An assessment of scup (*Stenotomus chrysops*) and black sea bass (*Centropristas striata*) discards in the directed otter trawl fisheries in the Mid-Atlantic Bight

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Abstract—This study was undertaken to re-assess the level of scup (*Stenotomus chrysops*) discards by weight and to evaluate the effect of various codend mesh sizes on the level of scup discards in the winter-trawl scup fishery. Scup discards were high in directed scup tows regardless of codend mesh—typically one to five times the weight of landings. The weight of scup discards in the present study did not differ significantly from that recorded in scup-targeted tows in the NMFS observer database. Most discards were required as such by the 22.86 cm TL (total length) fish-size limit for catches. Mesh sizes ≤12.7 cm, including the current legal mesh size (11.43 cm) did not adequately filter out scup smaller than 22.86 cm. The median length of scup discards was about 19.83 cm TL. Lowering the legal size for scup from 22.86 to 19.83 cm TL would greatly reduce discard mortality. Scup discards were a small fraction (0.4%) of black sea bass (*Centropristis striata*) landings in black-sea-bass–targeted tows. The black sea bass fishery is currently regulated under the small-mesh fishery gear-restricted area plan in which fishing is prohibited in some areas to reduce scup mortality. Our study found no evidence to support the efficacy of this management approach. The expectations that discarding would increase disproportionately as the trip limit (limit [in kilograms] on catch for a species) was reached towards the end of the trip and that discards would increase when the trip limit was reduced from 4536 kg to 454 kg at the end of the directed fishing season were not supported. Trip limits did not significantly affect discard mortality.

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Because of regulations, market factors, and other reasons, both commercial and recreational fishermen discard some of their catch. Discards are considered one of the principal sources of mortality for many fish species, including those of significant commercial and recreational fisheries (Howell and Langdon, 1987; Glass et al., 1999; Suuronen et al., 1996).

The Sustainable Fisheries Act (SFA), governing U.S. fisheries management in federal waters, states that "conservation and management measures shall minimize bycatch." Much has been written about the environmental impact of discarding (Mooney-Seus, 1999; Alverson, 1999; Kennelly, 1999). Discard mortality reduces population size by limiting the number of individuals that can reach maturity and spawn. Because EEZ (Exclusive Economic Zone) fisheries must be managed at B_{msy} (biomass at maximum sustainable yield) under SFA guidelines and discards must be included in estimates of the TAC (total allowable catch), discard mortality also reduces total allowable landings. Therefore, discarding is not just an environmental problem; it is a problem that affects all aspects of fisheries.

A recreational and commercial fishery for scup (*Stenotomus chrysops*) occurs in the Mid-Atlantic Bight (the portion of the U.S. Atlantic coast extending from Cape Hatteras to Cape Cod) and New England regions where scup are caught south and offshore in the winter and north and inshore in the summer (NEFSC[1]). In 1996, the legal size for commercially caught scup was raised to 22.86 cm total length (TL), more or less coincidently with the establishment of a legal codend mesh size of 11.43 cm to reduce discard mortality (MAFMC, 1996). Discarding is considered to be an important cause of mortality for this important commercial and recreational species (NEFSC[2]). Kennelly (1999) reported large amounts of scup

[1] NEFSC (Northeast Fisheries Science Center). 2002. SARC 35. 35th Northeast regional stock assessment workshop (35th SAW). Stock assessment review committee (SARC) consensus summary of assessments. Northeast Fisheries Science Center Reference Document 02-14, 259 p. Northeast Fisheries Science Center, NMFS, NOAA, 166 Water St., Woods Hole, MA 02543.

[2] NEFSC (Northeast Fisheries Science Center). 2000. SARC 31. 31st northeast regional stock assessment workshop (31stSAW). Stock assessment review committee (SARC) consensus summary of assessments. Northeast Fisheries Science Center Reference Document 00-15, 409 p. Northeast Fisheries Science Center, NMFS, NOAA, 166 Water St., Woods Hole, MA 02543.

discards from demersal trawlers operating in certain areas and depths in the Mid-Atlantic Bight. High numbers of scup discards occur in the directed scup fishery (Powell et al., 2004). It is generally believed that one of the keys to effective management of scup is to reduce discard mortality (NEFSC[2]; NEFSC[1]). Fisheries managers attempt to control discard mortality using a number of management measures, but principally through mesh regulations and time or area closures.

Analysis of NMFS observer data by Powell et al.[3] indicated that scup comprised 65% of the total catch in scup-targeted tows, but that the discards-to-landings ratio for scup in these tows was 1.05. Somewhat more than half of the scup taken in scup-targeted tows were subsequently discarded. However, this analysis was based on relatively few observations; many of the tows used codends with mesh sizes below the current legal mesh size of 11.43 cm. As a consequence, applicability of the NMFS observer data to the present-day scup fishery is unclear. The objective of the present study was to obtain additional observations in the directed scup fishery to re-assess the level of discards by weight and to evaluate the effect of simple variations in codend mesh size on the level of scup discards.

Data analysis focused on scup. However, we also analyzed black sea bass (*Centropristis striata*) catches using the same methods as those for scup. Black sea bass were included because one management option is to require a common codend mesh size for the two species. The present legal mesh size for black sea bass is 10.16 cm and the minimum size of black sea bass that can be harvested is 27.94 cm TL. Commonality would simplify fishing methods because the two species are often targeted on the same trip.

Methods

Description of data

This study was undertaken during the 2001 winter scup trawl fishery in the Mid-Atlantic Bight. The legal trip limit for scup was 4536 kg from 1 January through 24 January. After 24 January until the close of the season in late February, the legal trip limit for scup was lowered to 454 kg. An experimental fishing permit was obtained from NMFS 1) to allow the vessels to fish in the GRAs (gear-restricted areas), implemented to reduce scup discards in the *Loligo* squid, (*Loligo pealei)*, silver hake (*Merluccius bilinearis*), and black sea bass fisheries, 2) to allow the use of codends with meshes less than the legal 11.43-cm mesh, and 3) to allow commercial vessels to retain an additional 1361 kg of scup per trip to help defray study costs.

The four vessels participating in this study used the following codends: 1) the legal-size (11.43-cm) mesh codend; 2) a composite codend with 30 meshes of 10.16-cm mesh at the very end of the bag followed by 45 meshes of 11.43-cm mesh; and 3) codends with some meshes ≥12.7 cm (including codends with or without a composite design). Two tows with codends of smaller mesh size (between 6.35 and 10.16 cm) were also observed and these tows were included in data tabulations for completeness. The composite codend was designed as a mechanism to reduce large catches of small scup when abundant scup are encountered but was also designed to retain black sea bass and scup when abundance was low. Captains usually had two of the codends onboard the vessel during a fishing trip and were asked to fish the codends in an ABBA sequence (i.e., first tow with codend A, second tow with codend B, third tow with codend B, next tow with codend A, and so forth). These tows typically lasted no longer than one hour. Otherwise, the captain operated his boat using normal fishing practices, including selecting where and when to fish.

The catch from each tow was sorted to species and weighed. Fork lengths (FL) were obtained for a minimum of fifty scup discarded followed by a minimum of fifty scup landed. If time permitted, length-frequency information was collected for black sea bass and discarded individuals were measured. Because some regulations use TL, FL was converted when necessary to TL with the following equation: $TL(\text{cm}) = 1.14FL(\text{cm}) - 0.44$ (Hamer[4] in MAFMC [1996]).

Catch data obtained from this study of the winter 2001 scup fishery were compared to scup-targeted tows from the NMFS observer database for 1997 through mid-2000 (Powell et al.[3]). NMFS observer program methodology is detailed in the Northeast Fisheries Science Center Fisheries Observer Program Manual (NEFSC[5]). Mesh size reported in the NMFS observer database included an array of small-mesh codends less than present-day legal size, as well as the legal mesh size of 11.43 cm.

A depth was assigned for each tow as the mean of the depths of net deployment and retrieval. Swept area of the tow could not be calculated directly because door or wing spread were not recorded by us, nor were these metrics available in NMFS observed tows. A surrogate for true swept area was obtained as "the average of the recorded headrope and sweep lengths" multiplied

[3] Powell, E. N., E. A. Bochenek, S. E. Banta, and A. J. Bonner. 2000. Scup bycatch in the small-mesh fisheries of the Mid-Atlantic. Final Report, National Fisheries Institute Scientific Monitoring Committee, 74 p. Haskin Shellfish Research Laboratory, Rutgers University, 6959 Miller Ave., Port Norris, NJ 08349.

[4] Hamer, P. E. 1979. Studies of the scup, *Stenotomus chrysops*, in the Middle Atlantic Bight. N.J. Div. Fish. Game and Shellfish, misc. rep. no. 5M, 14 p. New Jersey Department of Environmental Protection, New Jersey Division of Fish and Wildlife, Division of Marine Fisheries, Nacote Creek Research Station, PO Box 418, Port Republic, NJ 08241.

[5] NEFSC (Northeast Fisheries Science Center). 2001. Fisheries observer program manual, 217 p. Northeast Fisheries Science Center, NMFS, NOAA, 166 Water St., Woods Hole, MA 02583.

by "the recorded tow time and speed." CPUE was then calculated by using estimated swept area as the effort term. Scope was calculated as "tow wire out" divided by "average water depth." For geographic location, each tow was assigned to a 10-minute square area (10-minute latitude and longitude) (Powell et al.[3]).

For some analyses, data from the present study's winter 2001 fishery and the NMFS observer database were assigned to categories by codend mesh size: the legal codend with 11.43-cm mesh; a composite codend with 10.16-cm mesh followed by 11.43-cm mesh; codends with meshes less than 6.35 cm; codends with meshes between 6.35 cm and 10.16 cm; and codends having some meshes greater than or equal to 12.7 cm. Gear type was assigned to either a millionaire or large-mesh box net based on the net styles used in our study and interpretations of NMFS observer-recorded net descriptions by knowledgeable fishermen.

Statistical analysis

Catch was evaluated by using the ratio of scup discards to landings, total catch of all species, total discards of all species, total scup discards, total scup landings, and a comparison of whether the catch of scup per tow was above or below the median for all tows in the study. In addition, we examined the influence of fishing decisions on discards 1) by distinguishing tows where scup discards exceeded scup landings from tows where landings exceeded discards and 2) by distinguishing between the scup catch of tows taken in the first and last half of the trip. For the latter, we also analyzed tows by their fractional position in the trip (whether a tow occurred at the start of a trip, $^1/_4$, $^1/_2$, $^3/_4$, or at the end of the trip). This approach yielded results equivalent to the simpler assignment of tows to the first and last half of the trip. Only the results of the simpler analysis are presented. Finally, we evaluated the impact of fishing decisions on the length frequencies of scup caught. ANOVAs were run by using ranked raw variables with class variables that defined fishing practice (mesh size, gear, scope, effort), time, and catch. The variable time was used to allocate tows to three categories:

1 Those trips from the present study taken from 1 to 24 January 2001 with a legal trip limit of 4536 kg of scup;
2 Those trips from the present study taken after 24 January 2001, with a legal trip limit of 454 kg of scup; and
3 Those scup trips taken in 1997–2000 from the NMFS observer reports.

Length frequencies were analyzed by ANOVA by using the 25th, 50th, and 75th percentiles and the mean as descriptive variables. In initial analyses, the interaction terms between mesh size or time and the other independent variables were included. Interaction terms were not significant more frequently than expected by chance and, accordingly, were not included in our results. Significant differences identified by the ANOVA were further investigated by using Tukey's studentized range test and, for covariates, by Spearman's rank correlation.

Results

Catch statistics—scup

Ten trips were taken during our study and 62 tows were successfully completed; 39 tows targeted scup and 12 tows targeted black sea bass (Table 1). For the remaining tows, the captain targeted *Loligo* squid as part of the normal fishing process and used a much smaller codend mesh size. These *Loligo*-targeted tows were excluded from further analyses. However, frequent changes in target species emphasize the need for tow rather than trip-aggregated data in discard analyses (Powell et al., 2004) because multiple targets within trips commonly occur in Mid-Atlantic Bight fisheries.

The majority of tows were taken in NMFS statistical area 622. Scup-targeted tows occurred primarily during daylight and at depths ranging from about 73.2 to 137.2 m in our study and from 54.9 to 109.7 m in the NMFS observer data set. A few tows from both the NMFS observer database and our study were deleted from the analysis because the catch was released overboard rather than brought onboard. Bycatch estimates from these tows were assumed to be inaccurate in comparison to other tows. This phenomenon occurs sporadically in many fisheries (e.g., Roel et al., 2000). In our study, six scup-targeted tows were disregarded for this reason. All four participating boats had at least one trip where one tow was released overboard. Observers reported that the net was so full of fish, primarily scup, in these tows that it could not be brought on deck. The catch for one black-sea-bass–targeted tow was released overboard. In addition, tows in which no discards were recorded were not analyzed. Generally, such tows occurred when the observer was asleep or sea conditions were too dangerous to collect data from the tow. Such tows did not occur in our study but did occur sporadically in the NMFS observer database. Regardless of the reason, we assumed that any tow without recorded discards represented incomplete sampling and, consequently, we discarded that tow from further analysis (Powell et al.[3]). Differences in the tabulated number of observed tows and the number of observed tows analyzed reflect the number of tows excluded from the analyses for these two reasons.

Length frequency—scup

The length frequencies of landings and discards were consistently significantly different (often $P \leq 0.0001$) (Fig. 1). The mean size of discarded scup was 17.7 cm and ranged from 13.2 to 21.4 cm in our study. Fifty percent of the scup discarded fell between 16.8 cm (25th percentile) and 18.5 cm (75th percentile). In contrast, the average size of scup landed was 24.2 cm and ranged from 22.2 to 29.2 cm. Fifty percent of the scup landed

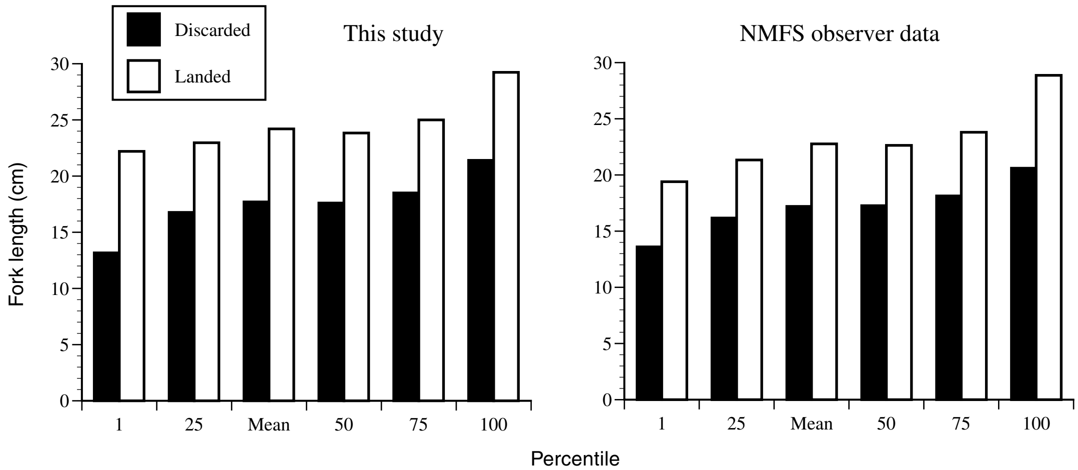

Figure 1

Mean length-frequency fractions for scup (*Stenotomus chrysops*) discarded and landed in our study and in the NMFS observer database. 1=smallest size. 100=largest size.

Table 1

Synopsis of scup and black-sea-bass–targeted tows by study, gear, and codend mesh size, including those tows where the catch was released overboard.

Scup-targeted tows						
Study	Gear	6.35–10.16 cm mesh	11.43-cm mesh	10.16+11.43 cm composite	≥12.7 cm	Totals
This study	Millionaire net	2	3	0	0	5
	Large box net	0	14	19	7	40
Totals		2	17	19	7	45
Study	Gear	<6.35-cm mesh	6.35–10.16 cm mesh	11.43-cm mesh	Unknown	Totals
NMFS	Millionaire net	9	5	3	0	17
	Large box bet	5	4	2	7	18
Totals		14	9	5	7	35
Black-sea-bass–targeted tows						
Study	Gear	6.35–10.16 cm mesh	11.43-cm mesh	10.16+11.43 cm composite	Totals	
This study	Millionaire net	0	0	0	0	
	Large box net	0	3	9	12	
Totals		0	3	9	12	
Study	Gear	<6.35-cm mesh	6.35–10.16 cm mesh	11.43-cm mesh	Unknown	Totals
NMFS	Millionaire net	0	0	0	0	0
	Large box net	0	6	0	0	6
Totals		0	6	0	0	6

fell between 22.9 cm (25th percentile) and 25.0 cm (75th percentile). For the NMFS observer data, the mean size of scup discards was 17.2 cm and ranged from 13.6 to 20.6 cm. Fifty percent of the scup discarded fell between 16.2 cm (25th percentile) and 18.2 cm (75th percentile). For scup landed, the mean size was 22.8 cm and ranged from 19.4 to 28.9 cm. Fifty percent of the scup landed fell between 21.3 cm (25th percentile) and 23.8 cm (75th percentile).

Codend and gear

Vessels participating in this study and in the NMFS observer program used either millionaire or box nets (Table 1). More tows were made with the box net in both data sets (Table 1). Most tows in our study were made with the composite and 11.43-cm codends because comparison of these two codends was one focus of our study. Most scup-targeted tows in the NMFS observer database were made with codends ≤10.16 cm mesh (Table 1).

Codend mesh size did not have a significant effect on catch length frequencies when data from our study and the NMFS observer data were analyzed separately or combined. We deleted codends with the smallest meshes (meshes ≤10.16 cm) and re-analyzed the data for the remaining larger codend meshes. Again, catch length frequencies were not significantly different for any of the codend mesh sizes. Finally, we considered the landed and discarded scup separately. For landings, codend mesh size had a moderately significant effect on median length (P=0.0220) and a stronger significant effect on mean length (P=0.0062). Codends with some meshes ≥12.7 cm caught more of the landed size fraction than the composite and slightly more than the 11.43-cm mesh codend; however, the actual difference in mean length between the three mesh-size groups was small, approximately one cm (Fig. 2).

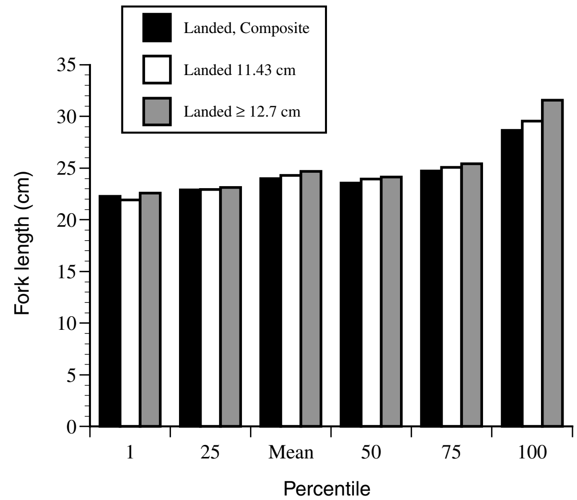

Figure 2

Mean scup (*Stenotomus chrysops*) length fractions for those tows with landed scup with a composite (10.16+11.43 cm) codend, 11.43-cm mesh codend, and a ≥12.7-cm mesh codend. 1=smallest size. 100=largest size.

The efficiency of the codend may change with the amount of fish caught such that selectivity declines with high catches. Accordingly, scup catches were divided into two groups: those above and those below the median catch for all tows. For catches above the median, codend mesh size had a significant effect (P=0.0441) on the 25th percentile of size for scup discarded in our study. The 25th percentile size was largest for codends with some meshes ≥12.7 cm and smallest for the composite codend. For landed scup, the 25th percentile sizes were about 22.0 cm regardless of codend mesh size. No significant differences existed between codend mesh sizes for scup length frequency in tows with catches below the median.

We examined the composition of the catch by weight. Codend mesh size had a limited effect on the ratio of scup discarded to landed, the total catch and total discards of all species, and total scup landed and discarded. Scup discards were greater with codends having some meshes ≥12.7 cm (P=0.0211). More scup were landed from these tows as well (P=0.0034) and therefore this codend style may contribute to a greater catch rate (Table 2). Very likely, this trend in increased catch is produced by the small number of tows (n=7) in this mesh size category rather than a real improvement in net performance.

No significant gear effects existed for any of the length-frequency fractions in the combined data set (our study and NMFS observer study). The only significant effect of scope (P=0.0175) was on total scup discarded in our study. This effect was not present in the NMFS observer data set.

Discards-to-landings ratio

Of the 62 tows completed in our study, 39 targeted scup. The NMFS observer program, from 1997–mid 2000, included 35 scup-targeted tows (Table 3). Overall, mean catch per tow for scup-targeted tows was 972.6 kg in our study and 945.3 kg for NMFS observed tows. In our study, the discards-to-landings ratio for all species combined ranged from 1.77 with the composite codend to 2.91 with a codend with some meshes ≥12.7 cm. In the NMFS observer data set, the discards-to-landings ratio for all species combined in scup-targeted tows ranged from 0.47 with codends having meshes of 6.35–10.16 cm to 3.43 with codends with meshes of 11.43 cm (Table 2). The mean discards-to-landings ratio for scup ranged from 1.1 for the NMFS database to 2.4 for our study (Table 3). Ratios varied from a low of 0.35 to a high of 5.72 among the various gear and mesh-size combinations (Table 4).

We analyzed cases where scup discards exceeded or were less than landings. When our data and the NMFS observer data were combined, the 25th (P=0.0219), 50th

Table 2

Mean weight (in kilograms) of scup discarded, scup landed, total discards of all species, total catch of all species, and total discards-to-landings ratio of all species per tow by codend mesh size for this study and the NMFS observer data.

Study	Codend	Scup discarded	Scup landed	Total discards	Total catch	Total discards-to-landings ratio	Total number of tows
This study	Composite	659.7	329.3	1078.1	1686.0	1.77	16
This study	11.43 cm	607.8	210.7	1060.2	1437.7	2.81	14
This study	≥12.70 cm	1020.7	404.9	1973.4	2652.8	2.91	7
NMFS	<6.35 cm	615.5	493.4	949.1	1530.1	1.63	14
NMFS	6.35–10.16 cm	230.5	510.5	321.1	999.2	0.47	9
NMFS	11.43 cm	535.2	260.0	1015.7	1311.6	3.43	5

Table 3

Mean catch and landings per tow for scup and black sea bass-targeted tows.

Scup						
Study	Tow type	Total no. of tows	Mean catch (kg)	Mean landed (kg)	Mean discarded (kg)	Ratio of scup discards to landings
This study	Target	39	972.6	286.3	686.3	2.40
NMFS	Target	35	945.3	461.3	484.0	1.05
Black sea bass						
Study	Tow type	Total no. of tows	Mean catch (kg)	Mean landed (kg)	Mean discarded (kg)	Ratio of black sea bass discards to landings
This study	Target	10	365.0	278.7	86.3	0.31
NMFS	Target	6	171.9	170.1	1.8	0.01

(P=0.0085), and 75th (P=0.0038) percentile sizes and the mean length (P=0.0001) were significantly lower for tows in which most scup were discarded (Fig. 3). When the data sets were analyzed separately, our study found that the 50th (P=0.0133) and 75th (P=0.0040) percentile sizes and the mean length (P=0.0338) were significantly lower for tows where discards exceeded landings. Not surprisingly, when fishermen caught larger scup, fewer scup were discarded. In the NMFS observer data set, no significant size effects were found for any of the percentile fractions.

When the discards and landings were analyzed separately, the lengths of fish discarded did not differ between tows for which discards exceeded landings and tows for which landings exceeded discards. However, for the landed fish, the 50th (P=0.0034) and 75th (P=0.0018) percentile sizes and the mean length (P=0.0033) were larger for tows where landings exceeded discards (Fig. 4). Discards decline when larger scup are proportionately more abundant in the catch.

We examined the influence of total catch (all species combined) on the length-frequencies of scup in tows where scup landings exceeded or did not exceed scup discards. For those tows with total catches below the median catch, a significant effect was noted for the median (P=0.0039), the 75th percentile (P=0.0006), and the mean (P=0.0288) length of scup. In those tows where total catch weight was relatively low, the median, mean, and 75th percentile lengths were larger in tows where scup landings exceeded discards. No significant effects on the length-frequency distribution of scup were observed for total catches that were above the median. The analysis identifies a strong trend towards the landing of larger-size scup in tows yielding total catches below the median for all tows.

Both landings and discards were affected in those tows in which total catch fell below the median. For landed scup, the median (P=0.0062), the 75th percentile (P=0.0051), and the mean (P=0.0113) length were higher in tows with total catches below the median when scup landings exceeded discards. For those scup that were discarded from tows with total catches below the median, a significant size effect was observed for the 75th percentile (P=0.0265). Discarded scup were larger in

Table 4

Synopsis of catch and landings data (kg) by study, gear, and codend mesh size for scup-targeted tows in our study and those in the NMFS observer database.

Gear	Mesh size	Total scup/tow	Scup landed	Scup discarded	Ratio of scup discards to landings	Number of tows
This study						
Large box	10.16+11.43 cm composite	1332.3	519.3	813.0	1.57	9
	11.43 cm	1572.8	431.6	1141.2	2.64	5
	≥12.70 cm	2609.7	624.1	1985.6	3.18	2
Millionaire	6.35–10.16 cm	32.7	16.3	16.3	1.00	1
	10.16+11.43 cm composite	547.5	85.0	462.5	5.44	7
	11.43 cm	399.5	88.1	311.5	3.54	9
	≥12.70 cm	951.9	317.2	634.8	2.00	5
Unknown		636.8	94.8	542.0	5.72	1
NMFS						
Large box	<6.35 cm	1076.7	196.0	880.8	4.49	5
	6.35–10.16 cm	20.8	3.4	17.4	5.12	4
	11.43 cm	176.9	131.5	45.4	0.35	2
Unknown		988.2	477.6	510.6	1.07	7
Millionaire	<6.35 cm	1126.6	658.6	468.1	0.71	9
	6.35–10.16cm	1317.1	916.2	401.0	0.44	5
	11.43 cm	1207.3	345.5	861.8	2.49	3

Table 5

Total discards and total catch of all fish species (in kg) and scup discarded and landed (in kg) for only those tows characterized by having more or less discards of scup than the median catch per tow.

Study	More or less discards	Scup discarded	Scup landed	Total discards	Total catch	Total number of tows
This study	Less	145.4	355.6	565.4	1027.5	11
This study	More	898.9	259.0	1451.6	1982.3	28
NMFS	Less	235.1	521.1	426.3	1058.3	20
NMFS	More	815.9	381.5	1242.8	1761.5	15

these tows, reflecting the overall larger size of the scup catch in tows where total catch was relatively low.

Finally, for tows in which scup discards exceeded landings, total catch of all species and total discards of all species were also high. This trend was significant for total catch ($P=0.0273$) and total discards ($P=0.0038$) in our study (Table 5) and for total discards ($P=0.0017$) and total catch ($P=0.0112$) in the NMFS observer data set (Table 5). Therefore, scup discards tended to increase with respect to landings as total catch increased.

Time and effort

For our study, effort significantly affected the 25th ($P=0.0247$) and 50th ($P=0.0466$) percentiles of the size-frequency distribution of discards. The size frequencies for landings were not similarly affected. In both former cases, the 25th and 50th percentile sizes were larger when effort was less (shorter tows). No significant effects were observed in the NMFS observer data set. Because the length frequency of the entire catch did not change significantly, this is likely an effect of processing onboard the boat.

Given trip limits, one might anticipate discards to increase in tows made at the end of the trip. We examined the amount of scup caught either in the first half of the tows or in the last half of the tows on each trip. For this study, more scup were landed ($P=0.0008$) and discarded ($P=0.0001$) in tows that occurred during the last half of the trip. Total catch and total discards were unaffected. For the NMFS observer data set, more scup were landed ($P=0.0001$) and discarded ($P=0.0001$)

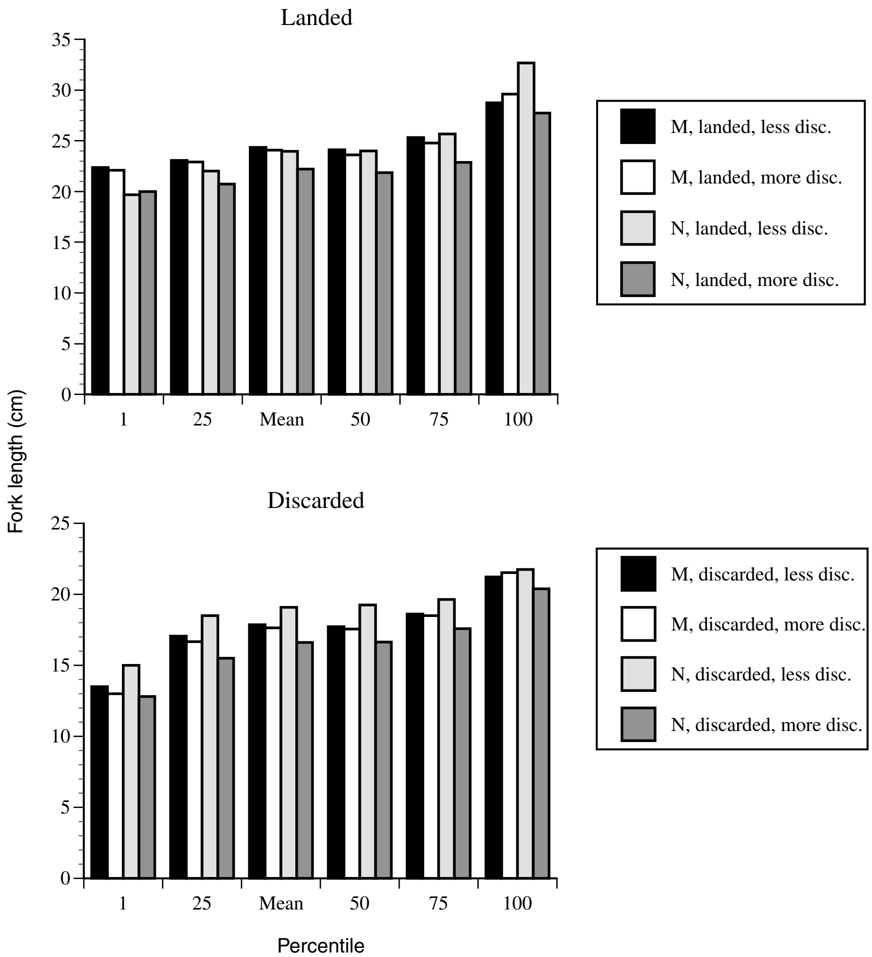

Figure 3

Percentiles of scup (*Stenotomus chrysops*) length frequency for those tows in which discards exceeded or failed to exceed landings for landed and discarded scup. "M" represents this study and "N" represents NMFS observer data. Landed, less disc. = for scup landed, tows with less discarded scup than landed scup. Discarded, less disc. = for scup discarded, tows with less discarded scup than landed scup. Landed, more disc. = for scup landed, tows with more discards of scup than landed scup. Discarded, more disc. = for scup discarded, tows with more discards of scup than landed scup. 1=smallest size. 100=largest size.

and the total catch of all species (P=0.0195) and total discards of all species (P=0.0004) were higher in tows taken during the last half of the trip (Table 6). More scup being landed and discarded in the last half of the trip indicates that captains learn where to fish for scup during the trip and CPUE rises as a consequence. No evidence exists that discards increased with respect to landings during the trip.

We anticipated that reduction of the trip limit from 4536 kg to 454 kg on 24 January would influence the total weight of discards. Time did influence total weight of scup discards (P=0.0056) in our study. More discards per tow occurred on trips taken prior to 24 January, likely because of the larger trip limit (weight limit per species for each trip) for the 1–24 January period. With a larger trip limit, more scup can be caught per tow and therefore more scup will be discarded. The discards-to-landings ratio, however, was not significantly affected—indicating that captains controlled total scup catch in proportion to the landing limit.

The present study versus the NMFS observer study

We compared trends in our data with those in the NMFS observer data. The subset of directed scup tows in the two data sets rarely disagreed, despite the disparity in codend mesh sizes reported (Table 1).

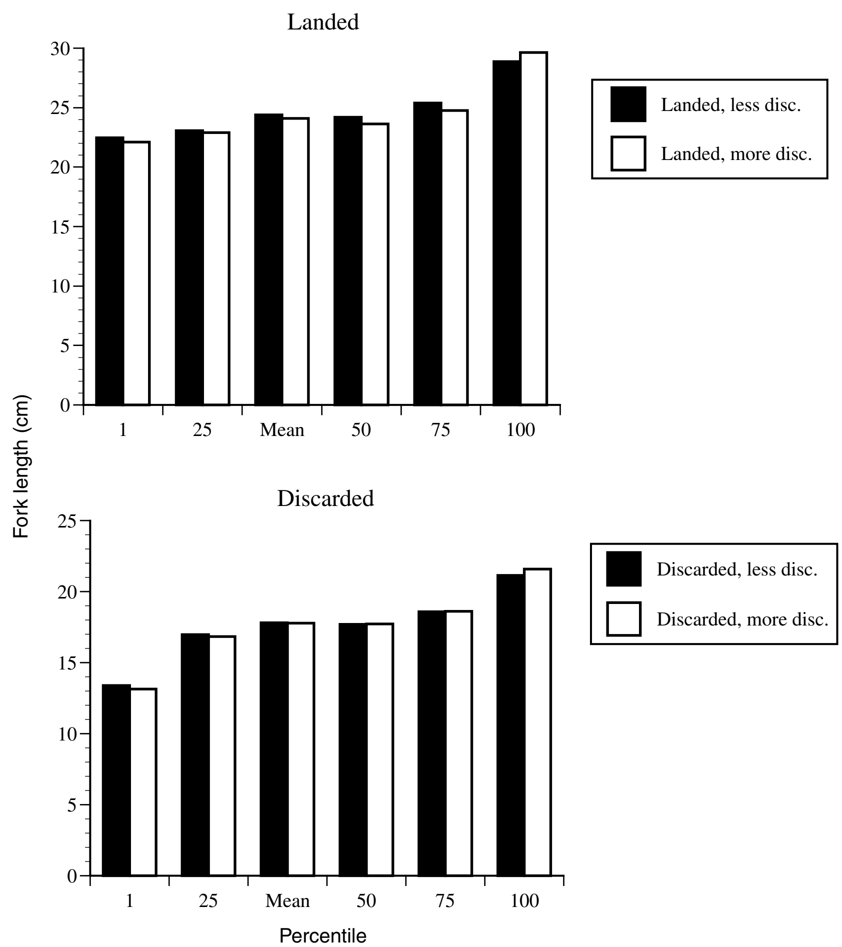

Figure 4

Percentiles of scup (*Stenotomus chrysops*) lengths (FL) for those tows in which discards exceeded or failed to exceed landings for landed and discarded scup. Codends included the composite (10.16+11.43 cm), 11.43 cm, and ≥12.7 cm meshes. Landed, less disc. = for scup landed, tows with less discarded scup than landed scup. Discarded, less disc. = for scup discarded, tows with less discarded scup than landed scup. Landed, more disc. = for scup landed, tows with more discards of scup than landed scup. Discard, more disc. = for scup discarded, tows with more discards of scup than landed scup. 1=smallest size. 100=largest size.

Table 6

Mean weight (in kg) of scup discarded and landed and the total of all fish species landed and discarded per tow for scup-targeted tows in the first half of the trip and the second half of the trip.

Study	First half or second half of trip	Scup discarded	Scup landed	Total discards	Total catch	Total number of tows
This study	First	253.3	125.2	970.2	1279.7	22
This study	Second	1246.8	494.7	1501.2	2273.8	17
NMFS	First	43.2	23.2	463.0	670.3	19
NMFS	Second	1007.5	981.5	1148.3	2178.3	16

Table 7

Mean weight (in kg) of black sea bass discarded, black sea bass landed, total discards of all species, total catch of all species, and total discards-to-landings ratio of all species per tow by codend mesh size and gear for this study and the NMFS observer data.

Study	Gear	Codend	Black sea bass discarded	Black sea bass landed	Total discards	Total catch	Total discards to landings	Ratio of Total number of tows
This study	Large box	10.16+11.43 cm composite	119.2	366.7	845.6	1306.9	1.83	7
This study	Large box	11.43 cm	5.0	25.9	1201.8	1250.3	24.78	2
This study	Millionaire	11.43 cm	18.6	168.3	368.1	683.8	1.17	1
NMFS	Large box	6.35–10.16 cm	1.8	170.1	23.7	224.2	0.12	6

Catch statistics—black sea bass

During the winter scup season, black sea bass are legally caught with 10.16-cm mesh codends in offshore waters. A boat captain often will target scup and black sea bass on the same trip, but will use different mesh codends. A total of 12 black-sea-bass–targeted tows were observed in our study and 6 black-sea-bass–targeted tows were documented in the NMFS observer data set (Table 1).

Length frequency—black sea bass

Black sea bass length-frequency distributions were highly significantly different (often $P=0.0001$) between those fish landed and those discarded. The mean size of discarded black sea bass from our study was 22.9 cm and ranged from 18.4 to 25.4 cm. Fifty percent of the black sea bass discarded fell between 22.1 cm (25th percentile) and 24.3 cm (75th percentile). In contrast, the mean size of landed black sea bass was 31.1 cm and ranged from 25.4 to 40.9 cm. For black sea bass landed, fifty percent of the fish were found between 28.6 cm (25th percentile) and 33.3 cm (75th percentile). For the NMFS observer data, the mean size of black sea bass discarded was 23.4 cm and ranged from 20.7 to 27.0 cm. Fifty percent of the black sea bass discarded fell between 22.3 cm (25th percentile) and 24.7 cm (75th percentile). The mean size of landed black sea bass was 28.5 cm and ranged from 24.5 to 34.0 cm. For landed black sea bass, fifty percent fell between 25.0 cm (25th percentile) and 31.5 cm (75th percentile).

Codend and gear

Nine tows were made with the composite codend and three tows were made with the 11.43-cm legal mesh codend in our study. For the NMFS observer data, all six targeted tows fell into the 6.35–10.16 cm mesh-size group that included the legal mesh size of 10.16 cm (Table 1).

We found no significant effects of codend mesh size on the percentile length-frequency fractions of black sea bass. We considered landed and discarded black sea bass separately for those tows with total catches above and below the median and, once again, no significant codend mesh-size effects were observed. The total number of tows, however, was small. A significant codend mesh-size effect ($P=0.0389$) was observed for black sea bass landed. Landings were higher with the larger mesh codends (composite 10.16+11.43 cm codend and the 11.43-cm codend) rather than with the ≤10.16-cm mesh codend (Table 7). The small number of total tows with the larger codend mesh sizes (10.16+11.43 cm and the 11.43 cm) is probably responsible for this difference in landings rather than differences in net performance. Gear effects (net types) were not determined because only the box net was used.

Discards-to-landings ratio

Total mean catch per tow was 365 kg and total mean landings per tow was 279 kg for the 10 tows in our study. For the six directed tows in the NMFS observer data, average total catch was 172 kg and average total landings were 170 kg (Table 3). In black-sea-bass–targeted tows, the black sea bass catch comprised 34.2% of the total catch. The discards-to-landings ratio for black sea bass was 0.230. Relatively few black sea bass were discarded. Scup comprised 0.9% of the total catch in black sea bass targeted tows. Less than one percent (0.4%) of the scup catch in black-sea-bass–targeted tows was discarded.

We analyzed cases where black sea bass discards exceeded or were less than landings in tows where total catch (all species combined) was above or below the median. For total catches above the median, a significant size effect was noted for the median length ($P=0.0040$), the 75th percentile size ($P=0.0007$), and the mean length ($P=0.0026$). Larger fish were present in tows where discarding was lower (Fig. 5). No significant effects on the size distribution of black sea bass were observed in tows with total catches below the median. We further divided the catches above the median into discards and landings. For those black sea bass that were landed from tows with total catches above the median, a significant size effect was observed for the 25th ($P=0.0199$), the

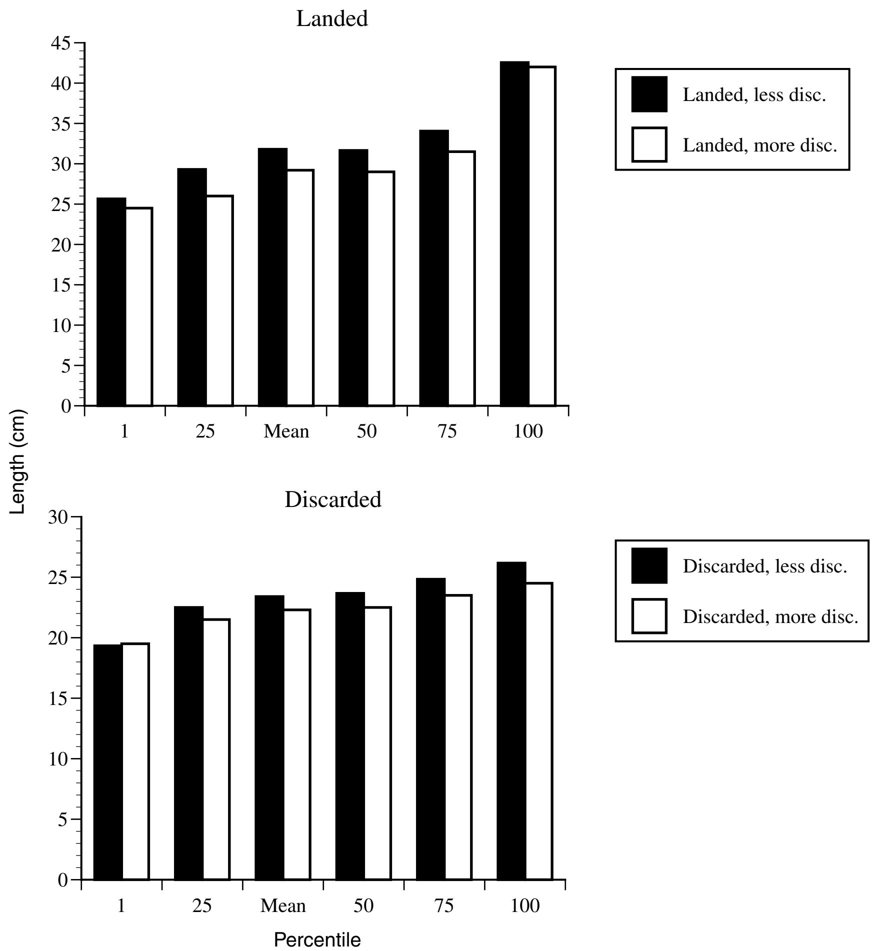

Figure 5

Percentiles of black sea bass (*Centropristas striata*) length frequencies for those tows in which discards of black sea bass exceeded or failed to exceed landings for landed or discarded black sea bass. Landed, less disc. = for black sea bass landed, tows with less discards of black sea bass than what was landed. Discarded, less disc. = for black sea bass discarded, tows with less discards of black sea bass than what was landed. Landed, more disc.: for black sea bass landed, tows with more discards of black sea bass than what was landed. Discarded, more disc. = for black sea bass discarded, tows with more discards of black sea bass than what was landed. 1=smallest size. 100=largest size.

50th (P=0.0280), and the 75th (P=0.0090) percentile size fractions and the mean length (P=0.0133). The size of landed black sea bass was larger in tows where discarding was low (Fig. 5).

Time and effort

Because of trip limits, discards could increase in tows taken near the end of a trip. Therefore, we compared the catch of black sea bass in the first and the last half of the tows. The quantity caught and the length-frequency percentiles were not significantly different between the first and last half of the tows. In contrast, for scup trips, discards and landings tended to be higher in tows made in the last half of the trip.

Effort significantly affected the 25th (P=0.0010), 50th (P=0.0003), and 75th percentile (P=0.0153) size fractions of black sea bass for the combined data sets (NMFS study and our study). In these cases, higher effort was associated with more smaller fish. When the two data sets were analyzed independently, most of the effort effects were no longer present.

Discussion

Scup

The type of net (gear) and the size of codend mesh had only a minor effect on the length frequencies of scup caught. Although variations in codend mesh size normally influence catch in other studies (Hastie, 1996; Petrakis and Stergiou, 1997; Stergiou et al., 1997; Broadhurst et al., 1999), a wide range in codend mesh sizes produced similar results for scup. Codends with some meshes ≥12.7 cm appeared to catch more of the size classes of fish chosen for landing than the composite codend and just slightly more than the legal 11.43-cm mesh codend; therefore the ≥12.7-cm mesh condend may reduce discards. The actual difference in scup lengths between the three codends was only about one cm. In terms of kilograms caught, more scup were caught in tows with the larger codend mesh. Landings increased, but so did discards, so that the discards-to-landings ratio remained unchanged. This finding indicates that the small upward bias in sizes caught did not significantly reduce total catch. In general, the smaller mesh codends (6.35–10.16 cm) and the composite codend (10.16+11.43 cm) performed similarly to the current legal mesh design (11.43 cm). Overall, discards of scup remained high regardless of the type of gear (nets) and codends used.

In our study, more larger scup were caught in longer tows. When a boat encounters a large school of scup, the mean length of the catch tended to be smaller. In addition, the larger-size scup tended to be caught more often in those tows with total catches below the median. This trend is probably a biological effect, but an effect of mesh size or gear cannot be excluded. Most populations contain relatively few larger fish and, therefore, more smaller individuals. Morse[6] (in Steimle et al., 1999) noted that scup schools are size-structured. When larger scup are less common in schools, then schools with these larger individuals most likely would be smaller and more effort would be required to achieve the same catch of these individuals. The same result would occur if larger scup tended to be on the outside or above smaller scup in schools. Little is known about scup behavior. However, any spatial size structure in the population could promote a direct relationship between effort and the mean length of fish caught and an inverse relationship between total catch (all species) and mean length of fish caught.

As an alternative explanation for the lower catch rate of larger individuals, clogging of the codend may occur when catch rates are high and, as a consequence, size-selectivity would decline. Different codend mesh sizes do not seem to affect the number of discarded scup as much as one might anticipate because codends clog during the interception of large schools. Accordingly, lower CPUE could produce greater size selectivity resulting in increased mean length when catches are relatively low. However, the trends observed in length frequency with effort and total catch were not significantly influenced by codend mesh size. Accordingly, the observed trend is likely a direct consequence of fishing on size-structured populations.

In general, more scup were landed and discarded in the last half of a trip. This finding indicates that the captain learns where to fish for scup by the second half of the trip and CPUE increases as a consequence. We had expected an increase in discards as the trip limit was reached towards the end of the trip. However, no effect of trip limits on the total weight of discards could be discerned in our data set or the NMFS observer data set.

More scup were discarded per tow in tows observed during the first half of the 2001 season, namely 1–24 January, than in the second half of the season, 25 January–February, but the discards-to-landings ratio did not vary for either half of the season. The fact that the ratio did not differ indicates that more scup are discarded per tow when fishermen are allowed a larger trip limit (4536 kg). The higher discards of scup per tow during the first half of the season are likely due to the increased total catch per tow that might be anticipated when allowable landings are higher. Accordingly, captains are able to reduce catch rate and, thus, discards when landing limits are low.

We compared the NMFS observer database to our observer data. Despite a substantial variation in the distribution of codend mesh sizes between the two data sets, the discards-to-landings ratio was not significantly different. Concerns raised by the high discards-to-landings ratio observed in the NMFS observer data were supported by our study. The discards-to-landings ratio for the directed scup fishery consistently exceeded 1.0.

In summary, the objective of our study was to evaluate the effect of codend mesh size on the amount of scup discards and to identify mechanisms to reduce scup discards. Although we observed a number of trends in discards in our study, neither the current legal mesh nor any of the experimental codends seem to adequately filter out scup smaller than 22.86 cm. Neither did trip limits seem to influence the total weight of scup discards. In fact, the only consistent trends produced by variations in effort and total catch seem most likely due to biological effects not easily controlled for by the captain of a fish vessel. Overall, the total weight of discards seems to be primarily a function of the regulated size limit, abetted by the tendency for smaller fish to be captured when encounter rates are high. The present study found that the length of the median discards was about 17.78 cm FL (19.83 cm TL based upon a conversion factor of Hamer[4] [in MAFMC, 1996]). O'Brien et al. (1993) and NEFSC (1993) reported that 50% of both male and female scup reach maturity at 15.49 cm FL (17.27 cm TL). Therefore, lowering the scup minimum size limit to 17.78 cm FL (19.83 cm TL) would greatly

[6] Morse, W. W. 1978. Biological and fisheries data on scup, *Stenotomus chrysops* (Linnaeus). NMFS, NEFSC, Sandy Hook Lab. tech. ser. rep. no. 12, 41 p. James J. Howard Marine Sciences Laboratory, Northeast Fisheries Science Center, 74 Magruder Rd., Sandy Hook, NJ 07732.

reduce scup discards, yet permit the majority of scup to attain sexual maturity. Kilograms discarded might be reduced by more than half. Fishermen would reach their trip limit sooner and thus stop fishing earlier. As a result, fishing mortality rate even on larger scup would be reduced. This single change would reduce discards more than any change in net or codend design tested to date and would not result in any increase in fishing-induced mortality for scup.

Black sea bass

Estimates of discards of black sea bass are low in the black-sea-bass–targeted fishery, based on the few observed tows in our study and data from the NMFS observer database. Regardless of which codends were used, the same size fractions of black sea bass were caught. The composite codend (10.16+11.43 cm mesh) caught more black sea bass than were landed. Discards was also higher. As with scup, mesh size and gear type had minor effects on the size frequency, the discards-to-landings ratio, and the kilograms of black sea bass caught. The majority of tows where black sea bass were caught had ratios of black sea bass discarded to landed of less than 0.3, indicating that few discards occur in this fishery. In contrast, most of the scup tows were characterized by discards-to-landings ratios greater than one. The differences in discards-to-landings ratios between black sea bass and scup may be due to a combination of biological factors controlling the average size of scup in the larger schools and to regulatory factors that do not match well with the size range of scup in schools.

Unlike scup, black sea bass size frequencies and total weight caught were similar in tows taken during the first and last half of the trip. Trip limits are in effect for both black sea bass and scup. The difference between the two species in the distribution of catch through the time course of the trip may be the result of biological effects in that the schooling of scup would tend to produce higher catches during the middle or latter part of the trip as the captain finds schools of fish.

Powell et al.[3] showed that black sea bass and scup are caught simultaneously more frequently than expected by chance in tows in the Atlantic mackerel (*Scomber scombrus*), *Loligo* squid, scup, and silver hake fisheries and suggested that they should be regulated together. Our analysis also showed this pattern in that the two species were frequently caught in the same tows (39 out of 40 scup-targeted tows and seven out of 10 black-sea-bass–targeted tows caught both scup and black sea bass). In addition, Shepherd and Terceiro (1994), Musick et al., (1985), and Musick and Mercer (1977) also found that both scup and black sea bass were caught in the same tow. Use of a common codend mesh size regulation for both fisheries may prove useful. The failure to find significant differences between mesh sizes suggests that the 10.16+11.43 cm composite bag might be a reasonable choice for both fisheries. However, scup discards were a small fraction of black sea bass landings in black-sea-bass–targeted tows (0.4%)—very small in comparison to the percentage in scup-targeted tows. This finding indicates that there is considerable discrimination between the two species at the level of the fishery. The black sea bass fishery is currently regulated under the small-mesh fishery GRA plan in which fishing is prohibited in some areas to reduce scup mortality. This investigation finds no evidence to support the efficacy of this management approach. Scup discards do not appear to be an important attribute of the black sea bass fishery.

Conclusions

Because fishermen catch both scup and black sea bass in the same tow and because the current regulations require fishermen to use an 11.43-cm mesh codend when targeting scup, and, a 10.16-cm mesh codend when targeting black sea bass, two different codend mesh sizes are used on the same trip. The composite codend was designed to retain the smaller black sea bass catches and some scup when catch rates are low but permits more scup to escape at higher catch rates. The composite codend (10.16+11.43 cm mesh) performed as well as the other codends used in our study, including the 11.43-cm legal-size codend. The composite codend with 10.16-cm mesh followed by the 11.43-cm or 12.7-cm mesh codends should be further evaluated on both black sea bass and scup-directed tows. If this composite codend works equally as well as the legal 11.43-cm mesh codend currently in place for scup (and the data presented here suggest that it does), consideration should be given to using this codend because it permits the retention of smaller black sea bass without negatively influencing scup. This change would eliminate the need to carry two codends onboard and thus would reduce overall trip costs without impacting the number of scup discards. However, neither codend successfully addresses the need to significantly reduce scup discarding in the scup-directed fishery.

Codends with some 12.7-cm meshes tended to reduce discards by reducing the catchability of smaller scup, but the trends were often not significant, possibly due to the small sample size, but possibly also because nets were clogged by schools of smaller-size scup. The data indicate that further studies with 12.7-cm or greater mesh composites may identify codend configurations that will produce fewer discards. DeAlteris and La Valley (1999) have documented that scup can survive capture in a trawl net and subsequent escapement. Therefore, optimizing codend mesh size could reduce discard mortality.

Larger scup were caught in tows where the total catch weight was low. Large catches tended to accompany the interception of scup schools. These large catches can clog the nets and thus reduce size selection even at larger mesh sizes. Alternatively, larger scup may not be associated with smaller scup in schools. We cannot discriminate between the two explanations. Regardless of the reason, the tendency of the largest catches to contain proportionately more smaller fish will likely minimize the positive influence of net management in reducing scup discards. Rather, the tendency of the largest catches to contain proportionately more smaller fish suggests that fisheries managers may want to lower the legal-size limit for scup from 22.86 cm to 17.78 cm FL. The median size of scup discards in our study was 17.78 cm FL. Setting the size limit at 17.78 cm FL (19.83 cm TL) would greatly reduce discards and thus overall discard mortality. This management change would likely have a much greater effect in reducing scup discards than any other single management measure directed at gear modification or area closure and would not endanger the stock (most discarded scup fail to survive); thus, any approach significantly reducing discards must significantly increase overall survival of the population.

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