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# EVALUATION OF CATCH EFFICIENCY AND SIZE SELECTIVITY OF INSHORE NEW ENGLAND FISH POTS FOR BLACK SEA BASS AND SCUP AS A FUNCTION OF ESCAPE VENT SIZE

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ABSTRACT

Effects of increasing escape vent size on catch efficiency and size selectivity were studied in the New England inshore pot fisheries targeting black sea bass (*Centropristis striata*) and scup (*Stenotomus chrysops*). Commercial fishing vessels fished experimental fish pots equipped with circular escape vents of varying size (2.38, 2.75, 3.10, and 3.40 inches); an unvented pot served as the control. In general, the catches of undersize black sea bass and scup werereduced as vent size increased. However, the results suggested that fishing pots with larger size escape vents also reduced the catch of legal-size fish. Selection characteristics for each vent size and species were generated using the SELECT method. The estimated selectivity patterns suggested that increasing the escape vent size in fish pots could alleviate fishing pressure on smaller size fish, though the probabilities of retaining larger size fish could be compromised. Changes in the size of the circular escape vents affected black sea bass and scup differently. As such, proposed management measures need to consider the gear and species-specific nature of selectivity parameters.

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## INTRODUCTION

Black sea bass, *Centropristis striata*, are a warm-temperate species that occur along the entire US Atlantic coast (Scott and Scott 1988; Bowen and Avise 1990; Steimle et al. 1999a; Shepherd 2000). There are two separate stocks of black sea bass that occur in U.S. Atlantic coastal waters – one north and one south of Cape Hatteras, North Carolina (Steimle et al. 1999a; Shepherd 2000). When water temperatures decline in the fall, the northern group tends to migrate to deeper waters, wintering between central New Jersey and North Carolina. As temperatures increase in the spring, the population migrates inshore into coastal areas and bays in Southern New England and the Mid-Atlantic Bight. During their residency in inshore water, black sea bass become associated with structured bottom habitats such as reefs, oyster beds, and wrecks. Black sea bass are protogynous hermaphrodites, changing sex from female to male (Lavenda 1949). In the Mid-Atlantic Bight, black sea bass begin to mature at age-1 and 50% reach full maturity at about age-2 – 3 and 19-cm standard length (O'Brien et al. 1993; Shepherd 2000). The transformation from female to male generally occurs between ages 2 and 5 and a total length of 23.9 – 33.7-cm (Mercer 1978; Wenner et al. 1986; Chesapeake Bay Program 1996; Steimle et al. 1999a). Black sea bass can grow to a size of 60-cm in length (Bigelow and Schroeder 1953; Robins and Ray 1986).

Scup, *Stenotomus chrysops*, are a schooling species that occur in temperate waters on the continental shelf (Morse 1978). Though tagging studies (e.g. Cogswell 1960, 1961; Neville and Talbot 1964; Hamer 1970, 1979) have suggested the possibility of two stocks of scup occurring along the Atlantic seaboard, subsequent studies found the evidence for two separate stocks to be weak and the concept of a single unit stock extending from Cape Hatteras north to New England is now supported (Pierce 1981; Mayo 1982). Scup undergo extensive migrations, moving in response to changes in water temperature. In the spring and summer, scup migrate to northern inshore waters to spawn as water temperature rises. Larger scup tend to arrive first, followed by waves of smaller individuals (Neville and Talbot 1964; Sisson 1974). As water temperatures begin to cool in the fall, scup move south and offshore – arriving in offshore wintering areas by December (Hamer 1970; Morse 1978). Scup are found in a variety of bottom types; for instance, they utilize structured habitat for feeding as well as shelter (Steimle et al. 1999b). Most scup mature when they reach age-2; about 50% are sexually mature at a total length of around 17-cm (O'Brien et al. 1993). Scup attain a maximum fork length of about 40-cm and ages of up to 20 years have been reported (Dery and Rearden 1979; Crecco et al. 1981).

Both black sea bass and scup support important commercial and recreational fisheries. These species are managed under the Mid-Atlantic Fishery Management Council's (MAFMC) Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP). The principal commercial fishing gears used to catch black sea bass and scup are trawls, fish traps, and fish pots. In the New England area, the inshore pot fishery is a mixed species fishery targeting both black sea bass and scup. Lobster, summer flounder, tautog, and conger eel commonly occur as bycatch, which are often sold.

Managers, scientists, and fishermen have expressed concern about discard levels in black sea bass and scup fisheries. Fishery regulations contribute to the discarding problem. While management measures are intended to maximize benefits to user groups and the public as well as to maintain sustainable resources, regulations such as quotas and trip limits can result in a considerable amount of discarding and associated discard mortality. The degree of regulatory-induced discards can be influenced by a variety of factors including gear design. For example, the openings of pots are designed to allow fish easy entry into the gear while precluding escape. This can result in discarding of undersize fish when minimum size regulations are in place. Growth overfishing is a potential consequence if discard mortality of those small, immature fish is high – too many small fish are captured before given a chance to grow to a substantial size and contribute to the future stock biomass, reducing the potential yield of the fishery.

Fish pots can be designed to reduce the retention of undersize fish; modifications such as escape vents can allow smaller fish to escape the gear. Factors such as size and shape of the vent will determine the composition of the catch. The ability of the gear to retain fish is a function of the gear's selectivity, which depends on various gear characteristics. Previous studies evaluating the selectivity of pots and traps have demonstrated that escape vent size can be effective in reducing retention of undersize fish (Munro 1974; Krouse and Thomas 1975; Skud 1984; Millar 1990; Treble et al. 1998). Increased escapement of smaller size fish can result in an increase in yield as fish are allowed to grow to a larger size before capture, contributing to the future fishable biomass. Allowing undersize fish to escape can also result in potentially fewer discards, which in turn reduces the incidence of discard mortality.

A quantitative evaluation of gear selectivity is necessary for understanding the effects of escape vent size on the catch composition. Empirical data describing how selection characteristics vary with changes in the size of the escape vent are especially useful to fisheries managers; development of minimum size limits (MSL) needs to consider gear selectivity in order to effectively reduce discards and reduce fishing pressure on smaller size fish. This study evaluated the effects of varying sizes of circular escape vents in fish pots on the catch efficiency and size selectivity for black sea bass and scup. The results of this study provide quantitative information that can be incorporated into considerations of gear-specific management actions (i.e. changes in escape vent size) intended to regulate the black sea bass and scup resources.

General Objective

The aim of this study was to evaluate the effects of varying the size of experimental circular escape vents on catch efficiency and size selectivity for black sea bass and scup using data collected by commercial fishing vessels operating in the New England inshore pot fishery. The experimental escape vent sizes were: 2.38-in (6.0-cm), 2.75-in (7.0-cm), 3.10-in (7.9-cm), and 3.40-in (8.6-cm).

*Specific objectives*:

(1) Evaluate the catch efficiencies of the experimental pots by statistically comparing the mean number per haul of sublegal- and legal-size black sea bass and scup retained in the experimental pots.

(2) Investigate the size selection properties of the experimental pots by:

   a. Comparing the length-frequency distributions of the catches retained in the experimental pots.

   b. Comparing the length-frequency distributions of black sea bass and scup caught in the experimental pots to the length-frequency distributions observed in the control pots and generating parameter estimates that characterize the selectivity of experimental pots with varying escape vent sizes.

## METHODS

### Fieldwork

A study of the catch efficiency and selectivity of commercial fish pots was conducted in the spring of 2002 aboard commercial fishing vessels targeting black sea bass and scup. Two vessels participated in the study, the F/V*Gale* and F/V*Long Haul*. Each vessel fished 4 strings (or trawls) of 10 pots each for a total of 40

pots. The pots were made of 1.5-in x 1.5-in vinyl coated wire mesh. They were standard black sea bass traps, i.e. a singular mesh parlor nozzle and one entry head. The pot size was 22-in (width) x 15-in (height) x 42-in (length). Four experimental circular escape vents were studied: 2.38-in, 2.75-in, 3.10-in, and 3.40-in; an unvented pot served as the control. Each pot contained 2 escape vents – one in the bottom vertical wall of the parlor section and one in the top vertical wall of the parlor section of the trap. Location of escape vents was based on known characteristic behaviors of scup and black sea bass escapement from pots; scup escape at the top and black sea bass escape at the bottomof the pot(Shepherd et al. 2002). A trawl of 10 pots contained 8 experimental pots (2 of each experimental vent size) and 2 control pots. The pots were randomly positioned along each trawl. Soak times varied from 1 to 10 days.

The catch was brought on board and then sorted by species to obtain catch composition. Fishermen measured black sea bass and scup for total length to the whole centimeter. Legal-size fish were retained by the vessel. Data were categorized into single centimeter increments, representing a range from a size smaller than the number to that number (e.g. 20-cm includes fish from 19.1 – 20.0-cm).

Analysis

*Catch Efficiency*

Catch efficiency was investigated as a function of escape vent size and fish length for black sea bass and scup. The hypotheses were as follows:

$H_0$: Escape vent size has no significant effect on the catch rate of sublegal- and legal-size black sea bass or scup in a pot.

$H_1$: Escape vent size has a significant effect on the catch rate of sublegal- and legal-size black sea bass or scup in a pot.

As the data did not follow a normal distribution, attempts were made to normalize it. First, catch was regressed against soak time and the relationship was found to be non-linear. The Shapiro-Wilk test for normality was applied to catch in numbers, catch-per-unit-effort (CPUE) where effort was soak time, and catch in numbers transformed using $\sqrt{X+0.5}$. All three types of data resulted in non-normal distributions. Therefore, non-parametric analyses of variance were used to compare catches. The mean numbers of sublegal- and legal-size black sea bass and scup caught per haul were compared using the Kruskal-Wallis non-parametric ANOVA. If a significant difference among

means was found, the Wilcoxon rank-sum test was applied to determine where significant differences were observed through a statistical pairwise comparison of means for the various vent sizes (Cody and Smith 1997).

*Size Selection*

The Kolmogorov-Smirnov (KS) two-sample test ($\alpha$ = 0.05) was used to determine whether the observed length-frequency distributions caught by the control pots were significantly different (Steel et al. 1997).

The SELECT approach was used to estimate selectivity parameters for each escape vent size (Millar 1992; Millar and Walsh 1992). This method fits a curve to the observed proportions of fish retained at each length by the experimental pot and from this curve a selection curve is derived (Cadigan and Millar 1992; Millar and Fryer 1999). The SELECT model assumes that the observed number of fish caught in the experimental pot is binomially distributed with probability:

$$\phi(l)_e = \frac{r(l)}{1 + r(l)}$$

where $r(l)$ represents the contact-selection (or *retention*) curve (Millar and Fryer 1999).

The retention probability $r(l)$ is the probability that a fish of length $l$ is captured given that it contacted the gear. The catch retained by the control pot is assumed to represent the range of size compositions encountered by the control and experimental gears. So, the selectivity of the control pot is assumed to be unity ($r_C$ = 1) over the range of lengths encountered (Millar 1992; Millar and Fryer 1999). The probability that a fish enters and is retained by an experimental pot was described by a logistic function:

$$r(l)_e = \frac{e^{(a+bl)}}{1 + e^{(a+bl)}}$$

where $r(l)_e$ represents the selection curve of the experimental pot and $a$ and $b$ represent the slope and intercept, respectively.

Relative fishing efficiency, $p$, was assumed to be equal for the experimental and control pots ($p$ = 0.5). The SELECT method does allow the option of assuming unequal efficiency between the pots, though preliminary analyses suggested the equal $p$ assumption was adequate (Cadigan and Millar 1992; Millar 1992; Millar and Walsh 1992; Wileman et al. 1996; Millar and Fryer 1999; Mous et al. 2002).

The parameters $a$ and $b$ were estimated by maximizing the log-likelihood, $L$:

$$L = \sum_l n(l)_e \ln[\phi(l)] + n(l)_c \ln[1 - \phi(l)]$$

where $n(l)_e$ and $n(l)_c$ are the number of fish at length $l$ that were caught in the experimental and control pot, respectively.

Additional parameters were calculated to characterize the selection of fish in each experimental pot. The length at 25% retention ($L_{25}$), length at 50% retention ($L_{50}$), length at 75% retention ($L_{75}$), selection range ($SR$), and the selection factor ($SF$) were computed as:

$$L_{25} = \frac{-a - \ln(3)}{b} \qquad L_{50} = -\frac{a}{b} \qquad L_{75} = \frac{-a + \ln(3)}{b}$$

$$SR = L_{75} - L_{25} \qquad SF = \frac{L_{50}}{meshsize}$$

**RESULTS**

Four experimental pots were investigated with various circular escape vent sizes (2.38-in, 2.75-in, 3.10-in, and 3.40-in) during the period June to August 2002. The F/V *Gale* conducted 15 days of fishing and the F/V *Long Haul* conducted 14 days of fishing. The vessels fished the inshore coastal waters off Rhode Island and Massachusetts (Figure 1). A total of 1158 (out of 1160) trap hauls were made. One pot was lost and replaced the next fishing day and therefore was not fished for 2 days resulting in 2 lost trap hauls.

The proportion of fish at length observed in the control and experimental pots are shown in Figures 2 and 3. A total of 2,351 black sea bass and 4,451 scup were captured and measured in this study. The observed

size ranges for black sea bass and scup were 9 – 53-cm and 6 – 49-cm, respectively.

The results of the KS analyses indicated no significant difference (*D*-statistic < critical value) between the length-frequency distributions of samples observed in the control pots for both species. This suggests that the observed catches were sampled from a similar length distribution. Figures 2 and 3 illustrate the similarity of the length distributions observed in the control pots for black sea bass and for scup via visual comparison.

The results of the Kruskal-Wallis test detected significant differences ($p < 0.05$) among the mean numbers of sublegal- and legal-size black sea bass and scup caught per haul in the experimental pots (Tables 1 and 2). The Mann-Whitney U-test revealed that the mean number of sublegal-size black sea bass caught by the 2.38-in vent was significantly larger ($p < 0.05$) from the means observed in the 2.75-in, 3.10-in, and 3.40-in escape vents (Table 1). There was no significant difference between the mean catches observed in the 2.75-in and 3.10-in vents, but the 2.75-in retained significantly more sublegal-size black sea bass than the 3.40-in escape vent. The mean numbers caught per haul by the 3.10-in and 3.40-in did not differ significantly. The 2.38-in and 2.75-in vents did not differ significantly in catches of legal-size black sea bass. However, the 2.38-inand 2.75-in vents did retain significantly more legal-size black sea bass than both the 3.10-in and 3.40-in vents. Mean catches by the 3.10-in and 3.40-in vents did not differ significantly.

For sublegal-size scup, the mean number caught per haul by the 2.38-in vent did not differ significantly from the 2.75-in escape vent (Table 2). The 2.38-in and 2.75-in escape vents retained significantly more sublegal-size scup than the 3.10-in and 3.40-in vents. The mean numbers per haul caught by the 3.10-in vent were significantly larger than the 3.40-in vent. The mean numbers of legal-size scup caught by the 2.38-in vent did not differ significantly from the mean number caught by the 2.75-in and 3.10-in escape vent. However, the mean number caught per haul by the 2.38-in escape vent was significantly greater than the mean catches observed in the 3.40-in escape vent. The

mean number caught by the 2.75-in vent did not differ from the mean observed in the 3.10-in vent but did catch significantly more than the 3.40-in escape vent. Mean catches for the 3.10-in were significantly larger than the 3.40-in vents.

The SELECT statistical model was applied to the observed length-frequency data to generate selectivity curves for black sea bass and scup for all experimental vent sizes (Figures 4 and 5). Estimated and derived parameter values are presented in Tables 3 and 4. Estimates of length at 50% retention length for black sea bass ranged from 19.4 – 35.3-cm and increased with increasing vent size (Table 3). The $L_{25}$ estimates for the 3.40-in escape vent ($L_{25}$ = 28.2-cm) is similar to the current minimum size limit (MSL = 28.0-cm; Figures 4 and 6). Overall retention probabilities for black sea bass at lengths less than the MSL (< 28.0-cm) were generally lower as vent size increased (Figure 4). The model predicted little difference between the 2.38-in and 2.75-in escape vents in the retention probabilities at lengths considered to be legal-size (≥ 28.0-cm) for black sea bass. Increasing to the 3.10-in and 3.40-in vent sizes demonstrated progressive decreases in the retention probabilities at lengths for legal-size black sea bass (≥ 28.0-cm).

Selectivity parameter estimates for scup observed in the experimental vents tended to be less than the corresponding parameter estimates for black sea bass for each vent size (Table 4). For example, the $L_{50}$ estimated for scup observed in the 2.75-in vent was 17.0-in (Figure 7), while the $L_{50}$ estimate for black sea bass was 26.0-in. The $L_{75}$ estimate for the 3.10-in vent ($L_{75}$ =23.2-cm) and the $L_{50}$ estimated for the 3.40-in escape vent ($L_{50}$ = 23.5-cm) were similar to the current minimum size limit for scup (MSL = 23.0-cm; Figures 5 and 7). Like black sea bass, estimates of length at retention increased with increasing vent size (Table 4). Selection curves suggested a general decrease in the retention probabilities at lengths less than the current MSL with increasing vent size (Figure 5). Retention probabilities for scup at lengths larger than the current MSL for the three smallest vents were near or equal to 100%, while increasing to the largest vent size (3.40-in) showed the only appreciable decrease in retention probabilities at lengths of

legal-size scup (≥ 23.0-cm).

There was a noticeable difference in the steepness of the selection curves between the two species. The selection range (*SR*) parameter describes the steepness of a size selectivity curve. Estimated selection ranges were consistently larger for black sea bass than for scup (Tables 3 and 4; Figures 4-7). The selectivity curves predicted for scup were markedly steeper than those predicted for black sea bass. Selection factor (*SF*) increased with increasing vent size for both species (Tables 3 and 4).

**DISCUSSION**

Implementing measures to restrict discarding are needed in order to reduce discard mortality. As part of a comprehensive management program, such measures can provide long-term benefits including an increase in fishery yield, spawning stock biomass, and improved economic efficiency. The MAFMC management plan for black sea bass and scup includes objectives to improve fishery yield and to improve spawning stock biomass by reducing fishing mortality on immature fish (MAFMC 1998). Currently, both the black sea bass and scup fisheries are in the midst of a rebuilding program; meeting these management objectives would benefit the fishery and fishermen that rely on it. Modifying gears to increase escapement of immature fish requires understanding of the gear's selectivity in order to be effective. Quantifying the selection properties of fish pots – one of the principle gears used in the harvest of black sea bass and scup – could provide managers with an analytical basis for recommending regulations on fishing gear.

The effectiveness of escape vents size can be evaluated by comparing the catch efficiency of sublegal- and legal-size fish among different gear configurations (DeAlteris and Castro 1991). A study by Shepherd et al. (2002) found that while increasing vent size reduced the number of sublegal-size black sea bass, catches of legal-size fish also decreased. The current study found similar results – increasing the escape vent size showed some significant decreases in the catch of sublegal-size black sea bass but in most cases this was coupled with a significant loss of legal-size fish. The catch efficiency analysis showed that using vent sizes larger than 2.75-in resulted in the loss of legal-size black sea bass, even though there was a reduction in sublegal-size fish. For

scup, increasing to the two largest vent sizes showed significant reduction in catch of sublegal-size fish. However, using the largest vent size compromised the catch of legal-size scup. These results are consistent with the predicted selection curves. The selectivity curves estimated for black sea bass showed that retention probabilities for legal-size fish were noticeably lower for vent sizes larger than 2.75-in. Predicted retention probabilities for scup by the largest vent size were markedly lower than for the three smaller vent sizes. Catch of sublegal-size black sea bass and scup could be reduced by increasing the vent size (Table 5). However,the catch efficiency of legal-size fish could also be significantly reduced as selection curves predicted lower retention probabilities of larger size fish with the larger vent sizes.

The modeling approach assumes that control and experimental gears sampled from populations with similar length distributions. If the gear variations under consideration sample from populations with different length distributions, then comparisons will be trivial; apparent differences in the selection properties of various experimental gears may be a consequence of differences in the size composition of the populations being sampled. The results indicated that the control fish pots sampled from the same size distribution for both species; this suggests that the size composition encountered by the various experimental vent sizes were similar.

Increasing the escape vent size resulted in different trends for black sea bass and scup, not only for the catch efficienciesbut also forthe size selectivities. Selection curves are used to evaluate the probability that fish of a given length are retained. Implementing minimum size limits and gear regulations based on selectivity data can reduce harvest pressure on undersize fish, which has long-term benefits for the resource and the fishery. The selectivity curves estimated in this study suggest that increasing the escape vent size increases the size at which the fish have a 25, 50, or 75% chance of being retained. Estimates of $L_{25}$, $L_{50}$, and $L_{75}$ sometimes serve as a basis for setting MSL. For black sea bass, the $L_{50}$ estimated for the two larger escape vents was greater than the current minimum size limit for the commercial fishery (MSL = 28.0-cm). With the exception of the largest vent, the $L_{25}$ values estimated for black sea bass observed in the experimental vents were less than the MSL. For scup, the $L_{25}$ and $L_{50}$ estimates for each of the experimental vents were almost always below the current commercial MSL (MSL=23.0-cm). The one

exception was the $L_{50}$ estimate for the largest vent, which was very similar to the MSL ($L_{50,\ 3.40\text{-in}}$ = 23.5-cm).

The size at which the species of interest becomes sexually mature is another consideration when setting a MSL to further ensure protection of immature fish. The selectivity parameters estimated for black sea bass suggest that most black sea bass are at or near maturity when caught in any of the escape vent sizes evaluated here. Estimates of $L_{50}$ and $L_{75}$ generally exceeded the length at 50% maturity ($L_{50\%\ \text{maturity}}$ = 19.0cm). The only exception was the $L_{50}$ value estimated for the 2.38-in vent size, which was slightly larger then the 50% maturity length ($L_{50,\ 2.38\text{-in}}$ = 19.4-cm). The estimated selectivity curves suggest that the majority of scup caught by the two smallest escape vents have not reached sexual maturity. Scup reach maturity at a total length of 17.5-cm for females and 17.6-cm for males (O'Brien et al. 1993; Froese and Pauly 2003). These sizes exceed the $L_{75}$ estimated for the 2.38-in vent ($L_{75,\ 2.38\text{-in}}$ = 16.4-cm) and fall between the $L_{50}$ and $L_{75}$ values estimated for the 2.75-in escape vent ($L_{50,\ 2.75\text{-in}}$ = 17.0-in; $L_{75,\ 2.75\text{-in}}$ = 18.5-cm). That is, the model estimates suggest that scup that have not reached sexual maturity have a high probability of being retained by the smaller experimental vents. Gears can be modified to facilitate compliance with MSL regulations by reducing the retention of those undersize fish. However, adapting gears to the MSL does not guarantee that smaller size fish won't be caught and so cannot be effective if mortality on the discarded fish is high. Mortality of larger size fish is another consideration, as reducing the exploitation of small fish without increasing the mortality of larger fish is predicted to improve equilibrium yield in the fishery (Beverton and Holt 1957).

The results presented here clearly demonstrate that gear selectivity is species-specific. Differences were observed in overall selection patterns among vent sizes for black sea bass and scup. The sharpness, or steepness, of a selectivity curve is measured by the selection range (*SR*) parameter. A larger *SR* indicates a steeper, more selective curve. A visual inspection of selection curves allows a quick comparison of steepness. Here, the *SR* estimates for scup were consistently smaller than those for black sea bass over all vent sizes evaluated and so, expectedly, the selectivity curves predicted for scup were markedly steeper than those predicted for black sea bass. This suggests that fish pots with vents of the sizes investigated here are more selective for scup than black sea bass. That is, the predicted size range of scup caught in these fish pots is narrower than the size range of black sea bass.

The results of this project could be incorporated into stock assessment models for these species or considered in development of a management program that includes gear regulations. Designing or modifying gear to select for larger sizes of black sea bass and scup should improve the economic return to the industry while improving the sustainability of the stocks. Varying escape vent size clearly has different

effects between the species and this variation needs to be considered when determining the maximum benefits associated with proposed regulations.

In addition to gear selectivity, the exploitation pattern of a fishery is influenced by factors such as the time of year, areas that are fished, and the species life history (e.g. migration patterns). For these reasons, interpreting selectivity estimates requires consideration of the experimental design and the assumptions of the model(s) used to estimate selection parameters.

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**Table 1.** Results of the Kruskal-Wallis test ($\alpha$ = 0.05) for differences among the mean numbers-per-haul of black sea bass observed in the experimental pots with the Mann-Whitney U-test results.

ublegal-size (< 28.0 cm)

Kruskal-Wallis Test

| | |
|---|---|
| Chi-square | 120.14 |
| df | 4 |
| p-value | <0.0001 |

Mann-Whitney U-test (df=1)
chi-square (p-value)

| | **2.75"** | **3.10"** | **3.40"** |
|---|---|---|---|
| **2.38"** | 25.94 (p<0.0001) | 39.09 (p<0.0001) | 48.74 (p<0.0001) |
| **2.75"** | | 2.54 (p=0.1111) | 5.25 (p=0.0219) |
| **3.10"** | | | 0.44 (p=0.5057) |

egal-size (≥28.0-cm)

Kruskal-Wallis Test

| | |
|---|---|
| Chi-square | 19.61 |
| df | 4 |
| p-value | 0.0006 |

Mann-Whitney U-test (df = 1)
chi-square (p-value)

| | **2.75"** | **3.10"** | **3.40"** |
|---|---|---|---|
| **2.38"** | 0.02 (p=0.8903) | 4.98 (p=0.0257) | 12.76 (p=0.0004) |
| **2.75"** | 5.51 (p=0.0189) | 13.51 (p=0.0002) | |
| **3.10"** | 1.31 (p=0.2520) | | |

**Table 2.** Results of the Kruskal-Wallis test ($\alpha$ = 0.05) for differences among the mean numbers-per-haul of scup observed in the experimental pots with the Mann-Whitney U-test results.

Sublegal-size (< 23.0 cm)

Kruskal-Wallis Test

| | |
|---|---|
| Chi-square | 200.47 |
| df | 4 |
| p-value | <0.0001 |

Mann-Whitney U-test (df = 1)
chi-square (p-value)

| | **2.75"** | **3.10"** | **3.40"** |
|---|---|---|---|
| **2.38"** | 2.91 (p=0.0881) | 71.94 (p<0.0001) | 134.86 (p<0.0001) |
| **2.75"** | | 52.09 (p<0.0001) | 114.98 (p<0.0001) |
| **3.10"** | | | 24.52 (p<0.0001) |

Legal-size (≥23.0-cm)

Kruskal-Wallis Test

| | |
|---|---|
| Chi-square | 28.22 |
| df | 4 |
| p-value | <0.0001 |

Mann-Whitney U-test (df = 1)
chi-square (p-value)

| | **2.75"** | **3.10"** | **3.40"** |
|---|---|---|---|
| **2.38"** | 0.0008 (p=0.9780) | 3.10 (p=0.0782) | 7.49 (p=0.0062) |
| **2.75"** | 3.65 (p=0.0561) | 8.47 (p=0.0036) | 21.06 (p<0.0001) |
| **3.10"** | | | |

**Table 3.** Summary of selectivity parameter estimates for black sea bass observed in the pot escape vent experiment.

| | Escape Vent Size | | | |
|---|---|---|---|---|
| | 2.38" | 2.75" | 3.10" | 3.40" |
| $L_{25}$ (cm) | 13.2 | 21.4 | 23.1 | 28.2 |
| (*inches*) | 5.2 | 8.4 | 9.1 | 11.1 |
| $L_{50}$ (cm) | 19.4 | 26.0 | 29.7 | 35.3 |
| (*inches*) | 7.6 | 10.2 | 11.7 | 13.9 |
| $L_{75}$ (cm) | 25.7 | 30.6 | 36.4 | 42.4 |
| (*inches*) | 10.1 | 12.0 | 14.3 | 16.7 |
| *SR* | 12.5 | 9.2 | 13.2 | 14.2 |
| *SF* | 3.2 | 3.7 | 3.8 | 4.1 |

**Table 4.** Summary of selectivity parameter estimates for scup observed in the pot escape vent experiment.

| | Escape Vent Size | | | |
|---|---|---|---|---|
| | 2.38" | 2.75" | 3.10" | 3.40" |
| $L_{25}$ (cm) | 13.5 | 15.4 | 17.6 | 19.9 |
| (*inches*) | 5.3 | 6.1 | 6.9 | 7.9 |
| $L_{50}$ (cm) | 14.9 | 17.0 | 20.4 | 23.5 |
| (*inches*) | 5.9 | 6.7 | 8.0 | 9.2 |
| $L_{75}$ (cm) | 16.4 | 18.5 | 23.2 | 27.0 |
| (*inches*) | 6.4 | 7.3 | 9.1 | 10.6 |
| *SR* | 2.9 | 3.1 | 5.5 | 7.0 |
| *SF* | 2.5 | 2.4 | 2.6 | 2.7 |

**Table 5.** Visual interpretation of catch efficiency results for black sea bass and scup.

| Black Sea Bass | 2.75" | | 3.10" | | 3.40" | |
|---|---|---|---|---|---|---|
| | Sublegal | Legal | Sublegal | Legal | Sublegal | Legal |

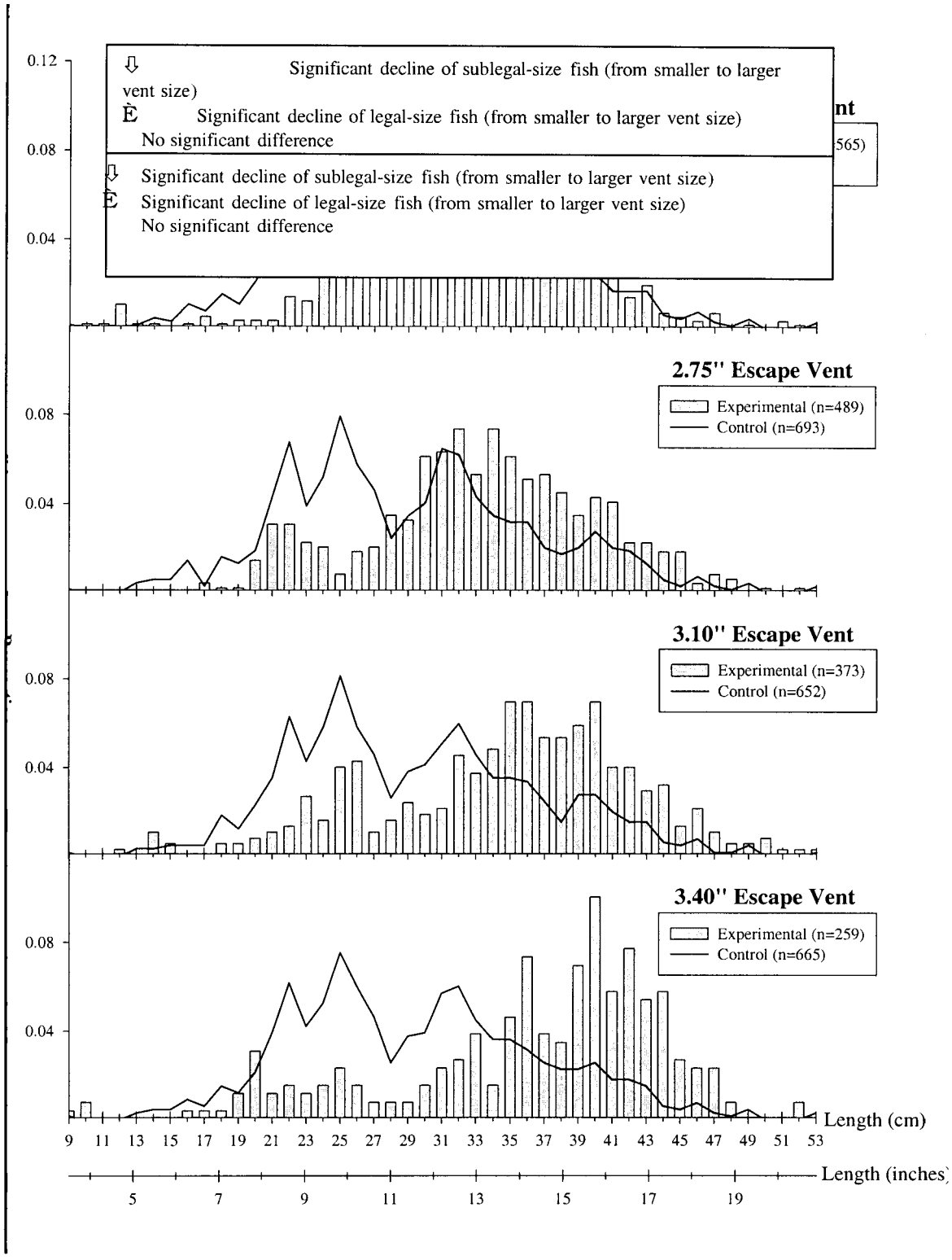
2.38" ⇩ ⇩ ◡ ⇩ ◡ 2.75" ◡ ⇩ ◡ 3.10"

| **Scup** | **2.75"** | | **3.10"** | | **3.40"** | |
|---|---|---|---|---|---|---|
| | **Sublegal** | **Legal** | **Sublegal** | **Legal** | **Sublegal** | **Legal** |

**2.38"** ⇩ ⇩ È **2.75"** ⇩ ⇩ È **3.10"** ⇩ È

⇩ Significant decline of sublegal-size fish (from smaller to larger vent size)
⇧ Significant decline of legal-size fish (from smaller to larger vent size)
No significant difference

**Figure 1.** Location of sites fished by the F/V *Gale* and F/V *Long Haul* in the spring of 2002; these vessels collected data used to evaluate the effect of varying the size of experimental circular escape vents in commercial fish pots.


Significant decline of sublegal-size fish (from smaller to larger vent size)
Significant decline of legal-size fish (from smaller to larger vent size)
No significant difference
Significant decline of sublegal-size fish (from smaller to larger vent size)
Significant decline of legal-size fish (from smaller to larger vent size)
No significant difference
nt
565)
2.75" Escape Vent
Experimental (n=489)
Control (n=693)
3.10" Escape Vent
Experimental (n=373)
Control (n=652)
3.40" Escape Vent
Experimental (n=259)
Control (n=665)
0.12
0.08
0.04
Length (cm)
9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53
Length (inches)
5 7 9 11 13 15 17 19

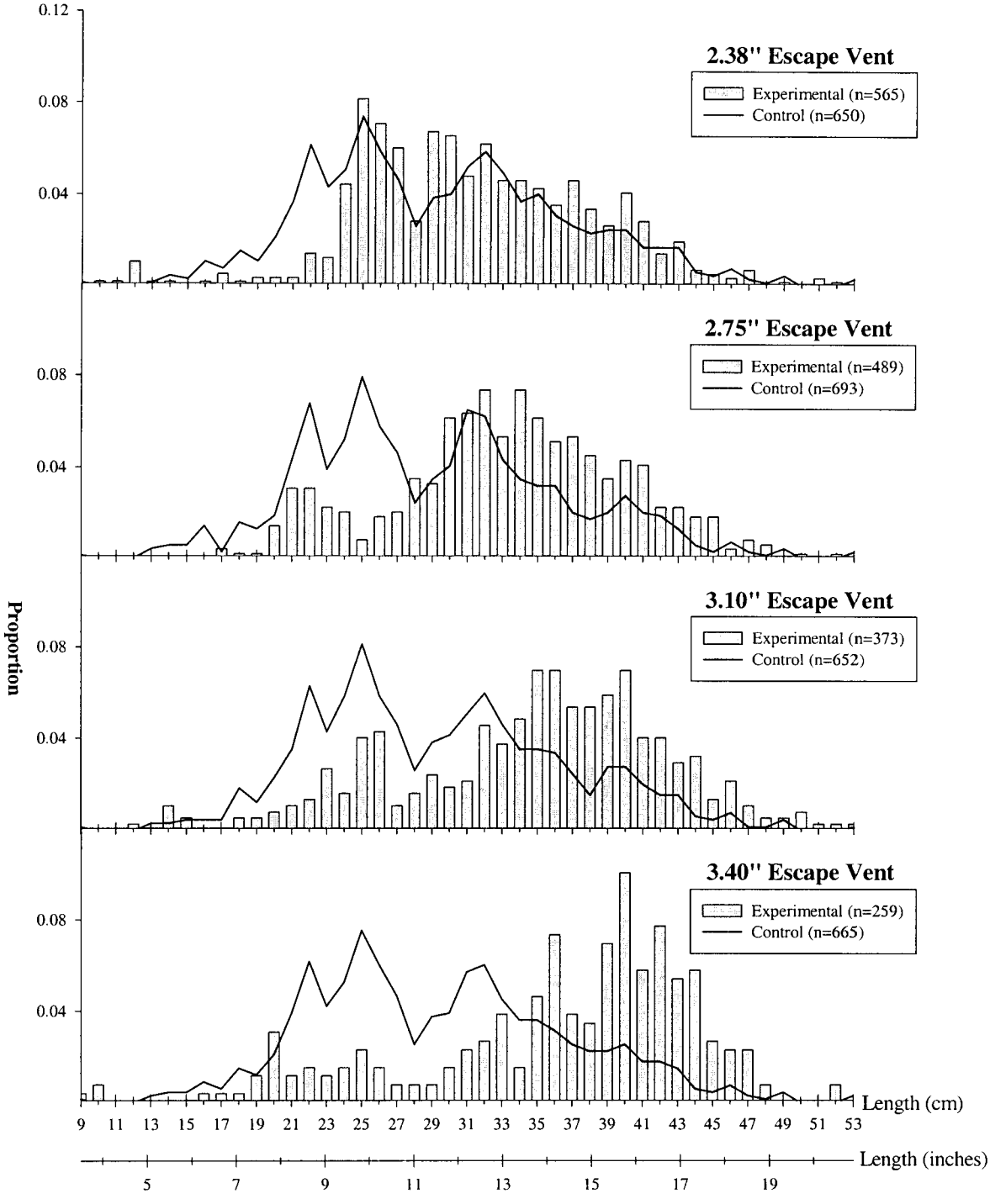

2.38" Escape Vent
Experimental (n=565)
Control (n=650)
2.75" Escape Vent
Experimental (n=489)
Control (n=693)
3.10" Escape Vent
Experimental (n=373)
Control (n=652)
3.40" Escape Vent
Experimental (n=259)
Control (n=665)
Proportion
0.12
0.08
0.04
Length (cm)
9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53
Length (inches)
5 7 9 11 13 15 17 19

**Figure 2.** Length-frequency distributions of black sea bass observed in control fish pots (no vent opening) and experimental fish pots with varying escape vent sizes. The lines represent distributions for the control fish pots and bars represent distributions for the experimental pots.

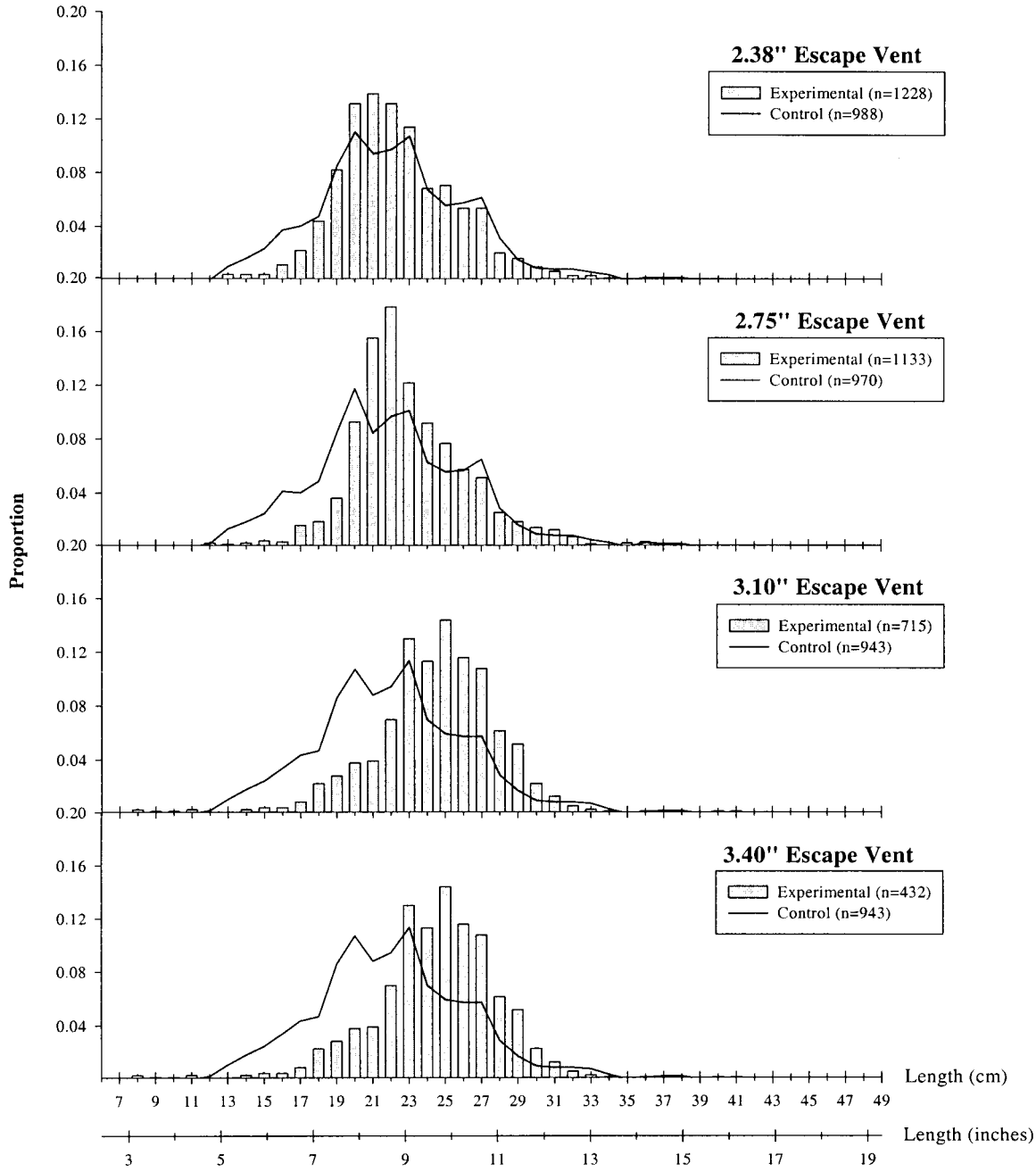

2.38" Escape Vent
Experimental (n=1228)
Control (n=988)
2.75" Escape Vent
Experimental (n=1133)
Control (n=970)
3.10" Escape Vent
Experimental (n=715)
Control (n=943)
3.40" Escape Vent
Experimental (n=432)
Control (n=943)
Proportion
0.20
0.16
0.12
0.08
0.04
Length (cm)
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Length (inches)
3 5 7 9 11 13 15 17 19

**Figure 3.** Length-frequency distributions of scup observed in control fish pots (no vent opening) and experimental fish pots with varying escape vent sizes. The lines represent distributions for the control fish pots and bars represent distributions for the experimental pots.

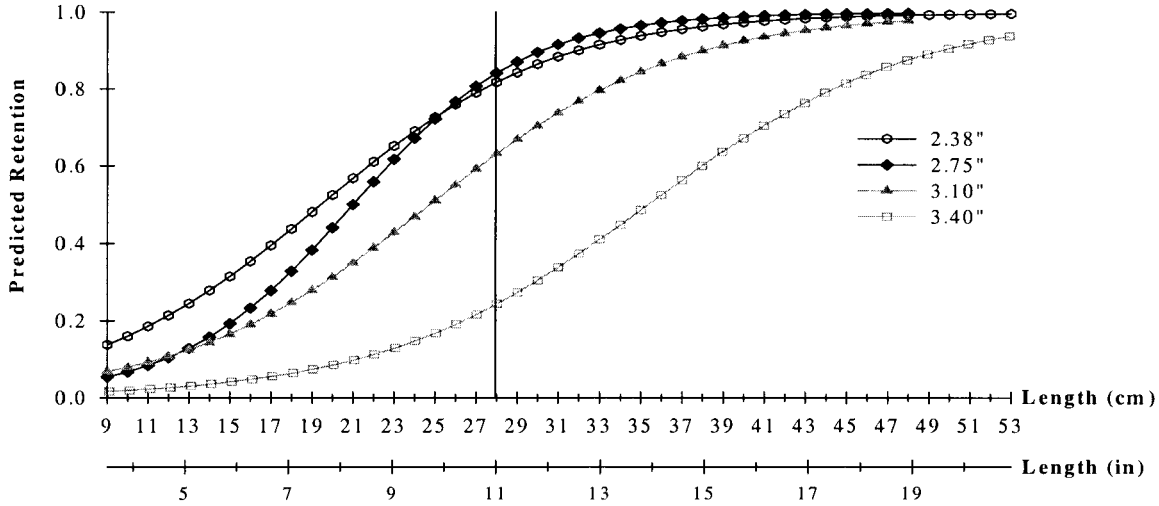



**Figure 4**. Predicted selection curves for black sea bass. Solid line represents current minimum size limit (MSL = 28.0-cm *or* 11.0-in).

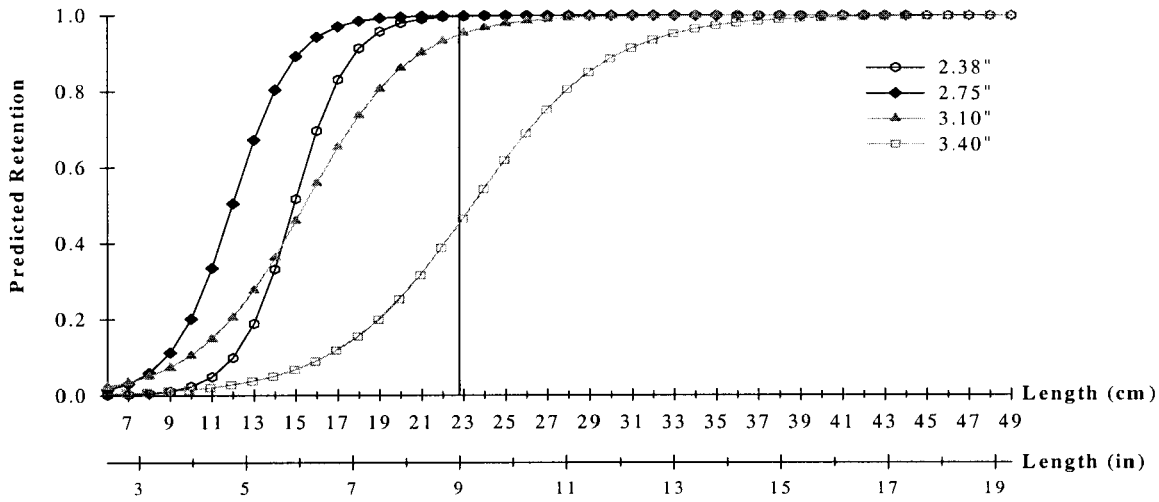



**Figure 5**. Predicted selection curves for scup. Solid line represents current minimum size limit (MSL = 23.0-cm *or* 9.0-in).

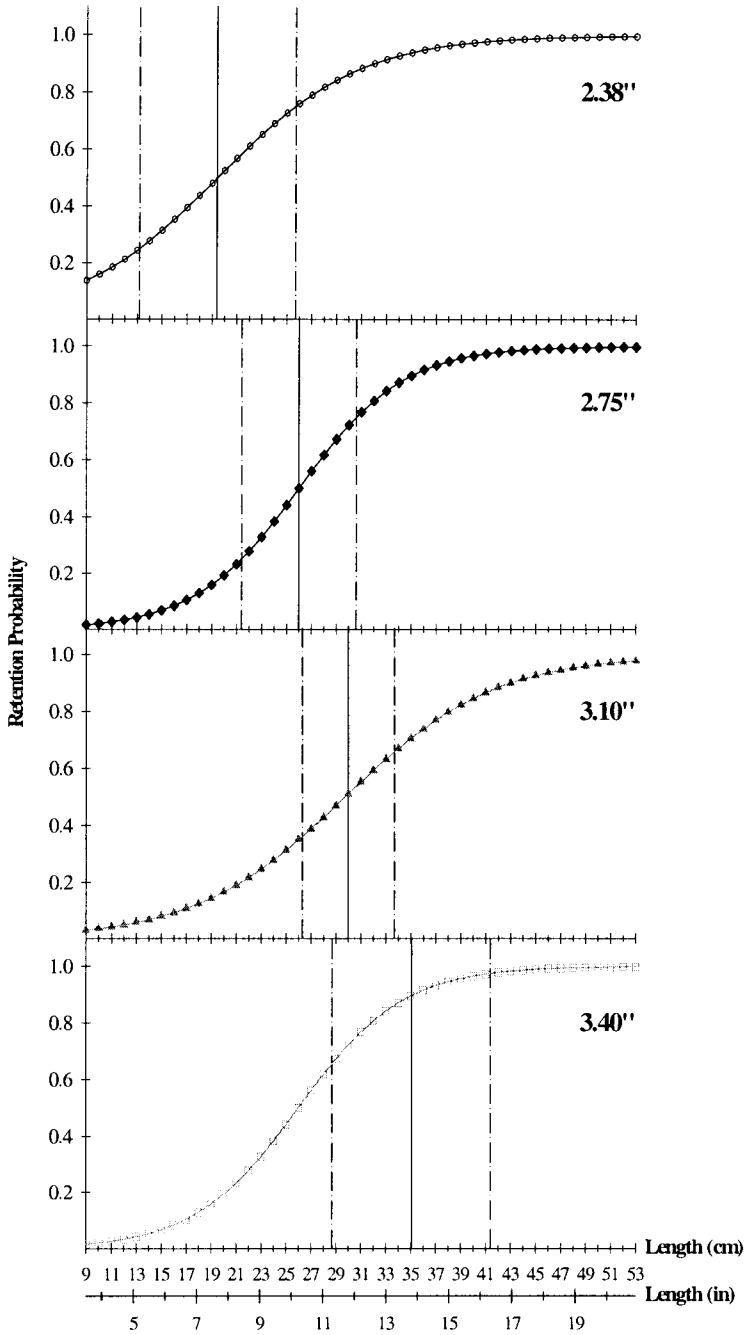
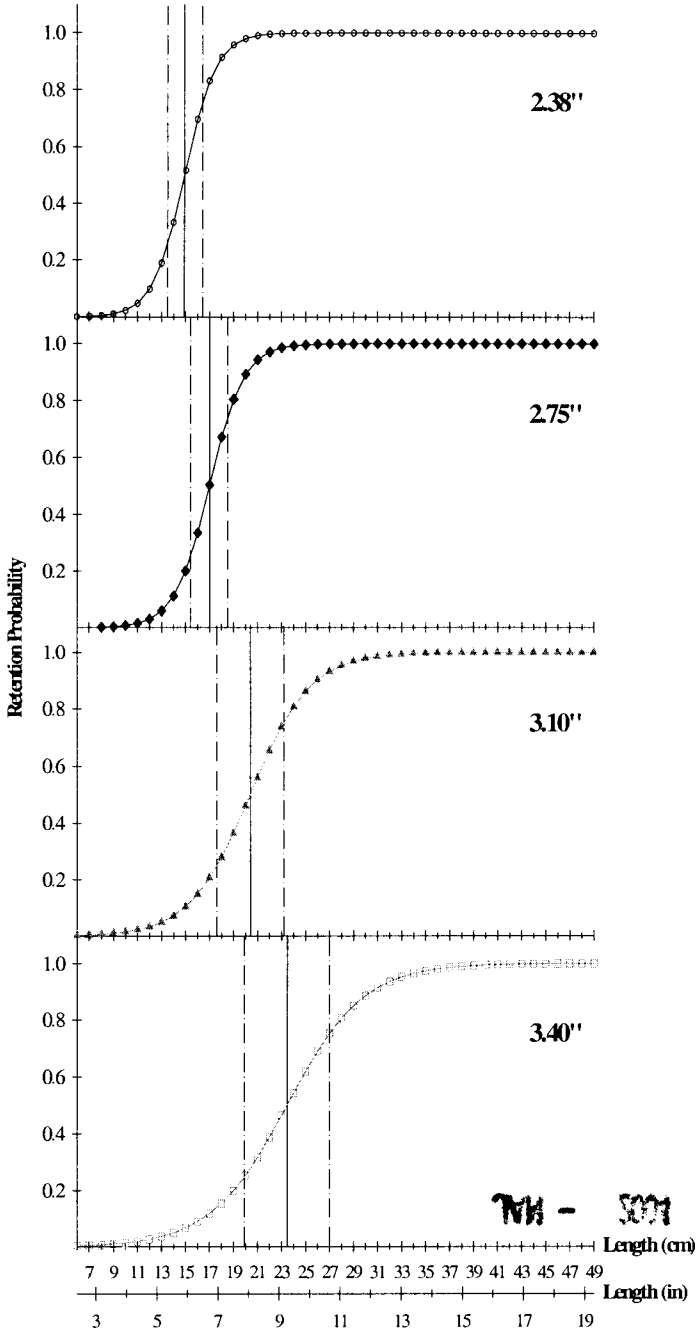

Retention Probability
1.0
0.8
0.6
0.4
0.2
2.38"
2.75"
3.10"
3.40"
Length (cm)
9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53
Length (in)
5 7 9 11 13 15 17 19

**Figure 6.** Predicted selection curves for black sea bass. The reference lines indicate the lengths at 25%, 50%, and 75% retention that were estimated for each experimental codend. The solid line represents $L_{50}$ with dashed-dotted lines denoting $L_{25}$ and $L_{75}$ to the left and right, respectively.

**Figure 7.** Predicted selection curves for scup. The reference lines indicate the lengths at 25%, 50%, and 75% retention that were estimated for each experimental codend. The solid line represents $L_{50}$ with dashed-dotted lines denoting $L_{25}$ and $L_{75}$ to the left and right, respectively.


Retention Probability
1.0
0.8
0.6
0.4
0.2
2.38"
2.75"
3.10"
3.40"
Length (cm)
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Length (in)
3 5 7 9 11 13 15 17 19