FINAL REPORT

An Evaluation of Size Selectivity and Relative Efficiency of Black Sea Bass, *Centropristis striata*, Habitat Pots Equipped with Large Mesh Panels

Award Number: NA06NMF4540013

Submitted to:

National Marine Fisheries Service
Northeast Regional Office
One Blackburn Drive
Gloucester, Massachusetts 01930-2298

Submitted by:

David B. Rudders
Robert A. Fisher
Noelle Yochum

Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

VIMS Marine Resource Report No. 2008-5

May 29, 2008

Project Summary

The black sea bass, *Centropristis striata*, fishery is in a state of transition. Regulatory changes found in Amendment #9 to the Summer Flounder, Scup and Black Sea Bass Fishery Management Plan implemented measures intended to both rebuild the stock and to maintain it at sustainable levels into the future. These measures included commercial quotas, commercial gear requirements, minimum size limits, recreational harvest limits, and permit and reporting requirements. One vital component contributing to the efficacy of these regulatory measures and future sustainability of the fishery are regulations that effectively protect sub-legal fish. The protection of sub-legal fish not only increases yield to the fishery, but also allows individuals to contribute to the reproductive output of the stock. While measures under Amendment #9 are in place to reduce the capture of sub-legal fish mortality of discarded sub-legal fish, this issue remains a cause of concern to managers. Information gathered by the proposed project will address that concern by demonstrating a means by which the survival of sub-legal fish can be increased over currently mandated methods.

For this study, three variants of an experimental coated wire mesh habitat pot designed to reduce the capture of sub-legal black sea bass were tested. This experimental gear design consisted of a large mesh panels on the bottom, top and posterior end (relative to the bridle) of the pot. The rationale behind this design is to provide sub-legal fish multiple escape routes not only throughout the entire capture process but specifically during haul-back. Three different mesh sizes were tested relative to a control pot (no escape vent) and the currently mandated escape vent (2 inch square escape vent).

From the data collected during this study, size selectivity for the three variants of the experimental gear was estimated. Additionally, catch rates were examined to assess differences in relative efficiency between the gear types. These results provide baseline information that will be beneficial to managers not only to improve the survival of discarded sub-legal black sea bass under the current minimum landing size requirements, but also to have information available to support future increases in the minimum legal landing size.

Project Background

The black sea bass, *Centropristis striata,* supports a commercial fishery that in 2006 landed 3.49 million pounds with an ex-vessel value of US $8.64 million (Van Voorhees, 2007). While commercial landings are far reduced from historical highs in the 1950's, population levels seem to have stabilized, having benefited from a management plan implemented in 1996. Amendment #9 to the Summer Flounder, Scup and Black Sea Bass Fishery Management Plan implemented measures intended to both rebuild the stock and to maintain it at sustainable levels. These measures included commercial quotas, commercial gear requirements, minimum size limits, recreational harvest limits, and permit and reporting requirements.

The management measures found in Amendment #9 were intended to incrementally reduce fishing mortality with the intent of facilitating stock rebuilding. Of the strategies available to managers, the use of quotas sets an overall quantity of fish harvested. Just as important as the total quantity harvested, the size (age) composition of the catch is equally important. If fish are harvested at too small a size, both potential yield to the fishery and reproductive output are not fully realized. Minimum landing sizes in concert with gear restrictions attempt to set a minimum size to be harvested by the fishery. Most gear restrictions are intended to manipulate the size selectivity characteristics of the fishing gear. Mesh shape size, and escape vent size and shape can be manipulated to change the probability of capture for specific size classes of fish. Fish that are able to escape the gear and avoid capture and onboard processing are thought to have higher chances of survival. As a result, gear selectivity is an important component of the overall management strategy.

Fish traps are widely used in the black sea bass fishery, and have accounted for roughly 45% of the commercial landings in the Mid-Atlantic since 1990 (NMFS, 2008). Prior to Amendment #9, black sea bass traps were fished without an escape vent. This was especially problematic in the mid-Atlantic region where traps are fished at depths to 40 meters and quickly hauled to the surface with pot-pullers. Discarded fish captured from this depth often have difficulty submerging upon release and may experience physiologic complications resulting from the rapid ascent, decompression and thermal differences (Stewart, 2008; Collins *et. al.*, 1999). Mortality can result from both physical damage as well as an increase in predation as the discarded sub-legal fish are unable to return to bottom and the safety of habitat structures. In cases where the mortality of discarded sub-legal fish is high, the benefits in terms of increased fishery yield and reproductive potential from setting an appropriate theoretical minimum landing size may not be realized (Waters and Huntsman, 1986).

Size selectivity of traps can be accomplished by both the use of escape vents and the size of the mesh used to construct the trap. Escape vents are a common method to promote the escapement of certain size classes of animals from trap gear. Generally, as escape vent size increases the probability of capture of smaller animals decreases (Wileman *et. al.*, 1996). Research conducted by MAFMC specific for the sea bass trap fishery, which formed the basis of Amendment 9 vent policy, demonstrated the significant reduction of sub-legal bass caught in traps with a vent (MAFMC, 1996). This study tested various sizes of rectangular vents. A vent opening of 1 1/8" x 5 3/4" (2.86 cm x 14.6 cm) was determined to be the most effective vent size for allowing escapement of fish below the then minimum legal size of 9 inches (23cm). No work was performed to determine the selectivity of traps using circular or square vents, though a large proportion of black sea bass trap fishermen in the Mid-Atlantic use either circle or square vents. Proposed, then mandated, dimensions for a circular and square vent were derived from black sea bass body length/depth relationships (Weber and Briggs 1983) and were 2" and 1.5" respectively.

Subsequent vent size selectivity studies examined the effect of different sizes of both circle and square shaped escape vents (Fisher and Rudders, 2003). In this study, square vents of 1 7/8”, 2”, 2 1/8”, 2 1/4" and circle vents of 2 1/4", 2 3/8”, 2 1/2", 2 5/8” were tested in sea bass habitat pots. Results indicated that the probability of capture of smaller fish decreased as vent size increased. This general pattern was consistent across both shapes of escape vent. Retention of small fish (<28 cm, sub-legal under current regulations), however, proved to be problematic in all vent configurations. Some of these smaller fish were retained in the forward part of the pot (kitchen). With the exception of the entrance funnel, there is no method of egress for fish in the kitchen. Additionally, it was hypothesized that behavioral factors contributed to the retention of smaller fish in the pot, even though they were of a size physically able to escape with given escape vent dimensions. High levels of abundance of small sea bass on the offshore structure off Virginia Beach, VA varied temporally, and corresponded to the fall offshore migration. It was during this time of high abundance, that retention of small fish in the habitat pots was most problematic. Results from this study suggest that a single escape vent placed in the parlor area of the pot may be insufficient to maximize escapement of sub-legal black sea bass.

In contrast to habitat pots that focus on the habitat seeking behavior of the sea bass, another trapping strategy is also utilized to capture the fish. A baited pot is placed directly on structure, and sea bass enter the trap to feed. Relative to the habitat pot strategy where soak time can range from 7-14 days, the baited drop pots are fished for much shorter time periods, generally hours. Selectivity of a drop pot with an alternative design was recently examined (Fisher and Rudders, 2004). This experimental gear consisted of the standard drop pot design, equipped with a 2" square mesh panel on the top, bottom and posterior end (relative to the bridle) of the pot. The concept was to weight and bridle the trap in such a manner as to force the catch against the large mesh back of the pot upon haul-back. Given the contact of the catch with the large mesh panel, many potential escape routes were available to fish through the meshes. Results indicate that the experimental pot was highly effective at facilitating the release of smaller fish. This design reduced the capture of sub-legal (<28 cm) sea bass by 29 % relative to the pot equipped with the currently mandated escape vent configuration.

In a recovering fishery such as black sea bass, protecting incoming year classes of fish is vital. Many factors involving reproduction and recruitment are uncontrollable, however, one strategy available to mangers is to protect recruiting year classes through conservation gear engineering. By designing and refining fishing gear to select for certain size classes of fish both the yield and reproductive potential of the fish can be more fully realized. In the case of the black sea bass, protogynous hermaphrodites, the majority of smaller fish are females. By protecting these fish, females would have a higher probability of both reaching a size where they are able to spawn and contributing to the reproductive effort of the stock. Specifically, in the case of habitat sea bass pots that potentially inflict both physiological damage and increase the chance of predation, modifications to the existing gear that allow the release and survival of sub-legal fish before retrieval to the surface would be beneficial to both the stock and fishery.

The aim of this study was to explore alternative habitat gear designs that would facilitate the escapement of sub-legal sea bass. This designs tested integrated the success from prior work done with baited drop pots and result in the presentation of smaller fish with multiple escape routes by adding large mesh panels to portions of the trap. This study examined a size range of large mesh panels integrated into the top, bottom and posterior end of the pots. By estimating the selectivity of a range of mesh sizes in the experimental gear, information will be available to synchronize gear characteristics with both current and future management objectives. Selectivity information for larger size mesh will be available should a future increase in minimum landing size be warranted. Information of this nature is essential in order to maximize the effectiveness of the regulations set forth by Amendment #9 and to provide a basis for future management decisions.

Methods

Sampling gear

The gear used in this study consisted of single funnel, wire mesh black sea bass habitat pots with dimensions of 36” x 21” x 14” (Figure 1). Prior to any modifications, the habitat pots were constructed out of 14-gauge 1.5” square vinyl coated wire mesh. Overall, there were five versions of the habitat pot tested: 3 experimental variants (equipped with large mesh panels), a version compliant with current regulations (equipped with two 2.5” escape vents in the parlor of the pot), and a control pot with no escape vent). The experimental gear in this study consisted of pots with the same overall dimensions, but modified to include large mesh panels on the bottom, top and posterior end (relative to the bridle) of the pot. Modifications were completed by removing portions of the 1.5” mesh along the top, bottom and posterior end of the pot These openings were covered with large mesh panels consisting of 2”, 2.5” or 3” inch square mesh (Figure 2). The large mesh portion of the pots was constructed of heavier gauge wire mesh to maintain the structural integrity of the pot. The remainder of the pot remained the standard 14-gauge, 1.5” square mesh. The use of this mesh on the sides of the pots will preserve the profile and have the gear remain attractive to the fish as habitat.

Experimental design and field sampling

Difficulties encountered in obtaining 2.5” mesh forced a departure from the original scope of work. Standard dimensions manufactured by producers of wire mesh do not generally include 2.5” wire mesh. These manufacturers indicated that custom orders were available, but minimum amounts far exceeded both quantities required and the allotted budget. As the time to deploy the experimental gear drew near, the decision was made to increase the numbers of the other pot configurations and test the 2” and 3” mesh panels (those mesh sizes were readily available). During the field season it became apparent that sea bass catch rates off of Virginia were very low, as a result, soak times were lengthened to try to increase catch rates (as is industry practice) and we were unable to complete the proposed number of sampling cruises. In addition to low catch rates, observations for the pots equipped with 3” mesh suggested that given the size structure of the sea bass resource, this mesh was too large to provide meaningful information. Given those factors, the decision was made to request a one-year extension, which was granted.

During the time prior to the second deployment of the experimental gear, a vendor was located that would manufacture small lots of 2.5” mesh. With the disappointing results of the 3” mesh, and the loss of some gear at the end of the prior season, the decision was made to replace the 3” panels with 2.5” panels. This replacement and consolidation of gear resulted in the ability to place 4 complete strings into the field for testing in the second year. Due to the changes in gear configurations, the experiment was broken into two stanzas. In the first stanza, control, vent, 3 Inch and 2 Inch pots were tested. In the second stanza, control, vent, 2 Inch and 2.5 Inch pots were tested.

For each stanza, a randomized block design of four traps per block (control, vent and 2 large mesh panel traps) was employed. The blocks were fished in strings (trawl lines) consisting of five blocks per string, with each string consisted 20 pots (Figures 2 and 3). Individual pots within a block and along the string were fixed to a mainline 15 meters apart. Each string was fished in relation to bottom structure, typically a specific hang. Soak times for each set of strings ranged from 12 to 63 days, largely dictated by weather conditions and prevailing catch rates.

All sampling trips were completed aboard the F/V *Grumpy*, a commercial black sea bass vessel based out of Virginia Beach, VA. Experimental fishing occurred during two time periods: July through December 2006 (stanza 1) and June through November 2007 (stanza 2). The traditional fishing grounds utilized during this study were 25 to 55 miles offshore between Currituck Light, North Carolina and Cape Charles, Virginia. Depths ranged from 24 to 36 meters.

While at sea, all black sea bass and by-catch were separated by species and measured to nearest half centimeter. A deck log was maintained recording location, weather, time, soak duration, water depth, catch information, and observations of amount and condition of discard. All information was stored in a custom Microsoft Access database designed specifically for this project. Statistical analyses were performed using SAS v.9 and Microsoft Excel.

Data Analysis

Catch Comparisons

For this study, the following null hypothesis was evaluated.

H_o: Escape mechanism had no significant effect upon the catch rate of black sea bass.

Catch per unit effort (CPUE) was defined as either the number or weight of sea bass captured per pot haul. The weights of individual fish were calculated (in kg) by the following length-weight relationship:

$\ln W = \ln a + b*\ln L$

where W=weight in kilograms, L=length in centimeters, a = y-intercept and b=slope. The parameters a and b used were: –11.4782 and 3.0742, respectively (Wigley, 2003).

The catch data was further divided into two size classes: 1. legal (≥ 28 cm TL) and 2. sub-legal (<28 cm. TL). The raw catch data for both stanzas and size classes was tested for normality (Shapiro-Wilk) and transformed as necessary. Several data transformations were attempted (natural log, square root) and while improvements with respect to normality were made by the various transformations attempted all treatments in both stanzas and size classes remained non-normal. Due to the persistence of non-normality, the non-parametric analog to the one factor ANOVA was used to test for differences in catch rates between the experimental gears. A Kruskal-Wallis test was performed on the raw catch data to detect differences among groups. If the Kruskal-Wallis test indicated a significant differences between groups, non-parametric multiple comparisons were performed to discern statistical differences between treatment pairs (Zar 1996).

Size Selectivity

Size-selectivity curves for the experimental pot configurations were generated using the Share Each LEngth's Catch Total (SELECT) model developed by Millar (1992). This model compares catch-at-length data from the experimental gear to that from a non-selective control gear. The SELECT model provides an estimate of two factors often used to characterize selection. These are: the 50% retention length (l_{50}), the length at which a fish has a 50% probability of being retained after entering the gear, and the selection range (SR), the difference between the 75% and 25% retention lengths (l_{75} - l_{25}), which is a measure of how quickly 100% retention is approached, i.e., the steepness of the curve. The model also incorporates a parameter that denotes relative fishing intensity between two gears (experimental and control). This is the split parameter, p_j, which accounts for how catch among gears (j=1,…, n) will vary due to affects such as differential fishing effort, fish avoidance behavior and localized fish concentrations (Millar 1992).

The SELECT model equates the proportion of fish (of length l) that are caught in the experimental gear out of the total catch from both the experimental and control gears ($\Phi_E(l)$) to:

$$1. \qquad \Phi_E(l) = \frac{p_E r_E(l)}{p_E r_E(l) + (1 - p_E)}$$

Selectivity of the experimental gear, $r_E(l)$, is the probability that a fish of length l will be retained given that it contacts that gear, and the split parameter, p_E, describes the relative fishing intensity or relative efficiency of the experimental gear (Millar 1992). If selection of the experimental gear follows the logistic model, it is equal to:

$$2. \qquad r_E(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)}$$

Substituting this into the SELECT model yields:

$$3. \qquad \Phi_E(l) = \frac{p_E \exp(a + bl)}{(1 - p_E) + \exp(a + bl)}$$

where a and b are the logistic selectivity parameters and p_E is the split-parameter.

Estimates of these parameters were generated by maximizing the likelihood:

4.

$$L(a,b,p_E|data) = \prod_{l=10}^{59} \left(\frac{p_E \exp(a+bl)}{(1-p_E)+\exp(a+bl)}\right)^{C_E} \left(1-\frac{p_E \exp(a+bl)}{(1-p_E)+\exp(a+bl)}\right)^{C_C}$$

In this equation, C_E is the number of length l fish caught in the experimental gear and C_C is the number of length l fish in the control gear. To generate the selectivity curve, estimated values for parameters a and b are reinserted into the logistic equation (Equation 2). The resultant curve is symmetric about the l_{50} and the slope is determined by the selection range. The l_{50} and the SR relate to parameters a and b by:

5. $$SR = \frac{2\ln(3)}{b}$$ and 6. $$l_{50} = \frac{-a}{b}$$

An alternative SELECT model was also used, where the split parameter, p_E, was set equal to the relative effort between the two traps (the number of hauls completed by the experimental trap divided by the total number of hauls completed by both the experimental and control traps) and its value was not estimated by the model. In order to determine which of the two SELECT models best fits the data, the Akaike Information Criterion (AIC) was used. The AIC is:

7. $$AIC = 2k - 2\ln(L)$$

In this equation, k is the number of parameters included in the model and L is the maximized value of the likelihood function for the estimated model. The smaller AIC is that of the better model.

The calculations for this analysis were completed using the Solver tool in Microsoft Excel.

Results

A total of 14 cruises and 1,898 pot hauls were accomplished for a total catch of 4,913 black sea bass, with a size range of 10 cm to 59 cm total length. Since the total number of pot hauls by gear configuration varied slightly due to lost gear, total number and weight caught is slightly misleading. Mean catch (numbers or weight) per pot is a better indicator of relative performance. Results indicate that as expected, the control pot captured the most fish followed by the vent, 2 inch panel, 2.5 inch panel and 3.5 inch panel in order of diminishing catch rate (Table 1 & 2). Overall, mean catch per pot haul was low, however the highest values were observed in the fall and winter of the year. This generally coincided with the traditional times of high catches in this area corresponding to times of offshore migration. Results using the 3 inch mesh were very low, with only 34 fish captured over the 8 trips in which this configuration. The catches from the pots equipped with the 2.5 inch mesh were slightly better, however, only 110 fish were caught in that configuration over 6 trips.

Length frequency distributions for the two stanzas are shown in figure 3. The total effort (pot hauls) for the each pot configurations varied slightly, but the trends in catch are well exhibited by the two plots. Differences in the length frequency distributions clearly show the results that were obtained from the Kruskal-Wallis test. For stanza 1 in terms of numbers and weight of sub-legal fish, the 3 inch configuration was different from all other treatments, and the vent and 2 inch configuration was different from the control. The only treatments that were not different were the vent and 2 inch configuration (Tables 3 & 7). For stanza 1 in terms of numbers and weight of legal fish, the 3 inch configuration was different from all other treatments. There was no difference observed between any combination of the remaining treatments (vent vs. control, vent vs. 2 inch and control vs. 2 inch) (Tables 4 & 8). For stanza 2 in terms of numbers and weight of sub-legal fish, all treatment configurations were statistically significantly different except for the vent and 2 inch large mesh panel (Tables 5 & 9). For stanza 2 with respect to legal fish, differences were found between the results based on examining catch rates either by numbers or weight caught per pot haul. For the analysis that looked at numbers caught, all combinations with the 2.5 inch pot were statistically different, however there was no difference found in the other combinations (Table 6). The analysis that examined the catch data for Stanza 2-legal fish with respect to weight found only one statistically significant different treatment pair. This combination was the 2.5 inch vs. the 2 inch. The other combinations involving the 2.5 inch mesh were not significantly different, although the test statistics were very close to the critical values, indicating that the lack of rejection of the null hypothesis was marginal. These differences in results between the examination of the catch data with respect to numbers and weigh for this stanza and size class combination was in part due to low catch rates and differential size composition of the catch.

The selectivity analysis was completed using both the SELECT model that estimated the split parameter and that fixed the value. In both cases, AIC values and residual patterns were similar. However, the AIC values were smaller when the split parameter was estimated and this model appeared to fit the data better. For these reasons, the results from this model were selected (Table 11 and Figures 4 and 5). This model generated l_{50} values for the 2 inch trap of 27.5 cm (Stanza 1) and 28.4 cm (Stanza 2); the 3 inch trap of 68.5 cm (Stanza 1 only); the 2.5 inch trap of 41.9 cm (Stanza 2 only); and the vent trap of 29.7 cm (Stanza 1) and 32.1 cm (Stanza 2). The selection range values for the 2 inch trap were 2.2 cm (Stanza 1) and 4.7 cm (Stanza 2); the 3 inch trap was 7.9 cm (Stanza 1 only); the 2.5 inch trap was 8.4 cm (Stanza 2 only); and the vent trap were 7.3 cm (Stanza 1) and 13.0 cm (Stanza 2). Estimated split parameter values for the 2-inch trap were 0.56 (Stanza 1) and 0.58 (Stanza 2); the 3-inch trap was 1.00 (Stanza 1 only); the 2.5-inch trap was 0.73 (Stanza 2 only); and the vent trap were 0.67 (Stanza 1) and 0.64 (Stanza 2). All of the estimated split parameters were greater than the expected values, which only reflect relative fishing effort. If the two gears were equally efficient, then the difference in catches between gears would be a function of the number of hauls completed by each gear type. The difference between the observed and expected split parameter values indicates that other factors are affecting efficiency.

Finfish and invertebrate bycatch is shown in table 12.

Discussion

For a recovering resource such as black sea bass, high rates of discard mortality have the potential to slow recovery efforts. This potential problem is even of more concern due to the fact that these rates are often little studied and unobserved. Gear conservation engineering is one approach used to mitigate the deleterious effects of high discard mortality rates. In the case of black sea bass captured by pot gear, an effectively designed gear would allow the fish to escape lower in the water column and avoid the potential damaging effects of barotrauma, on-board handling and predation. By allowing these fish to survive, potential gains in yield per recruit as well as potential increases in egg production could be realized. This project attempted to build off the experiences of two of our previous projects involves with sea bass pot gear and design a highly modified trap that would in effect present the fish with multiple avenues of escape. Care must be taken that any modifications do not result in a trap that has a high concomitant rate of loss of legal size fish, as well as designing a gear that is too complicated or unable to withstand the rigors of commercial use.

Our study examined the incorporation of large mesh panels into certain portions of the pot. Based on observations from our prior work, it appeared that fish were being retained in the kitchen portion of the pot where no escape vent was present. We also observed retention of small fish that were far smaller than would be able to escape out of the mesh of the body of the trap, regardless of any size or shape escape vent present (Fisher and Rudders 2003). These observations led to the approach of presenting fish with multiple routes of egress from the pot, and testing various mesh sizes to determine the size selective characteristics of these modified pots.

Results showed that the approach of giving the fish multiple routes of egress could be effective in reducing the retention of sub-legal fish. It appeared that the 2 inch mesh panel and the vented pot operated fairly closely with respect to both catch rates and estimated size selectivity. The difference in the estimated L_{50} estimates was due to the difference in the size of the escape vent (2.5”), although the estimates for the vented pot might be lower than would be expected due to retention of fish that would theoretically be able to escape from a 2.5 inch square escape vent, due to the limited number of escape routes available. Visual examination of the length frequency distributions clearly shows retention of numbers of 18-25 cm fish that were not captured by the 2 inch pot. This phenomenon is also reflected in the wider selection range of the vented pot relative to the 2 inch pot.

Contrasting the L_{50} for the vented pot with the L_{50} for the 2.5 inch large mesh panel shows a marked increase in the pot equipped with the large mesh panel. Unfortunately, catch rates for this gear were low and for a pot design such as this, the mesh size was too large given the current age structure of the black sea bass population encountered. This observation was definitely true for the 3 inch mesh pot, where only the largest fish were caught. The results related to this treatment should be taken as guidance only as this mesh size is not appropriate for black sea bass at this time. Given our experimental results, for a pot designed to incorporate a large mesh panel, an appropriate size is probably in between 2 and 2.5 inches. This size range would effectively eliminate sub-legal fish while consistently selecting for a larger class of sea bass.

The approach taken in this project was to test a radical modification to a well established gear design. This approach seems to have some promise to be able to reduce the retention of smaller, sub-legal fish. Unfortunately, the 3 inch mesh treatment was too large to provide meaningful information. The 2.5 inch mesh panel was a little large given the current stock structure, but selectivity estimates suggest that the probability of capture for sub-legal fish was greatly reduced; however the loss of legal fish in that treatment was also high. The black sea bass fishery is interesting in that it is characterized by three disparate gear types (hook and line, trawl, and pot). It is vital given the potential widely disparate selectivity characteristics of those gear types to continue to monitor, asses and refine these fishery components to promote the reduction of sub-legal bycatch and reduce the mortality of juvenile fish for this recovering resource.

Problems Encountered

We encountered numerous problems during the course of the study. Most of them related to the paucity of fish in the study area. First, the lack of fish resulted in low catch rates and extended soak times in an attempt to increase our catch per pot. This increase in soak time resulted in our inability to complete the proposed number of trips in year 1. We were granted an extension to continue the research portion of the study into year 2.

In addition to the impact upon the catch rates of the research portion of the project, low abundance of sea bass resulted in our inability to harvest the full amount of compensation for the project. This was even with the help of two commercial pot fishermen fishing in Massachusetts and one trawler out of New Jersey. Financially, we were well under our proposed budget, which made it difficult to complete our research trips in the second year of the project.

Acknowledgements

The authors would like to thank Capt. Jack Stallings and his crew from the F/V *Grumpy* for his efforts in completing this project. Thanks also go to David Pierce and Dan McKiernan of the Massachusetts Department of Marine Fisheries and personnel from the New Jersey Division of Fish and Wildlife of for their assistance in facilitating the harvest of some of the allotted compensation by fishermen from their respective states.

Literature Cited

Collins, M.R., J.C. McGovern, G.R. Sedberry, H.S. Meister, and R. Pardieck. 1999. Swim bladder deflation in black sea bass and vermillion snapper: potential for increasing postrelease survival. North American Journal of Fisheries Management. 19:828-832.

Fisher, R.A. and D. B. Rudders. 2003. The effect of circle and square escape vents on discard reduction in the black sea bass, *Centropristis striata*, trap fishery. Virginia Institute of Marine Science Marine Resource Report 2003-4.

Fisher, R.A., D. B. Rudders and J. Dawson. 2004. Discard reduction concerning selectivity and overall gear design in the black sea bass, *Centropristis striata*, trap fishery. Virginia Institute of Marine Science Marine Resource Report 2004-9.

MAFMC. 1996. Amendment 9 to the Summer Flounder Fishery Management Plan: Fishery Management Plan and Final Environmental Impact Statement for the Black Sea Bass Fishery. June 1996. 152 pp+appendices.

Millar, R. B. 1992. Estimating the size-selectivity of fishing gear by conditioning on the total catch. J. Am. Statist. Assoc. 87: 962-968.

National Marine Fisheries Service. 2008. Commercial Fisheries Landings Data. http://www.st.nmfs.gov/st1/commercial/

Stewart, J. Capture depth related mortality of discarded snapper (*Pagurus auratus*) and implications for management. Fish. Res. 90: 289-295.

Van Voorhees, D. 2004. Fisheries of the United States, 2003. NMFS Office of Science and Technology, Fisheries Statistics Division.

Waters, J.R. and G.R. Huntsman. (1986). Incorporating mortality from catch and release into yield-per-recruit analyses of minimum-size limits. North American Journal of Fisheries Management. 6:463-471.

Wigley, S.E., McBride, H,M, and McHugh, N.J. 2003. Length-weight relationships for 74 species collected during the NEFSC research vessel bottom trawl surveys, 1992-99. NOAA Technical Memorandum NMFS-NE-171. 36 pp.

Wileman, D. A., R.S.T. Ferro, R.Fonteyne, and R.B. Millar. 1996. Manual of methods of measuring the selectivity of towed fishing gears. ICES Cooperative Research Report No. 215, Copenhagen, 126 pp.

Zar, J.H. (1996). Biostatistical Analysis. Prentice-Hall Inc. Upper Saddle River, N.J. 662 pp.

Table 1 Total number and mean number per pot of Black Sea Bass by escape mechanism and trip.

		Escape Mechanism											
		Control		Vent		2 Inch		3 Inch		2.5 Inch		Overall	
Trip Date	Pot hauls	No. of Fish	No. per Pot	No. of Fish	No. per Pot	No. of Fish	No. per Pot	No. of Fish	No. per Pot	No. of Fish	No. per Pot	No. of Fish	No. per Pot
7/19/2006	200	232	4.64	141	2.82	115	2.30	4	0.08	*	*	492	2.46
7/31/2006	198	287	5.74	131	2.62	114	2.38	8	0.16	*	*	540	2.73
8/14/2006	198	241	4.82	150	3.00	137	2.85	4	0.08	*	*	532	2.69
8/30/2006	196	285	5.94	178	3.56	88	1.83	1	0.02	*	*	552	2.82
9/18/2006	192	211	4.22	100	2.00	75	1.63	3	0.07	*	*	389	2.03
10/19/2006	196	75	1.50	87	1.74	42	0.84	8	0.17	*	*	212	1.08
12/21/2006	88	194	8.82	112	5.09	63	2.63	5	0.25	*	*	374	4.25
1/4/2007	80	96	4.80	100	5.00	60	3.00	1	0.05	*	*	257	3.21
6/21/2007	158	389	10.24	132	3.14	111	2.92	*	*	33	0.83	665	4.21
7/9/2007	120	136	4.86	80	2.50	52	1.73	*	*	15	0.50	283	2.36
9/4/2007	40	50	5.00	38	3.80	46	4.60	*	*	15	1.50	149	3.73
9/24/2007	80	65	4.06	90	4.09	49	2.23	*	*	24	1.20	228	2.85
10/9/2007	40	50	5.00	31	3.10	36	3.60	*	*	13	1.30	130	3.25
11/29/2007	112	63	2.10	17	0.61	20	0.77	*	*	10	0.36	110	0.98
Total	1898	2374	5.12	1387	3.08	1008	2.38	34	0.11	110	0.95	4913	2.76

Table 2 Total estimated weight (kg.) and mean weight per pot of Black Sea Bass by escape mechanism and trip.

		Escape Mechanism											
		Control		Vent		2 Inch		3 Inch		2.5 Inch		Overall	
Trip Date	Pot hauls	Wt. of Fish	Wt. per Pot	Wt. of Fish	Wt. per Pot	Wt. of Fish	Wt. per Pot	Wt. of Fish	Wt. per Pot	Wt. of Fish	Wt. per Pot	Wt. of Fish	Wt. per Pot
7/19/2006	200	70.56	1.41	58.76	1.18	51.22	1.02	5.71	0.11	*	*	186.25	0.93
7/31/2006	198	79.68	1.59	52.95	1.06	50.72	1.06	9.80	0.20	*	*	193.15	0.98
8/14/2006	198	69.10	1.38	65.24	1.30	65.03	1.35	4.62	0.09	*	*	203.98	1.03
8/30/2006	196	75.71	1.58	76.01	1.52	35.26	0.73	0.87	0.02	*	*	187.86	0.96
9/18/2006	192	51.10	1.02	38.96	0.78	29.07	0.63	1.48	0.03	*	*	120.60	0.63
10/19/2006	196	17.77	0.36	27.11	0.54	21.07	0.42	10.02	0.22	*	*	75.97	0.39
12/21/2006	88	37.51	1.71	31.19	1.42	25.45	1.06	2.56	0.13	*	*	96.71	1.10
1/4/2007	80	22.92	1.15	30.81	1.54	26.68	1.33	1.09	0.05	*	*	81.50	1.02
6/21/2007	158	90.98	2.39	60.40	1.44	52.98	1.39	*	*	22.90	0.57	227.25	1.44
7/9/2007	120	31.21	1.11	26.32	0.82	20.75	0.69	*	*	11.70	0.39	89.98	0.75
9/4/2007	40	24.68	2.47	27.33	2.73	25.38	2.54	*	*	12.78	1.28	90.16	2.25
9/24/2007	80	17.46	1.09	26.96	1.23	21.06	0.96	*	*	16.51	0.83	82.00	1.02
10/9/2007	40	12.79	1.28	14.40	1.44	18.55	1.86	*	*	12.27	1.23	58.01	1.45
11/29/2007	112	29.19	0.97	6.39	0.23	11.43	0.44	*	*	9.19	0.33	56.20	0.50
Total	1898	630.65	1.39	542.83	1.23	454.64	1.11	36.16	0.11	85.34	0.77	1749.62	1.03

Table 3. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for sub-legal numbers of Black Sea Bass with non parametric multiple contrasts for stanza 1. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Legal fish (>28 cm TL)

Kruskal_Wallis Test	
Chi-Square	348.71
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
3 Inch vs. 2 Inch	114.37	19.84	5.76	2.64	Reject Ho: treatments are not equal
3 Inch vs. Vent	156.34	19.73	7.93	2.64	Reject Ho: treatments are not equal
3 vs. Control	360.45	19.75	18.25	2.64	Reject Ho: treatments are not equal
2 Inch vs. Vent	41.97	19.70	2.13	2.64	Accept Ho: treatments are equal
Control vs. 2 Inch	246.09	19.72	12.48	2.64	Reject Ho: treatments are not equal
Control vs. Vent	204.11	19.61	10.41	2.64	Reject Ho: treatments are not equal

Table 4. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for legal numbers of Black Sea Bass with non parametric multiple contrasts for stanza 1. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Sub-legal fish (<28 cm TL)

Kruskal_Wallis Test	
Chi-Square	200.71
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
3 vs. Control	213.69	20.53	10.40	2.64	Reject Ho: treatments are not equal
3 Inch vs. 2 Inch	235.35	20.62	11.41	2.64	Reject Ho: treatments are not equal
3 Inch vs. Vent	257.54	20.50	12.56	2.64	Reject Ho: treatments are not equal
Control vs. 2 Inch	21.66	20.50	1.05	2.64	Accept Ho: treatments are equal
Control vs. Vent	43.85	20.38	2.15	2.64	Accept Ho: treatments are equal
2 Inch vs. Vent	22.18	20.47	1.08	2.64	Accept Ho: treatments are equal

Table 5. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for sub-legal numbers of Black Sea Bass with non parametric multiple contrasts for stanza 2. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Legal fish (>28 cm TL)

Kruskal_Wallis Test	
Chi-Square	111.35
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
2.5 Inch vs. 2 Inch	45.01	12.61	3.57	2.64	Reject Ho: treatments are not equal
2.5 Inch vs. Vent	67.17	12.44	5.40	2.64	Reject Ho: treatments are not equal
2.5 vs. Control	131.70	12.71	10.36	2.64	Reject Ho: treatments are not equal
2 Inch vs. Vent	22.16	12.48	1.78	2.64	Accept Ho: treatments are equal
2 Inch vs. Control	86.69	12.75	6.80	2.64	Reject Ho: treatments are not equal
Vent vs. Control	64.53	12.58	5.13	2.64	Reject Ho: treatments are not equal

Table 6. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for legal numbers of Black Sea Bass with non parametric multiple contrasts for stanza 2. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Sub-legal fish (<28 cm TL)

Kruskal_Wallis Test	
Chi-Square	29.42
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
2.5 vs. Control	55.87	13.54	4.13	2.64	Reject Ho: treatments are not equal
2.5 Inch vs. Vent	56.01	13.25	4.23	2.64	Reject Ho: treatments are not equal
2.5 Inch vs. 2 Inch	64.59	13.44	4.81	2.64	Reject Ho: treatments are not equal
Vent vs. Control	0.14	13.41	0.01	2.64	Accept Ho: treatments are equal
2 Inch vs.Control	8.72	13.59	0.64	2.64	Accept Ho: treatments are equal
2 Inch vs. Vent	8.58	13.30	0.64	2.64	Accept Ho: treatments are equal

Table 7. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for sub-legal weight of Black Sea Bass with non parametric multiple contrasts for stanza 1. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Legal fish (>28 cm TL)

Kruskal_Wallis Test	
Chi-Square	326.02
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
3 Inch vs. 2 Inch	124.25	19.88	6.25	2.64	Reject Ho: treatments are not equal
3 Inch vs. Vent	160.22	19.77	8.11	2.64	Reject Ho: treatments are not equal
3 vs. Control	352.01	19.80	17.78	2.64	Reject Ho: treatments are not equal
2 Inch vs. Vent	35.97	19.74	1.82	2.64	Accept Ho: treatments are equal
2 Inch vs.Control	227.76	19.77	11.52	2.64	Reject Ho: treatments are not equal
Vent vs. Control	191.79	19.65	9.76	2.64	Reject Ho: treatments are not equal

Table 8. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for legal weight of Black Sea Bass with non parametric multiple contrasts for stanza 1. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Sub-legal fish (<28 cm TL)

Kruskal_Wallis Test	
Chi-Square	165.93
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
3 vs. Control	191.50	20.60	9.30	2.64	Reject Ho: treatments are not equal
3 Inch vs. 2 Inch	217.32	20.69	10.50	2.64	Reject Ho: treatments are not equal
3 Inch vs. Vent	234.44	20.57	11.40	2.64	Reject Ho: treatments are not equal
Control vs. 2 Inch	25.82	20.57	1.26	2.64	Accept Ho: treatments are equal
Control vs. Vent	42.94	20.44	2.10	2.64	Accept Ho: treatments are equal
2 Inch vs. Vent	17.12	20.54	0.83	2.64	Accept Ho: treatments are equal

Table 9. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for sub-legal weight of Black Sea Bass with non parametric multiple contrasts for stanza 2. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Legal fish (>28 cm TL)

Kruskal_Wallis Test	
Chi-Square	110.24
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
2.5 Inch vs. 2 Inch	48.59	12.64	3.84	2.64	Reject Ho: treatments are not equal
2.5 Inch vs. Vent	69.25	12.46	5.56	2.64	Reject Ho: treatments are not equal
2.5 vs. Control	131.85	12.74	10.35	2.64	Reject Ho: treatments are not equal
2 Inch vs. Vent	20.66	12.51	1.65	2.64	Accept Ho: treatments are equal
2 Inch vs.Control	83.26	12.78	6.51	2.64	Reject Ho: treatments are not equal
Vent vs. Control	62.60	12.61	4.97	2.64	Reject Ho: treatments are not equal

Table 10. Results of the Kruskal-Wallis non-parametric ANOVA by ranks for sub-legal weight of Black Sea Bass with non parametric multiple contrasts for stanza 2. For the table containing the non-parametric multiple comparisons, Difference is the difference in the sum of the ranked data, SE is the standard error, Q is the test statistic and $Q_{0.05,4}$ is the critical value at an alpha level of 0.05 with 4 degrees of freedom.

Sub-legal fish (<28 cm TL)

Kruskal_Wallis Test	
Chi-Square	10.15
Df	3
Pr>Chi-Square	<.0001

Non-parametric multiple comparisons

Comparison	Difference	SE	Q	$Q_{0.05,4}$	Conclusion
2.5 Inch vs. Vent	29.55	13.34	2.22	2.64	Accept Ho: treatments are equal
2.5 vs. Control	32.61	13.63	2.39	2.64	Accept Ho: treatments are equal
2.5 Inch vs. 2 Inch	39.99	13.53	2.96	2.64	Reject Ho: treatments are not equal
Vent vs. Control	3.06	13.49	0.23	2.64	Accept Ho: treatments are equal
2 Inch vs. Vent	10.44	13.39	0.78	2.64	Accept Ho: treatments are equal
2 Inch vs.Control	7.38	13.68	0.54	2.64	Accept Ho: treatments are equal

Table 11. Estimated parameters from the logistic SELECT analyses on catch-at-length data, including: logistic selectivity parameters *a* and *b*, and the relative efficiency split parameter (p_E). The 50% retention length (l_{50}), the selection range (SR= l_{75}-l_{25}), the Akaike Information Criterion (AIC) values and the Solver (Excel) starting values are also listed.

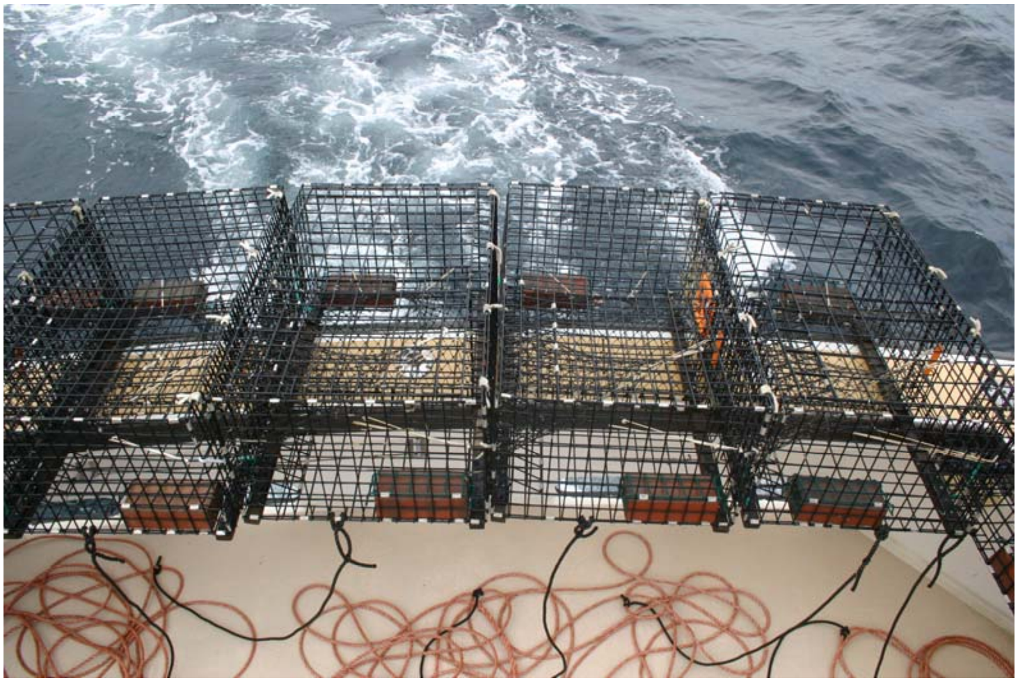
	Stanza 1			**Stanza 2**		
	2-inch	3-inch	Vent	2-inch	2.5-inch	Vent
a	-27.69	-18.99	-8.95	-13.22	-10.93	-5.44
b	1.01	0.28	0.30	0.46	0.26	0.17
p_E	0.56	1.00	0.67	0.58	0.73	0.64
AIC	2089.16	199.31	3110.95	1063.47	452.50	1376.68
l_{50}	27.53	68.48	29.74	28.45	41.90	32.15
SR	2.18	7.92	7.30	4.73	8.42	12.97
Start Values	(-27, 1, .5)	(-17, .3, 0.8)	(-9, 0.3, 0.5)	(-12, 0.5, 0.5)	(-11, 0.3, .05)	(-6, 0.2, 0.5)

Table 12. Finfish and invertebrate bycatch

Common Name	**Scientific Name**	**Total Caught**
Tautog	*Tautoga onitis*	201
Pigfish	*Orthopristis chrysoptera*	122
Scup	*Stenotomus chrysops*	61
Conger Eel	*Conger oceanicus*	51
Summer Flounder	*Paralichthys dentatus*	47
Gray Triggerfish	*Balistes capriscus*	19
Atlantic Croaker	*Micropogonias undulatus*	15
American Lobster	*Homarus americanus*	10
Hake Uncl.	*Gadidae*	9
Atlantic Spadefish	*Chaetodipterus faber*	8
Spot	*Leiostomus xanthrus*	2
Octopus uncl.	*Octopoda*	1
Channeled Whelk	*Busycotypus calaniculatus*	1
Northern Searobin	*Prionitus carolinus*	1
Sculpin uncl.	*Cottidae*	1

Figure 1. Commercial black sea bass wire trap used in the research. Trap entrance funnel on left (kitchen section) and fish holding section (parlor section) with vent on right.

Figure 2. Photographs of experimental Black Sea Bass pots used in the study. In the upper photograph, from right to left, 3 Inch, Vent, 2 Inch and Control pots. In the lower photograph is an experimental pot equipped with 3 Inch mesh panels.



<u>Figure 3</u> Length frequency distributions for Black Sea Bass by escape mechanism during the stanza 1 (A) and stanza 2 (B) of the experiment. The vertical line represents the MLS of 28 cm.

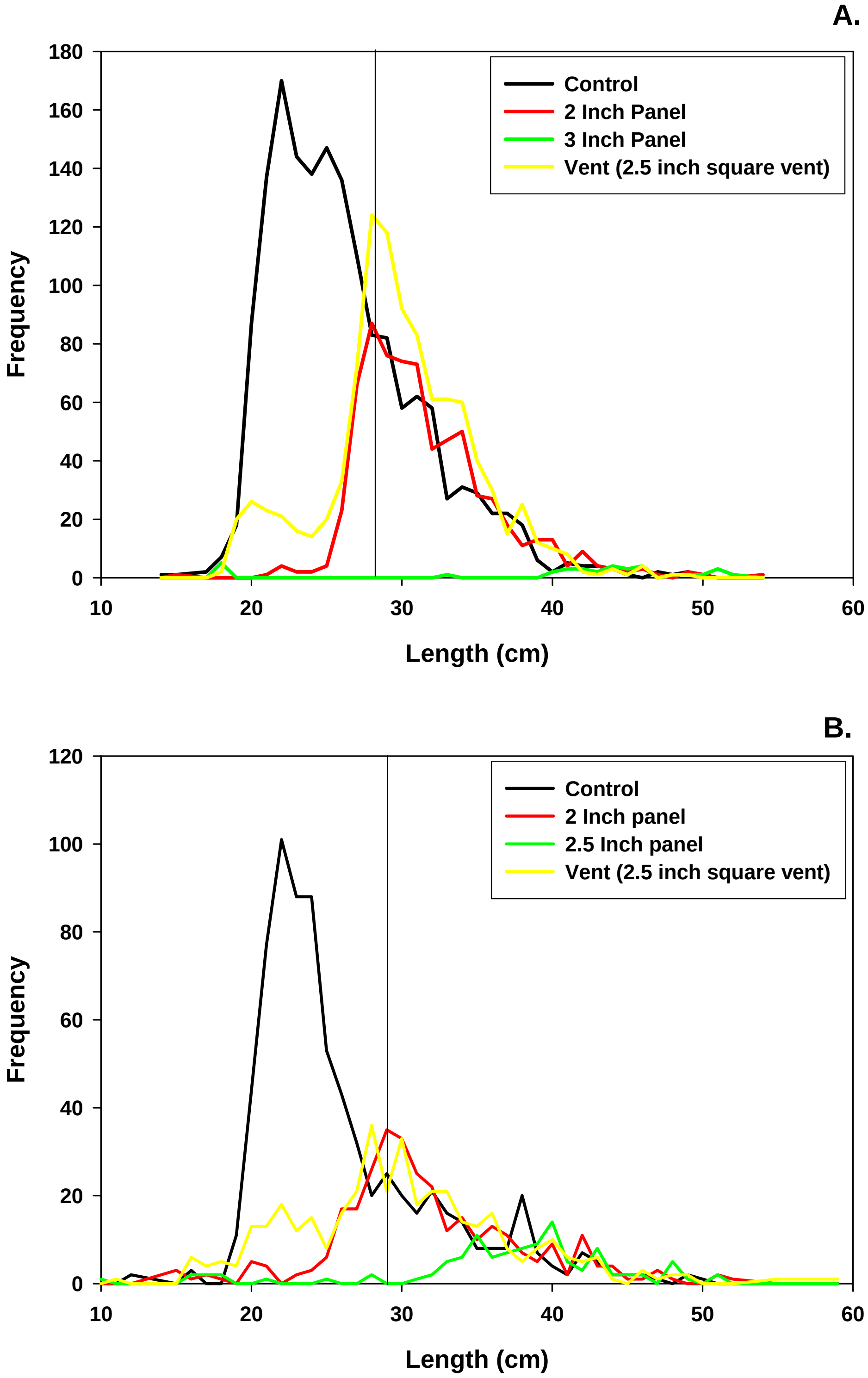


Figure 4. Logistic SELECT curves fitted to the proportion of the total catch in the experimental gear (left) and deviance residuals (right) for each experimental gear configuration for stanza 1.

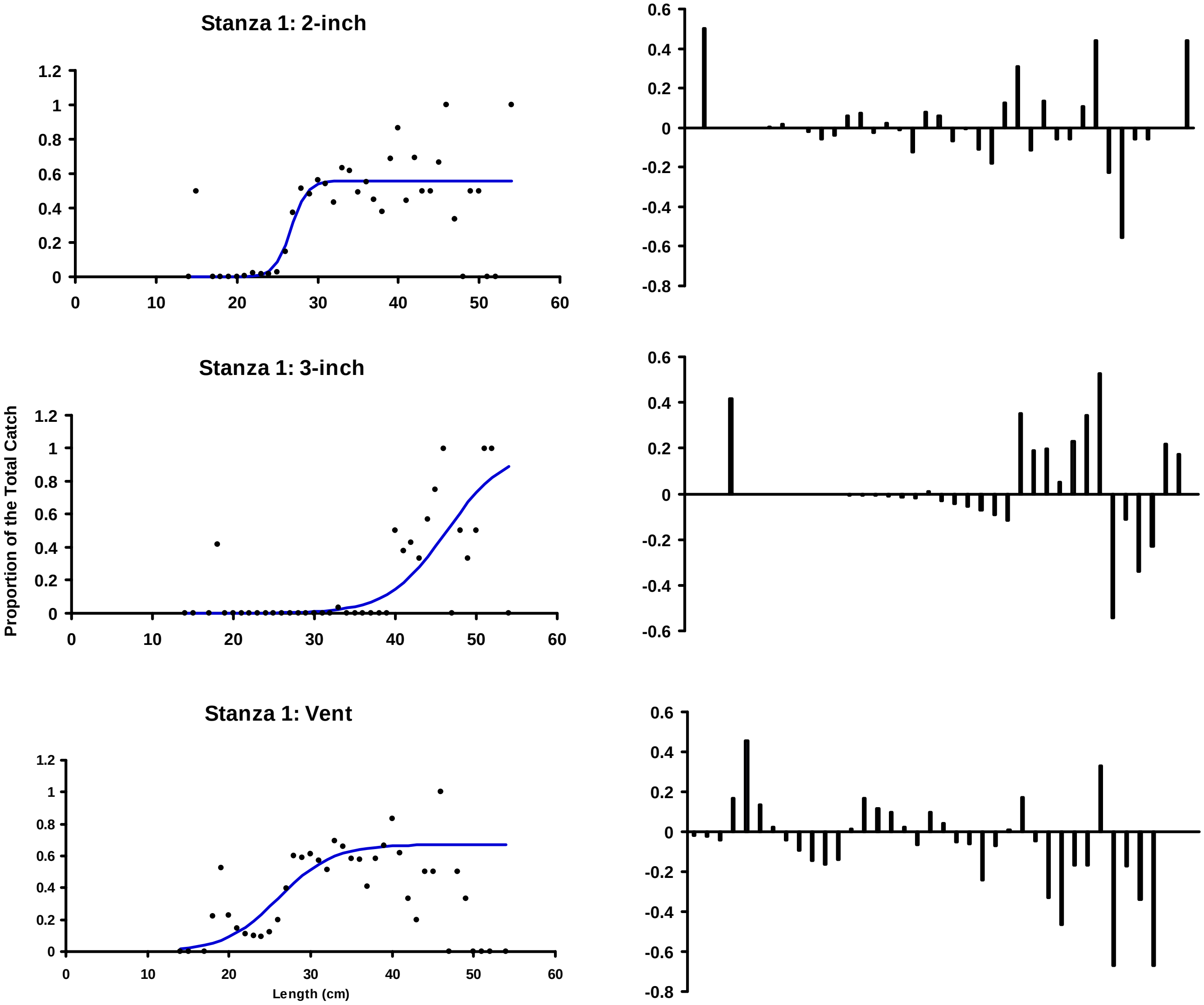


Figure 5. Logistic SELECT curves fitted to the proportion of the total catch in the experimental gear (left) and deviance residuals (right) for each experimental gear configuration for stanza 2.