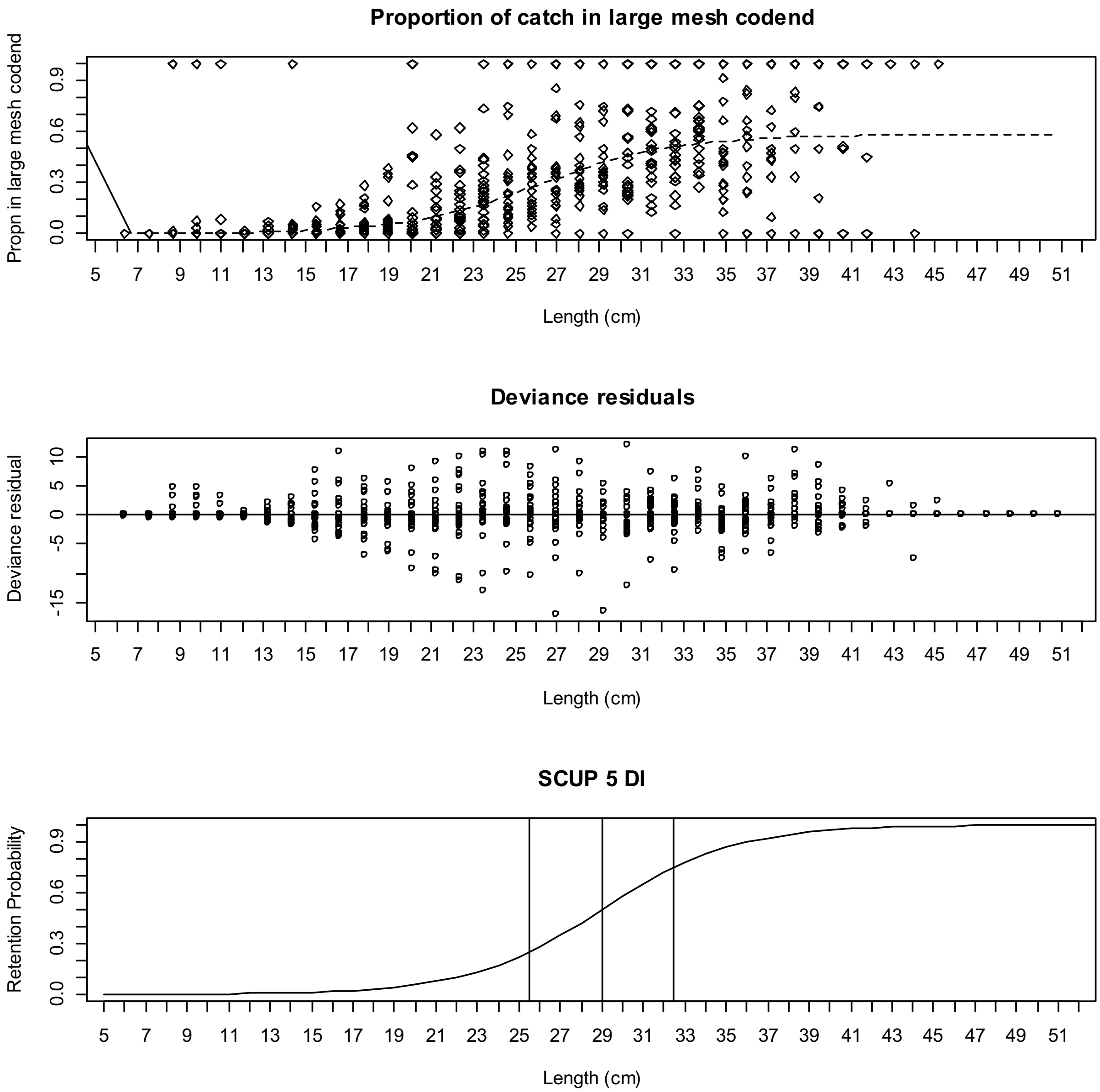


Figure 7. Length frequency distributions in the treatment (5" Diamond) and control codends for scup. (All scup lengths are total lengths.)

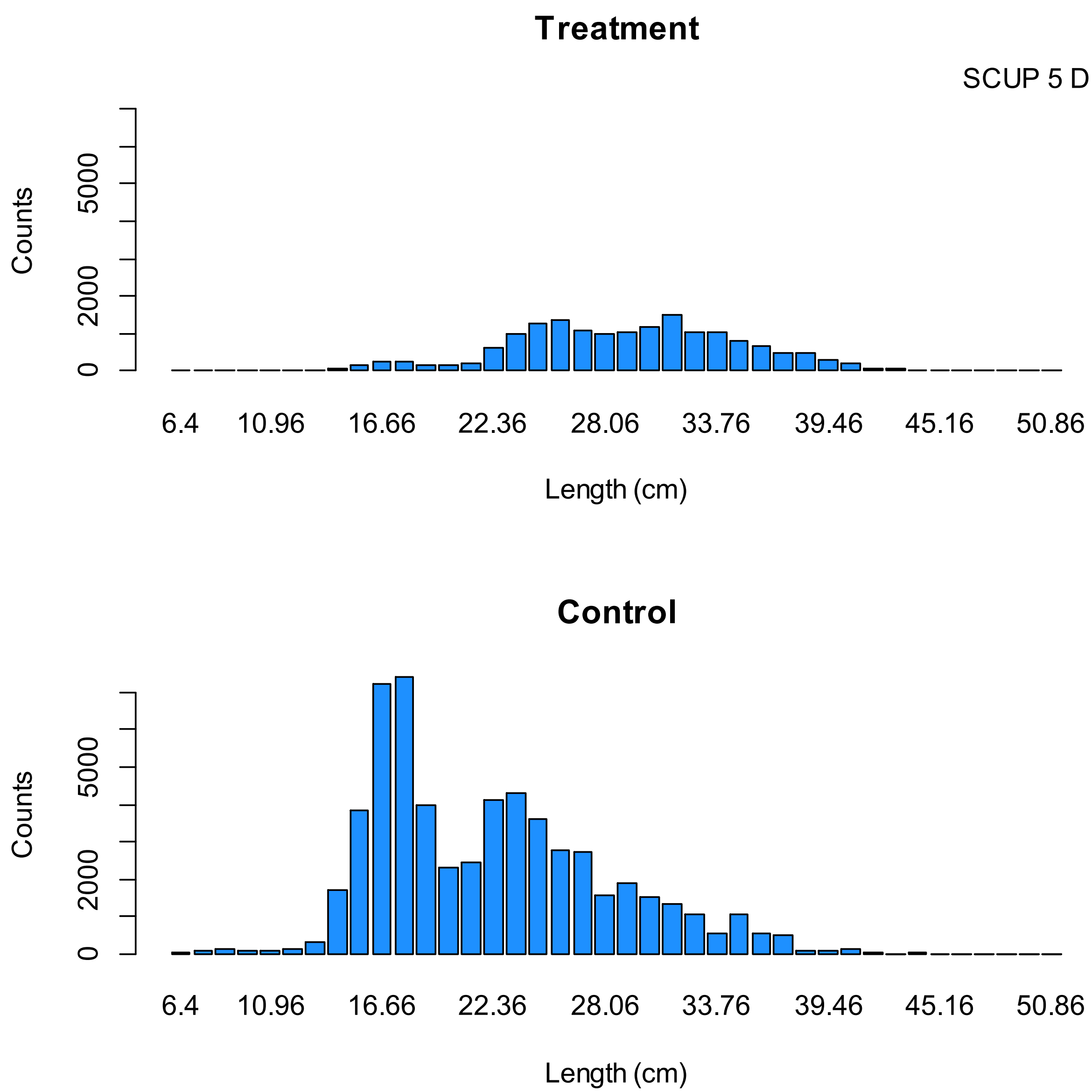


Figure 8. Length frequency distribution of scup in the 5" diamond codend. (All scup lengths are total lengths.)

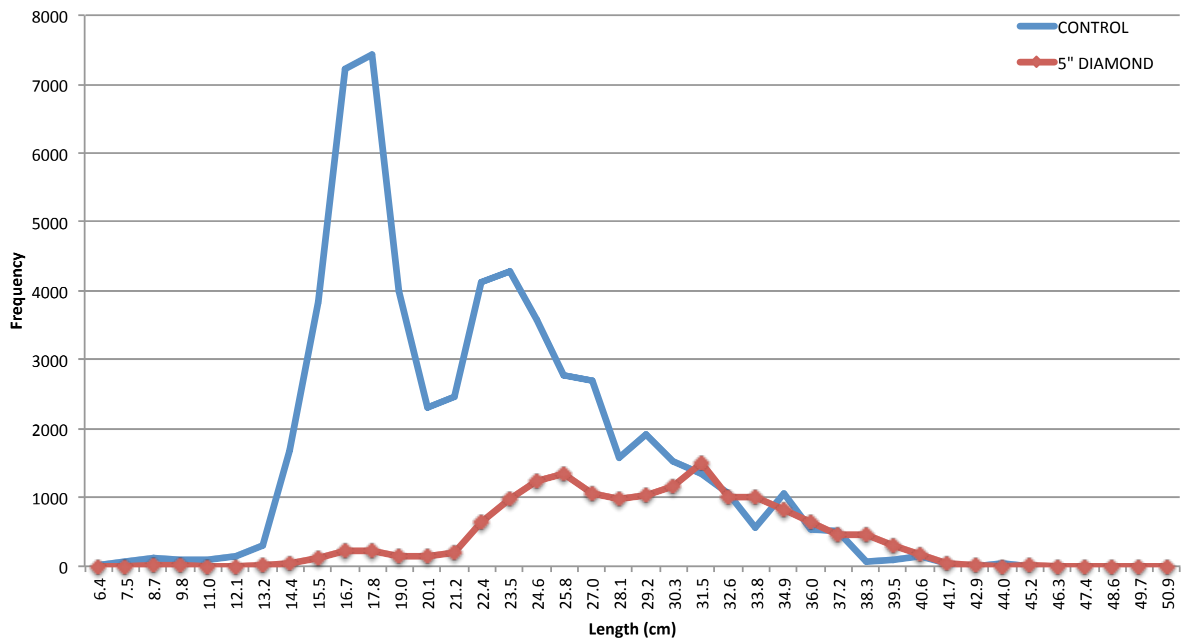


Figure 9. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for scup in the 5.5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}. (All scup lengths are total lengths.)

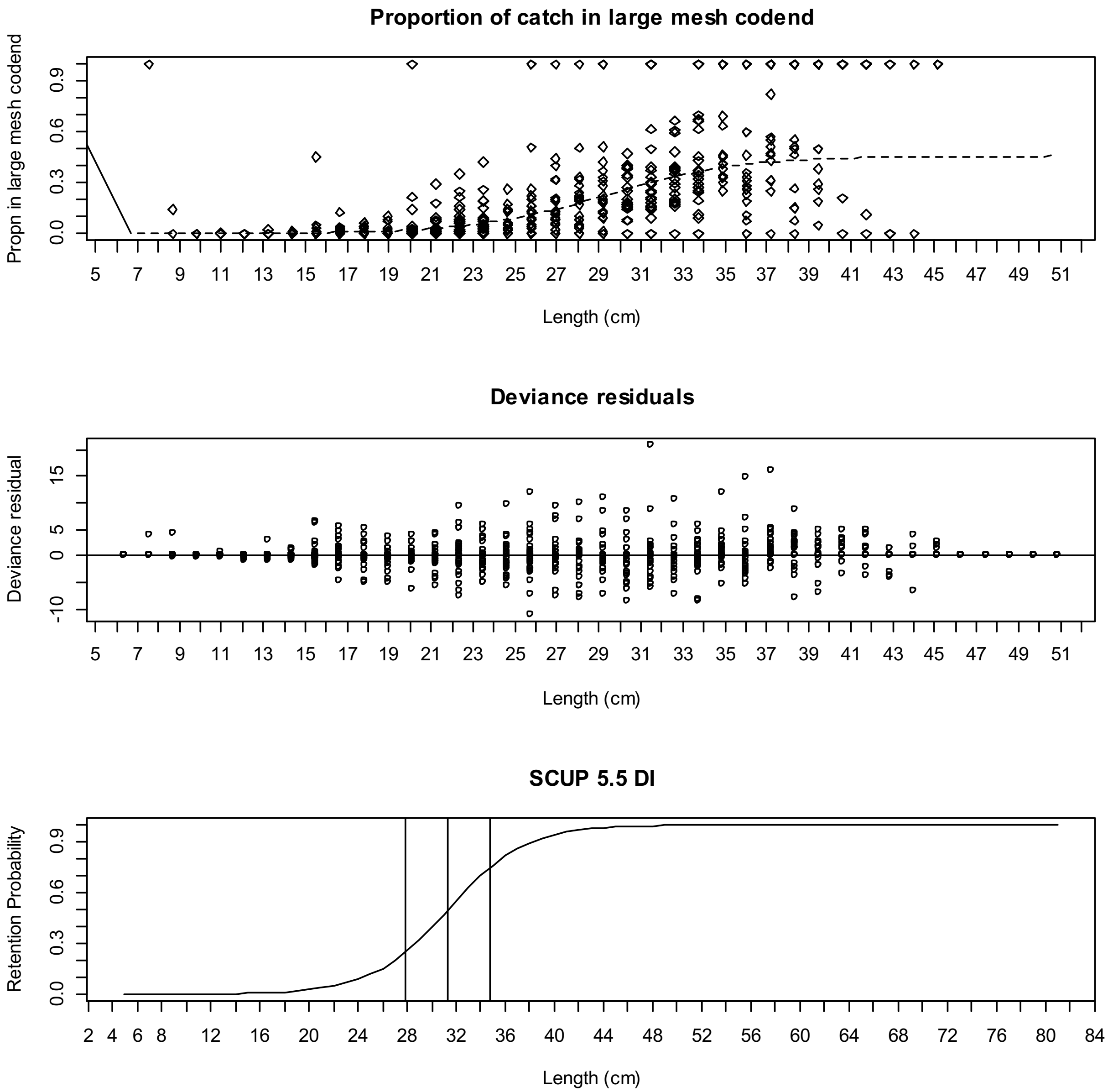


Figure 10. Length frequency distributions in the treatment (5.5" Diamond) and control codends for scup. (All scup lengths are total lengths.)

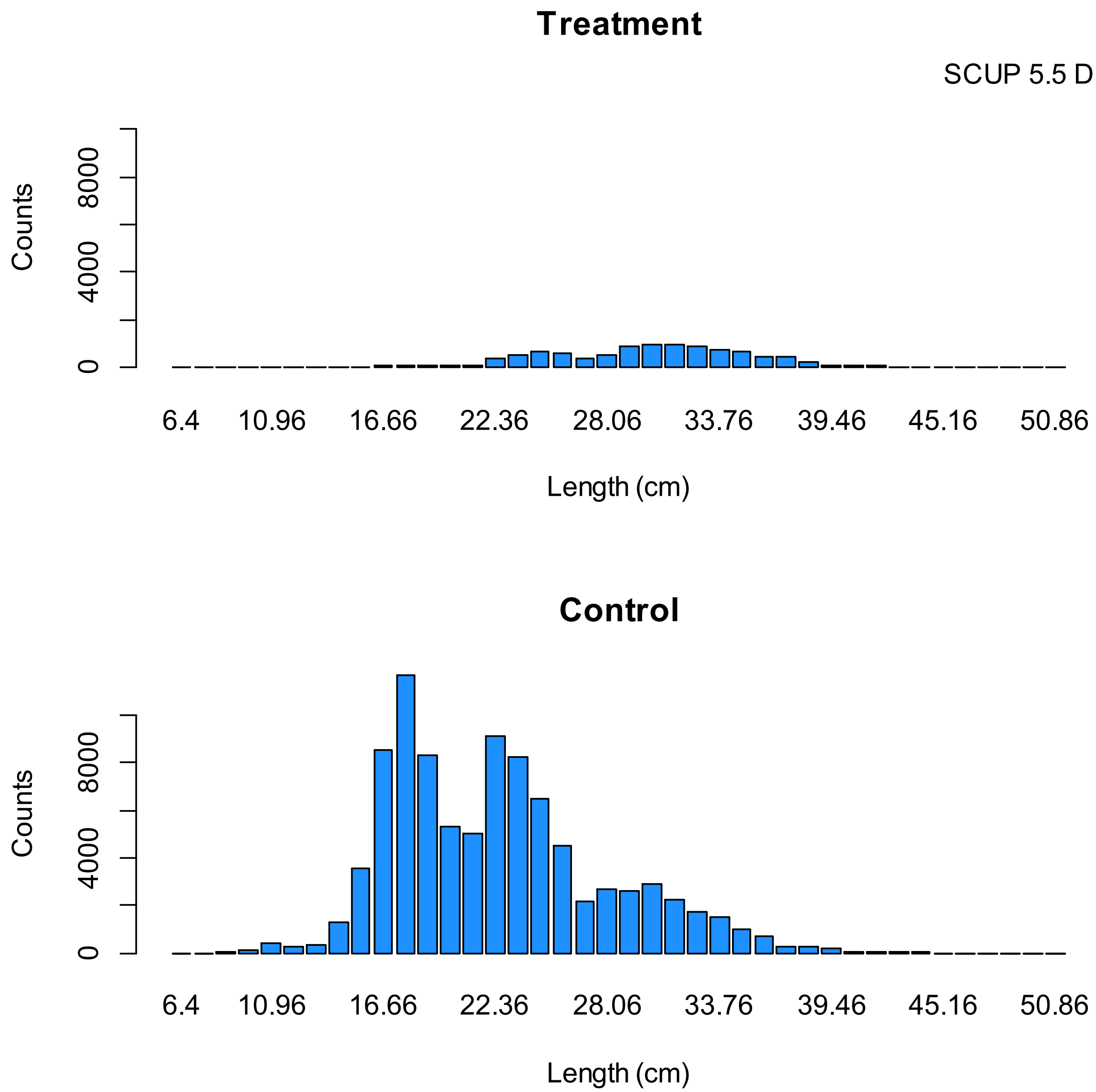


Figure 11. Length frequency distribution of scup in the 5.5” diamond codend. (All scup lengths are total lengths.)

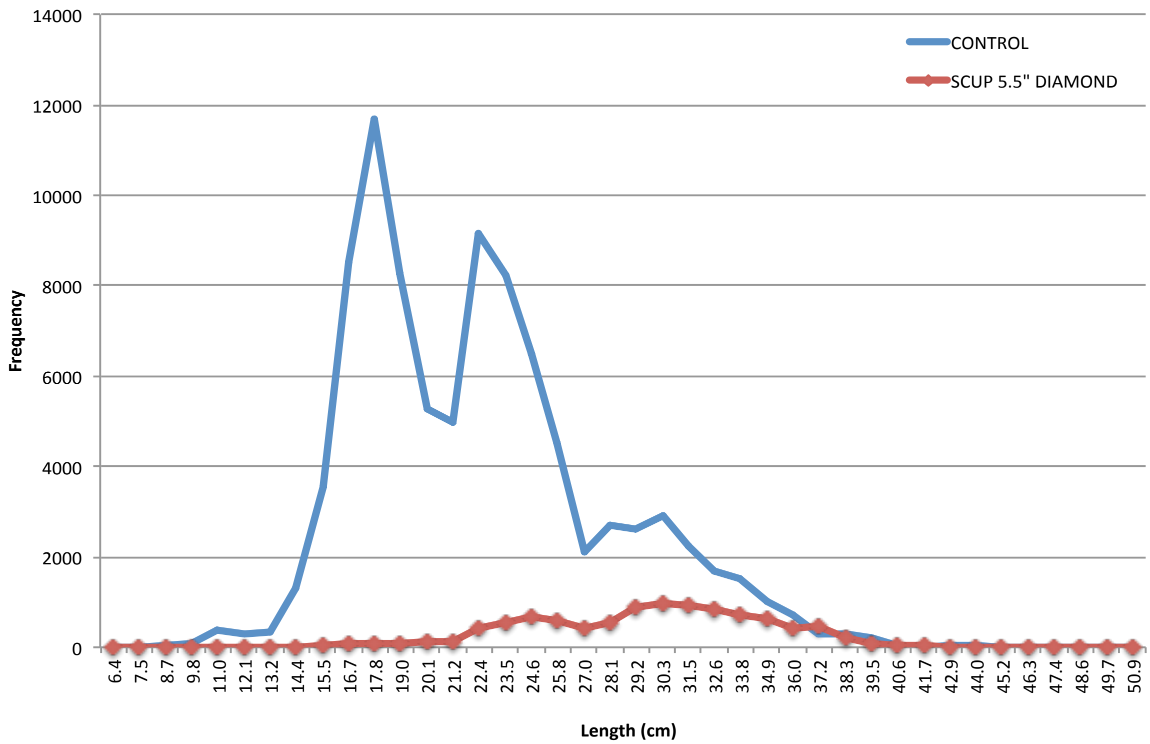


Figure 12. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for scup in the 6” diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}. (All scup lengths are total lengths.)

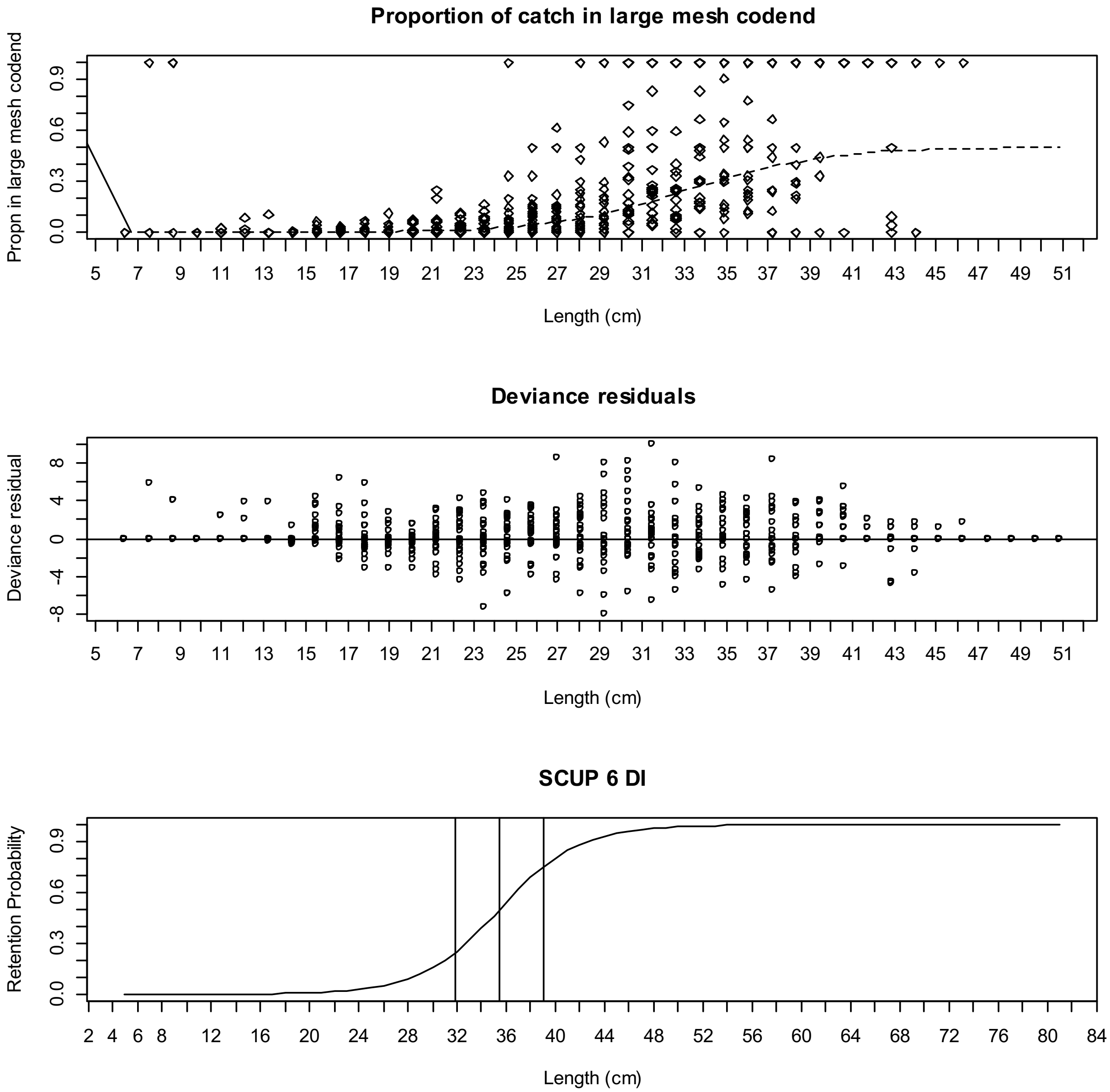


Figure 13. Length frequency distributions in the treatment (6" Diamond) and control codends for scup. (All scup lengths are total lengths.)

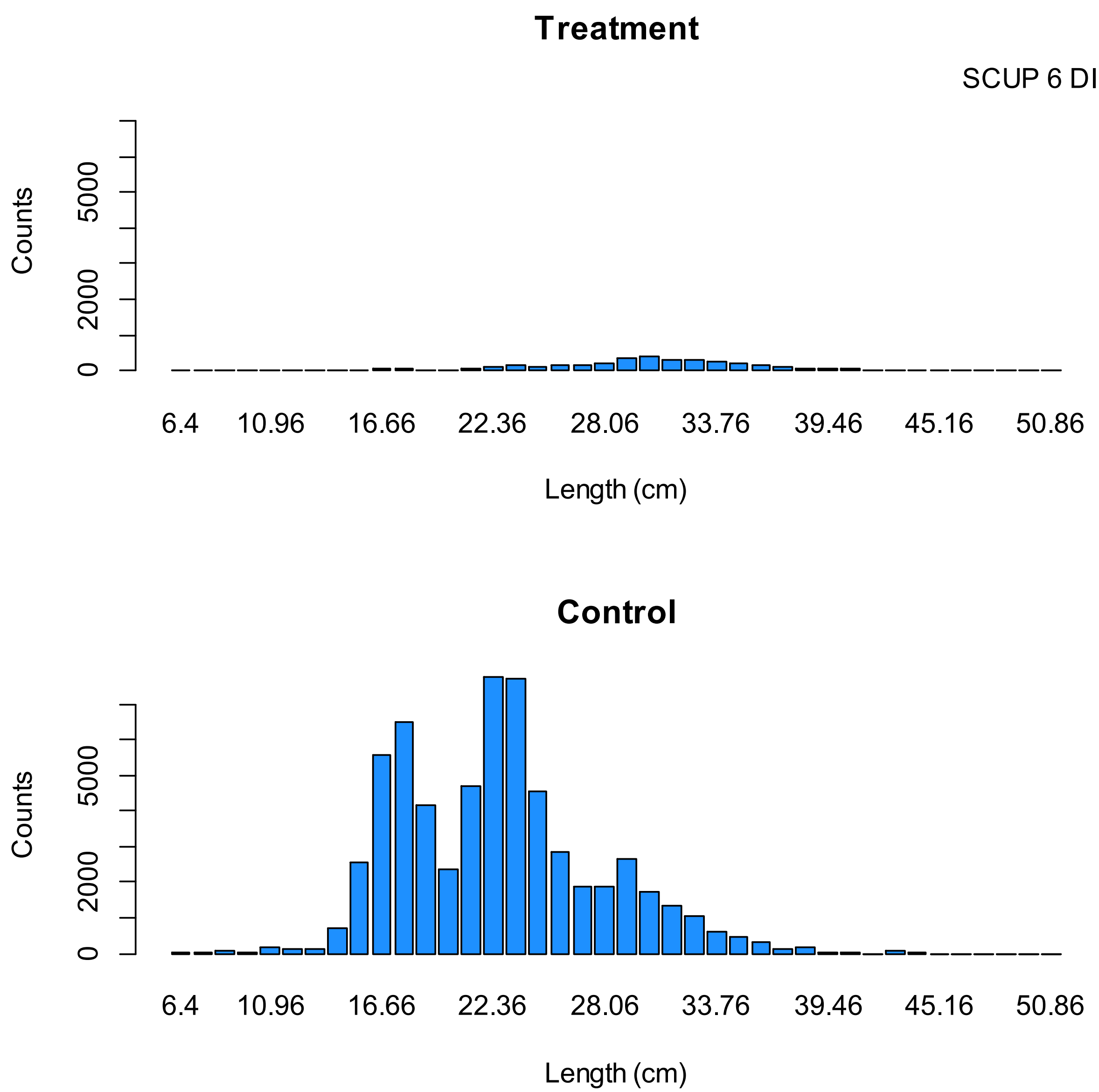


Figure 14. Length frequency distribution of scup in the 6” diamond codend. (All scup lengths are total lengths.)

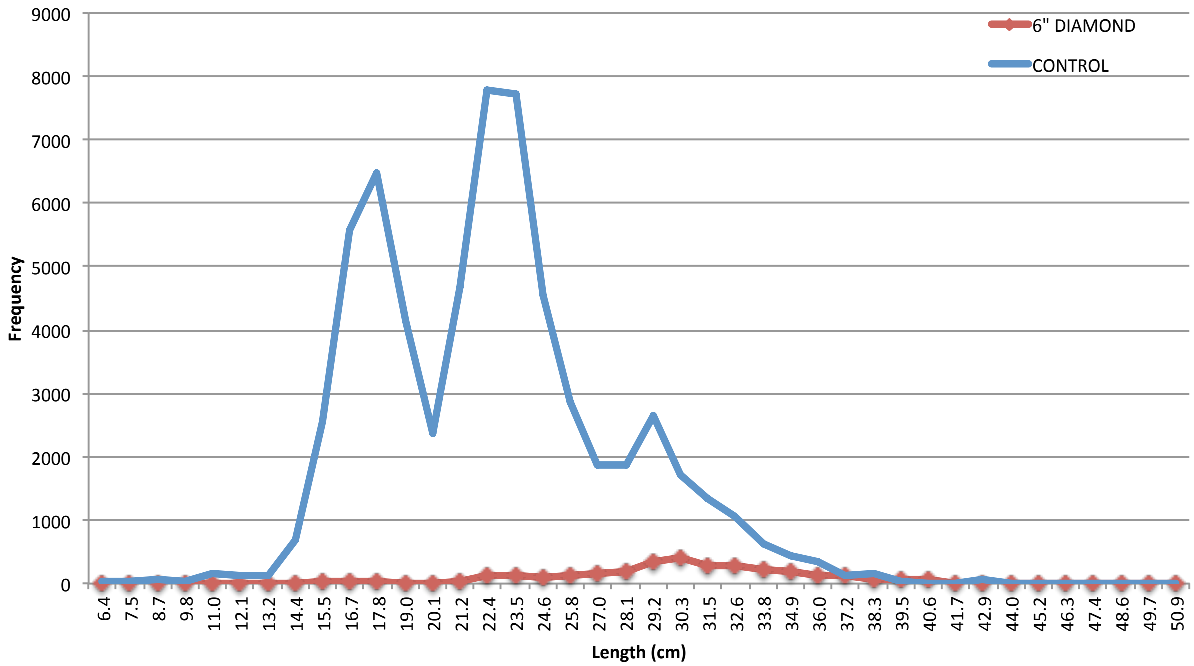


Figure 15. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for scup in the 6" square codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}. (All scup lengths are total lengths.)

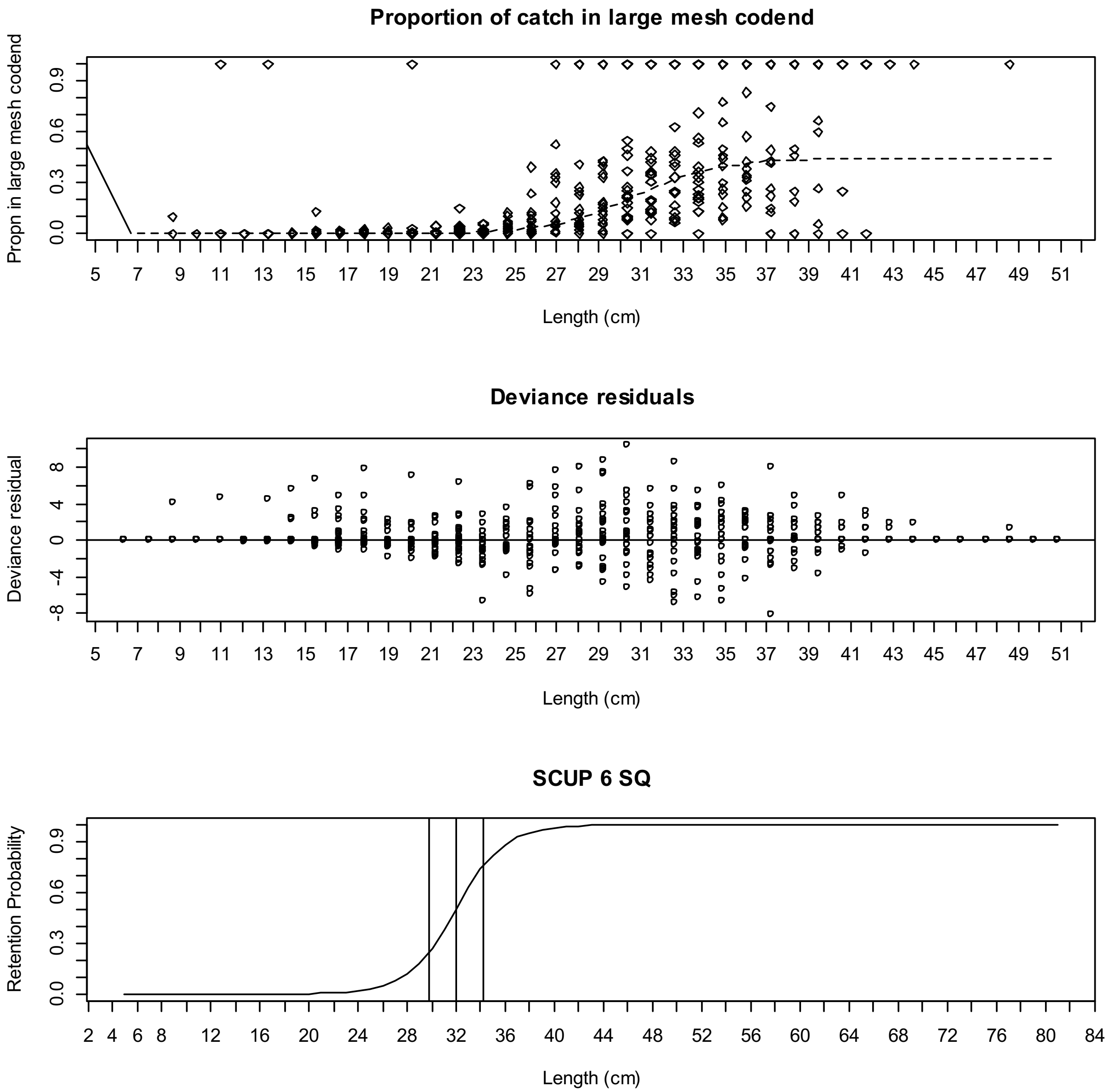


Figure 16. Length frequency distributions in the treatment (6" Square) and control codends for scup. (All scup lengths are total lengths.)

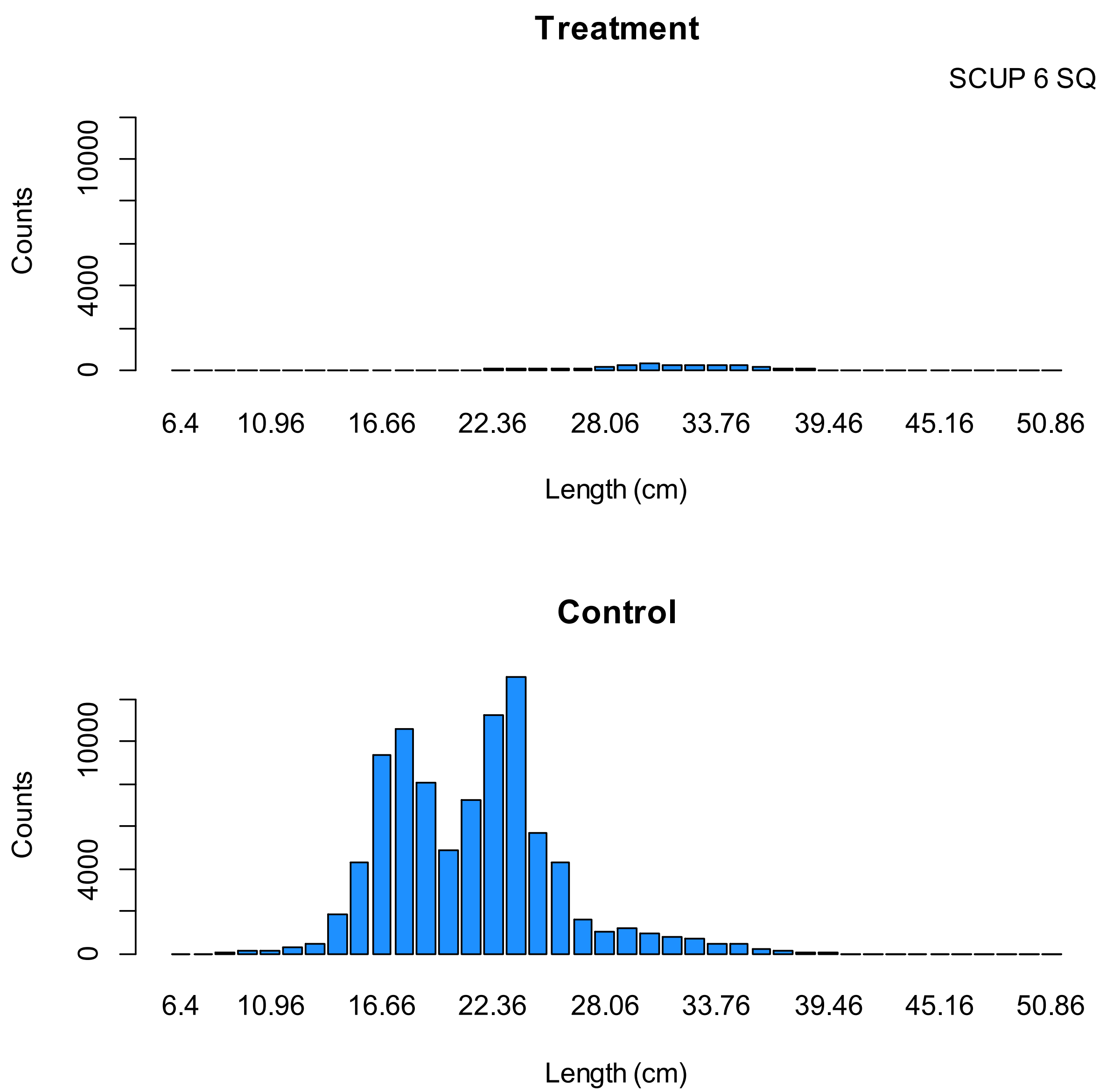


Figure 17. Length frequency distribution of scup in the 6" square codend. (All scup lengths are total lengths.)

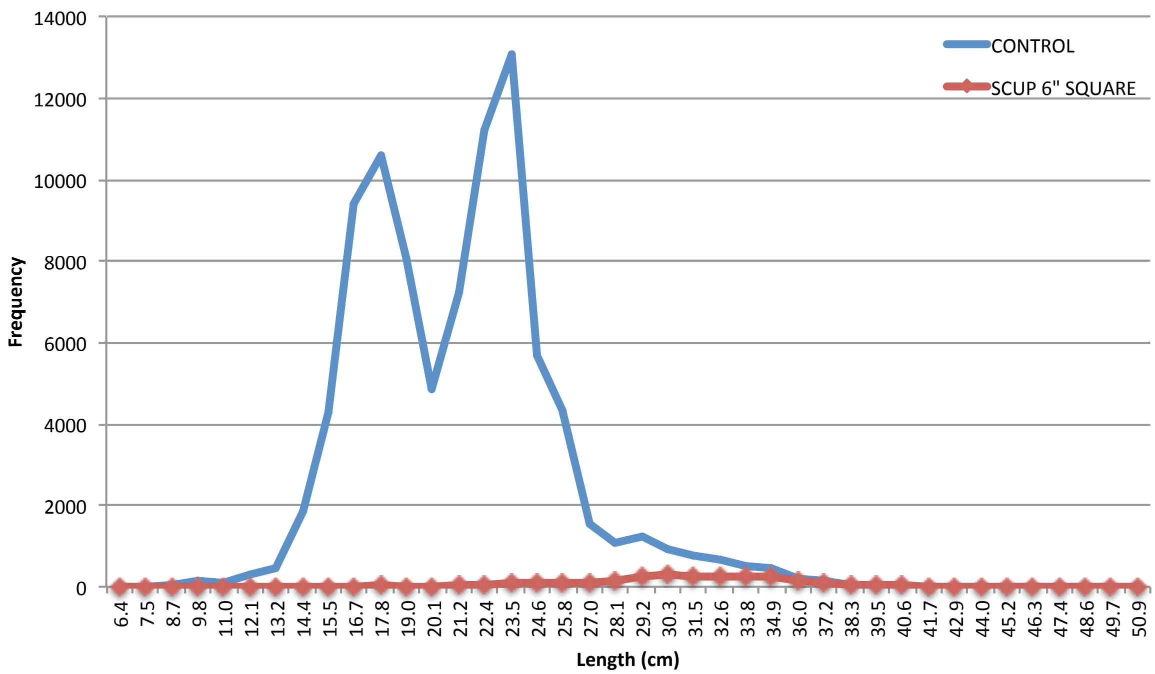
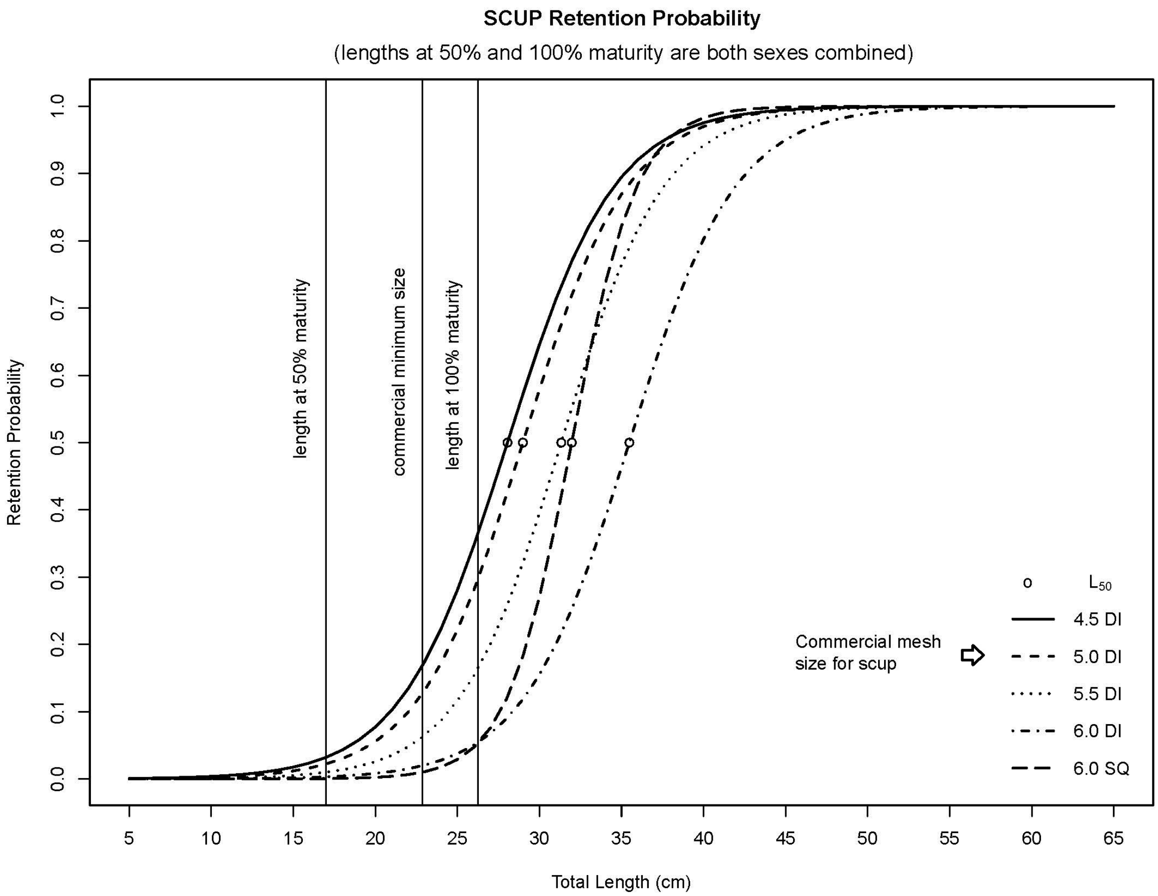


Figure 18. Logistic selectivity curve for scup catches with 5 codends (4.5” diamond, 5” diamond, 5.5” diamond, 6” diamond and 6” square). (All scup lengths are total lengths.)



Black Sea Bass

Table 3. Maximum likelihood fit of logistic selectivity curve parameters for 5 codend mesh sizes and SELECT model goodness-of-fit measures for black sea bass
Standard error is shown in parentheses. Coefficient of variation is shown in double parentheses. 4.5" Diamond is the current regulation minimum mesh.

	4.5" Diamond	5" Diamond	5.5" Diamond	6" Diamond	6" Square
N tows (paired)	24	24	24	24	22
N length classes	49	47	45	49	46
Length class range (cm)	13-61	14-60	14-58	10-48	13-58
a	-10.46	-14.59	-12.70	-11.08	-14.43
b	0.36	0.45	0.31	0.29	0.30
p - relative fishing efficiency	0.47 (0.03)	0.50 (0.04)	0.57 (0.08)	0.39 (0.05)	0.52 (0.13)
L_{25} (cm)	25.77 (0.82) ((0.032))	29.85 (1.05) ((0.035))	37.53 (1.88) ((0.050))	34.12 (1.55) ((0.045))	44.07 (2.69) ((0.061))
L_{50} (cm)	28.8 (1.21) ((0.042))	32.28 (1.31) ((0.041))	41.08 (2.16) ((0.053))	37.87 (1.87) ((0.049))	47.70 (3.08) ((0.065))
L_{75} (cm)	31.82 (1.65) ((0.052))	34.71 (1.60) ((0.0046))	44.63 (2.47) ((0.055))	41.63 (2.23) ((0.054))	51.33 (3.51) ((0.068))
Selection range	6.05 (0.96)	4.86 (0.68)	7.1 (0.82)	7.51 (0.83)	7.26 (1.08)
Selection factor	6.4	6.43	7.47	6.31	7.96
Model deviance	73.394	41.128	71.609	168.412	24.552
df	38	16	17	73	13
p-value	0.0005	0.0005	<0.0001	<0.0001	0.0264

Figure 19. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for black sea bass in the 4.5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

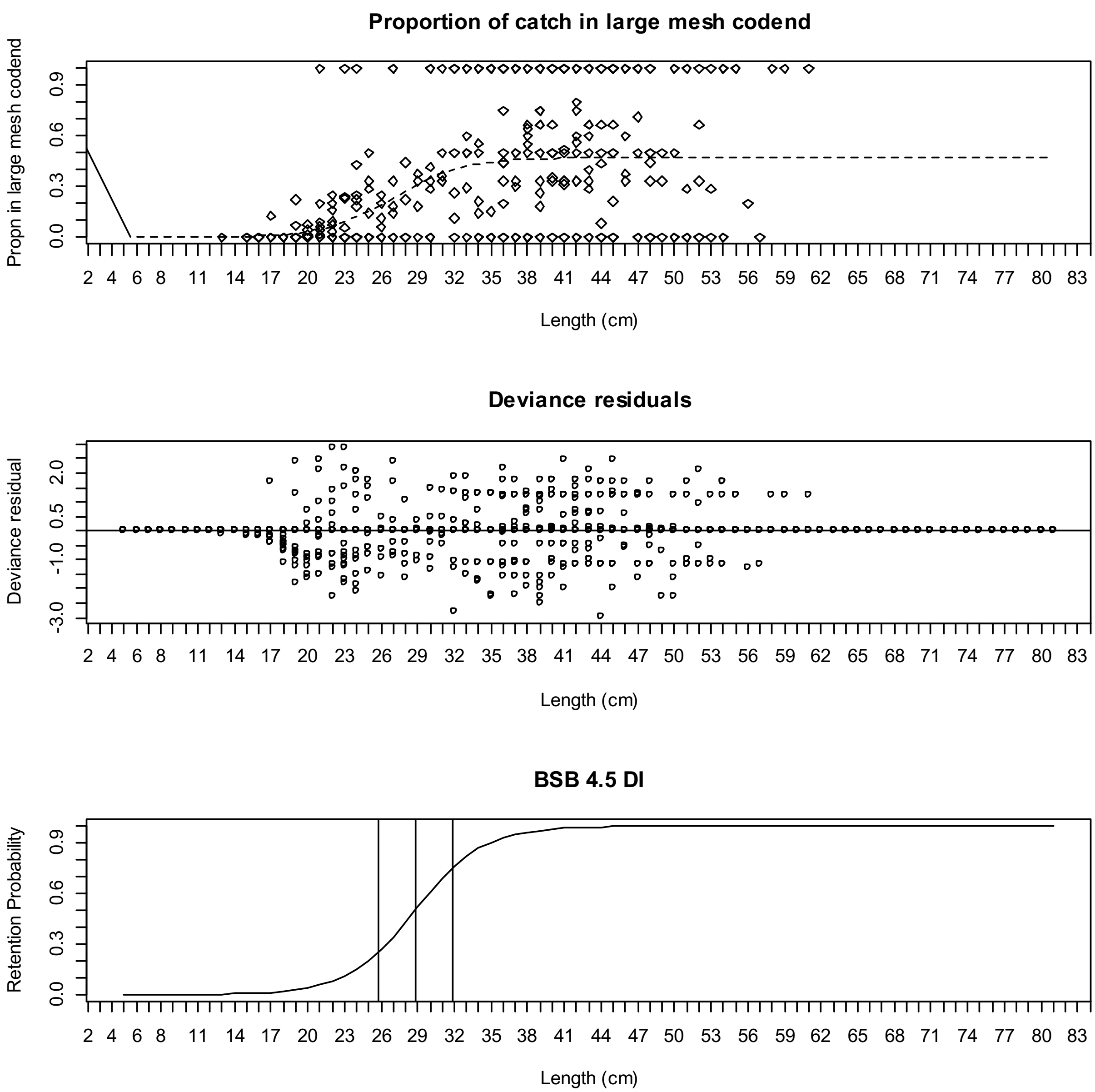
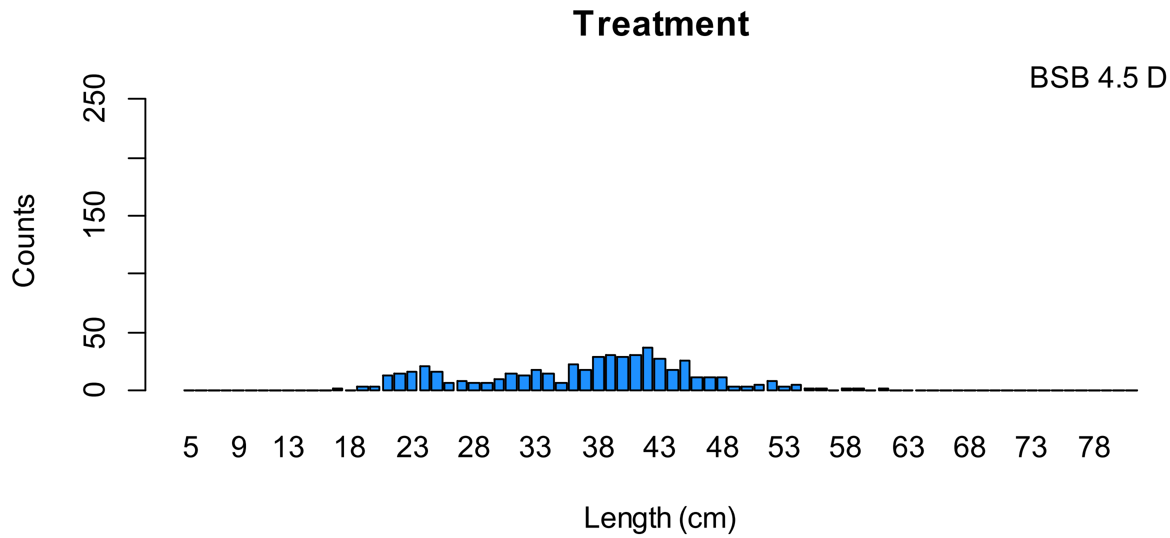


Figure 20. Length frequency distributions in the treatment (4.5" Diamond) and control codends for black sea bass



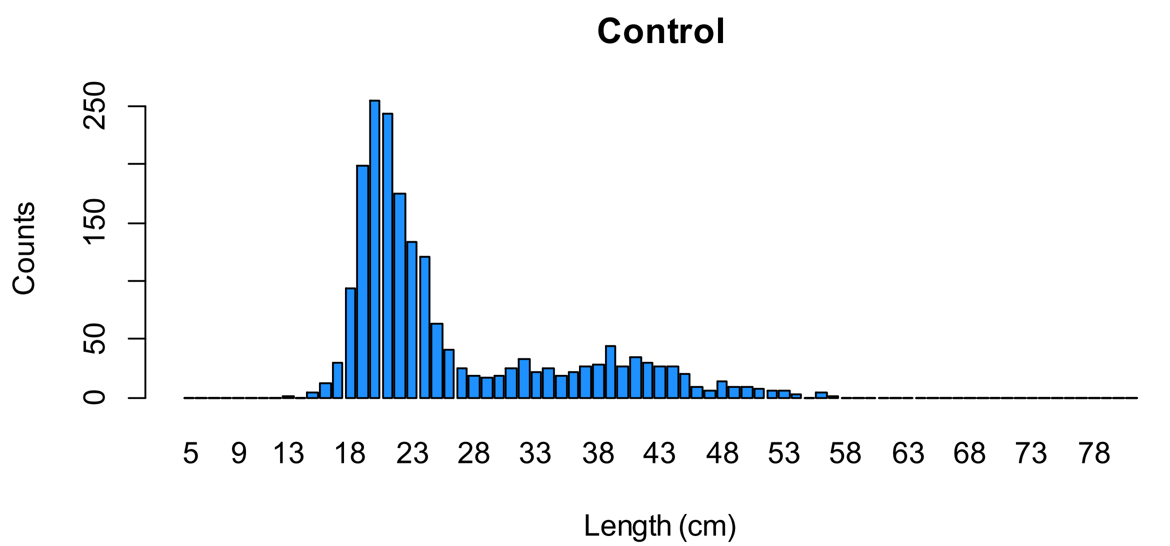


Figure 21. Length frequency distribution of black sea bass in the 4.5" diamond codend

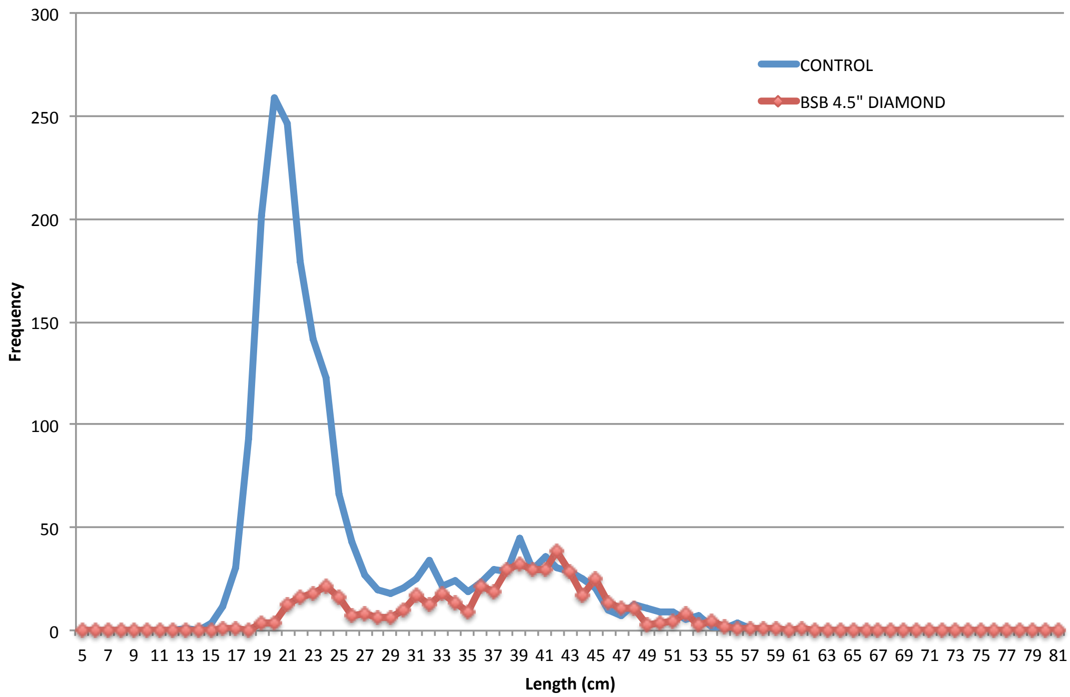


Figure 22. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for black sea bass in the 5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

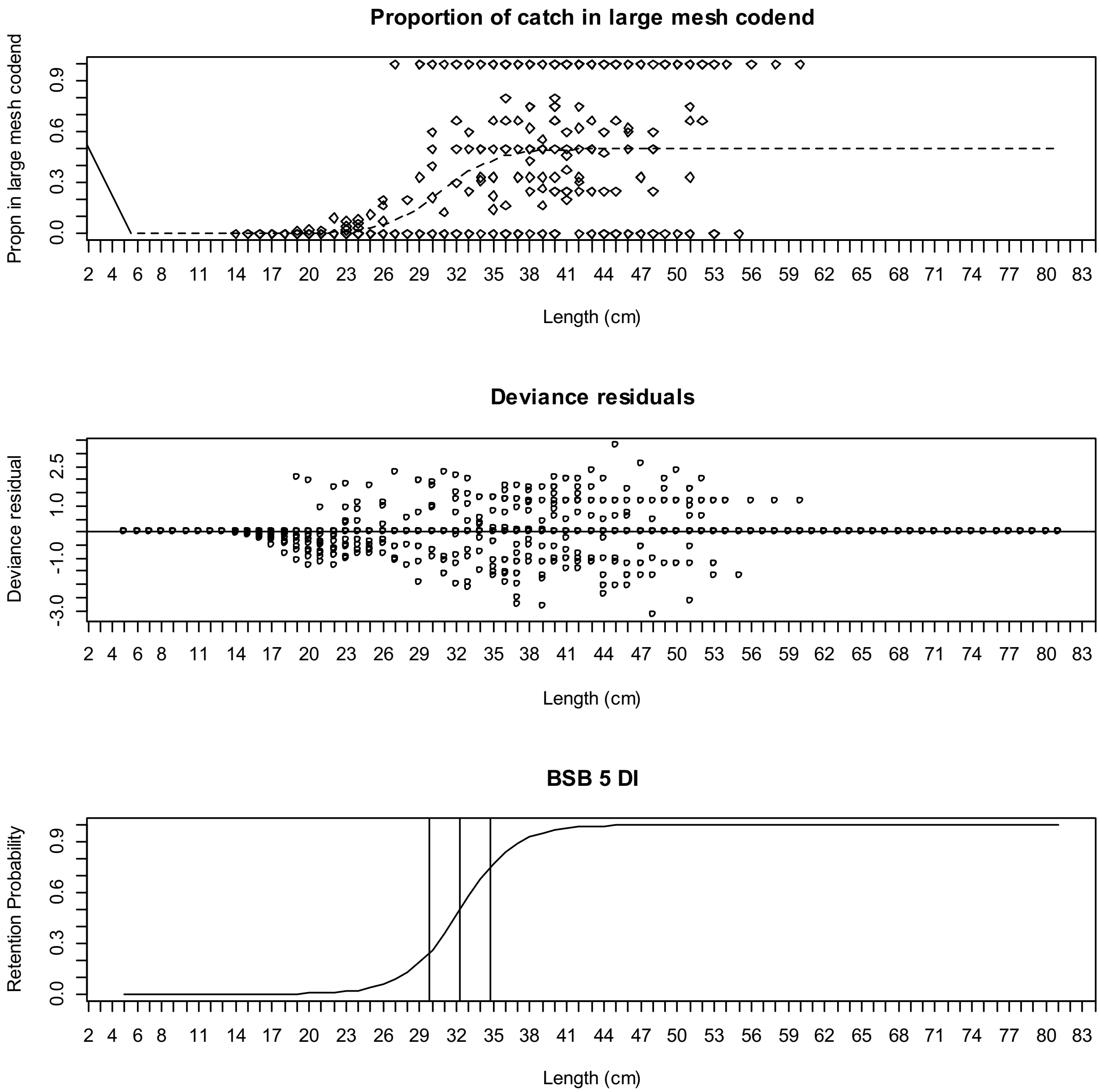


Figure 23. Length frequency distributions in the treatment (5" Diamond) and control codends for black sea bass

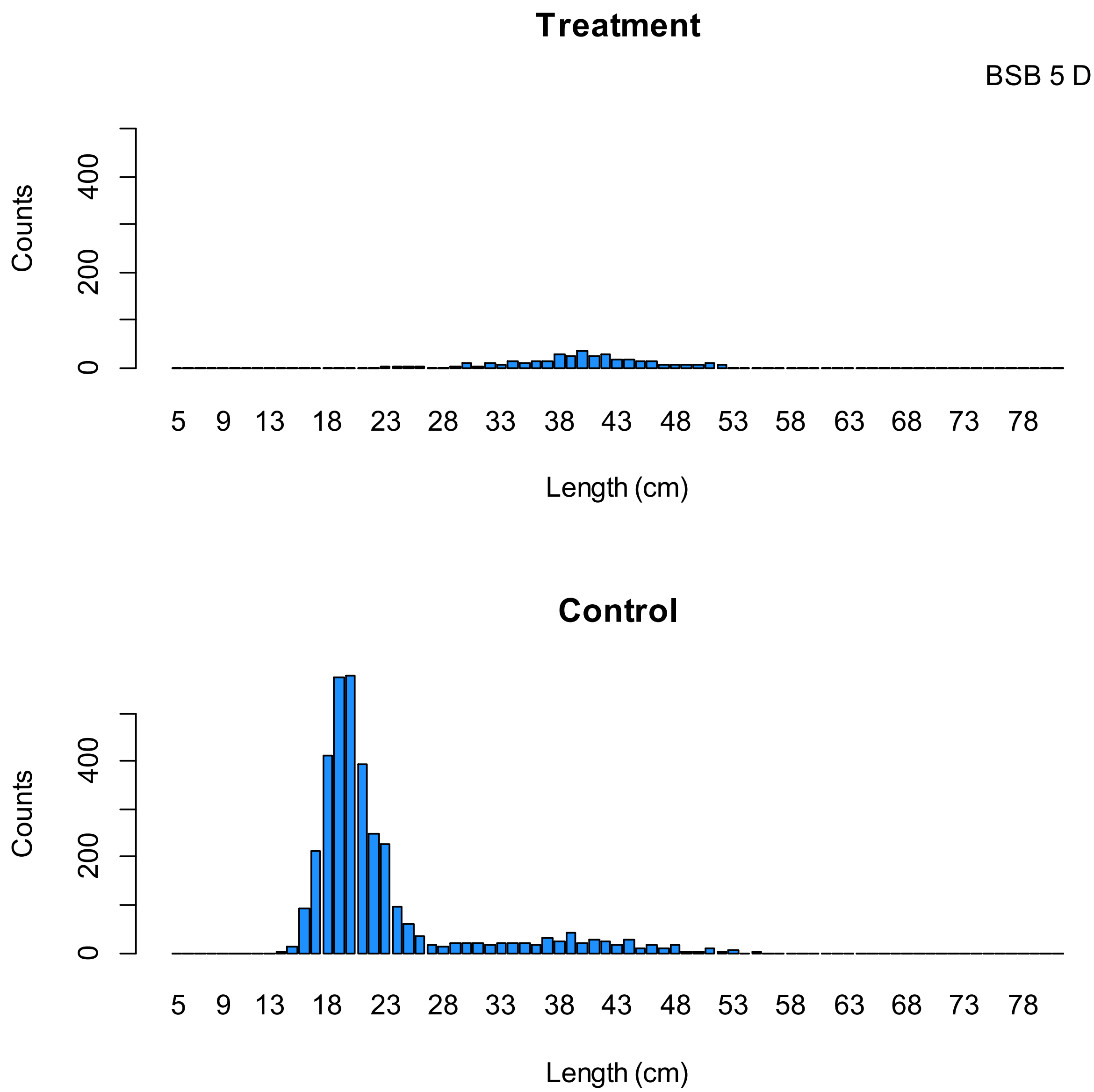


Figure 24. Length frequency distribution of black sea bass in the 5” diamond codend

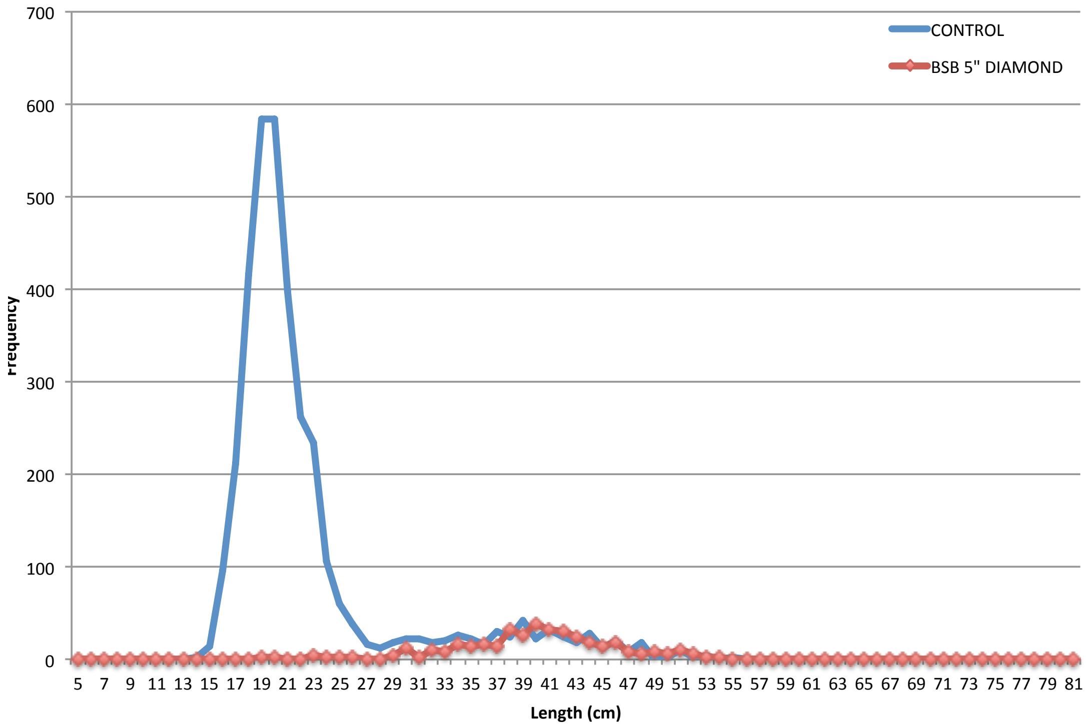


Figure 25. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for black sea bass in the 5.5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

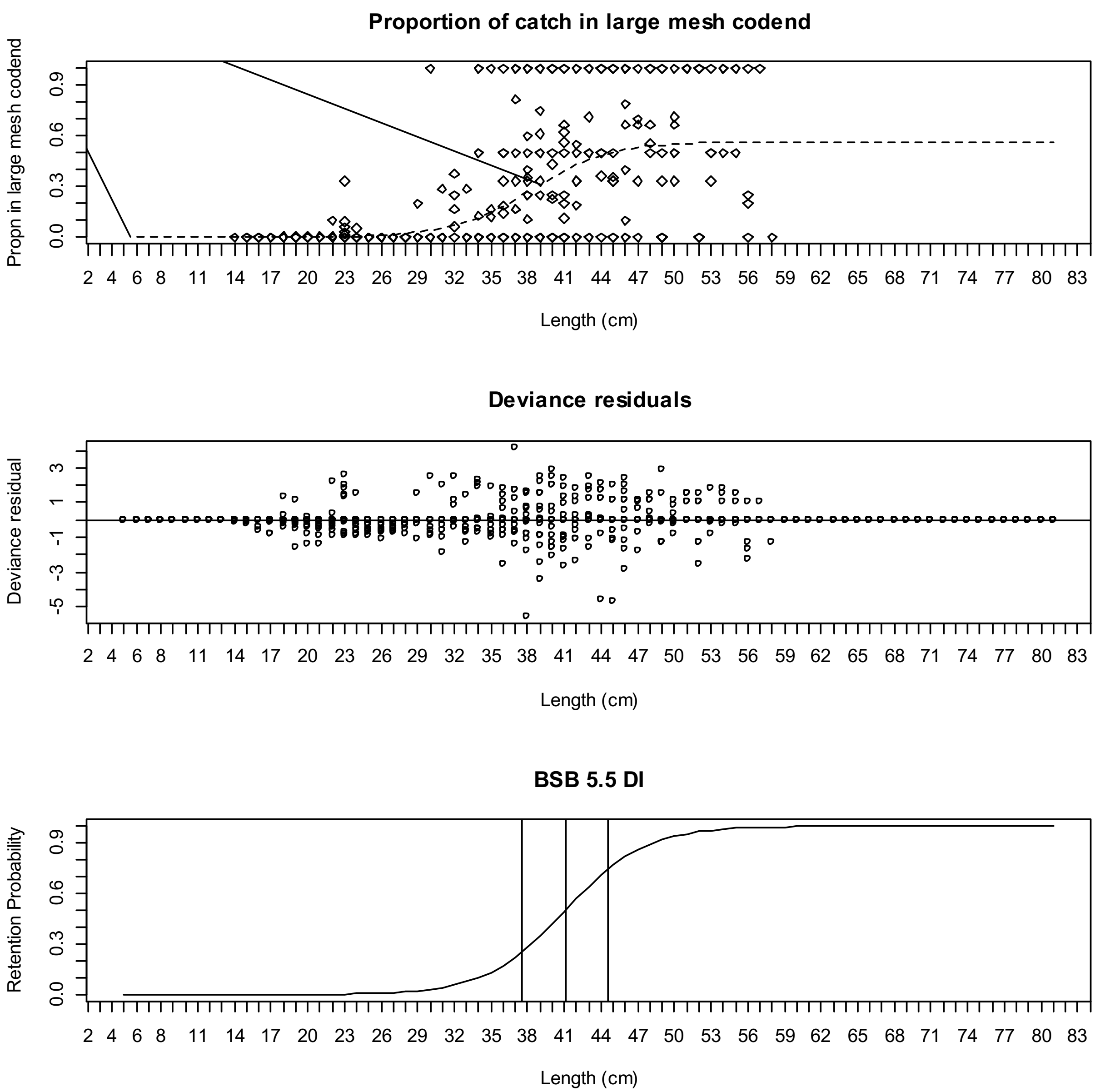


Figure 26. Length frequency distributions in the treatment (5.5" Diamond) and control codends for black sea bass

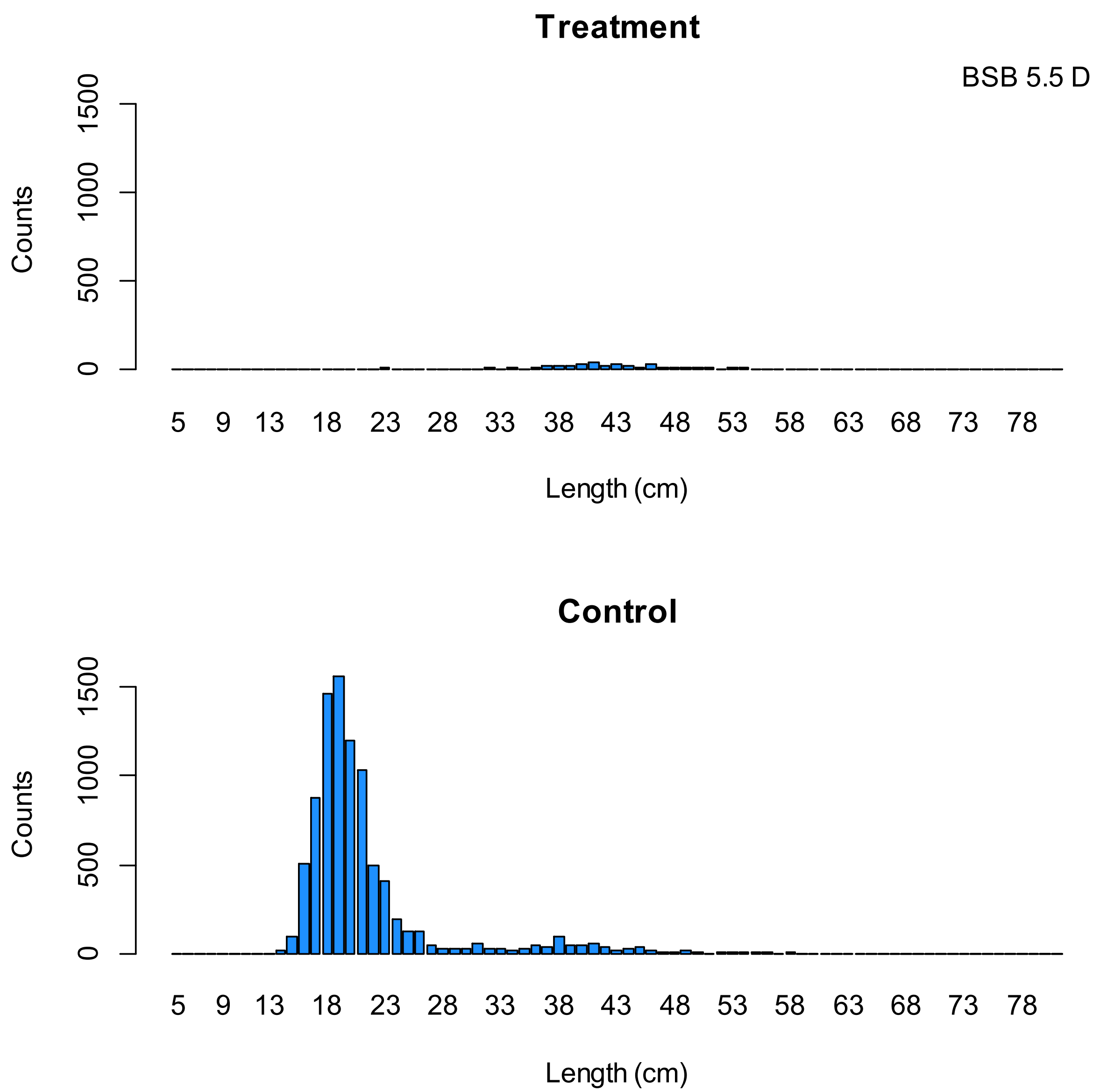


Figure 27. Length frequency distribution of black sea bass in the 5.5” diamond codend

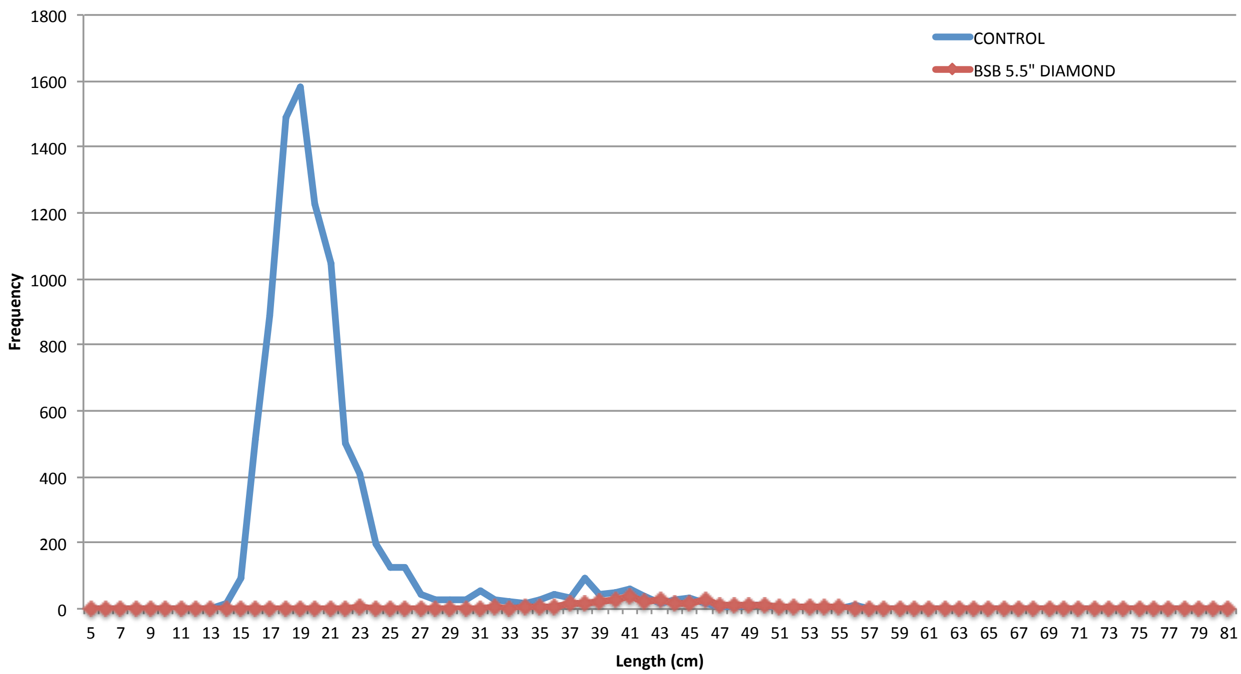


Figure 28. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for black sea bass in the 6” diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

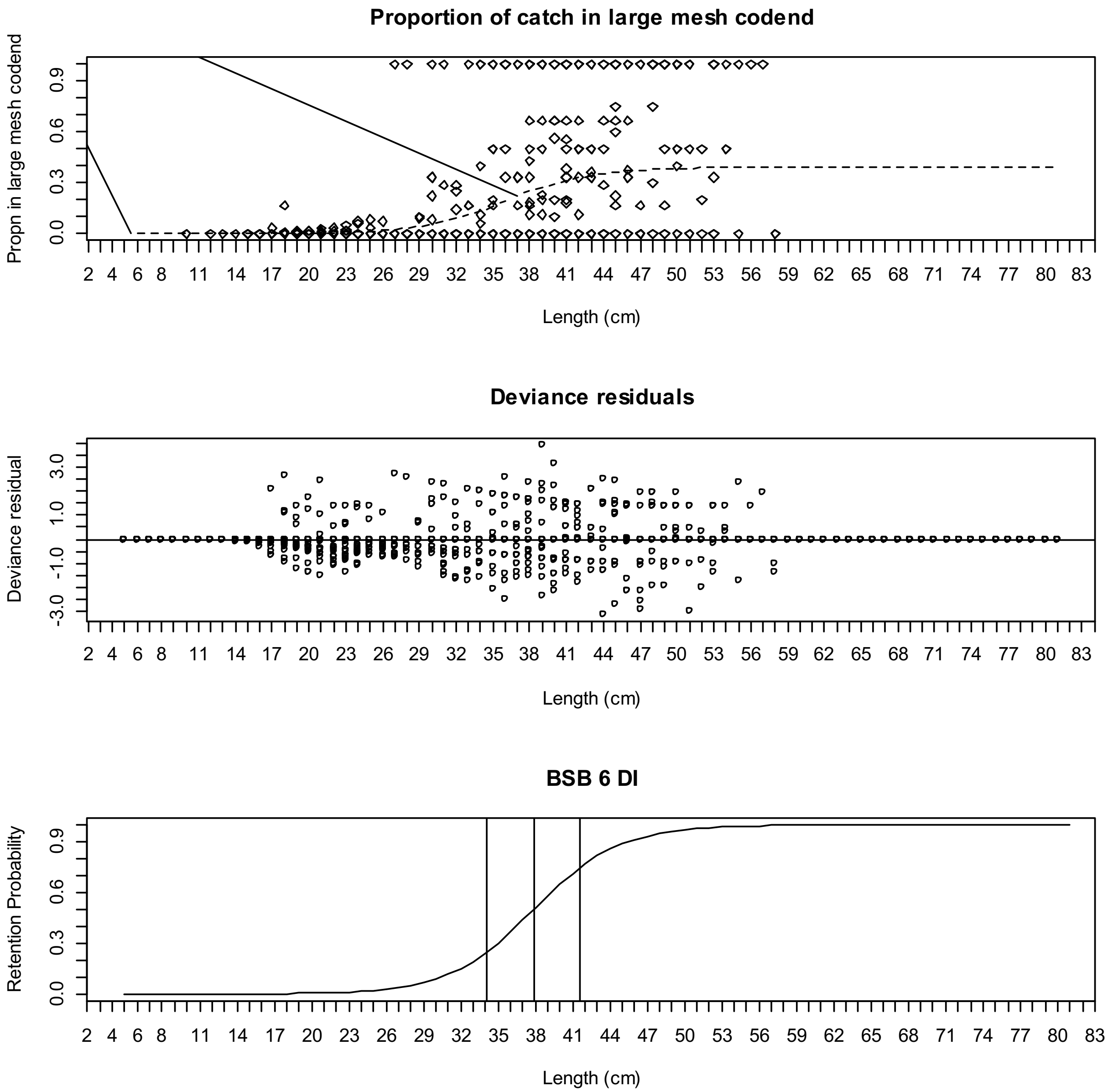


Figure 29. Length frequency distributions in the treatment (6" Diamond) and control codends for black sea bass

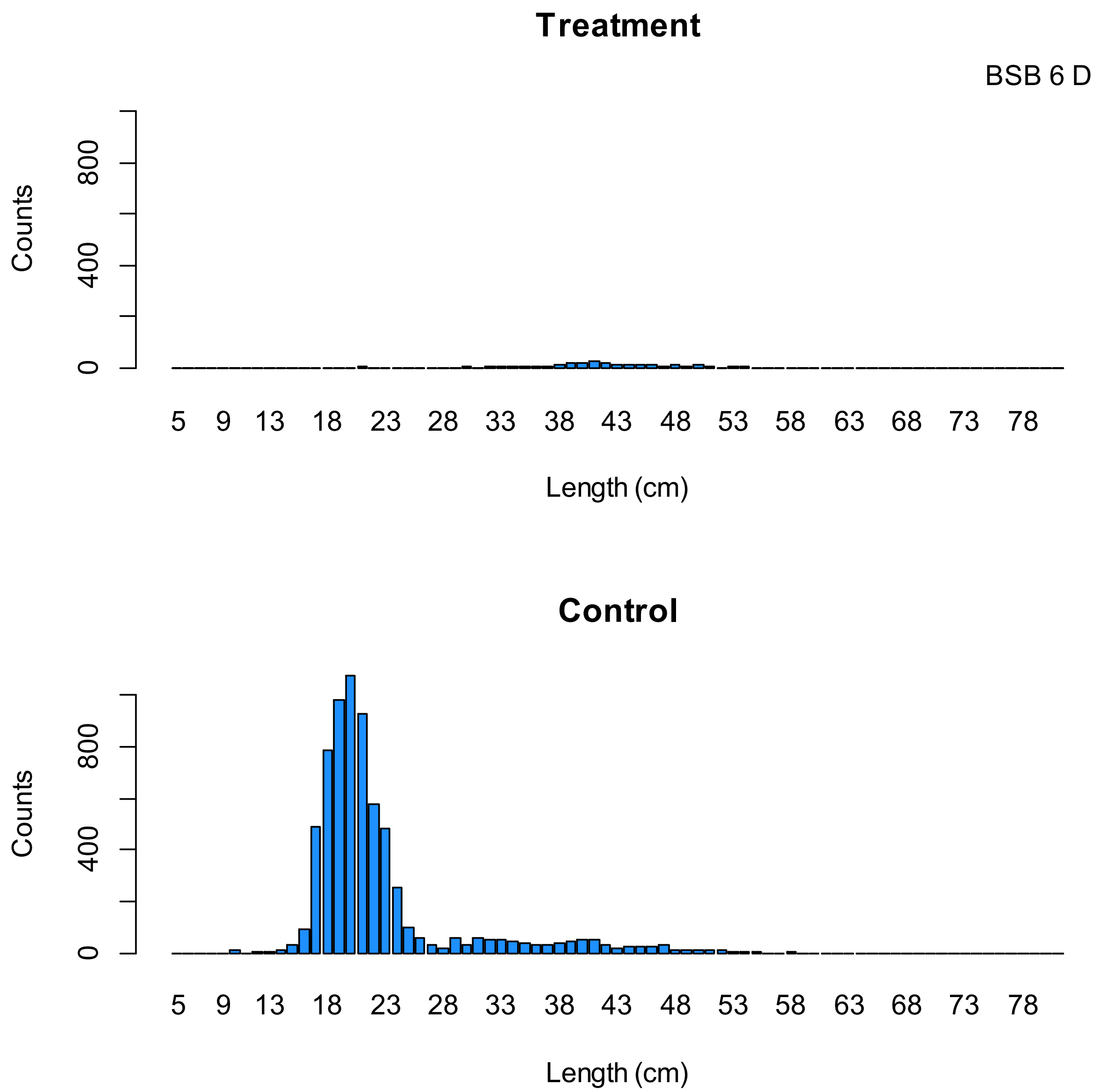


Figure 30. Length frequency distribution of black sea bass in the 6" diamond codend

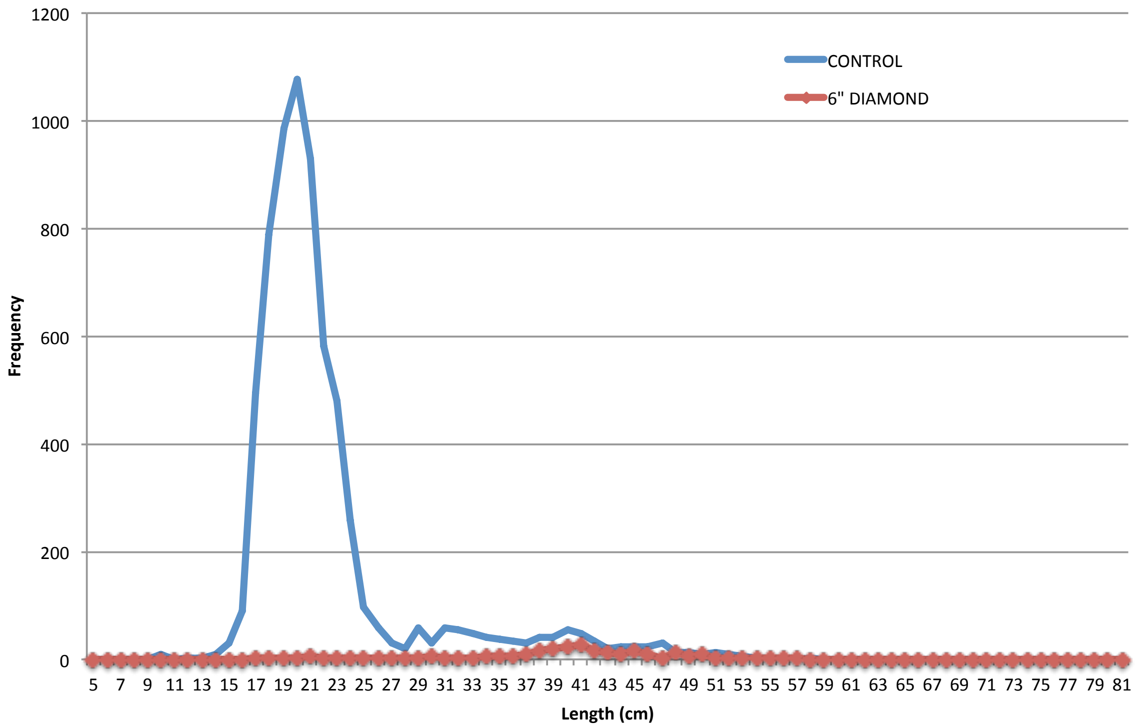


Figure 31. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for black sea bass in the 6" square codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

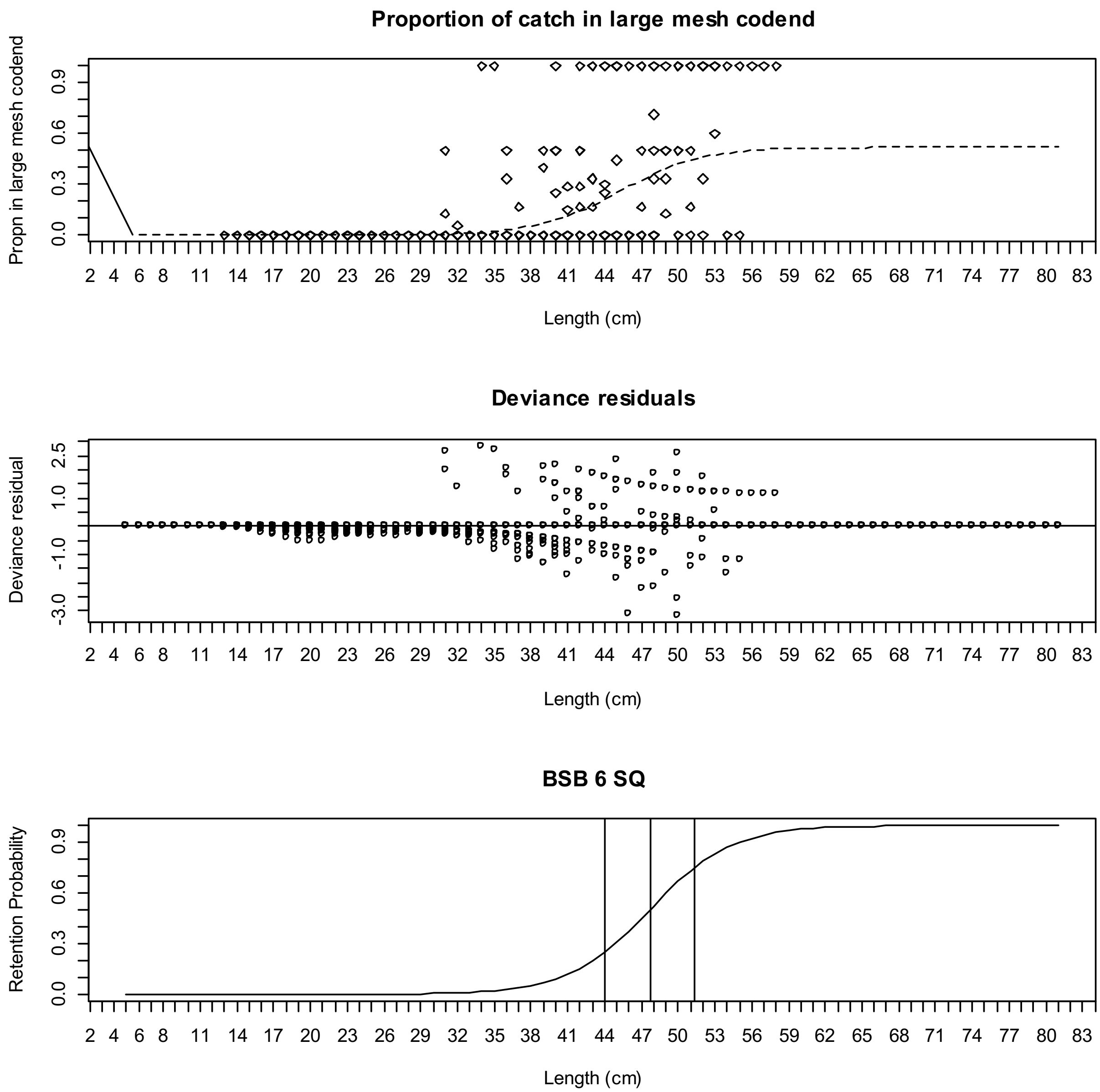


Figure 32. Length frequency distributions in the treatment (6" Square) and control codends for black sea bass

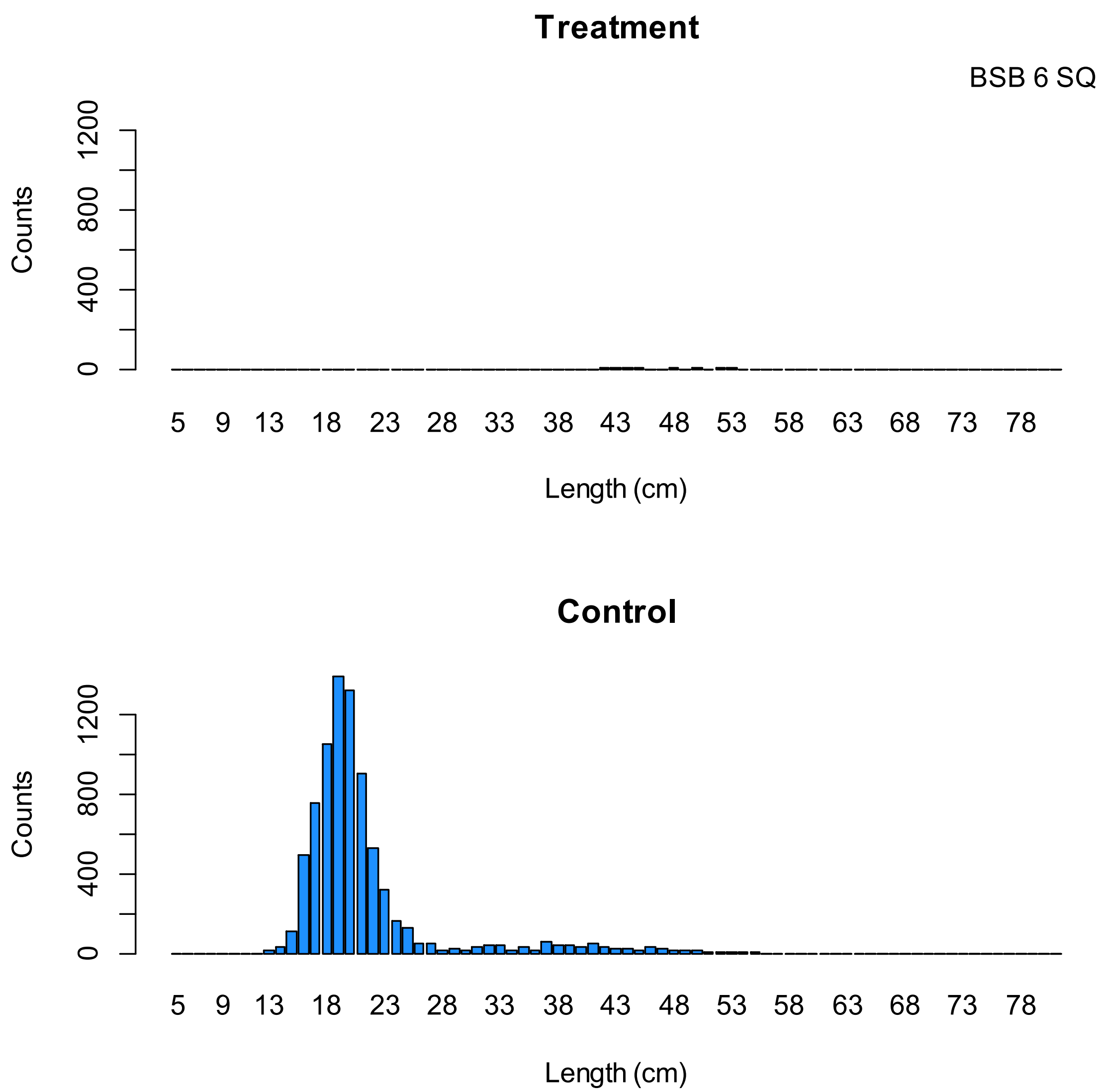


Figure 33. Length frequency distribution of black sea bass in the 6” square codend

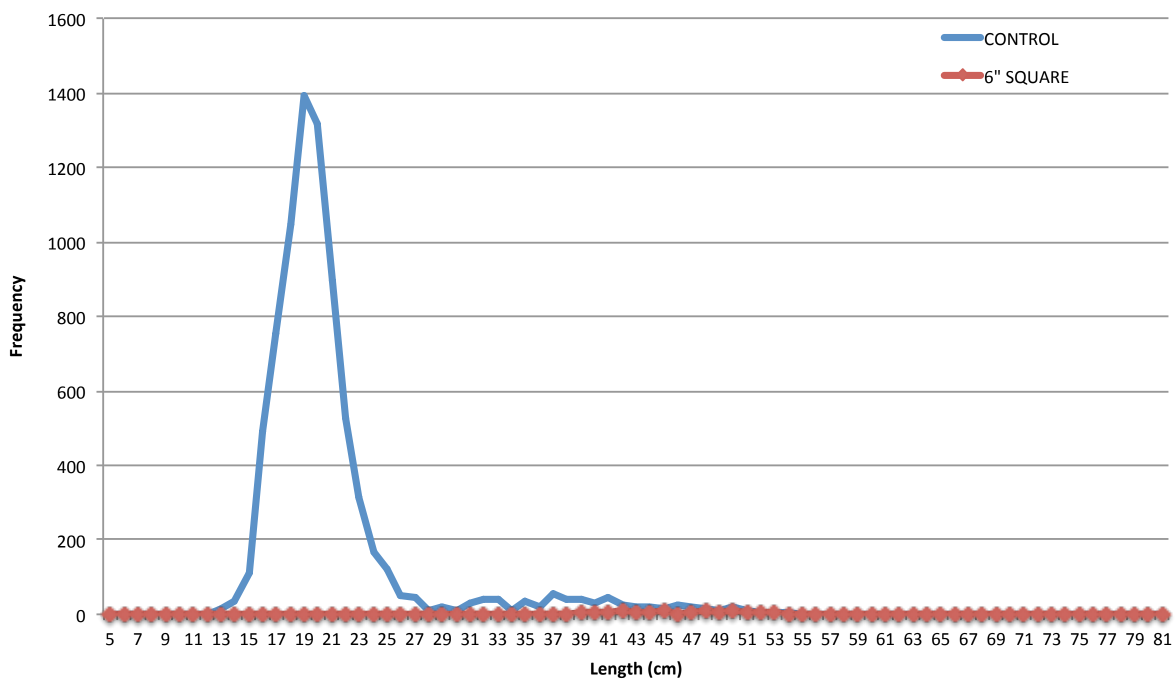
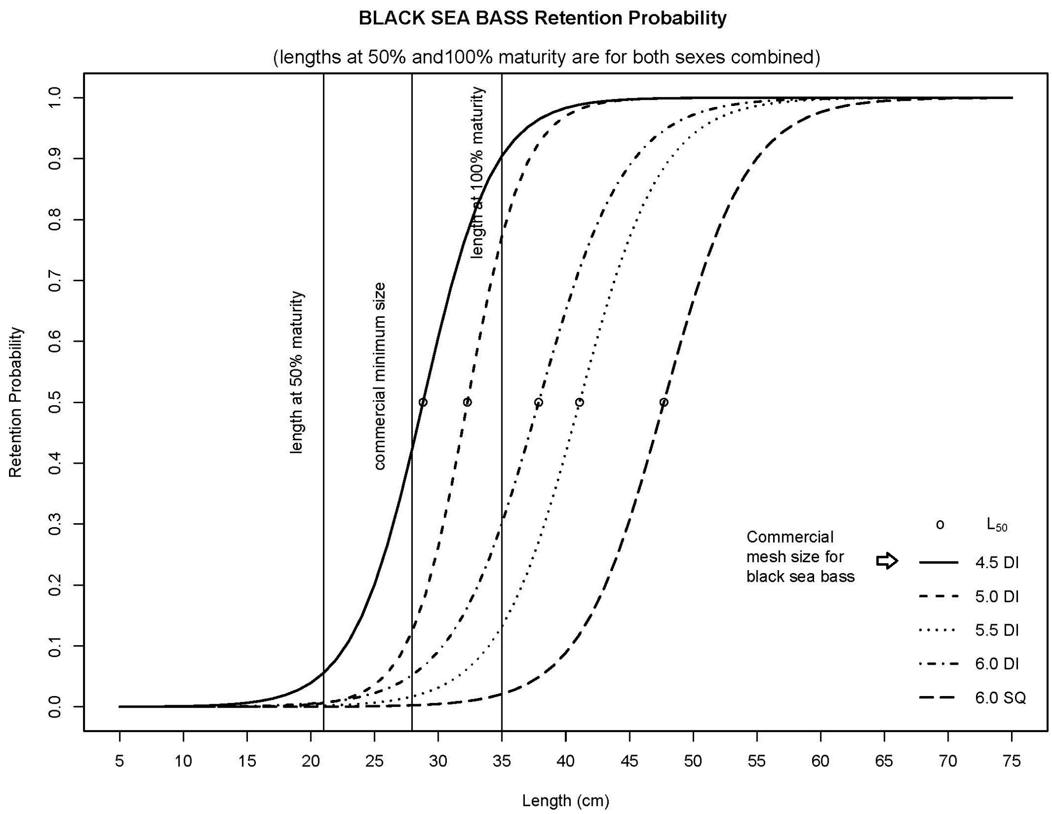


Figure 34. Logistic selectivity curve for black sea bass catches with 5 codends (4.5” diamond, 5” diamond, 5.5” diamond, 6” diamond and 6” square)



Summer Flounder

Table 4. Maximum likelihood fit of logistic selectivity curve parameters for 5 codend mesh sizes and SELECT model goodness-of-fit measures for summer flounder
Standard error is shown in parentheses. Coefficient of variation is shown in double parentheses. 5.5” Diamond and 6” Square are the current regulation minimum mesh sizes.

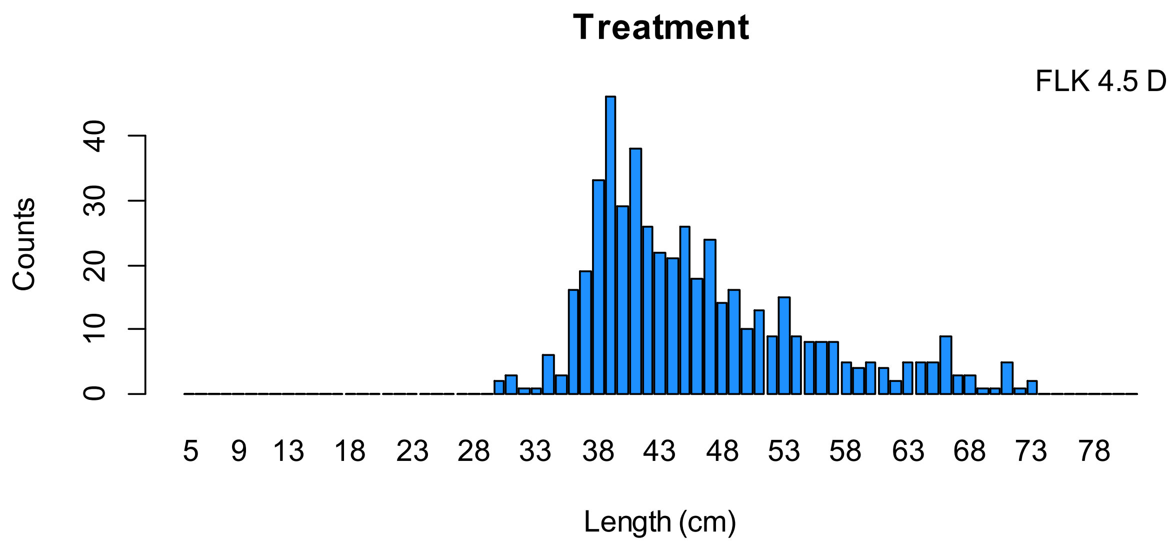
	4.5" Diamond	5" Diamond	5.5" Diamond	6" Diamond	6" Square
N tows (paired)	24	24	24	24	22
N length classes	55	50	51	47	57
Length class range (cm)	21-75	27-76	28-78	32-78	25-81
a	N/A	-47.78	-16.30	-14.42	-27.72
b	N/A	1.37	0.43	0.35	0.80
p - relative fishing efficiency	N/A	0.49 (0.02)	0.55 (0.02)	0.55 (0.03)	0.50 (0.02)
L_{25} (cm)	N/A	34.07 (0.72) ((0.021))	35.03 (1.19) ((0.034))	38.09 (1.05) ((0.028))	33.29 (1.51) ((0.045))
L_{50} (cm)	N/A	34.87 (0.67) ((0.019))	37.56 (0.87) ((0.023))	41.23 (1.22) ((0.030))	34.67 (1.16) ((0.034))
L_{75} (cm)	N/A	35.67 (1.04) ((0.029))	40.1 (1.39) ((0.035))	44.37 (2.00) ((0.045))	36.04 (1.66) ((0.046))
Selection range	N/A	1.6 (1.17)	5.06 (1.92)	6.28 (2.07)	2.75 (2.18)
Selection factor	N/A	6.94	6.83	6.87	5.78
Model deviance	N/A	144.45	230.77	133.48	92.49
df	N/A	113	178	93	73
p-value	N/A	0.0245	0.0047	.0038	0.0615

The SELECT model can not fit a selectivity curve for summer flounder with the 4.5” diamond codend. As mentioned above, we ran the model with the minimum number of individuals per length bin set at 3 and 1 and in both cases the model can not fit a selectivity curve. As can be seen in Figure 36, the length frequency distribution for the 4.5” diamond codend is nearly identical to the length frequency distribution of the control codend. There is no difference in selectivity for summer flounder in the 4.5” diamond codend.

In the tows using the 4.5” diamond codend we did not catch many small summer flounder in either the control or experimental codends. There were many tows with zero or very few individual summer flounder in the small size length bins. This was also the case for summer flounder in the tows for the other mesh sizes as well.

Other recent studies have also experienced reduced catches of summer flounder at smaller sizes. Length frequency distribution from the NEAMAP survey shows decreasing numbers of small fish in the fall survey from 2012 to 2016 (VIMS, 2017). Likewise, the NMFS trawl survey shows decreasing numbers of small fish during the 2016 spring and 2017 spring surveys (NEFSC, 2018). The NMFS 2017 Sweep Efficiency Survey for Summer Flounder also caught very few smaller fish (Manderson, NEFSC, personal communication).

Figure 35. Length frequency distributions in the treatment (4.5" Diamond) and control codends for summer flounder



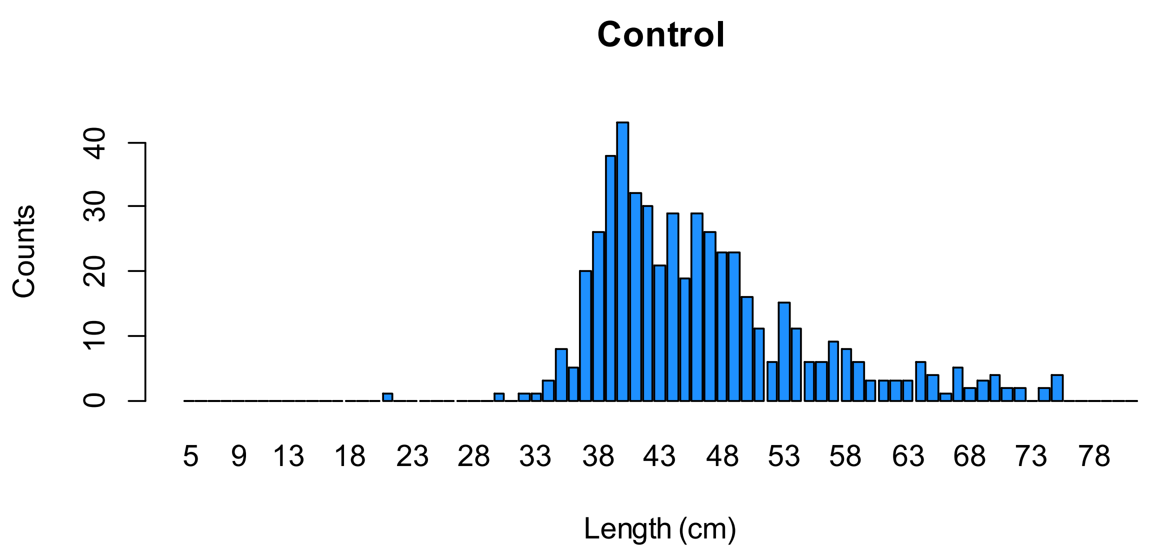


Figure 36. Length frequency distribution of summer flounder in the 4.5” diamond codend

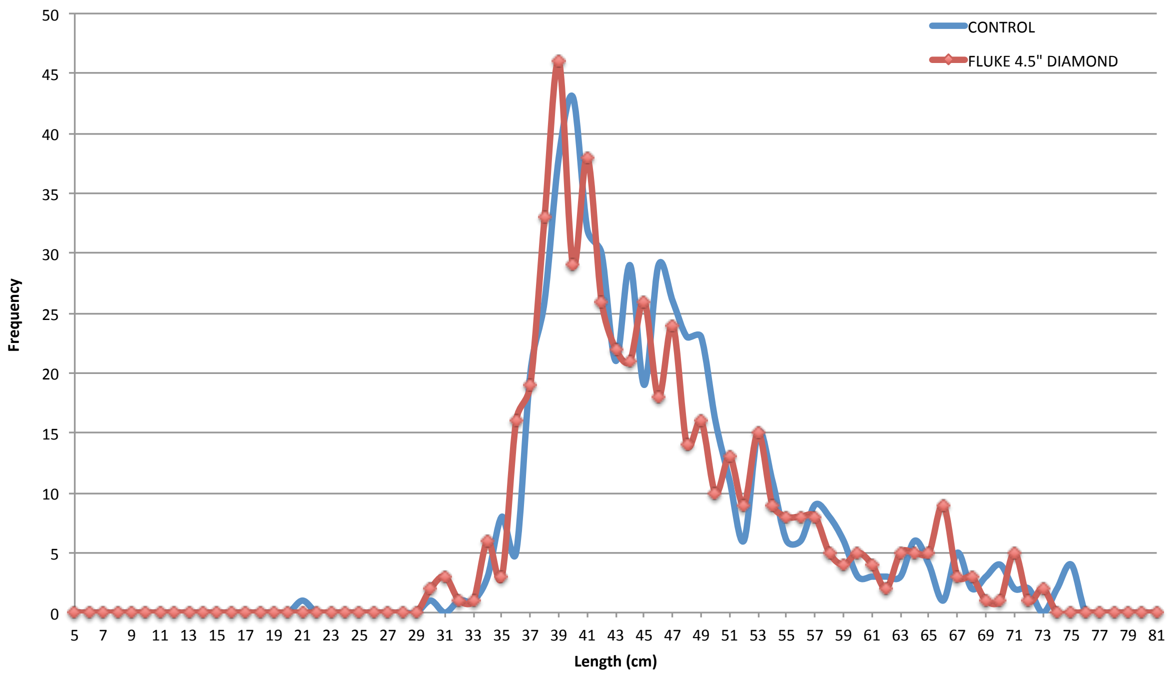


Figure 37. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for summer flounder in the 5" diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

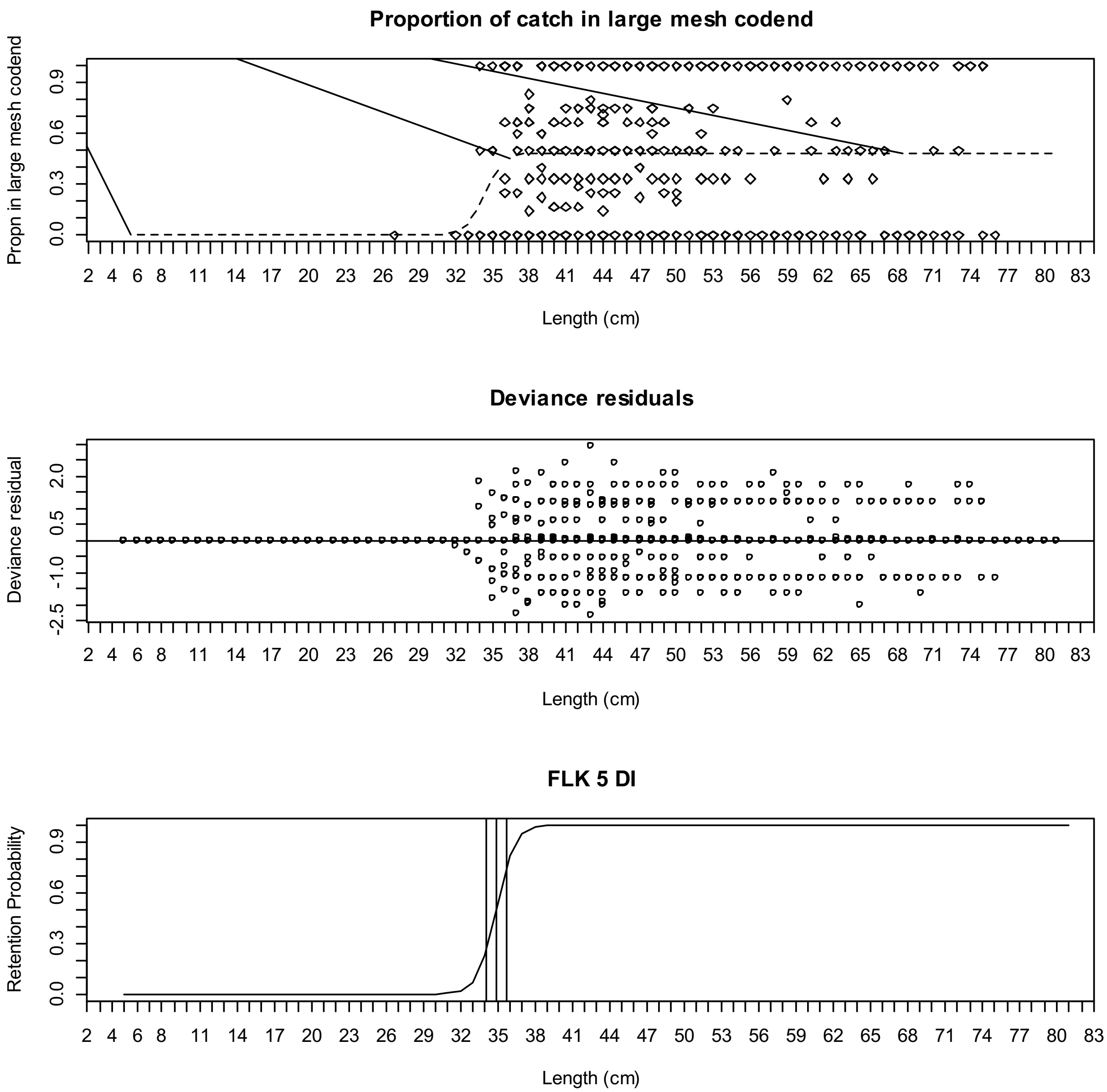


Figure 38. Length frequency distributions in the treatment (5" Diamond) and control codends for summer flounder

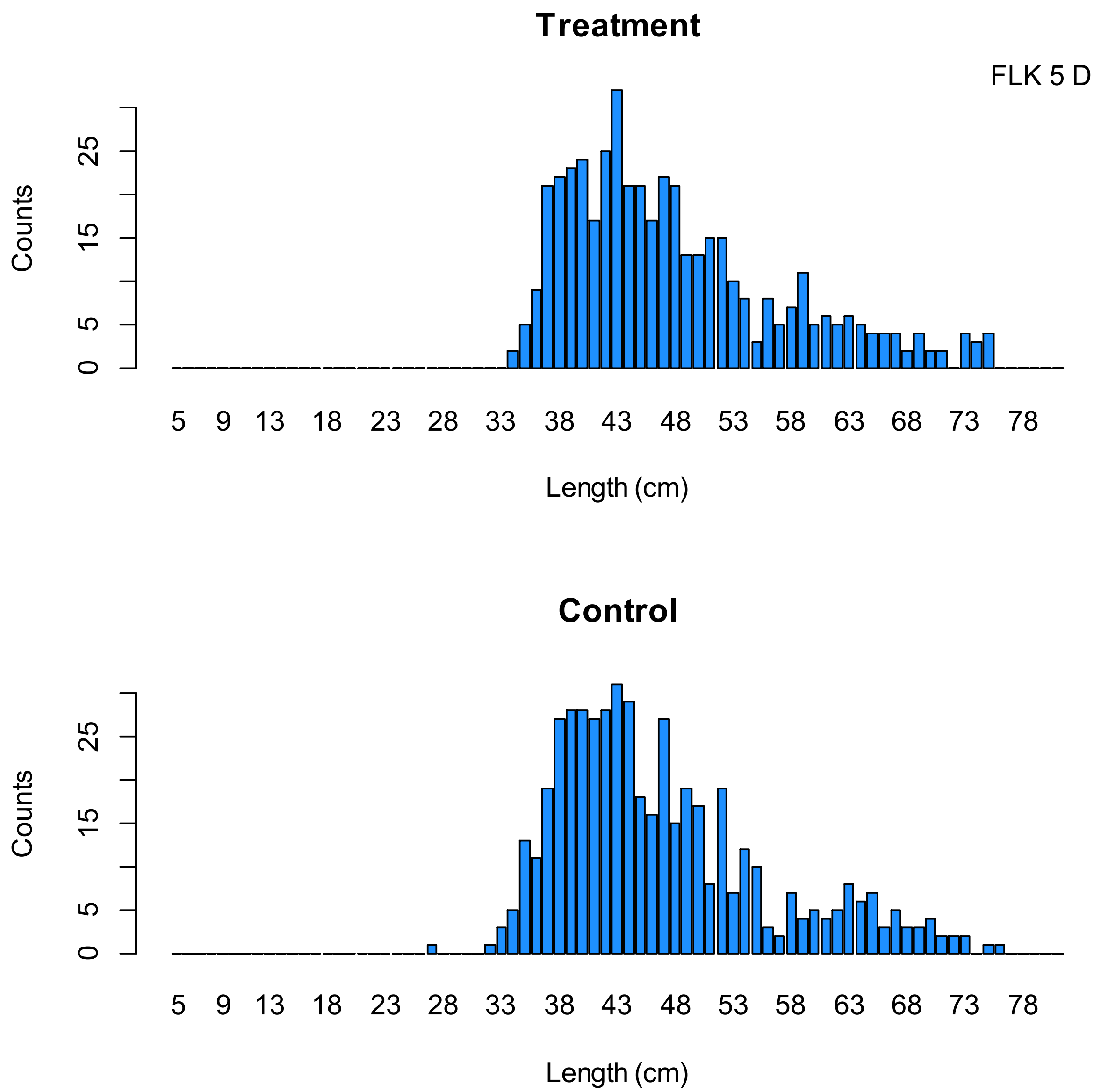


Figure 39. Length frequency distribution of summer flounder in the 5" diamond codend

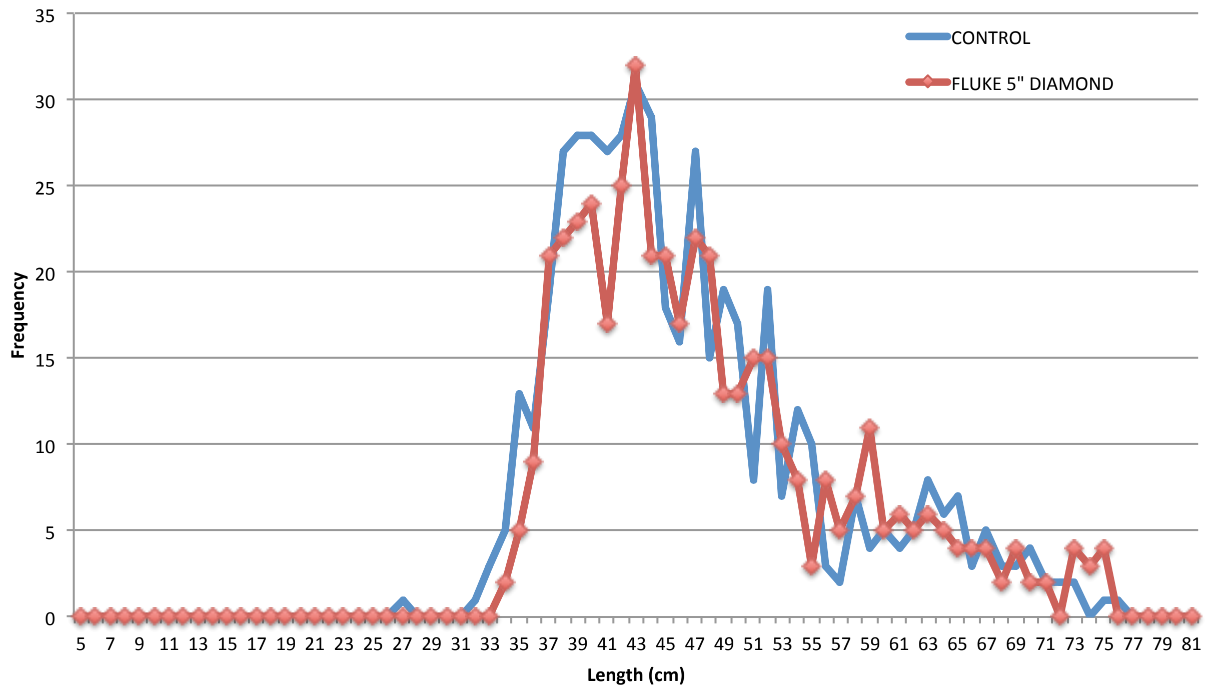


Figure 40. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for summer flounder in the 5.5” diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

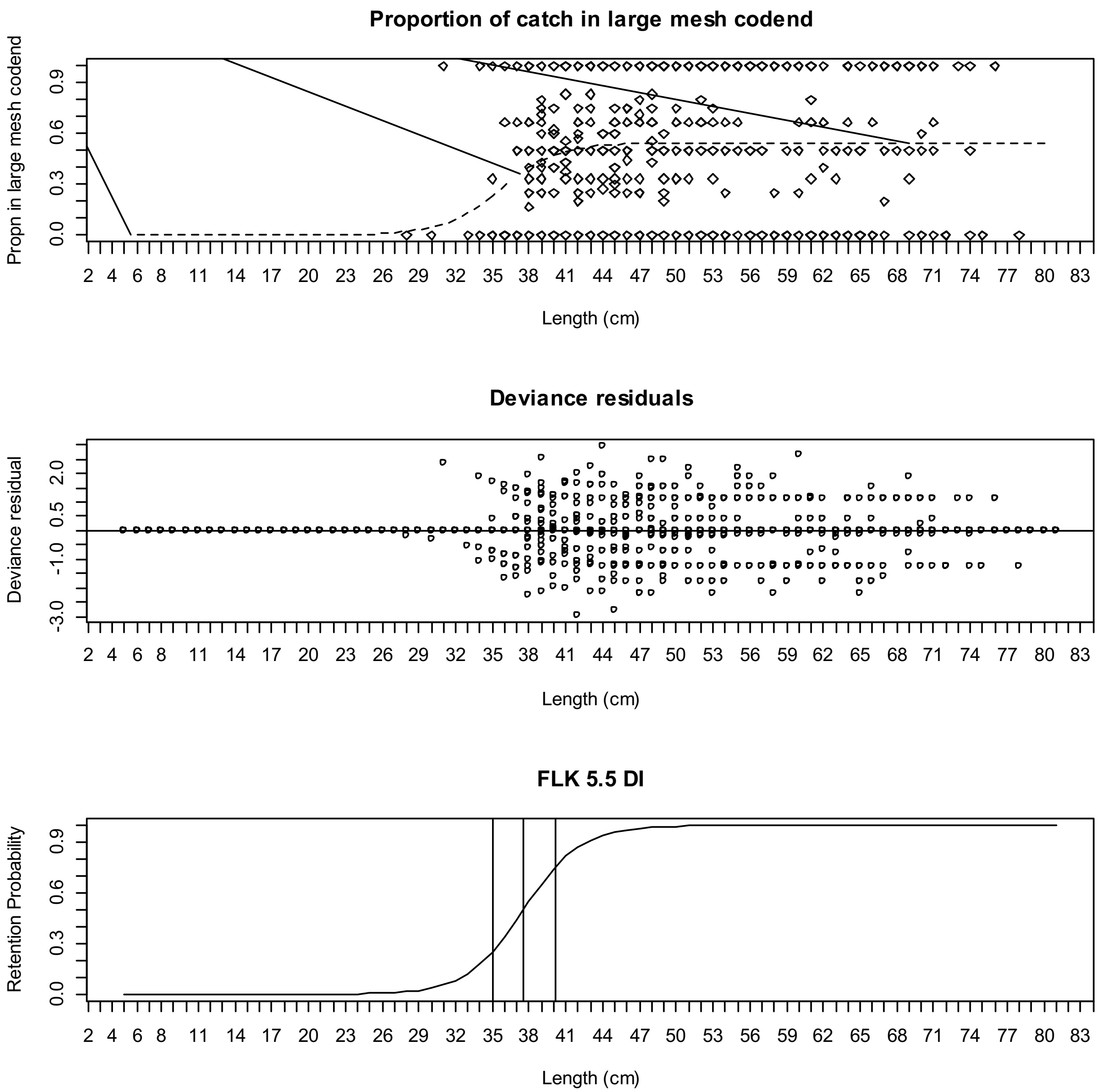


Figure 41. Length frequency distributions in the treatment (5.5” Diamond) and control codends for summer flounder

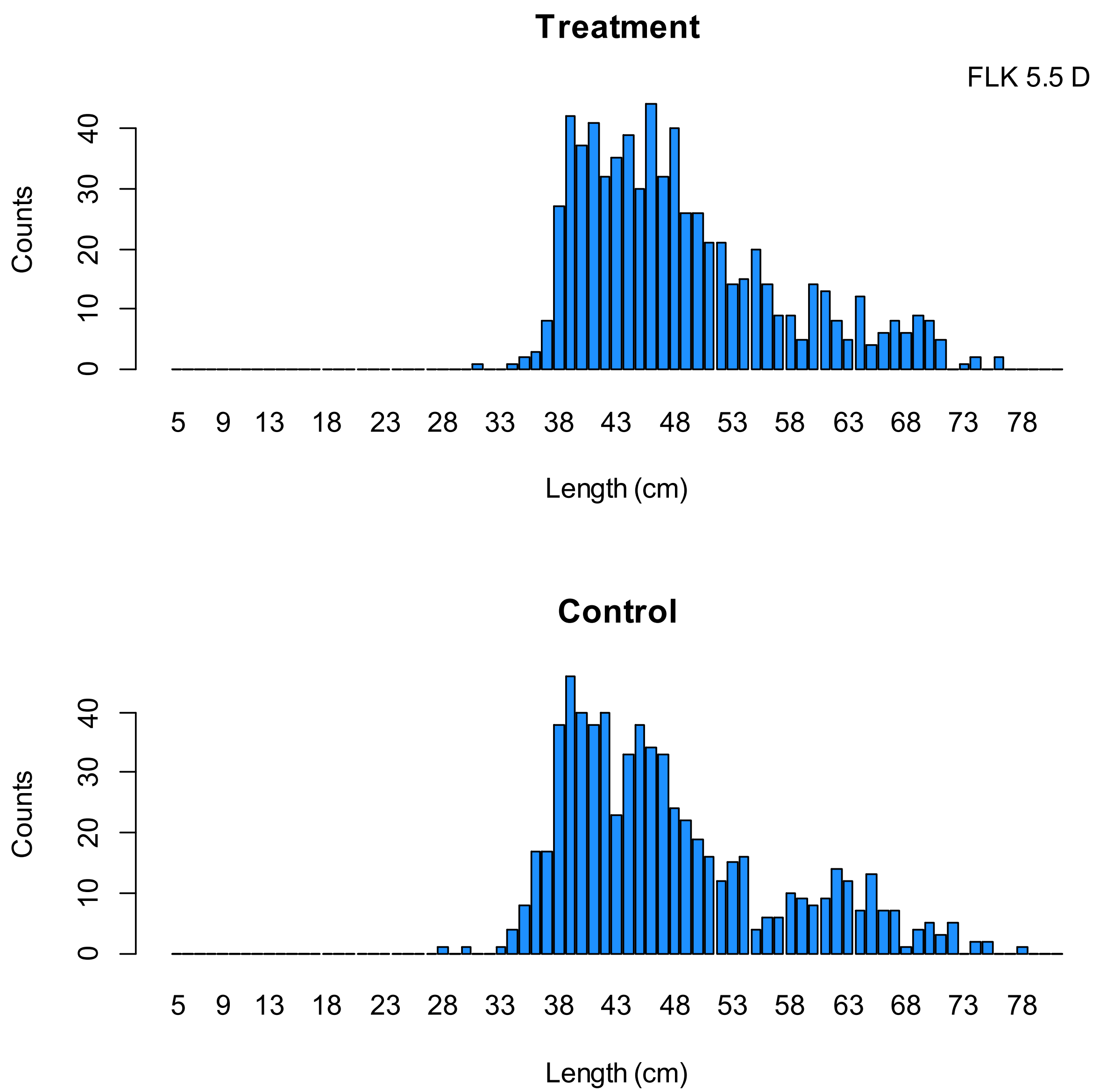


Figure 42. Length frequency distribution of summer flounder in the 5.5" diamond codend

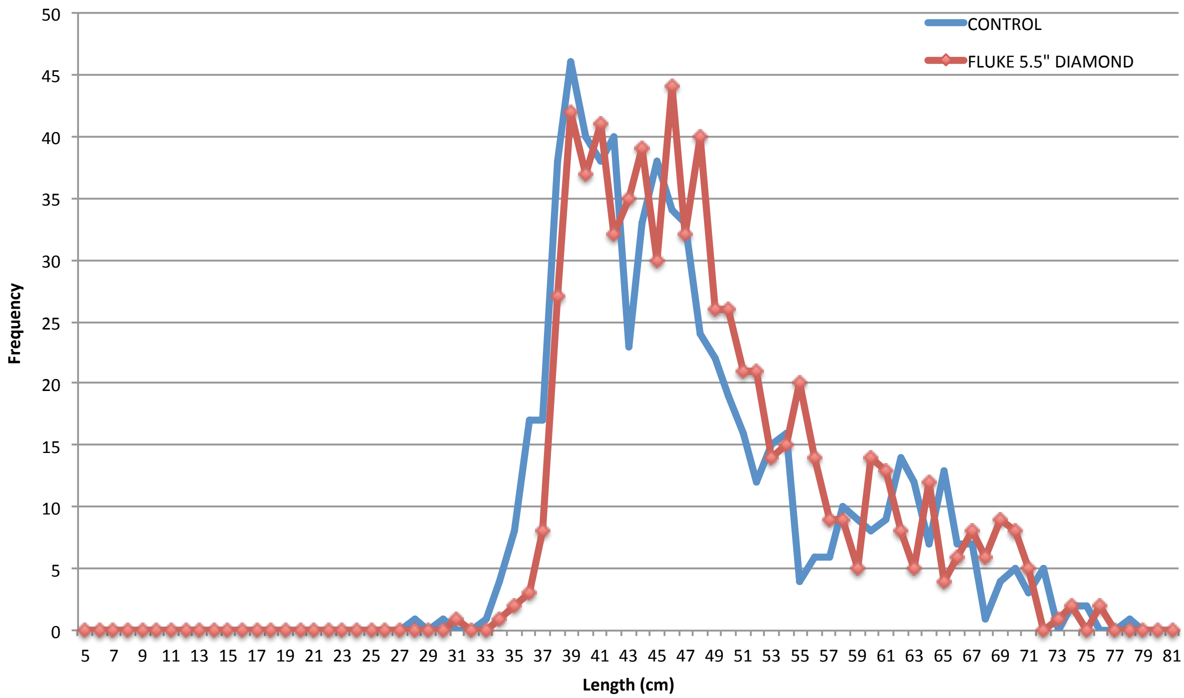


Figure 43. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for summer flounder in the 6” diamond codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

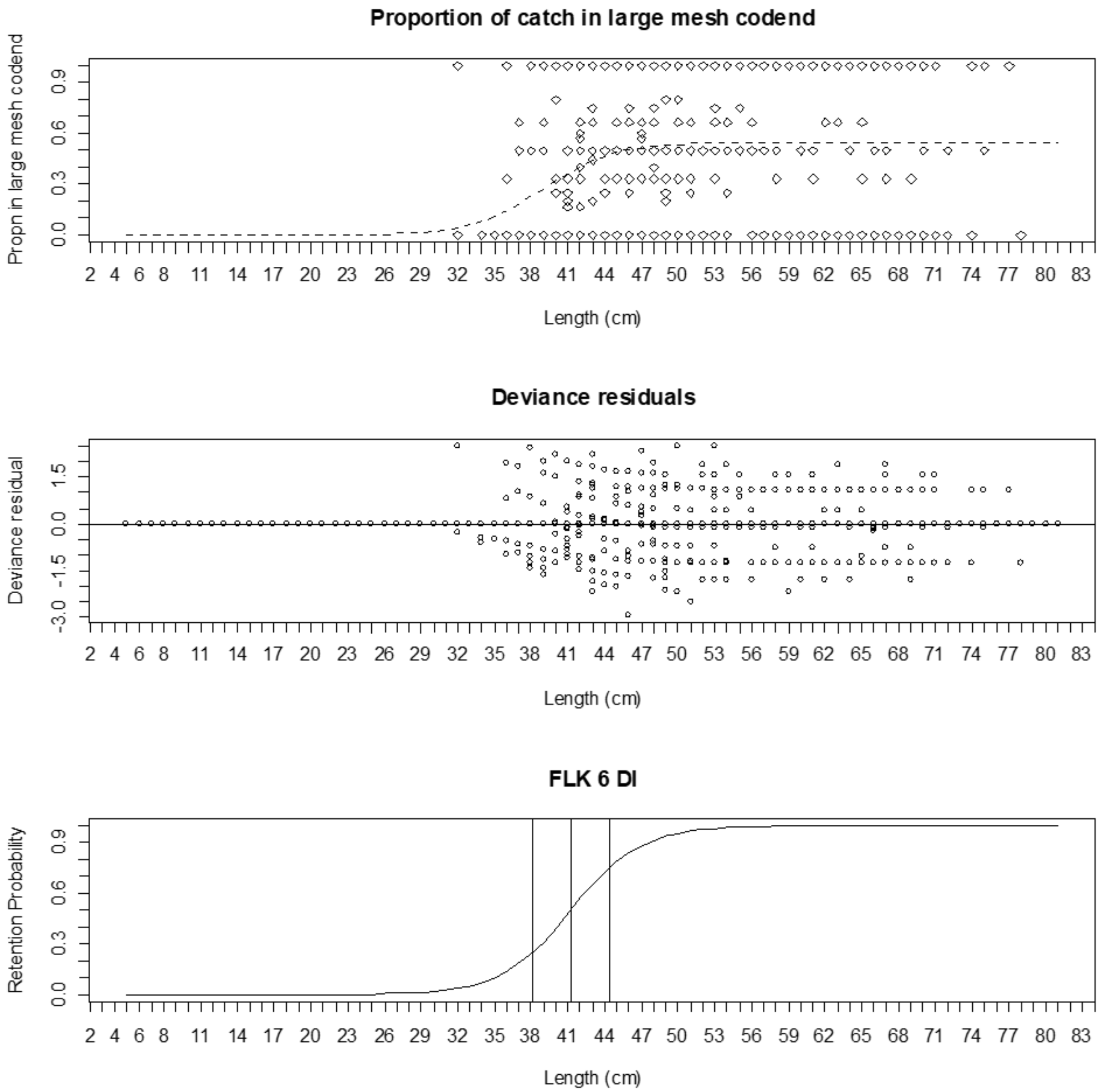


Figure 44. Length frequency distributions in the treatment (6" Diamond) and control codends for summer flounder

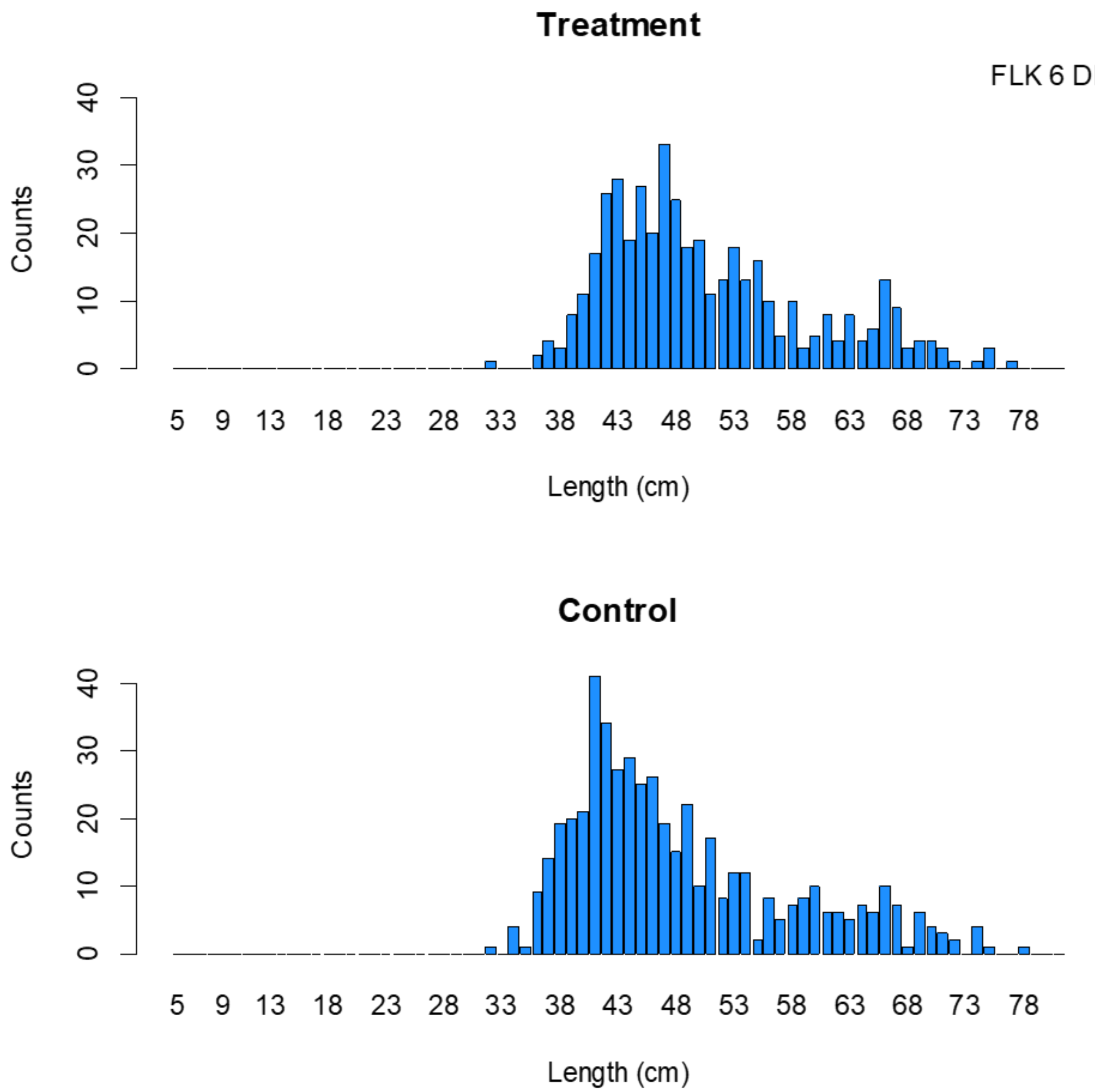


Figure 45. Length frequency distribution of summer flounder in the 6" diamond codend

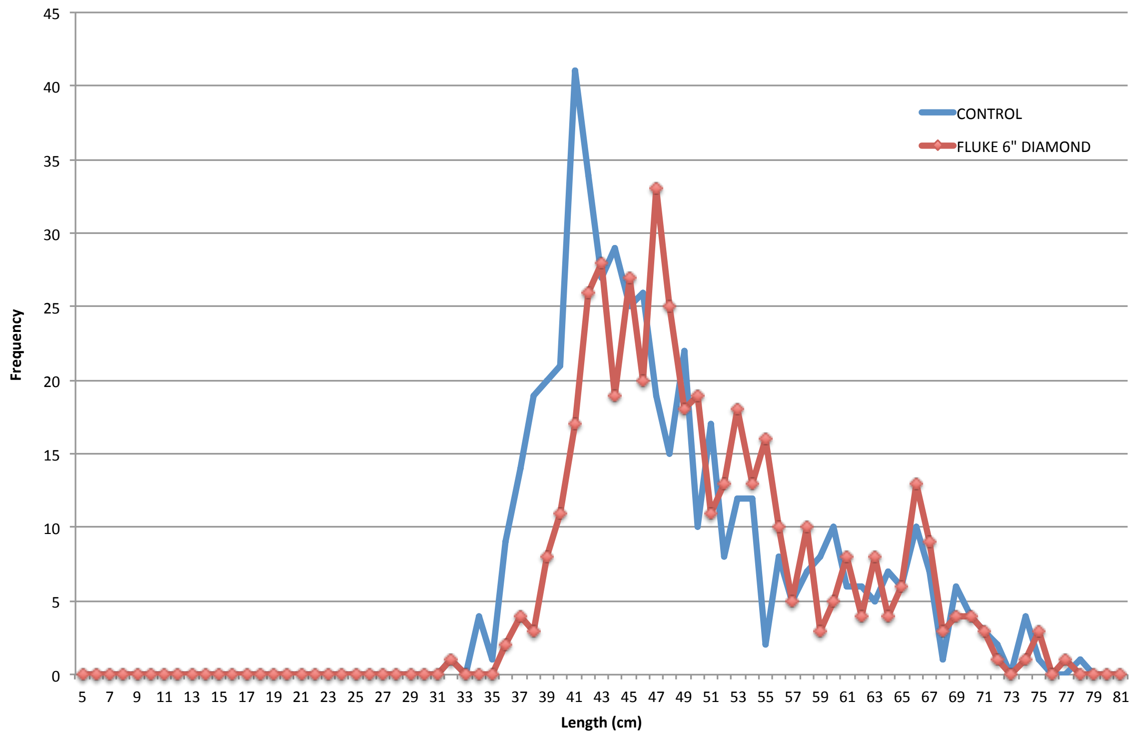


Figure 46. Proportion of catch in treatment codend, deviance residuals, and selectivity curve for summer flounder in the 6" square codend. Vertical lines on the selectivity curve represent L_{25}, L_{50} and L_{75}.

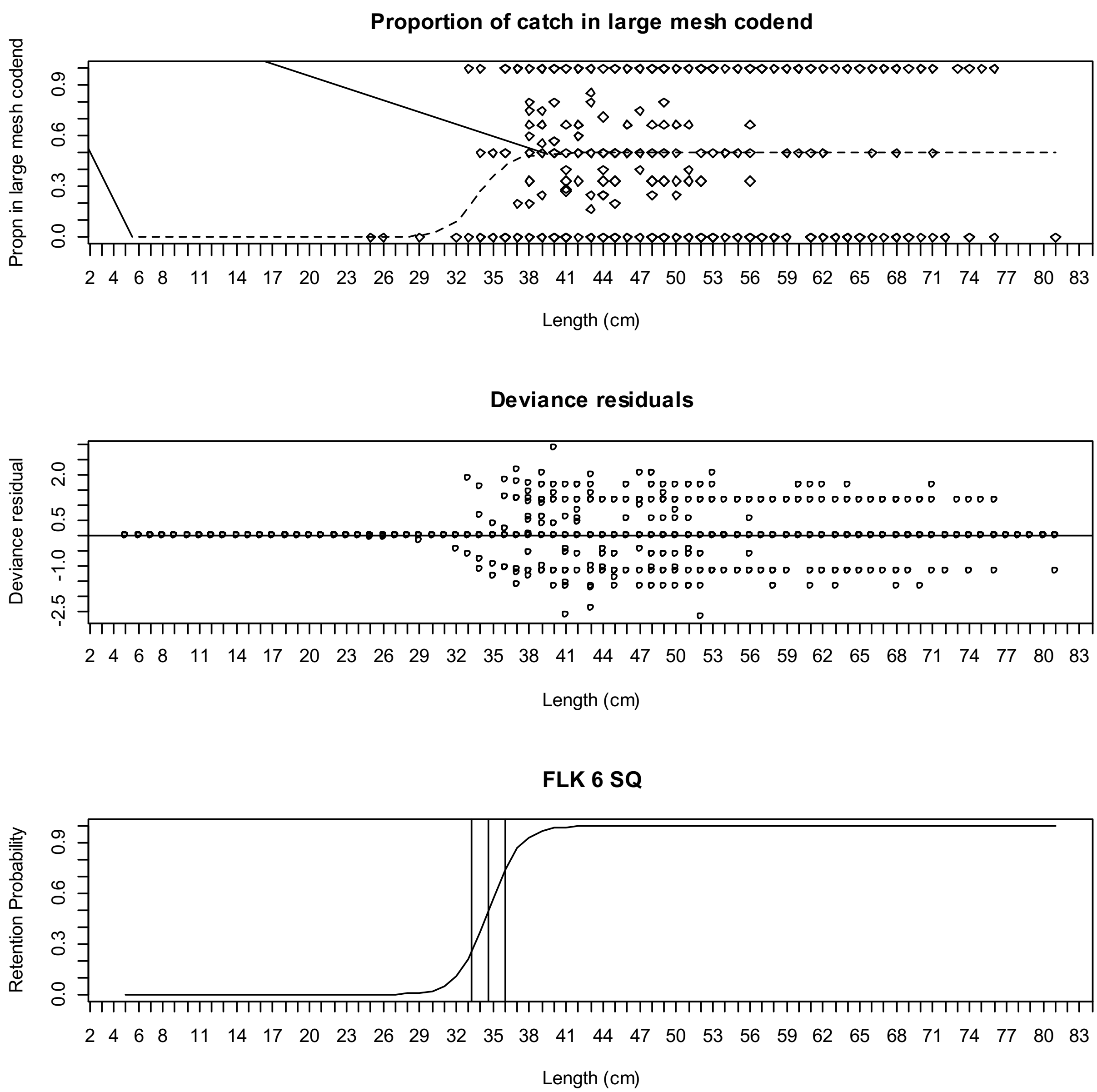


Figure 47. Length frequency distributions in the treatment (6" Square) and control codends for summer flounder

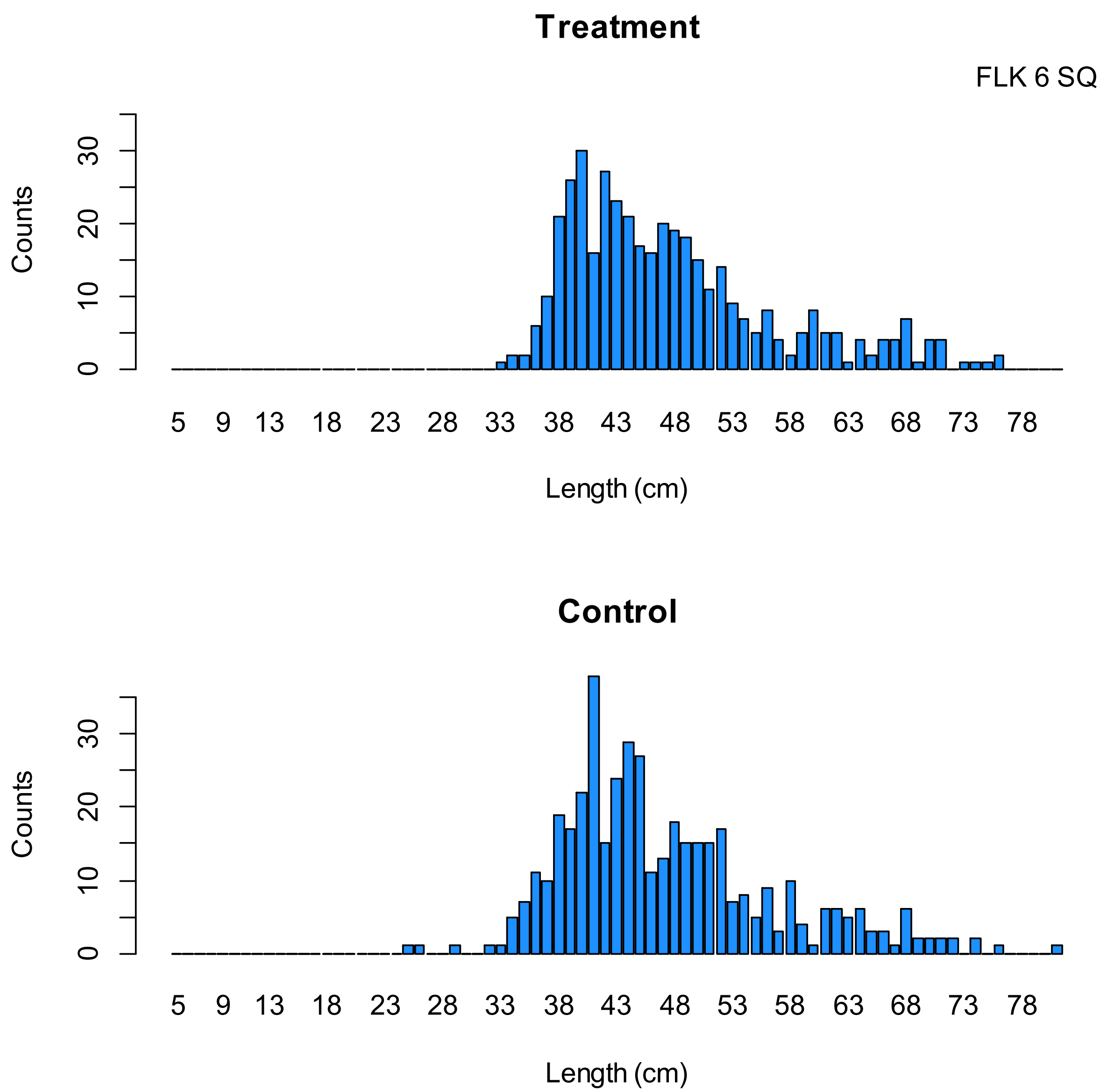


Figure 48. Length frequency distribution of summer flounder in the 6" square codend

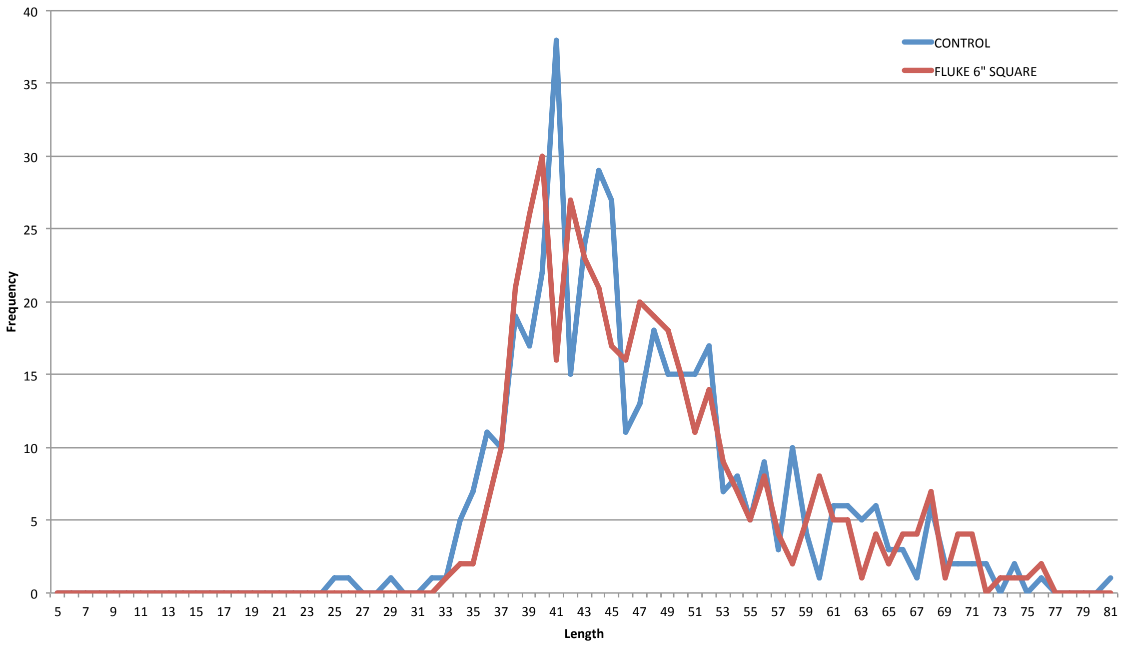
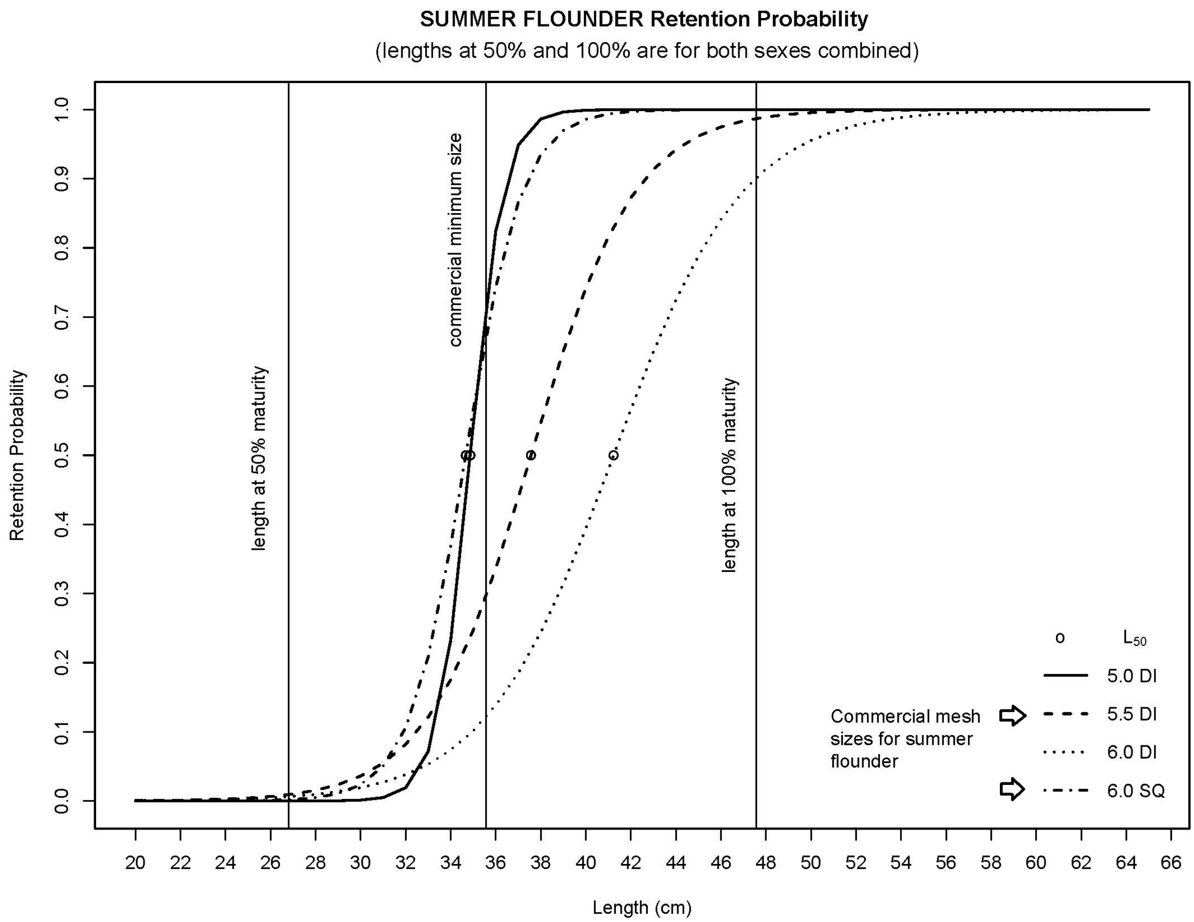


Figure 49. Logistic selectivity curve for summer flounder catches with 5 codends (4.5" diamond, 5" diamond, 5.5" diamond, 6" diamond and 6" square)



The selectivity curves were also plotted by codend mesh size with all species on each plot.

Figure 50. Logistic selectivity curves for 4.5” diamond mesh codend for black sea bass and scup. (Note: No selectivity was observed for summer flounder)

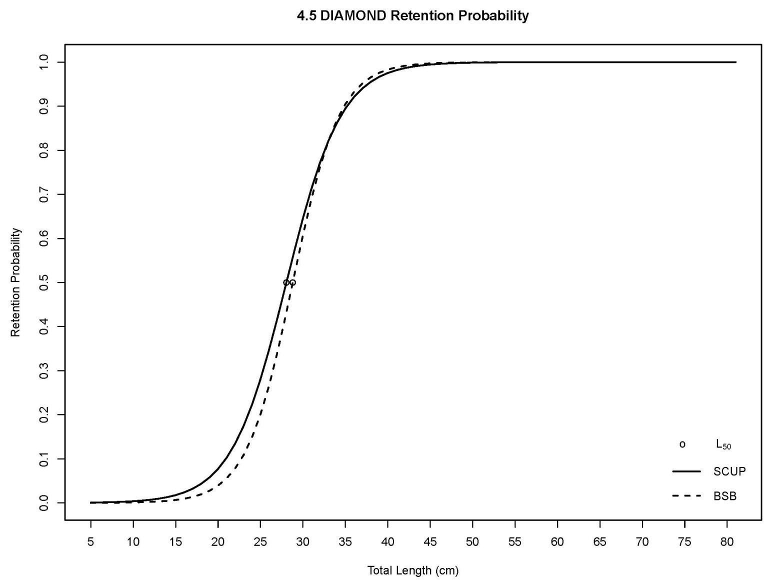


Figure 51. Logistic selectivity curves for 5” diamond mesh codend for black sea bass, summer flounder and scup

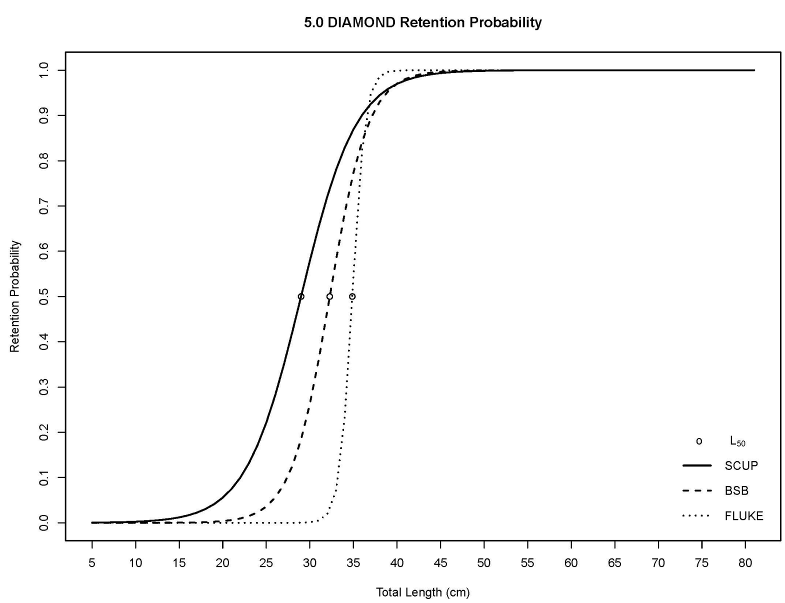


Figure 52. Logistic selectivity curves for 5.5" diamond mesh codend for black sea bass, summer flounder and scup

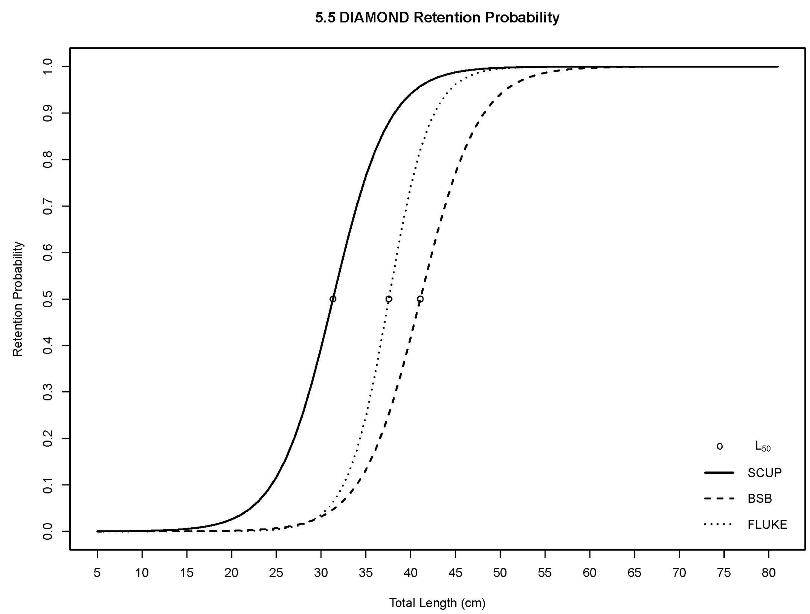


Figure 53. Logistic selectivity curves for 6" diamond mesh codend for black sea bass, summer flounder and scup

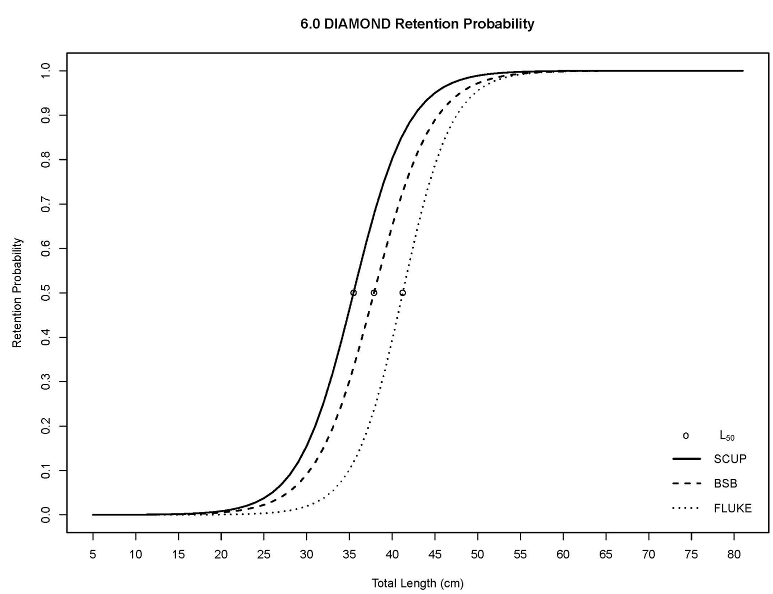
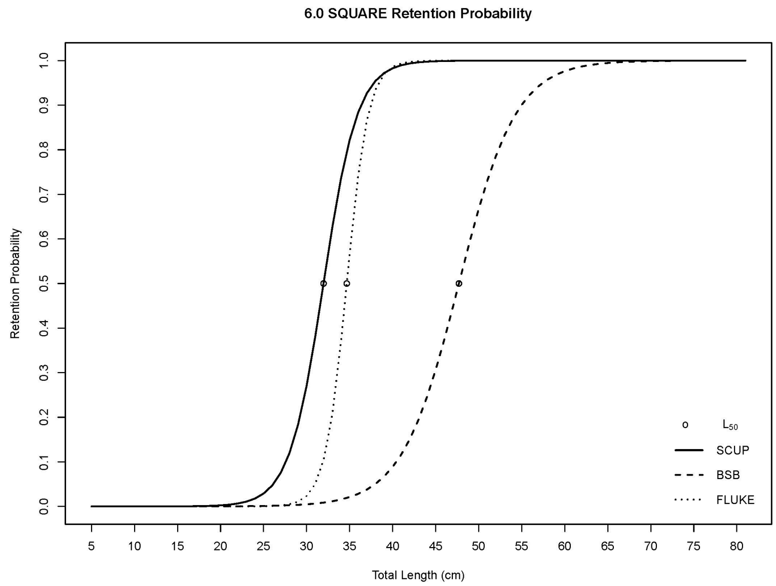


Figure 54. Logistic selectivity curves for 6" square mesh codend for black sea bass, summer flounder and scup



DISCUSSION

In Table 5 we provide the commercial minimum size, the length at 50% maturity (sexes combined) and length at 100% maturity (sexes combined) for scup, black sea bass and summer flounder. Using these values and the selectivity parameters generated for each species/codend combination we can evaluate the effectiveness of each codend mesh size to help meet management goals.

Table 5. Commercial Minimum Size and Length at Maturity For Scup, Black Sea Bass, and Summer Flounder

	Commercial Minimum Size (cm)	Length at 50% maturity (cm) for both sexes combined	Length at 100% maturity (cm) for both sexes combined
Scup (Total Length)	22.86[1]	17.0[2]	26.24[2]
Black Sea Bass	27.94[1]	21.0[3]	35.0[3]
Summer Flounder	35.56[1]	26.8[4]	47.57[4]

[1]New York State Department of Environmental Conservation (NYSDEC, 2018) [2] 60th Stock Assessment Workshop Report, Scup (Northeast Fisheries Science Center, 2015) [3] 62nd Stock Assessment Report, Black Sea Bass (NEFSC, 2017) [4] 57th Stock Assessment Workshop, Summer Flounder (NEFSC, 2013)

Scup

For scup, the current regulation mesh size is 5.0" diamond. The commercial minimum fish size (22.86 cm TL) is less than the L_{25} for all the experimental codend mesh sizes of this study. All tested codend sizes are effective at releasing at least 75% of scup that are at or less than the minimum size. All experimental codend mesh sizes release a large proportion of all legal sized fish, particularly with the 5.5" diamond, the 6" diamond and the 6" square. The size of scup at 50% maturity (sexes combined) is 17.0 cm TL (NEFSC, 2015). This is considerably less than the L_{25} for all the experimental codend mesh sizes. All tested codend mesh sizes are effective at releasing at least 75%, and likely at least 95%, of scup at or less than the length at 50% maturity. The size of scup at 100% maturity (sexes combined) is 26.24 cm (NEFSC, 2015). This is less than the L_{50} for all the experimental codend mesh sizes and is less than the L_{25} for 5.5" diamond, 6" diamond and 6" square. All tested codend mesh sizes are effective at releasing at least 50% of scup which are 100% mature. Further, the 5.5" diamond, 6" diamond and 6" square codends release at least 75% of scup that are 100% mature.

It is also interesting to note that the L_{25}, L_{50} and L_{75} parameters for the 6" square codend are less than these parameters in the 6" diamond codend. Given the same size mesh, scup escape more effectively through diamond meshes than through square meshes.

Black Sea Bass

For black sea bass, the current regulation mesh size is 4.5" diamond. The minimum commercial fish size (27.94 cm TL) is less than the L_{50} for all the experimental codend mesh sizes and is less than the L_{25} for all the experimental codend mesh sizes except for the 4.5" diamond. All codends release at least 50% of black sea bass that are at or less than the minimum fish size, and 4 of the 5 codends release at least 75% of black sea bass that are at or below the minimum size. The size of black sea bass at 50% maturity (sexes combined) is 21.0cm TL (NEFSC, 2017). This is considerably less than the L_{25} for all the experimental codend mesh sizes. All tested codends are effective at releasing at least 75%, and likely at least 90%, of black sea bass that are at or below the length at 50% maturity. The size of black sea bass that are at 100% maturity (sexes combined) is 35.0cm (NEFSC, 2017). This is less than the L_{50} for 5.5" diamond, 6" diamond and 6" square. Those three codends are effective at releasing at least 50% of black sea bass which are 100% mature. The other two codends release less than 50% of black sea bass that are 100% mature.

Summer Flounder

As mentioned above, there are no selectivity parameters for the 4.5" diamond codend as there are no differences in the length frequency distribution in the control codend and in the 4.5" diamond experimental codend.

For summer flounder, the current regulation mesh is 5.5" diamond or 6" square. The minimum commercial size is 35.56 cm. This is less than the L_{50} for the 5.5" diamond and the 6" diamond codends. These two codends are effective in releasing at least 50% of the fish that are at or below the minimum size. For the other two codends, the L_{50} is less than the minimum size so they release less than 50% of minimum size fish. The 6" diamond is the only codend where the minimum size is less than the L_{25}. The size of summer flounder at 50% maturity (sexes combined) is 26.8 cm (NEFSC, 2013). This is considerably less than the L_{25} for all 4 experimental codend mesh sizes. All 4 codends are effective at releasing at least 75% or more of summer flounder that are at the length of 50% maturity. The size of summer flounder at 100% maturity (sexes combined) is 47.57 cm (NEFSC, 2013). This is above the L_{75} for all experimental codends. None of our tested codends are effective at releasing summer flounder that are 100% mature. It should also be noted that for the 6" square codend the L_{25} and L_{50} are less than these parameters for the other three codends. The L_{75} for the 6" square is less than for the 6" diamond and the 5.5" diamond. The selectivity curves for the 5" diamond and the 6" square are very similar. However, as mentioned above, we did not catch a lot of smaller size fish.

CONCLUSIONS

The mesh selectivity study as proposed was successfully developed and implemented. Maximum likelihood fit of selectivity parameters and selectivity curves were developed for scup, black sea bass and summer flounder for the following experimental codend mesh sizes: 4.5" diamond (except for summer flounder); 5" diamond; 5.5" diamond; 6" diamond; 6" square.

For scup, the 5" diamond regulation mesh is very effective in releasing fish that are at or less than the minimum size as well fish that are at 50% maturity and 100% maturity. In fact, all tested codends are effective at releasing scup at minimum length, 50% maturity and 100% maturity. For the 4.5" diamond codend, minimum size and size at 50% maturity are less than the L_{25}. The size at 100% maturity is less than the L_{50} and only slightly greater than the L_{25}. For these reasons a 4.5" diamond codend could be considered as a common regulation mesh codend for both scup and black sea bass. Figure 50, Logistic selectivity curves for 4.5” diamond mesh codend for black sea bass and scup shows that for the 4.5” codend the selectivity curves for scup and black sea bass are nearly identical. Input would be needed from industry to determine how this might affect catch, market and market price for scup. Since the 5.5” diamond, the 6” diamond and the 6” square allow many large fish to escape, these meshes would likely be impractical in the fishery.

For black sea bass, the 4.5” diamond regulation mesh is effective at releasing fish that are at or less than the minimum size and is very effective at releasing fish that are at 50% maturity. All tested codends are effective at releasing black sea bass at the minimum size and at 50% maturity. The regulation mesh is less effective at releasing fish of the size at 100% maturity than the 5.5” diamond, the 6” diamond and the 6” square. A 5” diamond mesh could be considered as a common regulation mesh codend for both black sea bass and scup. Input would be needed from industry to determine how this might affect catch, market and market price for black sea bass. Since the 5.5” diamond, the 6” diamond and the 6” square allow many large fish to escape, these meshes would likely be impractical in the fishery.

For summer flounder, the 5.5” diamond regulation codend is effective at releasing fish that are at or less than the commercial minimum size and fish that are at 50% maturity. The 6” square regulation mesh codend is less effective at releasing fish that are at minimum size. The minimum size is slightly greater than the L_{50} for this codend. The 6” square codend is effective at releasing fish at 50% maturity. None of the mesh sizes tested are effective at releasing summer flounder at 100% maturity.

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Appendices

Appendix A. Background Information

Summer Flounder

In 1988 the summer flounder Fishery Management Plan (FMP) was developed. The original FMP required a 13-inch total length (TL) commercial minimum fish size. Under the FMP the mesh size for otter trawl nets was not regulated (MAFMC, 1988). Amendment 2 further designated a 5.5-inch diamond and 6-inch square mesh to be the minimum mesh requirements for the cod end only (MAFMC, 1992). A 5.5-inch diamond mesh was found to retain about 70% of the 14-inch summer flounder that encounter the net (Anderson et al., 1983). Anderson et al. experienced many obstacles and the results of this study leave lessons to learn from. Multiple mesh size cod ends were used because each boat used a different twine type. Also, the data collected and analyzed used outdated statistical methods (Anderson et al., 1983). The MAFMC review of Commercial Management Measures reports

> At the time the Council and Commission recognized that 5.5-inch diamond mesh would also retain some 13-inch summer flounder, and believing that fishermen would target 14-inch and larger summer flounder, implemented a 13-inch size limit to minimize discards of 13 to 14-inch fish. [MAFMC, 2015, p. 2]

In efforts to make regulations more consistent between commercial and recreational the minimum size for summer flounder was revised to 14 inches in 1997 (MAFMC, 2015). As stated in Amendment 2, square mesh selectivity data was "limited" when developing the summer flounder FMP (MAFMC, 1992). The equivalency of a 5.5" diamond mesh net selectivity to a 6.0" square mesh net for summer flounder reported in Amendment 2 was based on the following sources:

> First, Amendment 4 to the Northeast Multispecies FMP from NEFMC in 1990 states: "The use of square mesh codends is known to significantly increase the retention of small flounders. Preliminary information indicates that a 5.5" square mesh codend may have roughly the same flatfish selectivity characteristics as a 5" diamond mesh codend." Second, in a selectivity study for nets for winter flounder in Connecticut, Simpson in 1989 states: "Diamond mesh was found to have a length at 50% retention about 1 cm longer (L60 = 22.6 cm), and a selection range (3.4 cm) about 1 cm narrower, than square mesh in 1.02 mm codends." (conversion from metric is 1 cm = 0.39") The third source is from Canadian researchers in Nova Scotia, Cooper and Hickey, in 1989 who, while exploring selectivity behavior mainly for cod and haddock, observed: "For flounder, the diamond mesh codends always have higher 50% retention lengths and selection factors." [cited by MAFMC, 1992, p. 43]

The ASMFC Report of the Fishing Gear Technology Work Group (FGTWG) to the Management and Science Committee (2008) provided further identification and evaluation of studies relative to fishing gear selectivity. The FGTWG report states

> Using data collected by Anderson et al. off Long Island, NY, Lange in 1984 determined a 14.0 cm (5.5 in) diamond mesh has an L_{50} of 34.3 cm (13.5 in) TL for summer flounder, meaning

> 50% of 34.3 cm (13.5 in) TL flounder encountering 14.0 cm (5.5 in) diamond mesh are retained. Similar results were reported from a study of the North Carolina winter trawl fishery performed by Gillikin et al. in 1981. [cited by ASMFC, 2008, p. 8]

For later research the FGTWG reports

> DeAlteris et al. in 1999 calculated L_{50} values for summer flounder of 41.2 cm (16.2 in) TL for both 15.2 cm (6.0 in) diamond and 16.5 cm (6.5 in) square codend mesh and Beutel et al. in 2004 investigated four codend mesh sizes 16.5 cm (6.5 in) diamond, 17.8 cm (7.0 in) square, 17.8 cm (7.0 in) diamond, and 20.3 cm (8.0 in) square. Only slight variations in L_{50} values for the 16.5 cm (6.5 in) diamond (L_{50}= 43.9 cm (17.3 in)), 17.8 cm (7.0 in) square (L_{50} = 43.4 cm (17.1 in)), and 17.8 cm (7.0 in) diamond (L_{50} = 45.0 cm (17.7 in)) meshes were observed. The 20.3 cm (8.0 in) square mesh had an L_{50} value of 51.9 cm (20.4 in) for summer flounder. While length at retention values were greater than the legal minimum size for each of these experimental mesh sizes, the 20.3 cm (8.0 in) square mesh significantly reduced the catch of legal-size summer flounder. [cited by ASMFC, 2008, p. 8-9]

The studies performed by DeAlteris et al. and Beutel et al. were useful in evaluating mesh size increases but they never re-evaluated the regulation 5.5" diamond mesh that is currently in use. This needs to be addressed and analyzed with current statistical methods.

Table 6. Summer Flounder Trawl Selectivity Results (Source: ASMFC, 2008.)

Mesh size (in.)	Mesh shape	L50 (TL in.)	Reference
5.5	diamond	13.5	Lange (1984); Gilliken *et al.* (1981)
6.0	diamond	16.2	DeAlteris *et al.* (1999)
6.5	square	16.2	DeAlteris *et al.* (1999)
6.5	diamond	17.3	Beutel *et al.* (2004)
7.0	square	17.1	Beutel *et al.* (2004)
7.0	diamond	17.7	Beutel *et al.* (2004)
8.0	square	20.4	Beutel *et al.* (2004)

Scup

Amendment 8 to the summer flounder FMP added scup management requirements (MAFMC, 1996a). Owners or operators of otter trawl vessels possessing 4,000 lbs. or more of scup would only be allowed to fish with nets that have a minimum mesh size of 4.0" in the codend (MAFMC, 1996a). The Regulatory Impact Review performed in development of Amendment 8 states

> The Council and Commission were presented with data that indicated that the L_{50} is 8.3 inches for this mesh size. Retention lengths for scup were calculated by Mayo in 1982 and are based on the relationship between length and body depth as derived by Smith and Norcross in 1968. These retention lengths were derived using body measurements and the results agree very well with selectivity experiments conducted by personnel at the University of Rhode Island. [cited by MAFMC, 1996a, p. RIR-26]

The ASMFC Report of the Fishing Gear Technology Work Group (FGTWG) to the Management and Science Committee (2008) evaluated mesh size selectivity studies relative to scup. The FGTWG evaluation resulted in the following measure

> The size selectivity of 12.0 cm (4.7 in) square and diamond mesh codends investigated by DeAlteris and Riefsteck in 1992 revealed L50s of the square and diamond mesh codends were found to be 21.3 and 21.0 cm (8.4 and 8.3 in) respectively, based on total length, and the selection curves had steepness values of 0.74 and 0.71. Based on a mean selection factor (SF) of 1.76 for the 12.0 cm (4.7 cm) codends, and assuming the girth to length ratio remains constant for fish in the 17.8-22.9 (7-9 in) size range, the L_{50}s of 11.4, 12.7, 14.0 cm (4.5, 5.0, 5.5 in) codends were estimated by DeAlteris and Lazar in 2004 to be 20.1, 22.4, 24.6 cm (7.9, 8.8 and 9.7 in) TL, respectively. [as cited in ASMFC, 2008, p. 12]

The FGTWG recommended

> given the current minimum mesh in the fisheries targeting scup in either the codend or the extension section is 12.7 cm (5.0 in) and the L50 of this mesh is 22.4 (8.8 in) TL, there is strong agreement between the minimum mesh size and the minimum fish size, balancing the discarding of retained sub-legal scup with the escape of legal size scup from the codend. The 11.4 cm (4.5 in) codend retains 90% of the 22.9 cm (9 in) TL scup, resulting in excessive discards of sub-legal size fish. [ASMFC, 2008 p. 12]

These studies are outdated and use estimates and methods that are questionably deficient in statistical strength. The 1992 study simulated commercial fishing practices in a flume tank and used a covered codend method (DeAlteris and Riefsteck, 1992).

In the Final Environmental Impact Statement (FEIS) of Amendment 8, reports from public comments include remarks from fishermen supporting a 4" mesh regulation. The FEIS states

> They suggested that the results of the URI study were flawed because researchers had used a covered cod end technique to estimate selectivity and, in fact, based on their personal experience at sea, a significant portion of the 9" TL fish that would encounter a 4.0" mesh would escape. Furthermore, these fishermen suggested that because most fishermen knew that this mesh was the appropriate size, compliance would be higher with the 4.0" mesh than it would be with a larger mesh size. As such, a greater reduction in the discard of small scup would occur with this mesh size then it would with a larger mesh. [MAFMC, 1996a, p. EIS-8]

MAFMC Review of Commercial Fishing Measures document summarized the following:

> Scup minimum mesh size was increased to 4.5 inches in 1997 and modified in 2002 to require that no more than 25 meshes of 4.5-inch mesh be used in the codend with at least 100 meshes of 5.0-inch mesh forward of the 4.5-inch mesh. The minimum mesh size was increased to 5.0 inches throughout the codend in 2005, in response to increasing abundance and corresponding increasing discards of smaller scup. [MAFMC, 2015, p. 4]

The ASMFC Report of the Fishing Gear Technology Work Group (FGTWG) to the Management and Science Committee (2008) assessed mesh size and discard rates in relation to time and area activity for scup. The FGTWG found studies performed by Bochenek et al. in 2001, Bochenek et al. in 2005 and Kennelly et al. in 1997 reported scup discard rates between July 1990 and June 1994 indicated roughly 44.5% (by weight) of scup were discarded due to small size (cited by ASMFC, 2008, p.12). The FGTWG states that these studies were used to pin point spatial and temporal discarding and assisted the ASMFC in creating time-area closures to reduce discard of small scup (ASMFC, 2008). The FGTWG investigated studies performed by Powell et al. in 2003 revealing observer data discards surpassed landings in multiple years (cited by ASMFC, 2008). Bochenek et al. in 2005 studied various codend mesh sizes and configurations and states, “Overall, discards of scup remained high regardless of the type of gear (nets) and codends used” (Bochenek et al., 2005, p. 12).

Research assessing gear modifications were summarized by the FGTWG in 2008. The FGTWG concluded

> By placing a 45 mesh section of 14.0 cm (5.5 in) square mesh webbing ahead of the codend, Glass et al. in 1999 was able to reduce the bycatch and discarding of small scup with little effect of the catch of Loligo squid. While this modification appeared to work well in this experimental setting, its performance was less consistent when applied to the commercial fishery according to Powell et al. 2004. [cited by ASMFC, 2008, p. 13]

Multiple studies were investigated by the FGTWG but none were successful enough to be used in commercial fishing practices (ASMFC, 2008).

Scup caught during the NEFSC bottom trawl survey from 1981- 2013 suggest that 97% of scup are mature when reaching 9 inches in length (Mark Terceiro, personal communication, cited by MAFMC, 2015). “These data also support the fact over the past 15 years the amount of scup mature at age 2 has decreased by about 30%” (NEFSC 2015, cited by MAFMC, 2015, p. 9). Mark Terceiro supports the information, “Though scup maturity at age has changed, length at age has not” (Terceiro, 2015, cited by MAFMC, 2015, p.9). Scup are reported to be about 3 years old at the 9” commercial minimum size. One hundred percent of scup are mature at 3 years of age. (NEFSC 2015; Terceiro 2015, cited by MAFMC, 2015).

The MAFMC’s Monitoring Committed and ASMFC’s Technical Committee (MC/TC) review detailed suggested commercial measures for summer flounder, scup and black sea bass in 2015. The MC/TC recommended, “No change to the minimum mesh size for scup be made due to the fact that they examined no new information on mesh selectivity” (MAFMC, 2015, p.15). This proposed research by CCE in collaboration with the commercial fishing industry would enhance management decisions in this respect.

Black Sea Bass

In 1996, black sea bass was added to the summer flounder and scup FMP in Amendment 9 (MAFMC, 1996b). The minimum mesh size for vessels possessing more than 100 pounds of black sea bass was 4.0-inch diamond or 3.5-inch square (MAFMC, 1996b). In the 2015 Commercial Management Measures Review, MAFMC states

> In 1998 the incidental possession limit was increased to 1,000 pounds. In 2002 the Council and Commission increased the minimum mesh size to 4.5-inch diamond mesh, required for a minimum of 75 meshes from the codend. This requirement was intended to be consistent with the simultaneous increase in the commercial minimum fish size to 11 inches. [MAFMC, 2015, p.19.]

During Amendment 9 development mesh selectivity studies had not been conducted for black sea bass. Amendment 9 states, "The relationship between body depth and total length as derived by Weber and Briggs in 1983 was used to calculate the retention lengths for black sea bass (Table 2). A mesh size of 4.5" was found to retain 25% of black sea bass at 10.6" (MAFMC, 1996b, p. App 1-8). This was a study evaluating retention of black sea bass in vented and unvented lobster traps (Weber and Briggs, 1983). Research on black sea bass has focused more on the trap fishery than the trawl fishery over the years.

In 2015, The MC/TC recommended

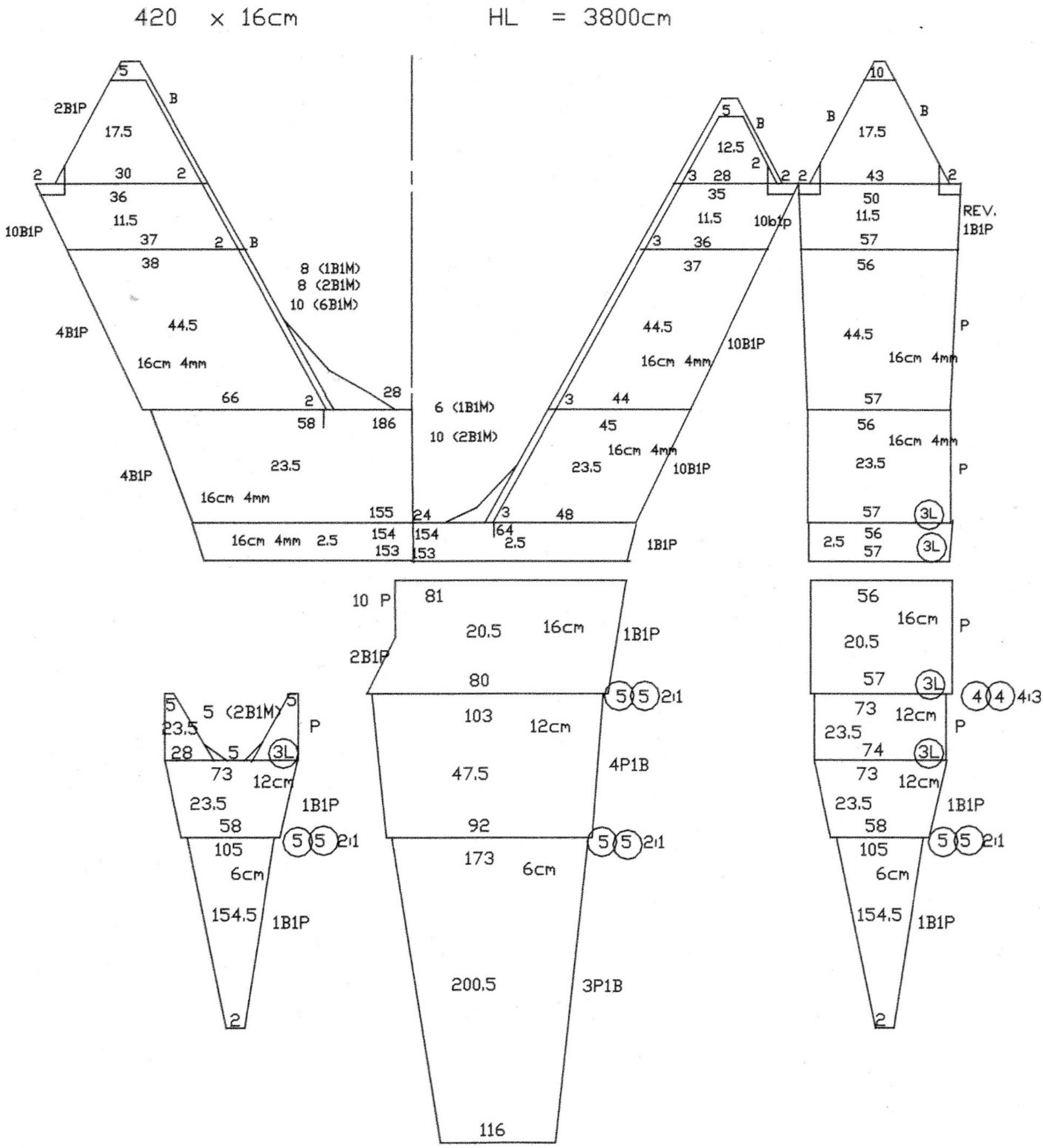
> no changes to the minimum mesh size and incidental possession limits for black sea bass; however, they acknowledged that further analysis could be done to determine if changes are warranted. They agreed that gear studies would be the best way to determine if changes in mesh size are warranted. [MAFMC, 2015, p. 19]

Advisor comments included, "Four respondents recommended a 5-inch minimum mesh size for black sea bass" (MAFMC, 2015, p.19). One AP member stated, "a 5-inch minimum mesh size for all three species could be beneficial to fishermen who target all three species" (MAFMC, 2015, p. 25). Another AP member mentioned, "Many fishermen are already using five-inch mesh for black sea bass (consistent with the scup regulations, but larger than required for black sea bass)" (MAFMC, 2015, p.25). These concerns based on insufficient information can be resolved with the proposed research to re-evaluate the current mesh sizes relative to current fish minimum retention size and contribute to the body of information on which management decisions are made.

Table 7. The length at which 25% of the black sea bass would be retained by a particular mesh size. Estimates represent L_{25}'s and are based on retention lengths as calculated from the body depth/total length relationship for black sea bass derived by Weber and Briggs in 1983. (Source: MAFMC, 1996b.)

Mesh size	Total Length
2.0	4.0
2.5	5.3
3.0	6.6
3.5	7.9
4.0	9.3
4.5	10.6
5.0	11.9

Appendix B. Trouser Trawl Net Plan



Appendix C. PAC Meeting Notes

A Program Advisory Committee (PAC) meeting was held via Webinar on 8/30/16

- PAC members in attendance included: Henry Milliken (NOAA-NEFSC); Kiley Dancy (MAFMC); Kirby Rootes-Murdy (ASMFC); Pat Sullivan (Cornell University); Mark Terceiro (NOAA-NEFSC); Rich Seagraves (MAFMC); Jon Knight (Superior Trawl Inc.); John Maniscalco (NYSDEC); Dave Aripotch (F/V Caitlin Mairead) and Bonnie Brady (LICFA)
- CCE discussed project goals and objectives and work plan with the PAC and all were approved
- The following specific issues needing further clarification were examined and the PAC made recommendations to resolve these issues
    - Tow duration in regard to large catches or day & night tows
        - The PAC recommended the project should begin with 1-hour tows. The PAC also suggested decreasing tow duration to 30 minutes if needed or establish a cutting off point
            - CCE decided to use a net sensor alarm in the control as a cutoff point (See discussion in problems encountered section about switching vessels. This eventually directed tow duration.)
        - The PAC questioned if there was a specific interest in day vs. night fishing. The group decided that there was not a specific interest in day vs. night. The PAC suggested the project should fish when fishermen fish. It was agreed that the project would perform research fishing during standard fishing hours for the 3 species and that we would fish during daytime hours. It was determined that we would set in/haul back within 10-15 minutes of either side of sun up or sun down.
    - Random codend rotation procedure and measurement frequency
        - The PAC recommended the order of the treatments should be randomized within the 5 treatment blocks using a random sequence generator. The PAC suggested the port and starboard placement of the experimental and control be switched after two tows. To reduce side effect port and starboard should be represented equally for all codends.
            - CCE worked with Pat Sullivan after webinar to develop random net plan. See attached.
        - Committee agreed with proposed codend measurement protocol of measuring the experimental codend mesh when first installing it before the two tow block of testing and measuring it again before removing it and switching to another experimental codend. Stretched mesh measurement was taken using calipers.
    - Data Analysis
        - The PAC agreed to only calculate selectivity of each codend.
        - The PAC agreed that we cannot compare experimental codends to each other
    - Species Priority-What if all species are not present in the tow
        - The PAC decided that all 3 species are of equal high priority. If we find we are not catching all 3 then go after the missing species. A similar recommendation was made relative to size. The PAC recommended that CCE find a random distribution of sizes.
    - Length Frequency- Fork or total length for scup (Regulations are based on total length)
        - The PAC recommended measuring fork length and converting to total length.
            - After the meeting a committee member provided CCE with a scientifically accepted conversion from fork length to total length for scup.
    - Timing- weather or other issues including fish migration may delay completion until

spring

- The PAC agreed we should do as much as we can in the fall. If the project cannot be completed this fall it can be finished up in the spring.

Appendix D. Mesh Measurements

Date	Codend Mesh (Treatment #)	Start or End	Mesh measurements 1	2	3	4	5	6	7	8	9	10	AVG.
10/2/16	4.5 (1)	Start	4.4	4.5	4.4	4.6	4.3	4.4	4.4	4.5	4.4	4.4	**4.43**
10/2/16	4.5 (1)	End	4.6	4.6	4.9	4.5	4.6	4.5	4.4	4.4	4.3	4.4	**4.52**
10/2/16	5 (2)	Start	4.8	4.9	4.8	5	4.9	5.1	4.9	4.9	4.8	5	**4.91**
10/2/16	5 (2)	End	4.9	4.6	5	4.8	4.7	4.7	4.9	5.1	4.9	4.7	**4.83**
10/2/16	6 sq (5)	Start	5.5	5.9	5.9	5.7	5.8	5.9	6	5.8	5.7	5.6	**5.78**
10/2/16	6 sq (5)	End	6	6.2	6	6.1	6.4	6.4	6	6.2	6	6.5	**6.18**
10/2/16	5.5 (3)	Start	5.4	5.5	5.5	5.4	5.6	5.6	5.5	5.5	5.6	5.5	**5.51**
10/2/16	5.5 (3)	End	5.4	5.4	5.1	5.3	5.4	5.4	5.5	5.2	5.4	5.5	**5.36**
10/2/16	6 (4)	Start	5.9	5.9	6	6	5.9	5.9	5.8	5.8	6	5.9	**5.91**
10/3/16	6 (4)	End	6.1	6.1	5.7	6	6	6.1	6.2	5.8	5.9	6	**5.99**
10/3/16	4.5 (1)	Start	4.4	4.4	4.6	4.3	4.4	4.4	4.4	4.4	4.4	4.5	**4.42**
10/3/16	4.5 (1)	End	4.4	4.5	4.4	4.5	4.3	4.5	4.5	4.5	4.5	4.5	**4.46**
10/3/16	5 (2)	Start	4.9	4.8	4.8	5.1	5	4.9	5	4.9	4.8	4.9	**4.91**
10/3/16	5 (2)	End	4.9	5.1	5	5.1	5.1	5.1	5	5	5.1	4.9	**5.03**
10/3/16	6 (4)	Start	6.1	6	6.1	6	5.9	6.1	6	6.1	6	5.9	**6.02**
10/3/16	6 (4)	End	5.9	6	6	6	6	6	5.8	5.9	6.1	5.8	**5.95**
10/3/16	5.5 (3)	Start	5.5	5.4	5.3	5.4	5.4	5.5	5.5	5.4	5.4	5.6	**5.44**
10/4/16	5.5 (3)	End	5.5	5.6	5.5	5.6	5.4	5.5	5.5	5.4	5.4	5.4	**5.48**
10/4/16	6 sq (5)	Start	5.9	6	6	5.9	5.9	5.8	5.9	5.8	5.8	6	**5.9**
10/4/16	6 sq (5)	End	6.1	6.1	5.9	6	6.1	6	6	6.1	5.9	6	**6.02**
10/4/16	5 (2)	Start	5	5.1	5.2	5	5.3	5.2	5.1	5.1	5.1	5.1	**5.12**
10/4/16	5 (2)	End	4.9	5.2	5	5.1	5.1	5.1	5.1	5.1	5	5	**5.06**
10/4/16	4.5 (1)	Start	4.4	4.5	4.5	4.6	4.5	4.4	4.5	4.6	4.6	4.5	**4.51**
10/4/16	4.5 (1)	End	4.4	4.7	4.5	4.5	4.5	4.5	4.4	4.6	4.5	4.4	**4.5**
10/6/16	5.5 (3)	Start	5.6	5.5	5.6	5.5	5.5	5.7	5.6	5.4	5.4	5.5	**5.53**
10/6/16	5.5 (3)	End	5.6	5.6	5.8	5.6	5.7	5.5	5.5	5.6	5.6	5.7	**5.62**
10/6/16	6 sq (5)	Start	5.8	6	6.2	6.2	6.1	5.8	6.1	6.1	6.2	6.1	**6.06**
10/6/16	6 sq (5)	End	6.1	5.8	6.1	5.7	6.1	6	6.1	6.3	6	5.7	**5.99**
10/6/16	6 (4)	Start	6	5.9	6	5.8	5.8	6	6.1	6	6	6	**5.96**
10/6/16	6 (4)	End	6	6	6	6	5.9	6.1	5.9	6	5.9	6	**5.98**
10/6/16	4.5 (1)	Start	4.5	4.5	4.7	4.6	4.5	4.6	4.5	4.5	4.4	4.7	**4.55**
10/6/16	4.5 (1)	End	4.4	4.5	4.6	4.6	4.5	4.5	4.5	4.4	4.5	4.4	**4.49**
10/6/16	6 (4)	Start	6.1	6.2	6.1	6.2	6.2	6.2	6.1	6	6.1	6	**6.12**
10/7/16	6 (4)	End	6.1	6	6.1	6	6	5.9	6	6	6	5.9	**6**
10/7/16	5.5 (3)	Start	5.5	5.4	5.4	5.5	5.6	5.7	5.8	5.6	5.8	5.6	**5.59**
10/7/16	5.5 (3)	End	5.5	5.7	5.5	5.7	5.5	5.5	5.5	5.4	5.6	5.6	**5.55**
10/7/16	5 (2)	Start	5.1	5.1	5.3	5.2	5.2	5.1	5.2	5.1	5.2	5.1	**5.16**
10/7/16	5 (2)	End	5	5.2	5	5	5	5.1	5.1	5	5.1	5.1	**5.06**
10/7/16	6 sq (5)	Start	6	6	6.1	5.9	6	6	6	6	6.2	5.9	**6.01**
10/7/16	6 sq (5)	End	6	6	5.9	6.1	6.1	6.2	6.1	6	6.1	6	**6.05**
10/7/16	6 (4)	Start	6	6	5.9	6.1	6	6.2	6.1	6	6.1	6	**6.04**
10/7/16	6 (4)	End	6.1	6	6.1	6	5.9	6	6	6.2	6.1	6.2	**6.06**
10/8/16	5.5 (3)	Start	5.5	5.4	5.6	5.5	5.5	5.6	5.4	5.5	5.6	5.5	**5.51**
10/8/16	5.5 (3)	End	5.5	5.6	5.5	5.5	5.5	5.6	5.5	5.6	5.5	5.5	**5.53**
10/8/16	4.5 (1)	Start	4.7	4.6	4.6	4.5	4.6	4.5	4.5	4.6	4.5	4.6	**4.57**
10/8/16	4.5 (1)	End	4.4	4.5	4.5	4.5	4.6	4.5	4.3	4.5	4.5	4.6	**4.49**
10/8/16	6 sq (5)	Start	5.9	6	6	6	6.2	6	6.2	6	6.1	6.2	**6.06**
10/8/16	6 sq (5)	End	6.1	6	6	6.1	6	6.2	6.1	5.9	5.9	6.1	**6.04**
10/8/16	5 (2)	Start	4.9	5.2	5	5	5	5	5.1	5.2	5.1	5	**5.05**
10/8/16	5 (2)	End	5	5	5	5.1	5	5	4.8	5	5.1	5.2	**5.02**
4/9/17	5.5 (3)	Start	5.4	5.3	5.5	5.4	5.3	5.3	5.4	5.5	5.5	5.5	**5.41**
4/9/17	5.5 (3)	End	5.3	5.5	5.4	5.5	5.4	5.5	5.6	5.3	5.5	5.3	**5.43**
4/9/17	4.5 (1)	Start	4.3	4.5	4.4	4.4	4.3	4.4	4.3	4.5	4.5	4.4	**4.4**
4/9/17	4.5 (1)	End	4.4	4.6	4.6	4.4	4.2	4.5	4.5	4.4	4.6	4.4	**4.46**
4/9/17	5 (2)	Start	4.9	5.1	5	5.1	5.1	4.9	5	5	5.1	4.9	**5.01**
4/9/17	5 (2)	End	4.9	4.9	4.9	5.1	5	5	4.9	5.1	5	4.9	**4.97**
4/9/17	6 (4)	Start	5.9	5.9	5.9	5.8	5.9	5.9	6	6	5.9	6.1	**5.93**
4/10/17	6 (4)	End	5.9	5.8	6	6	5.9	6	5.8	5.8	6.1	5.9	**5.92**
4/10/17	6 sq (5)	Start	5.9	6	6	5.9	5.9	6	5.8	6.1	5.9	6.1	**5.96**
4/10/17	6 sq (5)	End	5.8	5.8	5.8	6.1	6.1	6	6.1	6.1	6	6.1	**5.99**
4/10/17	4.5 (1)	Start	4.4	4.6	4.5	4.4	4.6	4.4	4.4	4.6	4.5	4.6	**4.5**
4/10/17	4.5 (1)	End	4.4	4.5	4.5	4.6	4.5	4.5	4.5	4.4	4.4	4.5	**4.48**
4/10/17	5 (2)	Start	5	5	4.9	5	5	4.9	4.8	5	4.9	4.9	**4.94**
4/10/17	5 (2)	End	5	5	4.8	5	4.9	4.8	5.1	5	5.1	5	**4.97**

4/11/17	5.5 (3)	Start	5.5	5.4	5.6	5.6	5.4	5.4	5.4	5.4	5.5	5.4	**5.46**
4/11/17	5.5 (3)	End	5.4	5.5	5.3	5.5	5.5	5.4	5.5	5.6	5.4	5.5	**5.46**
4/11/17	6 (4)	Start	6	6	5.9	5.8	5.9	6	6	5.9	6	5.9	**5.94**
4/11/17	6 (4)	End	6	6	6	6.1	5.9	6	6	5.9	6.1	6	**6**
4/11/17	6 sq (5)	Start	5.9	6	6	5.8	5.9	6.1	6	5.8	5.9	6	**5.94**
4/11/17	6 sq (5)	End	5.9	6	6	5.9	5.9	5.8	5.9	6.1	6.2	6	**5.97**
4/11/17	6 sq (5)	Start	5.9	6	6	5.9	5.9	5.8	5.9	6.1	6.2	6	**5.97**
4/12/17	6 sq (5)	End	5.9	5.9	5.9	6	6	6	5.9	5.9	6	6.1	**5.96**
4/12/17	6 (4)	Start	6.1	6	6	6.2	6.1	5.9	6.1	5.9	5.9	6	**6.02**
4/12/17	6 (4)	End	6	6.1	6	6	5.9	6	6.1	6	5.9	5.9	**5.99**
4/12/17	5.5 (3)	Start	5.5	5.6	5.4	5.4	5.5	5.6	5.6	5.4	5.4	5.5	**5.49**
4/12/17	5.5 (3)	End	5.5	5.4	5.5	5.5	5.6	5.5	5.5	5.4	5.5	5.5	**5.49**
4/12/17	5 (2)	Start	4.9	4.9	5	5.1	4.9	5	5	5.1	4.9	5.1	**4.99**
4/12/17	5 (2)	End	5.1	5.1	4.5	5	5.1	5.1	5.1	5.1	5.1	5	**5.02**
4/18/17	4.5 (1)	Start	4.4	4.6	4.5	4.6	4.4	4.4	4.6	4.5	4.5	4.4	**4.49**
4/18/17	4.5 (1)	End	4.5	4.6	4.7	4.6	4.5	4.4	4.5	4.4	4.4	4.5	**4.51**
4/18/17	4.5 (1)	Start	4.6	4.6	4.3	4.6	4.6	4.6	4.7	4.5	4.5	4.5	**4.55**
4/18/17	4.5 (1)	End	4.5	4.5	4.4	4.5	4.4	4.6	4.6	4.4	4.4	4.5	**4.48**
4/18/17	5 (2)	Start	5	5	5	4.9	4.9	5.1	5.1	5	5.1	5.1	**5.02**
4/18/17	5 (2)	End	4.9	5.2	5.2	5.1	5	5.1	5.1	5.1	5.2	5.2	**5.11**
4/18/17	6 sq (5)	Start	5.9	6.1	5.9	6	5.8	6	5.8	5.9	6	5.9	**5.93**
4/18/17	6 sq (5)	End	6.1	6.2	6	6.1	6.2	6.1	6.1	6.2	5.9	6	**6.09**
4/18/17	6 (4)	Start	5.9	5.9	5.9	6	5.9	6	6	6	6.1	5.9	**5.96**
4/18/17	6 (4)	End	6	6	6.1	6	6.2	6	6	6	6.2	6.1	**6.06**
4/19/17	5.5 (3)	Start	5.4	5.3	5.5	5.5	5.6	5.5	5.5	5.7	5.5	5.5	**5.5**
4/19/17	5.5 (3)	End	5.3	5.6	5.7	5.8	5.6	5.7	5.7	5.8	5.5	5.5	**5.62**
4/19/17	6 sq (5)	Start	5.8	6	6	5.8	5.9	6	6	6.1	5.9	6	**5.95**
4/19/17	6 sq (5)	End	6	5.9	6	6	6.1	6	6.1	6	6	6.1	**6.02**
4/19/17	4.5 (1)	Start	4.6	4.5	4.5	4.6	4.8	4.5	4.5	4.5	4.4	4.5	**4.54**
4/19/17	4.5 (1)	End	4.6	4.6	4.7	4.5	4.5	4.6	4.5	4.4	4.4	4.5	**4.53**
4/19/17	6 (4)	Start	6	6.1	6	6	6	6	6	5.9	6.2	6	**6.02**
4/19/17	6 (4)	End	6.1	6	5.9	6.2	6.1	6	6	6.1	6	6.2	**6.06**
4/19/17	5 (2)	Start	4.9	5.1	5	4.9	4.9	4.9	5	4.9	5.1	5.2	**4.99**
4/20/17	5 (2)	End	5	5	5	5	4.9	4.9	5	5.2	5.1	5.1	**5.02**
4/20/17	5.5 (3)	Start	5.4	5.6	5.5	5.4	5.5	5.5	5.4	5.4	5.4	5.7	**5.48**
4/20/17	5.5 (3)	End	5.5	5.5	5.6	5.5	5.7	5.6	5.5	5.4	5.4	5.6	**5.53**
4/20/17	6 (4)	Start	5.9	6.1	6	6	6	5.9	6	6.2	5.9	5.9	**5.99**
4/20/17	6 (4)	End	5.9	6	6.1	6	6.1	6.2	6	6	6	6.1	**6.04**
4/20/17	5.5 (3)	Start	5.6	5.6	5.4	5.5	5.5	5.5	5.5	5.5	5.4	5.5	**5.5**
4/20/17	5.5 (3)	End	5.5	5.7	5.6	5.5	5.4	5.5	5.5	5.5	5.4	5.6	**5.52**
4/20/17	4.5 (1)	Start	4.5	4.5	4.6	4.6	4.4	4.5	4.5	4.5	4.4	4.5	**4.5**
4/21/17	4.5 (1)	End	4.6	4.6	4.6	4.4	4.5	4.4	4.4	4.5	4.5	4.5	**4.5**
4/21/17	5 (2)	Start	5	5.1	4.9	5.1	4.9	5.1	5.1	5.1	5.1	4.9	**5.03**
4/21/17	5 (20	End	5.2	5.1	5.1	5.2	5.3	5.2	5.2	5.1	5.2	5.1	**5.17**
4/21/17	6 sq (5)	Start	5.9	5.9	5.9	5.9	6	6	6	5.8	6	5.9	**5.93**
4/21/17	6 sq (5)	End	6	6.1	6	6.1	6.1	6.2	6	6.1	6	6	**6.06**
4/21/17	6 (4)	Start	6	6.1	6.1	6	6	6	5.9	5.9	6	6	**6**
4/21/17	6 (4)	End	5.9	6.2	6	6.1	6	5.9	6	6.1	6	6	**6.02**
4/21/17	5 (2)	Start	4.9	5.1	5.1	5.2	5.1	5	5.1	5.1	5.3	4.9	**5.08**
4/21/17	5 (2)	End	5	5	5.1	5.3	5	5.2	5.1	5.2	5	5	**5.09**
4/21/17	4.5 (1)	Start	4.6	4.6	4.6	4.6	4.7	4.5	4.5	4.5	4.5	4.5	**4.56**
4/22/17	4.5 (1)	End	4.3	4.6	4.4	4.5	4.6	4.7	4.5	4.6	4.5	4.4	**4.51**
4/22/17	5.5 (3)	Start	5.4	5.4	5.5	5.4	5.4	5.4	5.5	5.5	5.4	5.5	**5.44**
4/22/17	5.5 (3)	End	5.5	5.5	5.5	5.6	5.4	5.6	5.5	5.7	5.6	5.5	**5.54**

Appendix E. Net Switching Plan

Mesh Selectivity Project Net Switching Plan

Day	Tow	Port	Starboard
Day 1	Tow 1	1	Control
	Tow 2	1	Control
	Tow 3	Control	2
	Tow 4	Control	2
	Tow 5	5	Control
	Tow 6	5	Control
Day 2	Tow 7	Control	3
	Tow 8	Control	3
	Tow 9	4	Control
	Tow 10	4	Control
	Tow 11	Control	1
	Tow 12	Control	1
Day 3	Tow 13	2	Control
	Tow 14	2	Control
	Tow 15	Control	4
	Tow 16	Control	4
	Tow 17	3	Control
	Tow 18	3	Control
Day 4	Tow 19	Control	5
	Tow 20	Control	5
	Tow 21	2	Control
	Tow 22	2	Control
	Tow 23	Control	1
	Tow 24	Control	1
Day 5	Tow 25	3	Control
	Tow 26	3	Control
	Tow 27	5	Control
	Tow 28	5	Control
	Tow 29	4	Control
	Tow 30	4	Control
Day 6	Tow 31	Control	1
	Tow 32	Control	1
	Tow 33	4	Control
	Tow 34	4	Control
	Tow 35	Control	3
	Tow 36	Control	3
Day 7	Tow 37	2	Control
	Tow 38	2	Control
	Tow 39	Control	5
	Tow 40	Control	5
	Tow 41	4	Control
	Tow 42	4	Control
Day 8	Tow 43	Control	3
	Tow 44	Control	3
	Tow 45	Control	1
	Tow 46	Control	1
	Tow 47	5	Control
	Tow 48	5	Control
Day 9	Tow 49	2	Control
	Tow 50	2	Control
	Tow 51	Control	3
	Tow 52	Control	3
	Tow 53	1	Control
	Tow 54	1	Control
Day 10	Tow 55	Control	2
	Tow 56	Control	2
	Tow 57	4	Control
	Tow 58	4	Control
	Tow 59	Control	5
	Tow 60	Control	5
Day 11	Tow 61	1	Control
	Tow 62	1	Control
	Tow 63	Control	2
	Tow 64	Control	2
	Tow 65	3	Control
	Tow 66	3	Control
Day 12	Tow 67	Control	4
	Tow 68	Control	4
	Tow 69	5	Control
	Tow 70	5	Control
	Tow 71	Control	5
	Tow 72	Control	5
Day 13	Tow 73	4	Control
	Tow 74	4	Control
	Tow 75	Control	3
	Tow 76	Control	3
	Tow 77	2	Control
	Tow 78	2	Control
Day 14	Tow 79	Control	1
	Tow 80	Control	1
	Tow 81	1	Control
	Tow 82	1	Control
	Tow 83	Control	2
	Tow 84	Control	2
Day 15	Tow 85	5	Control
	Tow 86	5	Control
	Tow 87	Control	4
	Tow 88	Control	4
	Tow 89	3	Control
	Tow 90	3	Control
Day 16	Tow 91	Control	5
	Tow 92	Control	5
	Tow 93	1	Control
	Tow 94	1	Control
	Tow 95	Control	4
	Tow 96	Control	4
Day 17	Tow 97	Control	2
	Tow 98	Control	2
	Tow 99	3	Control
	Tow 100	3	Control
	Tow 101	Control	4
	Tow 102	Control	4
Day 18	Tow 103	Control	3
	Tow 104	Control	3
	Tow 105	1	Control
	Tow 106	1	Control
	Tow 107	Control	2
	Tow 108	Control	2
Day 19	Tow 109	5	Control
	Tow 110	5	Control
	Tow 111	Control	4
	Tow 112	Control	4
	Tow 113	2	Control
	Tow 114	2	Control
Day 20	Tow 115	Control	1
	Tow 116	Control	1
	Tow 117	3	Control
	Tow 118	3	Control

Treatment	
4.5" Diamond	1
5" Diamond	2
5.5" Diamond	3
6" Diamond	4
6" Square	5

Treatment (118 tows)						
	1	2	3	4	5	Control
# on Port	12	12	12	12	12	60
# on Starboard	12	12	12	12	10	58
Total Tows	24	24	24	24	22	118

Thick black line indicates end of 5 treatment "block"

Appendix F. Sampling Day Procedure

MESH SELECTIVITY STUDY
SAMPLING DAY PROCEDURE

DAY BEFORE TRIP
- Bench check Marel scales in the office
- Establish a float plan

ONBOARD BEFORE DEPARTURE:
- Checklist complete
- All equipment, staff, paperwork and permits on boat
- If necessary, call into NOAA Interactive Voice Response (IVR) system for start of trip. Use the vessel VMS system (McMurdo Fleet Management formerly Boatracs) to report the start of a research trip. Instructions for this procedure are in included in the project binder.
-

PRIOR TO THE **FIRST DAY** OF RESEARCH FISHING
- Experimental codends need to be marked so easily identifiable by CCE staff

WHILE STEAMING OUT AND/OR PRIOR TO EACH DAY OF FISHING
- Conduct safety drills.
- Fill out vessel info data sheet
- Set up scales and calibrate
- Mesh must be measured in **each** of the experimental codends used during the day's research fishing (codends determined by the **Net Switching Plan**).
- Be aware that there are 6 cod ends in use; a **control**, a **4.5" diamond** (treatment A), and **5" diamond** (treatment B), **5.5" diamond** (treatment C), **6" diamond** (treatment D), **6" square** (treatment E). There is no higher priority experimental cod end and as such each codend will be compared to the control following the project's randomly generated **Net Switching Plan.** This plan is to be followed for the duration of the project.
- Be aware that we are attempting to make a minimum of 7/8 tows per day that will include only **day** fishing. Tows may began before sunrise and extend past sunset (tows that fall in this category must include the time of sunrise or sunset on the appropriate data sheet). Each tow is scheduled to be **45** minutes in length. Tow duration may be adjusted if necessary due to factors in the field or catch sensors (determined by captain) are triggered.
- Be aware if a tow is shortened, the following tow should be continued at **45** minutes. If this tow also needs to be shortened, succeeding tows may then be shortened to less than 45 minutes. Tows should be returned to 45 minutes in length at the start of a new day of research fishing.
- Be aware that control and experimental net location relative to port/starboard will be switched during experimental fishing following the project **Net Switching Plan.**
- Use cameras as often as possible to document the project.

IMMEDIATELY PRIOR TO EACH TRAWL

- Locate the GPS outside and turn it on so that it can record our track. **CHECK BATTERY LEVEL** – be sure the batteries will last the tow – be sure to mark a waypoint and record lat/long at the beginning and end of each tow.

DURING TRAWL

- Make sure that all the info related to the tow is obtained from the captain or from the FLOUNDERS program (if possible) and properly recorded. This info should include:

1. Tow speed
2. Tow direction
3. Tow cable length
4. Ground gear length
5. Door spread
6. Water depth
7. Statistical area

POST TRAWL – The following procedure occurs after all tows and for both the control and experimental nets:

- The experimental codend should always be brought aboard the vessel first. The control codend should follow as quickly as possible to minimize any sifting that may occur if the codend remains in the water.
- Release fish on deck – be sure catch from each codend is separated (does not mix).
- If possible immediately remove random samples of **Black Sea Bass, Scup, and Fluke** from both the control and experimental codends for use in length frequencies. Each species will require a 200 count random sample collected from different locations in the pile (200 lengths if possible otherwise all individuals should be measured).
- Measure (length frequencies) and weigh sub-samples as quickly as possible and return to pile or if unable to return to pile make sure weights are included in **Total Catch.**
- Sort catch from each codend – **Black Sea Bass, Scup, and Fluke** are the only species that need to be separated completely to individual species. A **Total Weight** for each of these three species from each codend must be obtained. **Total Weight** must include both kept and discards and should be obtained by weighing directly (large catches may require basket/tote sub-sampling methods).
- **Total Catch Weight** from each codend must also be recorded. **Total Catch Weight** includes everything retained in the codend. Species other than **Black Sea Bass, Scup, and Fluke** do not need to be separated or sorted. They can be identified as miscellaneous discards, misc. kept, skates, etc. (for large catches, a sub-sample of basket/tote weight will be used to extrapolate the weight of the total catch).
- Be sure the data sheets are filled out correctly with all the gathered data including the new **Catch Description** sheet.
- Completed data sheets are to be stored in the cabin, off the open deck to avoid the possibility of loss.
- **All NON-LEGAL FISH OVERBOARD.**

- Review **Net Switching Plan** before successive tow begins to be certain the correct experimental codend is being set out and that codends are located correctly relative to port/starboard.

AT THE CONCLUSION OF EACH DAY OF RESEARCH FISHING

- Mesh must be measured again from **each** of the experimental codends used during the day (mesh should be measured twice each day – start and end).

WHILE STEAMING HOME

- Be sure ALL data sheets are filled out properly.
- Clean all sampling and scientific equipment.
- Pack up equipment and review checklist making sure everything is accounted for.
- Report the end of research fishing trip through the vessel's VMS system. Instructions for this procedure are included in the project binder.
- If returning to Montauk to unload CCE staff and equipment before vessel travels to New Jersey to offload catch be sure **NY DEC** is notified. Instructions for this procedure are included in the project binder.

BACK ON THE DOCK

- Unload boat.
- Go over checklist again and make sure everything is accounted for.
- Pack up truck and return to office.