Evaluation of the Large Mesh Belly Panel in Small Mesh Fisheries as a Method to Reduce Yellowtail Flounder Bycatch on Southeast Georges Bank

A Report to the Northeast Cooperative Research Program

FINAL REPORT
(Updated as per NEFMC Research Steering Committee request)

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ABSTRACT

This project was developed by the Northeast Cooperative Research Program funded Squid Trawl Network to address yellowtail flounder and windowpane flounder bycatch concerns on Georges Bank by evaluating the effectiveness of a standard net modified with a large mesh belly panel to reduce the bycatch of both of these flounder species. The project was proposed by Georges Bank small mesh fishermen as means to pursue gear certification to be used for yellowtail and windowpane bycatch avoidance in Georges Bank small mesh fisheries when Accountability Measures (AM) are triggered. The Georges Bank yellowtail and windowpane flounder stocks are currently considered overfished and overfishing is occurring. The evaluation of a large mesh belly panel net in deep water while targeting squid and whiting was recommended as a bycatch avoidance solution and was conducted through this project. In response to the NEFMC's action developing Accountability Measures and sub-Annual Catch Limits for windowpane flounder as well as yellowtail flounder, quantifying windowpane bycatch reduction concurrent with yellowtail bycatch reduction was conducted through this project.

Data analysis was conducted to determine if a statistically significant difference existed in yellowtail flounder and windowpane flounder catches in the experimental net with the large mesh belly panel compared to the control net. The difference in catch of target species (squid and whiting) between the experimental net and the control net was also analyzed. T-test results showed a significant difference in catch weights for yellowtail flounder and for windowpane flounder. The large mesh belly panel significantly reduced the bycatch of both flounder species. There was a 72.3% reduction in yellowtail flounder catch and 50.9% reduction in windowpane flounder catch in the net with the large mesh belly panel compared to the control net. T-test results showed a non-significant result for the catch difference of whiting in the net with the large mesh belly panel compared to the control net. T-test results showed a significant difference for squid. The large mesh belly net caught significantly more squid than the control net. The large mesh belly panel net retained 20% more squid that the control net. Since the experimental net did not cause significant reduction in the catch of the target species of whiting and squid but did significantly reduce bycatch of yellowtail flounder and windowpane flounder, the large mesh belly panel shows promise as a possible certified bycatch avoidance net.

INTRODUCTION

Currently, the Georges Bank (GB) yellowtail flounder stock is considered overfished and overfishing is occurring. The GB yellowtail flounder quota has been declining quite dramatically in recent years, and as a result, small-mesh discards of the stock are becoming an increasing proportion of the total U.S. catch. This project was developed to address an immediate fisheries

management need and pursue gear certification as an Accountability Measure for yellowtail bycatch in Georges Bank small mesh fisheries.

After considering the unique nature and management of the squid/whiting small mesh fishing in offshore areas, available data about relevant gear research, variability in Georges Bank yellowtail flounder catch rates on small-mesh fishery trips, the requirement to develop effective AMs in Framework Adjustment 51, and forecasts of substantially lower sub-ACLs (annual catch limits) for Georges Bank yellowtail flounder in 2014, the NEFMC Whiting and MAFMC Squid Advisory Panels made the following recommendations for management alternatives that the NEFMC should include and analyze in Framework Adjustment 51:

- Required year round use of a certified bycatch avoidance net when an AM is triggered. AM would be triggered at the end of a fishing year (April 30, 2014 at the earliest), determined a few months after the end of the fishing year, and the industry would have at least six months to procure and begin using a gear listed as an approved bycatch avoidance net at the beginning of the next fishing year (May 1, 2015 at the earliest). This timing would give industry or researchers sufficient time to evaluate experimental trawl performance. Examples of nets to be evaluated in deep water while targeting squid and whiting include a modified Ruhle trawl, a large mesh belly net, and a raised footrope trawl.

Existing research on the above nets are not directly applicable to the offshore squid/whiting fishery on Georges Bank, typically conducted using large vessels. The Ruhle trawl research was conducted using a modified squid rope trawl adapted to work with large mesh (Beutel, et al., 2008). It is not known how this net would work in the squid/whiting fishery when adapted to small mesh currently in use. The large mesh belly net has some promising features, but recent research has focused on reducing winter flounder bycatch in the inshore whiting and squid fisheries (Hasbrouck, et al., 2010, Hasbrouck, et al., 2014). Likewise, the raised footrope trawl research conducted by MADMF was completed in inshore, shallower areas and may not have the same results in deeper water with larger nets towed by larger vessels (McKiernan, et al., 1998).

As a Framework Alternative, the Council would identify a gear-based AM using approved yellowtail flounder bycatch avoidance nets that would be certified by the Regional Administrator based on submitted data and analysis of the above nets. The certification would be based on standards set by the Council in Framework Adjustment 51. If the Georges Bank yellowtail flounder AM is triggered, vessels using small-mesh trawls could only use certified yellowtail flounder bycatch avoidance nets throughout the year (NEFMC, 2013a).

Due to concerns for the declining quota, and increasing significance of small-mesh discards of GB yellowtail flounder, Framework 48 to the Northeast Multispecies Fishery Management Plan adopted a GB yellowtail flounder sub-annual catch limit (sub-ACL) for the small-mesh fisheries (NMFS, 2013). A sub-Annual Catch Limit (ACL) currently regulates small mesh fishing on

Georges Bank (GB). For the purposes of this sub-ACL, small-mesh bottom trawl fisheries are defined as those vessels that use a bottom otter trawl with a cod-end mesh size of less than 5 inches. Typical target species for vessels using this gear on GB are whiting and squid. Catches of GB yellowtail flounder by the small-mesh fisheries have generally been less than 100 mt in recent years (NEFMC, 2013b).

Recently the NEFMC council passed the following motion relative to accountability measures for small mesh fisheries on Georges Bank, to be included in Framework Adjustment 51: "To add an option as a possible Accountability Measure or as a Technical measure, any gear modifications in the small mesh fishery Georges Bank area."

The GB yellowtail flounder quota has been declining quite dramatically in recent years and as a result, small-mesh discards of the stock are becoming an increasing proportion of the total U.S. catch. If the U.S. quota for GB yellowtail flounder is exceeded, then the U.S. quota for the following fishing year must be reduced by the amount of the overage. The pound-for-pound reduction is applied to the sub-ACL of the fishery component that caused the overage. For example, if the small-mesh fisheries caused an overage of the U.S. quota in Year 1, the small-mesh fisheries sub-ACL would be reduced by the amount of the overage in the next fishing year (Year 2). However, the small-mesh fisheries are currently required to discard all GB yellowtail flounder caught. Thus, a pound-for-pound reduction of the quota, without corresponding measures to help reduce catches of GB yellowtail flounder, would not appropriately mitigate an overage, or prevent future overages from occurring, for the small-mesh fisheries (NMFS, 2014).

Small mesh trawl nets can be modified to become highly selective in terms of the size and species of fish that they retain. Many factors influence fish capture rates including morphological and behavioral characteristics of fish as well as differences in trawl net design and construction. Successful bycatch mitigation should focus primarily on changes to the trawl design that result in applicable fishing techniques and management tools. There is an urgent need for proven methods that will work within the Georges Bank small mesh fisheries to reduce yellowtail and windowpane flounder bycatch.

The most direct option available for significant yellowtail flounder bycatch reduction in the small mesh whiting and squid fisheries is through conservation engineering and gear technological improvements. 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. This is best achieved by involving fishermen in all program aspects, from idea conception to final results. Success is also dependent on the gear modification not reducing the catch of target species (whiting and squid).

This project was developed by the Northeast Cooperative Research Program funded Squid Trawl Network (STN) to address an immediate fisheries management need and pursue gear

certification for a large mesh belly panel net to be used for bycatch reduction as an Accountability Measure for yellowtail and windowpane bycatch in Georges Bank small mesh fisheries. Discussions at the NEFMC Whiting Advisory Panel meeting in September 2013 laid the groundwork for developing gear-based AMs for Georges Bank yellowtail flounder in the small mesh fisheries. A need for proven gear concepts seeking additional consideration for small mesh trawls under this AM was the premise of this research conducted by CCE and the STN. The STN is a collaborative industry/science effort to form a comprehensive network to identify and address the challenges of bycatch and selectivity in the longfin squid fishery through innovative research. The STN was created in order to establish a collaborative industry, science and management network approach to solving the bycatch challenges of the squid fishery occurring in the Northeast. A STN Program Advisory Committee provides guidance and direction to the STN on research efforts. The STN PAC includes commercial fishing industry members, gear designers, fisheries scientists and fisheries managers. The STN PAC decided that the Squid Trawl Network would focus on an immediate response to address the yellowtail bycatch concerns on Georges Bank by evaluating the effectiveness of the large mesh belly panel on Georges Bank based on previous successful research performed by CCE in SNE/MA small mesh fisheries. Results of this previous large mesh belly panel study showed that the use of this modification resulted in an 88% reduction in winter flounder and an 83% reduction in combined demersal species (all flounders, skates, dogfish, and sea robins) (Hasbrouck, et al., 2010). These reductions were statistically significant. In addition, it should be noted that these high percentages of bycatch reduction were achieved while showing no statistically significant loss of the target species, longfin squid (Hasbrouck, et al., 2010). Similar results were proven by Milliken and DeAlteris (2004) in a project aimed at reducing flatfish bycatch in small mesh bottom trawls targeting whiting. In that project large mesh panels in the lower belly of a typical small mesh whiting net were evaluated. Their results showed large mesh belly panels proved to be effective in reducing flatfish bycatch while not reducing the catch of silver hake. Another concept considered by the STN PAC was the 12" drop chain sweep, which also showed promise in reducing winter flounder bycatch. The 12" drop chain sweep resulted in a statistically significant 78% reduction in winter flounder bycatch and a statistically significant 76% reduction in combined demersal species without a significant loss of squid (Hasbrouck, et al., 2013).

CCE maintains an excellent working relationship with fishermen from the Northeast and continually engages the commercial fishing industry, specifically the small mesh fleet, in reference to gear modifications that may be appropriate or effective in addressing bycatch of species of concern such as yellowtail and windowpane flounder. Both the 12" drop chain sweep and the large mesh belly panel modifications were designed with the collaboration of fishermen and net builders. Ultimately, it was agreed upon by the STN PAC that the large mesh belly panel modification had proven to be more effective and was to be selected for further study on Georges Bank.

It was also decided that quantifying windowpane bycatch reduction concurrent with the yellowtail bycatch reduction would be conducted. This is in response to the NEFMC's action developing Accountability Measures and sub-Annual Catch Limits for windowpane flounder as well as yellowtail flounder. Additionally, this project will extend the knowledge developed to the Georges Bank small mesh fishery and regional fisheries management councils to facilitate the transition of the application of research projects to implementation, to ensure such practices and technologies are available to managers.

Through this project, the STN aims to help resource managers and fishermen work together to sustainably use, protect, maintain and rebuild marine fisheries. More specifically, this project will develop and evaluate a conservation gear technology approach to address the issue of Georges Bank yellowtail and windowpane flounder bycatch in the small mesh fishery with the use of a large mesh belly panel net and ultimately certify this gear for approved use when AMs for small mesh fisheries are triggered. These goals will be accomplished by comparing the bycatch rates of GB yellowtail flounder and windowpane flounder for the experimental (large mesh belly panel) net and the control net as well as comparing the catch rates of the target species (whiting/squid) for each net and determining the effectiveness of the large mesh belly panel net as a successful bycatch reduction device. By definition and net design these results would also be applicable to the use of a large mesh rope trawl.

As more members of industry adopt this modification to their current trawl gear it will improve current fishing practices therefore, providing a reduction in bycatch and bycatch mortality which will allow the stocks of yellowtail and windowpane flounder to rebuild at a faster rate.

METHODS

Study Area

Two study areas have been selected for this overall project (Figure 1). The project has thus been divided into two phases to quantify gear performance in each individual area. The first is an area designated as the southern flank of Georges Bank. The second is a northern area designated as Cultivator Shoals. Observer data, NEFMC and small mesh fishermen have identified these areas as small mesh fishing areas most likely to interact with yellowtail flounder. The southern flank of Georges is a productive area fished by small mesh fishermen for squid and whiting from January – March. This is the location where the first phase experimental fishing has been completed and is the basis of this report. Due to current closures to small mesh whiting fishing on Georges Bank, the Cultivator Shoals area is closed October 31st-June 15th. Experimental fishing for phase two in this study area will occur in August 2014.

Figure 1. Map of Project Study Areas (in red) on Cultivator Shoals and the Southern Flank of Georges Bank. Green shaded areas have been closed to fishing year-round since 1994, with exceptions.
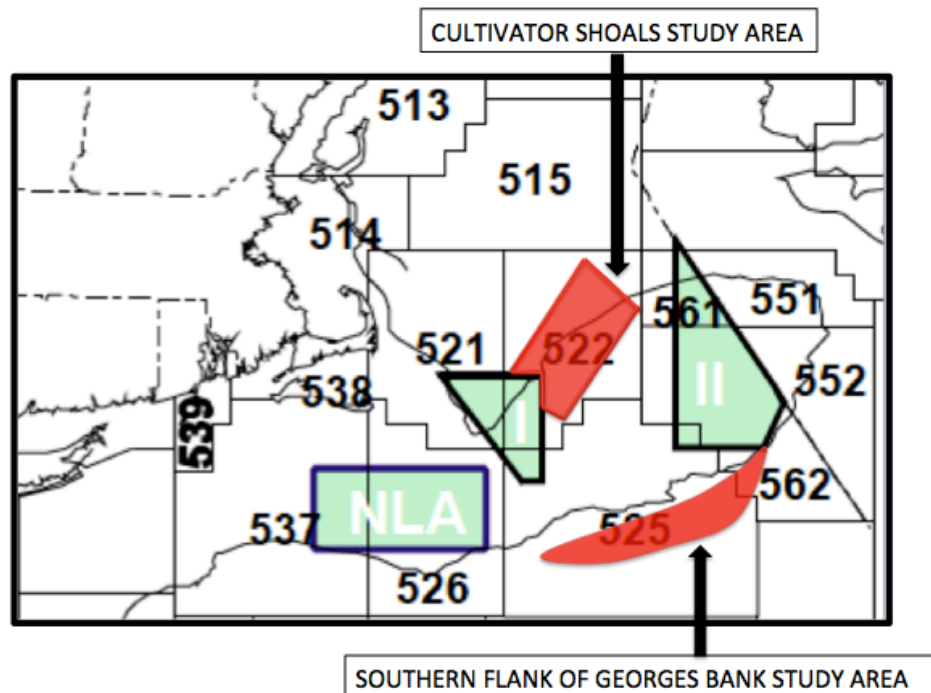
Research Design

The experimental design was intended to test the large mesh belly panel in the commercial small mesh squid and whiting fishery using existing gear and typical fishing practices. We tested for differences in both the target species catch and flounder species of concern, specifically yellowtail and windowpane flounder. We tested across appropriate identified strata of time, depth, area, and fishing practices. A single commercial twin trawl fishing vessel (F/V Karen Elizabeth) was used in this study to conduct paired replicate tows comparing a control trawl to a large mesh belly panel altered trawl (experimental trawl). This was accomplished by towing both the control and experimental nets at the same time over the same ground. A twin trawl vessel is rigged to tow two nets simultaneously in a twin-rig fashion. The study protocol used the same control/experimental trawls throughout the trip to evaluate the effectiveness of the experimental large mesh belly panel against the study objectives.

The vessel has two net reels and twin stern ramps. Both nets were set and hauled together. The vessel used one set of doors to spread the two nets (a door on each outside towing cable). The vessel used a 3-wire system with a middle winch. A "clump" (weighted sled) attached to the middle wire was towed between the two nets. Ground cables and bridles go from the clump to the inside wing of each trawl.   This vessel normally tows two nets in this fashion during its

normal offshore fishing operations. Most vessels of this nature are equipped with electronic instrumentation systems that include sensors on both doors and 2 sensors on the "clump". This allowed both nets to be fished square to the vessel, the same distance behind the vessel, and with the same wing spread. During the trip we once switched the port/starboard location of the control and experimental trawls in order to help normalize any port/starboard effect. We had an equal number of paired tows with the gear on different sides.

The control net used aboard the F/V Karen Elizabeth was an unaltered trawl net typical of the small mesh nets used in the squid and whiting fishery on Georges Bank along the southeastern area and Cultivator Shoals. The control net was a 420 x 16 cm 3-bridle 4-seam box trawl with a sweep length of 131 ft., a headrope length of 105 ft., 8" mesh (full mesh) webbing in the wings and jibs, and 6" mesh in the bunts and in the 1st bottom belly. The net had 8 cm webbing in the square, side squares, 1st top belly, 1st side bellies and the 2nd bellies. The last bellies were 6cm mesh. For the experimental trawl the 6" 1st belly was replaced with the large mesh belly (See Figure 27 – Net Diagram). The participating captain, Captain Chris Roebuck, has extensive experience fishing for squid and whiting in the project areas.

Tow procedure had the vessel essentially fish as it would in a standard commercial fishing trip, with the exception that all tows were 30 minutes in length. The standard control net is the net that the vessel normally uses in its standard commercial squid or whiting trip. The experimental net was a standard small mesh net with the large mesh belly panel installed in the first belly. The large mesh panel is made of 80cm (32") mesh 6mm poly webbing, 2 meshes deep X 16 meshes wide sewn into the standard 16cm (6") mesh of the belly. With the 'saw-toothing' of the 16cm mesh, this yielded an effective opening of 3 full meshes deep, a total of about 8' of large mesh. The panel was attached five 16cm meshes (approximately 2.5') behind the footrope and goes from gore to gore (22 meshes wide or approximately 30'). See Fig. 28 – Diagram of Large Mesh Belly Panel. See also the narrative following Fig. 28 for an explanation of how to scale and describe the large mesh belly panel to fit any net.

Number of trips and tows

This phase of the project was conducted during January 2014 in the Southern Flank of Georges Bank Study Area, near Munson Canyon. During this phase we conducted a total of 40 paired tows, all completed in one 6 day trip. All tows were 30 minutes in length. Tows occurred during both the day and night but most were conducted during the day.

On Board Catch Processing

Both nets are set and hauled together. Upon haul-back the catch from each net was kept separated on deck during the entire tow work-up procedure. The catch from each net was processed separately.

The onboard catch processing procedure followed standard NMFS survey methods as described below (NEFSC, 1988). The target was yellowtail flounder catch relative to quantifying differences in the retention between the control and experimental nets. As such, total catch of yellowtail flounder for each tow of both nets was accurately weighed. Yellowtail flounder was also sampled for length frequency. The goal was minimally 100 random length measurements per tow. When fewer individuals were caught, all were measured. We also quantified the catch of yellowtail flounder in terms of numbers as well as weights. This was accomplished by actually counting the fish (if the catch is small) or by utilizing the number of individuals in our length frequency and the weight of that sample extrapolated over the entire yellowtail flounder catch. We also quantified differences in windowpane flounder in the same manner as yellowtail flounder. Since we also wanted to quantify if the catch of whiting and squid was influenced by the experimental net modifications, the total whiting and squid catch was weighed on each tow and a length sample of at least 100 individuals was obtained. The total catch weight of all species in each tow was obtained either by direct weighing or by catch estimations. Catch estimations were based on basket or tote counts. An average weight was determined by weighing a minimum of 5 baskets or totes. Next, a count of the number of baskets or totes was made for the particular species and this number was multiplied by the average weight. This number was then recorded as the estimated total catch weight. This procedure for catch estimations, based on basket or tote counts, follows the NMFS At Sea Monitoring Program and the Observer Program Biological Sampling protocols as outlined in the NEFSC 2010 sampling manuals.

DATA ANALYSIS AND RESULTS

Below is a quantitative evaluation and summary of the data analysis. Data were analyzed primarily to determine if a significant statistical difference exists in the catch of two flounder species (yellowtail flounder and windowpane flounder) and the target species (squid and whiting) between the control and experimental nets, and to further quantify what the difference was. Since only one vessel was used there was no vessel effect in the analysis relative to the catch between tows or nets. Also, since both the control and experimental nets were constructed the same (with the exception of the belly panel) and fished the same, the gear effect is only related to the belly panel installation.

Statistical tests are based on pairing of the data. For each paired tow the control catch is compared to the experimental. The twin trawl design of the experiment lends itself well to pairing and a paired based analysis is the best approach. Both parametric and nonparametric statistics are used. All statistics are at the $\alpha = .05$ level. Box plots and plots of control/experimental catches by species show the distributions of each component separately (unpaired). Catch data for four key species and the catch differences between the control net and the experimental net for each tow are shown in Table 4 at the end of this report.

Unfortunately as is the case with many of these species interaction studies, it can be difficult to find commercial quantities of both target and bycatch species at the same time in the same area despite what the NMFS observer data indicates. This was the case in this study and we opted to concentrate on commercial size catches of yellowtail and windowpane flounder at the expense of smaller catches of whiting and squid.

Catch Comparisons

Yellowtail Flounder

First we looked at the difference in yellowtail flounder catch between the control net and the experimental net with the large mesh belly panel (Figures 2 and 3). Statistical analysis of the data was conducted to determine if the large mesh belly panel experimental net significantly affected retention of yellowtail flounder relative to the standard control net.

T-test results showed a significant difference in the catch weight between the control and experimental net (t = 5.7164, df = 39, **p-value <0.0001**, mean of x =219.015). The experimental net significantly reduced the catch of yellowtail flounder compared to the control net. The Wilcoxon test yielded similar results.

Figure 2. Boxplot Distribution of Yellowtail Flounder Catch Weight in the Control and Experimental Net
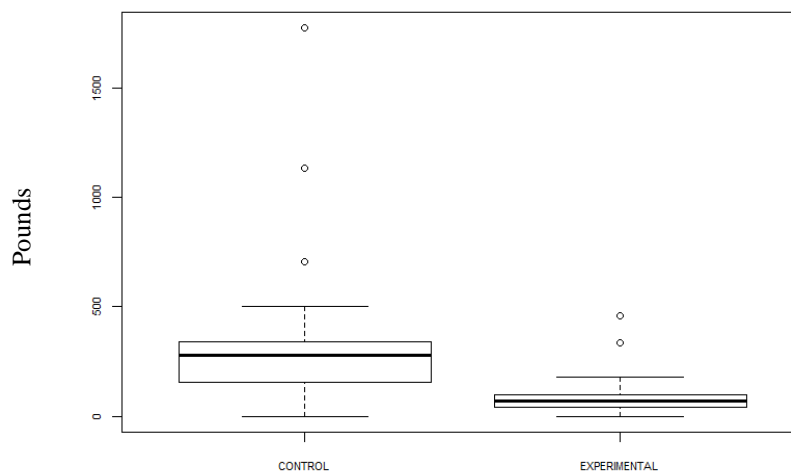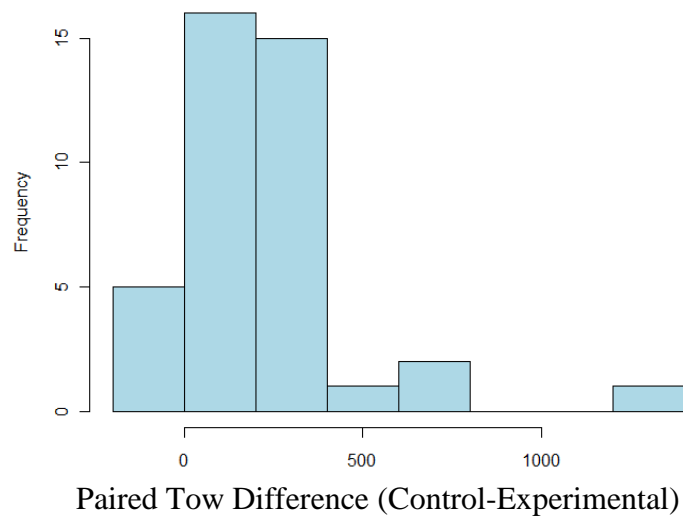
Figure 3. Distribution of Paired Tow Differences for Yellowtail Flounder

Paired Tow Difference (Control-Experimental)

In Figure 4 below, the total weight of yellowtail flounder caught by the experimental net and by the control net for all research tows combined are compared.

Figure 4. Total Catch Weight of Yellowtail Flounder (lbs) in the Experimental and Control Net for All Trips Combined
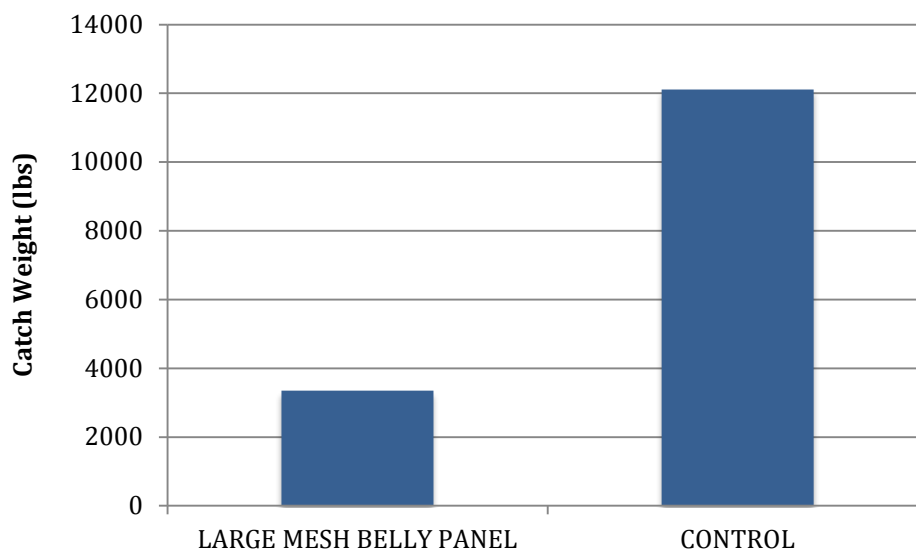
The overall reduction in yellowtail flounder catch due to the large mesh belly panel treatment was 72.3% compared to the control net.

<u>Windowpane Flounder</u>

Next we looked at the difference in windowpane flounder catch between the control net and the experimental net with the large mesh belly panel (Figures 5 and 6). For windowpane flounder, the t-test results showed a significant difference in the catch weight between the control and experimental net (t = 10.3161, df = 39, **p-value <0.0001**, mean of x =115.32). The experimental net caught significantly less windowpane flounder. The Wilcoxon test yielded similar results.

Figure 5. Boxplot Distribution of Windowpane Flounder Catch Weight in the Control and Experimental Net
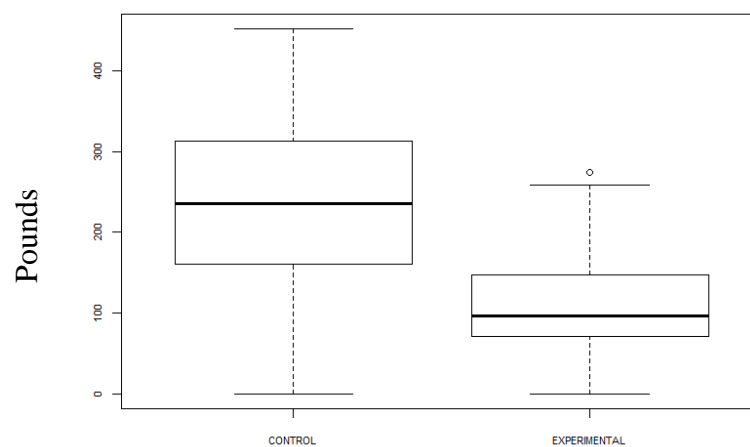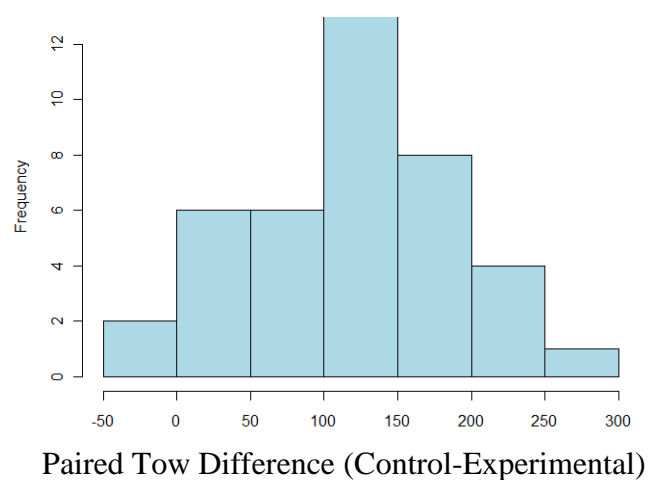

Figure 6. Distribution of Paired Tow Differences for Windowpane Flounder

Paired Tow Difference (Control-Experimental)

In Figure 7 below, the total weight of windowpane flounder caught by the experimental net and by the control net for all research tows combined are compared.

Figure 7. Total Catch Weight of Windowpane Flounder (lbs) in the Experimental and Control Nets for All Trips Combined
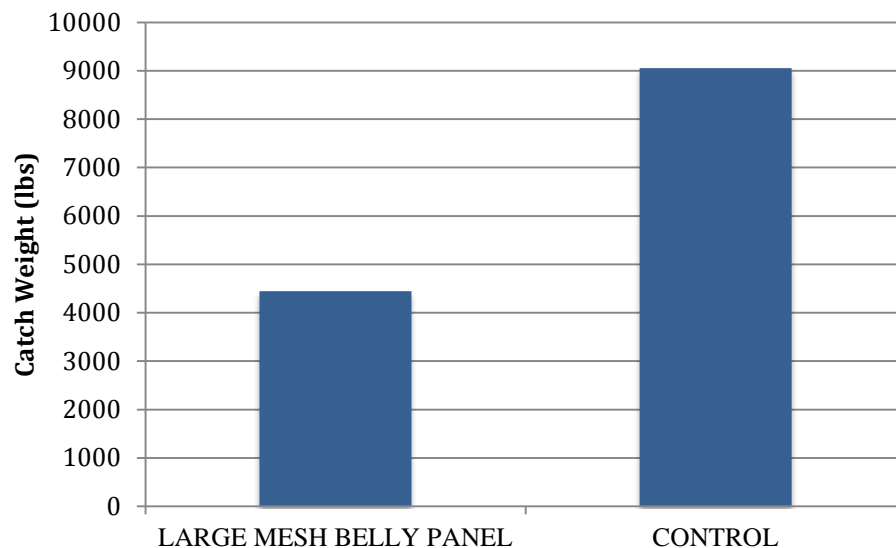
The overall reduction in windowpane flounder catch due to the large mesh belly panel treatment was 59.27% compared to the control net.

Whiting

Next, the data was analyzed to determine if a significant statistical difference exists in the catch of whiting between the control and experimental nets (Figures 8 and 9). For whiting, t-test results showed no significant difference in the catch weight between the control and experimental net (t = 0.1498, df = 39, **p-value = 0.8817**, mean of x = 0.4925). The experimental net did not affect retention of whiting compared to the control net. The Wilcoxon test however did return a significant result. This is due to 1 outlier in the data. However the data are Gaussian and the outlier is relevant and part of the variability. The t-test is better in taking into account variability. Therefore the t-test is the more relevant statistic.

Figure 8. Boxplot Distribution of Whiting Catch Weight in the Control and Experimental Net
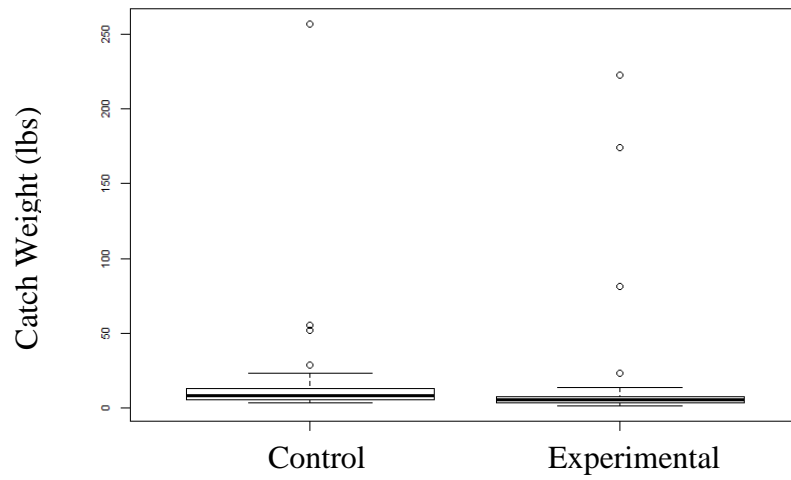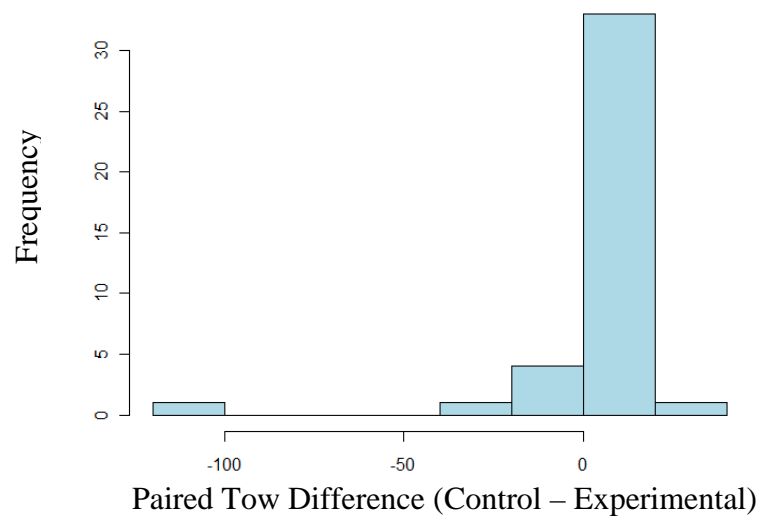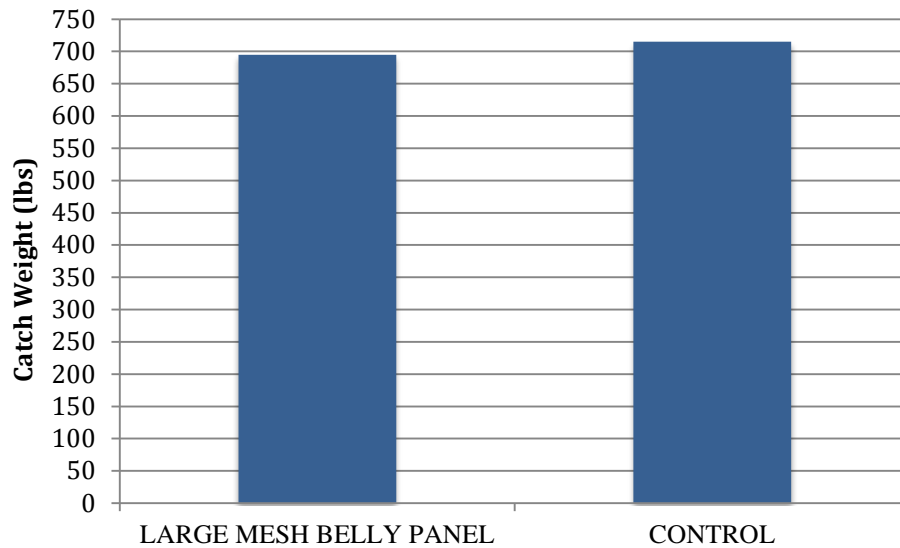

Figure 9. Distribution of Paired Tow Differences for Whiting

In Figure 10 below, the total weight of whiting caught by the experimental net and by the control net for all research tows combined are compared.

Figure 10. Total Catch Weight of Whiting (lbs) in the Experimental and Control Nets for All Trips Combined

There was no significant reduction in whiting catch due to the large mesh belly panel treatment compared to the control net.

Squid

Next, the data was analyzed to determine if a significant statistical difference exists in the catch of squid between the control and experimental nets (Figures 11 and 12). For squid, t-test results showed a significant difference in the catch weight between the control and experimental net ($t = -3.2734$, df = 39, **p-value = 0.002231**, mean of x = -5.2775). The experimental net actually retained significantly more squid than the control net. The Wilcoxon test yielded similar results.

Figure 11. Boxplot Distribution of Squid Catch Weight in the Control and Experimental Net
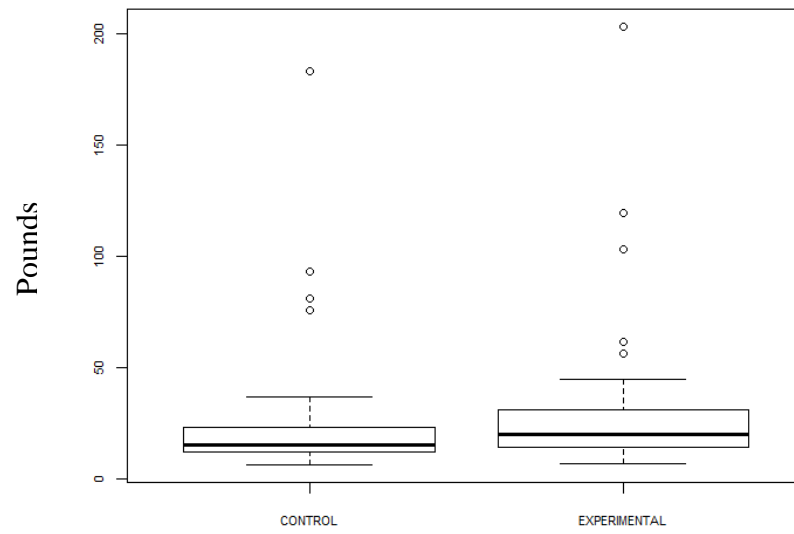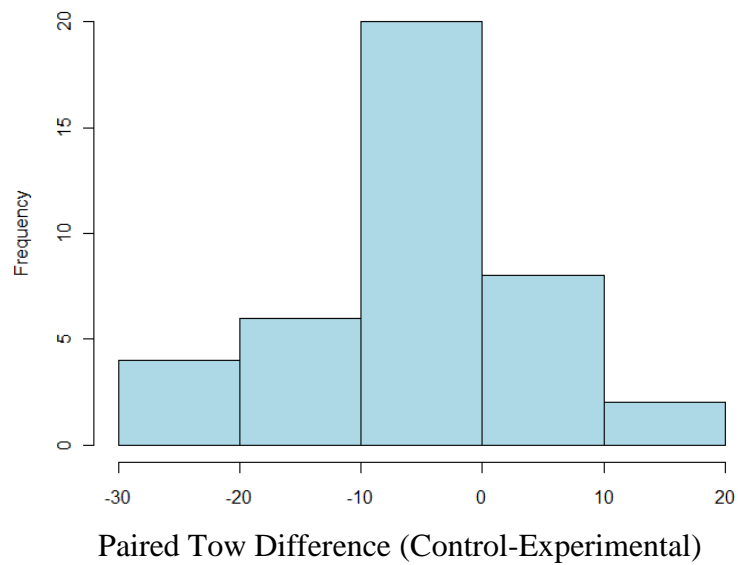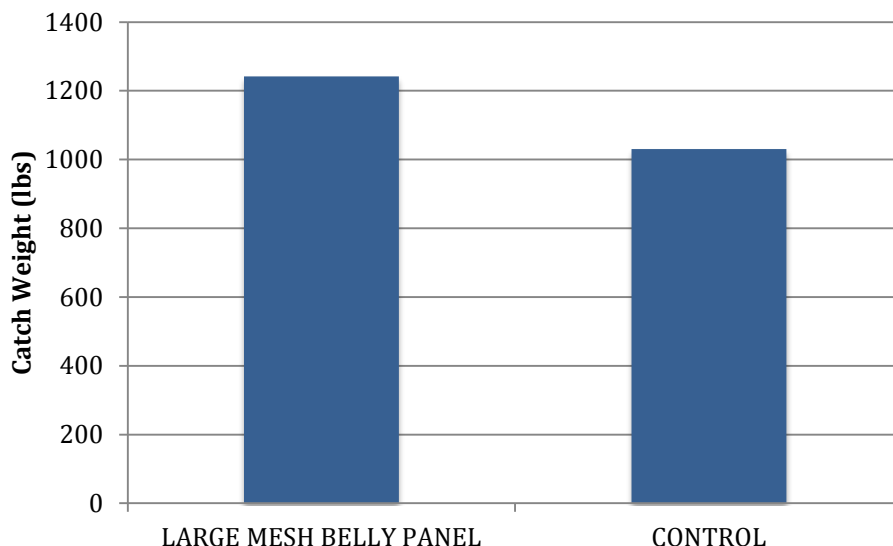

Figure 12. Distribution of Paired Tow Differences for Squid

In Figure 13 below, the total weight of squid caught by the experimental net and by the control net for all research tows combined are compared.

Figure 13. Total Catch Weight of Squid (lbs) in the Experimental and Control Nets for All Trips Combined

Compared to the control net, the experimental net with large mesh belly panel actually retained 20% more squid. The experimental large mesh belly panel net retained on average 199 lbs. of squid per tow compared to an average of 172 lbs. retained by the control net. The t-test for the squid catch returned the statistic of mean of x = -5.275. Therefore the mean difference in catch between the control and experimental nets was only about 5 ¼ pounds more in the experimental net per tow. Although this may be a statistically significant result for this project, it is probably not biologically or commercially significant. Although the data shows that the size of squid were on the average larger (11.56 cm) in the experimental than the control (11.33 cm), the experimental net also caught more in total number of squid and in pounds. It is difficult to speculate on why the experimental net may have retained more squid than the control net. This may be part of the randomness of the squid distribution in the ocean. Larger average size of squid in the experimental net and more squid in numbers contributes to the significant result based on pounds. We speculate that the large mesh panel had some effect on length frequency selectivity.

Catch Summary

In summary, statistical analysis indicates that there was a significant difference in catch of both yellowtail flounder and windowpane flounder in the control net compared to the experimental net with the large mesh belly panel. The experimental net reduced the quantity of yellowtail and

windowpane flounder bycatch. The overall reduction in yellowtail flounder catch due to the large mesh belly panel treatment was 72.3% compared to the control net. The overall reduction in windowpane flounder catch due to the large mesh belly panel treatment was 50.9% compared to the control net. There was no significant difference in whiting catch between the control and the experimental nets. The large mesh belly panel did not affect retention of whiting in the net. There was a significant difference in squid catch in the experimental net compared to the control net. Although the large mesh belly panel net actually retained more squid compared to the control net, the result may not be very meaningful. The more important point is that the experimental net did not cause any reduction in squid catch.

The catches of whiting and squid we encountered were small for commercial catches. This density level of fish is the situation that we experienced during the study. Unfortunately, as is the case in many species interaction studies, it can be difficult to find commercial quantities of both target and bycatch species at the same time in the same area despite what the NMFS observer data indicates. We opted to concentrate on commercial size catches of yellowtail and windowpane flounder at the expense of smaller catches of whiting and squid. This is part of the variability of the ocean. In this study, sample size is the number of paired tows, not the amount of fish. The sample size we had in terms of number of coupled tows was sufficient and the experiment has enough statistical power to detect a reasonable biological difference in the catch between the two nets for the four species we examined. Larger catches may have had a different effect on whiting and squid, but it was better to find out how the gear worked with yellowtail and windowpane flounder.

Length Frequency

Data analysis of yellowtail flounder, windowpane flounder, whiting and squid lengths was also performed to look for differences in length selectivity between the nets. The mean lengths for each tow and net were calculated for these four species. The paired differences in mean length were then compared in the control and experimental nets. Mean lengths are shown in Table 1.

Table 1. Mean Lengths (cm) of Four Species in the Control and Experimental Nets

|	CONTROL	EXPERIMENTAL
Yellowtail Flounder	34.83	35.30
Windowpane Flounder	26.13	26.20
Whiting	24.65	25.17
Squid	11.24	11.57

First we conducted an ANOVA to see if there were differences in length frequency by species and different length frequencies by treatment and the effect of the species/treatment interaction

term. Results of the ANOVA are in Table 2. As one would expect there are different mean lengths by species. There are also different mean lengths by treatment and, from the interaction term, the relationship in how the mean lengths differ by treatment is different by species. All results are significant. Figure 14 graphically shows the distribution of lengths by species and treatment.

Table 2. P-Value Results of ANOVA

	Mean Length
Treatment	p = <0.0001 Significant
Species	p = <0.0001 Significant
Treatment*Species	p = 0.0003 Significant

Figure 14. Boxplot of Mean Lengths by Species and Treatment
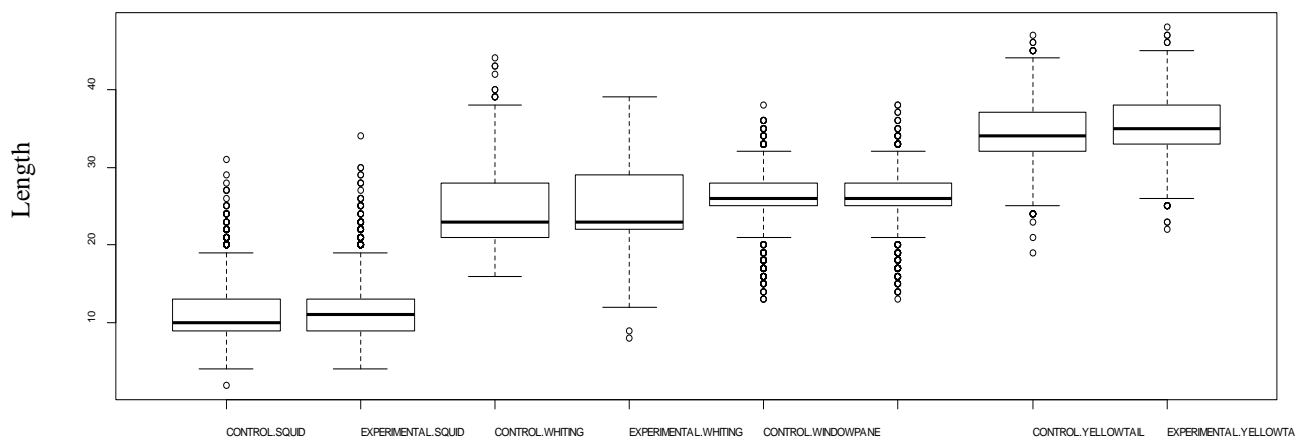
Next we conducted a series of t-tests. The t-test was performed for each species to look for significant differences in length by treatment. Results are shown in Table 3 and are described below.

Table 3. T-Test Results for Length Frequency Difference Between Nets

	p-value
Yellowtail Flounder	<0.0001 Significant
Windowpane Flounder	0.2990 Not Significant
Whiting	0.0016 Significant
Squid	0.0001 Significant

Yellowtail

Figure 15 below compares the length frequency distribution for yellowtail flounder between the two nets.

Figure 15. Yellowtail Flounder Lengths as a Percent of the Total in the Control and Experimental Nets
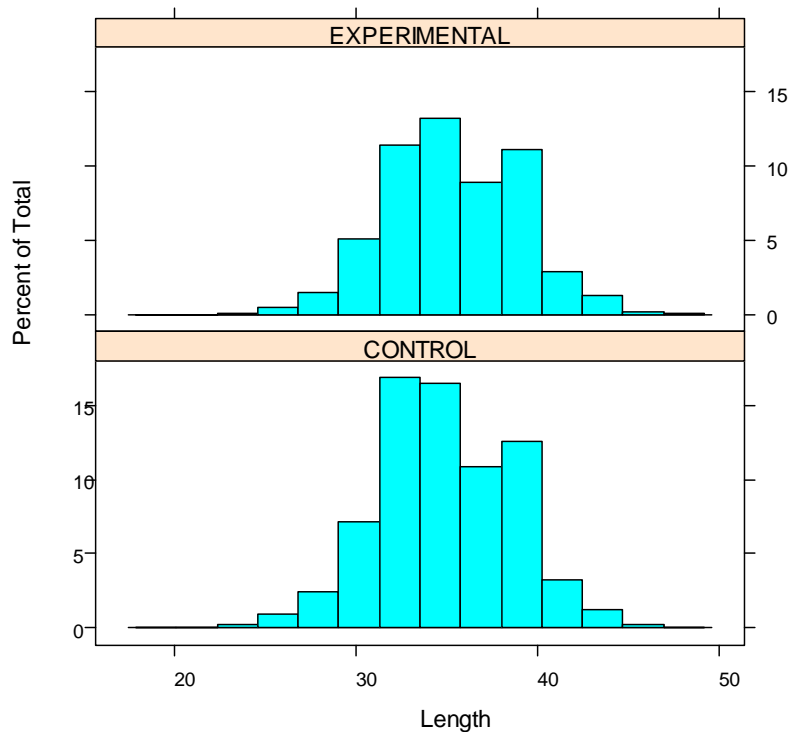
T-test results showed that yellowtail flounder were significantly larger in the experimental net (p=<0.0001). The average lengths for yellowtail flounder the experimental net were 0.37 cm larger than those in the control net.

Figure 16 compares the length frequency distribution for windowpane flounder between the two nets.

Figure 16. Windowpane Flounder Lengths as a Percent of the Total in the Control and Experimental Nets
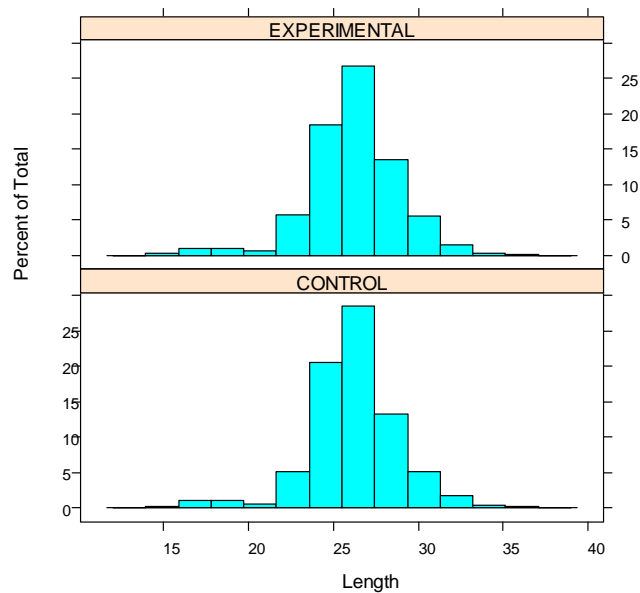
T-test results show that there is no significant size difference in the mean length of windowpane flounder between the control and experimental nets.

Whiting

Figure 17 compares the length frequency distribution for whiting between the two nets.

Figure 17. Whiting Lengths as a Percent of the Total in the Control and Experimental Nets
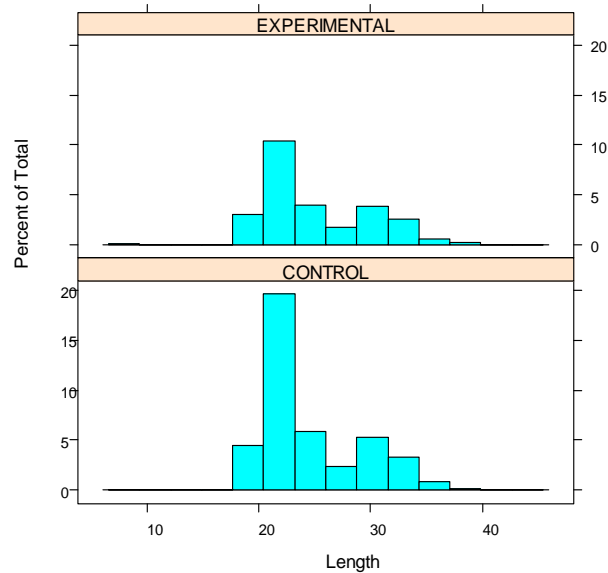
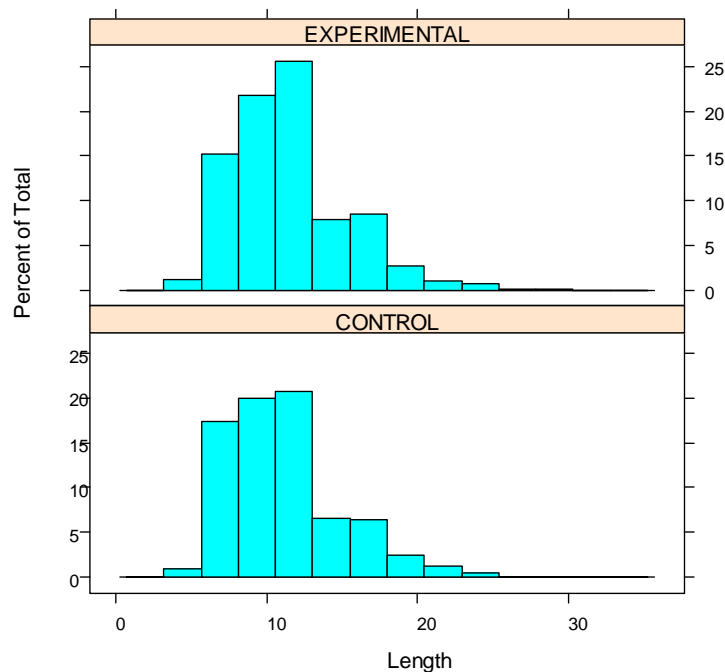T-test results show a significant size difference in whiting between experimental and control nets (p=0.0016). Significantly larger whiting were retained in the experimental net. The mean length of whiting in the experimental net was 0.52cm larger than in the control net.

Squid

Figure 18 compares the length frequency distribution for squid between the two nets.

Figure 18. Squid Length Frequency Distribution as a Percent of the Total in the Control and Experimental Nets

T-test results show a significant size difference in squid between experimental and control nets (p=0.0001). Significantly larger squid were retained in the experimental net. The mean length of squid in the experimental net was 0.33cm larger than in the control net.

Length Frequency Summary

For yellowtail flounder, squid, and whiting, the size differences are significant yet they are relatively small. These statistical differences may or may not be biologically significant. However, there is a measurable difference. The fact that larger fish were retained in the net with a large mesh panel was an unexpected result.

For yellowtail flounder, not only did the experimental gear allow for significant escapement, it also seems to provide greater escapement for smaller fish. For whiting, even though there is no significant reduction in whiting catch with the experimental gear, it does seem to allow for some escapement of smaller fish. For squid, not only did the experimental gear catch more squid, they were also of larger mean length.

Day Vs. Night

Experimental fishing occurred both day and night. Although the experiment was not designed to specifically test for differences at night and differences during the day, the data was analyzed for any differences between day/night catches since escapement through the large mesh belly panel may have been influenced by light. The day and night paired tow differences are analyzed below (Figures 19-22).

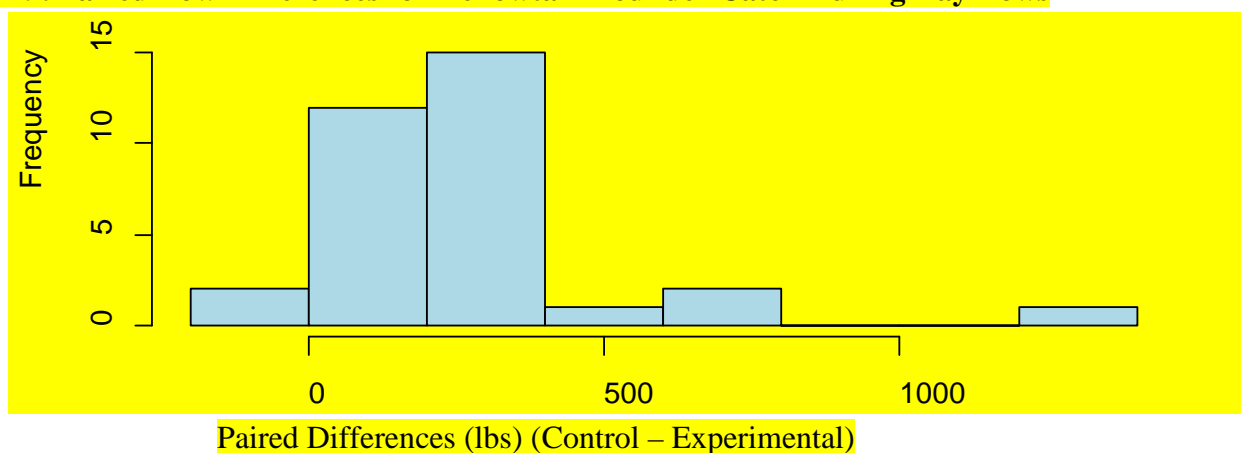**Figure 19. Paired Tow Differences for Yellowtail Flounder Catch During Day Tows**

Paired Differences (lbs) (Control – Experimental)

Figure 20. Paired Tow Differences for Yellowtail Flounder Catch During Night Tows
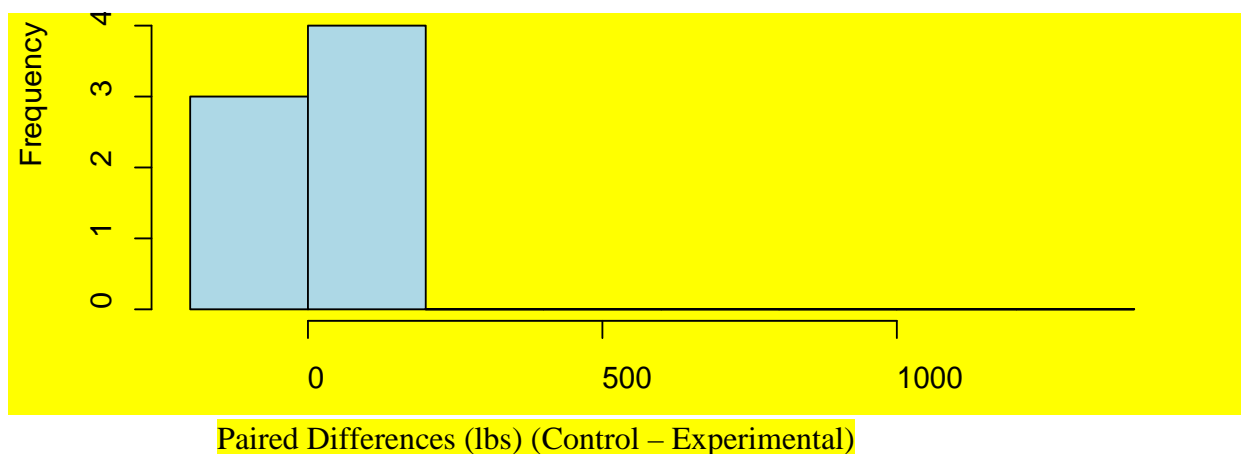
Paired Differences (lbs) (Control – Experimental)

For yellowtail flounder, t-test results showed a significant difference in the catch weight between the control and experimental net during day tows (t = 5.7091, df = 32, **p-value <0.0001**, mean of x = 251.403). Non-parametric bootstrap analysis provided similar results. The t-test results showed a non-significant result for catch differences at night (t = 2.039, df = 6, **p-value = 0.08757**, mean of x = 66.32857). However, the non-parametric bootstrap analysis returned a significant result (**p=0.026**). Since the two tests returned different results, we checked to see how the data are distributed. The data are Gaussian, so the t-test is the more appropriate statistic to use.

Figure 21. Paired Tow Differences for Windowpane Flounder Catch During Day Tows
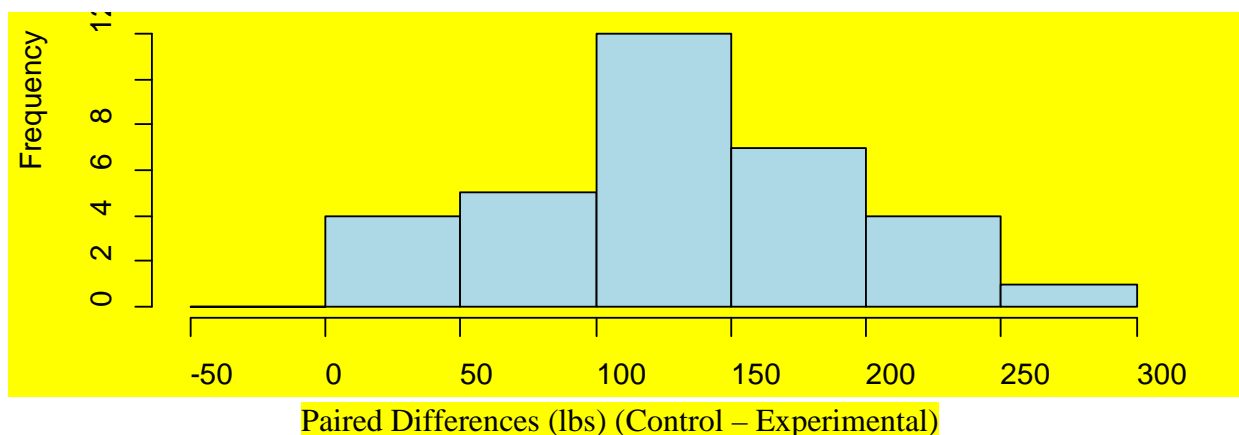
Figure 22. Paired Tow Differences for Windowpane Flounder Catch During Night Tows
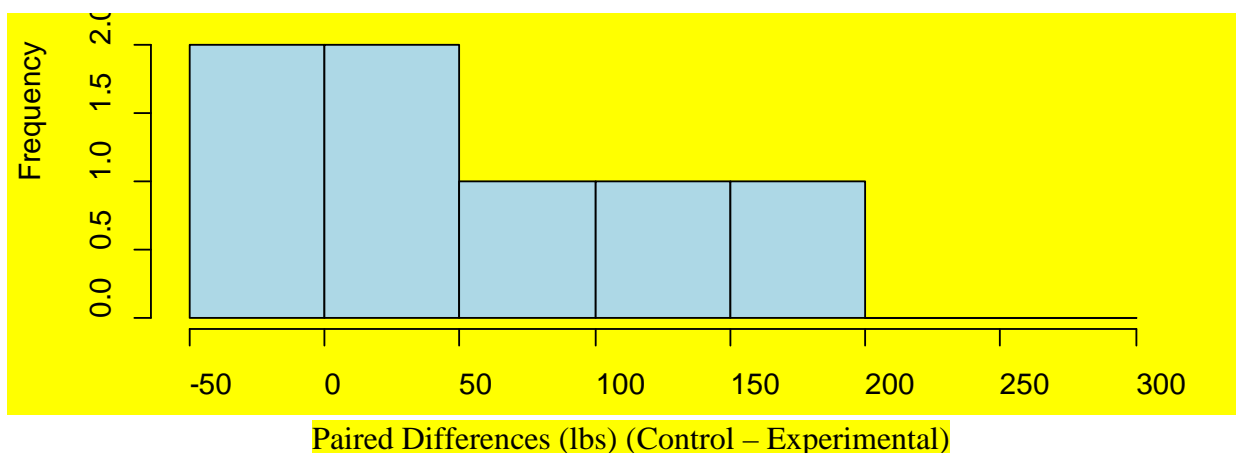
For windowpane flounder, t-test results showed a significant difference in the catch weight between the control and experimental net during day tows (t = 11.3104, df = 32, **p-value <0.0001**, mean of x = 128.3909). Non-parametric bootstrap analysis provided similar results. The t-test results showed a non-significant result for catch differences at night (t = 2.1319, df = 6, **p-value = 0.07701**, mean of x = 53.7). However, the non-parametric bootstrap analysis

returned a significant result (**p=0.008**). Since the two tests returned different results, we checked to see how the data are distributed. The data are Gaussian, so the t-test is the more appropriate statistic to use.

Day/Night Summary

In summary, there was a statistically significant difference in the mean catches between the control and experimental nets during the day for both windowpane and yellowtail flounder. There was no significant difference for catches of yellowtail and windowpane flounder at night. However, we need to take precaution in interpreting the statistical results for night tows for both flounders. As was stated above, the experiment was not designed to test for day/night differences. For this experiment, we had a total of only 7 tows that occurred at night. For yellowtail flounder, only 5 of those tows caught yellowtail flounder. For windowpane flounder, 2 of the night tows caught less than 1 pound (i.e.1 fish) of windowpane flounder. Night-time results on their own are therefore lacking statistical strength.

Side (Port Vs. Starboard)

We looked at yellowtail and windowpane flounder catches on each side of the vessel separately to see if the results were different based on which side of the vessel the control or experimental net was fished on (Figures 23-26). The experimental and control nets were switched once during the experiment in order to randomize for side. We performed t-tests and non-parametric bootstrap analysis on the paired tow differences in catch for side.

Figure 23. Paired Tow Differences for Yellowtail Flounder Catch With the Control Net on the Port Side

Paired Differences (lbs) (Control – Experimental)
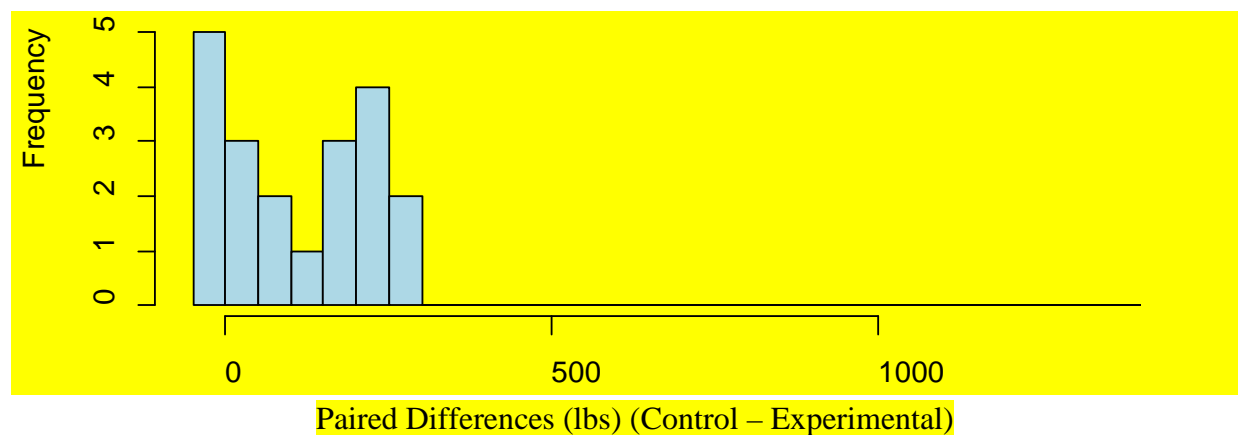
Figure 24. Paired Tow Differences for Yellowtail Flounder Catch With the Control Net on the Starboard Side

Paired Differences (lbs) (Control – Experimental)
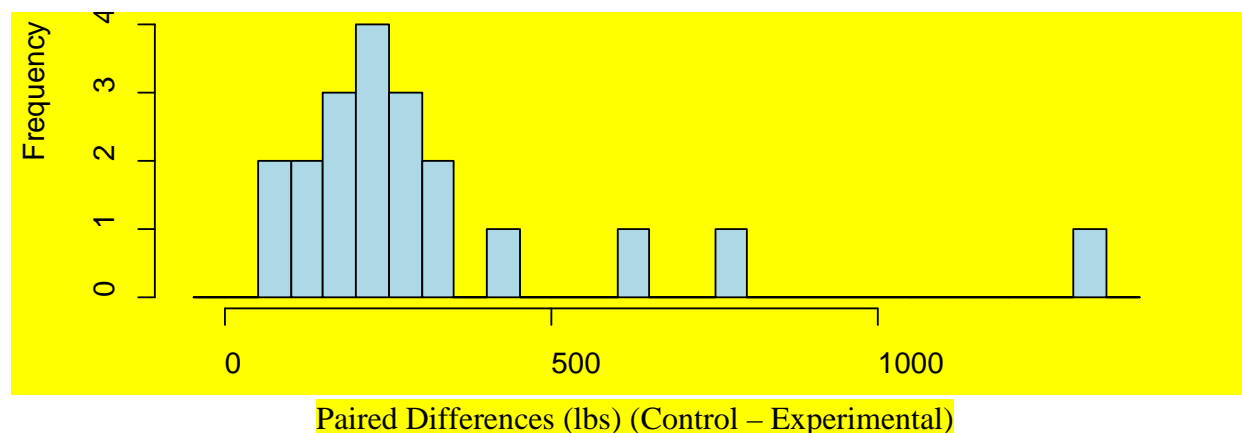
For yellowtail flounder, t-test results showed a significant difference in the catch weight between the control and experimental nets when the control net was on the port side (t = 4.5711, df = 19, **p-value =0.0002087**, mean of x = 114.83) and a significant difference when the control net was on the starboard side (t = 4.9561, df = 19, **p-value <0.0001**, mean of x = 323.2). Non-parametric bootstrap analysis provided similar results.

Figure 25. Paired Tow Differences for Windowpane Flounder Catch With the Control Net on the Port Side

Paired Differences (lbs) (Control – Experimental)
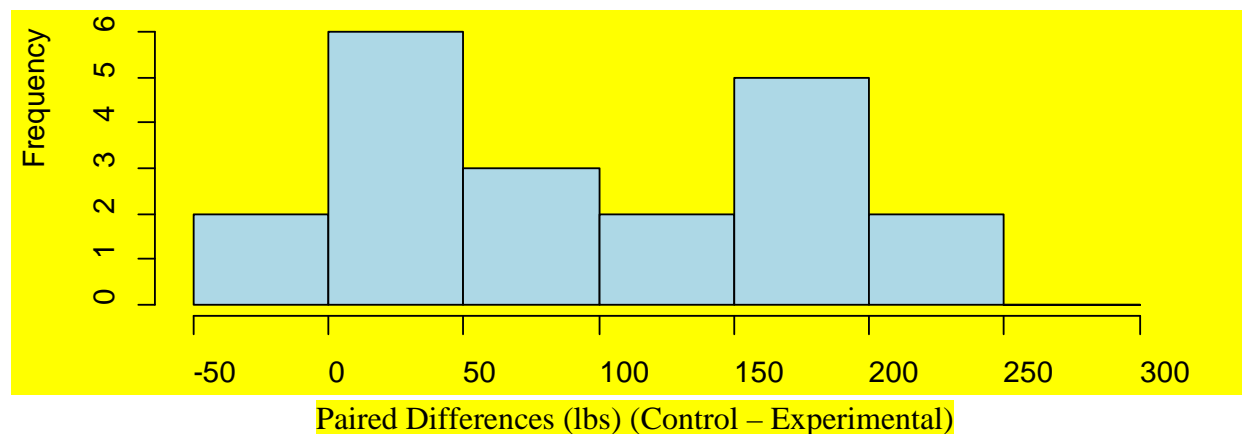
Figure 26. Paired Tow Differences for Windowpane Flounder Catch With the Control Net on the Starboard Side

Paired Differences (lbs) (Control – Experimental)
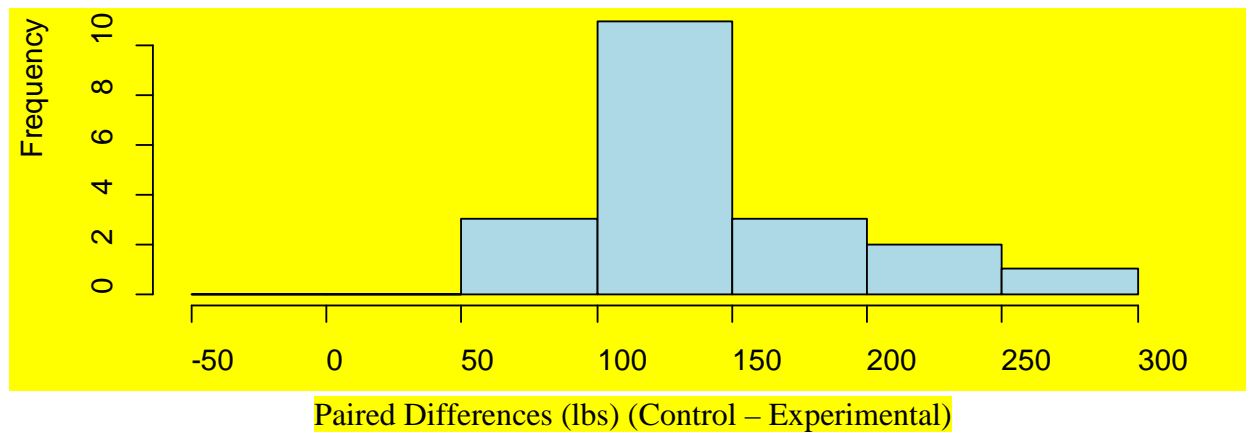
For windowpane flounder, t-test results showed a significant difference in the catch weights between the control and experimental nets when the control net was on the port side (t = 5.1658, df = 19, **p-value<0.0001**, mean of x = 92.38) and when the control net was on the starboard side (t = 11.7776, df = 19, **p-value <0.0001**, mean of x = 138.26). Non-parametric bootstrap analysis provided similar results.

Side Summary

For both yellowtail and windowpane flounder the difference in catch between the control and experimental nets is significantly different regardless of which side of the boat the nets are on. There is no side effect.

Door Spread

We tested for door spread to see if there was a statistically significant difference in door spread between the control and experimental nets. First we tested for differences in door spread at the start of each tow. T-test results showed no significant difference in door spread at the start of the tow (**p-value = 0.5554**). Next we tested for differences in door spread at the end of each tow. There was no significant difference in door spread at the end of the tow (**p-value = 0.2809**).

Door Spread Summary

Since there is no statistically significant difference in door spread for the two nets at the beginning or at the end of each tow, there is no reason to analyze actual catch as a function of door spread. Door spread has no effect. Most of the tows had a door spread of 37 fathoms (See Table 4). For most tows, the door spread was the same for both the control and experimental nets. In the instances where there was a difference, the difference was 2 fathoms or less.

DISCUSSION

For this project we looked mainly at the difference in yellowtail flounder and windowpane flounder catches in the experimental net with the large mesh belly panel compared to the control net. We also looked at the difference in catch of target species (squid and whiting) between the experimental nets and the control net. Statistics are based on the paired differences in catch by tow between the control and experimental nets. T-test results showed a significant difference in catch weights for yellowtail flounder and for windowpane flounder. The large mesh belly panel significantly reduced the bycatch of both flounder species. There was a 72.3% reduction in yellowtail flounder catch and 50.9% reduction in windowpane flounder catch in the net with the large mesh belly panel compared to the control net. T-test results showed a non-significant result for the catch difference of whiting in the net with the large mesh belly panel compared to the control net. T-test results showed a significant difference for squid. The large mesh belly panel experimental net retained more squid that the control net. Since the experimental net did not cause significant reduction in the catch of the target species of whiting and squid but did significantly reduce bycatch of yellowtail flounder and windowpane flounder, the large mesh belly panel shows promise as a possible certified bycatch avoidance net.

SUMMARY OF CONCLUSIONS

- The large mesh belly panel has proven to be functionally effective in significantly reducing the quantity of yellowtail flounder bycatch. The large mesh belly panel reduced yellowtail flounder bycatch by 72.3%.
- The large mesh belly panel has also proven to be functionally effective in significantly reducing the quantity of windowpane flounder bycatch. The large mesh belly panel reduced windowpane flounder bycatch by 50.9%.
- There was no significant difference in whiting catch between the control net and the net modified with the large mesh belly panel. Retention of this target species was maintained using the experimental net.
- There was a statistically significant difference in squid catch between the control net and the net modified with the large mesh belly panel. The experimental net retained more squid compared to the control net. The experimental net does not cause a reduction in the squid catch.
- Possible additional effects of day/night, side and door spread do not have an effect on the above results.

Table 4. Tow and Catch Data for Four Key Species

TRIP NUMBER	TOW NUMBER	TOW DATE	TOW START TIME	TOW END TIME	DAY (D)/NIGHT (N)	CONTROL NET							EXPERIMENTAL NET							CATCH DIFFERENCES (CONT-EXP)			
						SIDE – PORT (P) OR STARBOARD (S)	DOOR SPREAD @ TOW START (FA)	DOOR SPREAD @ TOW END (FA)	YELLOWTAIL (LBS)	WINDOWPANE (LBS)	LONGFIN SQUID (LBS)	WHITING (LBS)	SIDE – PORT (P) OR STARBOARD (S)	DOOR SPREAD @ TOW START (FA)	DOOR SPREAD @ TOW END (FA)	YELLOWTAIL (LBS)	WINDOWPANE (LBS)	LONGFIN SQUID (LBS)	WHITING (LBS)	YELLOWTAIL (LBS)	WINDOWPANE (LBS)	LONGFIN SQUID (LBS)	WHITING (LBS)
1	1	01/15/14	10:57	11:28	D	P	36	38	0	27.5	36.6	3.4	S	37	38	0	7.9	56.4	1.8	0	19.6	-19.8	1.6
1	2	01/15/14	11:56	12:26	D	P	38	37	3.8	31.6	81	4.5	S	38	38	1.3	15.2	61.7	1.7	2.5	16.4	19.3	2.8
1	3	01/15/14	13:49	14:19	D	P	36	37	5.2	53.5	182.9	28.9	S	37	37	3.2	30.3	202.9	23.4	2	23.2	-20	5.5
1	4	01/15/14	15:26	15:56	D	P	37	36	0	6.2	93.2	55.6	S	38	38	0.8	3.2	119.4	174	-0.8	3	-26.2	-118.4
1	5	01/15/14	17:21	17:50	N	P	38	38	0	0	25.5	256.6	S	36	37	0	0.8	32.9	222.8	0	-0.8	-7.4	33.8
1	6	01/15/14	18:26	18:57	N	P	38	38	0	0.5	75.8	51.7	S	38	38	0	0	103.1	81.6	0	0.5	-27.3	-29.9
1	7	01/16/14	6:38	7:07	D	P	37	37	44.9	180.7	18	16.3	S	37	37	11.6	97.2	23.3	13.1	33.3	83.5	-5.3	3.2
1	8	01/16/14	7:34	8:03	D	P	37	37	99.5	452	26.6	20.7	S	37	36	21.4	255.8	38.7	8.7	78.1	196.2	-12.1	12
1	9	01/16/14	8:35	9:05	D	P	37	37	223.4	281	20.7	6.3	S	37	37	46.1	56.1	24.4	5.5	177.3	224.9	-3.7	0.8
1	10	01/16/14	9:41	10:11	D	P	36	35	329.4	381.8	30.9	8.5	S	37	36	82.5	177.3	22.7	4.9	246.9	204.5	8.2	3.6
1	11	01/16/14	10:30	11:00	D	P	36	36	419.8	246.1	13.7	23.4	S	37	36	123.7	134.4	20.3	13.7	296.1	111.7	-6.6	9.7
1	12	01/16/14	12:03	12:33	D	P	36	37	204.7	159.4	9.4	12.9	S	36	37	74	83.9	25.3	6.2	130.7	75.5	-15.9	6.7
1	13	01/16/14	13:27	13:57	D	P	36	36	311.3	289.6	15.7	7.2	S	37	37	70.1	134.1	32.5	6.9	241.2	155.5	-16.8	0.3
1	14	01/16/14	14:19	14:49	D	P	37	38	336.9	311.5	18.6	16	S	37	37	47.6	123.3	15.8	6.3	289.3	188.2	2.8	9.7
1	15	01/16/14	15:15	15:46	D	P	NA	NA	311.7	439.2	20	13.2	S	NA	NA	90.3	258.1	30	5.6	221.4	181.1	-10	7.6
1	16	01/16/14	16:46	17:16	N	P	37	37	246.2	63.7	10.5	4.8	S	37	37	157.4	77.9	13.7	5.1	88.8	-14.2	-3.2	-0.3
1	17	01/16/14	17:35	18:05	N	P	37	37	326.2	126.8	6.5	4.9	S	38	38	168	78.1	9.2	4.1	158.2	48.7	-2.7	0.8
1	18	01/16/14	18:37	19:07	N	P	37	37	91	215.3	6.4	9.7	S	37	37	140.7	149.4	12.1	8.9	-49.7	65.9	-5.7	0.8
1	19	01/17/14	7:04	7:34	D	P	36	36	305.1	346.1	12.4	8	S	37	37	104.9	194.7	14.2	3.7	200.2	151.4	-1.8	4.3
1	20	01/17/14	7:52	8:22	D	P	37	37	246.5	255.6	13.4	5.1	S	37	38	65.4	142.8	14.1	2.2	181.1	112.8	-0.7	2.9
1	21	01/17/14	9:08	9:37	D	S	37	38	243.7	313.8	14.8	7.3	P	36	37	27.6	71.3	44.6	8.5	216.1	242.5	-29.8	-1.2
1	22	01/17/14	9:57	10:27	D	S	37	37	245.8	233.6	34.7	6.9	P	37	37	56.2	128.6	32	2.6	189.6	105	2.7	4.3
1	23	01/17/14	10:47	11:17	D	S	37	37	278.4	196.4	11.6	15.8	P	36	37	51.1	70.8	18.6	10.4	227.3	125.6	-7	5.4
1	24	01/17/14	11:37	12:07	D	S	38	39	343.9	160.4	17.9	9.5	P	38	39	87.6	94.8	12.4	6.5	256.3	65.6	5.5	3
1	25	01/17/14	12:26	12:56	D	S	38	39	170.1	279.5	12.5	6.2	P	38	38	54.8	120.7	17.4	2.4	115.3	158.8	-4.9	3.8
1	26	01/17/14	13:15	13:45	D	S	37	37	345.8	356.5	9.6	10.1	P	37	36	55.7	82.4	18.1	5.2	290.1	274.1	-8.5	4.9
1	27	01/17/14	14:09	14:39	D	S	37	38	149.7	266.9	20.9	4.1	P	38	38	64.2	158.9	20.9	5.5	85.5	108	0	-1.4
1	28	01/17/14	14:59	15:29	D	S	38	37	324.5	349.8	14.1	12.3	P	37	36	95.8	144.6	26.8	6.3	228.7	205.2	-12.7	6
1	29	01/17/14	15:51	16:21	D	S	36	37	223.4	295	13.5	8.7	P	38	38	91.2	199	14.3	4.4	132.2	96	-0.8	4.3
1	30	01/17/14	16:48	17:19	N	S	37	37	356.3	319.3	9.6	10.8	P	37	37	176.9	150.7	7.3	7	179.4	168.6	2.3	3.8
1	31	01/18/14	6:05	6:35	N	S	37	37	164.8	354.1	9.4	7.6	P	36	37	77.2	246.9	7	6.2	87.6	107.2	2.4	1.4
1	32	01/18/14	6:53	7:23	D	S	36	38	302.5	405.1	6.9	7.3	P	37	38	118.7	274	8.8	3.5	183.8	131.1	-1.9	3.8
1	33	01/18/14	7:42	8:12	D	S	37	37	274.5	169.9	14.5	5.1	P	36	37	35.7	52.1	14.6	2.1	238.8	117.8	-0.1	3
1	34	01/18/14	8:30	9:00	D	S	37	37	370.8	212.3	15.4	3.5	P	37	38	64.8	92.8	13.5	3.5	306	119.5	1.9	0
1	35	01/18/14	9:19	9:49	D	S	37	37	300.5	185.7	12	4.5	P	37	37	44	56.1	18.9	2.3	256.5	129.6	-6.9	2.2
1	36	01/18/14	10:07	10:36	D	S	37	37	503.9	227.5	12.5	5.1	P	37	38	97.3	96.5	19.2	2.1	406.6	131	-6.7	3
1	37	01/18/14	10:54	11:25	D	S	38	38	387	251.8	18.9	5.4	P	37	38	72.3	119	24.5	4	314.7	132.8	-5.6	1.4
1	38	01/18/14	11:42	12:12	D	S	37	38	706.7	238.4	16.7	7.4	P	37	38	75	83.4	18.9	5.1	631.7	155	-2.2	2.3
1	39	01/18/14	12:31	13:01	D	S	37	37	1135.9	210.1	14.6	8.8	P	36	37	336.4	81.3	9.1	4.1	799.5	128.8	5.5	4.7
1	40	01/18/14	13:20	13:50	D	S	36	37	1775.3	160.4	32.8	10.6	P	36	38	457	97.4	22.2	3.1	1318.3	63	10.6	7.5

Figure 27. Diagram of the 420 x 16 cm Trawl Net

Figure 27. Diagram of the 420 x 16 cm Trawl Net
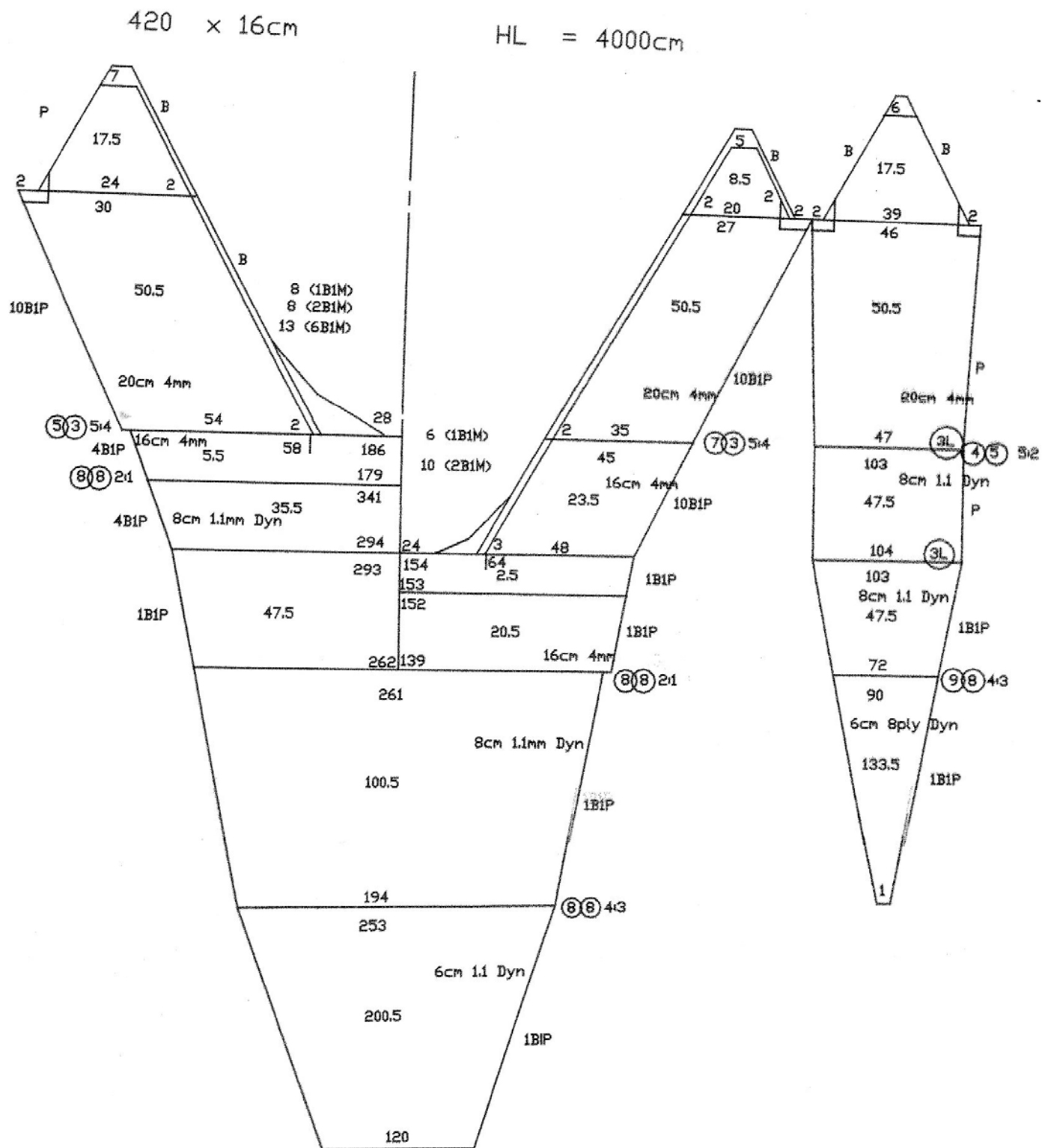
Figure 28. Diagram of Large Mesh Belly Panel

Large mesh 1st belly panel for 420 x 16cm

SEW 1:1 TO ROCKBAND

153   ROCKBAND

152   16cm 4mm

2.5 ◇   1B1M

151   ③④ 5:1

36   80cm 5mm

2.0 ◇   P

36

2.0 ◇   141 16cm 4mm   ④⑤ 5:1

139   1B1P
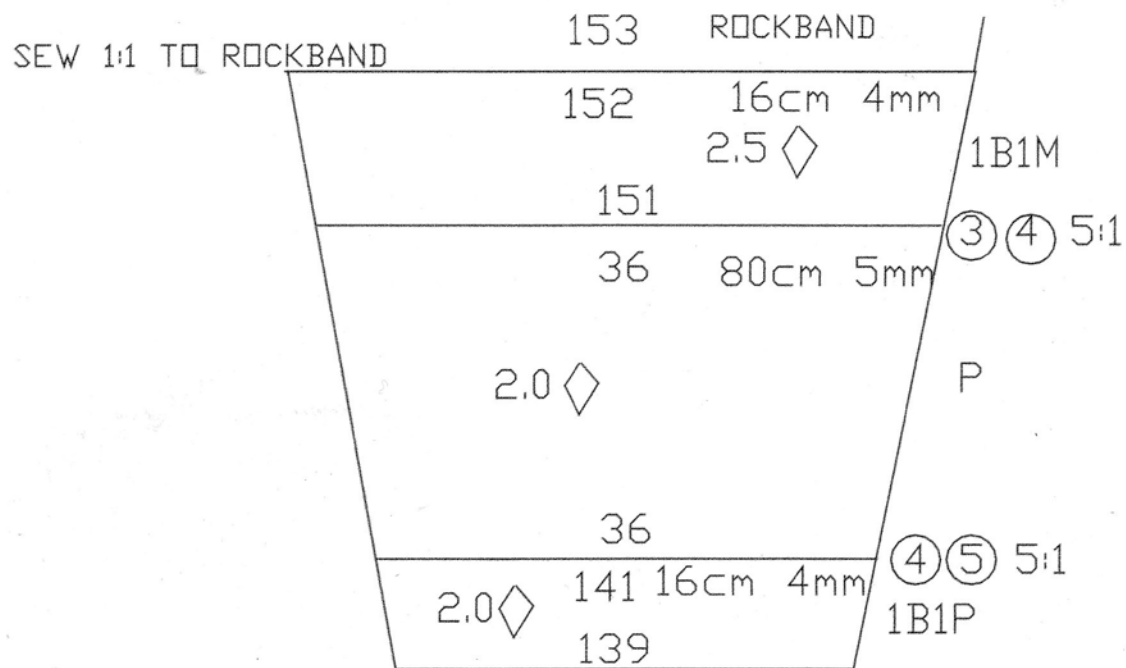
LEAVE 1/2 MESH OF BELLY AND SEW 1:1
(if new trawl bottom strip
should be 3 meshes deep)

Scaling the Large Mesh Belly Panel to Fit Other Nets

The design and construction of a large mesh belly panel to go into an existing small mesh trawl is based on the premise that the large mesh panel will have the same coverage area as the belly that it is replacing. To that end, the first step is to determine the ratio of the mesh sizes involved. The large mesh belly twine is 80cm KKFM (Knot center to Knot center Full Mesh), 2 meshes deep with a 40cm sowing seam on top and bottom. In most cases the existing 1st bottom belly twine sizes are 12cm KKFM and 16cm KKFM yielding ratios of 20:3 and 5:1, respectively. Therefore, to determine the width of large mesh panel, one takes the number of meshes of the existing belly and divides by the ratio. Some number of one to one meshes can be included on the edges to facilitate the lacing of the bottom panel to the top or sides.

In practice, it is beneficial to leave some number of meshes behind the sweep to facilitate installation and in many cases the second bottom belly is smaller mesh therefore leaving at least a half mesh of the narrow end of the 1st bottom belly facilitates installation. Then it is a matter of using ratio to determine the appropriate depth of the large mesh belly panel.

As an example, the 1st bottom belly of a common 420 x 16cm 4 – seam trawl is 154 meshes on the wide end, 139 meshes on the narrow end and is 23.5 meshes deep of 16cm webbing (a very common depth). The large mesh belly panel consists of 2 meshes deep of 80cm webbing with the sowing seam on either end yield 3 deep of 80cm.

> 80cm x 3meshes = 240cm
> 240cm / 16cm = 15 - 16cm meshes

Therefore, if 6 meshes are left behind the sweep and 2.5 meshes are left on the narrow end of the belly, the belly will sow in and be the correct depth.

To determine the width of the large mesh panel, take the width of the belly at 6 meshes behind the sweep, 150, and divide by the ratio, 80:16 (5:1) and you get the width of the large mesh belly, 30.

> 150 meshes of 16cm / 5 = 30 meshes of 80cm

In practice the large mesh panel is made wider so there can be some one to one meshes on the sides of the panel to facilitate goring to the top or sides. For the 420 x 16cm trawl a 36 mesh wide panel was used.

In terms of enforcement, the first thing is the mesh size. 80cm 6mm webbing has a BKFM (Between the Knot Full Mesh) of 30". Secondly, the width of the panel is that it should go all the way from one bottom gore to the other bottom gore. And lastly, the depth is 3 - 80cm meshes, but it is easier for enforcement if it was said that the depth was at least 90" of 30" BKFM mesh or greater.

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