EVALUATION OF THE EFFECT ON CATCH PERFORMANCE OF THE NMFS FLOUNDER TURTLE EXCLUDER DEVICE (TED) WITH A LARGE OPENING IN THE SOUTHERN NEW ENGLAND LONG FIN SQUID TRAWL FISHERY

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ABSTRACT

Previous studies of the catch performance of bottom trawls equipped with NMFS certified Turtle Excluder Device (TED) in the southern New England and mid-Atlantic regions have documented statistically significant losses of target species ranging from 35% in the summer flounder fishery (TED was 32x51 inches), (Lawson, DeAlteris and Parkins, 2007) to 7% in the sea scallop fishery (TED was 43x51 inches) (DeAlteris and Parkins, 2009a).

The purpose of the study reported herein was to investigate the effect on the catch performance of a certified large flounder TED in a directed squid trawl fishery. The use of the TED initially resulted in a significant loss of squid, approximately 55%, but after making a modification to the method that the TED extension was attached to the codend of the trawl, the loss of squid was reduced to 10%, and this was a non-significant loss. There was a significant effect on total catch in the initial paired comparisons, but again after modifying the method of attachment of the TED extension to the codend, there was no significant difference in the total catches of the control and TED equipped trawls. With regard to the catch of non-target species as a group, in the initial paired comparisons, the loss was non-significant and averaged 25%, but in the latter comparisons the loss was reduced to 3% and this was also non-significant. The dominant non-target species captured included sea scallops, spotted hake, and butterfish, and individually there was no significant difference in the catches of the control and TED equipped trawls, however due the highly variable and inconsistent catch of these species, the analyses are not considered statistically robust.

INTRODUCTION

The National Marine Fisheries Service (NMFS) published an Advance Notice of Proposed Rulemaking (ANPR) in February 2007 regarding their intent to reduce the mortality of sea turtles that interact with trawl fisheries in the Mid-Atlantic and southern New England regions, as well as other areas (72 FR 7382, February 15, 2007). NMFS is working to develop and implement bycatch reduction measures for trawl fisheries in the Atlantic and Gulf of Mexico when and where sea turtle bycatch has occurred or where gear, time, location, fishing method, and other similarities exist between a particular trawl fishery and a trawl fishery where sea turtle bycatch has occurred (74 FR 21627, May 8, 2009). NMFS has required the use of a Turtle Excluder Device (TED) in the summer flounder trawl fishery in the mid-Atlantic south of Cape Charles, VA during particular times of the year. More recently, NMFS has conducted scoping sessions to receive public input on mitigation measures to address sea turtle bycatch in trawl fisheries. TEDs are currently required in the south Atlantic and Gulf of Mexico shrimp trawl fisheries.

In January 2007 Dr. DeAlteris was contracted by NMFS to conduct a workshop with a broad range of stakeholders to discuss bycatch reduction technologies (BRTs) to reduce sea turtle interactions in southern New England and mid-Atlantic trawl fisheries. The participants at this workshop stressed the need for further work to develop a modified TED with better target catch retention in the summer flounder and scallop trawl fisheries. In the summer of 2007, Dr. DeAlteris was contracted by NMFS to perform a study evaluating the catch performance of a 32x51 inch flounder TED with a 36 x16 inch turtle escape opening in the summer flounder trawl fishery. This is the predominant TED currently used in the flounder fishery. That study demonstrated that there was 35% loss of the targeted summer flounder, but that there was no difference in the size distribution of retained summer flounder (Lawson, DeAlteris and Parkins, 2007). Other recent studies of the catch performance of a NMFS certified whelk TED and a NMFS certified, larger flounder TED in the scallop trawl fishery have demonstrated a 7% loss of scallops (Lawson and DeAlteris, 2006 and DeAlteris and Parkins, 2009a). More recently DeAlteris and Parkins (2009b) found a significant loss (average loss of 22%) of whiting or silver hake in the directed whiting trawl fishery, and significant loss (average loss of 27%) of non-target flounder catch in the directed whiting fishery.

The purpose of this report is to describe the results of an evaluation in 2009 of the catch performance of a 43x51 inch NMFS certified turtle excluder device (TED) with a large top opening and a single flap cover, designed to release leatherback sea turtles, in the long fin squid (*Loligo pealei)* trawl fishery of the southern New England and the mid-Atlantic. The term “squid” in rest of report refers to only long fin squid.

METHODS

The study was conducted during four trips late summer and fall of 2009 using the alternate tow design. In this design the same trawl with an extension section is alternatively rigged with either an additional extension section with a TED installed or no additional extension section (thereby being the traditional trawl with no modification). The NMFS flounder TED (Figure 1) is 43.4 x 51.0 inches in size, constructed of aluminum pipe around the perimeter, and is designed to have three windows or opening in the lower section that were 14.1x10.0 inches in size. The interior section of the TED was constructed of aluminum flat bars oriented vertically, and spaced to provide 4 inch openings. The TED was installed at 50^o, (the NMFS recommended angle of attack is $45\text{-}55^o$ for these TEDs) in an extension section constructed of double twine, braided polyethylene netting, 27 meshes in depth, and 100 meshes around. The mesh size in the TED extension section was 3.5 inches. The opening in the extension section above the TED was 41x28 inches (21x8 meshes), rectangular in shape and was designed to meet the large opening requirement. The opening was covered with a small mesh (1.5 inch) single flap cover. The control trawl had no additional extension section, as it was believed that this better represented a control trawl.

The FV Excalibur is owned and operated by Captain Joel Hovanesian, and is home ported in Point Judith, Rhode Island. The FV Excalibur is a 75-foot steel hull stern trawler, with a 750 HP engine. The bottom trawl used on the FV Excalibur had 110-foot sweep and had a 2.4 inch (6 cm) stretched mesh codend. All tows were commercial length in duration, ranging from approximately 60 to 90 minutes in duration depending on the abundance of squid in the fishing area, and all pairs of tows were of equal duration. Towing speed was approximately 3.0-3.2 knots. Most tows were conducted in the day as the squid tended to aggregate on bottom making them more susceptible to a bottom trawl. If the vessel encountered a hang and the trawl was damaged, or the tow was hauled in early for any reason, catch data for the tow was not collected, and the tow was repeated. Additionally, some short tows were made searching for the presence of squid in the catch, no catch data was collected for these tows. Hence, the tows included in the analysis are pairs of tows of commercial duration, where squid was captured in commercial quantities.

At the end of a tow, the cod-end of the trawl was dumped into a bin, and sorted by species. The entire squid catch was weighed in baskets, and a sub-sample of the squid catch was measured for total length to the next largest centimeter. All other catch was weighed and marketable catch was measured when possible. Observations were made of the condition of the TED, possible blockage of the TED, and condition of the trawl and cod-end. Digital still pictures were taken of the fishing operations, and underwater video was attempted during daylight when possible.

Approximately halfway through the field study, preliminary analysis of data indicated exceptionally high losses of squid in the TED equipped trawl. Captain Hovanesian suggested modifying the method of attaching the TED extension to the cod-end by adding a small mesh skirt to the TED extensions section. As a result the plastic rings and the zip line that joined the two sections were then outside the small mesh skirt, thereby preventing any escapement of squid at this junction. Although it is industry standard to simply attach the plastic rings to the first and last rows of meshes and to use a line laced through the rings to join the sections (note that the TEDs were installed and rigged in the extension sections by Superior Trawl Company), Captain Hovanesian speculated that the TED resulted in slower moving water on its back side, and this allowed the squid to escape through the openings associated with the plastic rings and zip line. The small mesh skirt solved this problem, and in the future we propose that the plastic rings be sewn in to the TED extension section several rows above the terminal row of meshes, thereby creating this skirt. As a result of the modification of the experimental gear, the data analysis is divided into two sections or portions, pre and post modification.

The data were analyzed by first comparing the paired squid catch weights in the TED and the control trawls for each set of tows in each portion of the study using a paired T-test calculated using Microsoft Excel. The null hypothesis was no difference in the catch weights, and this was evaluated at α=0.05. The mean ratio of the weight of the squid catch in the TED-equipped trawl to the squid catch in the control trawl for each pair was estimated, and evaluated using Excel to determine if it was significantly different from 1 at α=0.05 . The null hypothesis was that if there was no difference between the squid catch rates, the ratio would be 1. The value of the ratio test is that it is not as influenced by pairs of tows with large catches and hence potentially large differences between the experimental and the control nets, as compared to other pairs of tows with small catches and small differences. The paired T-test provides more importance to large differences than to small differences, whereas the ratio test essentially normalizes the differences by making a ratio of catch weights for the experimental to the control. The length-frequency (L-F) distributions of the squid catches in the TED and control trawls were evaluated using a Kolmorgov-Smirnoff test on the cumulative L-F distributions with α=0.05. The null hypothesis was that there was no significant difference in the L-F distributions. Finally, the total catch weights, non-target species catch weights, and individual dominant non-target species catch weights in the tows were also evaluated. A paired T-test was implemented in Excel at α=0.05. The null hypothesis was that there is no difference between the total catch weight, the catch weights of non-target species as a group, or individual non-target species in the TED equipped trawl as compared to the control trawl. The analyses were divided into two groups, as the gear was modified approximately half-way through the study in an attempt to improve the catch efficiency of the TED equipped trawl for the target species.

In all the T-tests α is the probability of making a Type I error, that is rejection of a null hypothesis that is in fact true, and β is the probability of making a Type II error, that is acceptance of a false null hypothesis (Sokal and Rohlf, 1995; Zar, 1984). The power of an analysis is the probability of rejecting the null hypothesis when it is in fact false and should be rejected. The power (1-β) of the T-tests was also evaluated in a post-hoc analysis using G-Power (Faul, et al. 2007). For a given level of variability in the catch data, if the null hypothesis is accepted, as the mean difference between the control and the experimental catches approaches 0, the power of the T-test diminishes to 0.05 or α. Thus, for the same level of inherent variability in the data, if the null hypothesis is accepted, as the mean difference between the experimental and control catches is becomes smaller, the only way to increase the power of the T-test is to increase the sample size, and even at large sample sizes the power remains low.

RESULTS

Field Observations

Data from four trips were used in the analyses, resulting in 42 tows, (21 pairs of tows) available for statistical analysis. The first trip (#2) of the study was 3 days in duration and was conducted between 11 and 13 August 2009. A total of 2 tows (1 pair) on squid were completed, other tows were directed for whiting and were summarized in a previous report. The second trip (#4) of the study was 4 days in duration and was conducted between 1 and 4 September 2009. A total of 6 tows (3 pairs) on squid were completed. The third trip (#5) of the study was 6 days in duration and was conducted between 8 and 13 October 2009. A total of 16 tows (8 pairs) were completed. As noted previously about half way through the third trip (#5) the rigging of the TED was modified in an attempt to improve the catch efficiency of the TED equipped trawl. The fourth trip (#6) of the study was 8 days in duration and was conducted between 20 and 27 October 2009. A total of 18 tows (9 pairs) were completed. The tows were conducted over a wide area ranging from an area south of Martha's Vineyard and Nantucket to the Hudson Canyon, to offshore of New Jersey and Maryland. The locations of all tows are shown in Figure 2, and listed in Table 1.

At sea observations noted that catches of the squid directed tows over the entire study were variable in quantity of squid captured. Both the control and TED-equipped tows experienced both clean and mixed species catches. During the study the trawl net did not encounter any large schools of dogfish or large rays that could potentially clog the TED. We were unsuccessful in obtaining any underwater video observations of fish behavior around the TED due to poor water clarity.

Data Analysis

The ratio squid catch in the TED trawl compared to the squid catch in the control trawl ranged from 0.14 to 6.52. Additionally, the percentage of non-target species in each tow ranged from 3 to 84 %.

The squid catch weights from trip #s 2, 4, 5, and 6 are listed in Table 2. During the first half of the field work, the mean catch per tow of squid in the control trawl was 600 kg, while the mean catch per tow of squid in the TED equipped trawl was 270 kg. The results of the paired T-test for squid catch weights indicated a significant difference (p=0.009) in squid catch between the TED equipped trawl and the control trawl with a power of 0.84. On average the TED equipped trawl caught 45% of the squid weight of the control trawl, representing a 55% loss of squid. The mean of the catch weight ratios for squid was significantly different from 1. After the modification was made to the method of attaching the TED extension to the codend, the mean catch per tow of squid in the control trawl was 521 kg, while the mean catch per tow of squid in the TED equipped trawl was 468 kg. The results of the paired T-test for squid catch weights indicated a non- significant difference (p=0.331) in squid catch between the TED equipped trawl and the control trawl with a power of 0.11. On average the TED equipped trawl caught 90% of the squid weight of the control trawl, representing a 10% loss of squid. The mean of the catch weight ratios for squid was not significantly different from 1. The L-F distribution of the squid catches between the TED equipped trawl and the control trawl are shown in Figure 3. Visual examination of the L-F plots for the squid catches indicates no difference in the distributions, and the results of the K-S test also indicate no significant difference in the L-F distributions.

The total catch weights for trip #s 2, 4, 5 and 6 are listed in Table 3. During the first half of the field work, the mean total catch in the control trawl was 685 kg per tow, while the mean total catch in the TED equipped trawl was 381 kg per tow. The results of the paired T-test for total catch weights indicated a significant difference (p=0.037) in total catch between the TED equipped trawl and the control trawl with a power of 0.59. On average the TED equipped trawl caught 56% of the total catch weight of the control trawl, representing a 44% loss in total catch. During the second half of the field work, after the modification was made to the method of attaching the TED extension to the codend, the mean total catch in the control trawl was 832 kg per tow, while the mean total catch in the TED equipped trawl was 774 kg per tow. The results of the paired T-test for total catch weights indicated a non-significant difference ($p=0.317$) in total catch between the TED equipped trawl and the control trawl with a power of 0.12. On average the TED equipped trawl caught 93% of the total catch weight of the control trawl, representing a 7% loss in total catch.

Total non-target species catch in the squid trawl nets included sea scallops, skate, various flounder species, dogfish, bluefish, butterfish, and spotted hake, and amounted to 23% of the total catch for the control trawl and 32% for the TED equipped trawl in the initial trials, and 38% of the total catch in the control trawl and 39% of the total catch in the TED equipped trawl after the modification was made to the attachment of the TED to the codend. Given the tot to tow variability, both control and TED equipped trawls had similar bycatch rates. The total non-target species catch weights for trip #s 2, 4, 5 and 6 are listed in Table 4. During the first half of the field work, the mean total non-target species catch in the control trawl was 160 kg per tow, while the mean total non-target species catch in the TED equipped trawl was 121 kg per tow. The results of the paired T-test for total catch weights indicated a non- significant difference ($p=0.186$) in total non-target species catch between the TED equipped trawl and the control trawl with a power 0.22. On average the TED equipped trawl caught 95% of the total non-target species catch weight of the control trawl, representing a 5% loss in total catch. During the second half of the field work, after the modification was made to the method of attaching the TED extension to the codend, the mean total non-target species catch in the control trawl was 313 kg per tow, while the mean total non-target species catch in the TED equipped trawl was 302 kg per tow. The results of the paired T-test for total catch weights indicated a non-significant difference (0.044) in total catch between the TED equipped trawl and the control trawl with a power of 0.07. On average the TED equipped trawl caught 94% of the total catch weight of the control trawl, representing a 6% loss in total catch. As noted in the field observations, the catch of non-target species was highly variable, from tow to tow and day to day and trip to trip, and this precludes a robust statistical analysis of data for a particular species. However, Tables 5, 6, and 7 list the catch weights per tow for the dominant non-target species captured.

The sea scallop catch weights for trip #s 2, 4, 5 and 6 are listed in Table 5. During the first half of the field work, the mean sea scallop catch in the control trawl was 57 kg per tow, while the mean sea scallop catch in the TED equipped trawl was 93 kg per tow. The results of the paired T-test for sea scallop catch weights indicated a non-significant difference ($p=0.088$) in sea scallop species catch between the TED equipped trawl and the control trawl with a power of 0.39. On average the TED equipped trawl caught 164% of the sea scallop catch weight of the control trawl, representing a 64% increase in sea scallop catch. During the second half of the field work, after the modification was made to the method of attaching the TED extension to the codend, the mean sea scallop catch in the control trawl was 30 kg per tow, while the mean sea scallop catch in the TED equipped trawl was 27 kg per tow. The results of the paired T-test for total catch weights indicated a non-significant difference ($p=0.390$) in sea scallop catch between the TED equipped trawl and the control trawl with a power of 0.08. On average the TED equipped trawl caught 89% of the total catch weight of the control trawl, representing an 11% loss in total catch.

The total spotted hake catch weights for trip #s 2, 4, 5 and 6 are listed in Table 6. During the first half of the field work, spotted hake were not captured in either the control or TED equipped trawls. During the second half of the field work, after the modification was made to the method of attaching the TED extension to the codend, the mean spotted hake catch in the control trawl was 94 kg per tow, while the mean spotted hake catch in the TED equipped trawl was 164 kg per tow. The results of the paired T-test for spotted hake catch weights indicated a non-significant difference (0.214) in spotted hake catch between the TED equipped trawl and the control trawl with a power of 0.20. On average the TED equipped trawl caught 174% of the spotted hake catch weight of the control trawl, representing a 74% increase in spotted hake catch.

The total butterfish catch weights for trip #s 2, 4, 5 and 6 are listed in Table 7. During the first half of the field work, the mean butterfish catch in the control trawl was 21 kg per tow, while the mean butterfish catch in the TED equipped trawl was 22 kg per tow. The results of the paired T-test for total catch weights indicated a non-significant difference (p=0.476) in butterfish catch between the TED equipped trawl and the control trawl with a power of 0.05. On average the TED equipped trawl caught 104% of the butterfish catch weight of the control trawl, representing a 4% increase in butterfish catch. During the second half of the field work, after the modification was made to the method of attaching the TED extension to the codend, the mean butterfish catch in the control trawl was 60 kg per tow, while the mean butterfish catch in the TED equipped trawl was 113 kg per tow. The results of the paired T-test for butterfish catch weights indicated a non-significant difference (p=0.169) in butterfish catch between the TED equipped trawl and the control trawl with a power of 0.24. On average the TED equipped trawl caught 188% of the total catch weight of the control trawl, representing an 88% increase in butterfish catch.

SUMMARY, DISCUSSION AND CONCLUSIONS

The goal of the research was investigate the effect on catch performance of the trawl for squid with the addition of a NMFS flounder TED with a large opening ahead of the cod-end of the net. Previous studies of the catch performance of bottom trawls equipped with NMFS certified flounder TEDs in the mid-Atlantic region have documented significant losses of target species ranging from 35% in the summer flounder fishery (Lawson, DeAlteris and Parkins, 2007), a 22% loss of whiting in the direct whiting trawl fishery (DeAlteris and Parkins, 2009b), to 7% in the sea scallop fishery (DeAlteris and Parkins, 2009a).

The results of all the T-test analyses are summarized in Table 7. The only results where the null hypothesis was rejected were the comparison of the squid and total catches in the pre-modification phase of the study. After the modification of the method of attaching the TED extension to the cod-end of the trawl, there was no statistical difference between any of the categories or species analyzed. The post modification phase of the study documented a 10% loss of squid in the direct squid trawl fishery, but as noted previously, this was not a statistically significant loss and was based on only 16 paired tows. It should be noted that these results are from a single vessel typical of the larger vessels in the squid fishery, and TED performance could vary in on other vessels. However the study was conducted over a large area of the southern New England and mid-Atlantic region and over two seasons, late summer and fall.

The results of this study indicate the need for additional research on improving the catch efficiency of TEDs on target species in temperate water trawl fisheries. The results of this study also point out the need for outreach education to describe specific methods for attaching the cod-end to the TED extension section, so as to avoid losses of target species.

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Figure 1. A diagram of the NMFS flounder TED, showing all dimensions in inches.

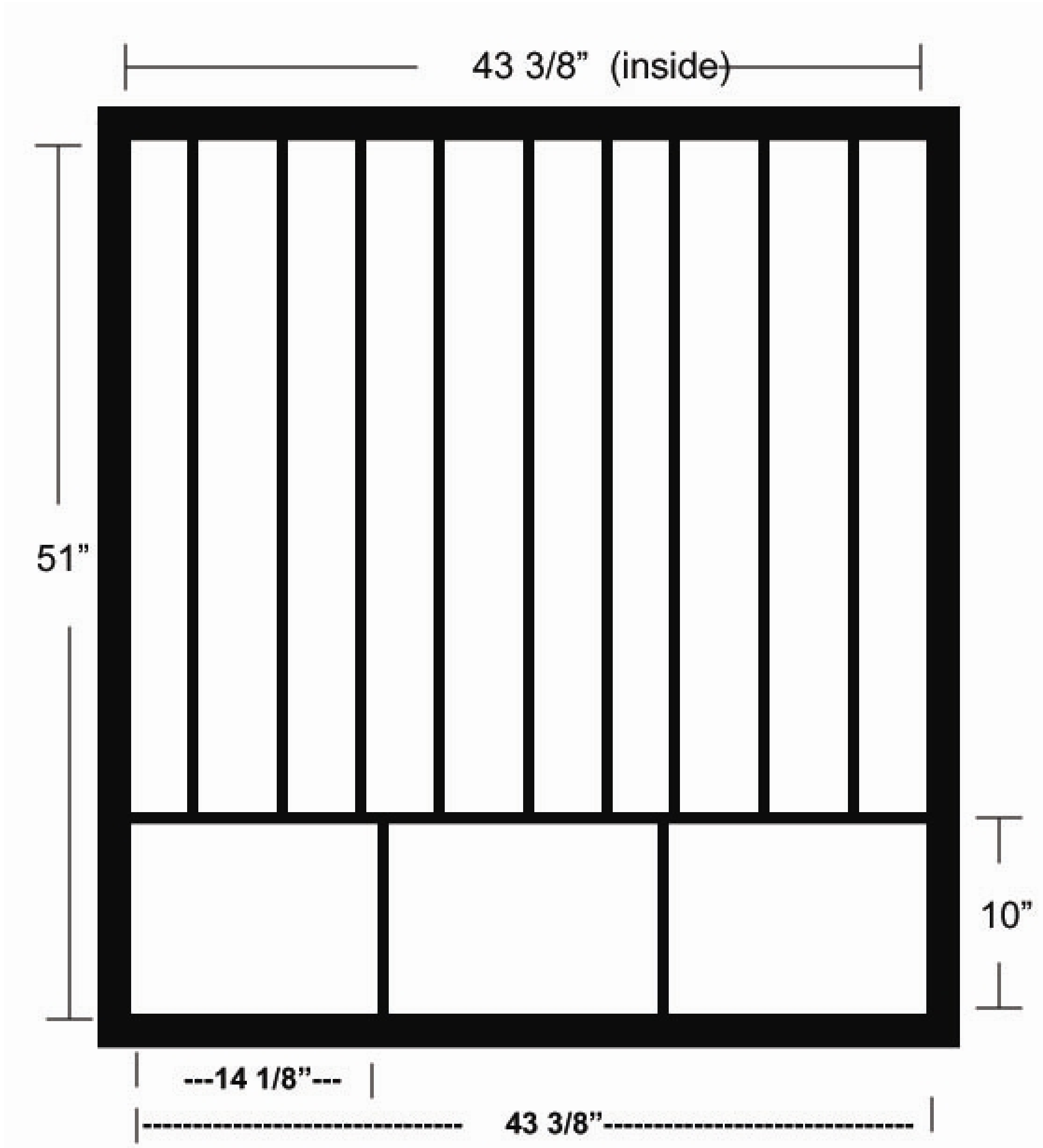

Figure 2. Chart showing the locations of the starting points of all tows conducted during trip #s 2, 4, 5, and 6 of this study.

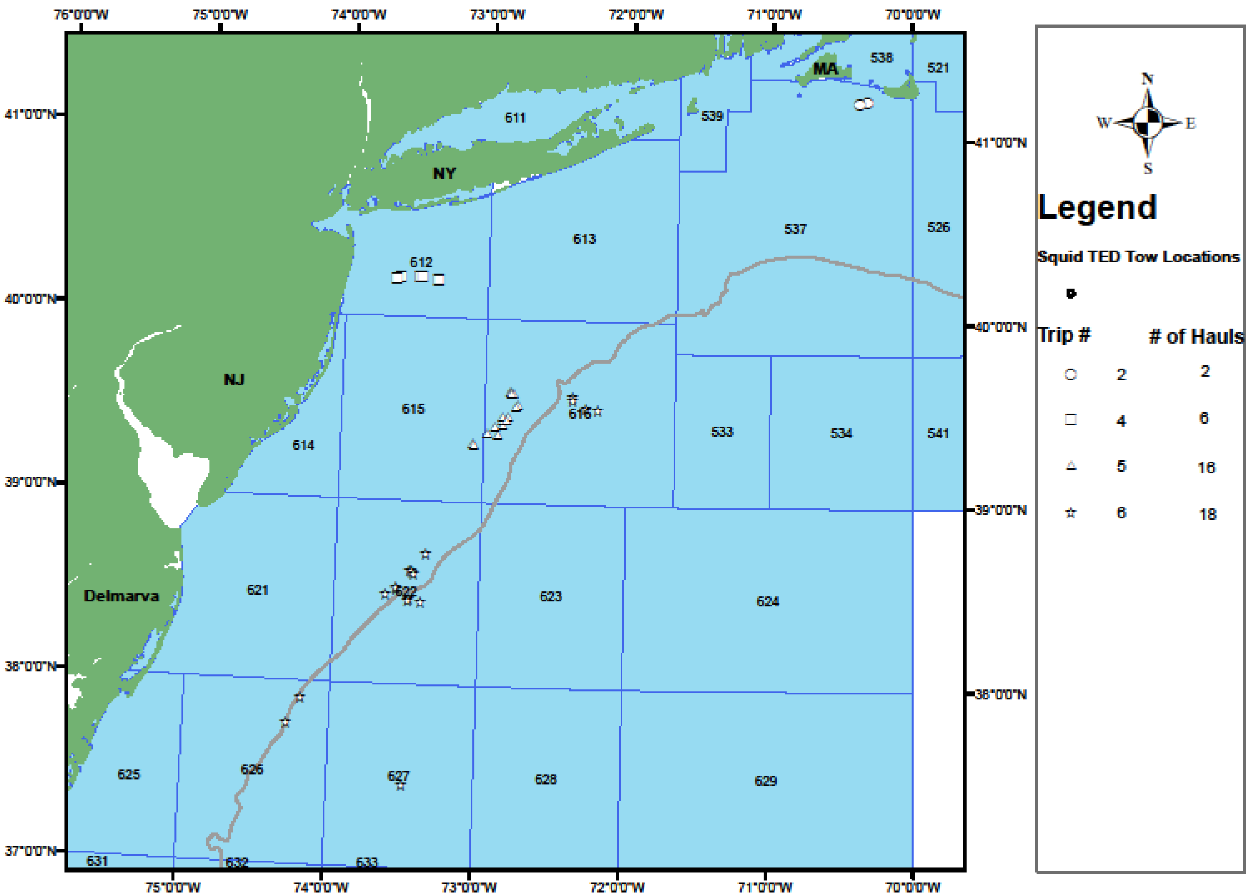

Figure 2. Length-frequency distribution for squid for the entire study. Lengths are mantle lengths in centimeters.

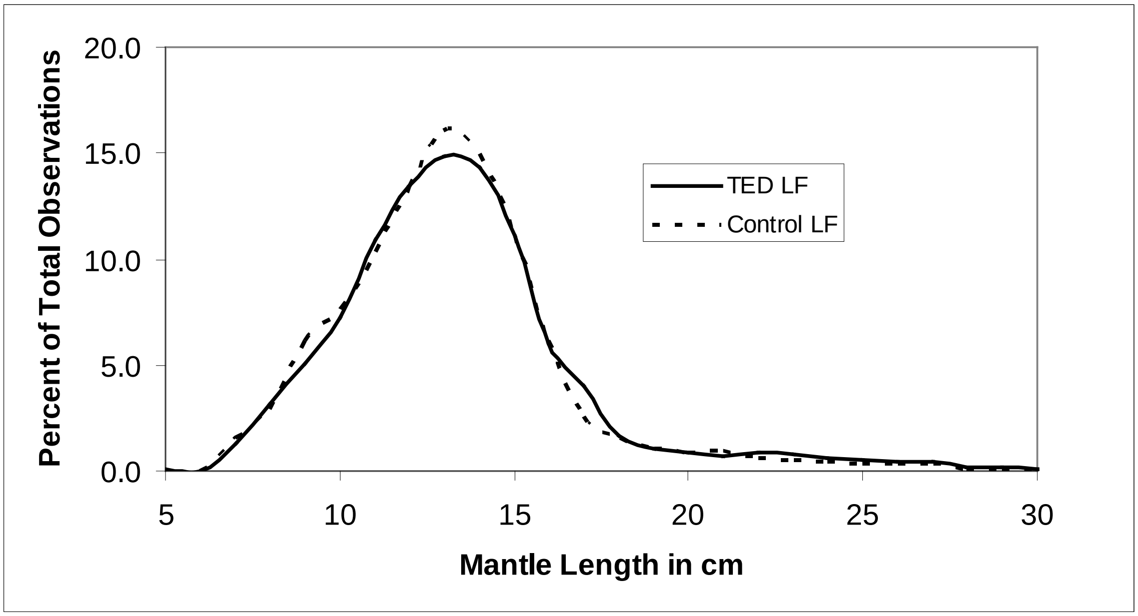

Table 1. Latitude and longitude (degrees. minutes. hundredths of a minute) of the starting locations of all control and experimental tows in trip #s 2, 4, 5, and 6.

Date	Trip	Haul	Time	Latitude	Longitude
14-Aug-09	2	1	640	41.10.62	70.19.36
14-Aug-09	2	2	925	41.12.11	70.22.51
2-Sep-09	4	1	1420	40.13.08	73.29.19
2-Sep-09	4	2	1650	40.12.52	73.36.90
3-Sep-09	4	1	615	40.13.12	73.28.79
3-Sep-09	4	2	925	40.12.22	73.38.69
3-Sep-09	4	3	1200	40.13.09	73.28.22
3-Sep-09	4	4	1410	40.11.82	73.21.19
9-Oct-09	5	1	1600	39.21.80	72.54.24
9-Oct-09	5	2	1830	39.24.91	72.51.78
10-Oct-09	5	1	715	39.18.74	73.04.39
10-Oct-09	5	2	1048	39.24.55	72.55.35
10-Oct-09	5	3	1440	39.18.47	73.03.72
10-Oct-09	5	4	1705	39.22.41	72.58.40
11-Oct-09	5	1	855	39.26.79	72.52.29
11-Oct-09	5	2	1145	39.31.81	72.46.11
11-Oct-09	5	3	1430	39.27.68	72.51.86
11-Oct-09	5	4	1640	39.30.97	72.46.64
12-Oct-09	5	1	1150	39.36.23	72.48.84
12-Oct-09	5	2	1530	39.36.20	72.48.70
13-Oct-09	5	1	650	39.35.48	72.48.12
13-Oct-09	5	2	940	39.28.03	72.50.12
13-Oct-09	5	3	1240	39.35.47	72.48.56
13-Oct-09	5	4	1600	39.26.64	72.50.49
22-Oct-09	6	1	2245	38.36.80	73.29.02
22-Oct-09	6	2	300	38.28.75	73.37.98
22-Oct-09	6	3	1200	38.28.03	73.28.68
22-Oct-09	6	4	1540	38.26.57	73.23.63
23-Oct-09	6	1	2230	38.31.00	73.34.07
23-Oct-09	6	2	345	38.42.46	73.21.94
23-Oct-09	6	3	1140	38.35.93	73.27.51
23-Oct-09	6	4	900	38.30.89	73.34.27
23-Oct-09	6	5	1415	38.36.79	73.27.83
23-Oct-09	6	6	1910	38.36.11	73.27.14
24-Oct-09	6	1	930	37.54.38	74.11.61
24-Oct-09	6	2	1610	37.46.10	74.17.31
25-Oct-09	6	1	840	37.27.17	73.28.74
25-Oct-09	6	2	1205	38.27.30	73.28.85
26-Oct-09	6	1	730	39.34.67	72.23.16
26-Oct-09	6	2	1030	39.31.52	72.17.41
26-Oct-09	6	3	1330	39.33.72	72.23.19
26-Oct-09	6	4	1700	39.31.21	72.12.34

Table 2. Squid catch weights for trip #s 2, 4, 5, and 6 of the study. Catch weights are in kilograms. Ratio T/C is ratio of TED catch weight to Control catch weight.

trip	date	tow #	control wt	tow #	TED wt	Ratio (T/C)
2	14-Aug-09	1	137	2	66	0.48
4	2-Sep-09	1	1129	2	396	0.35
4	3-Sep-09	1	203	2	242	1.19
4	3-Sep-09	4	183	3	176	0.96
5	9-Oct-09	1	228	2	131	0.57
5	10-Oct-09	1	545	2	327	0.60
5	10-Oct-09	4	781	3	108	0.14
5	11-Oct-09	1	1292	2	442	0.34
5	11-Oct-09	4	908	3	545	0.60
		subtotal	5406		2433	0.45
5	12-Oct-09	1	356	2	475	1.33
5	13-Oct-09	2	255	1	707	2.77
5	13-Oct-09	3	525	4	493	0.94
6	22-Oct-09	1	620	2	1012	1.63
6	22-Oct-09	4	98	3	636	6.52
6	23-Oct-09	1	1160	2	514	0.44
6	23-Oct-09	3	182	4	149	0.82
6	23-Oct-09	5	464	6	240	0.52
6	24-Oct-09	2	278	1	392	1.41
6	25-Oct-09	1	1332	2	574	0.43
6	26-Oct-09	2	397	1	232	0.58
6	26-Oct-09	3	596	4	198	0.33
		subtotal	6262		5622	0.90

Table 3. Total catch weights for trip #s 2, 4, 5, and 6 of the study. Catch weights are in kilograms. Ratio T/C is ratio of TED catch weight to Control catch weight.

trip	date	tow #	control wt	tow #	TED wt	Ratio (T/C)
2	14-Aug-09	1	242	2	159	0.66
4	2-Sep-09	1	1365	2	579	0.42
4	3-Sep-09	1	496	2	369	0.74
4	3-Sep-09	4	268	3	196	0.73
5	9-Oct-09	1	296	2	405	1.37
5	10-Oct-09	1	640	2	507	0.79
5	10-Oct-09	4	886	3	124	0.14
5	11-Oct-09	1	1521	2	464	0.31
5	11-Oct-09	4	454	3	634	1.40
		subtotal	6168		3437	0.56
5	12-Oct-09	1	434	2	519	1.20
5	13-Oct-09	2	546	1	930	1.70
5	13-Oct-09	3	559	4	516	0.92
6	22-Oct-09	1	771	2	1182	1.53
6	22-Oct-09	4	611	3	1061	1.74
6	23-Oct-09	1	1826	2	774	0.42
6	23-Oct-09	3	196	4	188	0.96
6	23-Oct-09	5	492	6	529	1.08
6	24-Oct-09	2	596	1	433	0.73
6	25-Oct-09	1	1801	2	1683	0.93
6	26-Oct-09	2	712	1	460	0.65
6	26-Oct-09	3	1450	4	1016	0.70
		subtotal	9994		9291	0.93

Table 4. Non-target species catch weights for trip #s 2, 4, 5, 6 of the study. Catch weights are in kilograms. Ratio T/C is ratio of TED catch weight to Control catch weight.

trip	date	tow #	control wt	tow #	TED wt	Weight Ratio (T/C)
2	14-Aug-09	1	105	2	93	0.89
4	2-Sep-09	1	237	2	183	0.77
4	3-Sep-09	1	293	2	127	0.43
4	3-Sep-09	4	84	3	20	0.24
5	9-Oct-09	1	69	2	274	3.97
5	10-Oct-09	1	96	2	180	1.88
5	10-Oct-09	4	105	3	16	0.15
5	11-Oct-09	1	229	2	17	0.07
5	11-Oct-09	4	227	3	180	0.79
		subtotal	1445		1090	0.75
5	12-Oct-09	1	77	2	44	0.57
5	13-Oct-09	2	291	1	223	0.77
5	13-Oct-09	3	33	4	23	0.70
6	22-Oct-09	1	151	2	171	1.13
6	22-Oct-09	4	513	3	425	0.83
6	23-Oct-09	1	666	2	260	0.39
6	23-Oct-09	3	47	4	6	0.13
6	23-Oct-09	5	28	6	287	10.25
6	24-Oct-09	2	319	1	41	0.13
6	25-Oct-09	1	469	2	1108	2.36
6	26-Oct-09	2	314	1	228	0.73
6	26-Oct-09	3	854	4	818	0.96
		subtotal	3762		3634	0.97

Table 5. Catch weights of sea scallops, a non-target species, for trip #s 2, 4, 5, 6 of the study. Catch weights are in kilograms. Ratio T/C is ratio of TED catch weight to Control catch weight.

trip	date	tow #	control wt	tow #	TED wt	Ratio (T/C)
2	14-Aug-09	1	0	2	0	
4	2-Sep-09	1	52	2	84	1.62
4	3-Sep-09	1	84	2	66	0.79
4	3-Sep-09	4	42	3	0	0.00
5	9-Oct-09	1	0	2	182	
5	10-Oct-09	1	17	2	151	8.88
5	10-Oct-09	4	0	3	0	
5	11-Oct-09	1	146	2	177	1.21
5	11-Oct-09	4	169	3	177	1.05
		subtotal	510		837	1.64
5	12-Oct-09	1	0	2	0	
5	13-Oct-09	2	254	1	180	0.71
5	13-Oct-09	3	0	4	0	
6	22-Oct-09	1	0	2	0	
6	22-Oct-09	4	0	3	108	
6	23-Oct-09	1	102	2	35	0.34
6	23-Oct-09	3	8	4	0	0.00
6	23-Oct-09	5	0	6	0	
6	24-Oct-09	2	0	1	0	
6	25-Oct-09	1	0	2	0	
6	26-Oct-09	2	0	1	0	
6	26-Oct-09	3	0	4	0	
		subtotal	364		323	0.89

Table 6. Catch weights of spotted hake, a non-target species, for trip #s 2, 4, 5, 6 of the study. Catch weights are in kilograms. Ratio T/C is ratio of TED catch weight to Control catch weight.

trip	date	tow #	control wt	tow #	TED wt	Ratio (T/C)
2	14-Aug-09	1	0	2	0	0.00
4	2-Sep-09	1	0	2	0	0.00
4	3-Sep-09	1	0	2	0	0.00
4	3-Sep-09	4	0	3	0	0.00
5	9-Oct-09	1	0	2	0	0.00
5	10-Oct-09	1	0	2	0	0.00
5	10-Oct-09	4	0	3	0	0.00
5	11-Oct-09	1	0	2	0	0.00
5	11-Oct-09	4	0	3	0	0.00
		subtotal	0		0	0.00
5	12-Oct-09	1	0	2	0	0.00
5	13-Oct-09	2	0	1	0	0.00
5	13-Oct-09	3	0	4	0	0.00
6	22-Oct-09	1	38	2	219	5.76
6	22-Oct-09	4	0	3	0	0.00
6	23-Oct-09	1	409	2	459	1.12
6	23-Oct-09	3	0	4	0	0.00
6	23-Oct-09	5	0	6	242	0.00
6	24-Oct-09	2	4	1	0	0.00
6	25-Oct-09	1	22	2	101	4.59
6	26-Oct-09	2	660	1	176	0.27
6	26-Oct-09	3	0	4	772	0.00
		subtotal	1133		1969	1.74

Table 7. Catch weights of butterfish, a non-target species, for trip #s 2, 4, 5, 6 of the study. Catch weights are in kilograms. Ratio T/C is ratio of TED catch weight to Control catch weight.

trip	date	tow #	control wt	tow #	TED wt	Ratio (T/C)
2	14-Aug-09	1	22	2	7	0.32
4	2-Sep-09	1	23	2	21	0.91
4	3-Sep-09	1	6	2	9	1.50
4	3-Sep-09	4	2	3	57	28.50
5	9-Oct-09	1	0	2	55	
5	10-Oct-09	1	1	2	13	13.00
5	10-Oct-09	4	62	3	3	0.05
5	11-Oct-09	1	78	2	12	0.15
5	11-Oct-09	4	0	3	25	
		subtotal	194		202	1.04
5	12-Oct-09	1	27	2	11	0.41
5	13-Oct-09	2	2	1	0	0.00
5	13-Oct-09	3	14	4	13	0.93
6	22-Oct-09	1	93	2	32	0.34
6	22-Oct-09	4	0	3	259	
6	23-Oct-09	1	14	2	0	0.00
6	23-Oct-09	3	0	4	0	
6	23-Oct-09	5	0	6	13	
6	24-Oct-09	2	51	1	0	0.00
6	25-Oct-09	1	428	2	998	2.33
6	26-Oct-09	2	20	1	34	1.70
6	26-Oct-09	3	76	4	2	0.03
		subtotal	725		1362	1.88

Table 8. Summary of all T-test statistical analyses.

Category	Pre or Post Modification	Sample Size	T-test P-value	Significance α=0.05	Power
Squid	Pre	9	0.009	*	0.84
Squid	Post	12	0.331	-	0.11
Total catch	Pre	9	0.037	*	0.59
Total catch	Post	12	0.317	-	0.12
Total non-target catch	Pre	9	0.186	-	0.22
Total non-target catch	Post	12	0.444	-	0.07
Sea scallop	Pre	9	0.088	-	0.39
Sea scallop	Post	12	0.390	-	0.08
Butterfish	Pre	9	0.476	-	0.05
Butterfish	Post	12	0.169	-	0.24
Spotted hake	Pre	9	no data	no data	no data
Spotted hake	Post	12	0.214	-	0.20