REDUCING THE CAPTURE OF FLATFISH IN SMALL MESH BOTTOM TRAWLS USING A RECESSED SWEEP 30.5 CM (12 IN.) DROP CHAIN CONFIGURATION

Barbara Somers
Kathleen Castro

University of Rhode Island
Fisheries Center
East Farm- Building 83
Kingston, RI 02881

In Cooperation with:

Steve Arnold
F/V Elizabeth Helen
200 Blueberry Lane
West Kingston, RI 02892

Jonathan Knight
Superior Trawl
74 Table Rock Rd
South Kingstown, RI 02879

Christopher Brown
F/V Proud Mary
35 Erica Court
West Kingston, RI 02892

July 2011

URI FISHERIES CENTER TECHNICAL REPORT: 01-11

URI Fisheries Center

THE UNIVERSITY OF RHODE ISLAND

ACKNOWLEDGEMENTS

We would like to thank the captain and crew from the fishing vessels that conducted the field sampling. Their help was instrumental in the collection of the data. From the F/V *Proud Mary*: Christopher Brown (Captain), and Dean West. From the F/V *Elizabeth Helen:* Steve Arnold (Captain) and Kevin Barber. We would like to acknowledge Jon Knight of Superior Trawl for the experimental net (MFN) design that allowed this research to be conducted.

Thanks also go to East West Technical Services (Karl Cygler, Mark Hager and Doug Brander) for their efforts in helping us collect data needed for the project and their flexibility in dealing with all the variability that comes with fisheries research.

We would like to thank Katherine Favreau from the University of Rhode Island (URI) , College of Environmental and Life Sciences (CELS) for her help with fiscal administration. In addition, we would like to recognize Chris Parkins from the University of Rhode Island Fisheries Center for creating the sampling area map.

Funding for this project was received as part of a Broad Agency Announcement from the National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS).

ABSTRACT

Several species of flatfish in the Southern New England (SNE) area have been assessed as overfished and in need of rebuilding. Many are targeted species in directed fisheries; others are bycatch/discard species, especially in the small mesh fishery in SNE for squid, (*Loligo pealeii*), butterfish (*Peprilus triacanthus*) and scup (*Stenotomus chrysops*); these species include summer (*Paralichthys dentatus*), winter (*Pseudopleuronectes americanus*), yellowtail (*Limanda ferruginea*) and windowpane (*Scophthalmus aquosus*) flounders. A modified fishing net (MFN) was designed using a standard bottom trawl squid net (SFN) with the addition of 30.5 cm (12 inch) extensions to the headrope and a 30.5 cm (12 inch) drop chain between the sweep and the footrope. This net was laboratory and field tested for its ability to reduce the capture of flatfish.

A total of 48 successful comparative paired tows (96 total tows) were completed. After checking for vessel effects, a paired t-test was used to test for differences between the combined mean weight (catch by species) per tow (in kilograms) of the SFN and MFN. Results show a significant difference between mean weights per tow for summer, winter, yellowtail, fourspot (*Paralichthys oblongus*) and windowpane flounders. There was no significant difference between mean weights captured by the SFN and MFN for all three potential target species. The findings of this research indicate the 30.5 cm (12 in.) drop chain trawl net design has the ability to reduce the capture of flatfish while retaining target species in the small mesh fishery of Southern New England.

INTRODUCTION

The small mesh trawl fishery occurs in the entire Northeast, USA and is of critical importance to the economic health of several USA commercial fisheries. It is a multi-species fishery that targets longfin squid (*Loligo pealeii*), butterfish (*Peprilus triacanthus*), scup (*Stenotomus chrysops*), mackerel (*Scomber scombrus*), and whiting (*Merluccius sp.*). Depending on target species, the fishery will use a mesh size codend that ranges from 5.4 cm (2.1 in) to 7.6 cm (3.0 in) (Milliken and DeAlteris, 2004). Bycatch of many species of flounder in addition to other commercial and non-commercial species have been documented (McKiernan & Pierce, 1995; Kennelly, 1995; Hendrickson and Jacobson, 2006). The inshore Loligo squid fishery is one of the few southern New England fisheries that do not close. Stricter regulations imposed on the Loligo squid fishery have included increased codend mesh size, annual total allowable catches (TACs) which have been partitioned into seasonal quotas since 2000, a moratorium on fishery permits and restricted fishing areas (MAFMC, 2010). Measures established by Amendment 10 to the Atlantic Mackerel, Squid and Butterfish (MSB) Fishery Management Plan (FMP) included a butterfish mortality cap program for the Loligo squid fishery and trip notification requirements. Although these measures may reduce overall bycatch, they have not helped to reduce the capture of flatfish (Pol, 2001).

This study focuses on the reduction of flatfish in the small mesh fishery. Flatfish species of interest include summer (*Paralichthys dentatus*), winter (*Pseudopleuronectes americanus*), yellowtail (*Limanda ferruginea*) and windowpane (*Scophthalmus aquosus*) flounders. The summer flounder stock is not overfished and overfishing is not occurring relative to the biological reference points established in the 2008 SAW 47 assessment (Terciero, 2010). The Groundfish Assessment Review Meeting (GARM III) report (2009) confirmed that Southern New England/Mid-Atlantic winter flounder is at very low biomass levels and is considered to be severely depleted. The current Interim Rule prohibits all possession of winter flounder in the SNE/MA stock area for federal commercial fishermen. Yellowtail flounder is considered to be overfished, with overfishing occurring based on the spawning stock biomass reference point. Gear restricted areas to protect the southernmost stocks of yellowtail are proposed in Amendment 16 of the New England Multispecies Fishery Management Plan. The Southern New England-Mid Atlantic yellowtail flounder stock is currently in a rebuilding plan with an end date of 2014. Discarding of windowpane flounders is the most important source of mortality for the assessment since it is usually not considered to be a commercially valuable species. However, the proposed rule for Amendment 16 to the NE Multispecies Fishery Management Plan prohibits landings of windowpane flounder. The basic impact of the research described in this report is to provide fishermen an alternative means of harvesting squid, butterfish and scup without impacting the flounder stocks.

One of the most important issues in fisheries management in the last two decades has been and continues to be bycatch and associated discard. Bycatch is the unintended capture of species of fish that is not the target and may be discarded back to sea based on regulatory requirements or low value (Harrington et al., 2005). Discarding is considered a threat to protected species, a waste of fisheries resources and it degrades the health of marine ecosystems. It has been demonstrated that decreasing the amount of bycatch in the Southern New England (SNE) small mesh trawl fishery can be accomplished using trawl modifications (Milliken and DeAlteris, 2004).

Conservation engineering research focuses on reducing both the bycatch of non-target species and undersized fish (Engås, 1994). Increasing effort has been directed to improve the selective performance of trawls. A trawl does not simply filter fish out of the sea passively; there is an interaction between the trawl and the fish (Main and Sangster, 1981; Thomsen, 1993). Reduction of the capture of undersized fish and smaller non-target species has been accomplished using mesh size regulations and more recently there has been expanded effort to develop species-selective trawl gears (Isaksen and Valdemarsen, 1994).

The modification of ground gears to increase trawl selectivity is a method that began to receive much attention in the 1990s. Most ground gear is designed to maintain contact with the seabed while safely passing over obstacles without causing damage. Experimental ground gear arrangements used in the small mesh silver hake (*Merluccius bilinearis*) fishery provided escape routes for flatfish by raising the net off the bottom (DeAlteris et al., 1996). A "raised footrope trawl" was introduced in the 1997 Southern Gulf of Maine experimental fishery (McKiernan et al., 1998) reducing bycatch in small-mesh whiting trawl fisheries. The raised footrope trawl fished 30-60 cm (1-2 feet) above the seafloor and caught primarily whiting, red hake, and dogfish. The modified sweep, which is separated from the footrope using drop chains, was the net's most innovative feature.

A change in gear design or fishing method can utilize behavior patterns to reduce the capture and discard of non-target species (Glass and Wardle 1995). As animals enter the trawl during the fishing operation, they exhibit species-specific behavior. Documented behavior patterns and proper design of trawl gear allows for separation of many species (Pol, 2001). The herding response of squid to trawls has been well documented (McKiernan & Pierce, 1995). Their endurance is considered limited; however burst swimming has been recorded for at least 5 minutes at 3 knots (Glass, 2000). Upon first detection of a net, the squid began to keep pace and appear to be distributed at the top and in the upper part of the sides of the net. For flatfish species, herding begins after direct or near contact with trawl doors, a chain sweep or sand cloud (Winger et al., 2004). Once disturbed, flatfish swim in the direction of the trawl path perpendicular to the advancing sweeps (Main and Sangster, 1981). Gear research indicates flatfish will swim short distances ahead of the sweep and then rest on the seabed floor (Ryer, 2008). This behavior is repeated as the mouth of the approaching net moves closer until the fish is overcome and captured (Ryer et al., 2010). Exploiting these behavior differences allows for the development of more selective trawls to separate the catch by species, possibly resulting in improved management of fish stocks (He et al., 2007; Wardle, 1993; Main and Sangster, 1981).

Initial testing of the modified net (MFN) design was required prior to the development of this research (Winger et al., 2006). Industry principal investigators designed and field tested the MFN prior to the development of this study. They utilized the flume tank facility at the Centre for Sustainable Aquatic Resources located at the Marine Institute of Memorial University of Newfoundland to make adjustments to the sweep design of a model net. The collaborative nature of this study makes it truly a success. Through collaboration between the fishing industry and the URI Fisheries Center, the project was developed and funded by the CRPP. The results presented herein are and outcome of this collaboration.

Project Goals and Objectives

The primary goal of this proposal is the reduction of mortality of summer, winter, yellowtail and windowpane flounders in the small mesh fishery through the use of gear that minimizes capture. The main objectives were:

(1) To test the effectiveness of a recessed sweep 12 inch drop chain on a small mesh net (MFN) on its ability to reduce the catches of summer flounder, winter flounder, yellowtail and windowpane flounders in the small mesh fisheries.
(2) To promote collaborative research directed by fishermen.

METHODS

Project Design

Field Methods

A catch characterization study was conducted by two commercial fishing vessels targeting squid using the "side-by-side" towing method comparing the SFN with the MFN. Side-by-side towing also referred to as parallel fishing, parallel tow technique, or parallel haul method, involves two boats fishing on the same ground at the same time, the only difference being the trawl design. Using the parallel haul method, the effects of the many uncontrolled variables inherent in the true alternate haul method are eliminated or greatly reduced (Wileman et al, 1996). These include towing direction, tide, wind speed, water depth, light levels or changes in stock composition and density.

The study was conducted aboard two commercial fishing vessels based in Point Judith, Rhode Island, USA. The F/V *Proud Mary* and the F/V *Elizabeth Helen* were approximately equal in length (17 m (55 ft)), horsepower (336 kW (450 hp)), and fishing capacity. The F/V *Proud Mary* used #8 Bison trawl doors, with dimensions (190 x 125 cm (75 x 49 in)) and weighing 325 kg

(715 lbs) each. The F/V *Elizabeth Helen* used # 63 Thyboron doors, with dimensions (171 x 104 cm (67 x 41 in)) and weighing 248 kg (545 lbs) each. These doors have been determined to have identical spread capability by net builders and trawl manufacturers (personal communication C. Brown).

Sampling was conducted in and around Block Island Sound and Rhode Island Sound (Figure 4). Eight fishing days were conducted in the summer of 2010 and 2011 (July 21, 22, August 4, 5, 16, 17, and 20, 2010 and May 5, 2011); six days were carried out in July and August in Block Island Sound, two days were completed in Rhode Island Sound in August 2010 and May 2011. A total of 96 paired comparison tows were completed and used for analysis for most species.

One attempt was made to collect video data on the MFN during the middle daylight hours. A Sony DCR-HC32 digital video camera mounted in underwater housing was positioned on top of the net looking back towards the footrope. Slack was added to the front of the camera rigging to allow it to face downward toward the modified sweep. Due to the amount of suspended sediments produced during trawling in sand and mud bottoms, visibility was extremely limited and no useful data was collected.

On each day of sampling, the two vessels towed side-by-side with one vessel towing the SFN and the other the MFN (Figure 3). Each fishing day consisted of six 40 minute tows. Vessels fished as close together as conditions permitted, never exceeding ½ mile apart. All tows began and ended at the same time, proceeding in the same directions and were coordinated and recorded by the vessels captains. Vessels alternated sides of towing within the fishing area to compensate for spatial effects. The amount of tow cable, and ground wire out for tows was identical for each vessel and was dependent on water depth in the area fished typically ranging from 50 to 75 fathoms (91 to 137 meters). Door spread data was calculated and monitored by the captains to verify that the doors were performing correctly. Nets were exchanged between vessels every 2 days and the nets were used an equal number of days on each vessel.

Data were recorded by observers on standard NMFS Observer logs. The information recorded for each comparative tow included position, time, depth, temperature and weather, as well as detailed catch data and length frequency data of flatfish. Total catch size (in kilograms) was determined prior to sampling. If necessary a sub-sample was taken with amounts being no less than 15% of the total catch of each species. All catch was sorted by species and total weights for species relevant to the research were recorded. For each tow, either all of the flatfish or a maximum of 100 fish were measured (to nearest cm). Flatfish species of interest were further subdivided into sublegal and legal fish prior to weighing and weights for each group was recorded. Each vessel had one observer or sea sampler onboard to weigh and measure fish.

Trawl Design

The standard squid trawl net (SFN) and the modified sweep drop chain trawl net (MFN) used for this research were both constructed by Superior Trawl, Narragansett, RI, USA. The nets were two seam squid nets with identical 362 x 12 cm (4.5 in) fishing circles and a hanging line length of 2900 cm (1142 in) (Figure 1). Both nets were constructed using 12 cm (4.75 in) polyethylene webbing (mesh). The headrope on each net was 26 m (86.5 ft) and the footrope was 29 m (95 ft). Vertical lift was achieved using approximately forty-eight 20 cm (8 in) center hole floats on the headrope. The groundline construction consisted of a 25 cm (10 inch) rubber cookie roller sweep with a 20 cm (8 in) roller sweep on the wings. 36.5 m (20 fm) ground cables were used during evaluation. The MFN is identical to the SFN except for the addition of a 30.5 cm (12 in) extension to the headrope (Figure 2a) and 30.5 cm (12 inch) drop chain between the sweep and footrope (Figure 2b).

Analysis

<u>Testing for vessel effect</u>

Tow data was entered into an Excel file and audited for quality assurance. To test for vessel effect, an indicator variable was created using the difference between the total catch weight per tow of the SFN and the MFN. The variable was then assigned to the vessel using the MFN on each fishing day. EH indicated the F/V Elizabeth Helen and PM indicated the F/V Proud Mary. A one way analysis of variance (ANOVA) with two levels and assuming unequal variance was performed on the differences to test for the mean effect for vessel (PROC GLM; SAS 9.2). The hypothesis tested was:

H_0: the mean of the difference in the catch weights per tow (of target and flatfish species) between vessels are the same, $\mu_{EH} = \mu_{PM}$.

H_A: the mean of the difference in the catch weights per tow (of target and flatfish species) between vessels are not the same, $\mu_{EH} \neq \mu_{PM}$.

<u>Catch comparison</u>

The parallel haul method has major advantages in analyzing catch differences between two nets, as it is possible to make paired comparisons. If vessel effect was non-significant, a paired *t*-test (PROC T-TEST; SAS 9.2) was conducted on the total weights of fish per tow to compare the effect of the SFN and the MFN on target species retention and the reduction of bycatch (Madsen et al., 2006). The paired *t*-test does not have the normality and equality of variances assumptions of the two-sample *t*-test. The assumptions for the test are that each pair of measurements is independent of other pairs and that differences are normally distributed (Zar, 1999). By considering the paired sample t-test to be a one sample t-test for a sample of difference, dj, it may be employed as a standard procedure for determining minimum detectable difference between the means (Zar 1999). Only paired tows with at least one fish present in either net was included. A significance level of α=0.05 was used for all statistical tests. For the target species, loligo squid, butterfish and scup in which we would expect there to be no difference in catch between the SFN and the MFN a two-tailed t-test was performed. The null hypothesis is:

H_0: the difference in catch weight between nets for target species is zero, $\mu_d = 0$

H_A: the difference in catch weight between nets for target species is not zero, $\mu_d \neq 0$

For the bycatch species, flatfish, we expect there to be a lower catch in the MFN, therefore a one-tailed t-test was utilized and the null hypothesis is:

H_0: catch weight for flatfish is reduced in the modified fishing net, $\mu_d > 0$

H_A: catch weight for flatfish is not reduced in the modified fishing net, $\mu_d \leq 0$

Length-frequency distribution

An independent *t*-test was used to compare mean length between the SFN and the MFN for each flatfish species measured not showing a vessel effect. The independent *t*-test is used to test for a difference between two independent groups on the means of a continuous variable (Hatcher, 2003). SAS 9.2 was used to conduct the *t*-test and the hypothesis tested was:

H_0: the mean size in the SFN and MFN is the same, $\mu_{SFN} = \mu_{MFN}$.

H_A: the mean size in the SFN and MFN is not the same, $\mu_{SFN} \neq \mu_{MFN}$.

To determine if the two nets had different size selectivity characteristics, catches at length for flatfish species were evaluated using a Kolmogorov-Smirnov (K-S) two-sample test (PROC NPAR1WAY; SAS 9.2). This would determine if statistically significant differences are evident. Application of the K-S test assumes that both nets encountered the same size distribution of fish. It can be used in testing gear selectivity in paired tow experiments where this assumption is reasonable. A significance level of α=0.05 was used for all statistical tests. The hypothesis tested was:

H_0: the length-frequency distributions of flatfish species in the SFN and MFN are the same.

H_A: the length-frequency distributions of flatfish species in the SFN and MFN are not the same.

Power analysis

If results of catch comparisons were non-significant and the null hypothesis was accepted, a power analysis was conducted using GPower (Buchner et al., 1997). Post-hoc power analysis is the retrospective power of an observed effect based on the sample size and parameter estimates derived from a given data set. Although power analysis in experimental design is generally accepted, the effectiveness of retrospective techniques is controversial (Hoenig and Heisey, 2001). GPower determined the effect size using the mean and the standard deviation of the differences in catch per tow between the nets for each of the target species of squid, butterfish and scup. This estimated the probability of making a Type II error, which is falsely accepting H_0 when there is in fact a difference. Using a α error probability of 0.05, the power or 1-β error probability (falsely accepting H_0) was calculated.

RESULTS

The total weight of all species captured was 17663 and 7640 kg in the SFN and the MFN respectively (Table 1). The SFN caught 31 different species while the MFN caught 30. For the SFN approximately 52 % of the catch was comprised of butterfish and skate which constituted 23.0 and 29.7 % respectively. Butterfish was the dominant species in the MFN which comprised 44.9 % of the total catch.

Vessel Effect

The results of the one way analysis of variance (ANOVA) to determine if a vessel effect was present is summarized in Table 2. Vessel effect was tested for loligo squid, scup and butterfish as well as summer, winter, windowpane, yellowtail, fourspot flounder and skate complex. It was determined that the weight of total catch of skate complex ($p<0.001$) was found to be affected by which vessel used the modified fishing net and therefore it was eliminated from further analysis. Vessel effect was not a factor for loligo squid ($p=0.140$), scup ($p=0.702$), butterfish ($p=0.820$), summer flounder ($p= 0.317$), winter flounder ($p=0.121$), windowpane flounder ($p=0.244$), yellowtail flounder ($p=0.093$) and fourspot flounder ($p=0.124$).

Catch Comparison

The catch weight per tow data for the paired tows of the two nets are presented in Tables 3-5 for total catch, summer, winter, yellowtail, windowpane, fourspot flounder, skate complex, and target species, respectively. All species of concern are reported. The results of further statistical analyses performed on species showing a non-significant effect for vessel are summarized in Table 6. A major bycatch species throughout the study were skates and rays (Rajiformes and Myliobatiformes). They were caught on every tow, and were subsequently treated as one complex.

The total catch data for all tows is reported in Table 3, and the results of the statistical analyses are summarized in Table 6. The mean total catch weight per tow for the combined 96 paired tows conducted aboard both vessels was 367 kg (809 lbs.) for the SFN and 159 kg (350 lbs.) for the MFN. Results of the *t*-test shows that the two nets differ in weight of total catch ($p= < 0.001$).

The flatfish catch data for all tows is presented in Table 4, shown in Figure 5a, and the results of the statistical analyses are summarized in Table 6. Summer flounder were present in 78 of the 96 tows that were conducted. There was a significant difference in the weight of catch of summer flounder for a one-tailed test when using non-zero tows ($p= <0.001$). Mean catch weight per tow for windowpane flounder for the combined 78 paired tows was quite low. However, the results of the one-tailed *t*-test indicate a significant difference between the catch performance of the two nets ($p= < 0.001$). Winter flounder was present in 90 of the 96 tows. Mean catches per tow were higher than other flatfish species and the results of the one-tailed *t*-test indicated a significant difference between the catch performance of the two nets ($p= <0.001$). Yellowtail and fourspot flounder were present in less tows that all other flatfish species (24 and 56 tows respectively). The results of the one-tailed *t*-test indicated a significant difference between the catch performance of the two nets for both yellowtail ($p= 0.020$) and fourspot flounder (<0.001).

The target species catch data (squid, butterfish and scup) for all tows is reported in Table 5, shown in Figure 5b and the results of the statistical analyses are summarized in Table 6. Mean catches of squid per tow were relatively low although there was squid in 94 of the 96 total tows. The results of the two-tailed paired *t*-test indicated no significant difference between the catch performance of the two nets ($p=0.090$). Butterfish exhibited no significant difference in catch weight between nets for all tows combined ($p=0.210$). Scup was present in only 48 of the 96 tows however mean catch per tow was considered average and the results of the two-tailed paired *t*-test indicated no significant difference between the catch performance of the two trawls ($p=0.387$). Figure 6 represents the tow by tow catch data for the SFN compared to the MFN. Data points below the red line represent a higher catch by the SFN and data points above the red line represent a greater catch by the MFN.

Length Frequency Distribution

A total of 6134 flatfish were measured, 4237 in the SFN and 1897 in the MFN (Table 7). The length frequency graphs illustrate the length distributions observed in the SFN and MFN and are shown in Figures 7a, 7b, 7c and Figures 8a and 8b. The lengths of summer flounder ranged from 21-70 cm for the SFN (n=551) and 31-65 cm for the MFN (n=183). Windowpane flounder lengths ranged from 10-40 cm (n=752) and 16-45 cm (n=83) for the SFN and the MFN, respectively. The lengths of winter flounder ranged from 14-49 cm for the SFN (n=2741) and 14-46 cm for the MFN (n=1506). Yellowtail flounder lengths ranged from 21-50 cm for the SFN (n=73) and 26-45 cm for the MFN (n=50). The lengths of fourspot flounder ranged from 23-50 cm for the SFN (n=120) and 26-45 cm for the MFN (n=75). The results of the *t*-test for the mean lengths indicated no significant difference for all the species of flatfish. A Kolmogorov-Smirnov test indicated no significant difference between the length frequency distributions for the SFN and the MFN for summer flounder (p=0.992), winter flounder (p=0.151), yellowtail flounder (p=0.534) and fourspot flounder (p=0.651), however there was a significant difference in the distributions of windowpane flounder (p=0.041) (Table 7).

Power Analyses

The post hoc power analysis results are reported in Table 6. The calculated effect sizes determined using the mean and standard deviation for the differences between the SFN and the MFN used for this assessment were as follows: squid (f2 = 0.363) butterfish (f 2 = 0.311), and scup (f 2 = 0.06). The alpha level used for this analysis was $p < .05$. The post hoc analyses revealed the statistical power for this study was 0.75 for squid and 0.65 for butterfish whereas the power for scup was 0.21.

DISCUSSION

This study relied on industry developed concepts for a reduction of discard mortality supported by scientific field work and data analysis. Industry members are currently using this gear voluntarily and are finding it highly effective in allowing them to avoid or target certain species. The directed nature of this selective gear allows for increased profitability for fishermen and can provide a higher quality of product to the consumer. Fishermen can maximize their catch, avoid bycatch, and in turn delay early closures in certain fisheries. The selective gear also allows them to fish closer to home and avoid the high fuel costs associated with trying to avoid stocks that are inshore at different times of the year. It is also reasonable to say that other members in the industry are benefiting from this change in fishing behavior because there is less likelihood of a market glut.

The cost of fitting a standard squid net with the drop chain design is minimal (personal communication S. Arnold). If fitted by the net designer, the one-time cost is an additional $400 which can easily be offset by economic benefit of selective fishing. Cost is less if the fisherman outfits the net himself with existing materials he already owns. There are no modifications necessary to the fishing vessel to accommodate this design.

The ability of the MFN to reduce the capture of flatfish is clearly demonstrated in the mean catch per tow (CPT) of flatfish captured by the SFN and MFN. For summer, windowpane, winter, yellowtail and fourspot flounder and there was a significant difference in catch weight between the SFN and MFN (Table 6). The difference in the catch composition of the two nets is also demonstrated in Figure 6. For all flatfish species the MFN captured significantly less than the SFN. For the target species of squid, butterfish and scup, the catch composition of the two nets is not significantly different. The importance of reducing the catch of flounder relates to the status of several of the stocks which are overfished and experiencing overfishing (Mayo and Terceiro 2005).

The significant difference in the size range of windowpane flounder caught in the SFN and the MFN should be noted (Table 7). While the SFN captured windowpane flounder that ranged from 10-40 cm, the MFN did not capture flounder smaller than 16 cm and the overall length-frequency distribution for the net shifted to the right (Table 7). This indicates that the MFN has the potential to reduce the harvest of juveniles. Increased populations of juvenile flatfish can possibly contribute to the rebuilding of the stocks. A behavioral difference between juvenile and adult windowpane flounder may contribute to the difference in catch. The MFN may also reduce the overall number of discarded windowpane flounder.

Despite a significant vessel effect for the skate complex, which eliminated it from the analysis, the catch composition between nets for other species of interest showed the modified sweep design to be effective (Figure 5). It is important to note that the elimination of the data due to vessel effect was most likely due to the low overall abundance of skate on August 4 and 5th (Table 4). On the days in question, the MFN did demonstrate the correct behavior regarding flatfish and groundfish, however it did not allow for an accurate representation of the escapement properties of the MFN for analysis purposes. Increased sampling could potentially correct the need to eliminate this species.

When comparing gear catch characteristics, an important component is the gears ability to maintain the catch of target species. Analysis of the performance of the SFN and the MFN showed that there was no significant difference in the total catch of squid ($p = 0.090$), butterfish ($p = 0.210$) or scup ($p = 0.387$). The post hoc power analysis performed on the differences in catch per tow between the SFN and the MFN for the target species revealed a more than adequate power to support H_0 for both squid and butterfish and safely assume that there is no effect on catch of the target species based on the type of net used (Table 6). There was less than adequate statistical power to support H_0 for scup and it can be assumed that there may be an effect on catch of target species based on net (Table 6).

Using this design in the small mesh fishery targeting squid provided an understanding into the specific reaction behavior of target and non-target species (Glass, 2000). It has been demonstrated by numerous studies that bottom disturbance by the sweep is a primary stimulus influencing flatfish escapement behavior in the trawl mouth, and can be used effectively for selectivity purposes (Ryer, 2008). The design of this net exploits behavioral differences and gear modifications to effectively separate flatfish from other catch prior to capture, reducing the impact of discard mortality and unwanted bycatch.

<u>Management implications</u>

The commercial fishing industry has already designed avoidance gear that will improve fishing practices and help fishermen fish more selectively; selective harvesting approaches will contribute to the rebuilding of fish stocks. The concept behind this research was simple; this net design allowed fishermen to catch what they wanted when they wanted. This was an industry based design voluntarily being used by fishermen to reduce bycatch and discard mortality. As Kennelly and Broadhurst (2002) have pointed out, integral to the success of any solutions that strive toward the goal of gear selectivity, is a corresponding improvement in the adoption of these methods by fishermen. Perhaps the lessoned learned from this research should be that it is not necessary to continually come up with mandated regulations to help manage fish stocks. Fishermen have the most invested in how fisheries are managed and in response have devised successful alternatives to traditional fishing gear that allow for the rebuilding and conservation of many species.

Conclusions

The primary goal of this research was to determine the functional performance of the recessed sweep 30.5 cm (12") drop chain sweep (MFN) as an effective tool to reduce flounder bycatch while maintaining target species capture in the small mesh fishery of Southern New England (SNE). The modified fishing net (MFN) successfully reduced the catch of flatfish species of concern which included summer flounder, winter flounder yellowtail flounder, and windowpane flounder. If the MFN continues to prove successful in separating target and non-target species, the same strategy might be applied to similar species in larger mesh fisheries. Because the MFN focuses on the front end of the net, it may have a wider application than simply the small mesh squid fishery. Future discussions regarding this modified design should include evaluating a mesh management alternative by utilizing a 30.5 cm (12") drop chain sweep. There is a need for proven methods, which will work within multiple fisheries.

The work conducted could be considered the basis for future pre-emptive research into the problem of both bycatch reduction and discard mortality. This net design allows the fishing industry the opportunity to evaluate fishing methods that avoid several flounder species and could be more widely adopted on a voluntary or required basis being easily retrofitted to pre-existing gear. This successful net design has demonstrated that it will not reduce the harvest of target species to levels below economic viability in the small mesh fishery. It is of critical importance to design avoidance gear adaptations that do not drastically impact fishermen economically.

REFERENCES

Buchner, A., Erdfelder, E., & Faul, F. (1997). How to Use G*Power [WWW document]. URL http://www.psycho.uniduesseldorf.de/aap/projects/gpower/how_to_use_gpower.html. Accessed March 30, 2011.

Dealteris, J., Milliken, H., and D. Morse. 1996. Bycatch reduction in the Northwest Atlantic small-mesh bottom trawl fishery for silver hake (*Merluccius bilinearis*). World Fishery Congress (2nd: l996: Brisbane, Qld). In: Developing and Sustaining the World's Fisheries Resources: The State of Science and Management: 2nd World Fisheries Congress Proceedings.

Engås, A. 1994. The effects of trawl performance and fish behaviour on the catching efficiency of demersal sampling trawls. In: Fernö, A. and S. Olsen. (Eds.), Marine Fish Behaviour in Capture and Abundance Estimation. Fishing News Books, London, pp. 45–68.

Glass, C. W., 2000. Conservation of fish stocks through bycatch reduction: A Review: Northeastern Naturalist **7(4)**: 395-410.

Glass, C.W., and C.S. Wardle. 1995. Studies on the use of visual stimuli to control fish escape from codends. II. The effect of a black tunnel on the reaction behaviour of fish in otter trawl codends. Fisheries Research **23**: 165-174.

Harrington, J.M., R.A. Myers, and A.A. Rosenberg. 2005. Wasted fishery resources: discarded by-catch in the USA. Fish and Fisheries **6(4)**: 350-362.

Hatcher, L., 2003. Step-by-step Basic Statistics Using SAS: Student Guide. SAS Institute, Inc., Cary, NC.

He, P., D. Goethel, and T. Smith. 2007. Design and test of a topless shrimp trawl to reduce pelagic fish bycatch in the Gulf of Maine pink shrimp fishery. Journal. of Northwest Atlantic. Fishery Science **38**:13–21.

Hendrickson, L. and L. Jacobson. 2006. Status of fishery resources off the Northeastern US – Longfin inshore squid. December 2006. Northeast Fisheries Science Center Resource Evaluation and Assessment Division. Accessed March 20, 2011: URL: http://www.nefsc.noaa.gov/sos/spsyn/iv/lfsquid/

Hoenig, J.M. and Heisey, D.M. (2001). The abuse of power: The pervasive fallacy of power calculations for data analysis. The American Statistician **55-1**: 19-24.

Isaksen, B. and J.W. Valdemarsen. 1994. Bycatch reduction in trawls by utilizing behaviour differences. In: Fernö, A. and S. Olsen (Eds.), Marine Fish Behaviour in Capture and Abundance Estimation. Fishing News Books, London, pp. 69–83.

Kennelly S.J., M.K. Broadhurst. 2002. Bycatch begone: Changes in the philosophy of fishing technology. Fish and Fisheries. Vol. 3, pp 340-355.

Kennelly, S.J. (1995) The issue of bycatch in Australia's demersal trawl fisheries. Reviews in Fish Biology and Fisheries **5**:213–234

Madsen, N., Tschernij, V., Hansen, K., and Larsson, P.O. 2006. Development and testing of a species selective flatfish otter trawl to reduce cod bycatch. Fisheries Research **78**, pp 298-308.

MAFMC 2010. Summer Flounder Stock Assessment Update. http://www.mafmc.org/fmp/Summer_Flounder_Things_to_Know_July_2010.pdf. Accessed Septmber 4, 2010.

Main, J. and G.I. Sangster. 1981. A study of the fish capture process in a bottom trawl by direct observations from a towed underwater vehicle. Scottish Fisheries Research Report No. 23.

Mayo and Terceiro, 2005 Mayo, R.K., Terceiro, M. (Eds.). 2005. Assessment of 19 Northeast groundfish stocks through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15–19 August 2005. US Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc. 05-13; 499 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

McKiernan, D.J. and S.E. Pierce. 1995. Loligo squid fishery in Nantucket & Vineyard Sounds. Massachusetts Division of Marine Fisheries. Internal Report.

McKiernan, D.J. R. Johnston, B. Hoffman, H. A. Carr, H.O. Milliken and D. McCarron. 1998. 1998 Southern Gulf of Maine Raised Footrope Trawl in the Whiting Fishery. Comm. Of Mass Div. Mar. Fish. 30 pp.

Milliken, H. O. and J. T. DeAlteris. 2004. Evaluation of a large-mesh panel to reduce the flatfish bycatch in the small-mesh bottom trawls used in the New England silver hake fishery. North American Journal of Fisheries Management **24(1):**20-32.

NEFSC (Northeast Fisheries Science Center) 2010. http://www.nefsc.noaa.gov/fsb/Manuals/JANUARY%202010%20MANUALS/NEFOPM_010110_BOOKMARKS_LONG1.pdf. Accessed November 25, 2010.

Pol, M.V. 2001. Effects of trawl net modifications during the 2000 Nantucket Sound squid fishery. Mass. Div. Mar. Fish. Cons. Eng. Rep. 21 pp.

Ryer, C. H. 2008. A review of flatfish behavior relative to trawls. Fisheries Research. **90:**138–246.

Ryer, C.H., Rose, C.S and P.J. Iseri. 2010. Flatfish herding behavior in response to trawl sweeps: a comparison of diel responses to conventional sweeps and elevated sweeps. Fisheries Bulletin **108**:145–154.

SAS 9.2. Statistical Analysis System, Release 9.2 for Windows, SAS Institute.

Terceiro, Mark 2010. Stock Assessment of Summer Flounder for 2010. Northeast Fisheries Science Center Reference Document 10-14. http://www.nefsc.noaa.gov/publications/crd/crd1014/crd1014.pdf. Accessed September 7, 2010.

Thomsen, B. 1993. Selective flatfish trawling. Pages 161-164 In C. S. Wardle and C. E. Hollingworth (eds). Fish Behaviour in Relation to Fishing Operations. ICES Marine Science Symposia 196. 215 pp.

Wardle, C.S. 1993. Fish behavior and fishing gear. In: T.J. Pitcher, Editor, Behaviour of Teleost Fishes, Chapman & Hall, London (1993), pp. 609–643.

Wileman, D. A., Ferro, R. S. T., Fonteyne, R., and Millar, R. B. 1996. Manual of methods of measuring the selectivity of towed fishing gears. ICES Cooperative Research Report. No. 215, Copenhagen. 126 pp.

Winger, P.D., Walsh, S.J., Pingguo, H., Brown, J.A., 2004. Simulating trawl herding in flatfish: the role of fish length in behaviour and swimming characteristics. ICES Journal of Marine Science **61**: 1179–1185.

Winger, P.D., H. DeLouche and G. Legge, 2006. Designing and testing new fishing gears: the value of a flume tank, Marine Technology Society Journal 40 (3): 44–49.

Zar, J.H. 1999. Biostatistical Analysis. 4th edition. Prentice Hall, New Jersey. pp 663.

Table 1. Total catch weights (kg) and percentages of all species for all trips combined.

	SFN		MFN	
Species	Total Weight	%	Total Weight	%
Alewife	0	0.00	1	0.01
American lobster	248	1.40	121	1.58
Atlantic Herring	114	0.65	66	0.86
Atlantic Mackerel	8	0.04	12	0.15
Barndoor Skate	21	0.12	0	0.00
Black sea bass	39	0.22	51	0.67
Blue crab	0	0.00	0	0.01
Bluefish	40	0.23	60	0.79
Butterfish	4063	23.00	3427	44.86
Cod	224	1.27	171	2.24
Fourspot Flounder	557	3.15	48	0.63
Grey Sole	0	0.00	0	0.00
Longfin Squid	590	3.34	480	6.28
Longhorn Sculpin	236	1.34	7	0.09
Monkfish	46	0.26	22	0.29
Ocean Pout	160	0.91	0	0.00
Red Hake	397	2.25	161	2.11
Scup	1587	8.98	1106	14.48
Sea Raven	32	0.18	3	0.04
Sea Robin	333	1.89	25	0.32
Sea Scallop	9	0.05	7	0.09
Silver Hake	801	4.53	560	7.33
Skate (uncl)	5243	29.68	179	2.34
Smooth Dogfish	54	0.30	26	0.35
Spiny Dogfish	24	0.14	134	1.75
Striped Bass	63	0.36	186	2.43
Summer Flounder	806	4.56	220	2.88
Tautog	17	0.10	8	0.11
Torpedo Ray	78	0.44	45	0.59
White Hake	148	0.84	25	0.33
Windowpane Flounder	259	1.47	58	0.76
Winter Flounder	1244	7.04	403	5.28
Witch Flounder	1	0.00	2	0.03
Yellowtail Flounder	222	1.26	25	0.33
Weight is in kilograms	17663	100.00	7640	100.00

Table 2. Summary of one way analysis of variance (ANOVA) to determine vessel effect.

Species	Mean Difference Elizabeth Helen(kg)	Mean Difference Proud Mary(kg)	Sample size (n)	p-value
Summer Flounder	18	13	23	0.317
Winter Flounder	28	19	23	0.121
Windowpane Flounder	4	3	23	0.244
Yellowtail Flounder	1	2	9	0.093
Fourspot Flounder	28	13	13	0.124
Skate Complex	197	57	28	<.001
Squid	1	4	30	0.140
Butterfish	20	14	30	0.820
Scup	1	12	13	0.702

Table 3. Total catch weight (kg) by date and tow number for SFN and MFN for the F/V Elizabeth Helen and F/V Proud Mary (July-August 2010, May 2011).

Date	Tow #	SFN	MFN
7/21/10	1	937	298
7/21/10	2	819	225
7/21/10	3	759	175
7/21/10	4	434	154
7/21/10	5	284	100
7/21/10	6	520	411
7/22/10	1	470	318
7/22/10	2	263	37
7/22/10	3	94	24
7/22/10	4	287	164
7/22/10	5	298	37
7/22/10	6	280	172
8/4/10	1	79	131
8/4/10	2	407	314
8/4/10	3	583	95
8/4/10	4	635	244
8/4/10	5	154	100
8/4/10	6	125	22
8/5/10	1	80	81
8/5/10	2	168	305
8/5/10	3	679	221
8/5/10	4	191	197
8/5/10	5	55	82
8/5/10	6	34	95
8/16/10	1	224	180
8/16/10	2	100	47
8/16/10	3	784	29
8/16/10	4	1085	213
8/16/10	5	650	57
8/17/10	1	453	224
8/17/10	2	317	251
8/17/10	3	267	342
8/17/10	4	353	254
8/17/10	5	77	167
8/17/10	6	318	228
8/20/10	1	170	269
8/20/10	2	572	528
8/20/10	3	155	101
8/20/10	4	142	82
8/20/10	5	167	35
8/20/10	6	545	133
5/5/11	1	498	60
5/5/11	2	472	96
5/5/11	3	393	177
5/5/11	4	414	9
5/5/11	5	523	92
5/5/11	6	350	62

Table 4. Flatfish and skate weight (kg) by date and tow number for SFN and MFN on the F/V Elizabeth Helen and F/V Proud Mary (July - August 2010, May 2011.)

Tow	Date	summer		winter		yellow		window		fourspot		skate	
		SFN	MFN	SFN	MFN	SFN	MFN	SFN	MFN	SFN	MFN	SFN	MFN
1	7/21/10	25	0	41	18	0	0	5	0	96	1	384	2
2	7/21/10	21	0	53	8	0	0	7	0	33	0	322	4
3	7/21/10	33	0	34	4	0	0	5	0	16	0	199	1
4	7/21/10	14	0	55	8	0	0	5	0	5	0	170	3
5	7/21/10	8	0	32	9	0	0	3	0	5	0	148	1
6	7/21/10	3	2	50	10	0	0	1	0	10	0	102	4
1	7/22/10	10	4	52	19	0	0	6	0	15	0	134	7
2	7/22/10	1	0	6	0	0	0	0	0	1	0	223	0
3	7/22/10	6	4	2	0	0	0	2	0	0	0	43	0
4	7/22/10	5	2	24	1	0	0	3	0	3	0	112	8
5	7/22/10	0	0	20	1	0	0	0	0	0	0	182	0
6	7/22/10	9	0	29	5	0	0	2	0	4	0	109	3
1	8/4/10	6	0	0	0	0	0	1	0	0	0	6	0
2	8/4/10	33	23	1	0	0	0	1	0	0	0	67	0
3	8/4/10	20	8	1	0	0	0	3	0	0	0	6	1
4	8/4/10	30	6	3	0	0	0	7	0	0	0	28	0
5	8/4/10	21	7	0	0	0	0	3	0	0	0	17	1
6	8/4/10	11	3	0	0	0	0	0	0	0	0	6	1
1	8/5/10	38	20	3	1	0	0	4	0	0	0	7	0
2	8/5/10	32	5	0	0	0	0	4	1	0	0	2	0
3	8/5/10	50	22	44	20	0	0	13	2	0	3	10	0
4	8/5/10	17	4	3	2	0	0	1	0	0	0	18	0
5	8/5/10	14	23	1	1	0	0	0	0	0	0	2	2
6	8/5/10	18	18	1	1	0	0	0	1	0	0	5	1
1	8/16/10	38	11	0	0	0	0	6	0	0	0	15	0
2	8/16/10	9	4	1	0	0	0	0	0	0	0	9	0
3	8/16/10	56	0	69	0	0	0	7	0	55	0	347	0
4	8/16/10	51	2	74	34	0	0	14	1	68	3	656	32
5	8/16/10	33	0	28	5	0	0	5	0	40	0	276	9
6	8/16/10	0	0	0	0	0	0	0	0	0	0	0	0
1	8/17/10	26	8	76	43	0	0	39	14	35	9	200	35
2	8/17/10	9	5	38	37	0	0	5	1	11	2	163	10
3	8/17/10	11	9	31	32	0	0	4	0	21	0	97	8
4	8/17/10	23	9	29	22	0	0	10	1	10	2	72	0
5	8/17/10	5	10	5	5	0	0	2	1	0	0	56	0
6	8/17/10	9	8	65	27	0	0	4	0	22	0	55	0
1	8/20/10	0	0	26	35	9	7	0	0	19	13	37	10
2	8/20/10	0	0	25	17	4	1	0	0	20	10	105	9
3	8/20/10	0	0	15	7	4	1	0	0	8	3	15	0
4	8/20/10	0	0	5	2	5	8	0	0	10	0	7	0
5	8/20/10	0	0	10	1	7	3	1	0	0	0	5	0
6	8/20/10	0	0	15	3	10	2	0	0	0	0	11	0
1	5/5/11	4	0	34	1	12	1	4	0	4	0	86	1
2	5/5/11	8	0	34	4	56	1	9	0	7	0	39	1
3	5/5/11	12	0	49	2	25	0	10	0	0	0	99	1
4	5/5/11	10	1	67	8	23	1	21	0	11	0	115	3
5	5/5/11	75	2	51	10	60	1	32	5	35	0	372	6
6	5/5/11	0	0	38	0	7	0	37	0	23	2	0	0

Table 5. Target species weight (kg) by date and tow number for the SFN and MFN on the F/V Elizabeth Helen and F/V Proud Mary (July-August 2010, May 2011).

Tow	Date	Squid		Butterfish		Scup	
		SFN	MFN	SFN	MFN	SFN	MFN
1	7/21/10	18	24	218	170	0	0
2	7/21/10	15	18	246	141	0	0
3	7/21/10	14	8	305	41	0	0
4	7/21/10	35	35	91	82	0	0
5	7/21/10	24	30	20	23	1	0
6	7/21/10	14	15	281	343	0	0
1	7/22/10	11	10	174	196	0	0
2	7/22/10	13	15	6	10	0	0
3	7/22/10	31	14	5	2	1	0
4	7/22/10	18	10	53	99	21	0
5	7/22/10	1	14	14	3	0	0
6	7/22/10	18	13	61	99	1	0
1	8/4/10	13	0	16	0	17	0
2	8/4/10	32	10	150	82	100	135
3	8/4/10	11	12	57	25	52	45
4	8/4/10	13	19	69	30	326	173
5	8/4/10	12	8	15	24	43	54
6	8/4/10	9	5	28	6	1	0
1	8/5/10	7	6	4	11	10	20
2	8/5/10	9	8	32	27	42	255
3	8/5/10	43	8	35	130	428	15
4	8/5/10	10	6	53	20	58	148
5	8/5/10	10	9	2	15	12	25
6	8/5/10	1	4	2	15	1	39
1	8/16/10	11	30	42	42	53	94
2	8/16/10	11	11	19	23	14	8
3	8/16/10	4	4	102	23	0	0
4	8/16/10	2	3	7	132	0	0
5	8/16/10	0	3	140	38	0	0
6	8/16/10	0	0	0	0	0	0
1	8/17/10	6	5	52	26	15	7
2	8/17/10	7	3	80	94	0	0
3	8/17/10	3	4	93	231	0	0
4	8/17/10	4	0	194	192	6	0
5	8/17/10	1	0	3	134	0	0
6	8/17/10	5	2	147	115	0	0
1	8/20/10	32	14	40	60	0	0
2	8/20/10	6	13	409	454	0	0
3	8/20/10	23	11	72	25	0	0
4	8/20/10	13	11	109	50	0	0
5	8/20/10	12	15	128	1	0	0
6	8/20/10	22	15	472	110	0	0
1	5/5/11	0	1	11	5	6	3
2	5/5/11	2	0	13	1	9	12
3	5/5/11	8	2	10	2	0	0
4	5/5/11	1	6	5	0	30	4
5	5/5/11	11	2	5	10	0	0
6	5/5/11	4	9	18	16	340	24

Table 6. Summary of mean catch per tow (CPT) in kg and p-value of *t*-tests for paired tows with the SFN and the MFN for the F/V Elizabeth Helen and the F/V Proud Mary. Power test results reported for target species.

Species	SFN Mean CPT	MFN Mean CPT	Sample Size	p-value	Power test
Total Catch	367	159	96	<0.001	-
Summer Flounder	17	5	78	<0.001	-
Windowpane Flounder	4	1	78	<0.001	-
Winter flounder	23	9	90	<0.001	-
Yellowtail flounder	7	4	24	0.020	-
Fourspot Flounder	21	2	56	<0.001	-
Skate Complex	105	4	92	<0.001	-
Target Species					
Squid	11	10	94	0.095	0.75
Butterfish	85	70	94	0.210	0.65
Scup	66	44	48	0.387	0.21

Table 7. Summary of length data in cm for flatfish measured including range, number measured (*n*), mean length (cm) and p-value for Kolmogorov – Smirnov (K-S) test.

Species	SFN Range	n	Mean Length	MFN Range	n	Mean Length	k-s test p-value
Summer Flounder	21-70	551	46	31-65	183	46	0.992
Windowpane Flounder	10-40	752	26	16-45	83	27	0.041*
Winter Flounder	14-49	2741	25	14-46	1506	25	0.151
Yellowtail Flounder	21-50	73	38	26-45	50	38	0.534
Fourspot Flounder	23-50	120	28	26-45	75	27	0.651

Figure 1. Net plan for standard two-seam bottom trawl squid net (SFN).

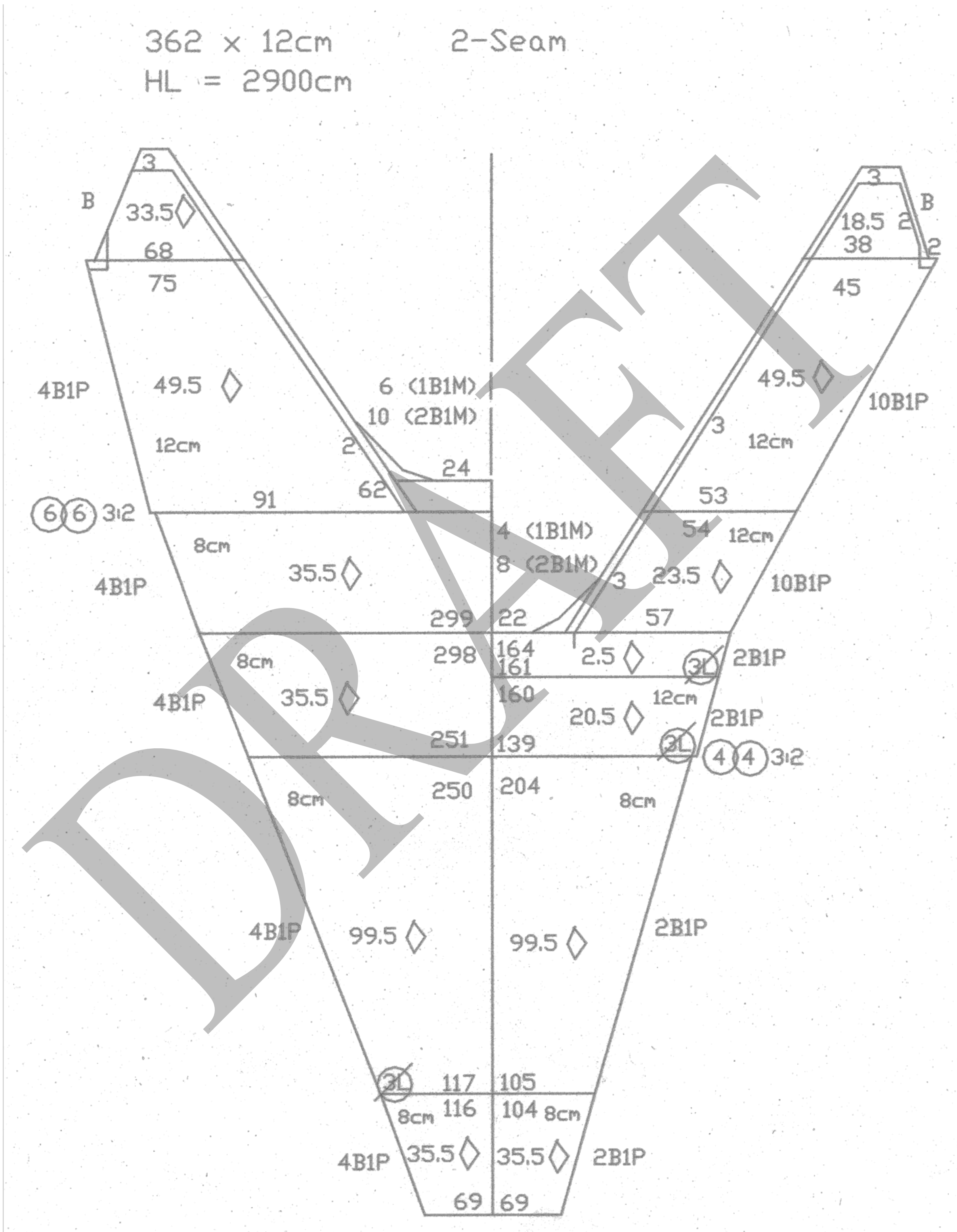


Figure 2. (a) 30.5 cm (12 in.) extensions added to model headrope (b) close up of drop chain configuration and (c) additional 15.2 cm (6 in.) center section of model sweep at flume tank.

(a)

(b)

(c)

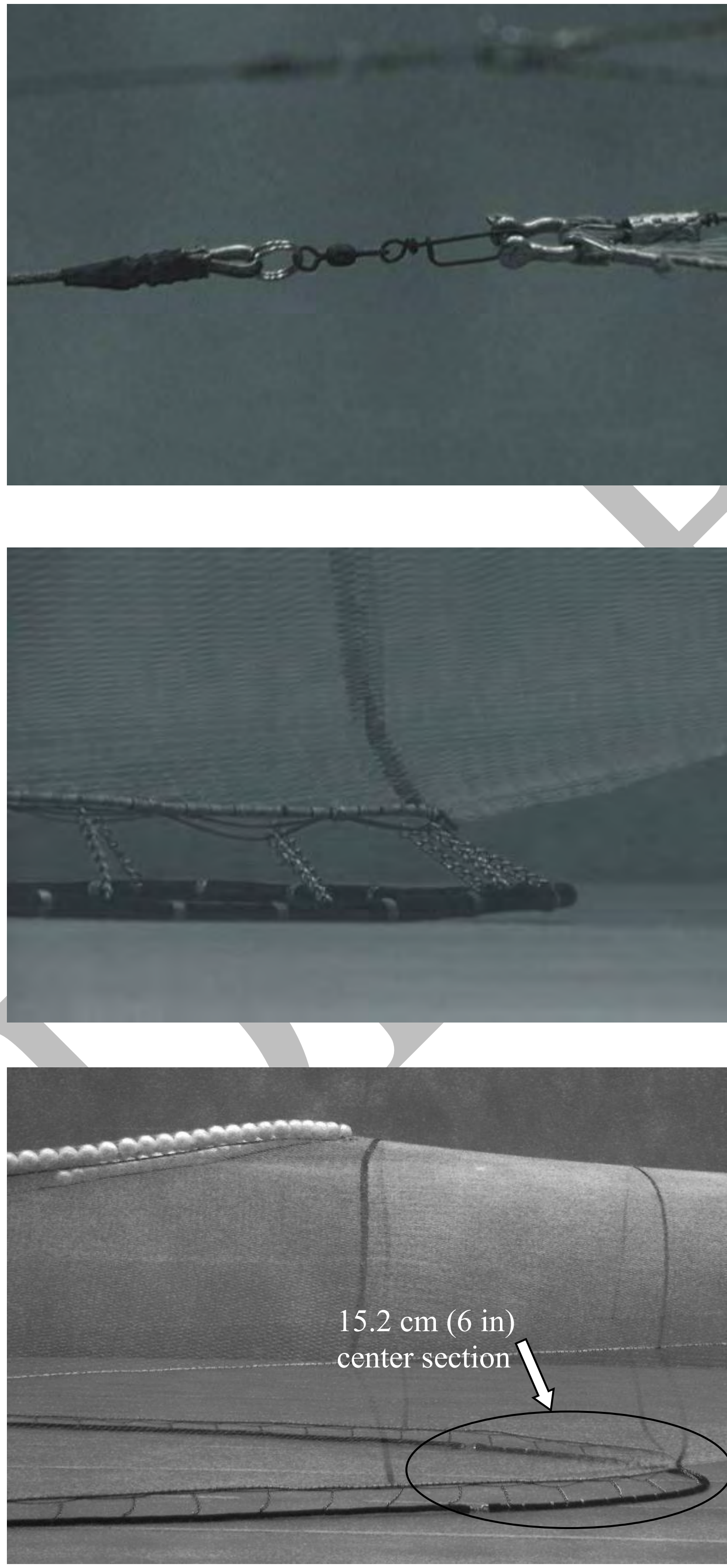


Figure 3. Photos of full scale MFN with (a) extensions on headrope and (b) 30.5 cm (12 in.) drop chains connected to footrope being deployed during field trials.

(a)

(b)

Figure 4. Map of Block Island and Rhode Island Sound, Rhode Island, USA. Tow locations are indicated by shape to represent each day of sampling.

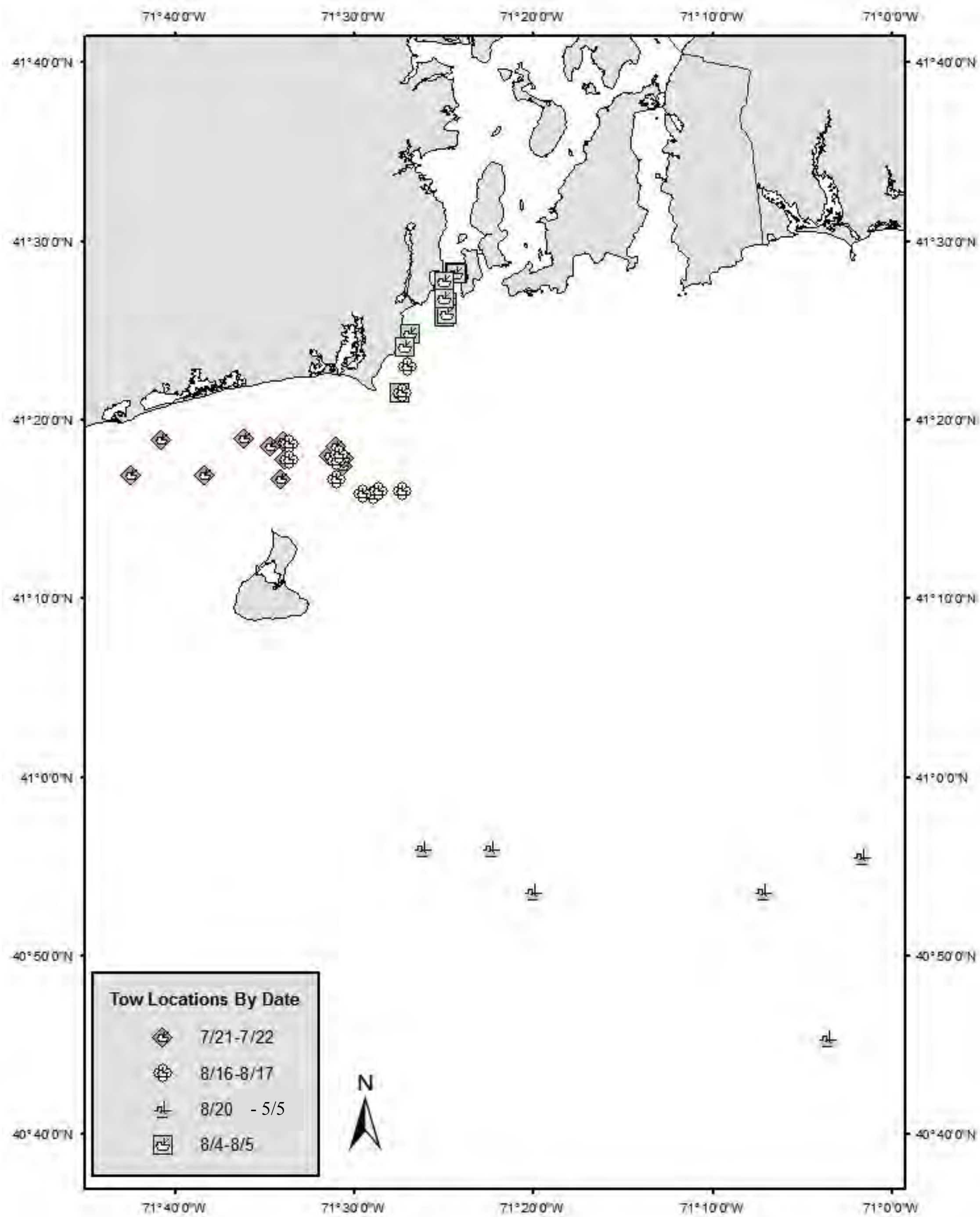
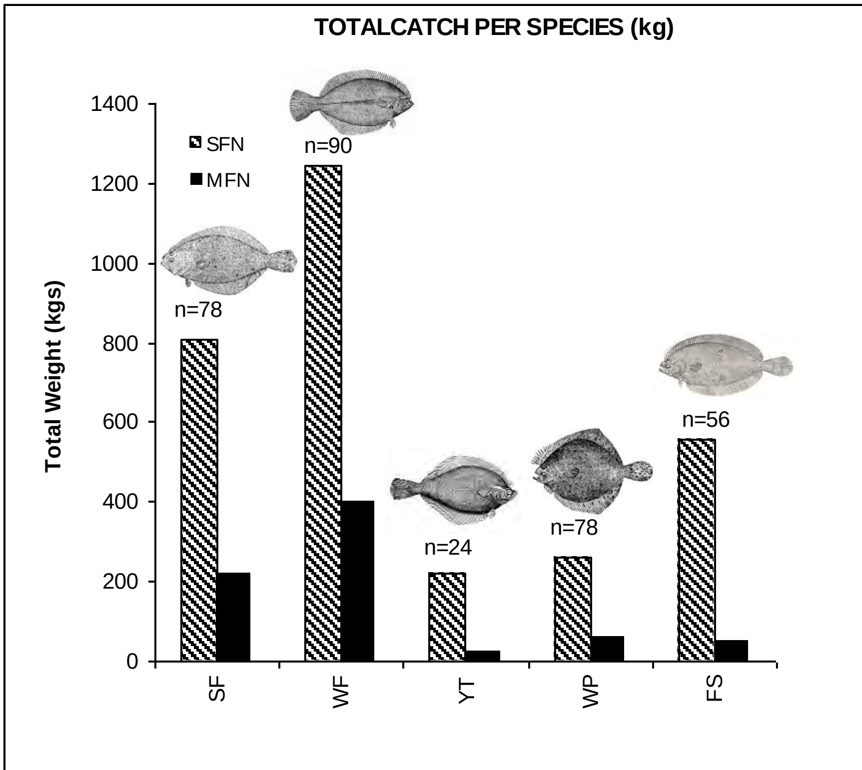


Figure 5. Total catch weight (kg) of (a) summer (SF), winter (WF), yellowtail (YT), windowpane (WP) and fourspot flounder (FS) and (b) target species for all tows combined for the standard fishing net (SFN) and modified fishing net (MFN).

(a)



(b)

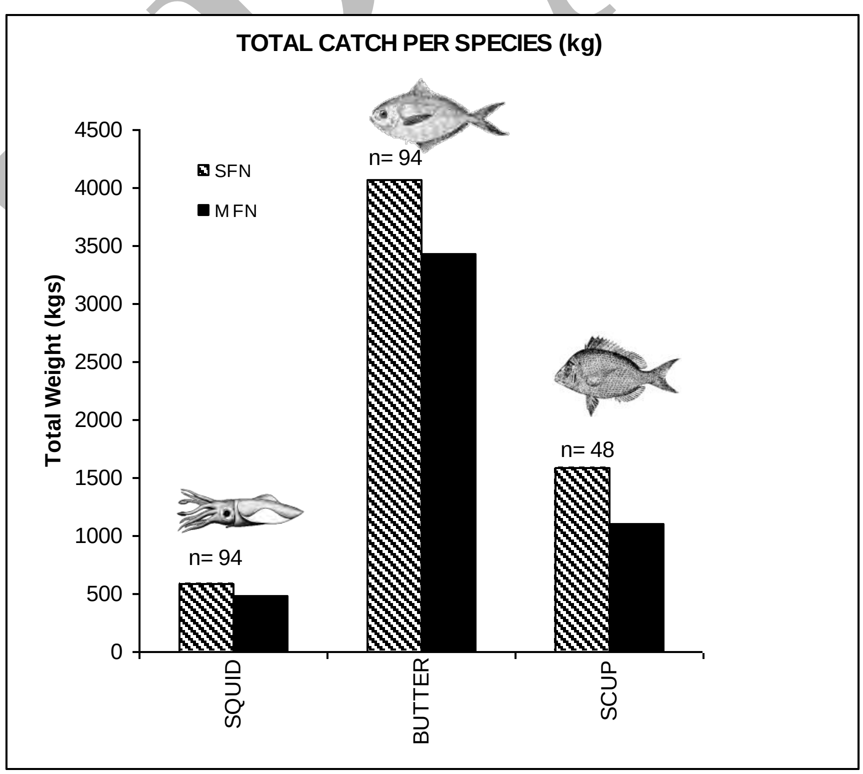


Figure 6. Graphical representations of tow by tow data comparing catch in standard fishing net (SFN) and modified fishing net (MFN). Red line represents the 1 to 1 line.

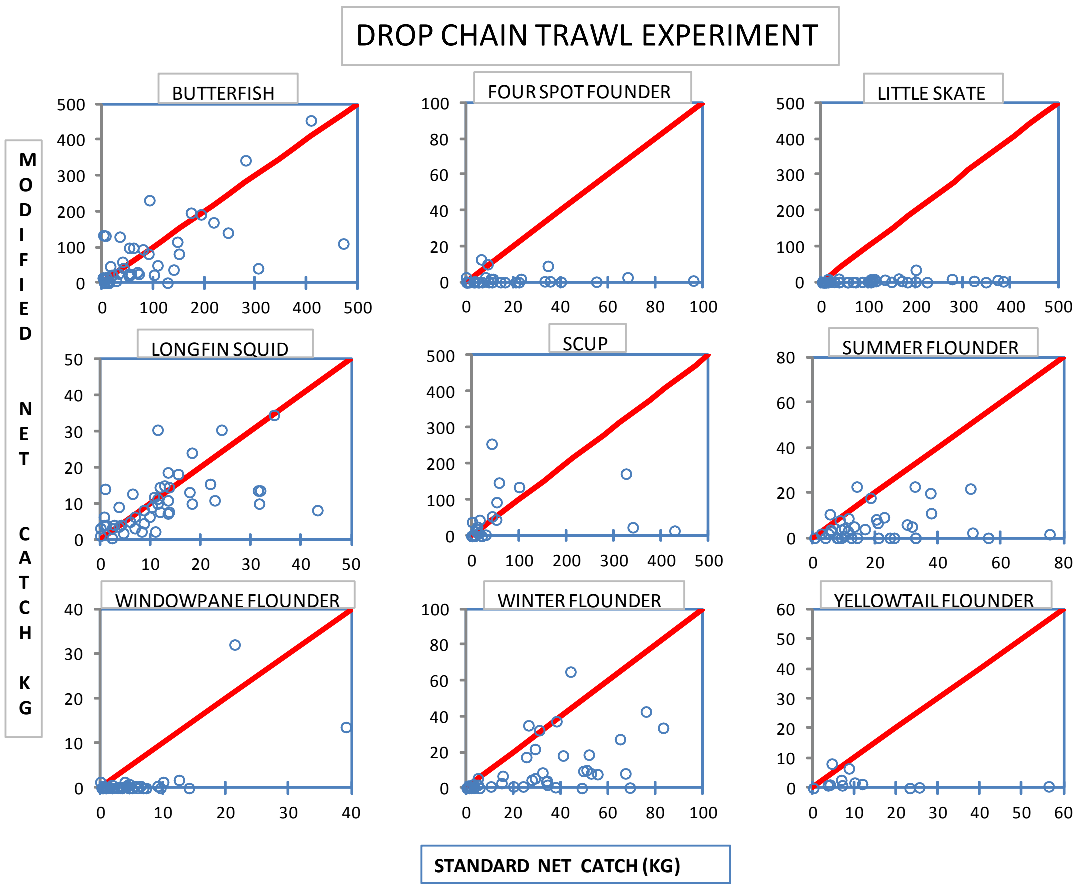
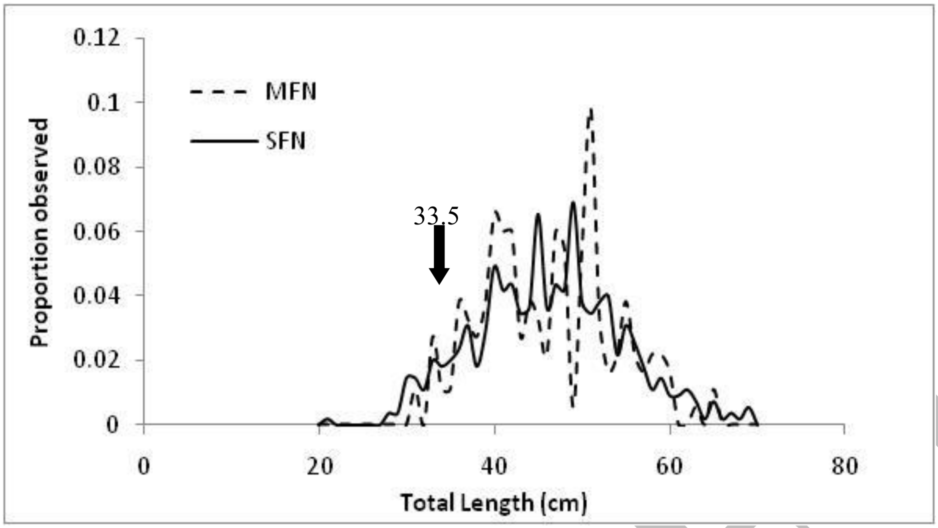
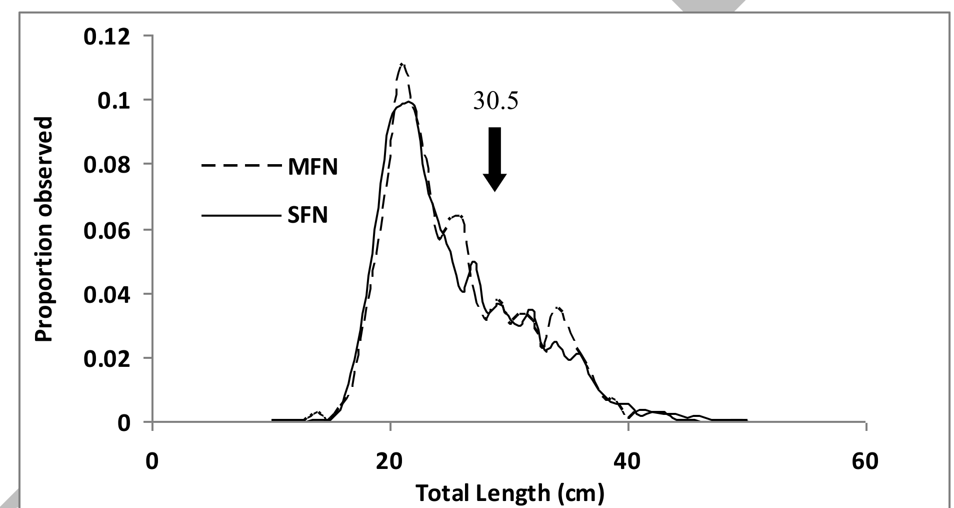


Figure 7. The length-frequency distribution of all measured (a) summer flounder (b) winter flounder and (c) yellowtail flounder in the standard fishing net (SFN) and the modified fishing net (MFN). Arrow indicates legal size for each species in cm..

(a)



(b)



(c)

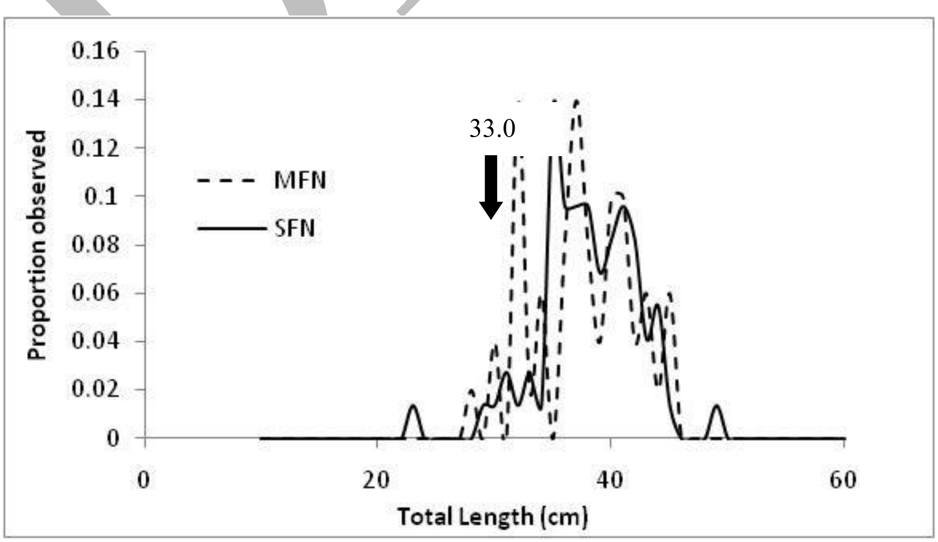
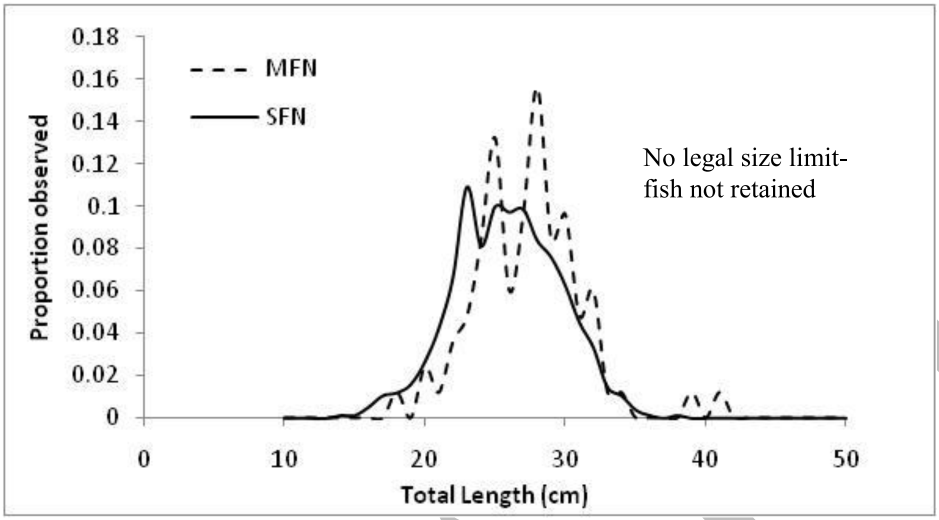


Figure 8. The length-frequency distribution of all measured (a) windowpane and (b) fourspot flounder in the standard fishing net (SFN) and the modified fishing net (MFN). No legal size for either species.

a)



b)