CHARACTERIZATION OF BYCATCH REDUCTION FROM CODEND MESH SIZE INCREASES IN THE DIRECTED SCUP BOTTOM TRAWL FISHERY

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May 2004

URI FISHERIES CENTER TECHNICAL REPORT: 01-04

Sea Grant
Rhode Island

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INTRODUCTION

Scup, *Stenotomus chrysops*, are a schooling species that occur in temperate waters on the continental shelf (Morse 1978). Along the Atlantic coast, the scup population are considered to be two stocks, the Middle Atlantic Bight and the South Atlantic Bight. The Middle Atlantic Bight population was once considered to be two separate stocks but the evidence is weak and therefore the concept of a single stock extending from Cape Hatteras, North Carolina north to Cape Cod, Massachusetts is now supported (Pierce 1981; Mayo 1982).

Scup utilize a variety of benthic habitats from open water to structured areas for feeding as well as for shelter (Steimle et al. 1999). Scup undergo extensive seasonal migrations, moving in response to changes in water temperature. In the winter, with the decline of inshore water temperatures, scup move from estuaries to warmer waters on the continental shelf. Then in the spring when water temperatures rise, they move back inshore (Morse 1978; Bowman et al. 1987). During the inshore migration, larger scup tend to arrive first, followed by waves of smaller fish (Neville and Talbot 1964; Sisson 1974).

Sexual maturity occurs approximately by age 2 and about 50% are sexually mature at a total length of around 17-cm (O'Brien et al. 1993); spawning occurs during the summer months (Terceiro 2001). Scup attain a maximum size of about 40-cm (fork length) and ages of up to 20 years have been reported (Dery and Rearden 1979; Crecco et al. 1981).

Scup support important commercial and recreational fisheries. They are jointly managed by the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC) under the MAFMC Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP). The principal commercial fishing gears used to catch scup are trawls as well as fish traps and fish pots. Management measures include a moratorium on commercial permits, annually adjustable commercial trawl mesh and minimum size restrictions, commercial quotas, recreational harvest limits, recreational minimum size and possession limit restrictions, and a fishing mortality rate reduction strategy (Terceiro 2001).

In order for the production of fishery resources to be optimized, effort has to be established to ensure that resources are harvested efficiently and in a sustainable manner. Reduction of bycatch is important for many reasons. One is the sustainability of the stock; looking out for the future stocks. Another is the quality of fish. Smaller bags of fish cause less damage resulting in more desirable fish in the marketplace (Mattera 1996).

Groundfish resources in the Northeast occur in mixed-species aggregations, resulting in significant bycatch interactions among fisheries directed to particular target species or species groups. Due to these interactions, management becomes complex. In addition to the target species, other fish caught that have some economic value will most likely be landed as well. Therefore, management approaches need to consider technological interactions that aid in effective conservation measures (Shepherd and Terceiro 1994). In the past, management strategies resulted in yields of certain species to be compromised due to the nature of the mixed-target fisheries. In order to develop management plans that maximize landings and minimize discards from mixed-species assemblages, understanding the role of various factors that impact discard rates is important. These include technical factors such mesh size and tow duration as well as oceanographic and biological factors (Murawski 1996).

Research on mesh studies have been investigated for a variety of species. However, limited amount of research has been conducted on scup and little information is available on the bycatch characterization of different mesh sizes in the directed scup fishery. In the scup fishery, decreasing quotas and an improving stock with increasing abundance results in discards of scup. In addition, bycatch of other species needs to be reduced. Increasing mesh size is an effective method to accomplish both. The increase of mesh size has many benefits. These include the reduction of discards of undersized fish and reduced catch of non target species caught incidentally. The mean size of fish caught will be increased with increasing mesh size. Therefore, going to a larger mesh will allow more fish to grow to a larger size which has the direct benefit of increasing the overall yields of the resource. In addition, increases in spawning potential and future year class strengths may result from an increase in the age groups and numbers of fish (Smolowitz 1983).

General Objective

The objective of this study is to characterize the bycatch in the directed bottom trawl scup fishery for the current regulated codend mesh size and two experimental codend mesh sizes. In addition, the bycatch composition will be evaluated.

METHODS

Fieldwork

A study of bottom trawl scup bycatch characterization was conducted during the fall of 2003 aboard commercial fishing vessels. Two vessels participated in the study, the F/V *Deborah Lee* and F/V *Grandville Davis*. The alternate tow method was used with experimental codend mesh sizes of 6.0-in and 6.5-in square shaped meshes, and a control codend that was the current regulated codend mesh size for scup (4.5-in diamond for 25 meshes with 100 meshes of 5.0-in immediately forward of the 4.5-in). The mesh sizes of the experimental codends were verified using three methods. These included the Massachusetts Division of Marine Fisheries (MADFM) mesh gauge, also known as the MARFISH, the International Council for the Exploration of the Sea (ICES) mesh gauge, and the National Marine Fisheries Service (NMFS) wedge gauge. There were no differences in measurements between the methods. Tow duration was 20 minutes.

Two sea samplers from the University of Rhode Island Fisheries Center were onboard each vessel to measure and weigh fish. The catch was brought on board, then sorted and weighed by species. Due to the large size of some catches, random subsampling of the catch was conducted. Subsamples were no less than 10% of the total catch. Scup were measured for total length to the whole centimeter. 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 codend mesh size and numbers of fish, fish length, and fish weight. The hypotheses were was follows:

> H_0: Codend mesh size has no significant effect on the catch rate of sublegal- and legal-size scup.
>
> H_0: The mean size of scup in the control and experimental codends is the same.
>
> H_0: The mean weight of bycatch in the control and experimental codends is the same.

A one-way ANOVA ($\alpha = 0.05$) was performed to test for a difference among the mean proportion of fish caught with each experimental mesh codend (Zar 1999). The mean proportion in number per tow of sublegal (< 22.9-cm) and legal (≥ 22.9-cm) scup caught by each experimental codend were examined, where mesh size was considered a factor. Proportion was calculated as the number of sublegal- or legal-size scup divided by the total number of scup. Analysis was performed on proportions which were transformed using the angular or arcsine transformation. The arcsine transformation finds $\theta = \arcsin\sqrt{p}$, where p is a proportion (Sokal and Rohlf 1995). The analysis was also conducted with vessel, date, and tow number as factors. If a significant difference was detected, the Tukey HSD test ($\alpha = 0.05$) was applied to determine where significant differences were observed through statistical pairwise comparison of values for the experimental mesh codends. An ANOVA was also performed on mean length of scup as well as proportion by weight of summer flounder, winter flounder, and black sea bass.

The Kolmogorov-Smirnov (KS) two-sample test ($\alpha = 0.05$) was used to evaluate length-frequency distributions for catches of scup between all codend mesh sizes. The hypothesis was:

> H_0: No difference in the length-frequency distribution of scup in the control and experimental codends.

The KS test is a nonparametric test that tests differences between two distributions (Sokal and Rohlf 1995). The null hypothesis is identity in distribution for the two samples and thus the test is sensitive to differences in location, dispersion, skewness, and so forth. The test is based on the unsigned differences between the relative cumulative frequency distributions of the two samples. Comparison between observed and expected values leads to decisions whether the maximum difference between the two cumulative frequency distributions is significant (Sokal and Rohlf 1995).

Size Selection

Absolute selectivity parameters of the codends could not be determined due to the lack of a small mesh control. However, relative selectivity parameters can be estimated and will be analyzed in the future. The parameters to be determined will be the difference (ΔL_{50} and ΔSR) in selectivity between the regulated and experimental codends (Revill and Holst in press). This analysis was not included in the original proposal.

RESULTS

Two experimental codends were investigated, 6.0-in and 6.5-in square mesh, during the period October to December 2003. The F/V *Deborah Lee* conduced 8 days of trawling and the F/V *Grandville Davis* conducted 4 days. The vessels fished the waters off the coast of Rhode Island and Block Island (Figure 1). There were a total of 24 paired tows for the 6.0-in square mesh codend and 25 paired tows for the 6.5-in square mesh codend.

The proportion of fish at length observed in the control and experimental mesh codends are shown in Figure 2. A total of 14,794 scup were measured in this study: 3,109 in the 6.0-in square, 3,735 in the 6.5-in square shaped mesh codend, and 7,951 in the control codend. The observed size range for scup was 10 – 40-cm.

The results of the ANOVA indicated that there was a significant difference among the mean proportion of sublegal- and legal-size scup caught by all three codends (Table 1). The control caught a significantly higher proportion of sublegal-size scup than both experimental codends. The 6.0-in square codend had significantly higher proportion of sublegal-size scup than the 6.5-in square. The experimental codends caught a significantly larger proportion of legal-size scup than the control codend with the 6.5-in square codend catching significantly greater proportion than the 6.0-in square codend. All three codends had significantly different mean lengths (Table 1). The regulated control codend had the smallest mean length and mean length increased with increasing mesh size. No significant differences were found for sublegal- and legal-size proportions and mean length of scup in regards to vessel, date, and tow number.

Results of the ANOVA on the proportion by weight of other commercially important species indicated no significant difference for summer flounder, winter flounder, and black sea bass by all the codends examined. Scup accounted for more than 50% of the total catch. Summer flounder, winter flounder, and black sea bass accounted for 2.3, 4.7, and 0.3%, respectively and were not present in all tows. Therefore, the small sample size of these species may not have been sufficient for analysis.

The results of the KS analyses indicated a significant difference (D-statistic > critical value) between the length-frequency distributions of samples observed in the experimental and control codends. This suggests that the observed catches were sampled from different length distributions. Figure 3 illustrates this dissimilarity of the length distributions observed in the catches for the three codend mesh sizes via visual comparison.

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 FMP for scup includes objectives to improve fishery yield and to improve spawning stock biomass by reducing fishing mortality in immature fish (MAFMC 1998). Currently the scup fishery is in the midst of a rebuilding program; meeting these management objectives would benefit the fishery and fishermen that rely on it.

The results of this study suggest potential conservation benefits by increasing codend mesh size for scup. One of the primary methods of regulating trawl fishing mortality on juveniles in a fish stock is through minimum mesh size regulation (DeAlteris and Reifsteck 1993). The basic principle is that fish smaller than the established minimum size will escape from the codend, survive, and become part of the future spawning biomass of the population (Wileman et al. 1996;

Pope et al. 1975). The results of the present analysis suggest that increasing the codend mesh size could reduce the number of small scup retained by the gear. Increasing from the regulated codend mesh to both experimental codend meshes shows a decrease in the proportion of sublegal fish caught and subsequent decrease in proportion when increasing from the 6.0-in square to the 6.5-in codend mesh size. In addition, the proportion of legal-size scup increases with increasing mesh size. The length distribution of the three codends are different and mean length is highest for the largest codend mesh size.

When conducting mesh size experiments, it is important that all other factors except what is being tested are kept constant. In this study two vessels were used to collect data. Analysis indicated that there were no vessel affects on the proportion of sublegal- and legal-size scup caught or mean length. In addition, time of day as well as date were also not influencing factors.

It is also important to investigate the changes in mesh size on other commercially important species. It is obvious from the catches in this study that in the directed fall scup trawl fishery, scup is the predominate species caught and the catch of all other species is fairly incidental. The proportion by weight of summer flounder, winter flounder, and black sea bass did not differ significantly for any of the codend mesh sizes but these results may be due to the small sample size.

In the most recent Stock Assessment Workshop on Scup (NEFSC 2002), status of the scup stock was determined to be not overfished. However, it was recommended that management should continue efforts to further reduce fishing mortality rates and minimize fishery discards to rebuild the stock. Based on the results of this study, increasing mesh size is a good step to accomplish this. Reduction of discards of sublegal fish can be accomplished by mesh size (Smolowitz 1983). Designing or modifying gear to select for larger sizes of scup should improve the economic return to the industry while improving the sustainability of the stocks.

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Table 1. Results of the single factor ANOVA test (α = 0.05) for differences among the mean proportion and mean length of scup.

	Test for Difference Among Means			Tukey HSD		
	Codend	***Mean***	SE*		6.0" Square	6.5" Square
Sublegal	4.5" Diamond	0.50	0.034	4.5" Diamond	**	**
< 22.9-cm	6.0" Square	0.33	0.037	6.0" Square	--	**
	6.5" Square	0.18	0.036	6.5" Square	**	--
	ANOVA	$p < 0.05$**				
	Codend	***Mean***	SE*		6.0" Square	6.5" Square
Legal	4.5" Diamond	1.07	0.034	4.5" Diamond	**	**
≥ 22.9-cm	6.0" Square	1.24	0.037	6.0" Square	--	**
	6.5" Square	1.39	0.036	6.5" Square	**	--
	ANOVA	$p < 0.05$**				
	Codend	***Mean***	SE*		6.0" Square	6.5" Square
Mean	4.5" Diamond	25.0	0.311	4.5" Diamond	**	**
Length	6.0" Square	27.0	0.342	6.0" Square	--	**
	6.5" Square	28.3	0.335	6.5" Square	**	--
	ANOVA	$p < 0.05$**				

* Standard error uses a pooled estimate of error variance
** Means are significantly different
n.s. not significantly different

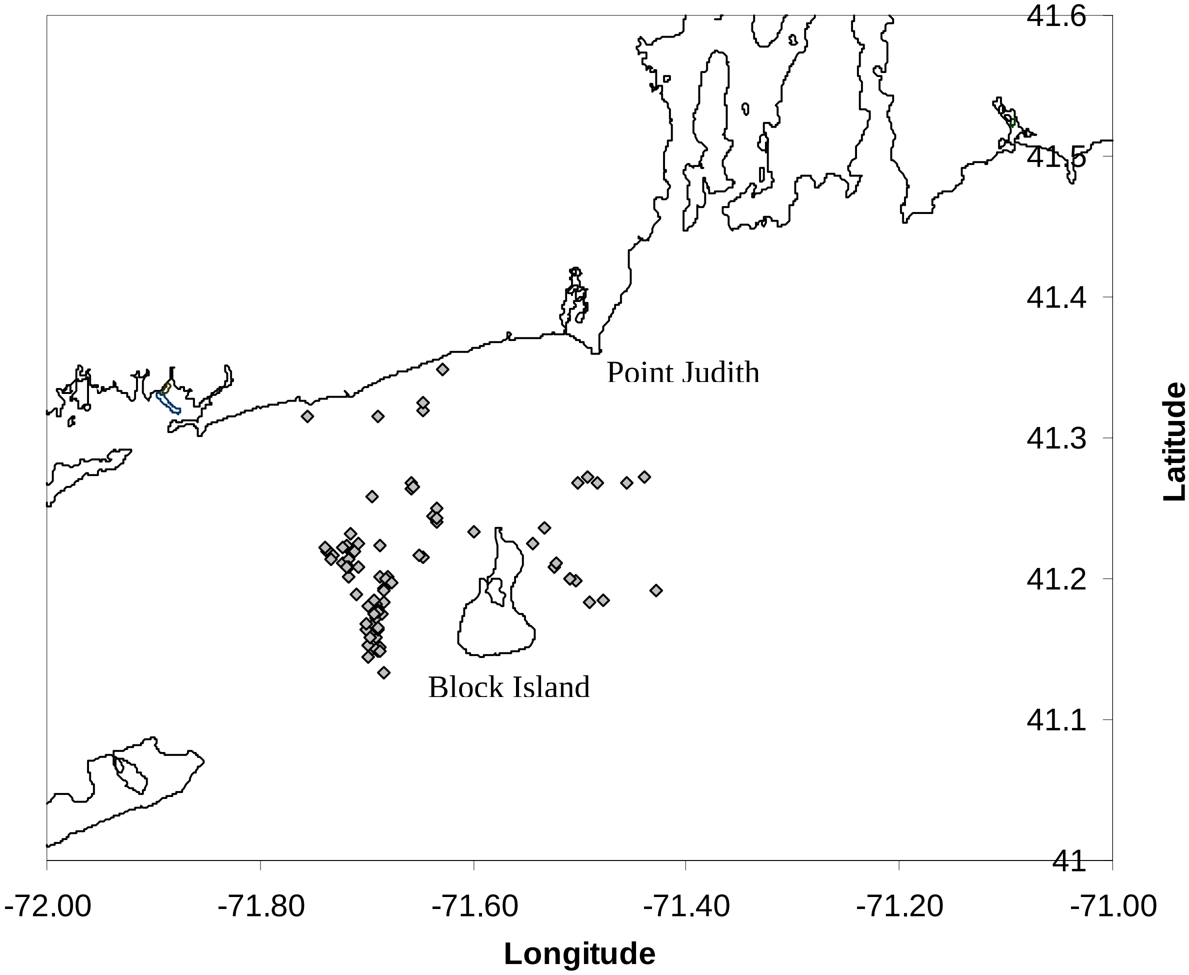

Figure 1. Location of tows by the F/V *Deborah Lee* and F/V *Grandville Davis*. Data points mark the starting coordinates.

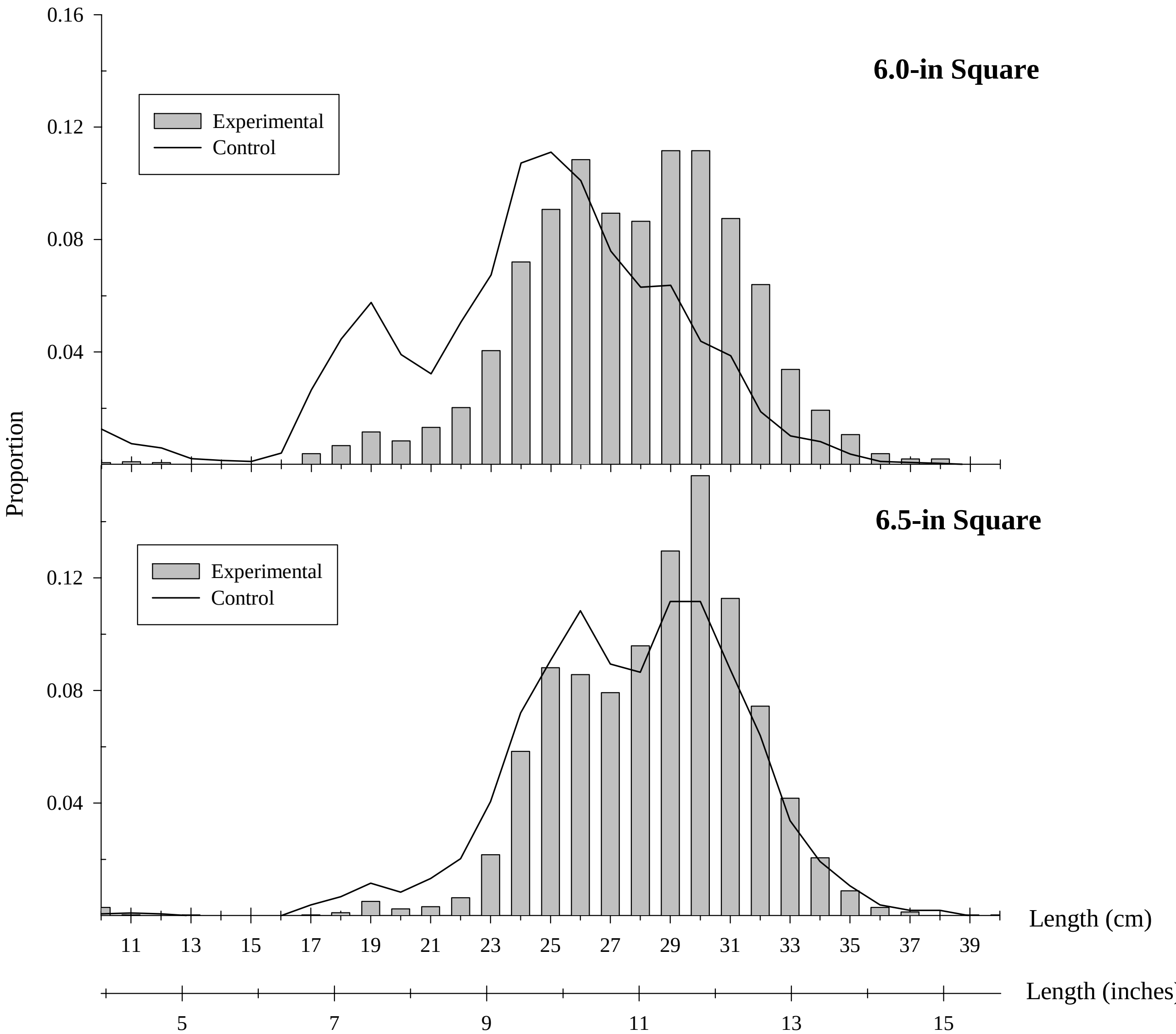

Figure 2. Length-frequency distribution of scup observed in control and experimental mesh codends. The lines represent distributions for the control codends and bars represent distributions for the experimental codends.

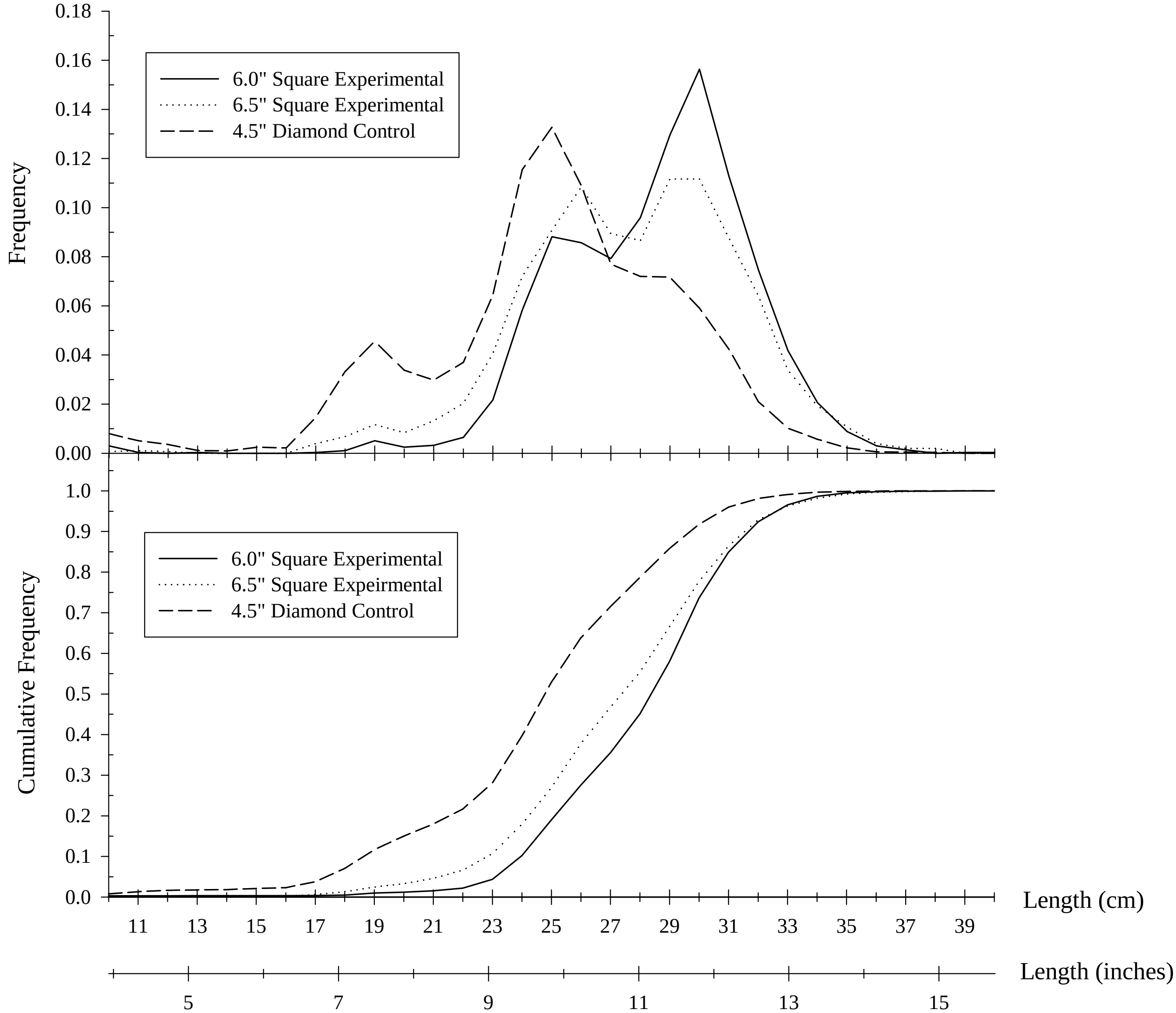

Figure 3. Length distributions of scup: (a) relative frequencies and (b) cumulative relative frequencies.