Northeast Fisheries Science Center Reference Document 05-05

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

by

Lisa Hendrickson

June 2005

Recent Issues in This Series

04-03 **Report of the 38th Northeast Regional Stock Assessment Workshop (38th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments.** [By Northeast Regional Stock Assessment Workshop No. 38.] January 2004.

04-04 **Report of the 38th Northeast Regional Stock Assessment Workshop (38th SAW): Advisory Report.** [By Northeast Regional Stock Assessment Workshop No. 38.] January 2004.

04-05 **Proceedings of the Seventh Meeting of the Transboundary Resources Assessment Committee (TRAC), Woods Hole, Massachusetts, May 27-29, 2003.** By W.J. Overholtz, TRAC chairman. [A report of Transboundary Resources Assessment Committee Meeting No. 7]. February 2004.

04-06 **Stock Assessment of the Gulf of Maine - Georges Bank Atlantic Herring Complex, 2003.** By W.J. Overholtz, L.D. Jacobson, G.D. Melvin, M. Cieri, M. Power, D. Libby, and K. Clark. February 2004.

04-07 **Identification and Description of the Common Sponges of Jeffreys Ledge as an Aid in Field Operations.** By K. McCarthy. April 2004.

04-08 **Revised Procedures for Calculating Regional Average Water Properties for Northeast Fisheries Science Center Cruises.** By D.G. Mountain, M.H. Taylor, and C. Bascuñán. April 2004.

04-09 **Estimation of Striped Bass Discards in the Multispecies Groundfish Fishery during the 2002 Fishing Year (May 2002 - April 2003).** By G.R. Shepherd. June 2004.

04-10a **39th Northeast Regional Stock Assessment Workshop (39th SAW) Assessment Summary Report.** [By Northeast Regional Stock Assessment Workshop No. 39.] July 2004.

04-10b **39th Northeast Regional Stock Assessment Workshop (39th SAW) Assessment Report.** [By Northeast Regional Stock Assessment Workshop No. 39.] July 2004.

04-11 **Bycatch of Sea Turtles in the Mid-Atlantic Sea Scallop (*Placopecten magellanicus*) Dredge Fishery during 2003.** By K.T. Murray. August 2004.

04-12 **Description of the 2003 Oceanographic Conditions on the Northeast Continental Shelf.** By C. Bascuñán, M.H. Taylor, and J.P. Manning. September 2004.

04-13 **Ninth Flatfish Biology Conference, December 1-2, 2004, Water's Edge Resort, Westbrook, Connecticut.** By R. Mercaldo-Allen (chair), A. Calabrese, D.J. Danila, M.S. Dixon, A. Jearld, D.J. Pacileo, C. Powell, and S.J. Sutherland, steering committee members. November 2004.

04-14 **Northeast Fisheries Science Center Publications, Reports, and Abstracts for Calendar Year 2003.** By L. Garner. November 2004.

05-01 **Results from the 2004 Cooperative Survey of Atlantic Surfclams.** By J.R. Weinberg, E.N. Powell, C. Pickett, V.A. Nordahl, Jr., and L.D. Jacobson. February 2005.

05-02 **Proceedings of a Workshop to Review and Evaluate the Design and Utility of Fish Mark - Recapture Projects in the Northeastern United States; October 19-21, 2004; Nonantum Resort, Kennebunkport, Maine.** By Workshop Organizing Committee (S. Tallack, editor, P. Rago, chairperson, T. Brawn, workshop coordinator, and (alphabetically) S. Cadrin, J. Hoey, and L. Taylor Singer. March 2005.

05-03 **Description of the 2004 Oceanographic Conditions on the Northeast Continental Shelf.** By M.H. Taylor, C. Bascuñán, and J.P. Manning. April 2005.

05-04 **40th SAW Assessment Report.** By 40th Northeast Regional Stock Assessment Workshop. April 2005.

Northeast Fisheries Science Center Reference Document 05-05

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

by

Lisa Hendrickson

Woods Hole Lab., National Marine Fisheries Serv., 166 Water St., Woods Hole, MA 02543-1026
Lisa.Hendrickson@noaa.gov

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

June 2005

Northeast Fisheries Science Center Reference Documents

This series is a secondary scientific series designed to assure the long-term documentation and to enable the timely transmission of research results by Center and/or non-Center researchers, where such results bear upon the research mission of the Center (see the outside back cover for the mission statement). These documents receive internal scientific review but no technical or copy editing. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these documents.

All documents issued in this series since April 2001, and several documents issued prior to that date, have been copublished in both paper and electronic versions. To access the electronic version of a document in this series, go to *http://www.nefsc.noaa.gov/nefsc/publications/series/crdlist.htm*. The electronic version will be available in PDF format to permit printing of a paper copy directly from the Internet. If you do not have Internet access, or if a desired document is one of the pre-April 2001 documents available only in the paper version, you can obtain a paper copy by contacting the senior Center author of the desired document. Refer to the title page of the desired document for the senior Center author's name and mailing address. If there is no Center author, or if there is corporate (*i.e.*, non-individualized) authorship, then contact the Center's Woods Hole Laboratory Library (166 Water St., Woods Hole, MA 02543-1026).

This document's publication history is as follows: manuscript submitted for review -- July 27, 2004; manuscript accepted through technical review -- August 16, 2004; manuscript accepted through policy review -- May 25, 2005; and final copy submitted for publication -- June 2, 2005. This document may be cited as:

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. *U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc.* 05-05; 37 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

A small-mesh bottom trawl fishery for *Loligo pealeii* (longfin inshore squid) occurs throughout the year on the continental shelf of the east coast of the United States. During winter, the fishery is concentrated in the offshore waters of the Mid-Atlantic Bight and Southern New England. Several types of high-opening bottom trawls are used in the fishery, but all are comprised of small-mesh, diamond codends.

A minimum mesh size regulation (50 CFR § 648.23) has been in effect since May 2, 1996 for vessels which possess *L. pealeii*. The regulation states that a minimum mesh size of 4.76 cm (1 7/8 in.) diamond mesh (inside stretched mesh) may be used "throughout the codend for at least 150 continuous meshes forward of the terminus of the net, or for codends with less than 150 meshes, the minimum mesh size codend shall be a minimum of one-third of the net measured from the terminus of the codend to the head rope…". In addition, a codend cover or strengthener may be used provided that the effective mesh opening of the cover is at least 11.43 cm (4.5 in.) diamond mesh (inside stretched mesh) along the top 50% of the net surface. The codend cover may not constrict the effective mesh opening in the top 50% of the net to less than 48 mm. Vessel operators fishing for *Illex* during the months of June through September, seaward of a line which approximates the 50 fathom isobath, are exempt from the minimum mesh size regulation.

As a result of the small codend mesh size used in the *L. pealeii* fishery, a large portion of the biomass encountered by the net is retained. Consequently, the potential for bycatch is high for species which co-occur with *L. pealeii*. One such species is scup (*Stenotomus chrysops*), for which high discard rates of sublegal-sized individuals (< 22.86 cm or 9 in. TL), during winter and spring, have been identified as a major source of fishing mortality on the heavily-exploited scup stock (NEFSC 2000). Scup and *L. pealeii* are both schooling species that are distributed primarily between Cape Cod, MA and Cape Hatteras, NC. Research bottom trawl surveys conducted by the Northeast Fisheries Science Center (NEFSC), during 1992-2003, indicate that both species are distributed offshore during the winter (Figure 1) then migrate inshore during the spring (Figure 2).

In an effort to reduce discarding of juvenile scup in trawl fisheries, two Gear Restricted Areas (GRAs) have been in effect since December 27, 2000 (50 CFR § 648.122). Fishing with a codend mesh size smaller than 11.43 cm diamond mesh, throughout the codend and for at least 75 continuous meshes forward of the terminus of the net, is prohibited in the Northern GRA (NGRA) during November 1 through December 31 and in the Southern GRA (SGRA) during January 1 through March 15 (Figure 3). In 2005, the SGRA was moved westward by 3 minutes. Vessels fishing with a codend mesh size of less than 114.3 mm are subject to scup trip limits of 226.8 kg (500 lbs) during November 1 to April 30 and 45.4 kg (100 lbs) during May 1 to October 1. Effective January 2, 2003 (68 FR 68), such vessels were prohibited from fishing within the GRAs unless they possessed a Scup GRA Exemption Program Authorization, carried a NMFS-certified observer onboard, and fished with "a specially modified trawl net. A requirement of the modified trawl net included an escapement extension consisting of a minimum of 45 meshes of 14.0 cm (5.5 in.) square-mesh positioned behind the body of the net and in front of the codend.

In the subject study, the parallel haul method is used to evaluate the effectiveness of a square-mesh escape panel installed in a *L. pealeii* bottom trawl, similar to that required by the 2003 GRA regulations, in reducing the bycatch of scup in offshore waters during the winter. The bycatch of other finfish species, as well as *L. pealeii* catch, was also quantified during the study.

MATERIALS AND METHODS

Two *Loligo* fishing vessels of similar size, horsepower and gear configuration (Table 1), the F/V *Sea Breeze* and F/V *Iron Horse*, were chartered by the Northeast Fisheries Science Center (NEFSC) to conduct a parallel haul study. Both vessels fished with identical high-opening, two-seam "rope trawl" nets manufactured by Superior Trawl in Davisville, Rhode Island. Identical, detachable codends manufactured specifically for the study were laced onto the body of each net with a rope woven through plastic rings. One vessel fished the control codend while the other vessel fished the experimental codend on a parallel course with the two vessels located as close as possible throughout each tow. The control codend was constructed of 165 by 180 meshes of 6 cm (2 3/8 in.) diamond mesh nylon twine (inside stretched-mesh measurement). The codend cover was constructed of 50 by 60 meshes of 15.24 cm (6 in.) diamond mesh polyethylene twine (between the knots). The only difference between the control codend (Net C) and experimental codend (Net E) was a square-mesh escape panel installed in Net E between the codend and the extension (Figure 4).

The square-mesh escape panel was constructed with green, 4 mm Euro webbing hung square and was 45 meshes deep with a bar length of 8 cm (inside stretched-mesh measurement of 14.61 cm). The panel was constructed of green webbing to provide visual contrast between it and the adjacent white webbing to which it was attached. A hanging ratio of 33% was used to attach the panel to the codend and net extension (to hold the twine open 66%). The panel was installed 50 meshes forward of the codend terminus. The square-mesh panel was outfitted with ten gore lines to reduce any strain on the net. Inside stretched mesh measurements of ten randomly selected panel meshes were taken before and after the study to determine whether knot slippage had occurred.

Sampling was conducted in the Mid-Atlantic Bight at nineteen stations located inside and outside the SGRA (Figure 5). Stations 9 and 15 were omitted from the analyses because they were associated with major gear problems that may have affected the catch rates. Stations were selected according to depth, without regard for their location in relation to the SGRA, with the objective of sampling across the depth range of scup and *Loligo* habitats. Sampling was conducted during the day (0700-1700 hrs) when *Loligo* are located near the seabed (Brodziak and Hendrickson 1999; Roper and Young 1975). Assignments of vessel net type (experimental net versus control net) and towing location (seaward versus shoreward of the other vessel) were chosen at random during the first tow of each day via a coin toss. Thereafter, towing location was alternated and net assignments were either E-C-C-E-E or C-E-E-C-C.

The same towing protocol was implemented aboard both vessels and all tows made by each vessel were conducted by the same individual to further ensure consistent setting and haulback of the gear. A 3:1 scope ratio was used during all tows and amounts of warp payout and haulback were reported by radio at 50-fm. intervals from one vessel captain to the other to synchronize the timing of net touchdown, liftoff, and haulback. According to the NEFSC Observer Program Database, 85% of the tows conducted during the 1995 to 2003 winter *Loligo* fisheries were conducted at 3.0 to 3.3 nmi.$\cdot$ hr^{-1} and averaged 3.2 nmi.$\cdot$ hr^{-1} (knots). Similarly, the study incorporated a standardized towing speed of 3.2 nmi.$\cdot$ hr^{-1}. Based on Vessel Trip Report (VTR) data, the average tow duration during 97% of the *Loligo* trips conducted in winter, during 1997 to 2003, ranged from one to four hours, with a mode of three hours. A one-hour tow duration was used during the study to maximize the number of tows conducted per day and still remain within the range of commercial tow durations. Tow duration was monitored with a stopwatch and was defined as the time between net touchdown and lift-off which were determined from the headline sensor screen display that showed the trawl location in real-time. Actual bottom contact time was identified post-hoc based on data collected by an inclinometer attached to the footrope by two chains which allowed it to swing up and down but not side-to-side. During each tow, the angle of the inclinometer was recorded at one-second intervals and the resulting data were plotted against tow time to determine when the net was fishing on the bottom. Sampling was suspended when the inclinometer data indicated that the net was not fishing on the bottom for extended periods of time due to sea state. Tow distance was computed as the actual tow duration multiplied by the average speed over ground.

Catch weight, by species, recorded to the nearest 0.01 kg using a Marel M1100© scale. Catch weights of black sea bass (*Centropristis striata*) and scup were obtained separately for sublegal (< 27.94 cm or 11 in. TL and < 22.86 cm or 9 in. TL, respectively) and legal size categories. The weight of the largest scup catch (in Net C at station 7) was estimated by multiplying the average weight of 25 totes of scup by the total number of totes of scup, separately for the legal and sublegal-size categories, and then summing the catch weights of the two categories. Length measurements (mm) were obtained with a Limnoterra© digital measuring board for random subsamples of squid, scup and dominate round-bodied fish species. Fork length was recorded for scup and other species with forked caudal fins and total length was recorded for all other finfish species. Dorsal mantle length was recorded for squid. Length measurements of scup and black sea bass were obtained separately from random subsamples of the legal and sublegal size categories. Numbers at length were expanded to the total catch at each station by multiplying the ratio of the catch weight of each species to the weight of the length-frequency subsample. Number per tow was computed as the sum of the expanded numbers at length of each species.

Headrope height, wingspread, and doorspread were logged throughout each tow using a Simrad ITI Trawl System© and a Northstar Technical NetMind Trawl Monitor System© aboard the F/V *Sea Breeze* and F/V *Iron Horse*, respectively. Water depth, tow time, speed over ground, location, and heading were logged to a server at one-second intervals during each tow. Bottom water temperature and pressure were recorded at one-second intervals with an SBE 39 Temperature Recorder©, manufactured by Seabird Electronics, attached to the headline of each vessel and surface water temperature was recorded at one-second intervals from a thermistor mounted on the hull of the F/V *Iron Horse*. Length and weight data were automatically logged to a laptop computer via a wireless connection using the NMFS Fisheries Scientific Computing System (FSCS) software then uploaded wirelessly to a wheelhouse server. Computer clocks and the SeaBird clock were synchronized daily with the GPS clock.

Average wingspread, doorspread and headrope height were computed for the period of time that the trawl fished on the bottom. Catch rates were standardized for the volume of water sampled (m^3) during each tow, computed as the product of average wingspread, average headrope height and tow distance. Standardized catch rates were scaled by 10^6 and log-transformed prior to statistical analysis.

A paired-comparisons *t*-test, conducted in SAS (SAS Institute Inc. 1985), was used to determine whether the mean differences in standardized catch rates between Net C and Net E (loss in terms of number and weight per m^3) were significant for scup, *L. pealeii* and black sea bass. The GLM procedure in SAS was used to evaluate whether standardized catch rates of *L. pealeii*, scup and black sea bass in Net C were dependent on water depth, surface temperature or bottom temperature.

Selectivity parameters and the relative fishing intensity of Net E were estimated for scup, black sea bass, and *L. pealeii* using the SELECT model (Share Each LEngth's Catch Total) developed by Millar (1992). The SELECT model uses a conditional likelihood approach where the proportion of catch in each length category, in the experimental net, is modeled as a function of the logistic curve parameters *a* and *b* and the relative fishing intensity (*p*) of a gear type such that:

$$\varphi(L) = \frac{pe^{a+bL}}{(1-p)+e^{a+bL}}$$

Maximum likelihood parameter estimates were obtained by fitting the SELECT model to catch at length data (binned at 1 cm intervals), with the use of SOLVER, in an Excel spreadsheet program developed by Tokai (1997). The analysis only included data from stations where a particular species was caught in both nets and for consecutive length bins where the total catches were greater than zero.

Data from NEFSC research bottom trawl surveys conducted in the winter (February) and spring (March), during 1992-2003, were used to assess the general spatial overlap between the seasonal distributions of *L. pealeii* and either scup or black sea bass and to assess the co-occurrence of *L. pealeii* and each of the two species in relation to water depth. The stratified random survey design and sampling protocols are described in Azarovitz (1981). Co-occurrence was defined as the percentage of the combined catch (number per tow) of scup and *L. pealeii* that was comprised of scup. The percentage of scup from such tows was binned into quartiles (0.1-25%; 26-50%, 51-75% and 76-99.9% scup) to assess the degree of co-occurrence within the depth range of the winter *L. pealeii* fishery.

RESULTS

Ten stations were sampled inside and nine stations were sampled outside of the SGRA at depths of 83 to 155 m (Table 2, Figure 5). VTR data for 1997-2003 indicated that a large majority (89%) of the *L. pealeii* landings in the winter directed fishery (January through March) occurred at depths of 102 m to 183 m. Within this depth range, the percentage of *L. pealeii* landings was 6% higher after implementation of the SGRA (93% in 2001-2003) than before (87% in 1997-2000, Figure 6). The 6% increase in landings was attributable to a 10% decrease in landings from depths of 102 m to 137 m combined with a 16% increase in landings from depths of 138 m to 183 m. An additional 5% of the landings occurred at depths less than 102 m. All of the stations sampled during the study were located within the depth range of the winter *L. pealeii* fishery and most stations (84%) were located within the 102 m to 183 m depth range (Figure 6).

Catches in the control net (Net C) reflect the selectivity of one type of net used in the winter *L. pealeii* fishery. *L. pealeii* was caught in Net C at every station, at depths between 83 and 155 m, and comprised 22% of the combined weight of all species caught during the study. Bycatch (kg) in Net C consisted of 40 species but was dominated (89%) by three species (Table 3): spiny dogfish (36%), scup (34%), and black sea bass (19%). *L. pealeii* co-occurred most frequently with summer flounder (95%), butterfish (95%), silver hake (89%) and spiny dogfish (84%). Black sea bass and scup co-occurred less frequently with *L. pealeii*, at 79% and 63% of the nineteen stations, respectively. Most (94%) of the nominal *L. pealeii* catch (kg) in Net C occurred at depths of 129 m to 155 m and the remaining 6% occurred at depths of 83 m to 117 m (Table 3). Conversely, most of the scup catch (96%) occurred at depths of 83 m to 117 m and the remaining 4% occurred at depths of 129 to 155 m. Most (66%) of the black sea bass catch occurred at depths of 129 m to 155 m, but 34% of the catch also occurred at depths of 83 m to 117 m.

The study results suggested that, during the winter of 2004, scup and *L. pealeii* co-occurred primarily at depths of 83 m to 129 m, with smaller amounts of scup catch at depths of 129 m to 155 m (Figure 7). Black sea bass and *L. pealeii* co-occurred throughout the depth range of the study (83 m to 155 m), but a large portion (42%) of the black sea bass catch occurred within the depth range of 129 m to 155 m, where *L. pealeii* catch rates were highest (Figure 8). In comparison, co-occurrence data from NEFSC research bottom trawl surveys, where sampling was conducted across multiple years and a broader latitudinal range, suggest that *L. pealeii* co-occurs with scup and black sea bass at deeper depths than those sampled during the study. In NEFSC research surveys, tows with catches of both scup and *L. pealeii* occurred at depths of 30 m to 340 m during February and at depths of 20 m to 320 m during March (Figure 9). Co-occurrence during both months occurred throughout the depth range of the *L. pealeii* winter fishery, but was most common at depths of 40 m to 130 m (modes at 70 m and 120 m). Most survey tows with catches of both species were comprised of a low percentage of scup (0.1- 25%) in relation to *L. pealeii* (75-99.9%). The percentage of scup catch in tows with co-occurrence differed little by depth during either month (Figure 9).

Similar to scup, the distributions of black sea bass and *L. pealeii* overlap during winter and spring (Figures 10 and 11), primarily in the offshore waters between Hudson Canyon and Cape Hatteras. In NEFSC research surveys, black sea bass and *L. pealeii* co-occur at depths of 30 m to 320 m during February and at depths of 10 m to 310 m during March (Figure 12). Similar to scup, co-occurrence with *L. pealeii* during both months was most common at depths of 40 m to 130 m, with modes at 70 m and 120 m. Most of the survey tows with catches of both species were comprised of a low percentage of black sea bass (0.1- 25%) in relation to *L. pealeii* (75-99.9%). The percentage of black sea bass catch in tows with co-occurrence differed little by depth during either month (Figure 12).

Within the latitudinal range sampled, 39º 21.237' N to 38º 27.000' N (54 nmi.), neither surface nor bottom water temperatures were correlated with depth ($p > 0.05$). Surface water temperatures were fairly constant across station depths (83 m to 155 m) and ranged from 9.5 ºC to 10.9 ºC. Bottom water temperatures were more variable and ranged between 9.1 ºC and 12.6 ºC. Thermal stratification was present at some of the stations located near the shelf edge, at depths greater than 150 m, where bottom temperatures were warmer than surface temperatures. For example, the water column was not stratified at a station depth of 153 m (station 16, Figure 13A), but stratification was present at a station depth of 155 m (station 4, Figure 13B). At station 4, a rapid increase in water temperature occurred at depths beyond 100 m.

As expected for species which form schools or are distributed in aggregations, standardized catch rates ($kg/m^3 \times 10^6$) of scup, black sea bass, and *L. pealeii* were highly variable. Scup catch rates were the most variable of the three species, with sizeable catches at only five stations (Table 4). For the eight stations where both nets caught scup and where Net C caught more scup than Net E, paired *t*-tests indicated significant reductions (catch rates of Net C – Net E) in catch numbers ($p < 0.05$) and catch weights ($p < 0.01$). On average, standardized catch rates of scup in Net E were reduced by 79% and 78% in terms of numbers and weight, respectively. On average, standardized catch rates of black sea bass in Net E were significantly reduced by 75% and 69% in terms of numbers ($p < 0.0001$) and weight ($p < 0.0001$), respectively (Table 5). Loss of the target species, *L. pealeii*, in Net E was highly significant ($p < 0.0001$) for catch numbers and weight, and on average, was reduced by 88% and 84%, respectively (Table 6).

GLM results indicated that standardized catch rates of scup in Net C decreased significantly with depth for both numbers and weight (Table 7). However, depth explained only 42% and 30% of the variance in catch numbers and weight, respectively. The highest catch rates of scup occurred at shallow depths (83 m to 117 m) where *L. pealeii* catch rates were lowest. Depth did not have a significant effect on the catch rates of black sea bass in Net C ($p > 0.05$). Standardized catch rates of *L. pealeii* increased significantly with depth and decreasing bottom temperature (Table 7). Catch rates at depths of 129 to 155 m (1,576 $kg/m^3 \times 10^6$) averaged more than ten-fold the catch rates at shallower depths of 83 to 117 m (147 kg/m^3 x 10^6). Station depth and bottom temperature explained 75% and 76% of the variance in *L. pealeii* catch numbers and weight, respectively.

The size selectivity of scup and black sea bass catches differed by net type. Scup caught in Net C ranged in length from 11 cm to 37 cm with modes at 17 cm and 21 cm (Figure 14A). A large portion (44%) of the total scup catch, by number, was of sublegal size (Figure 15A). Black sea bass caught in Net C ranged in length from 17 cm to 58 cm with modes at 17 cm and 21 cm (Figure 14B). More than half (55%) of the total black sea bass catch, by number, was of sublegal size (Figure 15B). Smaller proportions of sublegal size scup and black sea bass were taken with Net E than Net C. The proportion of sublegal size fish retained in Net E versus Net C was reduced by 17% for scup, primarily in the 14 to 18 cm length range (Figure 15A), and by 20% for black sea bass (Figure 15B). *L. pealeii* caught in Net C ranged in mantle length from 2 cm to 27 cm with a mode at 10 cm (Figure 14C). For *L. pealeii*, there was little difference in size selectivity between the two net types (Figure 15C).

For scup, the SELECT model results indicated that the relative fishing intensity of Net E (p = 0.26) was 36% of that for Net C, resulting in a L_{50} estimate of 17.1 cm and a selection range of 0.98 cm (Table 8). A selection factor of 2.8 was estimated. However, the model fit for scup was poor, as evidenced by the high model deviance value, and an unrealistically-narrow selection range was estimated (Figure 16B). A second model run with the catch-at-length matrix truncated to 26 cm, beyond which fewer fish were caught, did not remedy either problem and resulted in similar parameter estimates. The model run for which p was estimated resulted in a lower Akaike Information Criterion value (AIC = 3,316) than a model run with p fixed at 0.5 (AIC = 4,599), confirming that the two codends did not fish with equal intensity.

For black sea bass, the results of the SELECT model indicated that the relative fishing intensity of Net E (p= 0.36) was 57% of that for Net C, resulting in a L_{50} estimate of 27.7 cm and a selection range of 7.4 cm (Table 8). A selection factor of 4.6 was estimated. A trend in the deviance residuals was present for fish larger than 46 cm, the length range where fewer fish were caught. The model fit was good with the exception of fish larger than 46 cm, which showed a positive trend in the residuals concurrent with low sample sizes (Figure 17B). The AIC value for the model run where p was estimated (AIC = 484) was lower than for the model run where p was fixed at 0.5 (AIC = 549)

L. pealeii catch-at-length data could not be fit to the SELECT model (Figure 18), which suggests that selectivity is not a logistic function of mantle length and that other factors also affect selectivity.

DISCUSSION

The study results indicate that within the depth range of the winter *L. pealeii* fishery, *L. pealeii* co-occurs most frequently with: summer flounder, butterfish, silver hake, spiny dogfish, black sea bass, and scup. The co-occurrence of *L. pealeii* and butterfish on the US shelf has been attributed to similar depth and water temperature preferences and the bycatch of butterfish in the *L. pealeii* fishery has previously been documented (Lange and Waring 1992). Within the depth range sampled, the study results suggested that scup and *L. pealeii* co-occur primarily at depths of 83 m to 129 m, which overlaps with the depth range of the *L. pealeii* winter fishery. However, since the study results are based on data collected within a single year and across a limited depth range, they were compared with co-occurrence data from the winter and spring NEFSC research surveys conducted during 1992-2003. The survey data confirm the persistence of the 2004 co-occurrence patterns observed for both scup and black sea bass and show that both species have been caught with *L. pealeii*, within the depth range of the winter *L. pealeii* fishery, during years other than 2004. However, tows with co-occurrence tended to contain a low percentage of scup or black sea bass (0.1 to 25%) and a high percentage of *L. pealeii* (75 to 99.9%).

Escapement of finfish from diamond-mesh trawls occurs primarily through codend meshes which are open the furthest, those located immediately in the front of the catch (Wardle 1993). Square-mesh panels installed in the codend or extension of a net provide an additional area for escapement by providing a larger area of open meshes. For example, small-mesh prawn (*Nephrops*) trawls which have a codend mesh size less then 100 mm are required to contain a square-mesh panel on the top side of the trawl to reduce catches of juvenile haddock and whiting (Zuur *et al*. 2001).

Fishing with a square-mesh escape panel installed in a *L. pealeii* bottom trawl reduced the average catches of scup by 78% in weight and 79% in numbers. Catches of black sea bass were reduced by 69% in weight and 75% in numbers. Large portions of the scup (44% in numbers) and black sea bass (55% in numbers) catches in the control net were of sublegal size. However, the square-mesh panel was effective in reducing catches of sublegal-size scup and black sea bass by 17% and 20%, respectively.

Utilization of the square-mesh panel did not affect the size distribution *L. pealeii* but resulted in significantly large losses of *L. pealeii* catch (on average, 88% in numbers and 84% in weight). As a result, the use of a square-mesh escape panel in the configuration tested is not a reasonable solution to the bycatch problem in the winter *L. pealeii* fishery. However, it may be possible to modify the panel configuration to reduce squid loss. If so, then its use in *L pealeii* nets would aid in increasing the spawning stock biomass of scup because the estimated L_{50} of the experimental net (17.1 cm FL) is slightly greater than 15.5 cm FL, the length at which 50% of the females are mature (O'Brien *et al*. 1993). Use of the panel would also aid in increasing the spawning stock biomass of black sea bass. For black sea bass, the estimated L_{50} of Net E (27.7 cm TL) is greater than 19.1 cm TL, the length at which 50% of the females are mature (O'Brien *et al.* 1993). Black sea bass are protogynous hermaphrodites and the majority of fish less than 19.1 cm are females (Steimle *et al.* 1999). In order to determine the reasons for squid loss and whether such losses can be substantially reduced will require video camera monitoring of squid behavior in the vicinity of the square-mesh panel, during towing and at haulback. If squid loss occurs passively through the bottom of the panel during haulback, a simple solution might be to install a small-mesh liner in the bottom half of the panel to retain squid but allow finfish escapement through the top half of the panel. Extension length and codend diameter have both been shown to affect trawl selectivity (Reeves *et al*. 1992). The effectiveness of a large-mesh panel is also dependent on its placement in the net (Armstrong *et al*. 1997; Graham *et al*. 2002). If squid loss occurs via active escapement through the panel meshes, varying the panel placement and/or extension length might be investigated. For example, Glass *et al*. (1999) studied the inshore *L. pealeii* fishery and found that the capture response of *L. pealeii* in bottom trawls under ambient light conditions involves herding in the net mouth, where squid move toward the wing ends then gradually rise to the top of the net while maintaining school structure. Squid then turn toward the codend and cease to swim upon tiring. Bycatch separation trials indicated that this behavior pattern allowed the separation of squid, caught primarily in the upper portion of the codend, from scup and other bycatch species caught in the lower portion and that legal-size scup tended to be caught in greater proportions in the top half of the codend (Glass *et al*. 1999).

Time-area closures may be feasible as a bycatch reduction measure in the *L. pealeii* fishery if there is some degree of temporal-spatial separation between the *L. pealeii* and the co-occurring species. However, this may not be possible if co-occurrence persists across years. For example, Gabriel (1992) found that species assemblages which include *L. pealeii* and many of the bycatch species from the subject study persist interannually in the Mid-Atlantic Bight. However, she also showed that patterns of species co-occurrence are highly variable interannually and linked to the variability in temperature-related oceanographic features. Consequently, the spatial distributions of such species are difficult to predict. As a result, implementation of time-area closures like the existing small-mesh gear restriction area for scup must be species-specific and must encompass areas large enough to encompass the temporal-spatial variability in co-occurrence in order to be effective.

Given the difficulties associated with implementing and enforcing species-specific time-area closures and the unknown increase in codend mesh size that is feasible, the preferred solution to bycatch reduction in the *L. pealeii* fishery is gear modification. However, until a gear modification solution can be found, other bycatch reduction measures can be implemented. For example, a codend mesh size increase would allow some escapement of juvenile finfish because the size compositions of bycatch species in the *L. pealeii* fishery are likely comprised of higher proportions of sublegal-size fish than have been reported herein. The Vessel Trip Report data indicate that a majority (44%) of the *L. pealeii* catch during 1997-2003 was obtained with 48-50 mm mesh codends. The codend mesh size used in the subject study was 60 mm, which fell within the mesh size range (60-63 mm) used to take 26% of the *L. pealeii* catch during this time. An additional 14% of the *L. pealeii* catch was taken with 76 mm mesh codends in a mixed fishery for *L. pealeii* and silver hake (*Merluccius bilinearis*). The NEFSC Observer Database indicates that codend covers used in the directed fishery during 1996-2003 consisted primarily of double-twine, 140 to 160-mm diamond mesh. The regulation of codend mesh size has historically been used in the squid fisheries (*Illex illecebrosus* and *L. pealei*i), in U.S. and Canadian (*Illex* only) waters, as a bycatch management measure. In addition, small-mesh bottom trawl fisheries have historically been limited to specific offshore areas and seasons in both the U.S. and Canada. Since 1977, a minimum codend mesh size of 130 mm has been required in bottom trawls that are fished on the Scotian Shelf shoreward of the 200 m isobath (ICNAF 1978). During 1978-1982, bottom trawlers engaged in directed fisheries for *Illex* and *L. pealeii* in U.S. waters were required to fish with a minimum codend mesh size of 60 mm (with specific chafing gear requirements) and were restricted to two time periods and two offshore fishing areas which straddled the 183 m isobath (ICNAF 1978). During this time, a portion of the bottom trawl fleet also targeted *Illex* with 80 to 90 mm-mesh codends (Hatanaka and Sato 1980; ICNAF 1979). However, the use of pelagic trawls was required for squid fishing throughout most of the year and within the offshore areas where small-mesh fishing was allowed. In order to determine the maximum mesh size increase possible, a mesh selectivity study of the *L. pealeii* fishery would need to be conducted to quantify juvenile finfish escapement and squid loss associated with a range of codend mesh sizes greater than the predominant mesh size currently in use and including testing of square-mesh instead of diamond-mesh codend covers.

ACKNOWLEDGMENTS

This research was funded primarily by the Marine Fisheries Initiative Program (MARFIN) Program, but was supplemented with NEFSC cooperative research funds. I thank Victor Simon for loaning us the portable FSCS equipment and for giving us endless technical advice. I am also grateful to Michele Thompson for her assistance with data processing and summarization and to Chris Glass (Manomet Center for Conservation Sciences) for providing valuable insights regarding the panel design. I also thank Fred Serchuk and Mark Terceiro for their thorough reviews of the manuscript and helpful suggestions. The study would not have been possible without the cooperative efforts of the following people:

Vessel Captains: Jim O'Grady (F/V *Iron Horse*) and Phil Ruhle Jr. (F/V *Sea Breeze*) and their crew members

Scientific party: Laurel Col, Lisa Hendrickson, Henry Milliken, Paul Nitschke, Kathy Sosebee, Azure Westwood, and Gregg Morris (Manomet Center for Conservation Sciences)

NEFSC staff: Chris Pickett, Nancy McHugh, Paul Kostovick, Dennis Shields, Victor Simon, Russ Brown, John Hoey, Jonathan Duquette, Nathan Keith, Larry Jacobson, Steve Murawski, Betty Holmes, Colleen Close, Dorine Westgate, Susan Allen, Edgar Kleindinst, Frank Almeida and Brian Hooker (NERO).

REFERENCES

Armstrong, M. J., Briggs, R. P., and Rihan, D. 1997. A study of optimum positioning of square-mesh escape panels in Irish Sea *Nephrops* trawls. Fish. Res., 34: 179-189.

Azarovitz, T. R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. *In* Bottom Trawl Surveys, pp. 62-67. Ed. by W. G. Doubleday and D. Rivard. Can. Spec. Pub. Fish. Aquat. Sci. 58.

Brodziak, J.K.T. and Hendrickson, L. C. 1999. An analysis of environmental effects on survey catches of squids *Loligo pealei* and *Illex illecebrosus* in the northwest Atlantic. Fish. Bull., 97: 9-24.

Gabriel, W.L. 1992. Persistence of demersal fish assemblages between Cape Hatteras and Nova Scotia., Northwest Atlantic. J. Northw. Atl. Fish. Sci., 14: 29-46.

Glass, C. W., Sarno, B., Milliken, H. O., Morris, G. D., and Carr, H. A. 1999. Bycatch reduction in Massachusetts inshore squid fisheries. Mar. Technol. Soc. J., 33(2): 35-42.

Graham, N., Kynoch, R.J. and Fryer, R.J. 2002. Square mesh panels in demersal trawls: further data relating haddock and whiting selectivity to panel position. Fish. Res., 62: 361-375.

Hatanaka, H. and T. Sato. 1980. Outline of the Japanese squid fishery in Subareas 3 and 4 in 1979. SCR Doc. 80/II/8. Ser. No. N040. 11 p.

International Commission for the Northwest Atlantic Fisheries [ICNAF]. 1978. Report of Standing Committee on Research and Statistics (STACRES). Special meeting on squid, February, 1978. ICNAF Redbook 1978, p. 29-30.

International Commission for the Northwest Atlantic Fisheries [ICNAF]. 1979. Special meeting of STACRES – February 1979, Japanese catches and fishing effort by week in fisheries where *Illex* were caught, 1977 and 1978. ICNAF WP 79/II/1. 16 p.

Lange, A. M. and G. T. Waring. 1992. Fishery interactions between long-finned squid (*Loligo pealei*) and butterfish (*Peprilus triacanthus*) off the Northeast USA. J. Northw. Atl. Fish. Sci. 12: 49-62.

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

Northeast Fisheries Science Center. 2000. Report of the 31st Northeast Regional Stock Assessment Workshop (31st SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. Northeast Fish. Sci. Center Ref. Doc. 00-15, 400 p.

O'Brien, L., J. Burnett, and R. K. Mayo. 1993. Maturation of nineteen species of finfish off the northeast coast of the Uniter States, 1985-1990. NOAA Tech. Rpt. NMFS 116. 66 p.

Steimle, F. W., Zetlin, C. A. , Berrien, P. L., and Chang, S. 1999. Essential Fish Habitat Source Document: Black Sea Bass, *Centropristis striata*, Life History and Habitat Characteristics. NOAA Tech. Mem. NMFS-NE-143. 42 p.

Tokai, T. 1997. Maximum likelihood parameter estimates of a mesh selectivity logistic model through SOLVER on MS-Excel. Bull. Jap. Fish. Oceanogr., 61, 288-298.

Reeves, S. A., Armstrong, D. W., Fryer, R. J., and Coull, K. A. 1992. The effect of mesh size, cod end extention length and cod-end diameter on the selectivity of Scottish trawls and seines. ICES J. Mar. Sci., 49: 279-288.

Roper, C.F.E., and Young, R.E. 1975. Vertical distribution of pelagic cephalopods. Smithsonian Contributions in Zoology, 209, 51 p.

SAS Institute Inc. 1985. SAS User's Guide: Statistics, Version 5 Edition. Cary, NC: SAS Institute Inc., 956 pp.

Wardle, C. S. 1993. Fish behaviour and fishing gear, p. 609-643 *In*: Behaviour of teleost fishes. Ed. Tony J. Pitcher. Chapman and Hall.

Zuur, G., Fryer, R. J., Ferro, R. S. T., and Tokai, T. 2001. Modelling the size selectivities of a trawl codend and an associated square mesh panel. ICES J. Mar. Sci., 58: 657-671.

Table 1. Characteristics of a *Loligo pealeii* bottom trawl and fishing vessels used in a parallel haul study conducted on the U.S. shelf during January 2004.

	F/V *Sea Breeze*	**F/V *Iron Horse***
Doors	Thyboron Type III (214 x 132 cm, 447 kg)	Thyboron Type III (214 x 132 cm, 447 kg)
Bridles	73.2 m (40fa.)	73.2 m (40fa.)
Ground Cables	73.2 m (40fa.) of 19 mm wire with 6-cm cookies	73.2 m (40fa.) of 19 mm wire with 6-cm cookies
Headrope	37.6 m of 19 mm Tenex with 72 20.3-cm floats	37.6 m of 19 mm Tenex with 72 20.3 cm floats
Footrope	43.3 m of 19 mm wire 7.6 cm cookies and toggles	43.3 m of 19 mm wire 7.6 cm cookies and toggles
Net Mouth Circumference	315 meshes x 40 cm	315 meshes x 40 cm
Wings	240 cm of 11.1 mm Polytron	240 cm of 11.1 mm Polytron
Belly	First bottom belly is 240 cm graduating to 6 cm (28th nylon)	First bottom belly is 240 cm graduating to 6 cm (28th nylon)
Extension (Control Net only)	100 x 180 meshes of 6 cm diamond (28th nylon)	100 x 180 meshes of 6 cm diamond (28th nylon)
Codend	165 x 180 meshes of 6 cm diamond (28th nylon)	165 x 180 meshes of 6 cm diamond (28th nylon)
Codend Cover	50 x 60 meshes of 15.24 cm BK* diamond (poly, double twine) with 8 girth ropes (15.8 mm Tenex)	50 x 60 meshes of 15.24 cm BK diamond (poly, double twine) with 8 girth ropes (15.8 mm Tenex)
Vessel Length Overall (m)	21.9	24.4
Engine Horsepower	670	650
Trawl monitoring system	Simrad ITI (door, wing and trawleye sensors)	Northstar Netmind (door, wing and headrope sensors)

* BK is the mesh measurement between the knots

Table 2. Stations sampled by the F/V *Sea Breeze* (SB) and F/V *Iron Horse* (IH) during a parallel haul study conducted in January 2004. The control net (Net C) consisted of a *Loligo pealeii* bottom trawl and the experimental net (Net E) consisted of an identical net with a 14.61 cm square-mesh escape panel installed between the extension and codend. SGRA represents the Southern Gear Restriction Area (I = inside and O = outside).

	Date	Net by Vessel		Water Depth		Inside or outside
Station	Sampled	SB	IH	(m)	(fm)	SGRA
1	1/25/2004	C	E	93	51	I
2	1/25/2004	E	C	133	73	I
3	1/25/2004	E	C	109	60	I
4	2/1/2004	C	E	155	85	O
5	2/1/2004	E	C	146	80	O
6	2/1/2004	E	C	136	74	I
7	2/1/2004	C	E	101	55	I
8	2/1/2004	C	E	113	62	I
9		Gear problem, no data				
10	2/2/2004	C	E	83	46	I
11	2/2/2004	E	C	93	51	I
12	2/2/2004	E	C	104	57	O
13	2/2/2004	C	E	117	64	I
14	2/2/2004	C	E	132	72	I
15		Gear problem, no data				
16	2/5/2004	E	C	153	84	O
17	2/5/2004	C	E	140	77	O
18	2/5/2004	C	E	129	71	O
19	2/5/2004	E	C	146	80	O
20	2/5/2004	E	C	155	84	O
21	2/5/2004	C	E	155	85	O

Table 3. Species composition (kg and %) and bycatch weight (%), in relation to *Loligo pealeii* catch, for catches from nineteen stations sampled with a *Loligo pealeii* bottom trawl (Net C which consisted of a 6 cm diamond mesh codend with a 15.24 cm diamond mesh codend cover) during January 2004. The percentage of stations with *L. pealeii* co-occurrence are also presented.

Species	Catch Weight All Stations		Catch Weight (%) by Water Depth Range		Bycatch Weight	Stations with *L. pealeii* Co-occurrence
	(kg)	(%)	83-117 m	129-155 m	(%)	(%)
Squalus acanthias (Spiny Dogfish)	10,311	27.9	3.4	96.6	35.9	84
Stenotomus chrysops (Scup)	9,867	26.7	95.7	4.3	34.3	63
Loligo pealeii (Longfin Inshore Squid)	8,203	22.2	6.3	93.7		
Centropristis striata (Black Sea Bass)	5,393	14.6	34.4	65.6	18.8	79
Prionotus evolans (Striped Sea Robin)	716	1.9	6.9	93.1	2.5	16
Urophycis regia (Spotted Hake)	627	1.7	0.2	99.8	2.2	79
Prionotus carolinus (Northern Sea Robin)	563	1.5	5.5	94.5	2.0	42
Paralichthys dentatus (Summer Flounder)	378	1.0	1.8	98.2	1.3	95
Peprilus triacanthus (Butterfish)	329	0.9	1.0	99.0	1.1	95
Merluccius bilinearis (Silver Hake)	192	0.5	1.6	98.4	0.7	89
Illex illecebrosus (Northern Shortfin Squid)	106	0.3	0.0	100.0	0.4	74
Alosa pseudoharengus (Alewife)	92	0.2	0.9	99.1	0.3	47
Zenopsis conchifera (Buckler Dory)	59	0.2	0.0	100.0	0.2	68
Lophius americanus (Goosefish)	35	0.1	0.1	99.9	0.1	53
Other species (N = 27)*	88	0.2	0.1	99.9	0.1	
Total	36,959					

Table 4. Standardized catch rates (number/m^3x10^6 and kg/m^3x10^6) and percent loss of scup, by station, during a parallel-haul study conducted with a *L. pealeii* bottom trawl (control net, "Net C") versus an identical net containing a 14.61 cm square mesh escape panel (experimental net, "Net E") during January 2004.

	Standardized Catch Rates					
	(no./m^3 x 10^6)		Percent	(kg/m^3 x 10^6)		Percent
Station	Net C	Net E	Loss	Net C	Net E	Loss
1	127	112	12	22.82	18.28	20
2	2	1	24	0.15	2.82	
3	71	23	67	12.29	6.86	44
4	0	7		0.00	1.85	
5	0	0		0.00	0.00	
6	0	0		0.00	0.00	
7	60,478	11,326	81	12,458.99	2,632.94	79
8	61	25	59	6.70	5.99	10
10	14	5	65	3.38	1.15	66
11	3	4		0.26	1.41	
12	10,033	2,801	72	3,918.06	919.83	77
13	866	669	23	438.74	119.60	73
14	2	3		0.86	1.75	
16	0	0		0.00	0.00	
17	0	0		0.00	0.00	
18	8	7	16	0.94	0.71	24
19	0	0		0.00	0.00	
20	2	0		0.67	0.00	
21	0	0		0.00	0.00	
Total	71,660	14,969	79	16,861.92	3,705.37	78

Table 5. Standardized catch rates (number/m^3x10^6 and kg/m^3x10^6) and percent loss of black sea bass, by station, during a parallel-haul study conducted with a *L. pealeii* bottom trawl (control net, "Net C") versus an identical net containing a 14.61 cm square mesh escape panel (experimental net, "Net E") during January 2004.

	Standardized Catch Rates					
	(no./m^3 x 10^6)		Percent	(kg/m^3 x 10^6)		Percent
Station	Net C	Net E	Loss	Net C	Net E	Loss
1	49	53		122.12	42.57	65
2	0	0		0.00	0.00	
3	818	92	89	404.05	71.81	82
4	0	31		0.00	19.46	
5	0	0		0.00	0.00	
6	0	0		0.00	0.00	
7	6,332	1,196	81	1,617.01	348.98	78
8	99	288		192.30	76.24	60
10	503	211	58	136.71	110.26	19
11	1,731	420	76	999.65	335.45	66
12	3,869	653	83	1,461.44	366.62	75
13	2,175	460	79	527.50	203.74	61
14	706	161	77	252.64	96.82	62
16	2,199	798	64	604.75	146.05	76
17	2,941	912	69	923.74	382.55	59
18	5,030	1,310	74	1,615.60	471.01	71
19	978	335	66	291.61	69.96	76
20	272	152	44	77.71	45.80	41
21	747	484	35	210.13	122.42	42
Total	28,302	7,183	75	9,436.95	2,890.28	69

Table 6. Standardized catch rates (number/m^3x10^6 and kg/m^3x10^6) and percent loss of *Loligo pealeii* during a parallel-haul study conducted with a *L. pealeii* bottom trawl (control net, "Net C") versus an identical net containing a 14.61 cm square mesh escape panel (experimental net, "Net E") during January 2004.

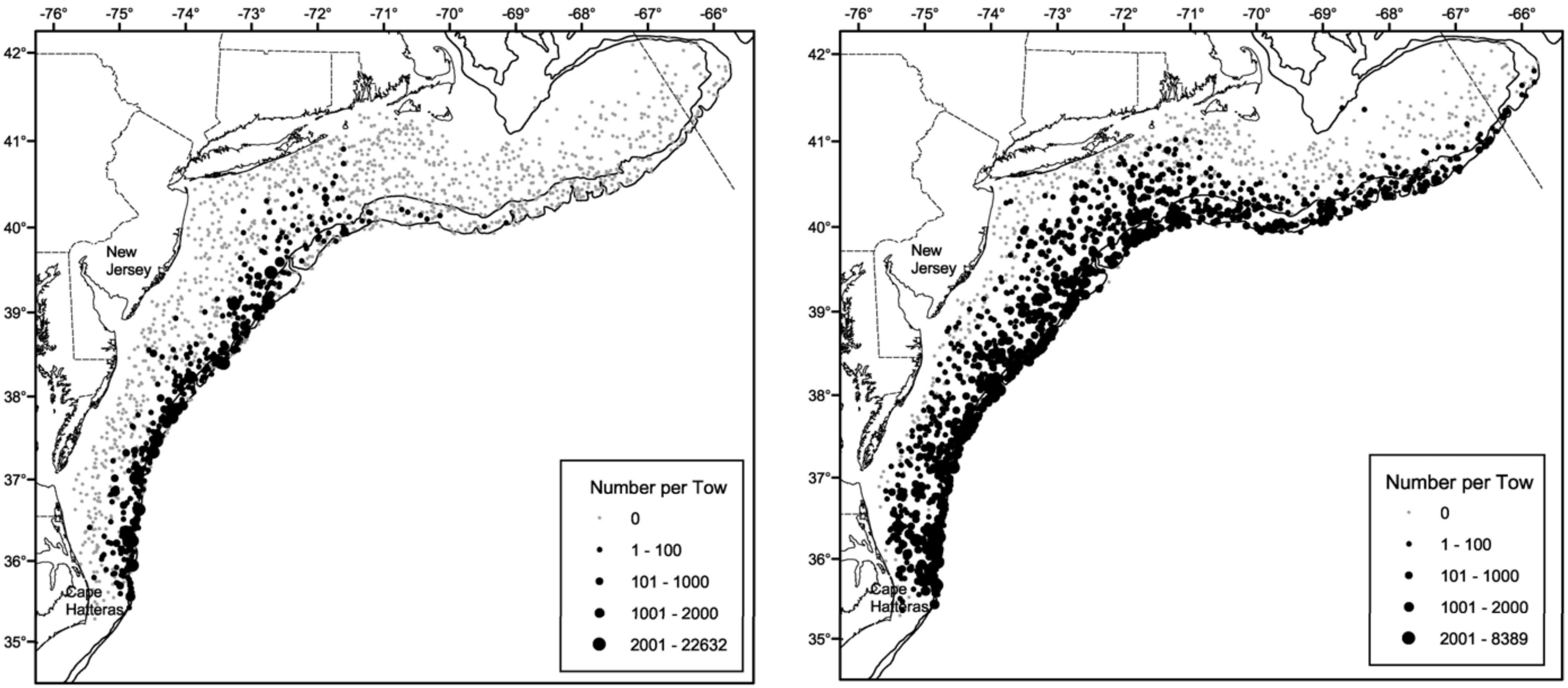
	Standardized Catch Rates					
	(number/m^3x10^6)		Percent	(kg/m^3x10^6)		Percent
Station	Net C	Net E	Loss	Net C	Net E	Loss
1	151	311	-106	77.65	21.20	73
2	1,724	370	79	79.52	30.92	61
3	593	458	23	66.45	30.31	54
4	14,846	2,105	86	2,216.08	83.55	96
5	4,698	249	95	230.26	49.38	79
6	9,376	1,107	88	309.98	43.41	86
7	1,122	254	77	108.83	39.30	64
8	5,214	181	97	356.49	53.82	85
10	4,746	1,980	58	298.34	92.93	69
11	960	137	86	54.82	16.64	70
12	321	84	74	22.89	10.19	55
13	3,659	1,337	63	189.93	63.69	66
14	11,049	1,769	84	704.26	92.93	87
16	125,098	90	99	6,086.32	899.71	85
17	25,792	2,904	89	990.03	201.73	80
18	2,380	684	71	174.00	50.23	71
19	31,868	10,875	66	1,922.25	606.68	68
20	23,593	10,302	56	1,351.32	365.50	73
21	59,561	4,689	92	3,269.30	288.14	91
Total	326,601	39,574	88	18,508.72	3,040.26	84

Table 7. Results from an analysis of variance for the effect of station depth on log-transformed, standardized catch rates (numbers and kg per m^3 x 10^6) of scup, and for the effect of station depth and bottom temperature on log-transformed, standardized catch rates of *Loligo pealeii* caught in a *L. pealeii* bottom trawl, at depths ranging from 83 to 155 m, during Janurary 2004.

Source	r^2	d.f.	Type III SS	F_s	p
Scup					
Number per m^3					
Station Depth	0.42	1	84.172	12.60	0.0025
Error		17	113.579		
Corrected Total		18	197.751		
Kg per m^3					
Station Depth	0.30	1	46.438	7.38	0.014
Error		17	106.904		
Corrected Total		18	153.342		
Loligo pealeii					
Number per m^3					
Station depth	0.75	1	30.525	35.83	< 0.0001
Bottom temperature		1	10.110	11.87	0.0043
Model total		2	40.635		
Error		13	3.131		
Corrected Total		15	43.766		
Kg per m^3					
Station depth	0.76	1	21.094	37.57	< 0.0001
Bottom temperature		1	9.263	16.50	0.0013
Model total		2	30.357		
Error		13	0.748		
Corrected Total		15	31.105		

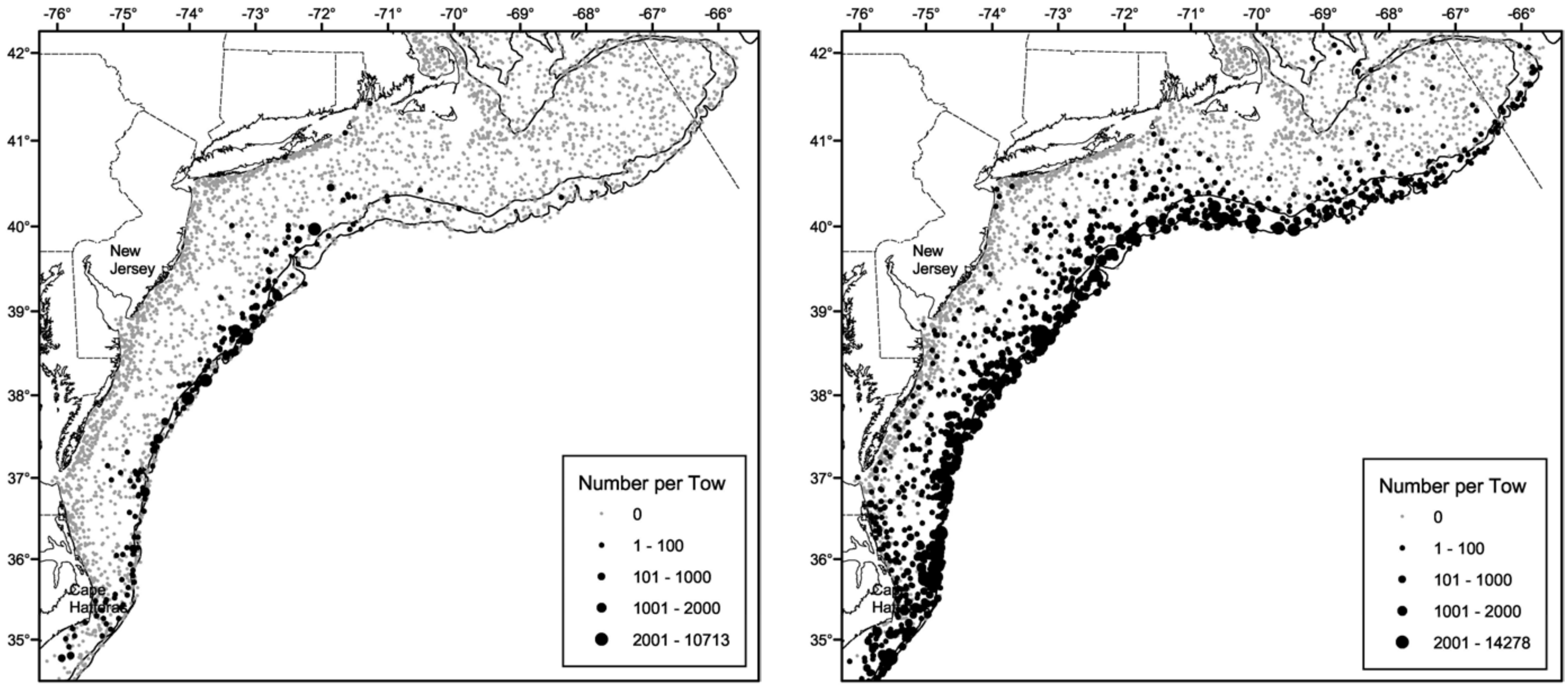
Table 8. Maximum likelihood estimates from the SELECT model for logistic curve parameters (*a* and *b*) and relative fishing intensity (*p*) for scup and black sea bass caught in Net E (*L. pealeii* bottom trawl containing a square mesh escape panel) during a January 2004 parallel haul study. Values for $L_{50\%}$ and selection range (S.R.) are also presented and standard errors are shown in parentheses.

p	*a*	*b*	L_{50} (cm)	S.R. (cm)	Model Deviance
			Scup		
0.26 (0.0023)	-38.36 (1.94)	2.24 (0.12)	17.1 (0.04)	0.98 (0.051)	3,316
			Black Sea Bass		
0.36 (0.011)	-8.19 (0.52)	0.29 (0.022)	27.7 (0.4)	7.4 (0.5)	286



Scup **Longfin Inshore Squid**

Figure 1. Distribution of scup (*Stenotomus chrysops*) and longfin inshore squid (*Loligo pealeii*) abundance (number per tow) during winter (February) research bottom trawl surveys (1992-2003) conducted by the Northeast Fisheries Science Center. Isobaths of 91 m and 183 m are shown.



Scup **Longfin Inshore Squid**

Figure 2. Distribution of scup (*Stenotomus chrysops*) and longfin inshore squid (*Loligo pealeii*) abundance (number per tow) during spring (March-April) research bottom trawl surveys (1992-2003) conducted by the Northeast Fisheries Science Center. Isobaths of 91 m and 183 m are shown.

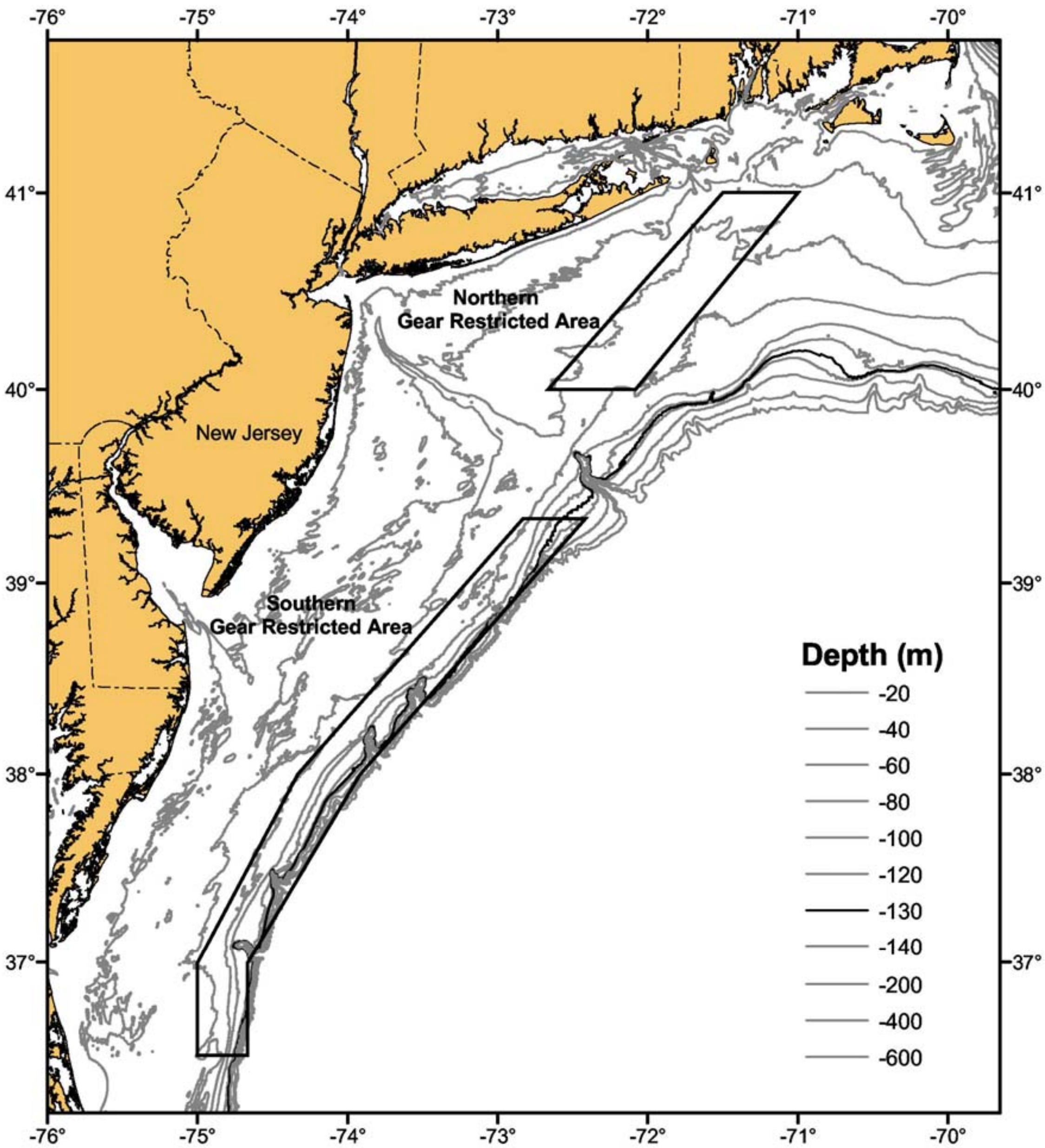


Figure 3. Bottom trawl fishing with a codend mesh size less than 114.3 mm diamond is prohibited in the Northern Gear Restricted Area during November 1-December 31 and in the Southern Gear Restricted Area during January 1-March 15.

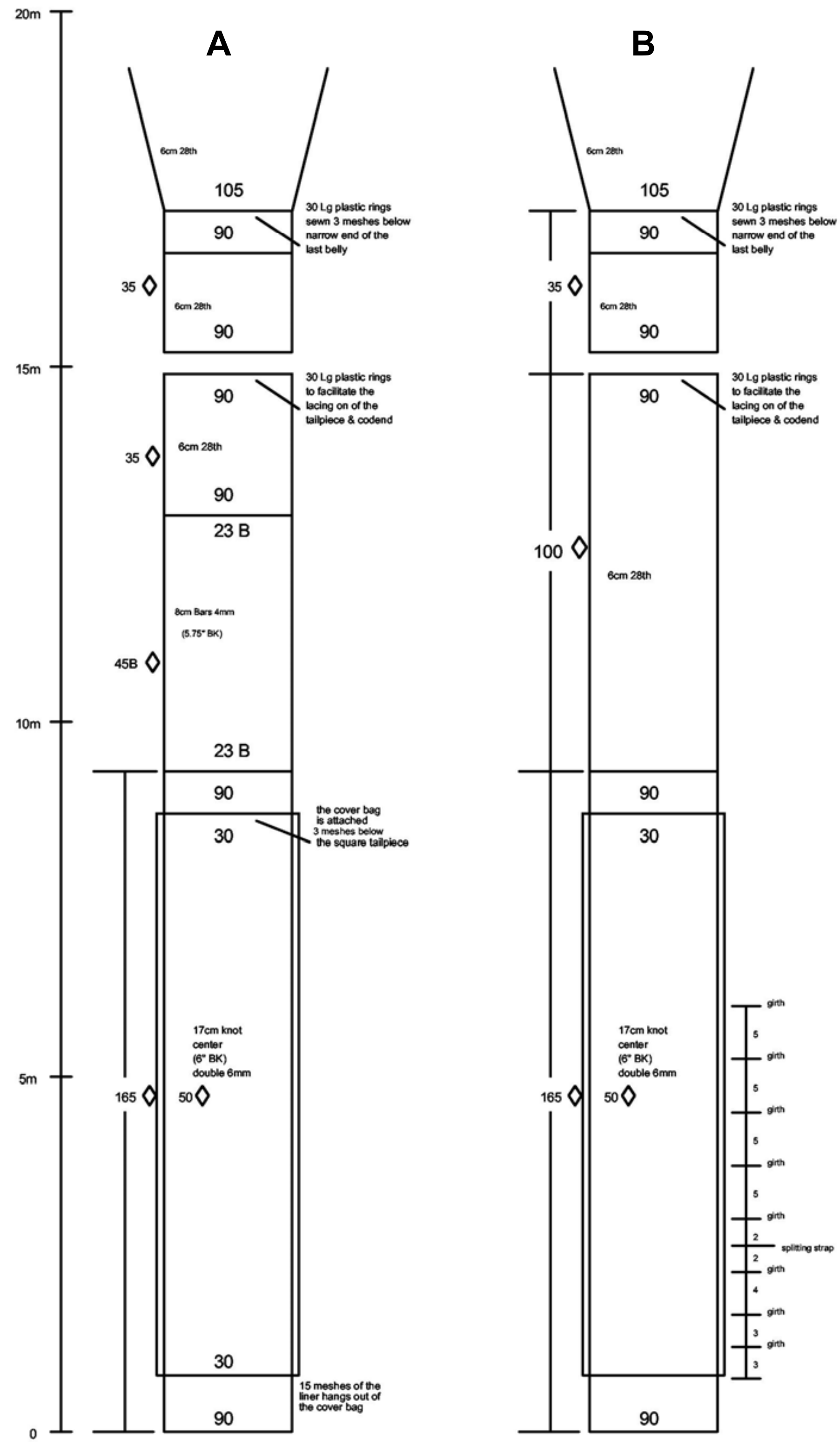


Figure 4. Experimental codend with attached square-mesh escape panel (A) and control codend (B) installed in the extension of a *Loligo pealeii* net. The square-mesh panel was attached to the codend and extension using a 33% hanging ratio and the net widths shown represent half the circumference.

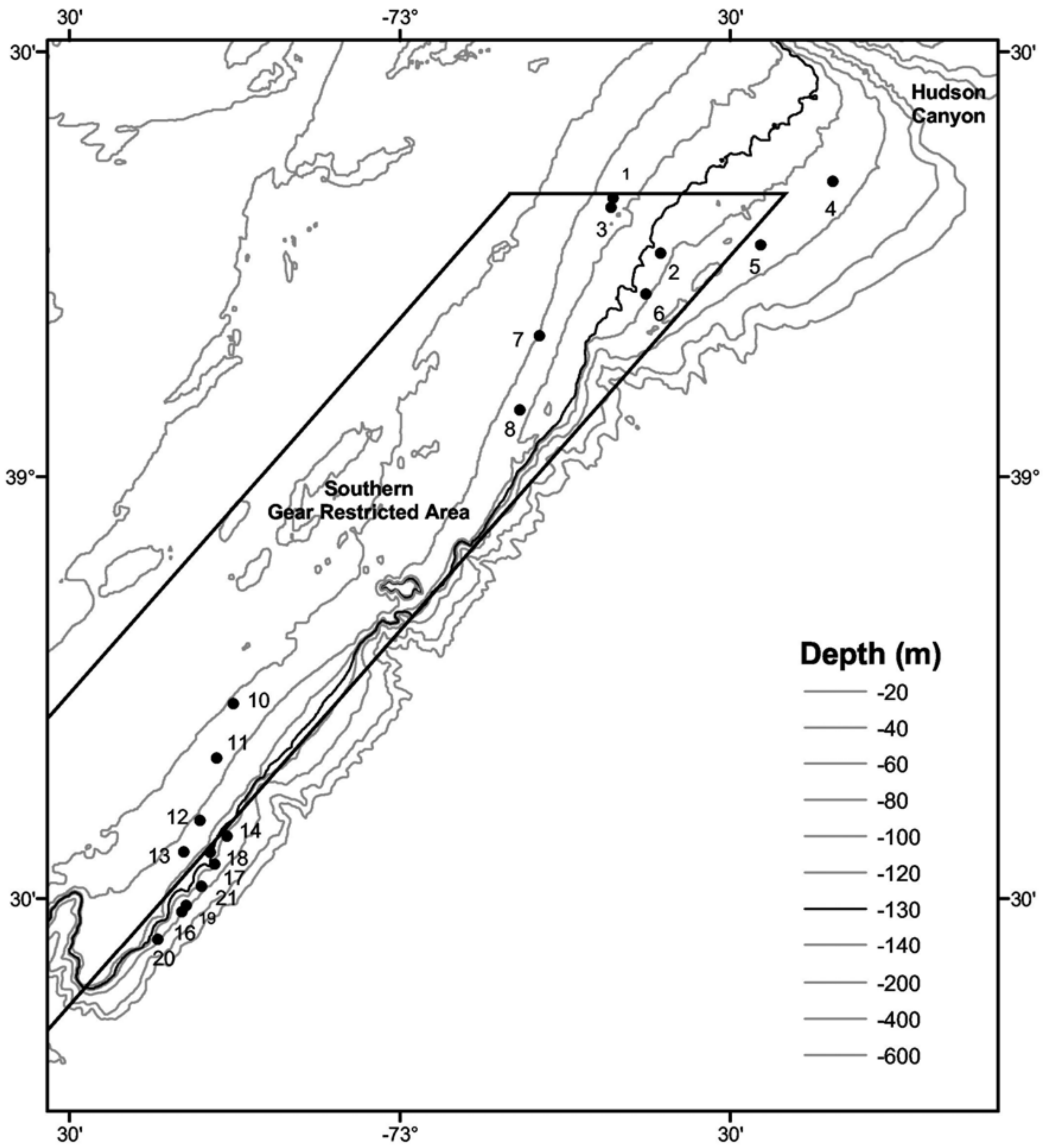


Figure 5. Locations of nineteen stations sampled during a parallel haul study conducted in the vicinity of the Southern Gear Restricted Area during January 25 – February 5, 2004.

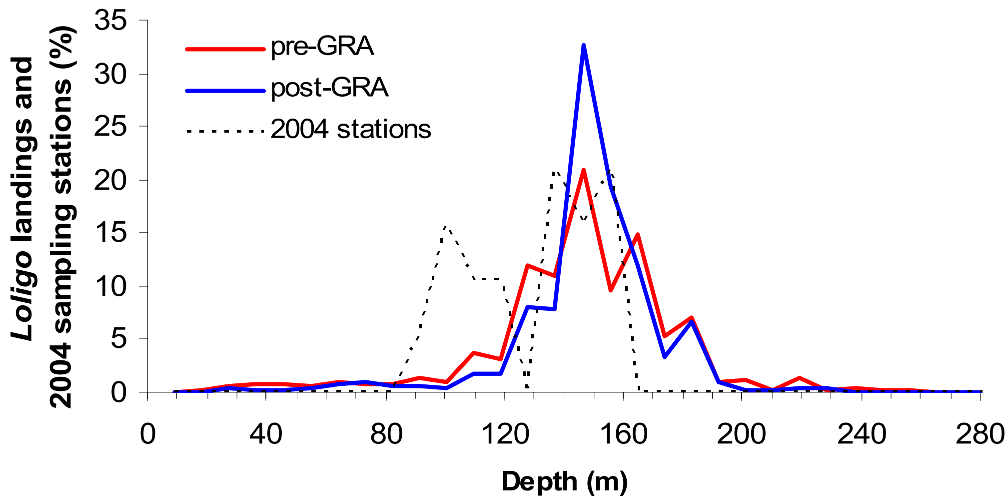


Figure 6. Depth distributions of the winter (January - March) *Loligo pealeii* fishery, based on percentages of *L. pealeii* landings reported by fishermen in the Vessel Trip Reports for 1997-2000 (before implementation of Gear Restricted Areas) and 2001-2003 (after implementation), compared with the depth distribution of stations sampled during the parallel haul study.

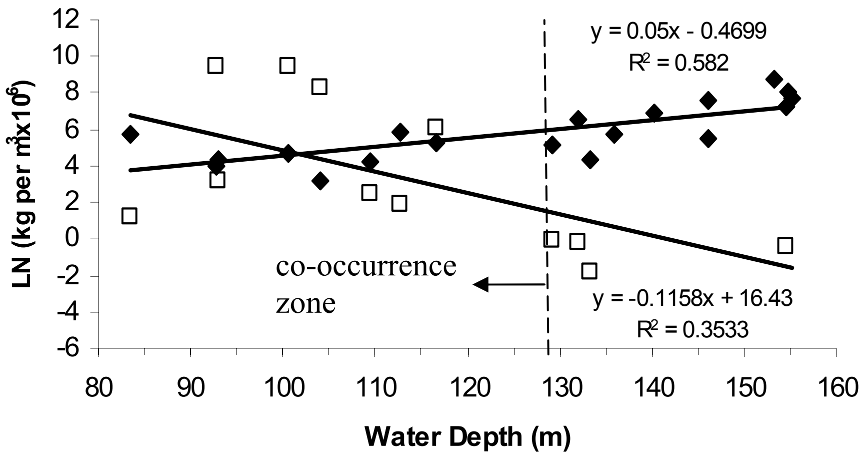


Figure 7. Linear regressions of log-transformed catch rates (kg/m^3x10^6) of *Loligo pealeii* (diamonds) and scup (squares), in Net C, against water depth (m) and the winter co-occurrence zone of both species during the January 2004 study.

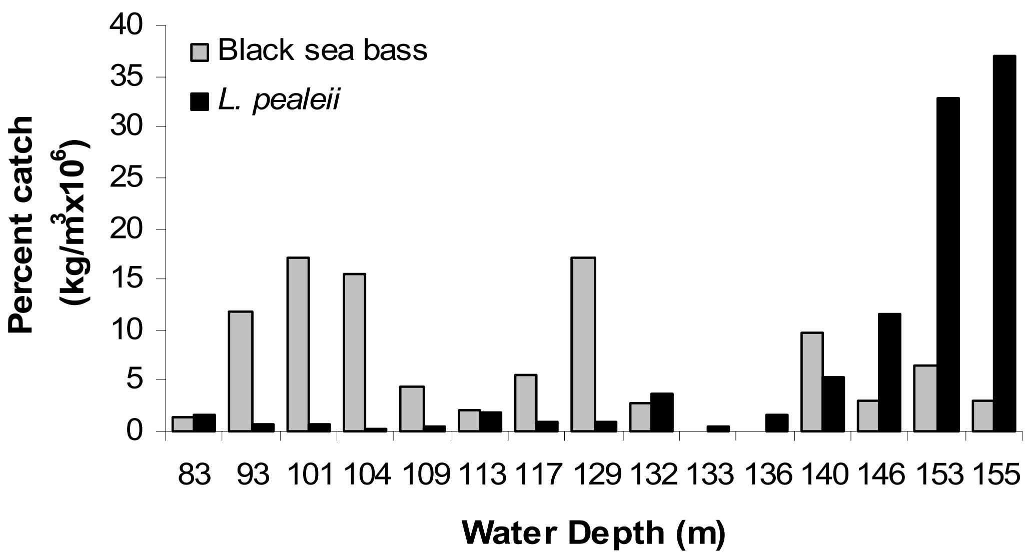


Figure 8. Percent catch (kg per m^3 x 10^6) of black sea bass and *Loligo pealeii*, by depth (m), at stations sampled with a *L. pealeii* bottom trawl (Net C) during winter of 2004 within the depth range of the winter *L. pealeii* fishery.

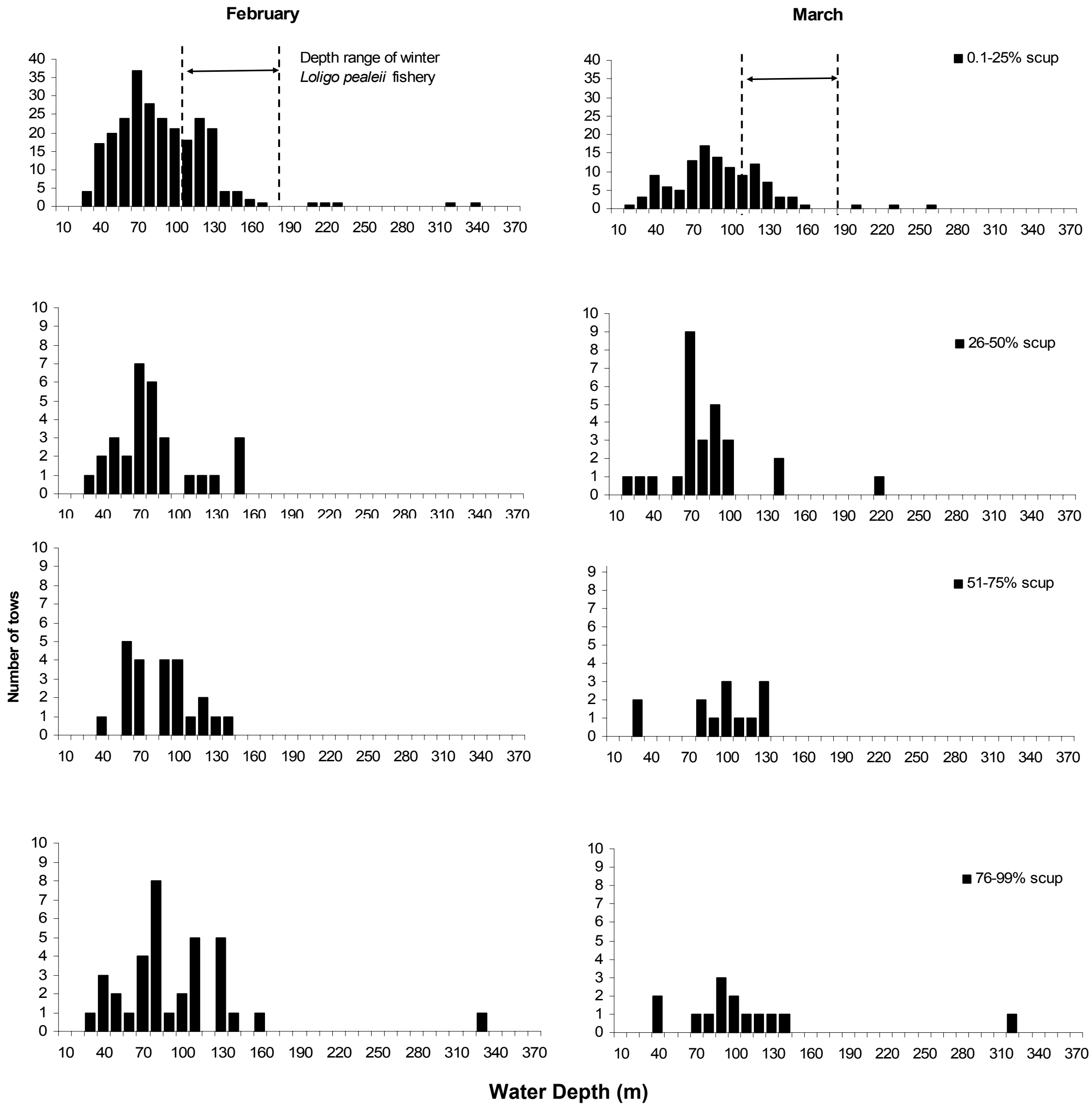
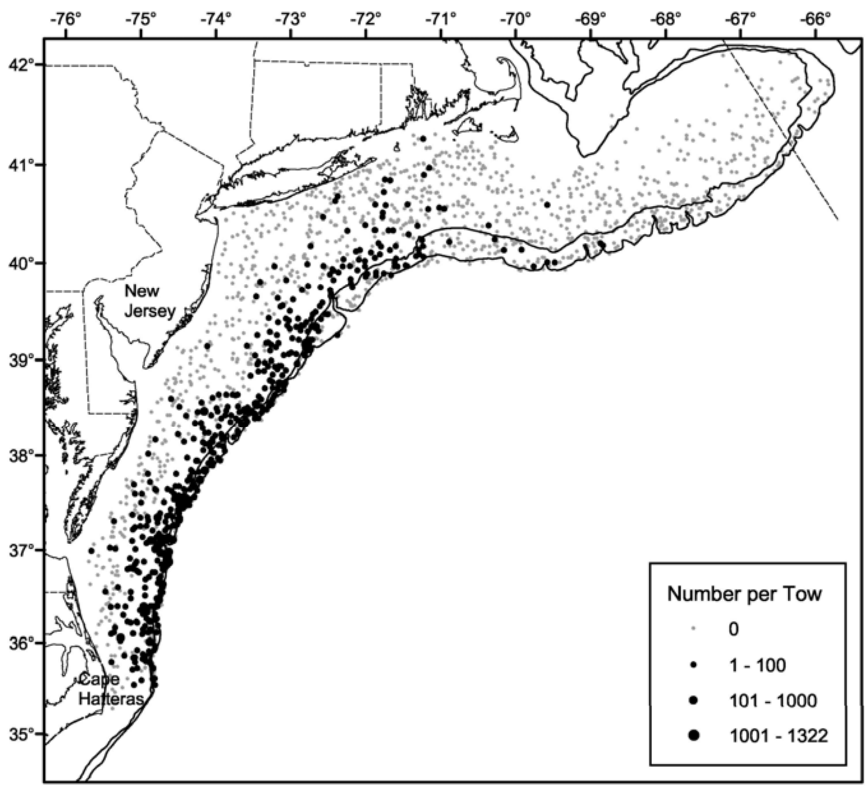
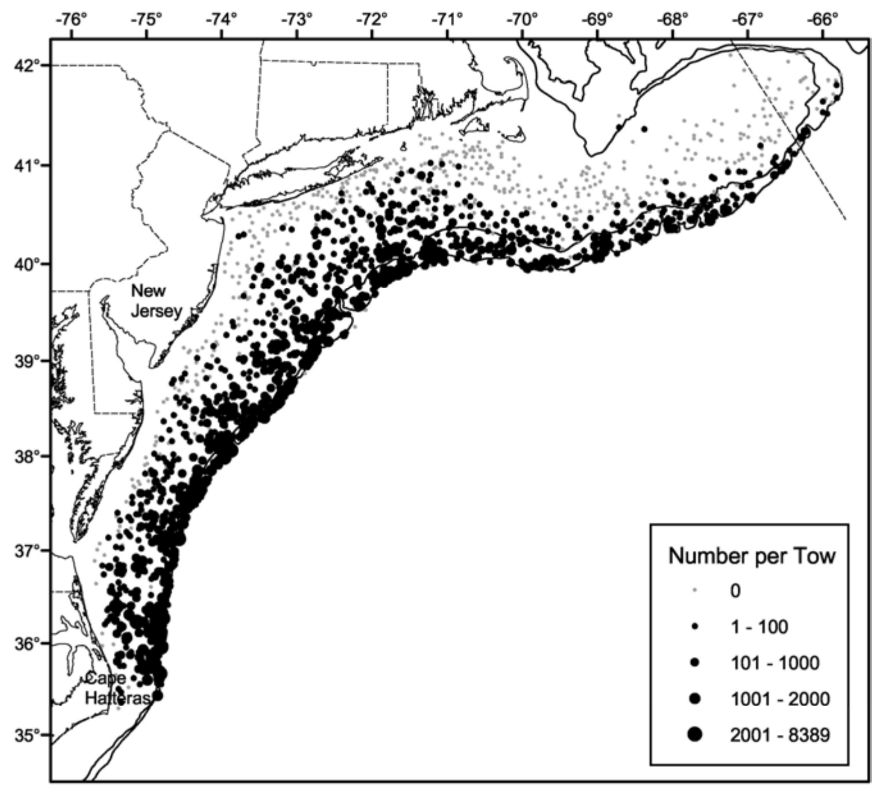


Figure 9. Co-occurrence of scup and *Loligo pealeii* (% scup, number per tow), by depth (m), during NEFSC winter (February) and spring (March) research bottom trawl surveys of the eastern U.S. shelf during 1992-2003. Catchabilities differ between sampling gears used during winter and spring surveys.

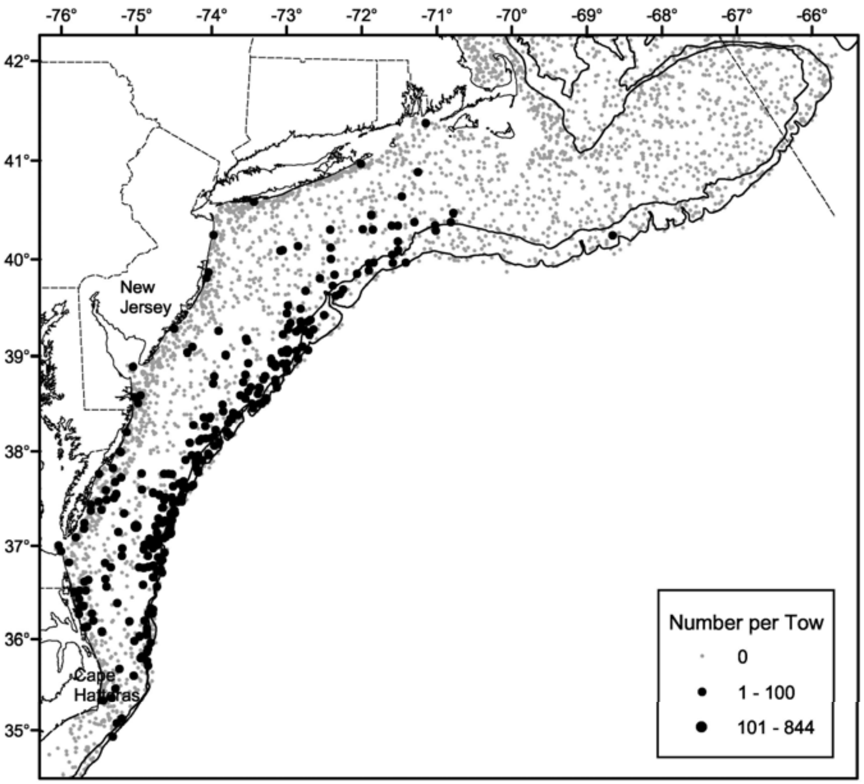


Black Sea Bass

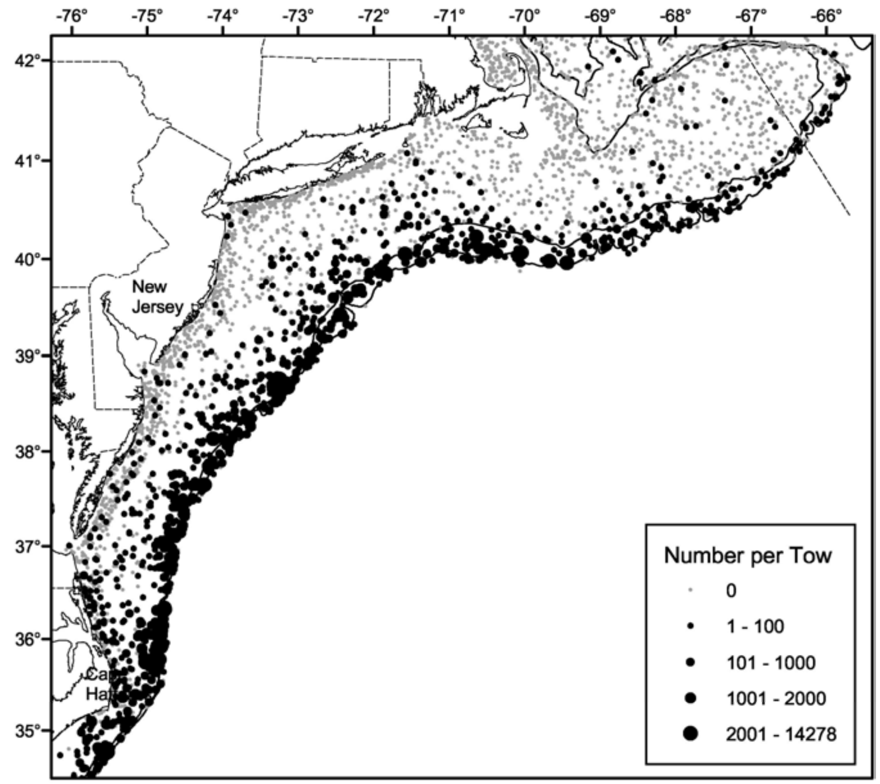


Loligo pealeii

Figure 10. Distribution of black sea bass and *Loligo pealeii* abundance (number per tow) during winter (February) research bottom trawl surveys (1992-2003) conducted by the Northeast Fisheries Science Center. The 91 m and 183 m isobaths are shown.



Black Sea Bass



Loligo pealeii

Figure 11. Distribution of black sea bass and *Loligo pealeii* abundance (number per tow) during spring (March) research bottom trawl surveys (1992-2003) conducted by the Northeast Fisheries Science Center. The 91 m and 183 m isobaths are shown.

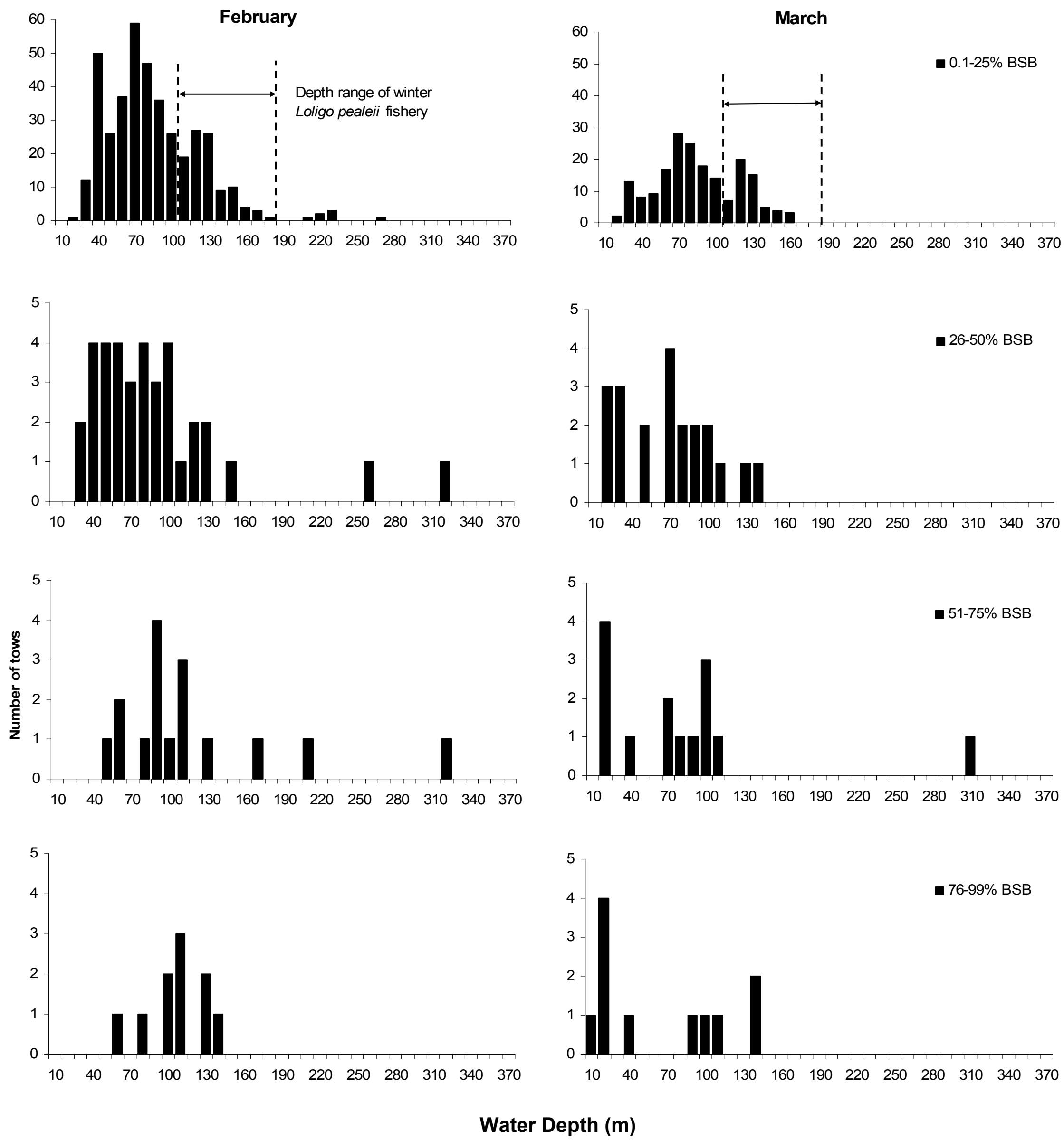


Figure 12. Co-occurrence of black sea bass and *Loligo pealeii* (% scup, number per tow), by depth (m), during NEFSC winter (February) and spring (March) research bottom trawl surveys of the eastern U.S. shelf during 1992-2003. Catchabilities differ between sampling gears used during winter and spring surveys.

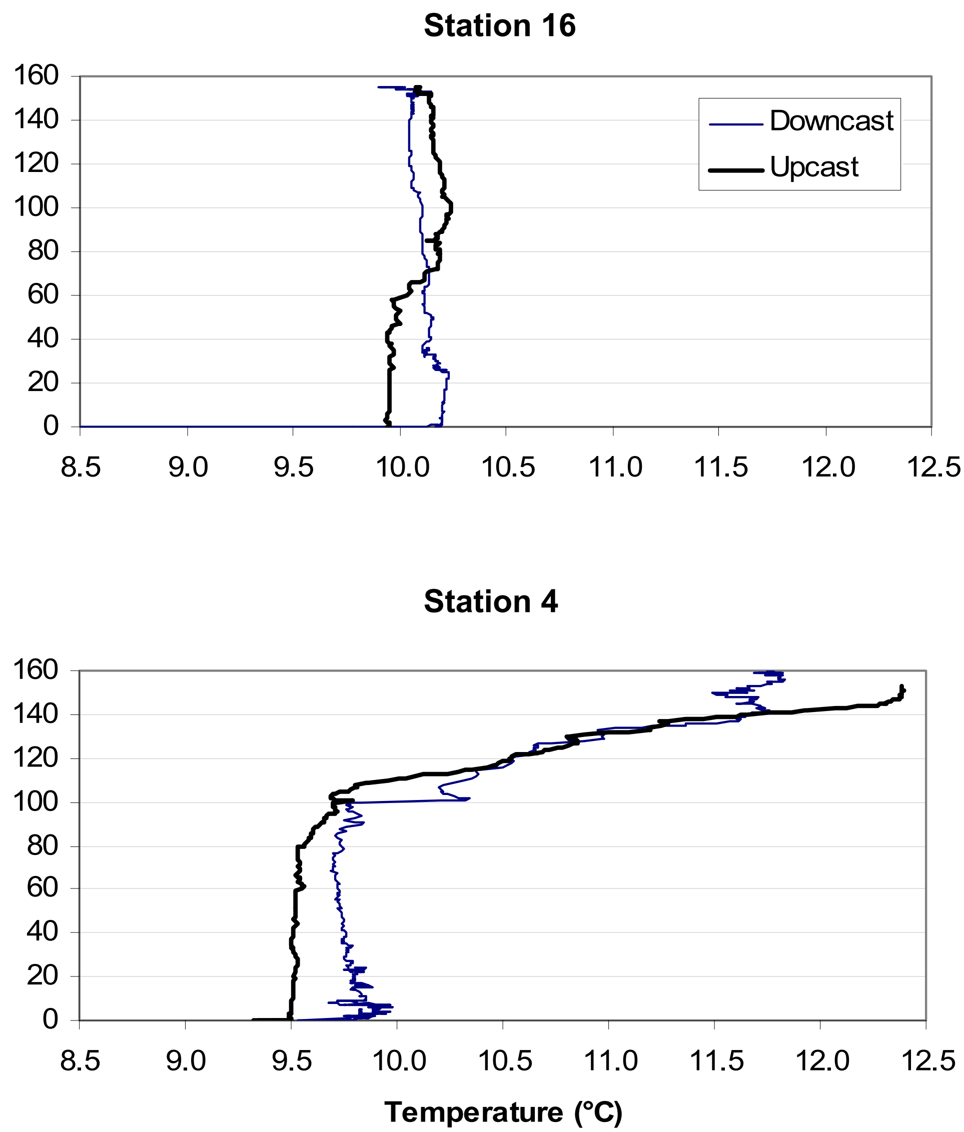


Figure 13. Water temperature profiles for downcasts (dark line) and upcasts (light line) of a Seabird SBE 39 water pressure-temperature probe at station 16 (153 m), sampled on 2/5/04, and at station 4 (155 m) sampled on February 1, 2004.

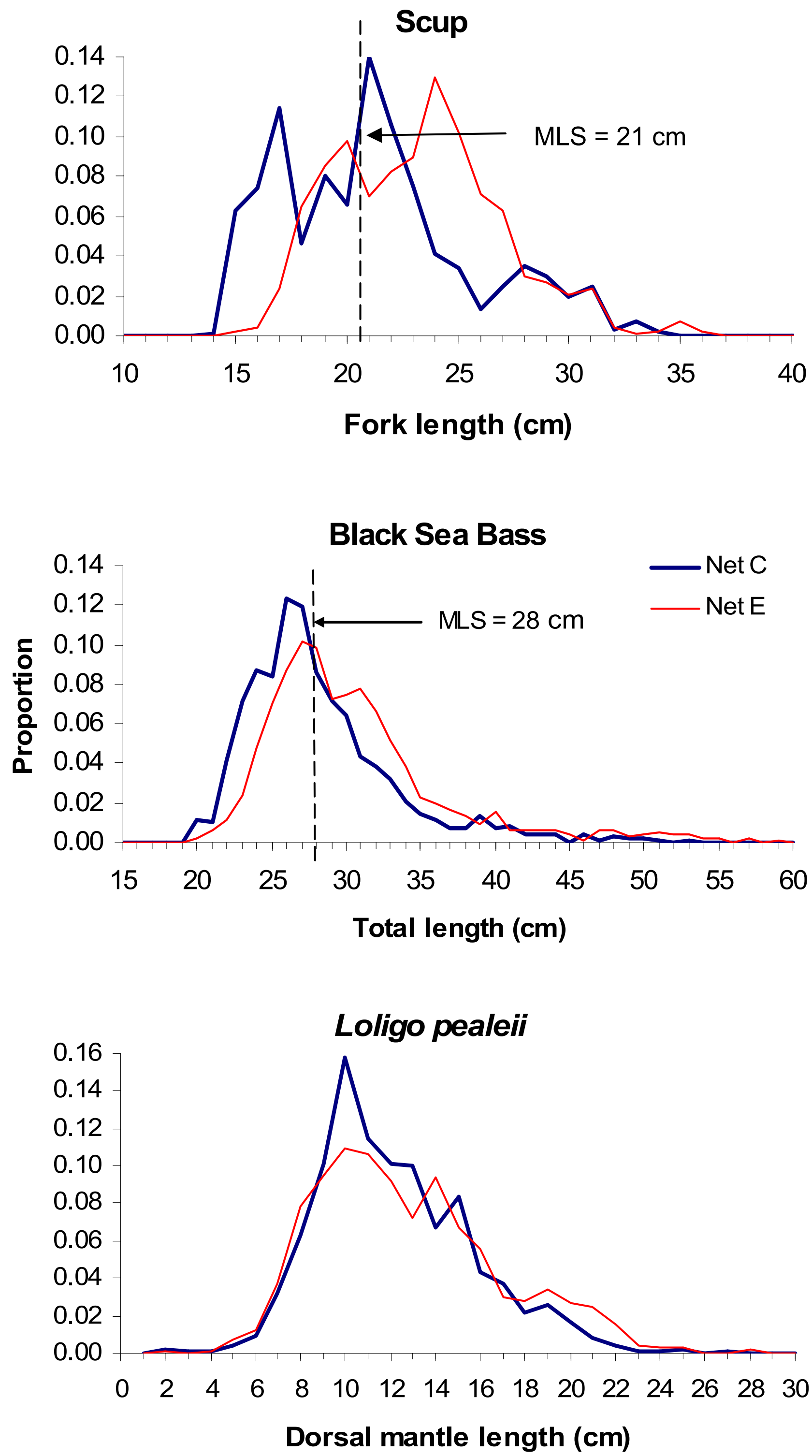


Figure 14. Length-frequency distributions of scup (A), black sea bass (B), and *Loligo pealeii* (C) caught in a *L. pealeii* bottom trawl rigged with (Net E) and without (Net C) a 14.61 mm square mesh panel during a parallel haul study conducted in January 2004. MLS is the minimum legal size that can be landed in the commercial fisheries.

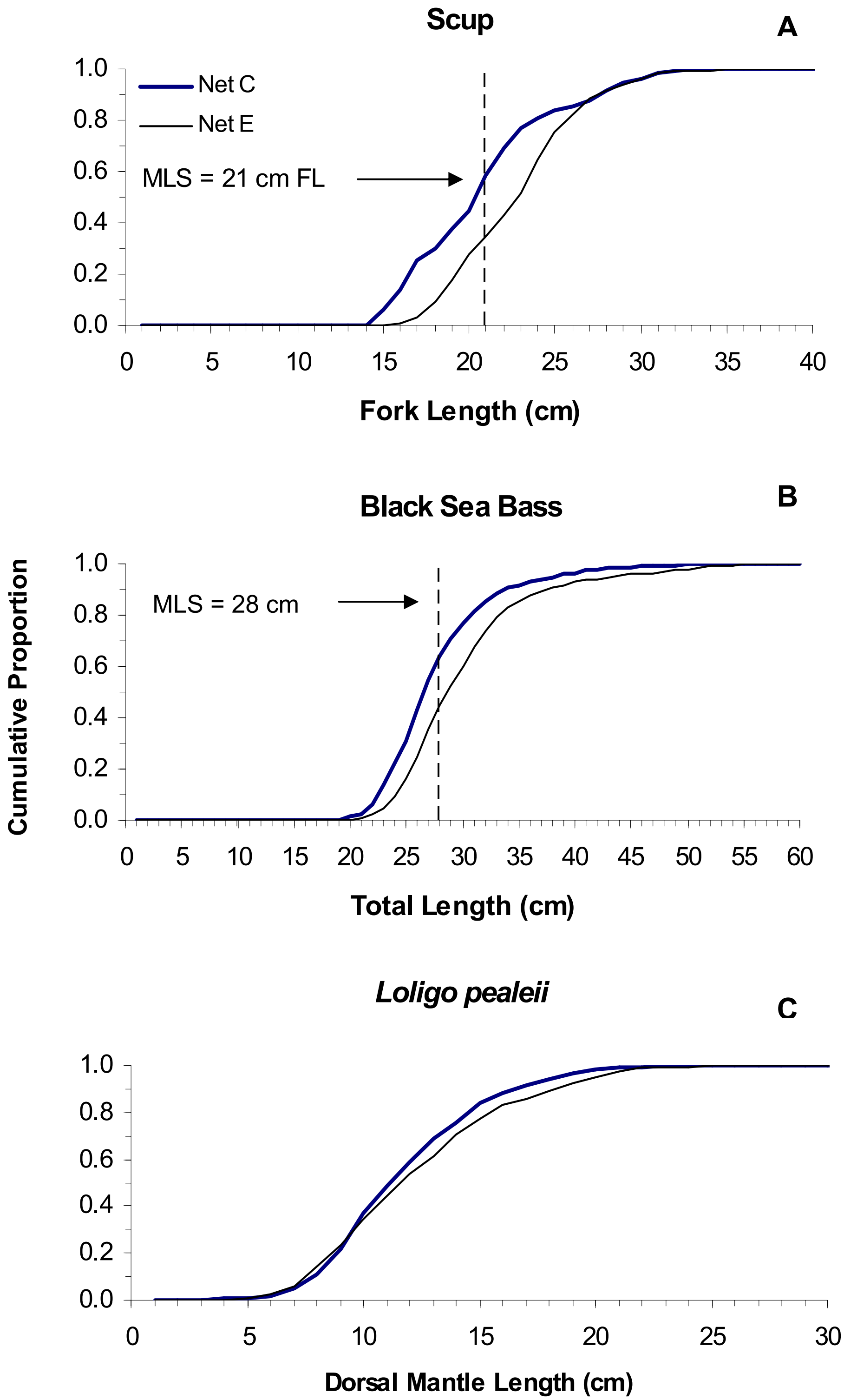


Figure 15. Cumulative proportions of scup (A), black sea bass (B), and *Loligo pealeii* (C) retained in a *L. pealeii* bottom trawl, rigged with (Net E) and without (Net C) a 14.61 cm square mesh escape panel, during a parallel haul study conducted in January 2004. MLS is the minimum legal size that can be landed in commercial fisheries.

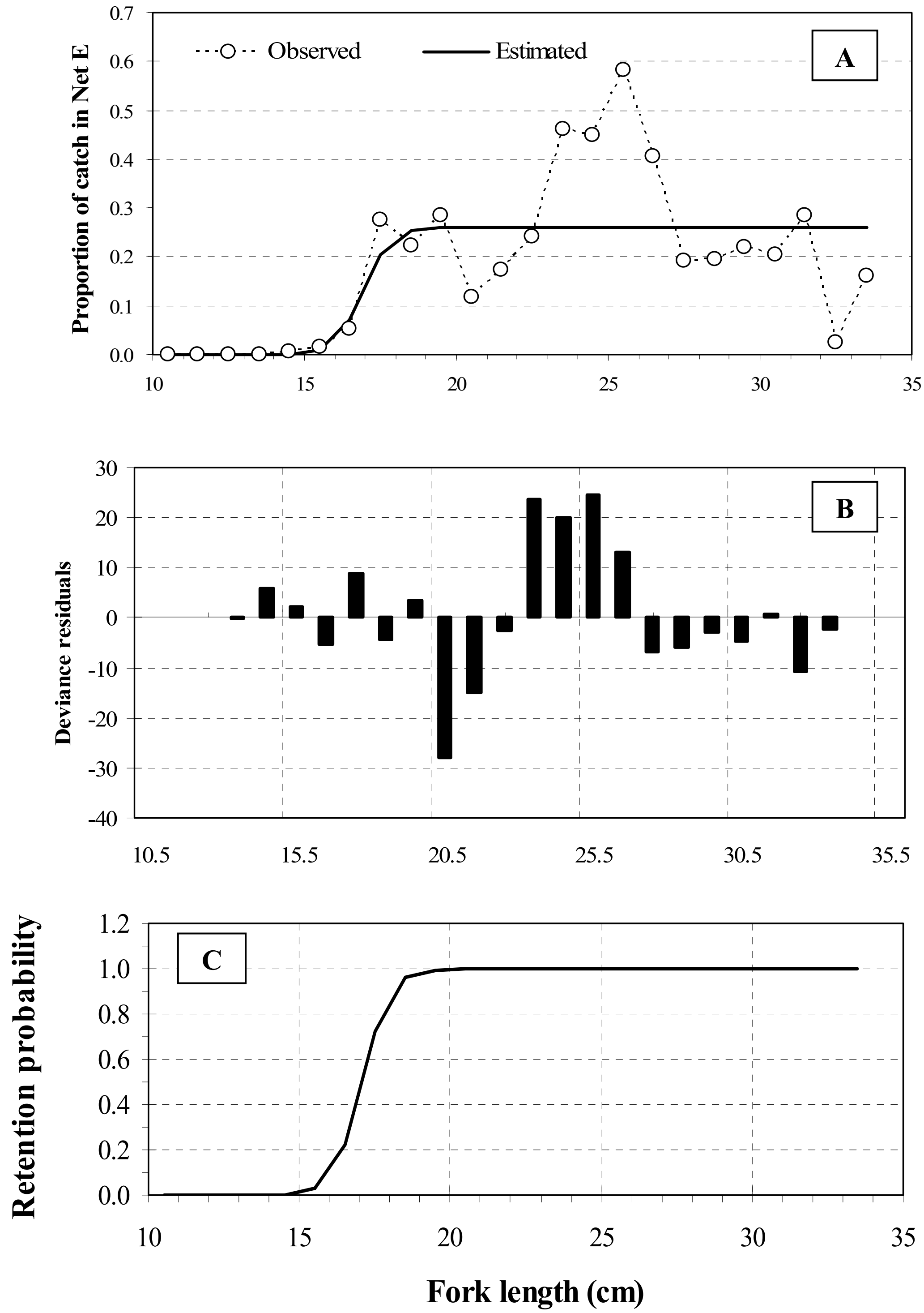


Figure 16. Plots of (A) observed and predicted proportions of scup catch in a *Loligo pealeii* bottom trawl containing a square-mesh escape panel, (B) deviance residuals from the SELECT model fit, and (C) the logistic selection curve predicted for scup.

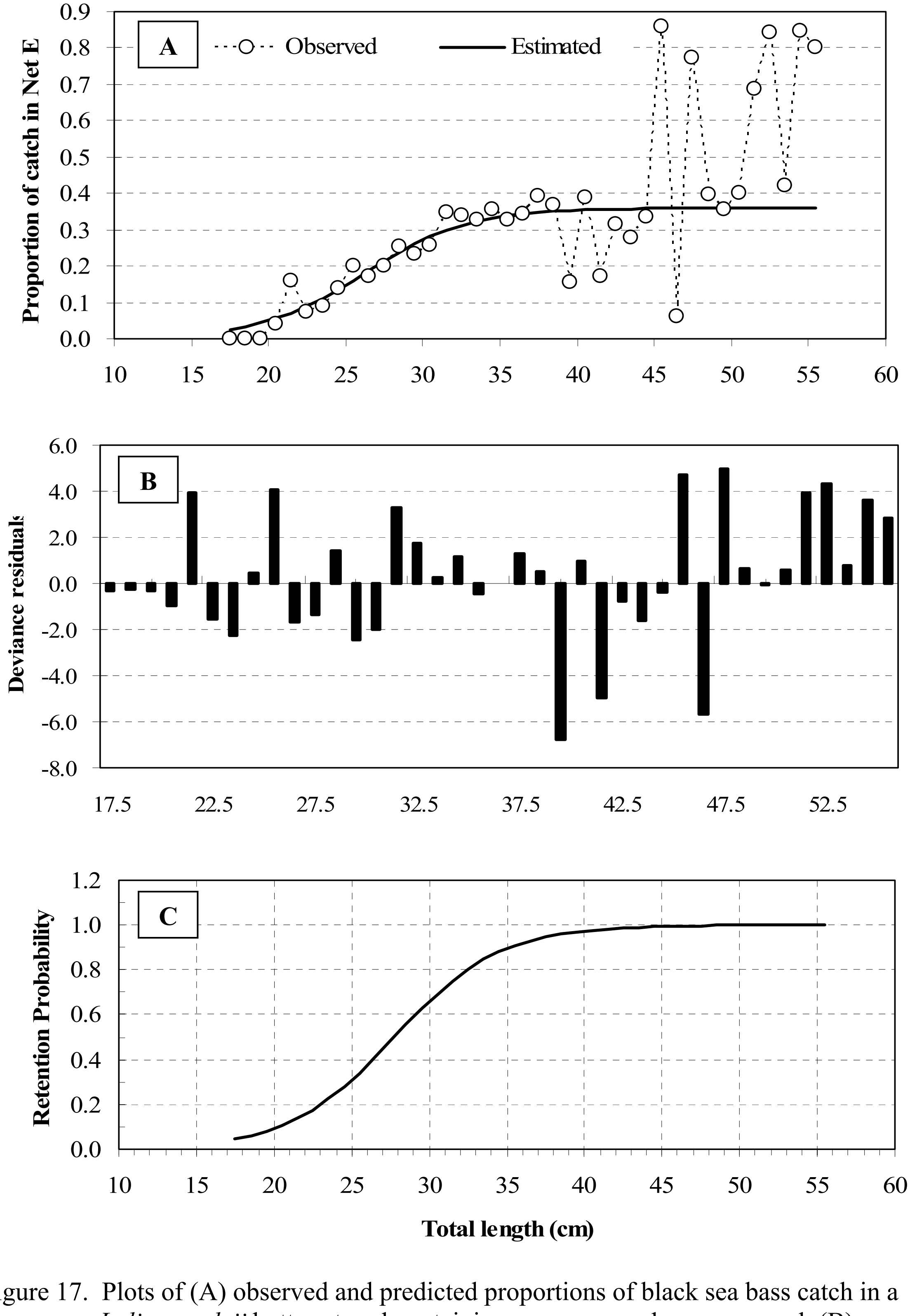


Figure 17. Plots of (A) observed and predicted proportions of black sea bass catch in a *Loligo pealeii* bottom trawl containing a square-mesh escape panel, (B) deviance residuals from the SELECT model fit, and (C) the logistic selection curve predicted for black sea bass.

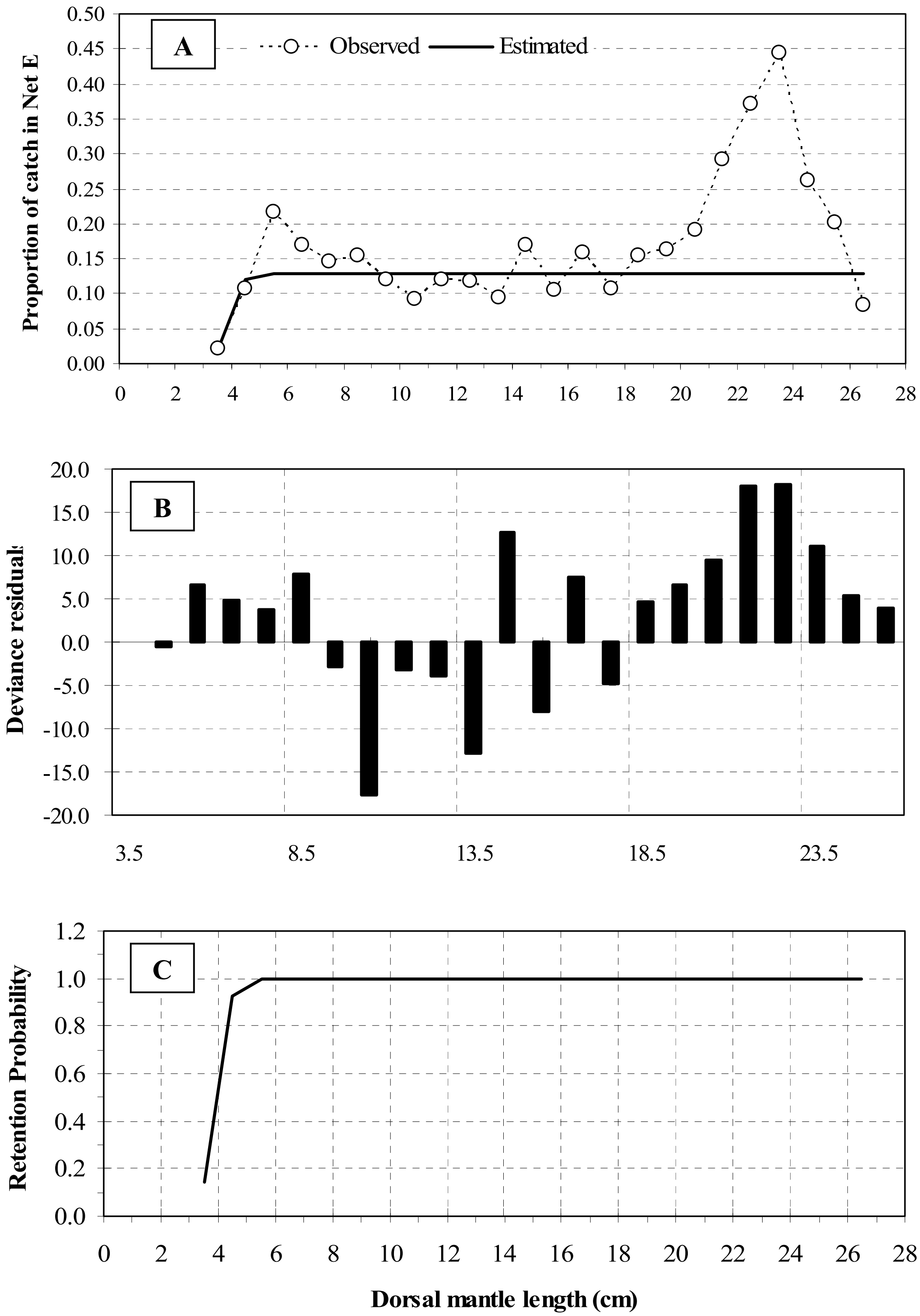


Figure 18. Plots of (A) observed and predicted proportions of *Loligo pealeii* catch in a *L. pealeii* bottom trawl containing a square-mesh escape panel, (B) deviance residuals from the SELECT model fit, and (C) the logistic selection curve predicted for *L. pealeii*.

Procedures for Issuing Manuscripts in the *Northeast Fisheries Science Center Reference Document* (CRD) Series

Clearance: All manuscripts submitted for issuance as CRDs must have cleared the NEFSC 's manuscript/abstract/webpage review process. If any author is not a federal employee, he/she will be required to sign an "NEFSC Release-of-Copyright Form." If your manuscript includes material lifted from another work which has been copyrighted, then you will need to work with the NEFSC's Editorial Office to arrange for permission to use that material by securing release signatures on the "NEFSC Use-of- Copyrighted-Work Permission Form."

Organization: Manuscripts must have an abstract and table of contents, and — if applicable — lists of figures and tables. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area"/"Experimental Apparatus," "Methods," "Results," "Discussion" and/or "Conclusions," "Acknowledgments," and "Literature/References Cited."

Style: The CRD series is obligated to conform with the style contained in the current edition of the *United States Government Printing Office Style Manual*. That style manual is silent on many aspects of scientific manuscripts. The CRD series relies more on the *CBE Style Manual*. Manuscripts should be prepared to conform with these style manuals.

The CRD series uses the American Fisheries Society's guides to names of fishes, mollusks, and decapod crustaceans, the Society for Marine Mammalogy's guide to names of marine mammals, the Biosciences Information Service's guide to serial title abbreviations, and the International Standardization Organization's guide to statistical terms.

For in-text citation, use the name-date system. A special effort should be made to ensure that all necessary bibliographic information is included in the list of cited works. Personal communications must include date, full name, and full mailing address of the contact.

Preparation: Type a clean/neat, single-spaced version of the document. The document must be paginated continuously from beginning to end and must have a "Table of Contents." Begin the preliminary pages of the document — always the "Table of Contents" — with page "iii." Begin the body of the document — normally the "Introduction" — with page "1," and continuously paginate all pages including tables, figures, appendices, and indices. You can insert blank pages as appropriate throughout the document, but account for them in your pagination (*e.g.*, if your last figure ends on an odd-numbered/right-hand page such as "75," and if your next page is the first page of an appendix, then you would normally insert a blank page after the last figure, and paginate the first page of the appendix as "77" to make it begin on an odd-numbered/right-hand page also). Forward the final version to the Editorial Office as both a paper copy and electronically (*i.e.*, e-mail attachment, 3.5-inch floppy disk, high-density zip disk, or CD). For purposes of publishing the CRD series only, the use of Microsoft Word is preferable to the use of Corel WordPerfect.

Production and Distribution: The Editorial Office will develop the inside and outside front covers, the inside and outside back covers, and the title and bibliographic control pages (pages "i" and "ii") of the document, then combine those covers and preliminary pages with the text that you have supplied. The document will then be issued online.

Paper copies of the four covers and two preliminary pages will be sent to the sole/senior NEFSC author should he/she wish to prepare some paper copies of the overall document as well. The Editorial Office will only produce three paper copies (*i.e.*, two copies for the NEFSC's libraries and one copy for its own archives) of the overall document.

A number of organizations and individuals in the Northeast Region will be notified by e-mail of the availability of the online version of the document. The sole/senior NEFSC author of the document will receive a list of those so notified.

Research Communications Branch
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

MEDIA
MAIL

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Resource Survey Report (formerly *Fishermen's Report*) -- This information report is a quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Resource Survey Report*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).