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NA03NMF4540076

HCMeen 9/19/06

Gear Modification Study to Reduce Scup Bycatch in the Directed *Loligo* Fishery

02-RSA-001

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5/1/03 - 4/30/04

Introduction

For a number of Mid-Atlantic trawl caught species, the Mid-Atlantic Fisheries Management Council, Atlantic States Marine Fisheries Council, and National Marine Fisheries Service have identified the targeting of mature adult fish and the avoidance of juvenile fish as a primary tool in achieving the rebuilding and mortality objectives of current management plans. Specifically for scup (*Stenotomus chrysops*), the reduction of catch and discards of juvenile scup is a primary objective of the rebuilding plan for scup. During a study to test various codends to reduce scup discards in the offshore directed scup fishery, scup discards were high in tows regardless of codend mesh size, typically one to five times landings (Bochenek et al., 2005). Kennelly (1999) studied NMFS observer trawl data from 1990 to 1994 and found high scup discards. Powell et al. (submitted a) estimated, in 2001, that scup discards in commercial fisheries were 1.91 times scup landings. In 2001, the *Loligo* squid fishery accounted for 6.8% of the scup discarded. Other fisheries with high scup discards were butterfish (18.7%), silver hake (4.7%), scup (56.0%), and black sea bass (12.1%) (Powell et al, submitted a and Powell and Bochenek, submitted b). Even though the discard rate of scup was lower in the directed *Loligo* fishery than in some of the other fisheries, regulations were put in place to reduce discards. These regulations established Gear Restricted Areas (GRAs), time and area closures, in 2000 to protect scup bycatch in the directed offshore *Loligo* fishery and other small-mesh fisheries (Anonymous 2003).

Glass (2002) tested a net modification, in which a 5.5-inch (13.97 cm) square mesh extension of 45 meshes was inserted 50 meshes above the terminus of the codend, that reduced the capture of scup, favored the release of smaller scup, and did not affect the capture of *Loligo* squid (*Loligo pealei*). In 2003, this net modification was required for use in the offshore *Loligo* fishery when fishing in the GRAs to reduce scup discards (Anonymous 2003). Powell et. al. (2004) tested this extension in commercial fishing mode inside the GRAs and noted that catches of smaller-sized finfish including scup were reduced, but *Loligo* catches were impaired on three of the four commercial vessels. In January 2004, NMFS-NEFSC carried out a further evaluation of the Glass design (Hendrickson 2005). Results from this NMFS study further indicate that both scup and *Loligo* squid catches are reduced. The decrease in *Loligo* catch makes this design impractical as a bycatch reduction tool.

The original intent of our study was to further test the Glass extension, but the 2004 NMFS mission confirmed our earlier results for this extension. In addition, less money was raised for this project then anticipated, because the *Loligo* squid fishery did not close in 2003. Without a closure, the research set-aside of squid received to support the project was not worth enough money for the fishermen to harvest. Finally, our field mission was time constrained due to the necessity of awaiting results from the NMFS-2004 program (Hendrickson 2005). As a consequence, the objectives of this study were significantly modified. This modification had two objectives. First, we chose to determine if a funnel inserted in the Glass extension would increase the retention of *Loligo* squid while still reducing scup bycatch. We recognized, due to financial constraints, that only preliminary results could be obtained for this objective since an insufficient number of tows could be taken to permit in-depth statistical evaluation. However, should this field effort produce promising results, further field testing with this net design would then be in order. Second, we chose to conduct some tows inside the Southern GRA to further evaluate the bycatch of scup in this area during the time the area was closed to the *Loligo* fishery. This choice was based on information obtained from the supplemental finfish survey (HSRL 2003a, HSRL 2003b, HSRL 2004a, and HSRL 2004b) that suggests little overlap of scup and *Loligo* squid within the region circumscribed by the GRA. The history behind this project is included in Appendix 1.

Methods

Description of Data

The study was conducted in February-March 2004 when the southern GRA was in effect to test an experimental net extension to reduce scup bycatch and retain *Loligo* squid in the offshore *Loligo* fishery using typical gear types (nets). The standard *Loligo* codend and extension, consisting of 1.875-inch (4.76 cm) diamond mesh, was tested against an experimental net extension. This modified net extension (experimental net) consisted of 10 meshes of 10-inch (25.4 cm) diamond mesh attached to the belly of the net followed by 100 meshes of 1.875-inch (4.76 cm) diamond mesh with a funnel attachment of 1.875-inch (4.76 cm) diamond mesh. The funnel was attached to the belly of the net with plastic rings and extended into the small mesh section of the extension (Figure 1). Two vessels participated in the study and used millionaire nets with slightly different modifications (Table 1). The 2004 standard net A (1.875-inch (4.76 cm) diamond mesh codend) and the modified net B were fished in an alternating sequential pattern of paired tows (AB BA AB, etc.). Paired tows of A_1A_2, B_1B_2, A_1B_2, and B_1A_2 were conducted with the paired tows offset.

Since *Loligo*-targeted tows can be three hours or more in duration, tow times were reduced to no longer than two hours to allow for more tows. Otherwise, the captain operated his boat using normal fishing practices including where to fish. Tow speeds ranged from 3-3.3 knots. Tow depths ranged from 79 to 118 fm.

Catch from each tow was sorted to species and weighed using NMFS observer protocols. A total of 100 discarded and 100 landed *Loligo* squid, scup, and other dominant bycatch species were randomly selected from each tow, total catch permitting, and length measurements taken. Spiny dogfish (*Squalus acanthias*) were measured and sexed.

Each vessel completed eight paired tows during a single trip from February 28 thru March 2, 2004. Some of these tows occurred inside and near the edge of the southern GRA

(Figure 2). During the second paired tow (B_1A_2), Boat 2 did not complete the tow because half of the catch was released overboard and this paired tow was not used in the analysis.

Some additional tows were taken on a trip initiated on March 31st on Boat 1 following the protocol stated above except the tows were not paired. These tows were along the eastern edge of the southern GRA (Figure 2).

Squid catchability has been shown to vary between tows even during daylight hours (e.g., NEFSC 2002). Since both *Loligo* and *Illex* squid (*Illex illecebrosus*) undergo vertical migration, the time-of-day of the tow may influence squid catches. In this study, tows were only conducted during daylight hours. For this analysis, tows were allocated to three daylight periods, namely, 0600-1100, 1100-1500, and 1500-2000 hours.

Effort could not be calculated directly because door and wing spread were not recorded. A surrogate for true effort was obtained as the average of the recorded headrope and footrope lengths multiplied by the recorded tow time and speed.

Statistical Analysis

Nonparametric ANCOVAs were used in the statistical analysis. Only bycatch species that occurred in at least 10 tows were analyzed as well as the target species (*Loligo* squid). The bycatch species were black sea bass (*Centropristis striata*), butterfish (*Peprilus triacanthus*), spotted hake (*Urophycis regia*), silver hake (*Merluccius bilinearis*), John Dory (*Zenopsis conchifera*), *Illex* squid, scup, summer flounder (*Paralichthys dentatus*), and female and male spiny dogfish. Catch weight per tow, the number of individuals of each species per tow, the 25th, 50th, and 75th percentile size frequencies and the mean size were used as dependent variables. Net extension configuration, time-of-day, and boat were used as independent variables. Time-of-day was included because catches of some species including *Loligo* are significantly affected by time-of-day (Walsh 1988; Serchuk and Rathjen 1974; NEFSC 2002; Gillis 1999). Interaction terms between main effects were also included. In some cases, total catch weight of all species and effort were used as covariates.

In addition, the information contained in the paired tows was directly utilized as the dependent variable by calculating the difference between the catch weights for the target or bycatch species. Instead of using net as the main effect, the four possible pair-wise net configurations (A_1A_2, B_1B_2, A_1B_2, and B_1A_2) were used with the expectation that $A_1=A_2$, $B_1=B_2$, $A_1<B_2$, and $B_1>A_2$. The differences in effort and total catch were used as covariates instead of effort and total catch.

To identify significant differences within the ANCOVAs, *a posteriori* Tukey's Studentized Range tests and Least Square Means tests were run. The significance level was set at $\alpha = 0.05$ for all tests.

Results

Descriptive Data

For the target species, the mean catch per tow of *Loligo* squid with the standard extension was 1157.65 kg for Boat 1 and 705.11 kg for Boat 2 and with the modified extension was 364.76 kg for Boat 1 and 440.14 kg for Boat 2. For Boat 1, the main bycatch species caught per tow with the standard extension were male and female spiny dogfish, spotted hake, black sea bass,

and *Illex* squid and with the modified extension were male and female spiny dogfish and spotted hake. The main bycatch species caught per tow for Boat 2 with the standard extension were male and female spiny dogfish, spotted hake, and silver hake and with the modified extension was male spiny dogfish. Other bycatch species caught in smaller amounts by both boats were butterfish, John Dory, scup, and summer flounder (Table 2). Scup mean catch per tow with both the standard and modified extension ranged from 1.42 to 4.37 kg (Table 2) with tows taken within and near the eastern edge of the southern GRA (Figure 2).

Mean total catch (kg) of all species per tow with the modified extension was 2288.35 for Boat 1 and 1035.43 for Boat 2. With the standard extension, mean total catch (kg) of all species per tow was 3102.20 for Boat 1 and 3137.28 for Boat 2 (Table 3).

The average size of *Loligo* squid caught in the modified extension was 11.87 cm and in the standard extension was 11.29 cm (Table 4). For scup, mean size captured in the standard extension was 18.30 cm and in the modified extension was 18.65 cm (Table 4). Scup mean and median sizes were smaller than the current legal size of 22.86 cm (Table 4).

General Tow Effects

We examined the effects of boat, net extension type, time-of-day, effort, and total catch of all species on catch weight per tow of the target species (*Loligo* squid) and bycatch species (black sea bass, butterfish, silver hake, spotted hake, *Illex* squid, John Dory, male and female spiny dogfish, summer flounder, and scup). Catch weight between the two net extension types was not significantly different for any species examined. Catch weight per tow of *Loligo* squid, *Illex* squid, black sea bass, butterfish, spotted hake, John Dory, scup, summer flounder, and male spiny dogfish was not significantly different between boats. A significant boat effect occurred for female spiny dogfish (p=0.0.049) with Boat 2 catching more female spiny dogfish than Boat 1. A slightly significant boat effect (p=0.0530) was noted for silver hake with Boat 2 catching more silver hake than Boat 1. Total catch of all species per tow had a significant effect on the catch per tow of *Loligo* squid (p=0.020), *Illex* squid (p=0.018), female spiny dogfish (p=0.0015), and male spiny dogfish (p=0.001). Effort was significant as a covariate for five of the eleven species (Tables 2 and 5), an occurrence rate greater than expected by chance (binomial test). Effort was significant even though tow time and speed were kept constant between the two vessels. This significant difference in effort is likely the result of the difference in net size between the two vessels (Table 1).

Both net configurations catch about the same amount of squid and fish. The two vessels differed significantly in catch for a number of species but most of this difference could be ascribed to different net dimensions. Taking net dimensions into account, the two vessels caught the same amount (kg) of fish in 9 of the 11 species examined. Only catch weights of female spiny dogfish and silver hake differed between boats with Boat 2 catching more than Boat 1. Whether tows were taken during the morning, afternoon or evening did not have an effect on the catch weight for any species examined (Tables 2 and 5).

Paired Tow Effects

We examined the differences in catch weight per paired tow by ANCOVA for the target species (*Loligo* squid) and bycatch species (black sea bass, butterfish, silver hake, spotted hake, *Illex* squid, John Dory, male and female spiny dogfish, summer flounder, and scup). The

differential in catch weight between paired tows was significant in only one case, female spiny dogfish (p=0.052). This occurrence rate is not greater than expected by chance.

Size Frequency and Number of Individual Species Effects

The modified extension was designed to permit escapement of small finfish while retaining *Loligo* squid. We anticipated that larger finfish would be retained in tows with the modified extension and *Loligo* sizes would remain unchanged. The size frequencies (25th, 50th, 75th, and mean) and number of individuals of *Loligo* squid, black sea bass, scup, and female and male spiny dogfish were evaluated. No significant differences in the number of individuals caught per tow were noted.

No significant differences in size frequencies were noted for *Loligo* squid, scup, black sea bass, and female spiny dogfish. Time-of-day, extension type, effort, and total catch of all species had a significant influence (p=0.0001) upon the 50th percentile and mean size fractions of male spiny dogfish. Males were somewhat larger with the modified net. This result at this alpha level would not be expected by chance (binomial test) (Table 4).

Conclusions

Boat, Extension Type and Size Frequency Effects

Glass (2002) recommended the use of an extension in the offshore *Loligo* fishery to reduce scup discards that consisted of a large square-mesh section with meshes of 5.5 inches (13.97 cm) in the extension placed 45 meshes in front of the codend, because his study showed that this gear configuration reduced scup bycatch and did not impact the *Loligo* catch. In 2003, this extension was required on vessels fishing for *Loligo* squid inside the GRAs (Anonymous 2003). A study conducted by Powell et al (2004), using commercial fishing vessels operating in commercial mode, tested this extension inside the GRAs and noted that this gear type reduced catches of smaller-sized finfish, but was inconsistent in catching *Loligo* squid since three of the four vessels had reduced catches of *Loligo* with this extension. In 2004, the Northeast Fisheries Science Center, NMFS conducted a study with commercial fishing vessels using this extension and results indicated that this gear type lost both *Loligo* squid and scup (Hendrickson 2005). As a result, our study was designed to test a modified configuration of the Glass extension that might retain *Loligo* squid while allowing escapement of scup. Halliday and Cooper (1999) in the silver hake small-mesh otter trawl fishery successfully used a funnel and grate system to reduce bycatch of finfish species. We modified the Glass extension by adding a section of 10 meshes of 10-inch diamond mesh attached to the belly of the net followed by 100 meshes of 1.87-inch diamond mesh. A funnel of 1.87-inch diamond mesh was then attached to the belly of the net with plastic rings and extended into the small mesh section of the extension (Figure 2).

In our study, no significant differences in catch weight between the modified extension (with the funnel) and the standard extension were found for *Loligo* squid. The strategy was to funnel squid into the codend by allowing them to bypass the large mesh extension while still permitting fish to escape. The funnel used in the modified extension directs the squid past the large 10-inch diamond mesh and into the codend. Unfortunately, we did not observe a reduction in finfish catch, even in the small and mobile species such as silver hake. The funnel configuration as tested does not appear to give finfish a chance to escape

Powell et al. (2004) found that *Loligo* catches varied significantly between boats. In contrast, *Loligo* catches did not vary between boats in this study. Only two bycatch species out of 11 analyzed, female spiny dogfish and silver hake, had catch weights that differed between vessels with Boat 2 catching more than Boat 1 in our study. In contrast, Powell et al. (2004) found differences in catches between boats conducting *Loligo* squid directed tows in the southern GRA for monkfish (*Lophius americanus*), butterfish, silver hake, smooth dogfish (*Mustelus canus*), and summer flounder.

We assumed the modified extension would catch less of the smaller-sized finfish and retain *Loligo* squid. Our study results indicate that the modified extension appeared to catch the same size frequencies as the standard extension for most of the bycatch species and *Loligo* squid.

Relationship to Current Scup Bycatch Management Measures in the *Loligo* Fishery

Scup GRAs were created in 2000 to reduce scup discarding in the directed *Loligo* fishery. In 2005, the NMFS moved the Scup GRA boundary in recognition of the spatial separation of scup and *Loligo* squid within the GRAs. Study results support this management change. A total of 18 directed *Loligo* tows were taken within and outside the southern GRA during the time of the closure in this study. Mean catch per tow of scup ranged from 1.42 to 4.37 kg per tow (Table 2). The mean scup-to-*Loligo* catch ratio per tow was 0.005349 with the modified extension and 0.006020 for the standard extension. Mean scup size was 18.65 (7.34 inches) cm with the modified net and 18.30 cm with the standard net (Table 4). In another study, commercial vessels conducted 34 *Loligo* targeted tows inside the southern GRA in 2003 and not a single scup was caught (Powell et al., 2004). The *Loligo* directed fishery only accounted for about 6.8% of the scup discards in 2001 from NMFS observer data (Powell et al., submitted a; Powell and Bochenek, submitted b).

Relationship to Current Scup Management Measures in the Scup Fishery

While this project focused on reducing scup bycatch in the directed *Loligo* fishery, the researchers note that most of the reported and documented scup discards (56.0%) occurred in the directed scup fishery (Powell et al., submitted a; Powell and Bochenek, submitted b). During a study to test various codends to reduce scup discards in the offshore directed scup fishery, scup discards were high in tows regardless of codend mesh size, typically one to five times landings (Bochenek et al., 2005). The overall reason given by commercial captains for discarding of scup from the NMFS observer database was the legal landing limit (Powell et al., submitted a). The current legal landing size is 22.9 cm (9 inches). Even in this study, the average catch of scup was 18.30 to 18.65 cm, a size well below the legal landing size. The median size was also well below the legal landing size (Table 4). As expressed in Powell et al. (2004) and Bochenek et al. (2005), the legal size limit for scup could be lowered to reduce scup discarding by converting discards of adult scup to landings. This study also supports lowering the legal size limit of scup. Further research might be warranted to investigate methods to reduce scup discards in the directed scup fishery including the effects of the recently implemented (2005 Scup specifications) increase in bag limit and codend mesh size as well as considering the impacts of a potential decrease in the scup size limit.

Overall

The experimental net appeared to fish the same as the standard net in our study. An increase in mesh size or reconfiguration of the funnel in the extension may permit escapement of finfish however, the cumulative data of three studies suggests that the insertion of a large mesh panel in the extension is unlikely to provide a successful net design. Campos and Fonsecca (2004) tested separator panels and square mesh windows to reduce bycatch in a crustacean trawl fishery off of southern Portugal. These researchers were able to reduce the catch of bycatch species (finfish) while maximizing the catch of the target species (*Parapenaeus longirostris*, rose shrimp and *Nephrops norvegicus*, Norway lobster). The use of a separator panel and square mesh window might be studied to reduce discards in the *Loligo* fishery even though Campos and Fonesecca (2004) found this design to be very complex and difficult to adopt in a commercial fishery. Another potential net design to investigate would be the use of a funnel and separator grate. Halliday and Cooper (1999) evaluated the use of separator grates and a funnel or panel forward of the grate in the silver hake fishery and was able to successfully impact the size selection and escapement levels of various bycatch species of finfish. *Loligo* fishermen have also expressed concern that squid might 'stick' to the grate and thus lower catchability of the target species.

One result of this project is that it continued to demonstrate the low bycatch of scup for the tows observed in the directed loligo fishery. We recommend that the inherent separation of these two species spatially, if properly taken advantage of by fishermen, provides the best current basis for reducing an already low bycatch rate of scup in the *Loligo* fishery. Further work on net configurations aimed at scup bycatch reduction in the *Loligo* fishery does not seem to be warranted at this time.

Acknowledgements

We especially acknowledge the Captains and crew of the two fishing vessels from Cape May who participated in this project. Special thanks to the National Fisheries Institute-Scientific Monitoring Committee (NFI-SMC), especially Daniel Cohen and Greg DiDomenico, for their support throughout the project. This project was funded by a grant from the NOAA NMFS Research Set-aside Program awarded to the NFI-SMC.

Literature Cited

Anonymous. 2003. Fisheries of the Northeast United States: Summer flounder, scup, and black sea bass fisheries; 2003 specifications. Federal Register, 50 CFR Part 648, 68(1), 60-68.

Bochenek, E.A., E.N. Powell, A.J. Bonner and S.E. Banta. 2005. Assessment of scup (*Stenotomous chrysops*) and black sea bass (*Centropristas striata*) discards in the directed otter trawl fisheries in the Mid-Atlantic Bight. Fishery Bulletin 103:1-14.

Campos, A., and P. Fonsecca. 2004. The sue of separator panels and square mesh windows for by-catch reduction in the crustacean trawl fishery off the Algarve (south Portugal). Fisheries Research 69(2004):147-156.

Gillis.D.M. 1999. Behavioral inferences from regulatory observer data: catch rate variation in the Scotian Shelf silver hake (*Merluccius bilinearis*) fishery. Canadian Journal of Fisheries and Aquatic Sciences 56:288-296.

Glass, C.W. 2002. Mid-Atlantic small-mesh research program. Final report to the Mid-Atlantic Fisheries Management Council. Manomet Center for Conservation Sciences. Manomet, MA. 7 p.

Halliday, R.G., and C.G. Cooper.1999. Evaluation of separator grates for reduction of bycatch in the silver hake (*Merluccius bilinearis*) otter trawl fishery off Nova Scotia, Canada. Fisheries Research 40(1999):237-249.

Hendrickson, L. 2005. Effectiveness of a square-mesh escape panel in reducing finfish bycatch in a small-mesh bottom trawl used in the longfin inshore squid (*Loligo pealeii*) fishery. NEFSC. Ref. Doc. 05-05. 46 pp.

HSRL. 2003a. Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species. March 2003 Cruise Report. Haskin Shellfish Research Laboratory, Rutgers University, 73 pp.

HSRL. 2003b. Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species. May 2003 Cruise Report. Haskin Shellfish Research Laboratory, Rutgers University, 98 pp.

HSRL. 2004a. Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species. January 2004 Cruise Report. Haskin Shellfish Research Laboratory, Rutgers University, 126 pp.

HSRL. 2004b. Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species. March 2004 Cruise Report. Haskin Shellfish Research Laboratory, Rutgers University, 129 pp.

HSRL. 2004c. Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species. May 2004 Cruise Report. Haskin Shellfish Research Laboratory, Rutgers University, 129 pp.

NEFSC. 2002. 34th Northeast Regional Stock Assessment Workshop (34th SAW); Stock assessment review committee (SARC) consensus summary of assessments. Northeast Fisheries Science Center Reference Document 02-06. 346 pp.

NEFSC. 2001. Fisheries observer program manual. National Marine Fisheries Service. Woods Hole, MA. 217 pp.

Powell, E.N., A.J. Bonner, B. Muller and E.A. Bochenek. 2004. Assessment of the effectiveness of scup bycatch-reduction regulations in the *Loligo* squid fishery. J. of Environmental Management 71:155-167.

Powell, E.N., A.J. Bonner, and E.A. Bochenek. (submitted a). Scup discarding in the fisheries of the Mid-Atlantic Bight.

Powell, E.N. and E.A. Bochenek. (submitted b). Discarding in the small-mesh fisheries of the Mid-Atlantic Bight.

Serchuk, F.M., and W.F. Rathjen. 1974. Aspects of the distribution and abundance of the long-finned squid, *Loligo pealei*, between Cape Hatteras and Georges Bank. Marine Fisheries Review 36(1):10-17.

Walsh, S.J. 1988. Diel variability in trawl catches of juvenile and adult yellowtail flounder on the Grand Banks and the effect on resource assessment. North American Journal of Fisheries Management 8:373-381.

Appendix 1

The regulation requiring a modified extension was an outgrowth of a larger issue that concerned scup bycatch in the *Loligo* fishery. This concern originated from a too cursory evaluation of the historical observer database and spawned an effort to reduce bycatch through the imposition of GRAs. The GRAs had a monumental impact on the *Loligo* squid fishery and this spawned an effort to provide access to the GRAs through net regulations that purported to effect the same outcome, namely the reduction in scup discarding in *Loligo*-targeted tows.

The net modification forwarded into regulation originated in the recommendation by Glass (2002) that the inclusion of a modified extension in nets used in *Loligo*-targeted tows reduced the bycatch of scup. Glass (2002) was careful at the time to recommend additional research rather than immediate codification of the recommendation into regulation, as the approach had not been thoroughly subjected to at-sea evaluation. Unfortunately, the MAFMC imposed the recommendation soon thereafter. This action proved to be extremely premature.

In this atmosphere, we proposed to conduct a further evaluation of the Glass extension, specifically focused on the degree to which it was successfully implemented in the fishery. That is, we wished to determine if the modified extension performed as promised under standard use. We carried out the first year of this research program and obtained results in Powell et al. 2004 that did not support the efficacy of the extension in reducing scup capture in *Loligo*-targeted tows; however ambiguities remained.

Accordingly, in the subsequent proposal period, we proposed additional sea trials of the Glass modification to resolve ambiguities unveiled by our first study. These originated from the failure of the net modification to operate adequately on three vessels, but the successful implementation of the net modification on the fourth. This latter might have been a chance event or point to the need to more carefully control implementation of the modified extension, as the original regulation permitted considerable leeway in how the extension was configured.

While this second proposal period was underway, two additional occurrences impacted its final implementation. The first was the continued support of the Supplemental Finfish Survey Targeting Migratory Species (the transect survey) that obtained a time series over several years identifying the degree of overlap between *Loligo* squid and scup. These new data proved that these two species rarely overlap significantly and permitted the reorientation of the southern GRA to better define that small area of overlap. As a result, the bycatch issue of scup in *Loligo* targeted trips was mostly resolved and the *raison d'ĕtre* for the modified extension disappeared.

The second was the development within NMFS-NEFSC of a competing research program with precisely the same goals as our second year's research effort. As a consequence of this duplication, we entered into a number of discussions to determine how best to proceed with our own research program. The decision was to await the results of the NMFS program (Hendrickson 2005) because, if that program produced positive results on the extension, additional tows testing it would be worthwhile. If that program produced negative results, in essence in agreement with Powell et al. (2004), then no further tests would be useful. Unfortunately, the NMFS program (Hendrickson 2005) was seriously delayed due to weather and finally got to sea towards the end of the winter *Loligo* season, thus constraining all subsequent activity. The program, however, provided data that strongly supported Powell et al. (2004). Thus, not only did the *raison d'ĕtre* for the program disappear, but the recommended solution for the non-problem was proven to have been prematurely invoked into regulation without adequate testing at sea.

This left us with a few weeks to test a net and few obvious approaches to take. It seemed to us that the best way to salvage something from what had become an unfortunate sequence of events was to determine if the extension could be modified to retain squid and exclude any finfish. Although scup is not a discarding issue for the *Loligo* fishery, some other finfish are more significant. We had several brainstorming sessions over a short time to determine what approach to take. The approach had to be one that could be rapidly put in place, as the original net design was no longer in play. The Captains involved felt that a funnel in the extension would retain squid. Our question then was simple: did squid `escape' the modified extension due to passive filtration -- the funnel should prevent that happenstance -- and could any finfish escape from an extension with a funnel that would retain squid?[1]

The field program proved two things. The first was that the funnel retains squid. That simply shows that the belief among Captains and scientists that the squid were being filtered out through the extension was correct and that this also explained the loss of finfish. The second was that the common finfish did not escape in acceptable numbers. This too is not a surprise, we do not think. As a consequence, our study put the final `nail' in the extension `coffin' and we recommend, correctly we think, that this line of research be terminated.

Reviewers of the project brought up several issues related to historical constraints that impacted on the study design. One of these was the location of the tests. *Loligo* squid and scup rarely overlap extensively. As consequence, it is rarely possible to test nets successfully in an area of substantial overlap without much time at sea identifying such a location. We agree completely that the original study was based on a `design flaw' that assumed that *Loligo* squid and scup overlapped over vast areas. This `flaw' was imposed upon us by the regulatory conditions at the time. The NMFS-NEFSC study (Hendrickson 2005) likewise had great trouble in finding locations to test the two species simultaneously. Our contribution to this point was to prove again that one catches few scup when targeting squid. A second issue concerned the hydrodynamics associated with the funnel. Our desire was to show that squid, which are caught passively, were `escaping' from the extension due to passive filtration. The funnel stopped that from occurring. We are not surprised that finfish likewise did not escape. This supports our contention that the extension design was fatally flawed in that finfish were not `escaping' purposefully either. Thus, the modified goal of our program was met, namely to explain in some measure why the modified extension option produced the results that it did.

A final issue concerned the conditions used for testing the extension in commercial fishing mode. Differential fishing prowess between boats is precisely why we have argued consistently for using multiple boats in these types of projects. One must recognize that research programs like this one are not experimental in design nor is the reason for them gear development. The objective of research programs of this type is to evaluate a regulated net under standard conditions of use in the fishery. As a consequence, we quite properly permitted Captains to conduct their activities as they normally do and we included several boats representative of the fleet. We are of the opinion that the results of these types of studies are more often limited by the number of boats that can be included rather than the number of tows on a boat. Had we had twice the funding, we would have doubled the number of boats, not the number of tows per boat. It is a critical mistake to believe that net modifications are consistently implemented across all boats in a fleet as diverse as the one that takes *Loligo*.

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[1] In passing, we would also note that the year of this study was a year when the *Loligo* fishery did not close. As a consequence, most of the requested set-aside to support this program did not produce the anticipated supporting funds and our field program, necessarily, was restricted in scope.

Figure 1. Diagram of the experimental 10-inch (25.4 cm) diamond mesh extension escapement panel with a funnel attachment.

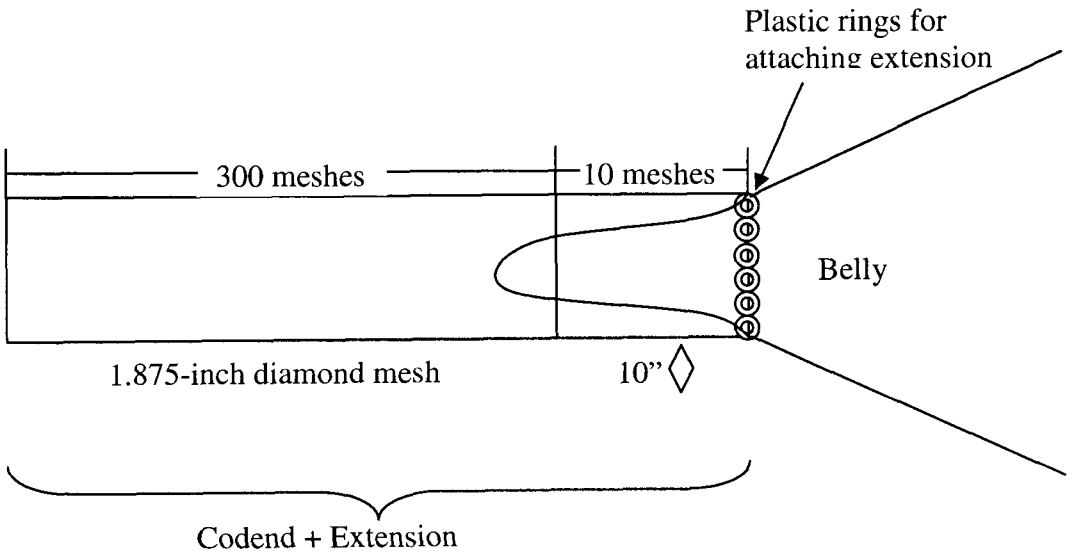

Figure 2. Map of the Mid-Atlantic Bight showing the location of the southern Gear Restricted Area that is in effect from January through March and the paired and non-paired tows targeting *Loligo* squid.

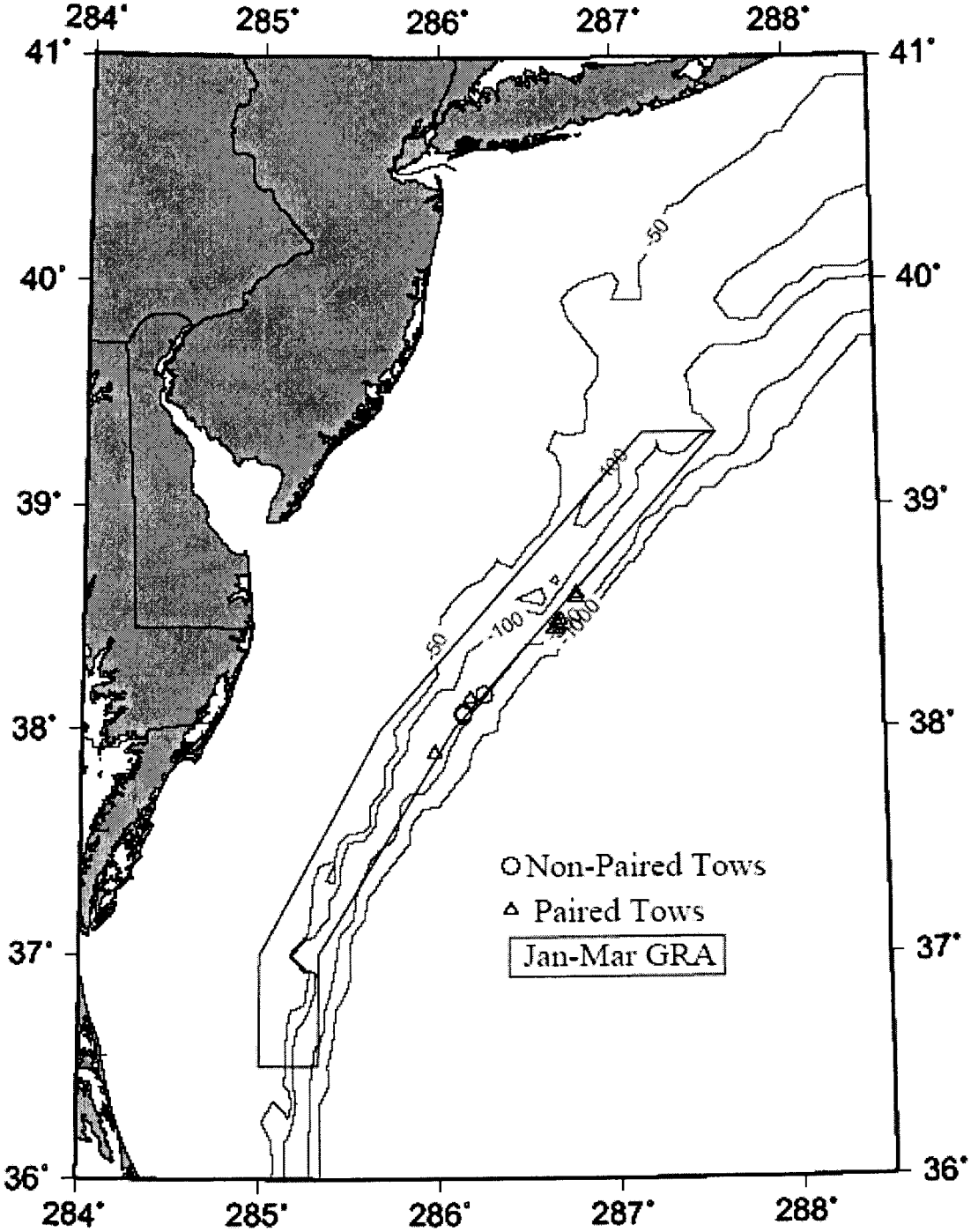

Table 1a. Descriptive data for the nets used on each boat. Net A=Legal codend extension. Net B=experimental codend extension.

Vessel	Extension	Net Style	Headrope	Footrope	Ground Cable	Codend
Boat 1 Net A	200 mesh codend extension with 1.875" diamond mesh	Millionaire, Polyethylene in net body	130ft, 24 floats 16" diameter	130ft	270ft	1.875" diamond mesh, polyethylene, liner, no strengthener, chaffing gear on bottom
Boat 1 Net B	300 mesh codend extension with 1.875" diamond mesh, 10 meshes of 10" diamond mesh above extension, funnel attached inside the large mesh panel (1.875" diamond mesh) and attached to belly of net with plastic rings	Millionaire, Polyethylene in net body	130ft, 24 floats 16" diameter	130ft	270ft	1.875" diamond mesh, polyethylene, liner, no strengthener, chaffing gear on bottom
Boat 2 Net A	200 mesh codend extension with 1.875" diamond mesh	Millionaire, Polyethylene in net body	140ft	140ft	300ft	Double twine diamond hung, 1.875" mesh, no chaffing gear
Boat 2 Net B	300 mesh codend extension with 1.875" diamond mesh, 10 meshes of 10" diamond mesh above extension, funnel attached inside the large mesh panel (1.875" diamond mesh) and attached to belly of net with plastic rings	Millionaire, Polyethylene in net body	140ft	140ft	300ft	Double twine diamond hung, 1.875" mesh, no chaffing gear

Table 1b. Additional descriptive data on boats and nets.

Vessel	Doors	Horsepower	Length	Winch Speed	Floats
Boat 1	Thyboron type-2-92 2,500x1490mm 634 kg	720 HP	86 ft	30 rev/min	24-16" diameter
Boat 2	Thyboron type 2-92 2,500x1490 mm 634 kg	700 HP	85 ft	28 rev/min	24-11" diameter

Table 2. Mean catch per tow (kg) and standard deviation by bycatch species, the target species *Loligo*, boat, and net extension type for *Loligo*-targeted tows. N= number of tows that contained the bycatch species.

Bycatch and Target Species	Boat 1 Standard Extension N=5	Boat 1 Modified Extension N=5	Boat 2 Standard Extension N=3	Boat 2 Modified Extension N=4
Loligo Squid	1157.65±1210.10	364.76±105.61	705.11±389.35	440.14±226.59
Black Sea Bass	118.22±162.48	25.46±36.71	12.63±5.53	72.27±110.28
Butterfish	15.73±12.42	8.43±13.51	31.01± 49.36	2.85±2.21
Spotted Hake	332.50±380.78	525.02±781.23	240.34±74.83	42.19±61.54
Silver Hake	47.90±25.89	31.23±33.07	130.80±71.79	48.93±17.58
John Dory	5.76±6.21	1.74±1.69	3.79±3.45	2.34±3.07
Illex Squid	106.98±109.16	42.19±61.54	67.22±74.34	31.29±34.41
Scup	4.37±4.19	1.42±1.71	1.89±1.64	3.02±3.47
Summer Flounder	9.14±10.98	12.66±16.39	15.73±12.06	5.35±9.29
♀ Spiny Dogfish	374.84±765.59	466.94±566.68	632.15±1343.36	28.21±45.57
♂ Spiny Dogfish	641.38±914.42	686.28±724.69	1041.66±1798.49	320.29±631.90

Table 3. Mean catch of all species per tow by boat and net extension type for *Loligo*-targeted tows. Standard deviation in parentheses.

Boat	Net Extension Type	Mean catch per tow (kg)	Number of Tows
Boat 1	Modified Net	2288.35(706.87)	4
Boat 2	Modified Net	1035.43(754.22)	4
Boat 1	Standard Net	3102.20(1788.65)	5
Boat 2	Standard Net	3137.28(3565.47)	3

Table 4. The mean (cm) and 25th, 50th, and 75th size-frequency distribution (cm) and standard deviation in parentheses for major bycatch species and the target species *Loligo* in *Loligo*-directed tows by codend extension.

Species	25th Percentile	50th Percentile	75th Percentile	Mean
Loligo Squid				
Modified Net	10.00(0.707)	11.56(1.130)	13.11(1.692)	11.87(1.280)
Standard Net	9.88(0.835)	10.88(0.835)	12.63(0.744)	11.29(0.792)
Summer Flounder				
Modified Net	49.33(2.082)	54.17(0.764)	58.33(1.528)	54.29(0.803)
Standard Net	52.00(1.414)	57.00(2.121)	61.00(2.828)	56.78(2.315)
Scup				
Modified Net	16.75(0.500)	18.13(1.315)	20.13(1.750)	18.65(0.709)
Standard Net	16.40(0.548)	17.60(0.894)	19.40(1.949)	18.30(1.097)
Black Sea Bass				
Modified Net	26.78(3.667)	28.61(4.256)	30.78(5.357)	29.23(4.919)
Standard Net	28.72(5.569)	30.36(5.404)	33.05(5.842)	31.25(5.934)
♂ Spiny Dogfish				
Modified Net	70.75(0.957)	73.25(0.957)	76.25(0.957)	73.60(1.009)
Standard Net	70.00(1.000)	72.67(0.577)	75.67(0.577)	72.49(0.895)
♀ Spiny Dogfish				
Modified Net	69.40(6.107)	73.50(5.500)	77.40(5.595)	72.85(3.824)
Standard Net	69.60(9.290)	72.50(9.421)	78.10(7.749)	73.36(8.681)

Table 5. Results of ranked ANCOVA on catch weight by tow of bycatch species and the target species *Loligo* squid. Total catch=catch weight of all species in the tow.

Variable	Loligo Squid	Black Sea Bass	Butterfish	Spotted Hake	Silver Hake	John Dory	Illex Squid	Scup	Summer Flounder	♀ Spiny Dogfish	♂ Spiny Dogfish
Boat	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0494	NS
Extension	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boat*Extension	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Effort	NS	NS	NS	0.0148	0.0131	NS	NS	0.0422	0.0032	0.0015	NS
Boat	NS	NS	NS	NS	0.0530	NS	NS	NS	NS	0.0494	NS
Extension	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boat*Extension	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Total Catch	0.0196	NS	NS	NS	NS	NS	0.0183	NS	NS	0.0015	0.0010