An assessment of hanging ratio and mesh orientation of twine tops on selectivity and bycatch in the general category scallop dredges fishery in scallop limited access areas

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EXECUTIVE SUMMARY

Three twine top configurations were tested on Limited Access General Category scallop vessels in the Atlantic sea scallop fishery in the Elephant Trunk Access Area in March, 2009 and in the Great South Channel Scallop Dredge Exemption Area in June, 2009. The goal of this project was to determine if changes to twine top configuration would affect catch rates and the selectivity of scallop dredges used by general category vessels in this fishery. The twine tops were attached to the dredge using either a 3:1, 2:1, or 3:1 turned hanging ratio, and a cover net was used to collect any scallops and bycatch that escaped through the meshes of the twine top.

In total, scallop and bycatch data was collected from 287 tows. By total weight the scallop catch represented just over 96% of the catch from all tows and areas combined. Skate species, monkfish, and flounders represented 3%, 0.5%, and 0.2% of the total catch weight respectively. Statistical analysis comparing twine top performance was hampered by marked area and vessel effects. However, with respect to scallops the catching efficiency of the dredge with a 3:1 turned twine top was consistently lower than that for the other twine tops (42-83% efficiency). In contrast, there was little difference in scallop catching efficiency between the 3:1 and 2:1 twine tops. The dredges with the 2:1 hanging ratio and the 3:1 turned hanging ratio allowed the escape of a greater proportion of flounders, skates, and monkfish than the 3:1 hanging ratio. There was a high degree of variability between sized based selectivity curve parameter estimates for scallops for each twine top, but there was evidence that a higher proportion of flounders in the dredge are able to escape capture using the 3:1 turned twine top.

Simple relative speed models were developed to predict the escape speed required for flounders to escape through each twine top. Flounders were expected to have sufficient swimming capacity to reach the mesh openings in the twine top although escape was hampered by their orientation with respect to mesh geometry. The 3:1 hanging ratio only permitted the escape of flounders less than 0.1 m (~4″) unless they pivot their body 90 degrees prior to reaching the mesh; in which case a flounder up to 0.3 m (~12″) would be permitted to escape. The 2:1 twine top would permit the escape of flounders 50% larger than that for the 3:1 twine top. While the behavior and orientation of flounders attempting escape through the twine top is not well understood, commonly used twine top hanging ratios appear to prevent the escape of all but the smallest of flounders. Low catches of flounders in this study prevented clear confirmation of this effect; however, it does flag a concern over twine top performance. In the absence of regulation pertaining to twine top hanging ratio it seems that twine top selectivity and bycatch reduction performance is currently not fully optimized in the Atlantic sea scallop fishery.

INTRODUCTION

In the US Atlantic sea scallop fishery, New Bedford style scallop dredges are used to displace sea scallops - *Placopecten magellanicus* - from the seabed and retain them in a steel ring-mesh bag. The rings used to construct the steel ring-mesh bag must have a diameter no smaller than 4 inches, and a large mesh twine top must be fitted to the upper section of the bag (50 C.F.R. § 648.51, 2009) to provide bycatch an opportunity to escape capture as the dredge is towed over the seabed. The twine top must also be constructed from a netting panel with a mesh size no less than 10 inches (25.4 cm). However, there are currently no regulations ensuring that twine top mesh geometry and opening is consistent or that all dredges in the fishery use identically designed and rigged twine tops. There are also no restrictions governing the minimum size (area) of the twine top netting panel, providing it is located a prescribed number of steel rings away from the posterior of the dredge (club stick). Twine top performance and bycatch reduction is therefore likely to be highly variable across time and space, and unlikely to be fully optimized at this time. Reviews of twine top performance can be traced back to at least the 1990's, and are available in NEFMC (2003), Smolowitz et al. (2004), Walsh (2008), and Smolowitz et al. (2009).

Fishing vessels with a permit to operate in the sea scallop fishery are nominally divided into two key permit categories, Limited Access or Limited Access General Category (LAGC) (50 C.F.R § 648, subpart D, 2009). The maximum combined dredge width a LAGC vessel may fish must not exceed 31 (9.4 m) feet unless the vessel participates in the small dredge program, which restricts the number of dredges to one that measures less than 10.5 feet (3.2 m) wide. LAGC vessels cannot have a combined dredge width that exceeds 10.5 feet.

While there has been significant fishing gear research in the Limited Access Fishery with respect to gear improvements and bycatch reduction, there does not appear to have been similar work with LAGC vessels. This project attempts to address this by evaluating the selectivity of three twine tops on LAGC vessels in the Elephant Trunk Access Area (ETAA) and the Great South Channel Scallop Dredge Exemption Area (GSC).

Yellowtail flounder and other bycatch

The predominant bycatch in the Atlantic sea scallop dredge fishery are yellowtail flounder, *Limanda ferruginea*, summer flounder, *Paralichthys dentatus*, monkfish, *Lophius americanus*, and skates, Rajidae (Harrington et al., 2005; NEFSC 2008a; NEFSC 2008b). According to NEFSC (2008a) all stocks of yellowtail flounder are overfished (Biomass/B_{MSY} < 0.5) and overfishing (F/F_{MSY} > 1) is still occurring, although there have been recent signs of significant stock recovery in some regions of the fishery. Hampering the recovery of yellowtail flounder is their discard by scallop vessels fishing from southern New England northward. Very few yellowtail flounder are retained for sale by scallop fishermen and most are discarded overboard. In 2007 NOAA observers onboard scallop vessels reported the discard of approximately 246 metric tons of flounders (all stocks combined) (NEFSC, 2008a). Catches of yellowtail flounder by scallop fishermen has also curtailed their access to viable scallop fishing grounds. In 2006 and 2008, the

Nantucket Lightship Scallop Access Area (NLAA) was closed prematurely due to catches of yellowtail flounder exceeding the total allowable catch (TAC) of this species (NEFMC 2010a). This prompted the New England Fishery Management Council to state:

> "The immediate problem before the Council ……. is to reduce or eliminate the impediment to achieving the optimum yield from the scallop fishery caused by the fishery's incidental catch of yellowtail flounder, and, perhaps, other species." (NEFMC, 2008a)

Currently the threat of premature closure remains in the scallop fishery due to the bycatch of yellowtail flounder. The TAC of yellowtail flounder available to the fishery is 10% of the entire annual TAC for this species in the region (Framework 21, 2010), and while there is a planned increase in this TAC scheduled between 2010 and 2013 (NEFMC, 2010b), overfishing and the risk of closure means that ongoing efforts are required to mitigate this bycatch problem.

Both monkfish and summer flounder are also important bycatch species of concern to this fishery. While monkfish is currently not considered overfished and overfishing is not occurring, annual monkfish discards in the scallop fishery are an estimated 2,560 metric tons (NEFSC, 2008a). According to NEFSC (2007), since 1996 the observed discard ratio of monkfish (ratio of discarded and kept monkfish) has been greater than regional gillnet or trawl fisheries. Summer flounder is also currently not overfished and overfishing is not occurring, although this species is not yet fully rebuilt (NEFSC, 2008b). Between 2004 and 2007, observer and vessel trip report data indicated that the percentage of summer flounder discards in the scallop fishery was 93% and 81% respectively, and NOAA observer data collected during 2007 indicated that an estimated 105 metric tons of summer flounder were discarded by this fishery (NEFSC, 2008b).

Skates are a bycatch species that are found in all regions of the fishery. A recent assessment of the skate complex between 1998 and 2007 indicated that scallop vessels discarded an estimated 13,000 mt of skate annually (NEFSC 2009). This is almost 20% of the total discards of all skate species from all Atlantic coastal fisheries combined, and is second only to the otter trawl fishery in total skate discards.

Twine top design and hanging ratio

The selection of finfish from a scallop dredge using a netting twine top is predicated upon i) fish having the ability to swim towards the twine top and ii) being an appropriate size and morphology to pass through the mesh openings in the netting. While the role of mesh size in the selectivity of a fishing gear is relatively easily understood – because it influences the maximum opening of each mesh and the size of fish that can escape – less easily understood but no less important is the hanging ratio of the netting. Hanging ratio (E) is typically defined as the ratio between the length of rope to which a piece of netting is hung and the stretched mesh distance of the netting. Hanging ratio plays an important role in fishing gear selectivity because it affects mesh geometry and the effective mesh area (Figure 1), which in turn influences the size and morphology fish that can escape.

With respect to netting twine tops, hanging ratio (E_{tt}) is defined as the number of twine top meshes attached to a single steel-mesh ring. Figure 2 shows a scallop dredge twine top with three meshes attached to an individual ring, thus the hanging ratio is 3:1. At lower hanging ratios (fewer meshes) the length of each mesh in the fore and aft direction is decreased and the lateral opening and effective open area of each mesh are increased. At higher hanging ratios, the opposite occurs and mesh opening is narrow. In the US Atlantic sea scallop fishery, fishermen can use any hanging ratio to attach the twine top to the dredge, hence there are no controls regulating twine top mesh geometry and orientation. While hanging ratio plays a very important role in twine top selectivity, current federal regulations do not preclude the use of sufficient netting to ensure that meshes in the twine top are effectively closed.

GOALS and OBJECTIVES

The goal of this project was to determine whether changes to the twine top configuration would affect the selectivity of general category scallop dredges. The null hypothesis is that there is no difference in size or species selectivity of the scallop dredge when changing the hanging ratio or mesh orientation of the twine top.

The specific objectives were to:

- Document catch rates of sea scallops and bycatch using a 10″ twine top and a hanging ratio of 3:1, 2:1 and 3:1 turned 90˚
- Examine the effects of 3:1, 2:1 and 3:1 turned 90˚ hanging ratios on species and size selectivity of a 10″ twine top, using a small mesh cover net to retain dredge escapees
- Provide video documentation of dredge and twine top cover performance and observe behavioral responses of bycatch to the dredge
- Provide recommendations on twine top configuration that will aid in the reduction of yellowtail flounder while optimizing sea scallop retention.

METHODS

Vessels & Gear

Field work was conducted aboard three general category permitted scallop vessels, F/V Donna Jean II (USCG Doc. # 656499), F/V Mary Ellen (State Reg. # ME10XMP) and the F/V Jocka (USCG Doc. # 939745) (Figure 4 a-c). Directed scallop tows were conducted under normal commercial operations using each vessels scallop dredge within the Elephant Trunk Access Area (ETAA) off Cape May, New Jersey and in the Great South Channel Scallop Dredge Exemption Area (GSC) off Chatham, Massachusetts (Figure 5). Tow duration and location were up to the captain's discretion based on his experience within the region.

Each vessel fished with three different twine top configurations that varied by hanging ratio (Table 1). Twine top 1 (3:1) was used as the control and consisted of a twine top hung using a ratio of three netting meshes to each ring across the width of the twine top opening (Figure 6 (a)). Twine top 2 (2:1) consisted of a twine top hung at a ratio of two netting meshes to each ring across the width of the twine top opening (Figure 6 (b)). Twine top 3 (3:1 turned) consisted of a twine top mesh panel turned 90 degrees and hung at a ratio of three netting meshes to each ring along the length (side) of the twine top (Figure 6 (c)).

A small mesh cover net constructed from 4.0″ (101.6 mm) polypropylene mesh was attached over the twine top opening (Figure 7) to retain sea scallops and bycatch that escaped the dredge via the twine top. The cover net was designed and used by Salerno et al. (2008), and was based on a design by Wileman et al. (1996). During haulback each vessel maintained slow forward speed to prevent surging and mixing of the catch between the dredge and cover net. Once this gear was hauled onboard, the catch from the cover net was deposited into marked totes/baskets and separated from the catch from the dredge.

Data Collection and Treatment

The following data was collected for all tows: vessel identification, area fished, twine top number, weather conditions, date, time and position of set and haul of the dredge, average depth of tow, average tow speed and amount of towing wire used.

Catches from the dredge and cover net were separated by species and disposition. Scallops retained in the dredge and in the cover net were weighed in-shell, and a sub sample of up to 100 scallops was collected from the dredge for measurement of shell height in 5 mm increments. All scallops from the cover net were similarly measured. Undersized scallops were defined by the fishermen using market standards. Damaged and undersized scallops were weighed and then discarded overboard. All bycatch was quickly sorted from the catch, separated by species, measured for total weight (pounds) and length (cm), and then returned to the water. Invertebrate discards were similarly sorted, weighed (pounds), and returned to the water.

To facilitate catch analysis, dredge and cover net catches of all species were standardized

by swept area (SA). Area swept catch rates (C_{SA}) were then pro-rated to represent an average general category (AGC) tow with average conditions specified by an 8 foot (2.4384 m) dredge towed for 15 minutes at 4 knots (30.8667 m/min). Average conditions reflected observed tow times and speed observed in this study (Appendix 1). Standardized catch rates for an average general category vessel (C_{AGC}) were calculated by:

$$C_{SA} = \frac{\text{Catch (lbs)}}{\left(\text{tow duration (min) x tow speed (m/min) x dredge width (m)}\right)}$$

$$C_{AGC} = C_{SA} \text{ x } \left(15 \text{ (min) x } 30.8667 \text{ (m/min) x } 2.4384 \text{ (m)}\right)$$

For comparisons of catching efficiency between twine top configurations, a retention and escapement rate was calculated from the standardized catch rates for all tows in which a twine top cover net was utilized. Conversion standardizes by the total biomass of a species collected during a tow, including the catch rate for the cover net (C^C) and dredge (C^D), and is calculated by:

$$\text{Retention (\%)} = C^D_{AGC} / \left(C^D_{AGC} + C^C_{AGC}\right)$$

$$\text{Escapement (\%)} = C^C_{AGC} / \left(C^D_{AGC} + C^C_{AGC}\right) = 1 - \text{Retention}$$

To control for spatial variability, tows were removed from the analysis when less than 5 tows were repeated within a 1 km area. Tows that resulted in hangs or significant gear damage were also removed from the analysis.

Data analysis

Standardized scallop catch rates (C_{AGC}) were modeled as a three-way ANOVA of management area fished, vessel type, and twine top configuration. Interaction terms between factors were also parameterized within the model. A Tukey honest significant difference (TukeyHSD) test was then used to evaluate all pairwise comparisons between modeled means. Mean estimates were then used to calculate relative dredge catching efficiency (100 x (experimental catch rate / control catch rate)) where the 3:1 twine top was used as the control twine top. When the assumptions of ANOVA were not met and could not be improved by transformation the nonparametric Kruskal-Wallis test was used.

Catch rates for individual species were pooled across species groups (Appendix 2), including: kept scallops, discarded scallops, flounder species, skate species, monkfish, and other fish species. Loss rates of target and non-target species within each area and twine top combination were modeled with a factorial design ANOVA using a generalized linear model (Agresti 1996). Observed loss percentages were weighted by the species-specific total catch for that tow. The response variable was assumed to be binomially distributed and transformed with a logit link function. Following model fitting,

simultaneous pairwise comparisons were calculated with Tukey's all-pair comparison using the glht procedure (Hothorn et al. 2008) in the R-Statistical Program (R; R 2010).

The entire catch from the dredge and cover net was measured for total length, except the scallop catch. A random sub-sample was collected when the scallop catch in the dredge or cover net exceeded 100 individuals in a tow. The proportion of scallops at each shell height in the dredge or cover net sub-sample was then multiplied by the respective total scallop catch weight for the dredge or cover net to estimate the number of individuals of that shell height in the total scallop catch.

Millars's (1992) Share Each LEngth's Catch Total (SELECT) modeling procedure was applied to fit species specific selectivity curves for each twine top configuration. The two parameter logistic model takes the form:

$$P(l \mid l_{50}, SR) = \left[1 + \exp\left(-2\ln(3)\left(\frac{l - l_{50}}{SR}\right)\right)\right]^{-1}$$

The model is described by the length (l) at 50% retention (l_{50}) and the selection range (SR) (Millar 1992; Millar and Walsh, 1992; Yochum 2006). The log-likelihood function of the model conditions on the catch at length in the dredge and cover net is defined by:

$$\ln L(l_{50}, SR \mid l) = \sum_{l} \ln\left(P(l \mid l_{50}, SR)^{C_{DR}} \left(1 - P(l \mid l_{50}, SR)\right)^{C_{cn}}\right)$$

Procedures to fit the SELECT model were adapted from those published on Dr. Millar's website (http://www.stat.auckland.ac.nz/~millar/). The model was fit by minimization of the negative log-likelihood with the Newton-type nlm procedure in R. Model fitness was evaluated by a χ^2 likelihood ratio test.

Following optimization, bootstrap confidence intervals (Efron and Tibshirani 1993) were generated. The observed selection at size was adjusted by iterative resampling of the deviance residuals. The model was then fitted to the adjusted selection values and individual prediction curves were stored. After 1000 replications quintiles were drawn from the bootstrap selection curves at 5% and 95% across the range of observed length classes.

Video documentation

The F/V Jocka was chartered for two days (May 11th and 12th, 2009) and video specialist Captain Bill Lee was hired to record video of the scallop dredge while under tow with a custom-built, live feed video camera. Tows were conducted within Massachusetts State waters. Tow duration was short and tow location was restricted to shallow depths due to the length of the live-feed camera cable and ambient light availability. The camera was affixed at several locations on the dredge to capture several angles of the dredge under tow.

RESULTS

In March 2009, the F/V Donna Jean II and F/V Mary Ellen completed a total of 68 scallop dredge tows (Table 2) in the Elephant Trunk Access Area (ETAA) off Cape May, New Jersey. In July 2009, a total of 219 scallop dredge tows (Table 3) were completed in the Great South Channel Scallop Dredge Exemption Area (GSC) by the F/V Donna Jean II, F/V Mary Ellen and F/V Jocka. All tow locations are plotted in Figure 5.

In decreasing order by weight, the total standardized combined catch from the dredge and cover net was scallops (96.04%), skates (2.89%), monkfish (0.49%), other fish (0.41%), other flounders (0.10%), summer flounder (0.04%), and yellowtail flounder (0.03%) from all tows and areas combined. As a result of low catches, all flounder species were grouped for further analysis.

Catch Rates

There were generally no significant differences between catch rates of scallops in the dredge when the cover net was present or absent in either area fished (*t*-test; $\alpha = 0.05$). Two exceptions occurred using the 3:1 twine top in the Great South Channel were the dredge catch when the cover net was present was higher than when the cover net was absent (F/V Donna Jean $p = 0.0180$, $df = 24.4$, power = 0.975; F/V Mary Ellen $p = 0.0320$, $df = 52.0$, power = 0.969).

Standardized catch rates for scallops using the cover net were somewhat variable between twine tops and fished area (Figure 8). Scallop catch rates were log transformed to satisfy residual normality (Shapiro-Wilk, $p = 0.1207$) and modeled with a thee-way ANOVA (Table 4). The main effects of management area, vessel, and twine top were all significant ($p < 0.05$). Two-way interaction effects were also significant while a three way interaction was not (Table 4). Catch rates were analyzed within areas by a two-way ANOVA (Table 5), and vessel, twine top, and interaction effects were significant in both the Elephant Trunk (Table 5(a)) and Great South Channel (Table 5(b)).

In the Elephant Trunk Area, vessel effects on catch (Table 6(a)) were found to be significant ($p = 0.0407$). Catch rates by twine top were then evaluated within vessels. For the F/V Donna Jean, catch rates were highest for the 3:1 twine top and lowest for the 3:1 turned twine top (Table 6(b)). There was a significant difference in catch rates between the 3:1 and 2:1 twine top ($p = 0.0138$), but not between the 2:1 and 3:1 turned twine top ($p = 0.6979$). For the F/V Mary Ellen, catch rates were highest for the 2:1 twine top and lowest for the 3:1 turned twine top (Table 6(c)). There was a significant difference in catch rates between the 3:1 and 2:1 twine top ($p = 0.0276$), but not between the 3:1 and 3:1 turned twine top ($p = 0.0003$).

Within the Great South Channel (Table 7 (a)) vessel effects were found to be significant ($p < 0.0001$). For each vessel, all comparisons of twine top configuration were significant, with the exception of the 3:1 and 3:1 turned twine top comparison on the F/V Donna Jean (Table 7 (b)).

With the exception of skates, standardized catch rates for flounders, monkfish, and other species were generally less than 5 lb per tow (Figure 12). Catches of all bycatch species in the Elephant Trunk Area were deemed insufficient for further catch rate analysis; although in the Great South Channel they were modeled using a Kruskal-Wallis non-parametric procedure (Table 8). This procedure was chosen after the assumptions of ANOVA could not be achieved even after Box-Cox optimal transformation. Dredge and cover net catch was pooled across vessels as the catch was too low within vessels for analysis. Median dredge catch rates (lbs/tow) of all bycatch species captured between twine tops was not significant ($p > 0.05$) in all but one case; the dredge catch rate of other species was significantly higher in the 3:1 twine top than the 3:1 turned twine top ($p < 0.0001$). Cover net catch rates were also analyzed using a Kruskal-Wallis test although in most instances the median catch rate was close to or equal to zero. Catch rates were significantly higher in the 3:1 turned twine top for all species except the other species category, were catch rates were similar to the 2:1 twine top ($p = 0.6$). The only difference between the 2:1 and 3:1 twine top was in the cover net catch other species ($p = 0.002$).

Escapement through the twine top

By weight and proportion the 3:1 turned twine top resulted in the greatest escapement of scallops through the twine top (Table 9), and in the Great South Channel this escapement was significantly greater than the remaining twine tops (Table 10). The escapement of scallop discards was highest by weight and proportion using the 3:1 turned twine top, although in the Elephant Trunk scallop discards was highest by weight using the 3:1 twine top and by proportion using the 3:1 turned twine top. In the Great South Channel this escapement was significantly greater than the remaining twine tops (Table 10). Overall the proportion of bycatch that escaped through the twine top was very low, particularly flounders (including yellowtail flounder) and monkfish from both areas, although the escapement of bycatch was always significantly higher using the 3:1 turned twine top (Table 10, Figure 13). The proportion of flounder escaping the 2:1 twine top was substantially greater (25%) than that for the 3:1 twine top, but this difference was not significant. Variation in the escapement of scallops and bycatch in both areas is shown in Figure 14 and 15.

Size-frequency analysis and selectivity curves

Shell height-frequency distributions for scallops and length-frequency distributions for bycatch are given in Figure 16 - 20. The distribution of scallops indicated that relativly few individuals escaped through the twine top (Figure 16). Selectivity curves were fitted to scallop catches in both areas for each twine top, and flounder in the Great South Channel using the 3:1 turned twine top (Table 11; Figure 16 & 17) but not to bycatch distributions due to insufficient catch numbers. In the Elephant trunk the l_{50} for scallops using the 3:1 twine top was higher (80.5mm) than for the other twine tops, while in the Great South Channel it was highest using the 3:1 turned twine top (92.4) (Table 11). The selection range of the 3:1 turned twine top was broader than for the other twine tops in both areas.

Video documentation

A total of four hours of video footage was recorded and stored on three compact discs (Appendix 3). The footage viewed the dredge under tow from several angles including facing forward, facing laterally at the cutting bar, facing laterally at the pressure plate, and facing rearward towards the twine top opening. While footage quality varied depending upon camera placement, no finfish were observed interacting directly with any component of the scallop dredge. Limited forward facing footage did indicate possible avoidance behavior by flounders, skates and lobsters to the approaching dredge while under tow. Footage quality of the twine top was generally poor as a result of the debris plume created by the dredge, although observations showed the twine top panel tended to stretch upward and 'balloon' away from the dredge for all hanging ratios.

DISCUSSION

The hanging ratio of a twine top affects mesh geometry and opening and consequently the retention of scallops and bycatch within the dredge. This research is some the first of its kind to be conducted on general category scallop vessels and has produced some interesting results. Specifically, the 3:1 turned twine top had a lower catch rate than the standard 3:1 twine top for scallops and an increased escapement of bycatch, including flounders, skates, and monkfish. Scallop catch rates and bycatch escapement was statistically similar between the 2:1 twine top and the 3:1 twine top, although in some instances there were sizeable differences in catch proportions between twine tops. Catches of yellowtail flounder bycatch (Figure 9 and Figure 13) were very low throughout the study and therefore were analyzed in aggregate with the other species of captured flounder.

Caveats to the investigation

Catch comparison between multiple vessels can be difficult, especially when experimental twine tops are under investigation due to the influence of multiple variables on catch analysis. In this study, each captain was allowed to choose the location of each tow and fishing effort was conducted as per normal practice in order to test the twine top under normal operating conditions. To account for these variables, an attempt was made to standardize their influence across vessels (by swept area), time (by conducting trips as concurrently as possible), and area (by restricting utilized tows to areas were there was maximum overlap between vessel and twine top combinations). Even so, statistical inquiry was ultimately reduced to twine top effects within areas and vessels.

While each captain naturally gravitated towards areas of suspected high scallop abundance, catches of bycatch were extremely low and it was not possible to fully evaluate the effect of hanging ratio and mesh geometry on their selection from the dredge. Another option would have been to test these twine tops in areas of high known scallop and bycatch density, in particular areas where yellowtail flounder are abundant. Unfortunately finding areas that satisfied these requirements was not possible within the study area.

Another point of consideration was the technical difficultly encountered when using the twine top cover net on the relatively small vessels typical of the general category scallop fleet. Deck space and hauling equipment are typically limited on these vessels, and separation of the dredge and cover net catch was challenging. In some situations the cover net could only be retrieved by hand-hauling it over the rail, and this lead to a somewhat understandable negative bias in cover net usage by some fishermen, especially in areas of thought to have relatively high bycatch abundance. As a result, several tows were completed without a cover net attached to the dredge.

Catch rate analysis of the twine top configurations

<u>Scallops</u>

Scallop catch rates were a function of both area and vessel, with prevalent interaction effects across variables (Table 4 and Table 5). Scallop catch rates were higher in the

Elephant Trunk Area than in the Great South Channel (Table 5) and vessel effects were inconsistent, with one vessel having a higher catch rate in the Elephant Trunk Area and a lower catch rate in the Great South Channel (Table 6(a) and Table 7(a)). The third vessel had a much lower catch rate but did not make tows in the Elephant Trunk Access Area (Table 7(a)). The difference in vessel affects across areas could be attributed to one vessel Captain having more traditional knowledge in the Great South Channel than the other, or to spatial variability in scallop abundance that could not be further controlled in this analysis.

Controlling for vessel effects showed that among all vessels the 3:1 turned twine top had a lower catch rate of scallops, which was significant in nearly all cases, and an efficiency ranging from 42 – 83% compared to the 3:1 twine top (Table 6 and Table 7). For some vessel and area combinations the 2:1 twine top caught more scallops while for others it caught less (Table 6 and Table 7), ranging from 66 – 135% efficiency compared to the 3:1 twine top. Differences between the 3:1 and 2:1 twine tops may be due to spatial variability of scallop abundance that could not be further accounted for in this study. Since the trend in catch rates between these two twine tops is inconsistent across vessels and areas it is likely that there is either little true difference between these twine tops or that further testing will be required to elucidate any difference. Due to the aforementioned consistencies, it is reasonably safe to assume that the 3:1 turned twine top truly retained fewer scallops than the other twine tops. How this might influence the possible uptake of this twine top by captains is an interesting notion given that the modest daily scallop trip limit of 400 lbs in the Elephant Trunk Area can still be easily achieved.

Bycatch

The catch rate of bycatch species was too low in the Elephant Trunk area to model and analyze. The occurrence of bycatch in the Great South Channel was also low, and inconsistent across vessels, but could be analyzed across twine tops in some detail. Proportionally the 2:1 and 3:1 turned twine tops have considerable impact on escapement of bycatch. The escapement of Flounders, for example, increased by 25% using the 2:1 twine top and almost 75% using the 3:1 turned twine top (Table 8(c)), although only the latter was significant. The 3:1 turned twine top reduced a relatively high proportion of bycatch, although the accompanying loss of valuable scallops is a concern.

Selectivity curves

Between areas fished in this study, there was a high degree of variability between sized based selectivity curve parameter estimates for scallops for each twine top (Table 11). While this could be explained in part due to the spatial separation between the two areas fished, low scallop catches in the cover net also contributed to this outcome. From the perspective of the fishermen this is a desirable outcome because it indicates that very few scallops escape capture from inside the dredge. Low catches of all bycatch species prevented selectivity-curve analysis with the exception of flounder in the Great South Channel using the 3:1 turned twine top. Comparing length frequency distributions, there is evidence that a higher proportion of flounders in the dredge are able to escape capture using the 3:1 turned twine top.

Gear efficiency

It seems apparent from the results that there was a lower retention of both scallops and bycatch in the 3:1 turned twine top. A useful exercise here is to consider possible trade-offs using this twine top in comparison to the 3:1 or 2:1 twine tops. If a fishing twine top is less efficient than another twine top, towing time would need to be increased to retain the same quantity of scallops. The additional time can be determined by the expression:

$$\text{Standardized tow time x} \left({}^{1}\!/_{\text{Efficiency}} \right) = \text{New tow time}$$

For example, consider the mean standardized catch rates observed for the F/V Mary Ellen fishing in the Great South Channel (Table 7). The twine top efficiency of the 3:1 twine top relative to the 3:1 turned twine top on the F/V Mary Ellen is 52.7% and the mean tow time of the vessel was 15 minutes (Appendix 1). Thus,

$$\text{New tow time} = 15\,\text{min. x} \left({}^{1}\!/_{0.527} \right) = 28.4\,\text{min tow}$$

Hence the vessel would need to fish 13 minutes longer per tow on average with the 3:1 turned twine top to recover the same quantity of scallops as the 3:1 twine top. However, intuitively this should also result in an increase in catches of flounders, skates, monkfish, and other bycatch. Unfortunately, solid comparisons of bycatch catching efficiency between twine tops was not possible, although there is an apparent trend for proportionally higher escapement uisng the 3:1 turned twine top (Figures 13-15).

Further thoughts on avoiding bycatch

The limited video footage collected in this study indicated that some flounder, monkfish, skates, and other bycatch species ahead of the approaching scallop dredge attempted to swim forward or laterally away from the dredge to avoid capture. Specific details regarding this response to a scallop dredge, such as swimming speed and duration by species or size, is not known. Most behavioral observations of these species, and in particular flounder species, are derived either from studies of fish in large aquaria or from at-sea observations using trawl gear (see Winger et al. (1999), Winger and Walsh (2001), and Ryer (2008)). A commonly observed avoidance response by flounder to avoid contact with an approaching trawl includes an alternating burst of high speed swimming followed by a gliding maneuver. The burst swimming speed used by flounder during these maneuvers has not been well quantified, although Winger and Walsh (2001) observed that winter flounder, *Pseudopleuronectes americanus*, attained sustained swimming speeds of 0.75-1.35 m/s. Winger et al. 1999 observed that American plaice, *Hippoglossoides platessoides*, attain sustained swimming speeds of 0.30 m/s or 0.7 to 2.1 body lengths per second, and Kim and Wardle (1997) applied a modeling approach to derive a burst swimming speed for 50 cm flounders of up to 3.0 m/s. Intuitively this modeled burst speed may not be too divergent from reality, given that Videler (1996) claims a first order estimate of burst swimming speed for roundfish is 10 body lengths per second for fish 10 – 20 cm in length

Simple theoretical modeling of fish escapement through the dredge twine top is helpful for a thoughtful discussion of bycatch reduction. Consider, for example, a fish at rest on the seabed. If the fish remains stationary and is overrun by the dredge, the netting twine top will present a moving window of multiple escape 'opportunities' through which the fish must pass through if it is to escape. If the fish begins to move upwards the moment the leading edge of the twine top passes directly overhead, an instantaneous, two-dimensional speed model can be generated to predict the minimum swimming speed (U_F) that must be generated by the fish to escape. Such a model could be built based on trigonometric properties and take the following form:

$$U_F = \frac{H_e}{D_W}$$

where;

$$D_W = \frac{D_{TT} + H_h}{U_D}$$

$$H_e = \frac{H_D - H_F}{\sin(90 - \theta_F)}$$

$$H_h = \frac{\sin(\theta_F)(H_D - H_F)}{\sin(90 - \theta_F)}$$

The escape distance (H_e) is a function of the height of the dredge (H_D), the height the fish is off the bottom (H_F) and the angle that the fish moves (θ_F) relative to vertical plane (0^0). The window duration (D_W) of the twine top is a function of fish position (H_F) above the seabed ($0 \leq H_F < H_D$), the horizontal distance added due to the angle of fish movement ($H_h > 0$ if the fish swims in the towing direction; $H_h < 0$ if the fish swims opposite the towing direction), the horizontal opening width of the dredge (D_{TT}), and the dredge speed (U_D). The frame of reference for fish swimming angle is set with vertical at 0^0, so that if a fish moves straight up off the bottom, H_h reduces to zero, and the denominator of H_e reduces to 1. Furthermore, the departure angle is constrained within the range -90 to 90 degrees, and a departure angle towards the oncoming dredge is negative while a movement away is positive.

Figure 21(a) presents a range of U_F required for a fish to escape through the dredge twine top opening, assuming that the meshes are absent. Given a towing speed of 4 knots (2.058 m/s) the model predicts that a swimming speed of 0.315 m/s is required to escape through the twine top. Based on the observations from Winger et al. (1999) and Winger and Walsh (2001), it is not too unreasonable to expect that yellowtail flounder will be able to reach the twine top and attempt to escape through the meshes in the netting. The effect of speed on swimming speed is dramatic: a reduction from 2.0 m/s to 1.5 m/s

(25%) reduces the required swimming speed by 50%. This model assumes that the fish is initially stationary, that swimming is in two dimensions and does not commence until the dredge passes directly overhead. It also assumes that swimming is unaffected by water turbulence generated by towing the dredge through the water. Swimming directly towards the towing direction or in the opposite direction show that the predicted escape swimming speed is relatively flat over a wide range of escape angles (Figure 21(b)), and certainly within the presumed capability of yellowtail flounder.

Once the fish nears the netting twine top it is useful to consider if the fish is capable of swimming through the mesh openings given the morphology of the fish and mesh, and the swimming and towing speed. He (1999) developed a model that predicts the minimum swimming speed required to successfully pass through a mesh (U_r) based on these parameters. This model takes the form;

$$U_r = U_t . K_x \left(\frac{M . E_{tt}}{L} - K_h \right)^{-1}$$

where

$$K_x = X_L . L^{-1}$$

$$K_h = H . L^{-1}$$

and incorporates tow speed (U_t), mesh size (M), hanging ratio in the fore-and-aft direction (E_{tt}), fish length (L), the ratio of maximum fish breadth to length (K_X), where X_h is the shoulder length, and the ratio of maximum fish depth to length (K_h), where H is the maximum body height. Results of this model, including morphometric relationships of yellowtail flounder taken from Cooper and Chapleau (1998), for the three twine tops tested in this study are shown in Figure 21. The maximum burst swimming speed derived by Kim and Wardle (1997) is also shown, and any swimming speed less than the burst speed for a given fish length indicates that escapement through the mesh is possible. The model predicts that only flounders less than 0.1 m (~4″) will be able to swim through a twine top mesh hung at 3:1 while at 2:1 flounders less than 0.16 m (~6″) will be able to escape. When the 3:1 turned twine top is used the maximum length of founders that can escape is increased to 0.3 m (~12″).

This model is useful because numerically it provides an estimate of the maximum length of flounders that can escape through the twine top for a given hanging ratio. It is based on the assumption that flounders are swimming in the towing direction before rising upwards and approach the mesh openings of the twine top. Given the narrow opening of the meshes at a hanging ratio of 3:1, only the smallest of flounders would be expected to escape unless they pivot their body 90 degrees around the vertical axis. The curve representing the 3:1 turned twine top is in fact indicative of the expected escape speed for flounders that approach a 3:1 twine top and have pivoted their bodies 90 degrees.

Implications for scallop management

A core objective of this project was to evaluate the effect of twine top hanging ratio and mesh geometry on bycatch, however, catch rates of key bycatch species were too low and

only fundamental analyses were possible. This hampered objective completion but it should not be viewed as a project failure; to the contrary, it suggests that the impact on the general category scallop dredge fishery on these bycatch species may be quite modest, as also concluded in Salerno et al. (2008), and perhaps contrary to general expectations.

Intuitively it might be expected that the 2:1 twine top would provide superior bycatch reduction performance compared to the 3:1 twine top. Fewer meshes hung to each scallop ring means that mesh opening is larger and more bycatch should escape. Observation of a 3:1 twine top indicates that the outer two meshes are relatively open and the middle mesh is almost closed. This study found that a 2:1 twine top substantially reduced the capture of flounder and other species in the dredge catch with little impact on the scallop catch. This result was statistically not significant, perhaps in part due to low catches of these species, but perhaps also because the difference in mesh openings between the two twine tops was too subtle to have an effect on bycatch reduction given the limited number of tows observed. Alternative hanging ratios such as 1:1 or 3:2, which would ensure wider mesh openings, may provide a better outcome. The comparative performance of the 3:1 turned twine top appears unequivocal; however, low catches of bycatch species prevent making a solid claim in all areas fished.

While the size of steel-mesh rings in the construction of a scallop dredge is prescribed in this fishery, it is interesting that aside from mesh size there are no further restrictions on the design, rigging, or size (area) of the twine top. The results of this study suggest there are substantial differences in the selectivity of commonly used twine tops in this fishery, and therefore the absence of a hanging ratio regulation does not fully optimize twine top performance or protect species such as yellowtail flounder. While some uncertainty exists vis-à-vis the results of this study, they suggest that the utility of a hanging ratio regulation requires further consideration by federal regulators.

CONCLUSIONS

The goal of this project was to determine if changes to twine top hanging ratio and mesh opening would affect the selectivity of scallop dredges used by general category vessels. This project concludes that the twine top hanging ratio does have an affect on size and species selectivity from that of the commonly used 3:1 hanging ratio. We observed variable differences in scallop catch between the 2:1 and 3:1 twine top and reduced rates in the 3:1 turned twine top. The 3:1 turned twine top had an increased escapement rate of bycatch through the twine top while there were little differences between the 2:1 and 3:1 twine tops. The 3:1 turned twine top is an interesting alternative that, although catching fewer scallops, also catches less non-target species. This twine top configuration should be investigated more thoroughly.

As a result of this project specific recommendations for LAGC vessels include:

- Conduct further work to evaluate twine top selectivity. While catches of bycatch by general category scallop vessels were low in this study, there is presumably considerable spatial and temporal variability in bycatch by vessels across the extent of the fishery. It would therefore be useful to i) determine if such variation existed (perhaps an evaluation of observer data and input from fishermen would be a useful starting point), and ii) determine the efficacy of twine tops commonly used by fishermen in areas where such variation exists
- Consideration of altering hanging ratio and/or increasing the minimum mesh size to increase mesh opening. As the 3:1 twine top hanging ratio may be preventing the escape of flounders, monkfish, and skates from the dredge such consideration is warranted. The escape speed models imply that these species should have little problem swimming upwards toward the meshes of the twine top, but that currently used hanging ratios may be impeding their escape. This is especially true for flounders that would be required to rotate 90° to maximize their escapement potential from a 3:1 twine top. A larger mesh size coupled with a wider mesh opening would also go a long way towards allowing a greater proportion of these species to escape (although care would be required not to weaken the dredge due to less material in twine top construction). An evaluation of the additional bottom time required to offset any scallop loss through this new twine top would also be required
- Continuing efforts to understand fish escape responses. The avoidance behavior of fish and other animals ahead of an approaching dredge is poorly understood, but could stimulate ideas for further modification to reduce bycatch. An interesting idea is situations where two dredges are towed simultaneously is that animals avoiding capture from one dredge may place themselves in the path of the second dredge. How this may affect bycatch rates is worthy of further investigation. Moreover, a better understanding of body orientation with respect to the twine top mesh openings would provide a better idea of the relationship between mesh opening and fish escape

- Commencing a dialogue regarding the future possible regulation of twine top hanging ratio, area, and location. The 2:1 hanging ratio appeared to outperform the 3:1 hanging ratio, particularly with respect to catches of flounder, and there seems little reason to continue to allow the uncontrolled use of twine tops in this fishery. The lack of twine top regulation is at odds with regulation of ring-mesh diameter.

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Tables

Table 1. Sea scallop dredge configurations and measurements by vessel.

	Vessel		
	Donna Jean II	Mary Ellen	The Jocka
Dredge frame height (in.)	13	13	13
Dredge frame width (in.)	95	95	118.5
Twine Top			
opening width (in.)	83	84	90
opening length (in.)	64	56	69
Twine top 1 (3:1 hanging ratio)			
number of meshes wide	60	72	60
number of meshes long	5.5	4.5	5.5
Twine top 2 (2:1 hanging ratio)			
number of meshes wide	40	48	40
number of meshes long	5.5	4.5	5.5
Twine top (3:1 turned hanging ratio)			
number of meshes wide	7	7	10
number of meshes long	30	30	36

Table 2. Number of dredge tows conducted by boat and twine top configuration in the ETAA. The number of hauls where the cover end was utilized is given within the parentheses.

	Donna Jean II Hauls	Mary Ellen Hauls	Total
Twine top 1	9 (4)	16 (6)	25 (10)
Twine top 2	6 (4)	11 (7)	17 (11)
Twine top 3	10 (5)	16 (7)	26 (12)
Total	25 (13)	43 (20)	68 (33)

Table 3. Number of dredge tows conducted by boat and twine top configuration in the GSC. The number of hauls where the cover end was utilized is given within the parentheses.

	Donna Jean II Hauls	Mary Ellen Hauls	The Jocka Hauls	Total
Twine top 1	27 (15)	54 (28)	22 (18)	103 (61)
Twine top 2	8 (8)	24 (24)	34 (18)	66 (50)
Twine top 3	14 (0)	28 (15)	8 (1)	50 (16)
Total	49 (23)	106 (67)	64 (37)	219 (127)

Table 4. ANOVA summary table of natural log transformed standardized scallop catch rates of all observed tows (including when cover net was absent) for a three-way model of management area, vessel, and gear configurations including interaction terms. Probability values significant at the 0.05 level are italicized.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Mgmt. Area	1	224.651	224.651	1409.655	*< 0.0001*
Vessel	2	85.551	42.776	268.411	*< 0.0001*
Gear	2	14.981	7.491	47.003	*< 0.0001*
Mgmt. Area X Vessel	1	3.324	3.324	20.857	*< 0.0001*
Mgmt. Area X Gear	2	1.609	0.805	5.049	*0.0071*
Vessel X Gear	4	5.055	1.264	7.930	*< 0.0001*
Mgmt. Area X Vessel X Gear	2	0.285	0.142	0.893	0.4108
Residuals	262	41.754	0.159		

Table 5. ANOVA summary table of natural log transformed standardized scallop catch of all observed tows (including when cover net was absent) for a two-way model of vessel and gear configurations including interaction. Results of the Elephant Trunk Area are given in (a) while the Great South Channel is given in (b). Probability values significant at the 0.05 level are italicized.

(a) Two-way ANOVA result table for the Elephant Trunk Area
Grand Mean = 806.47 (lbs_{AGC})

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Vessel	1	0.549	0.549	6.566	*0.0132*
Gear	2	1.730	0.865	10.349	*0.0002*
Interaction	2	1.068	0.534	6.388	*0.0032*
Residuals	55	4.597	0.084		

(b) Two-way ANOVA result table for the Great South Channel
Grand Mean = 91.79 (lbs_{AGC})

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Vessel	2	88.533	44.266	246.605	*< 0.0001*
Gear	2	14.654	7.327	40.819	*< 0.0001*
Interaction	4	4.272	1.068	5.950	*0.0001*
Residuals	207	37.157	0.180		

Table 6. One-way ANOVA results tables of natural log transformed dredge catch rate of all observed tows (including when cover net was absent) for scallops fishing within the Elephant Trunk Area. Vessel effects are shown in (a) while twine top effects by vessel are shown in (b) and (c). The matrix below presents mean response values on the diagonal (in bold) which have been re-transformed to base catch rates. Two tailed p-values from pairwise multiple comparisons procedure are shown below the diagonal (not bold). Twine top efficiency (%) is shown above the diagonal and is based on untransformed catches relative to the 3:1 twine top.

(a) Vessel effects in the Elephant Trunk Area

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Vessel	1	0.5488	0.5488	4.379	*0.0407*
Residuals	59	7.3943	0.12533		

	DJ	ME
DJ	**911.04**	
ME	0.0407	**749.10**

(b) Twine top effects of the FV Donna Jean fishing within the Elephant Trunk Area.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Gear	2	1.9158	0.95792	8.694	0.0009
Residuals	35	3.8565	0.11018		

	3:1	2:1	3:1 T
3:1	**1057.76**	65.5%	58.9%
2:1	0.0138	**692.91**	-
3:1 T	0.0007	0.6979	**623.45**

(c) Twine top effects of the FV Mary Ellen fishing within the Elephant Trunk Area.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Gear	2	0.88172	0.44086	11.911	0.0004
Residuals	20	0.74028	0.03701		

	3:1	2:1	3:1 T
3:1	**912.16**	135.2%	83.2%
2:1	0.0276	**1232.87**	-
3:1 T	0.1545	0.0003	**759.16**

Table 7. One-way ANOVA results tables of natural log transformed dredge catch rate of all observed tows (including when cover net was absent) for scallops fishing within the Great South Channel. Vessel effects are shown in (a) while twine top effects by vessel are shown in (b), (c), and (d). The matrix below presents mean response values on the diagonal (in bold) which have been re-transformed to base catch rates. Two tailed p-values from pairwise multiple comparisons procedure are shown below the diagonal (not bold). Twine top efficiency (%) is shown above the diagonal and is based on untransformed catches relative to the 3:1 twine top.

(a) Vessel effects in the Great South Channel

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Vessel	2	88.533	44.266	168.120	*< 0.0001*
Residuals	213	56.083	0.263		

	DJ	ME	JK
DJ	**104.85**		
ME	< 0.0001	**156.13**	
JK	< 0.0001	< 0.0001	**35.25**

(b) Twine top effects of the FV Donna Jean fishing within the Great South Channel

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Gear	2	3.6919	1.84596	6.208	0.0041
Residuals	46	13.6782	0.29735		

	3:1	2:1	3:1 T
3:1	**102.41**	180.7%	77.4%
2:1	0.0259	**185.09**	**-**
3:1 T	0.3369	0.0029	**79.29**

(c) Twine top effects of the FV Mary Ellen fishing within the Great South Channel

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Gear	2	10.707	5.3532	37.399	< 0.0001
Residuals	100	14.314	0.1431		

	3:1	2:1	3:1 T
3:1	**172.17**	128.0%	52.7%
2:1	0.0246	**220.34**	**-**
3:1 T	< 0.0001	< 0.0001	**90.81**

(d) Twine top effects of the FV The Jocka fishing within the Great South Channel

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Gear	2	4.5277	2.26384	15.067	< 0.0001
Residuals	61	9.1651	0.15025		

	3:1	2:1	3:1 T
3:1	**45.22**	76.9%	41.6%
2:1	0.0424	**34.79**	**-**
3:1 T	< 0.0001	0.0004	**18.81**

Table 8. Species group specific one-way Kruskal-Wallis results tables of catch rates of all observed tows (including when cover net was absent) in the Dredge (left column) and Cover Net (right column) including fishing within the Great South Channel. All vessels have been grouped by twine top due to low within vessel catch. Each sub-table includes the Kruskal-Wallis result and a lower matrix presenting median response values on the diagonal (in bold). Two tailed permutation based p-values from pairwise multiple comparisons procedure are shown below the diagonal (not bold). Twine top efficiency (%) is shown above the diagonal and is based on untransformed catches relative to the 3:1 twine top.

(a) Flounder species Dredge catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	0.807	0.6681

	3:1	2:1	3:1 T
3:1	**0.34**		
2:1	0.6557	**0.23**	
3:1 T	0.8218	0.9109	**0.30**

(b) Flounder species Cover net catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	13.340	0.0013

	3:1	2:1	3:1 T
3:1	**0.00**		
2:1	0.9846	**0.00**	
3:1 T	0.0022	0.0152	**1.54**

(c) Skate species Dredge catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	6.189	0.0453

	3:1	2:1	3:1 T
3:1	**5.78**		
2:1	0.8643	**6.30**	
3:1 T	0.3099	0.0777	**13.28**

(d) Skate species Cover net catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	60.319	< 0.0001

	3:1	2:1	3:1 T
3:1	**0.00**		
2:1	0.5939	**0.00**	
3:1 T	< 0.0001	< 0.0001	**4.98**

(e) Monkfish Dredge catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	0.332	0.8470

	3:1	2:1	3:1 T
3:1	**2.56**		
2:1	0.8889	**2.80**	
3:1 T	0.9903	0.8182	**3.23**

(f) Monkfish Cover net catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	44.347	< 0.0001

	3:1	2:1	3:1 T
3:1	**0.00**		
2:1	1.0000	**0.00**	
3:1 T	0.0001	< 0.0001	**0.76**

(g) Other species Dredge catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	21.915	< 0.0001

	3:1	2:1	3:1 T
3:1	**0.96**		
2:1	0.1196	**0.42**	
3:1 T	< 0.0001	0.1024	**0.00**

(h) Other species Cover net catch rates

	Df	$\chi 2$ value	Pr(>χ^2)
Gear	2	27.102	< 0.0001

	3:1	2:1	3:1 T
3:1	**0.00**		
2:1	0.0020	**0.37**	**-**
3:1 T	< 0.0001	0.6145	**0.97**

Table 9. Escapement calculated as a proportion by weight of standardized catch per tow for each area fished and twine top used. Data based only on tows where the twine top cover net was present. Total weight (unstandardized) observed within the cover net is also presented.

Area	Gear	Species Category	Cover Net Weight (lbs)	Mean	Median	Std. Dev	Num. Tows Present
Elephant Trunk	3:1	SCALLOP	204.0	2.5%	1.6%	0.03	10
		SCALLOP DISCARD	48.0	11.4%	9.4%	0.09	10
		FLOUNDERS	4.4	50.0%	50.0%	0.55	6
		SKATES	1.2	31.5%	1.6%	0.45	10
		MONKS	0.2	50.0%	50.0%	0.71	2
		OTHER SPECIES	0.2	25.0%	0.0%	0.50	4
	2:1	SCALLOP	38.7	0.5%	0.3%	0.00	11
		SCALLOP DISCARD	2.7	6.6%	6.4%	0.08	4
		FLOUNDERS	0.0	0.0%	0.0%	0.00	7
		SKATES	0.1	1.2%	0.0%	0.02	3
		MONKS	0.0	0.0%	0.0%		1
		OTHER SPECIES	0.0	0.0%	0.0%	0.00	3
	3:1 Turned	SCALLOP	977.5	11.2%	8.7%	0.09	12
		SCALLOP DISCARD	12.2	49.3%	48.1%	0.11	5
		FLOUNDERS	5.7	65.1%	85.3%	0.44	8
		SKATES	1.4	50.0%	50.0%	0.55	6
		MONKS	0.0	0.0%	0.0%		1
		OTHER SPECIES	5.1	66.1%	100.0%	0.48	8
Great South Channel	3:1	SCALLOP	35.7	0.3%	0.1%	0.01	59
		SCALLOP DISCARD	71.9	16.7%	1.1%	0.30	33
		FLOUNDERS	3.2	18.1%	0.0%	0.35	9
		SKATES	3.2	0.4%	0.0%	0.02	48
		MONKS	0.0	0.0%	0.0%	0.00	33
		OTHER SPECIES	52.8	27.5%	0.0%	0.40	36
	2:1	SCALLOP	62.2	0.3%	0.0%	0.00	50
		SCALLOP DISCARD	43.3	43.9%	30.2%	0.46	37
		FLOUNDERS	5.7	26.9%	0.0%	0.41	15
		SKATES	15.6	1.8%	0.0%	0.08	46
		MONKS	0.0	0.0%	0.0%	0.00	32
		OTHER SPECIES	112.3	47.1%	36.0%	0.42	34
	3:1 Turned	SCALLOP	504.9	28.0%	24.0%	0.19	12
		SCALLOP DISCARD	839.7	74.6%	86.0%	0.28	12
		FLOUNDERS	22.1	61.8%	67.9%	0.42	5
		SKATES	138.2	11.9%	10.3%	0.10	12
		MONKS	12.0	35.1%	25.5%	0.42	5
		OTHER SPECIES	30.9	95.5%	100.0%	0.15	11

Table 10. Logistic regression results (top) of escapement rates (% of total catch) through the twine top for the three twine top configurations fished in the Great South Channel area. The lower matrix shows the fitted estimate for escapement on the diagonal (bold) and probability value following TukeyHSD pairwise comparison below the diagonal (not bold).

(a) Kept Scallops

	Df	Residual Deviance	Pr(>|χ^2|)
Gear	124	285.12	<0.0001
Residuals	126	2038.54	

	3:1	2:1	3:1 Turned
3:1	**0.27%**		
2:1	0.120	**0.45%**	
3:1 Turned	<0.0001	<0.0001	**24.75%**

(b) Discarded Scallops

	Df	Residual Deviance	Pr(>|χ^2|)
Gear	84	423.75	<0.0001
Residuals	86	1292.11	

	3:1	2:1	3:1 Turned
3:1	**10.45%**		
2:1	0.925	**11.50%**	
3:1 Turned	<0.0001	<0.0001	**92.09%**

(c) Flounder Species

	Df	Residual Deviance	Pr(>|χ^2|)
Gear	32	17.47	<0.0001
Residuals	34	40.79	

	3:1	2:1	3:1 Turned
3:1	**10.90%**		
2:1	0.430	**34.53%**	
3:1 Turned	<0.0001	<0.0001	**85.06%**

(d) Skate Species

	Df	Residual Deviance	Pr(>|χ^2|)
Gear	109	120.83	<0.0001
Residuals	111	291.66	

	3:1	2:1	3:1 Turned
3:1	**0.54%**		
2:1	0.522	**1.29%**	
3:1 Turned	<0.0001	<0.0001	**21.21%**

(e) Other Fish Species

	Df	Residual Deviance	Pr(>|χ^2|)
Gear	84	103.58	<0.0001
Residuals	86	209.96	

	3:1	2:1	3:1 Turned
3:1	**8.30%**		
2:1	<0.0001	**35.69%**	
3:1 Turned	<0.0001	0.0005	**96.94%**

Table 11. Parameter estimates of logistic selectivity curves fit to the covered twine top shell height- and length-frequency distributions. Selectivity parameters reported in mm. Delta AIC values compare the fitted model to a null model and the significance of the fitted model is provided by a χ^2 probablity. Kolomogorov-Smirnoff (KS) test compare the dredge and twine top shell height- and length-frequency distributions results provided in the last two columns.

Species	Area	Gear	l_{50} (s.e.)	*SR* (s.e.)	**Δ|AIC|**	Pr(χ^2)	KS-D	KS-Pr(χ^2)
Scallop	Elephant Trunk	3:1	80.49 (1.56)	18.1 (1.03)	315.8	<0.0001	0.60	0.009
Scallop	Elephant Trunk	2:1	49.34 (9.28)	22.0 (3.68)	34.9	<0.0001	0.79	<0.0001
Scallop	Elephant Trunk	3:1 Turned	38.78 (5.87)	55.4 (4.58)	142.5	<0.0001	0.56	0.013
Scallop	Great South Channel	3:1	17.50 (7.13)	35.9 (3.69)	86.3	<0.0001	0.83	<0.0001
Scallop	Great South Channel	2:1	27.03 (5.64)	31.8 (3.19)	104.5	<0.0001	0.87	<0.0001
Scallop	Great South Channel	3:1 Turned	92.24 (1.47)	48.5 (2.96)	345.9	<0.0001	0.17	0.893
Flounder Species	Great South Channel	3:1 Turned	280.38 (9.56)	83.4 (20.90)	20.7	0.001	0.33	0.270
Skate Species	Great South Channel	3:1 Turned	365.35 (21.83)	142.8 (23.19)	56.7	<0.0001	0.64	<0.0001

Figures

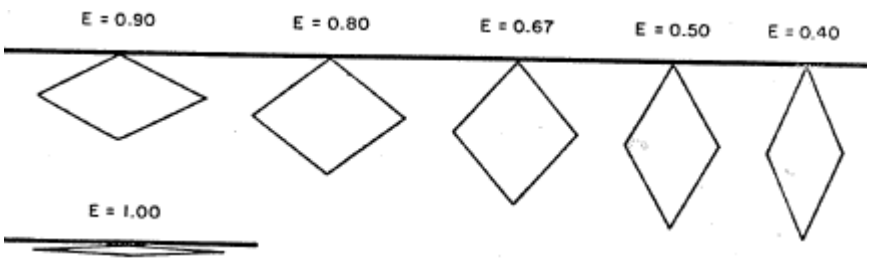


Figure 1. Various hanging ratios and the associated mesh shape for the same mesh size. Source: FAO 1978.

Figure 2. A scallop dredge twine top hung at E_{tt} = 3:1. Note the meshes are elongated in the fore/aft direction.

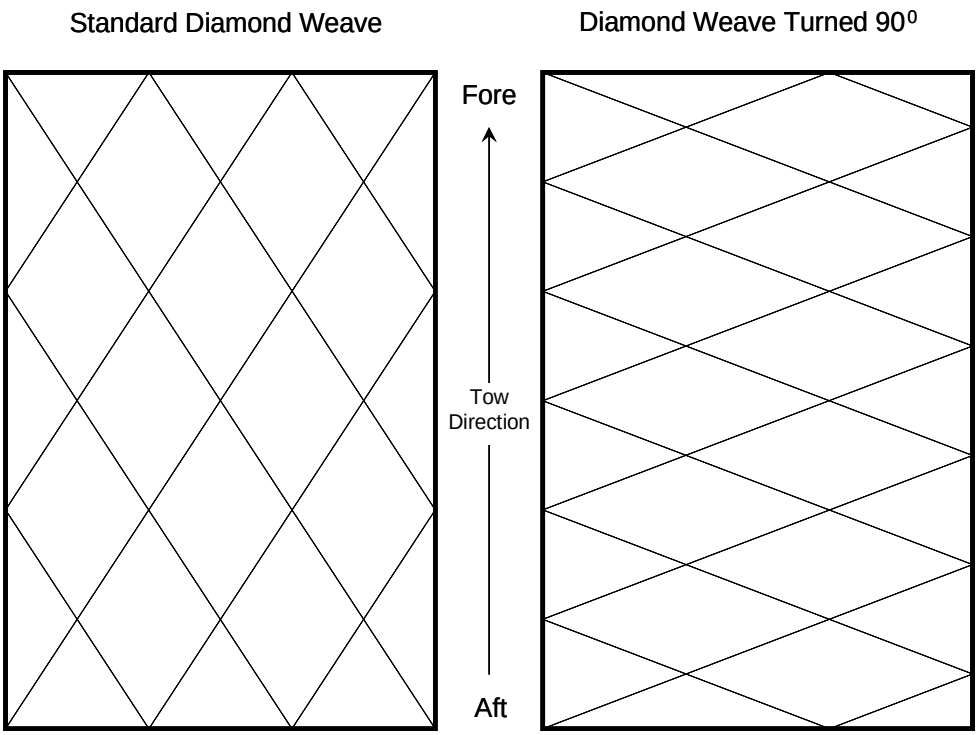


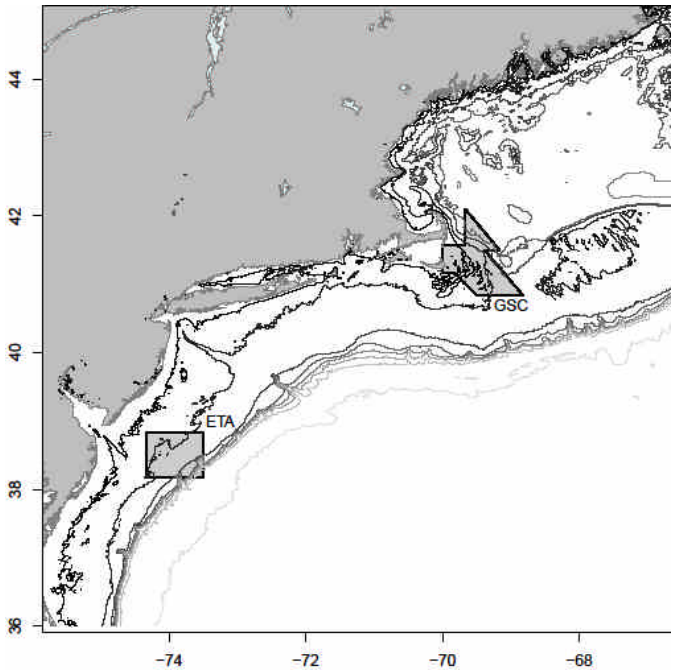
Figure 3. A comparison of a diamond knotted twine hung normal (left) and at a 90^0 angle (right). Both meshes are drawn as if they are under load.

(a) F/V Donna Jean II (USCG Doc. # 656499)

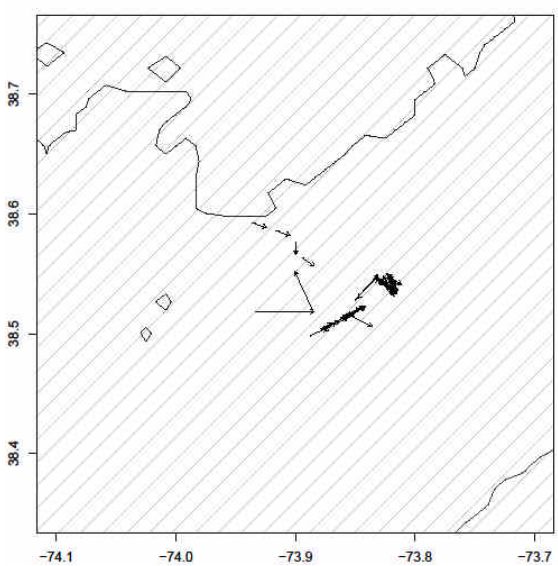
(b) F/V Mary Ellen (State Reg. # ME10XMP)

(c) FV The Jocka (USCG Doc. # 939745)

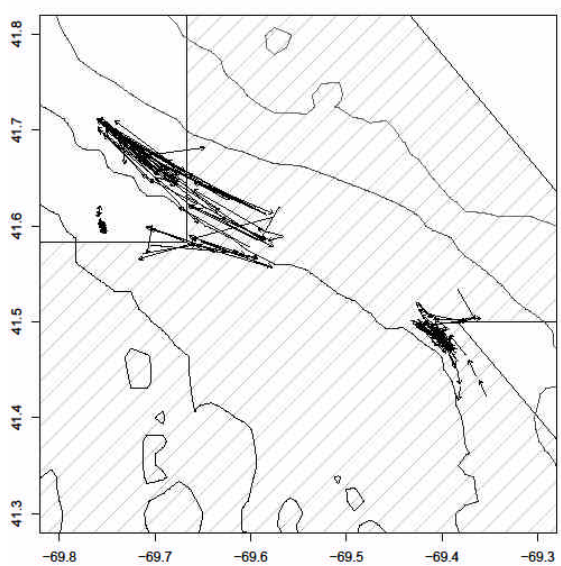
Figure 4. Commercial fishing vessels utilized in this study.



(a) Area of Study

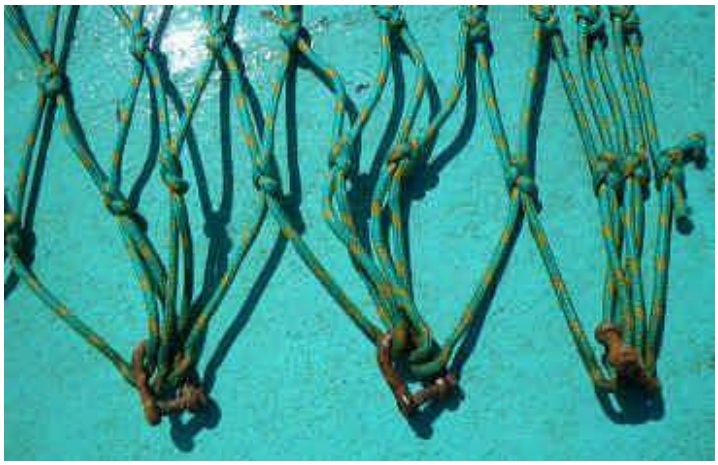


(b) Tow locations in the Elephant Trunk Access Area (ETAA)



(c) Tow locations in the Great South Channel Scallop Dredge Exemption Area (GSC)

Figure 5. Map plotting the relative position if the Elephant Trunk Access Area (ETAA) off Cape May, New Jersey and in the Great South Channel Scallop Dredge Exemption Area (GSC) off Chatham, Massachusetts. Chart of all tow locations utilized in this investigation. Bathymetric contours plotted at 25, 50, 75, 125, 150, 250, and 500 meters.



(a) Twine top 1: 3:1 normal hanging ratio (control net)

(b) Twine top 2: 2:1 hanging ratio

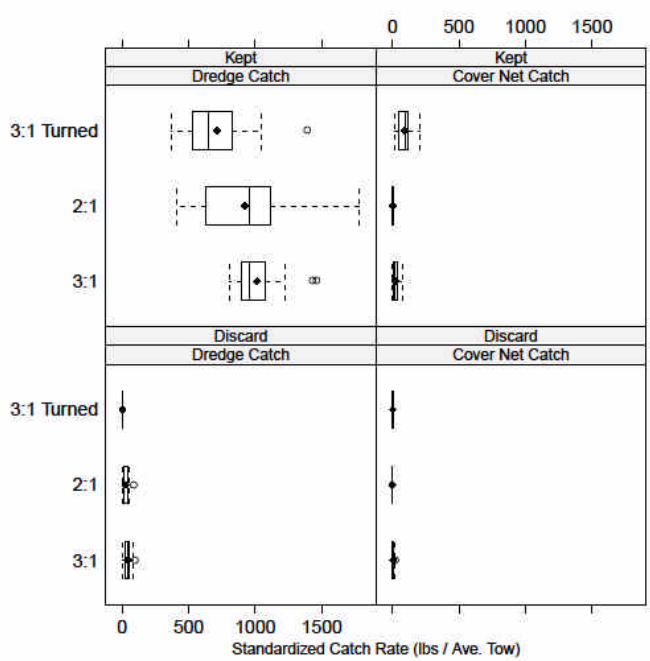
(c) Twine top 3: 3:1 hanging ratio turned 90^0

Figure 6. Twine top modifications utilized in this study

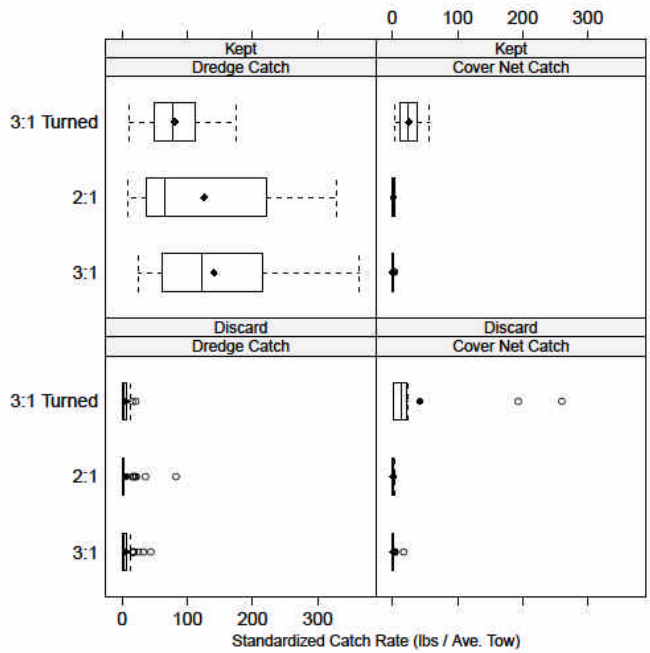
(a) Dredge with small mesh cover net being deployed off the starboard rail

(b) Small mesh cover net position over dredge twine-top

Figure 7. The small mesh (4 in, 101.6mm) cover net is positioned over the top of the twine top opening.



(a) Scallop catch rates in the Elephant Trunk Access Area



(b) Scallop catch rates in the Great South Channel

Figure 8. Standardized (untransformed) scallop catch rates (lbs / Ave Tow) for three twine top configurations in two management areas. Individual panels identify scallops retained in the dredge or in the cover net for all observed tows (including when cover net was absent). Scallops that were undersized are noted as 'Discard'. Note that the mean is plotted as a diamond and the abscissa scale changes between panels.

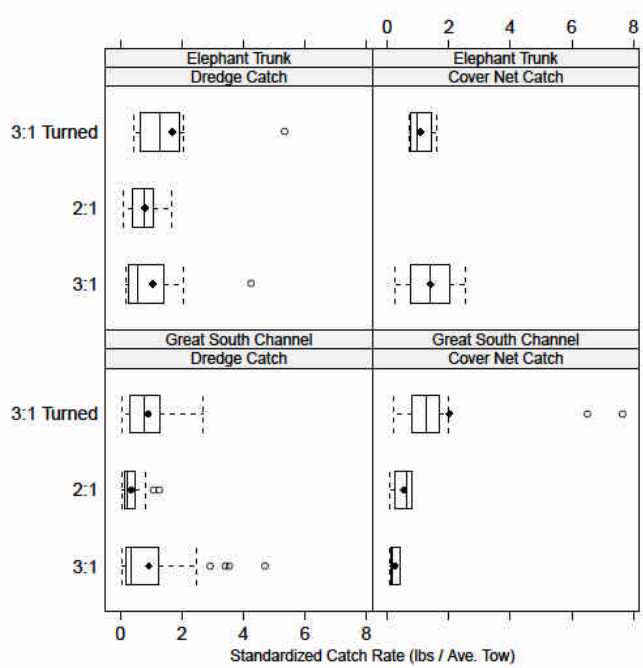


Figure 9. Standardized (untransformed) flounder species catch rates (lbs / Ave Tow) for three twine top configurations in two management areas. Individual panels identify flounders retained in the dredge or in the cover net for all observed tows (including when cover net was absent). Note that the mean is plotted as a diamond and the abscissa scale changes between panels.

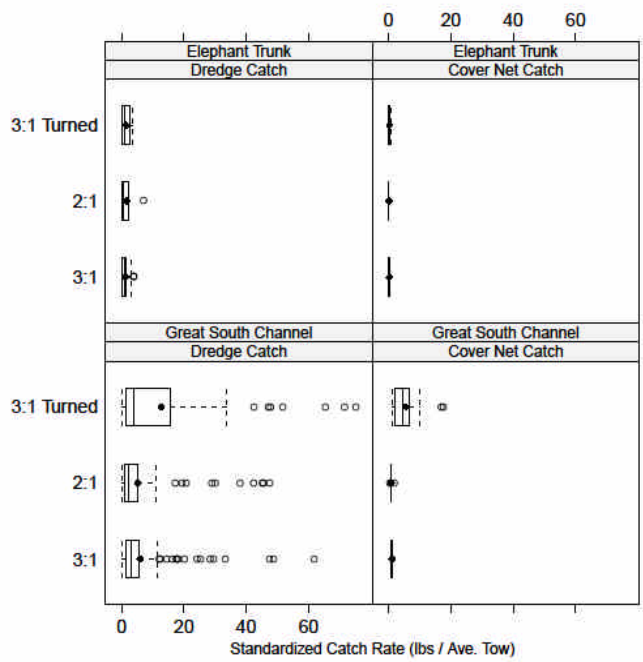


Figure 10. Standardized (untransformed) skate species catch rates (lbs / Ave Tow) for three twine top configurations in two management areas. Individual panels identify skates retained in the dredge or in the cover net for all observed tows (including when cover net was absent). Note that the mean is plotted as a diamond and the abscissa scale changes between panels.

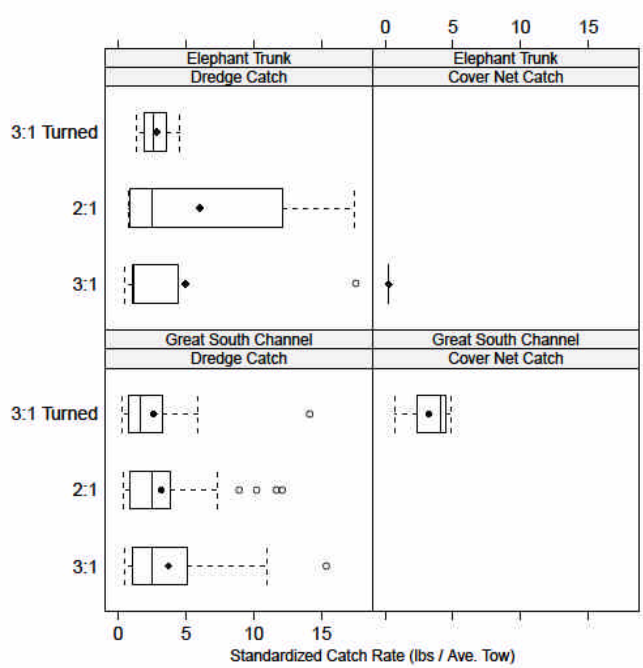


Figure 11. Standardized (untransformed) monkfish catch rates (lbs / Ave Tow) for three twine top configurations in two management areas. Individual panels identify monkfish retained in the dredge or in the cover net for all observed tows (including when cover net was absent). Note that the mean is plotted as a diamond and the abscissa scale changes between panels.

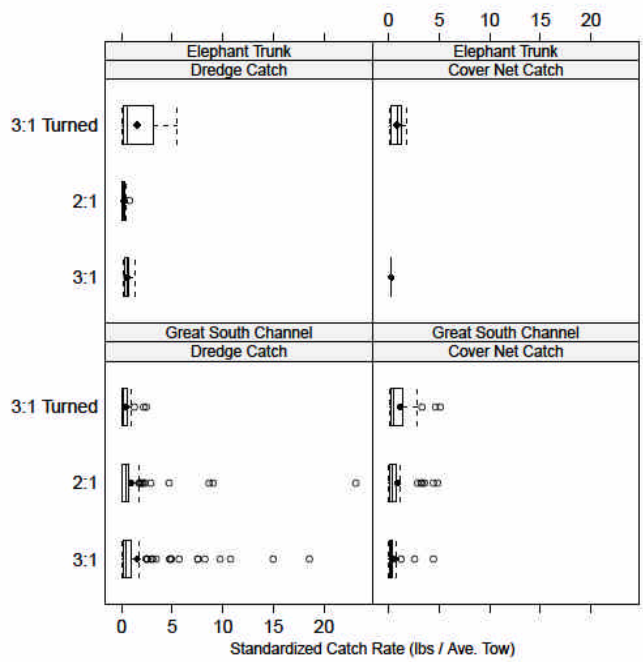


Figure 12. Standardized (untransformed) catch rates (lbs / Ave Tow) of other species for three twine top configurations in two management areas. Individual panels identify other species retained in the dredge or in the cover net for all observed tows (including when cover net was absent). Note that the mean is plotted as a diamond and the abscissa scale changes between panels.

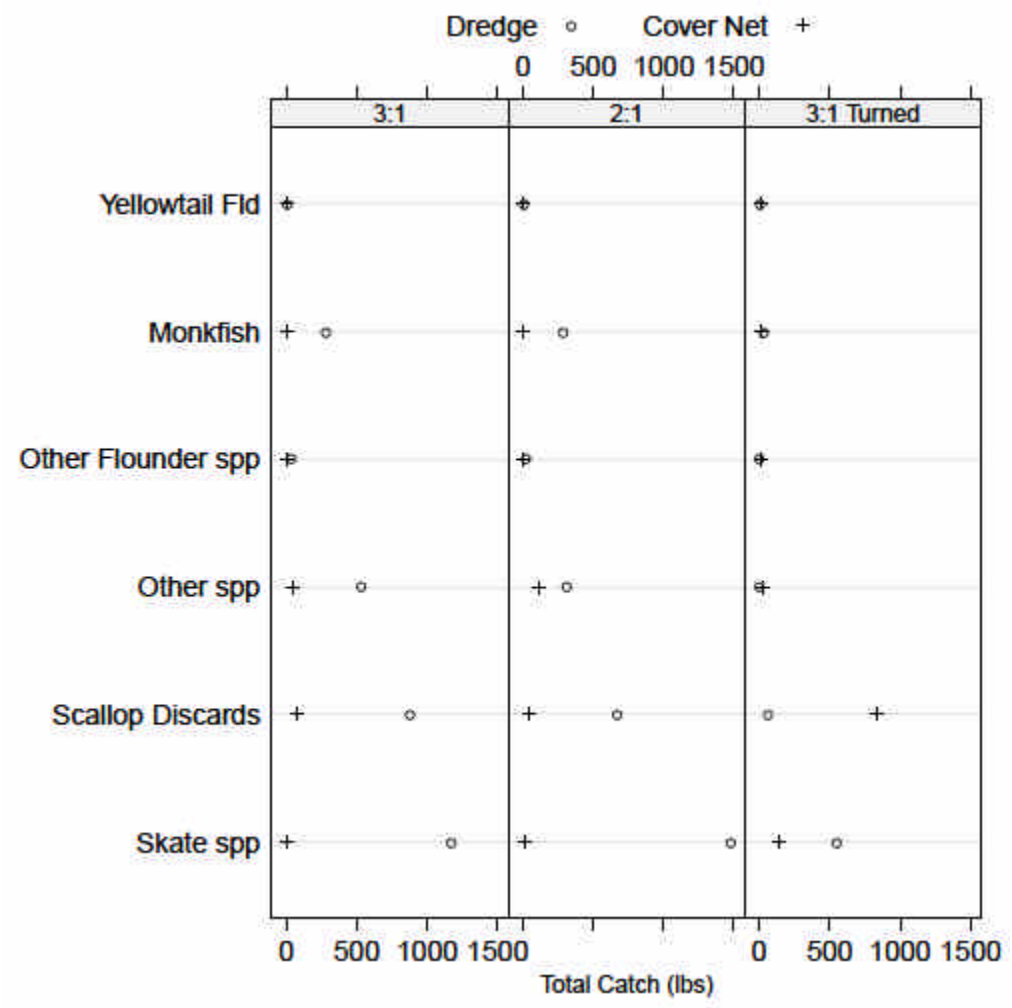


Figure 13. Total catch retained in the dredge and cover net by twine top fished within the Great South Channel. Catch has been summed across vessels. Comparison of catch by twine tops is done by looking across species categories. The closer the cover net catch is to the dredge catch the higher the escapement rate. Cover net catch values in excess of the dredge catch have escapement higher than 50%.

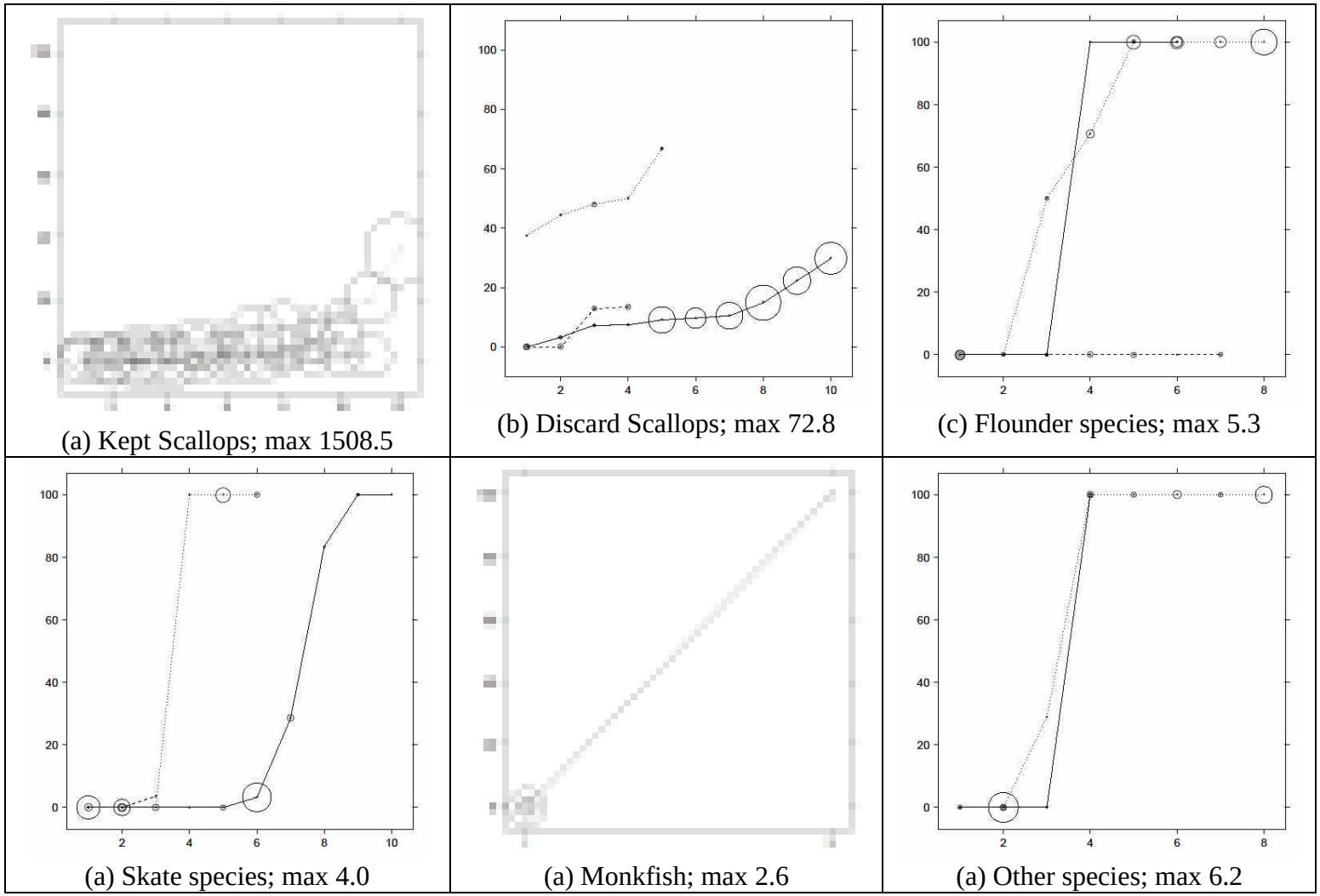


Figure 14. Escapement rates (vertical axis) plotted by twine top for catches from individual tows in the Elephant Trunk. The dependent axis is the number of tows the catch was present. Circles are drawn to represent relative total catch rate (dredge and cover net) observed during the tow, scaled independently for each plot, with the maximum catch rate (lbs/tow) provided below the plot. Twine tops are 3:1 (solid), 2:1 (dashed), 3:1 Turned (dotted).

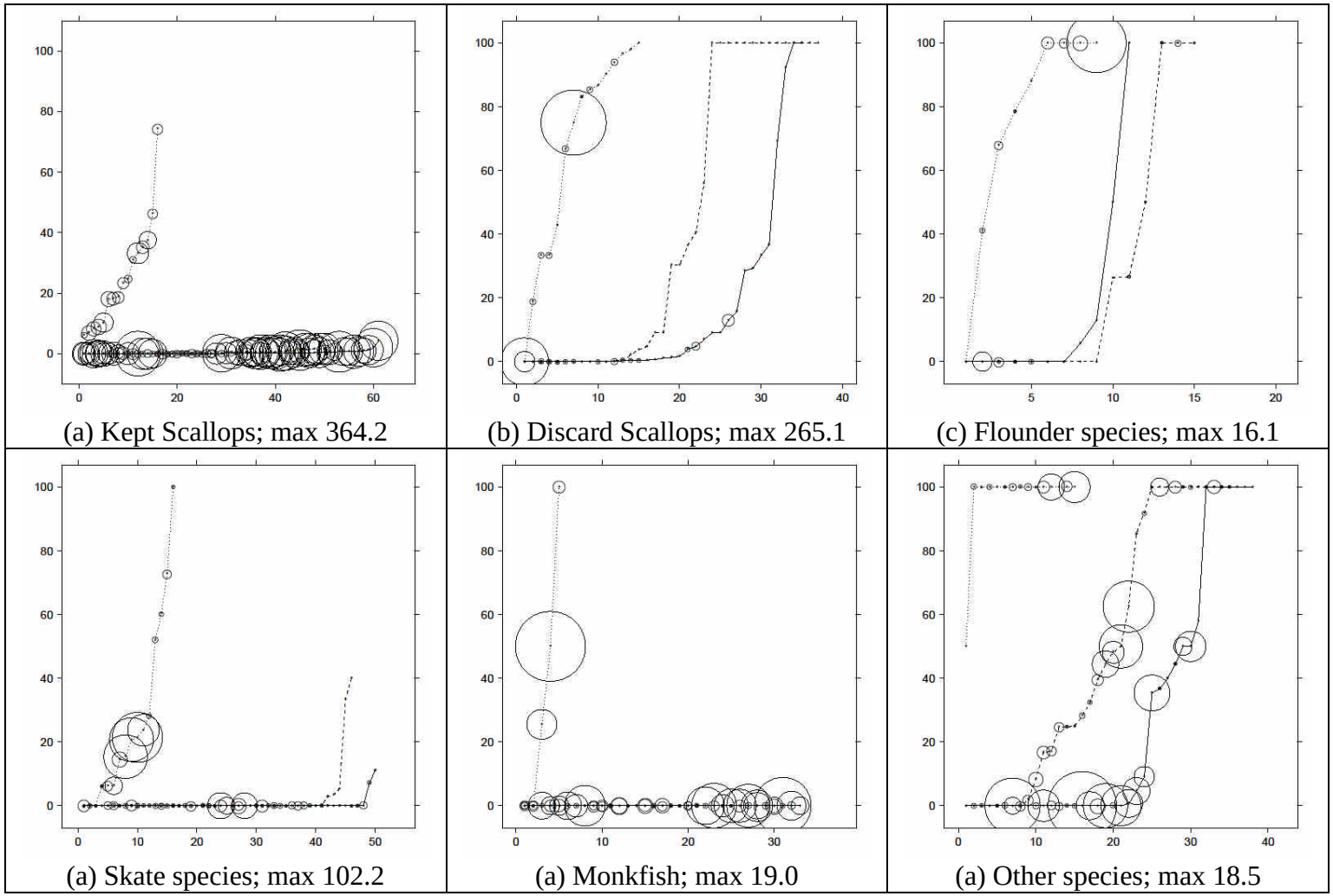


Figure 15. Escapement rates (vertical axis) plotted by twine top for catch from individual tows in the Great South Channel. The dependent axis is the number of tows the catch was present. Circles are drawn to represent relative total catch rate (dredge and cover net) observed during the tow, scaled independently for each plot, with the maximum catch rate (lbs/tow) provided below the plot. Twine tops are 3:1 (solid), 2:1 (dashed), 3:1 Turned (dotted).

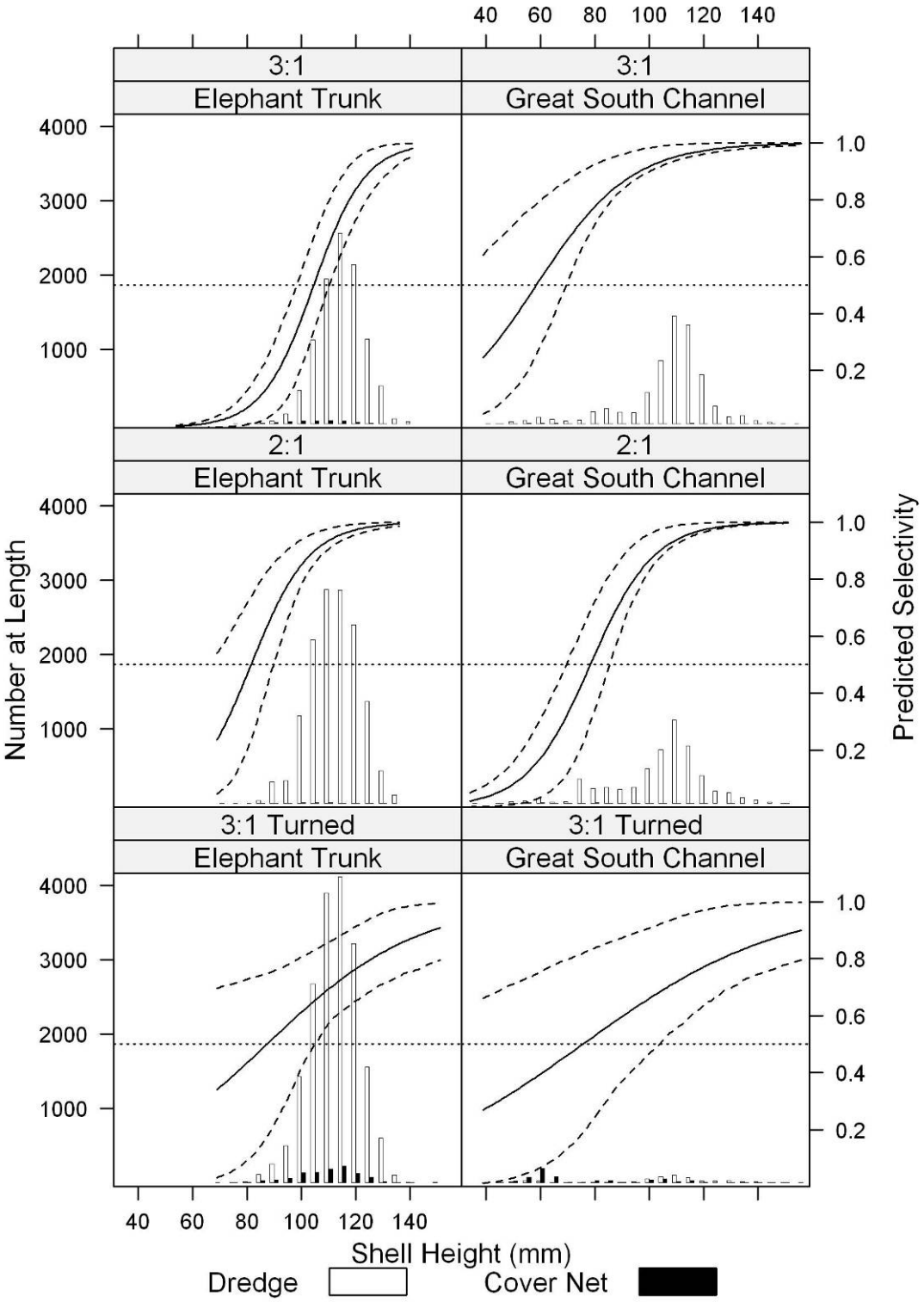


Figure 16. Shell height-frequency histograms and selectivity curves of scallop catch in dredge and cover net for the three twine tops in the Elephant Trunk and Great South Channel. Estimated logistic selectivity curves have been plotted and include 95% bootstrap intervals. Horizontal dashed line drawn at 50% selectivity. Generally less than 70 mm shell height scallops were discarded.

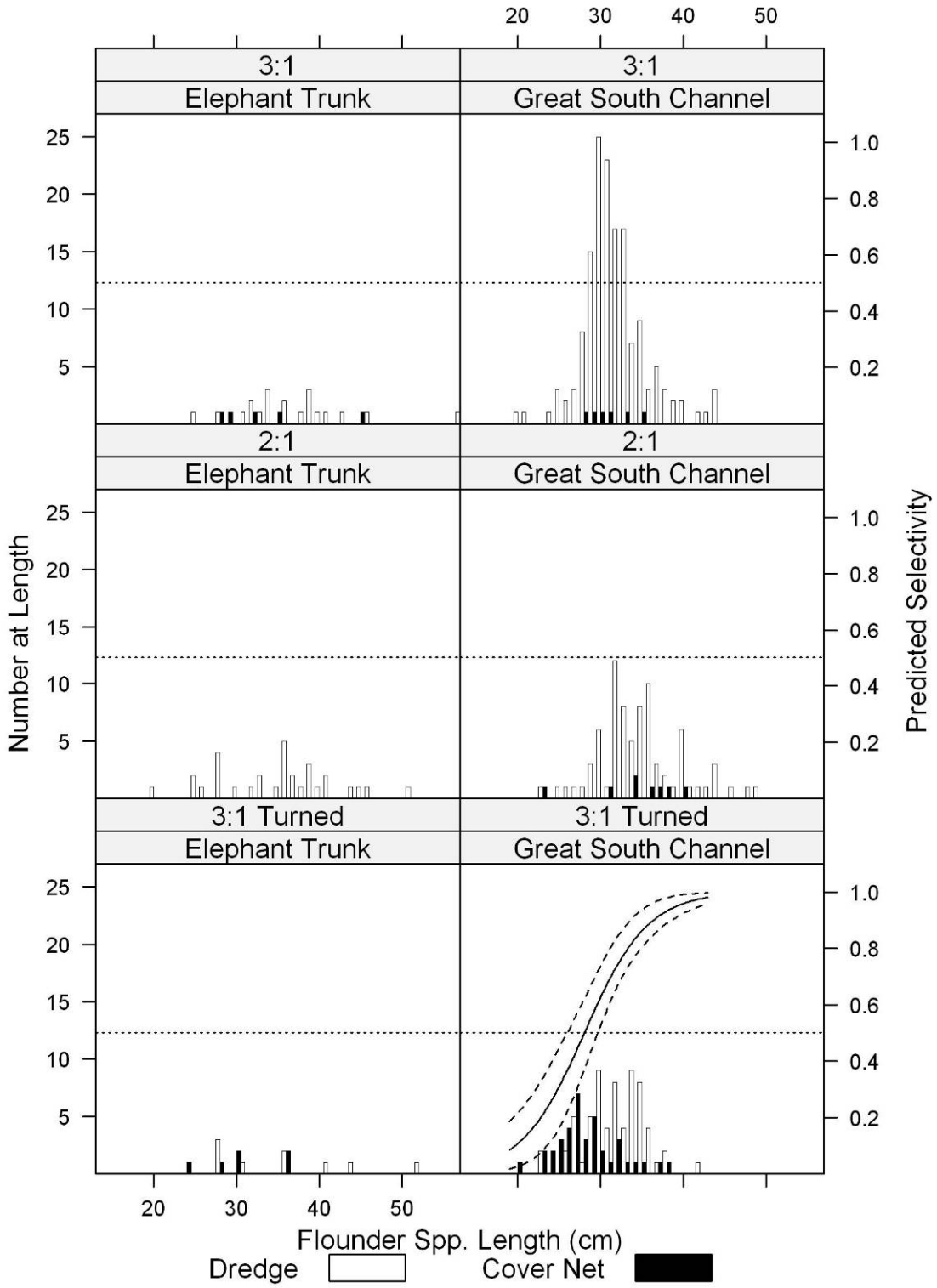


Figure 17. Length-frequency histograms and selectivity curves of Flounder spp. catch at length (cm) for dredge and cover net tows for three twine tops in the Elephant Trunk and Great South Channel. When possible, estimated logistic selectivity curves have been plotted and include 95% bootstrap intervals. Horizontal dashed line drawn at 50% selectivity.

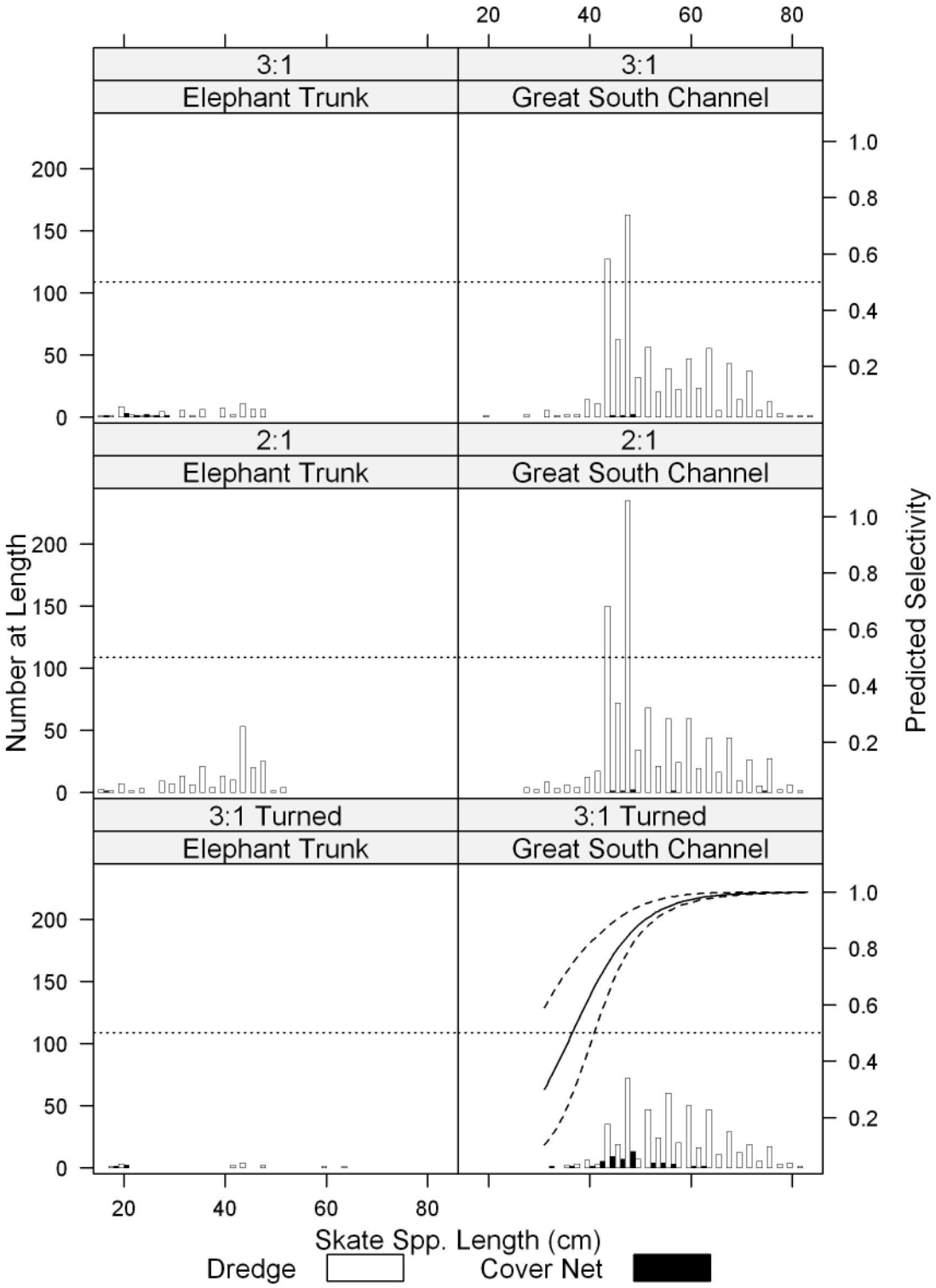


Figure 18. Length-frequency histograms and selectivity curves of Skate spp. catch at length (cm) for dredge and cover net tows for three twine tops in the Elephant Trunk and Great South Channel. When possible, estimated logistic selectivity curves have been plotted and include 95% bootstrap intervals. Horizontal dashed line drawn at 50% selectivity.

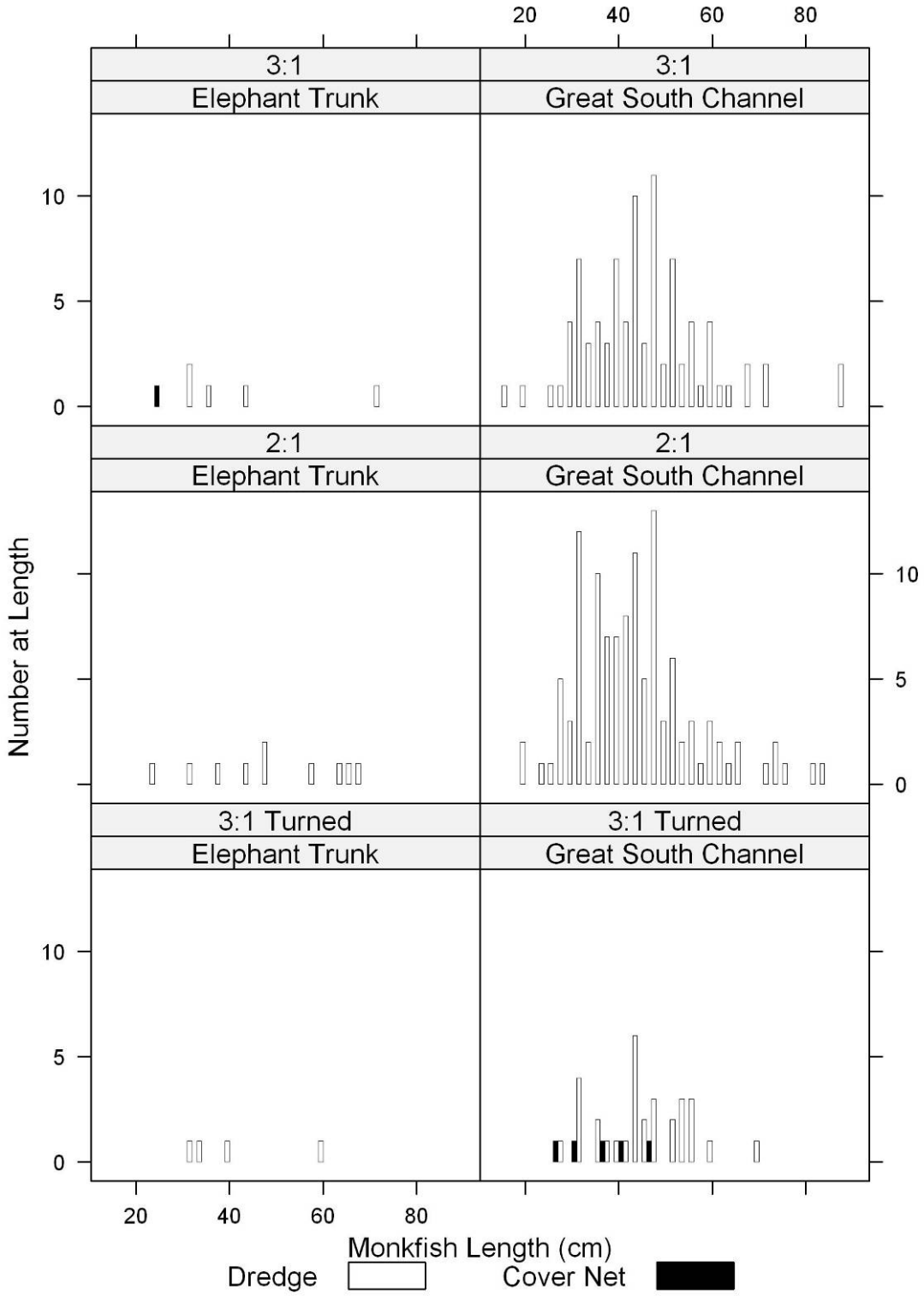


Figure 19. Length-frequency histograms of Monkfish catch at length (cm) for dredge and cover net tows for three twine tops in the Elephant Trunk and Great South Channel.

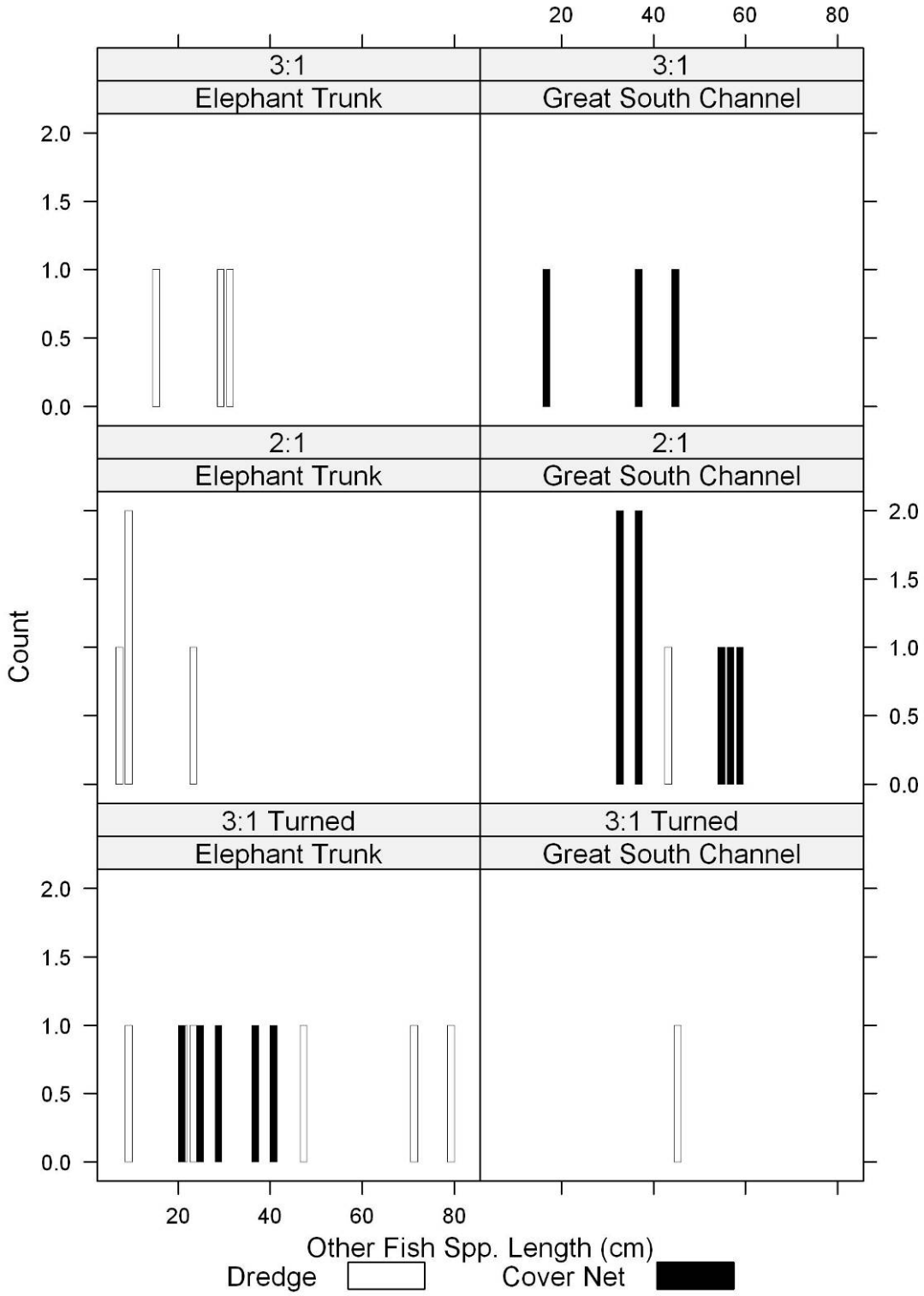
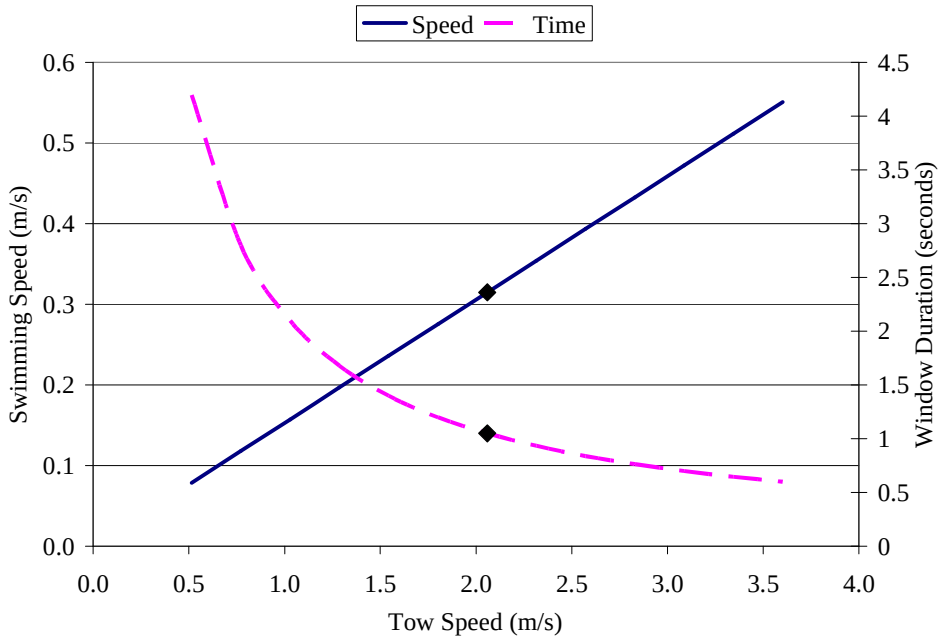
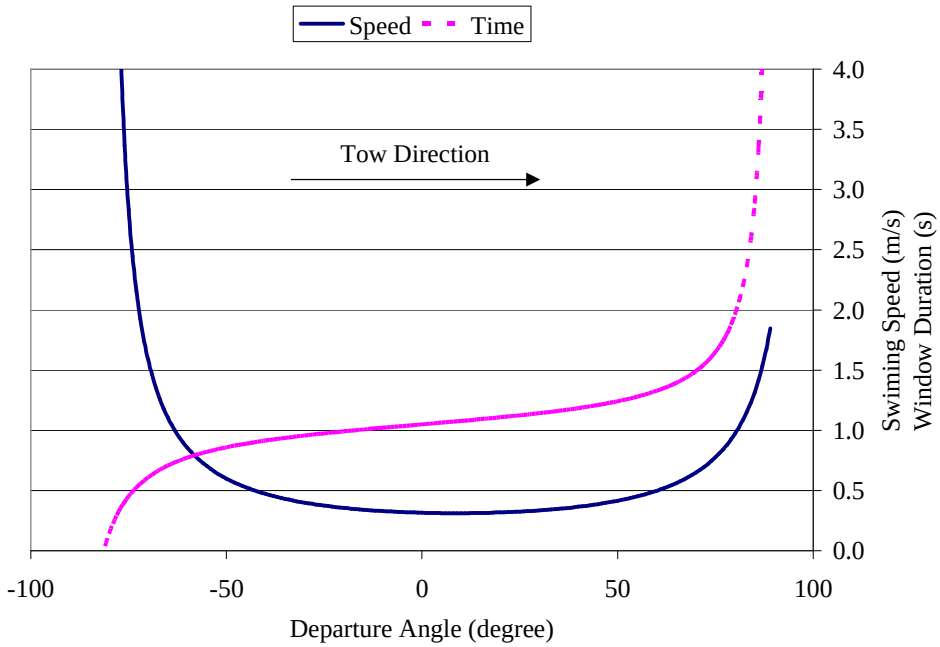


Figure 20. Length-frequency histograms of Other Species catch at length (cm) for dredge and cover net tows for three twine tops in the Elephant Trunk and Great South Channel.



(a) Parameterized with 33 cm (13 inch) dredge height and 2.2m (85 inch) opening



(b) Parameterized with a tow speed of 2.058 m/s (4.0 knots) and a twine top mesh size of 25.4 cm (10 inch)

Figure 21. Dredge escapement model evaluating minimum travel time and instantaneous speed required to successfully escape a moving scallop dredge. Travel times and speed required to move the vertical distance of the dredge given a range of tow speeds shown in (a). Travel times and speed required given a range of departure angles shown in (b). The fish was assumed on the bottom and stationary when the dredge passed overhead.

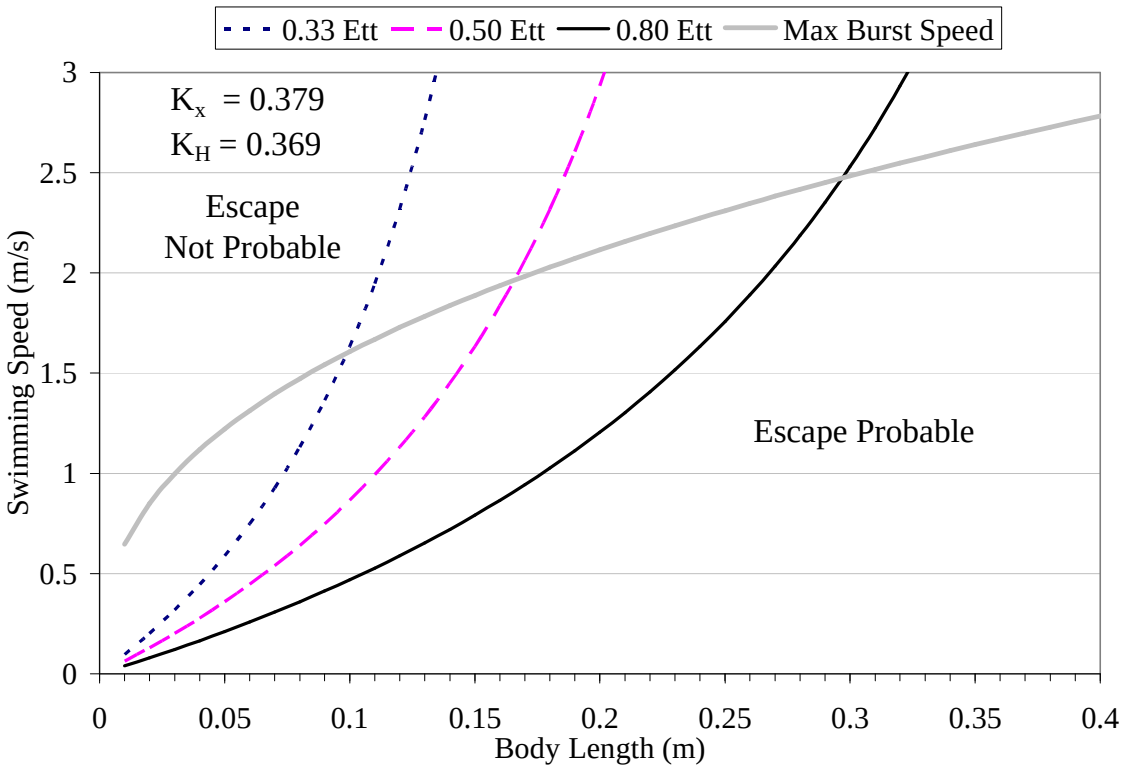


Figure 22. Graphical results of He's (1999) model of escapement through the twine top given three hanging ratios (E_{tt}), 3:1 (0.33), 2:1 (0.5), and 3:1 Turned (0.8). The model was parameterized with a towing speed of 2.1 m/s (4.0 knots) and a twine top mesh opening of 25.4 cm (10 inch). Maximum burst speed based on Kim and Wardle, 1997.

Appendix 1. Information on tows conducted during this investigation.

Area	Vessel	Twine Top	Dredge Width (m)	Cover Net Used	Date	Time	Tow Speed (knots)	Tow duration (min)	Longitude	Latitude	Depth (fm)	Wire out (fm)
ETAA	DJ	3:1	2.413	No	3/4/2009	9:08	4.2	34	-73.909	38.519	29	120
ETAA	DJ	3:1	2.413	No	3/4/2009	9:56	4.2	43	-73.893	38.535	29	120
ETAA	DJ	3:1	2.413	No	3/4/2009	11:14	4	21	-73.841	38.537	31	120
ETAA	DJ	3:1	2.413	No	3/5/2009	18:00	4.2	20	-73.840	38.539	31	120
ETAA	DJ	3:1	2.413	No	3/5/2009	18:25	4.5	20	-73.840	38.539	30	120
ETAA	DJ	2:1	2.413	No	3/14/2009	12:00	4.1	8	-73.824	38.540	31	110
ETAA	DJ	2:1	2.413	No	3/14/2009	12:16	4.1	10	-73.821	38.541	31	110
ETAA	DJ	2:1	2.413	Yes	3/15/2009	11:45	4.1	10	-73.821	38.538	31	110
ETAA	DJ	2:1	2.413	Yes	3/15/2009	12:16	4.1	14	-73.825	38.542	31	110
ETAA	DJ	2:1	2.413	Yes	3/18/2009	11:42	3.8	16	-73.823	38.539	31	120
ETAA	DJ	2:1	2.413	Yes	3/18/2009	12:32	3.9	11	-73.822	38.539	32	120
ETAA	DJ	3:1	2.413	Yes	3/21/2009	12:02	4.1	14	-73.823	38.540	31	120
ETAA	DJ	3:1	2.413	Yes	3/21/2009	12:42	4.1	16	-73.824	38.540	31	120
ETAA	DJ	3:1	2.413	Yes	3/22/2009	6:46	4.1	15	-73.823	38.540	31	120
ETAA	DJ	3:1	2.413	Yes	3/22/2009	7:29	4.1	16	-73.824	38.540	31	120
ETAA	DJ	3:1 Turned	2.413	No	3/26/2009	11:48	4.1	14	-73.823	38.539	31	115
ETAA	DJ	3:1 Turned	2.413	No	3/26/2009	12:14	4.1	16	-73.824	38.538	31	115
ETAA	DJ	3:1 Turned	2.413	No	3/26/2009	12:46	4.1	17	-73.822	38.539	31	115
ETAA	DJ	3:1 Turned	2.413	No	3/27/2009	11:45	4.1	14	-73.824	38.540	31	115
ETAA	DJ	3:1 Turned	2.413	No	3/27/2009	12:19	4.1	14	-73.825	38.541	31	115
ETAA	DJ	3:1 Turned	2.413	Yes	3/28/2009	6:48	4.1	10	-73.824	38.542	31	120
ETAA	DJ	3:1 Turned	2.413	Yes	3/28/2009	7:23	4.1	12	-73.825	38.540	31	120
ETAA	DJ	3:1 Turned	2.413	Yes	3/28/2009	8:10	4.1	10	-73.822	38.540	31	120
ETAA	DJ	3:1 Turned	2.413	Yes	3/31/2009	11:59	4.2	16	-73.822	38.540	31	120
ETAA	DJ	3:1 Turned	2.413	Yes	3/31/2009	12:40	4.2	10	-73.819	38.541	31	120
ETAA	ME	3:1	2.413	No	3/5/2009	11:13	3.8	10	-73.930	38.591	28	125
ETAA	ME	3:1	2.413	No	3/5/2009	11:29	3.8	11	-73.911	38.584	30	130
ETAA	ME	3:1	2.413	No	3/5/2009	11:48	3.8	10	-73.900	38.572	31	130
ETAA	ME	3:1	2.413	No	3/5/2009	12:06	3.8	10	-73.889	38.560	30	130
ETAA	ME	3:1	2.413	No	3/5/2009	12:43	3.8	10	-73.817	38.545	31	135
ETAA	ME	3:1	2.413	No	3/5/2009	13:03	3.8	10	-73.818	38.546	33	135
ETAA	ME	3:1	2.413	No	3/5/2009	13:25	3.8	6	-73.825	38.548	32	135
ETAA	ME	2:1	2.413	No	3/8/2009	12:12	3.8	10	-73.818	38.543	32	130
ETAA	ME	2:1	2.413	No	3/8/2009	12:30	3.8	10	-73.819	38.544	32	130
ETAA	ME	2:1	2.413	No	3/8/2009	12:54	3.8	16	-73.818	38.541	32	135
ETAA	ME	2:1	2.413	No	3/8/2009	13:20	3.8	11	-73.817	38.539	32	135
ETAA	ME	3:1	2.413	No	3/10/2009	12:22	3.8	15	-73.819	38.542	31	123
ETAA	ME	3:1	2.413	No	3/10/2009	12:46	3.8	12	-73.819	38.541	31	125
ETAA	ME	3:1	2.413	No	3/10/2009	13:14	3.8	10	-73.819	38.542	31	125
ETAA	ME	3:1	2.413	Yes	3/12/2009	12:09	3.8	11	-73.819	38.542	31	135
ETAA	ME	3:1	2.413	Yes	3/12/2009	12:32	3.8	10	-73.817	38.538	32	135
ETAA	ME	3:1	2.413	Yes	3/12/2009	13:06	3.8	10	-73.820	38.542	32	135
ETAA	ME	3:1	2.413	Yes	3/13/2009	12:30	3.8	10	-73.820	38.544	31	135
ETAA	ME	3:1	2.413	Yes	3/13/2009	12:54	3.8	10	-73.819	38.542	32	135
ETAA	ME	3:1	2.413	Yes	3/13/2009	13:21	3.8	10	-73.820	38.540	32	135
ETAA	ME	2:1	2.413	Yes	3/21/2009	11:56	4.1	12	-73.881	38.501	31	120
ETAA	ME	2:1	2.413	Yes	3/21/2009	12:16	4	15	-73.866	38.510	31	120
ETAA	ME	2:1	2.413	Yes	3/21/2009	12:44	4.1	16	-73.868	38.509	32	120
ETAA	ME	2:1	2.413	Yes	3/21/2009	13:13	4	9	-73.874	38.506	31	120
ETAA	ME	2:1	2.413	Yes	3/22/2009	6:54	3.7	10	-73.863	38.512	31	110
ETAA	ME	2:1	2.413	Yes	3/22/2009	7:12	3.8	11	-73.847	38.519	31	110
ETAA	ME	2:1	2.413	Yes	3/22/2009	7:33	3.8	15	-73.851	38.517	31	110
ETAA	ME	3:1 Turned	2.413	No	3/26/2009	11:59	3.8	10	-73.865	38.511	32	110
ETAA	ME	3:1 Turned	2.413	No	3/26/2009	12:16	3.8	11	-73.849	38.520	32	110
ETAA	ME	3:1 Turned	2.413	No	3/26/2009	12:35	3.8	13	-73.853	38.518	32	110
ETAA	ME	3:1 Turned	2.413	No	3/26/2009	12:57	3.8	13	-73.853	38.518	32	110
ETAA	ME	3:1 Turned	2.413	No	3/27/2009	11:58	3.8	10	-73.848	38.520	33	115
ETAA	ME	3:1 Turned	2.413	No	3/27/2009	12:15	3.8	10	-73.850	38.519	32	115
ETAA	ME	3:1 Turned	2.413	No	3/27/2009	12:33	3.8	11	-73.849	38.519	32	115
ETAA	ME	3:1 Turned	2.413	No	3/27/2009	12:53	3.8	13	-73.851	38.518	32	115

Appendix 1. Information on tows conducted during this investigation (continued).

Area	Vessel	Twine Top	Dredge Width (m)	Cover Net Used	Date	Time	Tow Speed (knots)	Tow duration (min)	Longitude	Latitude	Depth (fm)	Wire out (fm)
ETAA	ME	3:1 Turned	2.413	No	3/27/2009	13:13	3.8	12	-73.870	38.507	32	115
ETAA	ME	3:1 Turned	2.413	Yes	3/28/2009	6:55	3.8	10	-73.869	38.508	32	110
ETAA	ME	3:1 Turned	2.413	Yes	3/28/2009	7:15	3.8	11	-73.856	38.514	32	110
ETAA	ME	3:1 Turned	2.413	Yes	3/28/2009	7:37	3.8	14	-73.845	38.511	32	110
ETAA	ME	3:1 Turned	2.413	Yes	3/31/2009	11:47	3.8	10	-73.862	38.510	32	125
ETAA	ME	3:1 Turned	2.413	Yes	3/31/2009	12:06	3.8	11	-73.849	38.519	32	125
ETAA	ME	3:1 Turned	2.413	Yes	3/31/2009	12:26	3.8	11	-73.849	38.518	32	125
ETAA	ME	3:1 Turned	2.413	Yes	3/31/2009	12:46	3.8	11	-73.849	38.519	32	125
GSC	DJ	2:1	2.413	Yes	7/1/2009	17:10	4	55	-69.400	41.476	30	110
GSC	DJ	2:1	2.413	Yes	7/1/2009	18:45	4.1	55	-69.400	41.478	33	110
GSC	DJ	2:1	2.413	Yes	7/1/2009	20:30	4	45	-69.402	41.476	32	110
GSC	DJ	2:1	2.413	Yes	7/8/2009	5:14	4.3	31	-69.409	41.486	30	110
GSC	DJ	2:1	2.413	Yes	7/8/2009	6:21	4	28	-69.409	41.486	31	110
GSC	DJ	2:1	2.413	Yes	7/8/2009	7:08	4	33	-69.408	41.486	30	110
GSC	DJ	2:1	2.413	Yes	7/8/2009	8:06	4	26	-69.413	41.489	31	110
GSC	DJ	2:1	2.413	Yes	7/8/2009	8:54	4	35	-69.410	41.489	30	110
GSC	DJ	3:1	2.413	Yes	7/9/2009	5:06	4	31	-69.412	41.487	30	110
GSC	DJ	3:1	2.413	Yes	7/9/2009	6:09	4	32	-69.413	41.485	30	110
GSC	DJ	3:1	2.413	Yes	7/9/2009	7:04	4	29	-69.410	41.485	30	110
GSC	DJ	3:1	2.413	Yes	7/9/2009	7:56	4	28	-69.413	41.488	30	110
GSC	DJ	3:1	2.413	Yes	7/9/2009	8:46	4	36	-69.414	41.496	30	110
GSC	DJ	3:1	2.413	Yes	7/10/2009	3:44	4	49	-69.670	41.577	20	80
GSC	DJ	3:1	2.413	Yes	7/10/2009	5:07	4	48	-69.625	41.573	25	100
GSC	DJ	3:1	2.413	Yes	7/10/2009	10:29	4	31	-69.374	41.519	42	150
GSC	DJ	3:1	2.413	Yes	7/10/2009	11:38	4	34	-69.390	41.499	40	140
GSC	DJ	3:1	2.413	Yes	7/10/2009	12:32	4	51	-69.415	41.499	32	110
GSC	DJ	3:1	2.413	Yes	7/10/2009	13:55	4	33	-69.384	41.503	33	120
GSC	DJ	3:1	2.413	Yes	7/10/2009	15:14	4	22	-69.401	41.486	31	110
GSC	DJ	3:1	2.413	Yes	7/10/2009	16:16	4	30	-69.404	41.485	31	110
GSC	DJ	3:1	2.413	Yes	7/10/2009	17:29	4	22	-69.401	41.485	31	110
GSC	DJ	3:1	2.413	Yes	7/10/2009	18:14	4	22	-69.401	41.484	31	110
GSC	DJ	3:1	2.413	No	7/18/2009	11:35	4	47	-69.661	41.586	22	100
GSC	DJ	3:1	2.413	No	7/18/2009	12:32	4	36	-69.688	41.592	21	80
GSC	DJ	3:1	2.413	No	7/18/2009	13:18	4	39	-69.684	41.590	21	80
GSC	DJ	3:1	2.413	No	7/18/2009	14:06	4	43	-69.623	41.573	25	100
GSC	DJ	3:1	2.413	No	7/18/2009	15:00	4	44	-69.624	41.573	27	100
GSC	DJ	3:1	2.413	No	7/18/2009	15:56	4	34	-69.680	41.589	27	100
GSC	DJ	3:1	2.413	No	7/18/2009	16:45	4	34	-69.705	41.586	20	80
GSC	DJ	3:1	2.413	No	7/18/2009	5:29	4	33	-69.405	41.483	31	110
GSC	DJ	3:1	2.413	No	7/18/2009	6:19	4	34	-69.405	41.486	31	110
GSC	DJ	3:1	2.413	No	7/18/2009	7:19	4	30	-69.395	41.504	34	120
GSC	DJ	3:1	2.413	No	7/18/2009	8:04	4	27	-69.389	41.500	44	120
GSC	DJ	3:1	2.413	No	7/18/2009	10:05	3.8	68	-69.621	41.573	25	100
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	5:19	4	36	-69.408	41.485	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	6:34	4	35	-69.406	41.485	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	7:29	4	36	-69.406	41.485	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	8:22	4	35	-69.404	41.484	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	9:12	4	29	-69.404	41.483	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	9:59	4	39	-69.405	41.483	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	11:01	4	31	-69.405	41.482	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	11:47	4	39	-69.405	41.482	31	110
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	13:47	4	58	-69.618	41.569	25	100
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	15:05	4	44	-69.690	41.573	20	80
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	16:10	4	40	-69.686	41.576	16	80
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	17:03	4	55	-69.615	41.570	23	100
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	18:11	4	61	-69.620	41.598	25	100
GSC	DJ	3:1 Turned	2.413	No	7/19/2009	19:24	4	38	-69.633	41.579	24	100
GSC	JK	3:1 Turned	3.0099	Yes	7/2/2009	16:23	5	15	-69.579	41.593	33	125
GSC	JK	3:1 Turned	3.0099	No	7/2/2009	18:51	5	60	-69.627	41.608	33	125
GSC	JK	3:1 Turned	3.0099	No	7/2/2009	20:28	4.5	61	-69.620	41.615	35	125

Appendix 1. Information on tows conducted during this investigation (continued).

Area	Vessel	Twine Top	Dredge Width (m)	Cover Net Used	Date	Time	Tow Speed (knots)	Tow duration (min)	Longitude	Latitude	Depth (fm)	Wire out (fm)
GSC	JK	3:1 Turned	3.0099	No	7/3/2009	5:09	5.5	73	-69.714	41.679	34	150
GSC	JK	3:1 Turned	3.0099	No	7/3/2009	6:46	5	72	-69.718	41.677	39	150
GSC	JK	3:1 Turned	3.0099	No	7/3/2009	18:19	5	86	-69.692	41.654	32	150
GSC	JK	3:1 Turned	3.0099	No	7/3/2009	20:05	5.1	18	-69.733	41.678	36	100
GSC	JK	3:1 Turned	3.0099	No	7/3/2009	20:39	5.1	48	-69.686	41.677	43	150
GSC	JK	3:1	3.0099	Yes	7/9/2009	6:18	4.6	56	-69.723	41.677	35	125
GSC	JK	3:1	3.0099	Yes	7/9/2009	7:33	4.1	46	-69.726	41.675	32	125
GSC	JK	3:1	3.0099	Yes	7/9/2009	8:38	4.2	56	-69.727	41.671	32	125
GSC	JK	3:1	3.0099	Yes	7/9/2009	9:51	4	60	-69.732	41.675	33	125
GSC	JK	3:1	3.0099	Yes	7/9/2009	11:11	3.8	56	-69.728	41.678	33	125
GSC	JK	3:1	3.0099	Yes	7/14/2009	5:33	3.8	14	-69.574	41.587	33	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	6:20	4	45	-69.611	41.601	32	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	7:18	4.1	45	-69.660	41.637	35	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	8:16	4.1	35	-69.703	41.668	35	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	9:02	3.9	45	-69.697	41.663	33	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	10:05	3.9	45	-69.647	41.625	32	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	11:07	4.1	30	-69.602	41.596	31	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	12:52	4.1	45	-69.658	41.633	33	100
GSC	JK	3:1	3.0099	Yes	7/14/2009	14:08	4.4	58	-69.658	41.647	40	125
GSC	JK	3:1	3.0099	Yes	7/14/2009	15:20	4	60	-69.654	41.650	39	125
GSC	JK	3:1	3.0099	Yes	7/15/2009	7:51	3.8	40	-69.608	41.623	37	125
GSC	JK	3:1	3.0099	Yes	7/15/2009	8:59	4.1	49	-69.654	41.645	39	125
GSC	JK	3:1	3.0099	No	7/15/2009	10:15	4	50	-69.710	41.679	38	100
GSC	JK	3:1	3.0099	No	7/15/2009	11:17	4	45	-69.714	41.677	35	100
GSC	JK	3:1	3.0099	No	7/15/2009	12:15	4.3	57	-69.724	41.676	35	100
GSC	JK	3:1	3.0099	No	7/15/2009	13:24	4.1	59	-69.719	41.684	38	100
GSC	JK	3:1	3.0099	Yes	7/15/2009	6:13	4.3	63	-69.634	41.637	38	125
GSC	JK	2:1	3.0099	Yes	7/16/2009	7:22	4.1	60	-69.628	41.636	39	100
GSC	JK	2:1	3.0099	Yes	7/16/2009	8:33	3.8	62	-69.706	41.683	38	125
GSC	JK	2:1	3.0099	Yes	7/16/2009	9:48	4.1	60	-69.713	41.674	33	100
GSC	JK	2:1	3.0099	Yes	7/16/2009	11:10	4	45	-69.712	41.670	33	100
GSC	JK	2:1	3.0099	Yes	7/16/2009	12:09	4.3	45	-69.711	41.668	33	100
GSC	JK	2:1	3.0099	Yes	7/16/2009	13:09	3.9	55	-69.721	41.677	33	100
GSC	JK	2:1	3.0099	Yes	7/16/2009	14:17	4.2	50	-69.722	41.679	34	100
GSC	JK	2:1	3.0099	Yes	7/16/2009	15:20	4.1	58	-69.727	41.689	38	125
GSC	JK	2:1	3.0099	Yes	7/16/2009	16:32	4.1	60	-69.719	41.683	37	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	6:25	4.2	67	-69.669	41.653	38	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	7:46	4	42	-69.738	41.694	37	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	8:43	4.2	7	-69.748	41.703	37	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	9:03	4.5	48	-69.706	41.673	36	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	10:05	4.2	45	-69.701	41.671	38	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	11:03	4	60	-69.686	41.666	35	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	12:15	4.3	50	-69.610	41.627	37	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	13:20	4.3	57	-69.622	41.629	36	125
GSC	JK	2:1	3.0099	Yes	7/17/2009	14:31	4.4	53	-69.693	41.666	35	125
GSC	JK	2:1	3.0099	No	7/18/2009	7:07	4.2	56	-69.723	41.679	33	100
GSC	JK	2:1	3.0099	No	7/18/2009	8:13	4.3	60	-69.728	41.675	34	100
GSC	JK	2:1	3.0099	No	7/18/2009	9:29	4.6	62	-69.712	41.674	35	125
GSC	JK	2:1	3.0099	No	7/18/2009	10:45	3.9	69	-69.713	41.676	37	125
GSC	JK	2:1	3.0099	No	7/18/2009	12:14	4.2	60	-69.706	41.680	38	125
GSC	JK	2:1	3.0099	No	7/18/2009	13:26	4	72	-69.713	41.683	36	125
GSC	JK	2:1	3.0099	No	7/18/2009	14:55	4.2	68	-69.716	41.679	36	125
GSC	JK	2:1	3.0099	No	7/19/2009	6:18	4.5	65	-69.621	41.603	32	100
GSC	JK	2:1	3.0099	No	7/19/2009	7:35	4	34	-69.682	41.637	32	100
GSC	JK	2:1	3.0099	No	7/19/2009	8:18	4.2	47	-69.676	41.625	29	75
GSC	JK	2:1	3.0099	No	7/19/2009	10:47	4.1	60	-69.638	41.599	29	75
GSC	JK	2:1	3.0099	No	7/19/2009	11:56	4.4	60	-69.580	41.602	30	100
GSC	JK	2:1	3.0099	No	7/19/2009	13:07	4.4	60	-69.628	41.603	30	100
GSC	JK	2:1	3.0099	No	7/19/2009	14:18	3.9	70	-69.619	41.600	30	100
GSC	JK	2:1	3.0099	No	7/19/2009	15:38	4.5	61	-69.617	41.599	31	100

Appendix 1. Information on tows conducted during this investigation (continued).

Area	Vessel	Twine Top	Dredge Width (m)	Cover Net Used	Date	Time	Tow Speed (knots)	Tow duration (min)	Longitude	Latitude	Depth (fm)	Wire out (fm)
GSC	JK	2:1	3.0099	No	7/19/2009	16:49	4.2	48	-69.685	41.638	30	100
GSC	ME	3:1	2.413	Yes	7/3/2009	6:13	3.7	20	-69.416	41.497	32	110
GSC	ME	3:1	2.413	Yes	7/3/2009	7:40	3.5	13	-69.401	41.484	32	110
GSC	ME	3:1	2.413	Yes	7/3/2009	8:03	3.8	15	-69.403	41.487	32	115
GSC	ME	3:1	2.413	Yes	7/3/2009	8:28	4	21	-69.400	41.483	32	110
GSC	ME	3:1	2.413	Yes	7/3/2009	8:59	3.9	16	-69.400	41.484	32	110
GSC	ME	3:1	2.413	Yes	7/3/2009	9:24	3.9	15	-69.401	41.483	32	120
GSC	ME	3:1	2.413	Yes	7/3/2009	9:50	3.7	16	-69.402	41.485	32	120
GSC	ME	3:1	2.413	Yes	7/3/2009	10:14	3.6	15	-69.400	41.482	32	115
GSC	ME	3:1	2.413	Yes	7/3/2009	10:39	3.5	15	-69.401	41.483	33	115
GSC	ME	3:1	2.413	Yes	7/4/2009	6:21	3.5	15	-69.413	41.488	31	125
GSC	ME	3:1	2.413	Yes	7/4/2009	6:45	3.6	12	-69.399	41.473	31	125
GSC	ME	3:1	2.413	Yes	7/4/2009	7:06	3.6	15	-69.390	41.460	31	125
GSC	ME	3:1	2.413	Yes	7/4/2009	7:30	4	15	-69.388	41.465	31	125
GSC	ME	3:1	2.413	Yes	7/4/2009	7:55	3.8	16	-69.399	41.484	31	115
GSC	ME	3:1	2.413	Yes	7/4/2009	8:20	4	15	-69.400	41.485	32	120
GSC	ME	3:1	2.413	Yes	7/4/2009	8:45	4	15	-69.401	41.486	32	115
GSC	ME	3:1	2.413	Yes	7/4/2009	9:09	3.8	15	-69.414	41.502	33	115
GSC	ME	3:1	2.413	Yes	7/4/2009	9:40	4	15	-69.401	41.483	32	120
GSC	ME	3:1	2.413	Yes	7/4/2009	10:04	4	20	-69.404	41.486	32	120
GSC	ME	3:1	2.413	Yes	7/4/2009	10:33	4	10	-69.402	41.488	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	2:28	4	16	-69.402	41.486	31	115
GSC	ME	3:1	2.413	Yes	7/5/2009	2:55	3.9	14	-69.399	41.484	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	3:19	3.9	15	-69.399	41.482	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	3:44	4	15	-69.399	41.481	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	4:10	4	15	-69.397	41.479	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	4:35	4	14	-69.397	41.479	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	5:02	4	14	-69.396	41.480	32	115
GSC	ME	3:1	2.413	Yes	7/5/2009	5:26	3.8	14	-69.397	41.482	32	115
GSC	ME	2:1	2.413	Yes	7/6/2009	11:43	4	17	-69.395	41.478	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	12:37	4	14	-69.396	41.487	34	125
GSC	ME	2:1	2.413	Yes	7/6/2009	1:01	4	14	-69.398	41.485	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	1:25	3.8	15	-69.396	41.477	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	1:50	4	15	-69.395	41.476	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	2:24	4	15	-69.396	41.477	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	2:50	4	14	-69.394	41.474	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	3:14	4	15	-69.387	41.463	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	3:39	4	15	-69.390	41.469	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	4:13	4	16	-69.401	41.484	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	4:39	4	16	-69.399	41.483	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	5:07	4	9	-69.400	41.483	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	9:21	4	19	-69.401	41.483	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	10:06	4.1	14	-69.397	41.479	33	125
GSC	ME	2:1	2.413	Yes	7/6/2009	10:30	3.9	16	-69.397	41.479	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	10:54	4	17	-69.397	41.478	32	125
GSC	ME	2:1	2.413	Yes	7/6/2009	11:19	3.9	15	-69.395	41.477	32	125
GSC	ME	2:1	2.413	Yes	7/7/2009	8:55	4	15	-69.401	41.484	31	115
GSC	ME	2:1	2.413	Yes	7/7/2009	9:22	4	14	-69.399	41.481	32	115
GSC	ME	2:1	2.413	Yes	7/7/2009	9:47	3.9	15	-69.398	41.481	32	115
GSC	ME	2:1	2.413	Yes	7/7/2009	10:11	4	15	-69.400	41.483	32	115
GSC	ME	2:1	2.413	Yes	7/7/2009	10:38	4	17	-69.394	41.474	32	115
GSC	ME	2:1	2.413	Yes	7/7/2009	11:05	4	17	-69.398	41.480	32	115
GSC	ME	2:1	2.413	Yes	7/7/2009	11:30	4	18	-69.397	41.479	32	115
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	9:46	4	15	-69.400	41.484	32	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	10:10	4	16	-69.401	41.483	32	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	10:37	4	15	-69.400	41.482	32	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	11:03	4	16	-69.390	41.462	31	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	11:29	4	15	-69.383	41.443	30	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	11:53	4	14	-69.382	41.425	31	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	12:29	4	15	-69.357	41.431	34	125

Appendix 1. Information on tows conducted during this investigation (continued).

Area	Vessel	Twine Top	Dredge Width (m)	Cover Net Used	Date	Time	Tow Speed (knots)	Tow duration (min)	Longitude	Latitude	Depth (fm)	Wire out (fm)
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	12:54	4	15	-69.368	41.452	34	125
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	13:20	4	20	-69.383	41.476	35	135
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	13:50	4	15	-69.400	41.498	35	135
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	14:15	4	15	-69.420	41.514	34	135
GSC	ME	3:1 Turned	2.413	No	7/13/2009	16:46	4	15	-69.417	41.511	34	135
GSC	ME	3:1 Turned	2.413	No	7/13/2009	17:15	4	15	-69.415	41.509	34	135
GSC	ME	3:1 Turned	2.413	No	7/13/2009	17:39	4	15	-69.419	41.505	34	135
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	20:29	3.8	11	-69.753	41.598	17	75
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	20:39	3.8	10	-69.754	41.599	17	75
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	21:03	3.8	9	-69.753	41.598	17	75
GSC	ME	3:1 Turned	2.413	Yes	7/13/2009	21:22	3.8	10	-69.754	41.599	17	75
GSC	ME	3:1 Turned	2.413	No	7/13/2009	21:40	3.8	11	-69.754	41.600	17	75
GSC	ME	3:1	2.413	No	7/15/2009	10:40	4	11	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	10:56	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	11:11	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	11:26	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	11:41	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	11:57	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	12:13	4	10	-69.755	41.600	17	60
GSC	ME	3:1	2.413	No	7/15/2009	12:20	4	19	-69.756	41.600	17	60
GSC	ME	3:1	2.413	No	7/15/2009	12:44	4	11	-69.756	41.600	17	60
GSC	ME	3:1	2.413	No	7/15/2009	13:01	4	9	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	13:15	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	13:30	4	10	-69.756	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	13:46	4	11	-69.755	41.600	17	60
GSC	ME	3:1	2.413	No	7/15/2009	14:02	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	14:18	4	10	-69.755	41.599	17	60
GSC	ME	3:1	2.413	No	7/15/2009	14:33	4	10	-69.755	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	14:49	4	9	-69.754	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	15:03	4	10	-69.754	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	15:20	4	10	-69.755	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	15:37	4	10	-69.755	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	15:54	4	10	-69.756	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	16:09	4	10	-69.755	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	16:26	4	9	-69.756	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	16:40	4	10	-69.756	41.598	17	60
GSC	ME	3:1	2.413	No	7/15/2009	16:56	4	10	-69.756	41.597	17	60
GSC	ME	3:1	2.413	No	7/15/2009	17:12	4	10	-69.756	41.598	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	6:58	3.8	10	-69.754	41.599	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	7:20	3.8	10	-69.754	41.598	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	7:37	3.8	10	-69.753	41.597	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	7:55	2	20	-69.754	41.597	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	8:30	2	10	-69.759	41.611	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	8:48	4	9	-69.758	41.616	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	9:05	3	14	-69.758	41.616	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	9:25	4	10	-69.755	41.602	17	60
GSC	ME	3:1 Turned	2.413	No	7/15/2009	9:42	4	10	-69.756	41.602	17	60

Appendix 2. Species encountered during this investigation including NMFS species lookup codes, species category applied in this study, scientific and common names.

NMFS Species Code	Species Category	Scientific Name	Common Name
8009	Scallops	*Placopecten magellanicus*	SCALLOP, SEA
1200	Flounders	*Pseudopleuronectes americanus*	FLOUNDER, WINTER (BLACKBACK)
1219	Flounders	*Paralichthys dentatus*	FLOUNDER, SUMMER (FLUKE)
1220	Flounders	*Glypyocephalus cynoglossus*	FLOUNDER, WITCH (GREY SOLE)
1230	Flounders	*Limanda ferruginea*	FLOUNDER, YELLOWTAIL
1250	Flounders	*Scophthalmus aquosus*	FLOUNDER, WINDOWPANE (SAND DAB)
1270	Flounders	*Paralichthys oblongus*	FLOUNDER, FOURSPOT
0124	Monkfish	*Lophius americanus*	MONKFISH, WHOLE
3670	Skates	*Leucoraja ocellata*	SKATE, WINTER
3660	Skates	*Leucoraja erinacea*	SKATE, LITTLE
3690	Skates	*Malacoraja senta*	SKATE, SMOOTH
3680	Skates	*Dipturus laevis*	SKATE, BARNDOOR
3700	Skates	*Amblyraja radiata*	SKATE, THORNY
3720	Skates	*Raja eglanteria*	SKATE, CLEARNOSE
0818	Other Species	*Gadus morhua*	COD, ATLANTIC
1477	Other Species	*Melanogrammus aeglefinus*	HADDOCK
1520	Other Species	*Urophycis chuss*	HAKE, RED (LING)
1539	Other Species	*Urophycis tenuis*	HAKE, WHITE
2400	Other Species	*Sebastes fasciatus*	REDFISH, ACADIAN (OCEAN PERCH)
2500	Other Species	*Macrozoarces americanus*	OCEAN POUT
3240	Other Species	*Myoxocephalus scorpius*	SCULPIN, SHORTHORN
3250	Other Species	*Myoxocephalus octodecemspinosus*	SCULPIN, LONGHORN
3270	Other Species	*Hemitripterus americanus*	SEA RAVEN
3295	Other Species	*Stenotomus chrysops*	SCUP
3350	Other Species	*Centropristis striata*	SEA BASS, BLACK
3400	Other Species	*Prionotus carolinus*	SEA ROBIN, NORTHERN
3420	Other Species	*Prionotus evolans*	SEA ROBIN, STRIPED
3521	Other Species	*Squalus acanthias*	DOGFISH, SPINY
5090	Other Species	*Merluccius bilinearis*	HAKE, SILVER (WHITING)
5120	Other Species	*Anarhichas lupus*	WOLFFISH, ATLANTIC (CATFISH)
6600	Other Species	*Gadidae*	HAKE, NK
6602	Other Species	*Urophycis regia*	HAKE, SPOTTED
6606	Other Species	*Enchelyopus cimbrius*	ROCKLING, FOURBEARD
6730	Other Species	*Torpedo nobiliana*	RAY, TORPEDO
7110	Other Species	*Cancer borealis*	CRAB, JONAH
7120	Other Species	*Cancer irroratus*	CRAB, ROCK
7150	Other Species	*Majidae*	CRAB, SPIDER
7240	Other Species	*Limulus polyphemus*	CRAB, HORSESHOE
7270	Other Species	*Homarus americanus*	LOBSTER, AMERICAN
7540	Other Species	*Arctica islandica*	QUAHOG, OCEAN (BLACK CLAM)
7811	Other Species	*Modiolus modiolus*	MUSSEL, HORSE

Appendix 3. Summary of video collected of the scallop dredge fishing.

CD Number	***Date***	***Vessel***	***Video Length***
01	12 May 2009	F/V Jocka	1:49:33
02	12 May 2009	F/V Jocka	0:29:40
03	11-12 May 2009	F/V Jocka	1:41:46

CD Number	***Time***	***Angle of Footage***	***Details***
01	0:00:24	Hand Held/Cutting Bar looking back	Good footage of dredge being deployed from boat and into water
	0:19:27	Back of Dredge looking forward	Good footage of dredge in action
	1:17:10	Support Bar looking forward	Lobster moving out of the way
	1:18:05	Support Bar looking forward	Flounder moving out of the way
	1:20:14	Support Bar looking forward	Skate moving out of the way to the left of the screen
	1:20:40	Support Bar looking forward	Lobster moving out of the way, then a skate moving out of the way
	1:20:58	Support Bar looking forward	Two lobsters moving to the left of screen
	1:21:03	Support Bar looking forward	Skate moving out of the way
	1:21:20	Support Bar looking forward	Two flatfish moving out of the way

CD Number	***Time***	***Angle of Footage***	***Details***
02	0:09:28	Support Bar looking to Cutting Bar	Good footage of dredge being deployed into the water
	0:15:15	Support Bar looking forward	Sculpin moving out of the way
	0:16:20	Support Bar looking forward	Sand Lance moving out of the way in slow motion

CD Number	***Time***	***Angle of Footage***	***Details***
03	0:27:36	Support Bar looking back	Dredge being lowered into the water
	1:32:00	Forward Dredge looking at Cutting Bar	Dredge being brought up to boat and re-deployed