Testing of a Low Profile Excluder Dredge For Flatfish Bycatch Reduction

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For Flatfish Bycatch Reduction

Project Summary

A new low profile concept for a scallop dredge frame (LPD) has been designed and constructed based on experiences with the Cfarm turtle deflector dredge (CFTDD). The low profile dredge frame (LPD) was comparison fished against a CFTDD (which will be required in the scallop fishery in certain areas and seasons) and a New Bedford dredge (NBD) frame. The testing took place on Georges Bank and Southern New England, in areas of high yellowtail and/or winter flounder bycatch. Results indicate that the LP dredge frame with a wide depressor plate has the potential to select for larger scallops while decreasing the bycatch of flatfish and benthos. Four commercial vessels were utilized on research trips as follows:

F/V Diligence 2011-1	July 6-12, 2011	78 tows	LPD vs CFTDD
F/V Freedom 2011-1	August 15-21, 2011	81 tows	LPD vs CFTDD
F/V Monomoy 2011-1	October 10-16, 2011	82 tows	LPD vs CFTDD
F/V Monomoy 2011-2	November 1-5, 2011	49 tows	LPD vs NBD
F/V Westport 2012-1	April 10-13, 2012	55 tows	LPD vs NBD

Project Duration March 1, 2011 through May 31, 2012

Background

The scallop resource is in good condition but time and time again the optimized scallop harvest is reduced due to fish and turtle bycatch issues resulting in the loss of millions of dollars in revenues. The introduction of yellowtail ACLs and AMs may create a very complex regulatory environment if time and area restrictions are the only tool available. AMs may even require reduction in scallop yields. Gear solutions hold out the promise of a much simpler regime.

A new concept for construction of a New Bedford style sea scallop (*Placopecten magellanicus*) dredge frame was designed and tested with the goal of keeping loggerhead sea turtles (*Carretta carreta*) from snagging on top of the dredge frame and becoming trapped under the dredge bale while the gear is towed. The dredge frame was designed to smoothly guide turtles over the top of the dredge primarily by moving the cutting bar forward and eliminating most of the bale bars (**Smolowitz et al. 2010**; **Smolowitz et al. 2008**).

From May 2006 until November 2009 a total of thirty-three trips were made on thirteen different commercial scallop vessels to test dredge modifications for impacts on scallop catch, fish bycatch, and frame durability. Five general design modifications were tested by conducting paired tows using the modified dredge design along side a standard New Bedford dredge as a control. Both the modified dredge and control dredges were fished using identical tow parameters. A total of 4,059 paired tows were conducted in which tow data and scallop catch were recorded; total catch was quantified from 40% of these tows. In addition, flume tank testing was utilized for flow characterization to determine if there were any significant differences in cutting bar and frame hydrodynamics between the various design options.

The final dredge frame design, the Coonamessett Farm Turtle Deflector Dredge (CFTDD), tested in the study held up to the rigors of commercial fishing on most scallop grounds, maintained commercially acceptable levels of scallop catch, had significantly lower bycatch of several species, while applying features that could reduce injury to sea turtles. In addition, this dredge design was found to be readily acceptable and applied by fishers with no increase in costs or labor.

Overall the experimental dredge design concept (cutting bar forward of depressor plate, 45° cutting bar and strut angle, doubled outer bale, and reduced number of bale bars) increased the catch of scallops while decreasing the retention of important bycatch species. Of the 1,632 observed tows analyzed (student's t test for paired means a=0.05) relative to the standard New Bedford dredge, the experimental dredges increased scallop catch by 3% ($P = 0.0000$) while having significant decreases in summer flounder(-11%, $P= 0.003$), yellowtail flounder (-46%, $P_t=0.0000$), winter flounder (-69%, $P=0.0000$), barndoor skate (-18%, $P= 0.0000$), winter skate (-20%, $P_t = 0.005$), sand dab (-47%, $P=0.0000$), and fourspot flounder (-20%, $P=0.0000$). Interestingly there were no significant difference in the catch of little skate (-0.3%, $P_t = 0.404$) and monkfish (1%, $P= 0.309$).

Gear Description

The hypothesis on why the dredge reduces flatfish bycatch is that the forward cutting bar design encourages the fish to swim upwards and over the dredge. In a standard dredge, if a flatfish encounters the cutting bar and swims up it comes into contact with the depressor plate and can only head into the dredge bag. In the forward cutting bar design the depressor plate does not block this escape route.

The new idea we tested under this proposal was to lower the profile of the CFTDD dredge to make it easier for fish to swim over the oncoming frame. This was accomplished by changing the frame angle, on a 15-foot wide dredge, from 45° to 22.5° and lowering the dredge frame height by four inches. The resulting low profile dredge frame has a shoe 22 inches long compared to the existing standard dredge shoe of 15 inches (**Figure 1**). We maintained the turtle excluder dredge strut spacing of 9 inches, the reduced number of bale bars, the doubled outer bale, and the 45° cutting bar angle. We also tested a wider depressor plate as this reduces the opening above the cutting bar further blocking fish entering the dredge (**Figures 2 and 3**). Gear specifications can be found in **Table 1** and drawings of the LP dredge can be found in **Appendix A**.

Additionally, the scallop bag was redesigned to accompany the reduced height of the frame. We decreased the number of rows in the side pieces to compensate for the height change. In theory, the lower height of the frame and bag might aid in the escapement of fish that enter the dredge.

Methods

Approach

We compared dredges on five trips. Four of the trips occurred in the scallop special access areas within groundfish CAI and CAII; the F/V Westport conducted a fifth trip south of Block

Island (SNE). CAI and CAII have high ratios of bycatch to scallop catch on Georges Bank for yellowtail flounder (CAII), skates (CAI & CAII), winter flounder (CAI) and summer flounder (CAI). They also contain a range of habitat types from flat sand to occasional boulder. The SNE area had high bycatch levels of flatfish and skates.

On the first three trips each vessel was outfitted with a15-foot wide CFTDD and LPD rigged with a standardized bag that was held constant throughout the project except where described modifications occurred. The fourth trip investigated changes to the bag design. The fifth trip tested a LPD with a 20-inch wide depressor plate against a NBD. The vessels were told to tow at 4.6-4.8 knots using 3:1 wire scope but on the fifth trip the speed was held at 4.8 knots and scope was 3:1 minus 10 fathoms for the LP dredge. The tows were 30 minutes in duration. All tow parameters were recorded including start and end positions, depth, and sea conditions. On each trip a relative comparison was made between the two gear types for catch and bycatch.

For each paired tow, the catch from each dredge was separated by species and individually counted. The entire scallop catch was recorded as bushels (bu=35.2 liters). A one bushel subsample of scallops from each dredge was picked at random from each tow. These subsamples were measured in 5 mm incremental groups to estimate the length frequency of the entire catch. This method allows for the determination of the size frequency of the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. All of the commercially important finfish species and barndoor skates were measured to the nearest centimeter and counts were taken of winter and little skates.

Gear Comparisons

The objective of these experiments was to determine if the two different scallop dredges performed differently and how those differences might be affect catch rates and size selection of both scallops and the major finfish bycatch species. To examine the comparative data, we used a Generalized Linear Mixed Model (GLMM) to analyze the paired catch data and test for differences in both the pooled length catch data as well as test for differences in the length composition of the catch. Within this modeling framework, the random effects acknowledge the potential for differences that may have occurred at both the trip and individual tow levels. The GLMM groups all the data and gives an overall perspective on how the two gears compare over the entire experiment. Then, a Student t-test was used to compare the separate dredges on each individual trip.

The paired tow experiments were conducted within the context of a bycatch survey of the Georges Bank Closed Areas I and II covering a wide range of fishery conditions. This approach has the advantage of mirroring the actual biotic and abiotic conditions under which the dredge will operate. Multiple vessels and slight variations in gear handling and design were included in the experimental design and, while this variability exists, the GLMM modeling approach detailed in the next section accounts for the variability and allows for a more broad inference (relative to vessels) to be made. In contrast, the Student t-test approach is trip specific and therefore is not the most appropriate methodology for comparing data from two or more different trips.

Statistical Models – GLMM

Scallop catch data from the paired tows provided the information to estimate differences in the fishing power of each vessel/gear combination tested and is based on the analytical approach in Cadigan et al. 2006. Assume that each vessel/gear combination tested in this experiment has a unique catchability. Let q_r equal the catchability of the CFTDD and q_f equal the catchability of the standard dredge used in the study. The efficiency of the CFTDD relative to the standard dredge will be equivalent to the ratio of the two catchabilities:

$$\rho_l = \frac{q_r}{q_f} \qquad (1)$$

The catchabilities of each gear are not measured directly. However, within the context of the paired design, assuming that spatial heterogeneity in scallop and fish density is minimized, observed differences in scallop catch for each vessel will reflect differences in the catchabilities of the vessel/gear combinations tested. Our analysis of the efficiency of the CFTDD relative to the standard dredge consisted of two levels of examination. The first analysis examined potential differences in the total catch per tow. Subsequent analyses investigated whether size (i.e. length) was a significant factor affecting relative efficiency. Each analysis assumes a hierarchy of random variation and nests tow by tow variation within trip level variation.

Let C_{iv} represent the scallop catch at station i by dredge v, where $v=r$ denotes the CFTDD and $v=f$ denotes the standard New Bedford style dredge. Let λ_{ir} represent the scallop/fish density for the i^{th} station by the CFTDD and λ_{if} the scallop/fish density encountered by the standard dredge. We assume that due to random, small scale variability in animal density as well as the vagaries of gear performance at tow i, the densities encountered by the two gears may vary as a result of small-scale spatial heterogeneity as reflected by the relationship between scallop patch size and coverage by a paired tow. The probability that a scallop is captured during a standardized tow is given as q_r and q_f. These probabilities can be different for each vessel, but are expected to be constant across stations. Assuming that capture is a Poisson process with mean equal to variance, then the expected catch by the CFTDD is given by:

$$E(C_{if}) = q_f \lambda_{if} = \mu_i \qquad (2)$$

The catch by the standard dredge is also a Poisson random variable with:

$$E(C_{ir}) = q_r \lambda_{ir} = \rho \mu_i \exp(\delta_i) \qquad (3)$$

where δ_i =log ($\lambda_{ir}/ \lambda_{if}$). For each station, if the standardized density of scallops encountered by both vessels is the same, then δ_i=0.

If the dredges encounter the same scallop density for a given tow, (i.e. $\lambda_{ir}= \lambda_{if}$), then ρ can be estimated via a Poisson generalized linear model (GLM). This approach, however, can be complicated especially if there are large numbers of stations and scallop lengths (Cadigan et al. 2006). The preferred approach is to use the conditional distribution of the catch by the CFTDD at station i, given the total non-zero catch of both vessels at that station. Let c_i represent the observed value of the total catch. The conditional distribution of C_{ir} given C_i=c_i is binomial with:

$$\Pr\left(C_{ic} = x \middle| C_i = c_i\right) = \binom{c_i}{x} p^x (1-p)^{r_i - x} \quad (4)$$

where $p=\rho/(1+\rho)$ is the probability that a scallop taken in the survey is captured by the CFTDD. In this approach, the only unknown parameter is ρ and the requirement to estimate μ for each station is eliminated as would be required in the direct GLM approach (equations 2 & 3). For the binomial distribution $E(C_{ir})=c_ip$ and $Var(C_ir)=c_ip/(1-p)$. Therefore:

$$\log\left(\frac{p}{1-p}\right) = \log(\rho) = \beta \quad (5)$$

The model in equation 5, however, does not account for spatial heterogeneity in the densities encountered by the two gears for a given tow. If such heterogeneity does exist then the model becomes:

$$\log\left(\frac{p}{1-p}\right) = \beta + \delta_i \quad (6)$$

where δ_i is a random effect assumed to be normally distributed with a mean=0 and variance=σ^2. This model is the formulation used to estimate the gear effect $exp(\beta_0)$ when scallop catch per tow is pooled over lengths.

Often, modifications can result in changes to the length based relative efficiency of the two gears. In those instances, the potential exists for the catchability of scallops at length (l) to vary. Models to describe length effects are extensions of the models in the previous section to describe the total scallop catch per tow. Again, assuming that between-pair differences in standardized scallop density exist, a binomial logistic regression GLMM for a range of length groups would be:

$$\log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \delta_i + \beta_1 l, \delta_i \sim N(0,\sigma^2), i = 1,\ldots,n. \quad (7)$$

In this model, the intercept (β_0) is allowed to vary randomly with respect to cruise/station. The potential exists, however, that there will be variability in both the number as well as the length distributions of scallops encountered within a tow pair. In this situation, a random effects model that again allows the intercept to vary randomly between tows is appropriate (**Cadigan and Dowden 2009**). This model is given below:

$$\log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \delta_{i0} + \beta_1 * l, \delta_{ij} \sim N(0,\sigma_j^2), i = 1,\ldots,n,\ j = 0,1. \quad (8)$$

Adjustments for sub-sampling of the catch

Additional adjustments to the models were required to account for sub-sampling of the catch. In most instances, due to high volume, catches for particular tows were sub-sampled. This is accomplished by randomly selecting a one bushel sample for length frequency analysis. One approach to accounting for this practice is to use the expanded catches. For example, if half of the total catch was measured for length frequency, multiplying the observed catch by two would result in an estimate of the total catch at length for the tow. This approach would overinflate the sample size resulting in an underestimate of the variance, increasing the chances of spurious statistical inference (**Millar et al. 2004; Holst and Revill 2009**). In our experiment, the proportion sub-sampled was not consistent between tows as only a one bushel sub-sample was taken regardless of catch size. This difference must be accounted for in the analysis to ensure that common units of effort are compared.

Let q_{ir} equal the sub-sampling fraction at station i for the vessel r. This adjustment results in a modification to the logistic regression model:

$$\log\left(\frac{p_i}{1+p_i}\right) = \beta_0 + \delta_{i0} + (\beta_1 + \delta_{i1})l_i + \log\left(\frac{q_{ir}}{q_{if}}\right), \delta_{ij} \sim N(0, \sigma_j^2), i = 1,\ldots,n,\ j = 0,1. \quad (9)$$

The last term in the model represents an offset in the logistic regression (**Littell et al. 2006**). We used SAS/STAT® PROC GLIMMIX to fit the generalized linear mixed effects models.

Statistical approach – Student T-Test

Paired student t-tests were used for trip by trip comparisons to test for significance between the experimental and control dredges in terms of catch of scallops and ten other species. Significance was evaluated as a difference from zero. The methodology of towing two dredges simultaneously provided for the assumptions necessary to analyze the data using a paired t-test. **Zar (1984)** states, "the paired-sample t-test does not have the normality and equality of variances assumptions of the two sample t-test, but assumes only that the differences (d(t)) come from a normally distributed population of differences.... Whenever the paired-sample t-test is applicable, the Wilcoxon paired-sample test is also applicable. If, however, the d(t) values are from a normal distribution, then the latter (Wilcoxon) has only a 95% of detecting differences as the former (paired t-test)." Although Zar seems to suggest the paired student t-test as the better test, there is not universal agreement on this issue. Because of this, we also evaluated comparisons using the non-parametric Wilcoxon matched pairs test (**Wilcoxon 1945**) and found that the results were consistent with those provided by the paired Student t-tests. Catch ratios for each dredge were calculated in order to compare the total count of each bycatch species per sampled scallop bushel.

Results

The first trip of the project was conducted by the F/V Diligence from July 6-12, 2011. A total of 78 tows were made in CAI and CAII. Sixty tows were analyzed from CAII. The LPD compared to the CFTDD caught 20% less scallops (760 bu vs 948 bu); had 50% less yellowtail (163 vs 321); 40% less windowpane flounder (35 vs 65); 90% less winter flounder (1 vs 10); 80% less summer flounder (2 vs 10); and, 66% less plaice (21 vs 58).

In CAI, the F/V Diligence conducted 18 successful tow comparisons between the LPD and CFTDD. The LPD caught 22% more scallops (343 bu vs 282 bu) than the CFTDD; about the same amount of yellowtail flounder (28 vs 27); 25% less winter flounder (54 vs 72); 20% less windowpane flounder (75 vs 94); and 45% less summer flounder (6 vs 11).

The second trip onboard the F/V Freedom took place from August 15-21, 2011. The 57 tow comparisons in CAII examined three different depressor plate widths; 10-inch, 13-inch, and a 15-inch with a two inch slot. There was no discernible difference between the three modifications so we grouped the results. The LPD caught 15% less scallops (494 bu vs 584 bu) while catching 21% less yellowtail flounder and 36% less winter flounder (16 vs 25).

In CAI, the F/V Freedom conducted 10 tow pairs using the 10-inch depressor plate and the two dredges fished about the same on scallops (200 bu vs 209 bu) and winter flounder (314 vs 306). There were very few other fish in the catch. We laced up the space between the cutting bar and depressor plate for eight tows but there was no observable impact on catch compared to the unlaced tows. On the last 8 tow pairs we cut three windows in the LPD bag; second row up from the apron and each was 5 meshes across. The results were 24% less scallops (80 bu vs 105 bu) and 47% less winter flounder (99 vs 188).

The third trip was on the F/V Monomoy from October 10-16, 2011. In CAII, 13 tow comparisons were made with the LPD having the twine top hung 1:1 (one mesh to one ring on the skirt). The LPD caught 65% less scallops (7 bu vs 20 bu); 89% less yellowtail flounder (15 vs 132); 70% less windowpane flounder (10 vs 33) and 78% less summer flounder (2 vs 9). There was also a reduction of little skate (227 vs 1027). An additional 34 tow comparisons were made in CAII with a 2:1 hanging ratio resulting in 66% less scallops (35 bu vs 102 bu), 63% less yellowtail flounder (160 vs 428), and 25% less little skate (743 vs 996).

In CAI, the F/V Monomoy conducted 18 tow pairs with a 1:1 hanging ratio on the LPD twine top. The LPD caught 58% less scallops (56 bu vs 133 bu); 84% less winter flounder (30 vs 191); and, 75% less little skate (491 vs 1946). It was recognized that the LPD was also catching less trash (sand dollars, shell, etc) so we began a much more quantitative sampling of the trash. The LPD caught 42% less trash (56 bu vs 134 bu). An additional 15 tow comparisons were made with a 2:1 hanging ratio on the LPD twine top. The LPD catch had 8% less scallops (96 bu vs 104 bu); 13% less winter flounder (95 vs 109) and 11% more little skate (1057 vs 953). There was also a 62% reduction in trash.

The three trips described above utilized the same LPD and CFTDD yet the results from the third trip seem to differ than the first two trips. When we combine the results from all three trips in both areas (eliminating the tows with 1:1 twine tops and windows) we find that the LPD catches about 17% fewer scallops (in bushels); 51% fewer yellowtail; 8% fewer winter flounder; and 30% fewer summer flounder (**Tables 2 & 3**). The loss of scallop catch was considered unacceptable by the fishermen. It was the consensus of our fishing partners that the bag design on the LPD needed to be changed.

The F/V Monomoy made a second trip to test some bag modifications from November 1-5, 2011. It was a commercial trip into CAII and the trip was impacted by bad weather. The crew counted the catch of scallops (in bu) and fish (#'s) on 49 tows. A number of modifications were tried but the crew was not successful in increasing the scallop catch but new ideas were generated. One idea was to widen the depressor plate to 20 inches. In March 2012 the F/V Westport took a newly rigged LPD with the wider depressor plate on a commercial trip into the Hudson Canyon Access Area (HCAA) and found that towing the LPD with short wire (less than 3:1 scope) and at higher speeds (4.8 knots) improved the scallop catch while decreasing trash compared to a NBD.

From April 10-13, 2012 the F/V Westport conducted a research trip between Block Island and Shinnecock Inlet in water depths of 24-28 fathoms. There were 55 tow comparisons between the LPD (with 20-inch depressor) and a standard NBD where both dredges were rigged with the same bag (only the side pieces differed). The LPD caught 12% less scallops (246 bu vs 281); 32% less little skate (6434 vs 9456); 46% less winter skate (43 vs 80); 29% less windowpane flounder (594 vs 833); 64% less yellowtail flounder (190 vs 413); and, 5% less summer flounder (232 vs 244) (**Table 4**). In this area, with large amounts of sand dollars, the LPD caught 67% less trash (152 bu vs 455 bu) (**Figures 4-6**).

A closer examination of the scallop length frequency data from the three trips into CAII on George's Bank shows that the CFTDD caught smaller scallops than the LPD (**Table 5; Figure 7**) when the bags were of similar design and the depressor plates were between 8-13 inches. We converted the scallop catch in bushels to total scallops caught by expanding the one bushel length frequency sample by the total bushels caught per tow. In CAII, where smaller scallops were present, the CFTDD caught more than twice as many scallops under 110 mm as the LPD (1932 vs 912; P(T<=t), 0.009) but were about dead even on scallops larger than 110 mm (11115 vs 11113). This amounts to the CFTDD catching about 33 pounds of meat more in the 148 research tows (30 minute tows). The same tows yielded a 48% reduction in yellowtail flounder bycatch by the LPD.

The F/V Westport trip demonstrates significant scallop size selection differences between the LPD with a 20-inch depressor plate and a NBD with a standard 8-inch depressor plate. The LPD caught 5773 scallops vs 6617 for the NBD (**Table 6; Figure 8**). For scallops below 110 mm shell height the catch was 1072 vs 2149; for greater than 110 mm shell height the LPD caught 4701 vs 4468 for the NBD.

GLMM Partitioning of the data

The data was divided into two groups based upon the gear configurations tested. The first grouping contained the three trips (DIL-1-11, FRE-1-11, and MON-1-11) that tested the Low Profile dredge against the CFTDD. These cruises were conducted on Georges Bank with tows being completed in both GBCAI and GBCAII. Tows in which windows were cut into the LPD bag as well as tows where a 1:1 twine top hanging ration was used were excluded from the analysis. Overall, from this grouping 185 valid tow pairs were included in the analysis. Not all species were present in all tow pairs and for the species examined, individual tows with zero total catch were uninformative and excluded from the analysis.

A second grouping consisting of a single cruise (WES-1-11) tested the LPD versus a Standard New Bedford Style Dredge (SNBSD). This cruise was conducted in a different area (Southern New England) and due to the differences in the gear and spatial extent of the sampling and as a result, this cruise was analyzed separately. In total, 51 valid tow pairs were available for analysis from this grouping.

Statistical models

This analysis attempted to construct a model that would predict the relative efficiency of the LPD relative to the control dredge tested in the experiment based on a variety of covariates and two groupings of the catch data (pooled and unpooled). Utilizing the pooled data (expanded and summed over animal length), we were able to estimate the relative effect of the LPD in terms of the gross catch (i.e. total number of animals caught). In many instances, especially with gear modifications that can possibly alter the relative size composition of the catch, using the unpooled catch data and exploring the length based relative efficiency becomes informative. The second analysis utilizing the unpooled catch data predicts the changes that the LPD had on the relative catch at length for the two experiments. In addition to estimating relative gross catch and length based relative efficiency values, we were also able to test the effect that area (CI, CAII) as well as cruise (DIL-1-11, FRE-1-11, MON-1-11) had on the predicted proportion of relative catches of the two dredges. The experiment that tested the LPD vs. a SNBSD consisted of only a single cruise in one general area. As a result, additional covariates were not included in the modeling of these data.

Group 1 results

The first grouping tested the LPD vs. the CFTDD on three cruises to Georges Bank (CAI and CAII). In most cases, parameter estimates for the pooled data (random intercept model) are negative, indicating reduced catch for the LPD (**Tables 7-10**). Significant reductions were observed for little skates, fourspot flounder, yellowtail flounder, winter flounder, windowpane flounder and sea scallops. In addition area and cruise were found to be significant factors for some species. For example, area and cruise were significant factors describing the relative catch of both sea scallops and fourspot flounder, while only cruise had a significant effect for yellowtail flounder. Scatter plots showing the observed catch of the two dredges and an estimated relative efficiency value are shown in the top panel of **Figures 9-22**.

For the same group, when analyzed with respect to the catch at length data, results showed virtually no significant differences in length composition between the two gears. In many cases, the intercept term was significant; however, the interpretation of a significant intercept term indicates an overall difference in the total catch between the two gears and is the same interpretation as the results from the pooled analysis. The results of the unpooled analysis are shown in **Tables 11-14**. There was some support for significant effects of area and cruise as demonstrated by results for yellowtail flounder and sea scallops. Graphs depicting the observed length frequency distributions, and the proportions (observed and predicted) for all target and bycatch species area shown in the top panels of **Figures 23-32**. Overall, the LPD appears to be less efficient than the CFTDD with minimal differences in size selectivity.

Group 2 results

The second grouping tested the LPD versus a SNBSD on a single trip to the Southern New England area. Given this attribute of the data set, the analysis involved fewer covariates. With respect to the pooled analysis, the results were similar to group 1. Most parameter estimates were negative indicating a relative reduction in relative efficiency. Significant reductions were observed for winter skate, little skate, fourspot flounder, yellowtail flounder, windowpane flounder and sea scallops. Model output for the pooled data analysis is shown in **Table 11**. Scatter plots with estimated relative efficiency values are shown in the bottom panel of **Figures 9-22.**

The analysis of catch at length data demonstrated some interesting results. Examination of parameter estimates (**Table 15**) show that for some flatfish species (summer, fourspot, yellowtail and windowpane) as well as scallops, a significant length based effect existed. The sign of the parameter estimate was positive, indicating an increasing relative efficiency (LPD relative to the SNBSD) as a function of length. This is important because it suggests that the modified dredge is not capturing small individuals as effectively as the other dredge tested. If the predicted line crosses the equivalency line (0.5) and at what length will determine if the dredge is effectively excluding smaller individuals and maintaining or increasing the catch of larger individuals This appears to be the case for sea scallops where the LPD caught fewer small scallops, but then caught the same or more scallops at greater than roughly 100mm shell height. Graphs depicting the observed length frequency distributions, and the proportions (observed and predicted) for all target and bycatch species area shown in the bottom panels of **Figures 23-32**.

Discussion

Our original hypothesis was that by lowering the profile of a CFTDD, basically reducing the frame angle from 45° to 22.5°, we would increase the possibility of fish being able to swim over the oncoming dredge frame. We knew that lowering this angle also reduced the height of the dredge frame and we felt that this might provide added ability of fish to escape through the lowered twine top. We understood that both of these changes could influence the retention of the scallop catch.

What we found after completing the three trips on Georges Bank is that the LPD, when compared to a CFTTD, reduces the catch of smaller scallops, yellowtail, windowpane, and light benthos (sand dollars, sponge, shell). The effect on winter flounder is not as clear. When we tested methods to examine escapement through the twine top (1:1 hanging ratio and windows) we found increase in the reduction of scallops and flatfish catch. Lacing (blocking) the space between the cutting bar and depressor plate had little effect on catch but is a crude test at best. The above information leads us to believe most of the catch in the LPD enters under the cutting bar and then can escape (or be blown out) through the twine top. The angle of attack of the dredge then becomes a critical consideration as it impacts the height of the cutting bar off the bottom and the flow pattern through the skirt and twine top.

The depressor plate plays a key role in two ways; it occupies the space between the cutting bar and frame top and it influences the hydrodynamics. On the F/V Westport trip we compared a very wide, 20-inch, depressor plate on an LPD and a NBD. The tests were conducted at 4.8 knots and less than 3:1 scope for the LPD. The results were dramatic; we greatly reduced the catch of small scallops while increasing the catch of larger scallops with a small loss of overall catch by weight. At the same time we cut the yellowtail bycatch in half. The reduction of benthos and skates significantly cut the time to process the catch on deck.

The big remaining question is why we did not reduce the catch of winter flounder in any significant amount. The speed of towing may not be providing winter flounder an opportunity to escape in front of the dredge. Once in the dredge winter flounder can escape through the twine top or windows. However, increasing these openings tends to reduce the catch of scallops. Work will continue on the bag design to address this issue.

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Figure 1: Side by side comparison of a Cfarm turtle deflector dredge (CFTDD) with a Low profile dredge (LPD). Note the differences in frame height and shoe length.

Figure 2: Basic Low profile design with standard 10-inch depressor plate.

Figure 3: Wide depressor plate (20-inch) design.

Figure 4: Deck shot of the catch on the F/V Westport with the catch of the New Bedford dredge (top) and the low profile (bottom) dumped on deck before sorting.

Figure 5: Deck shot of the catch on the F/V Westport with standard (top) vs low profile (bottom)

Figure 6: Close up view of the catch with standard (top) vs low profile (bottom)

Figure 7: The length frequency plot for the three trips combined into CAII on Georges Bank comparing the LPD with a CFTDD rigged with similar bags.

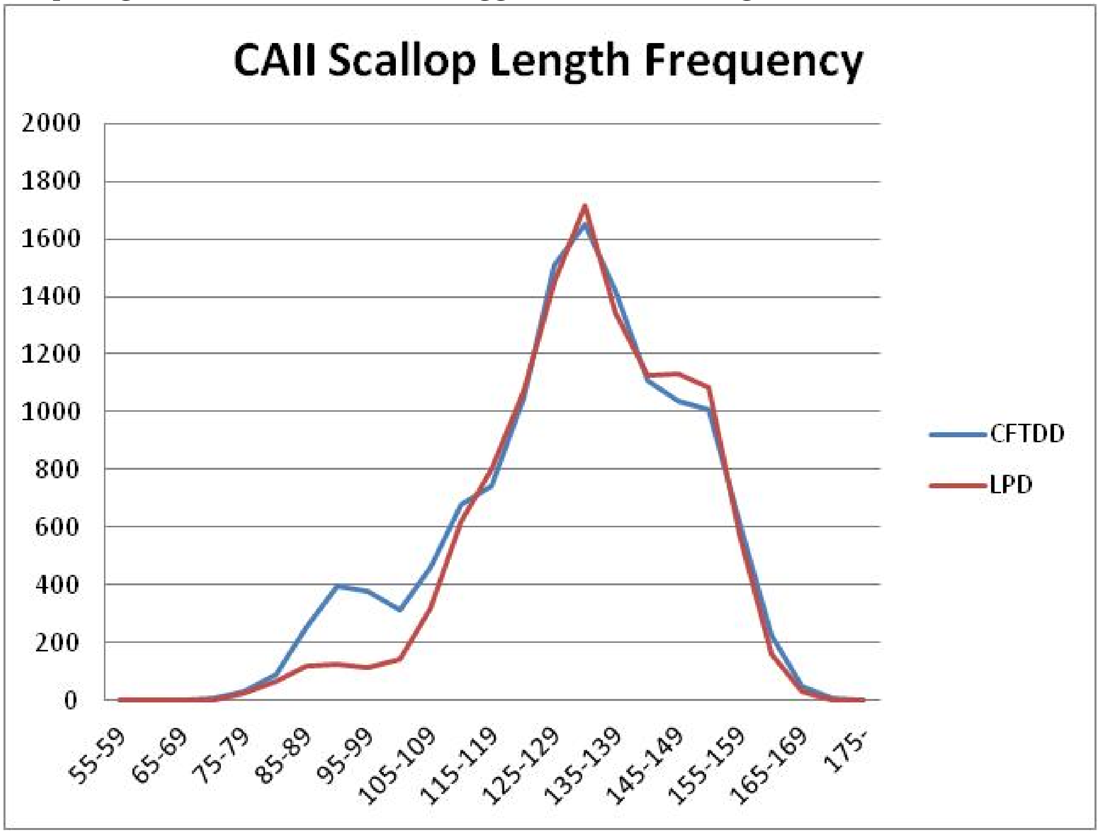


Figure 8: The length frequency plot from the F/V Westport trip comparing the LPD with a 20-inch wide depressor plate to a NBD rigged with similar bags.

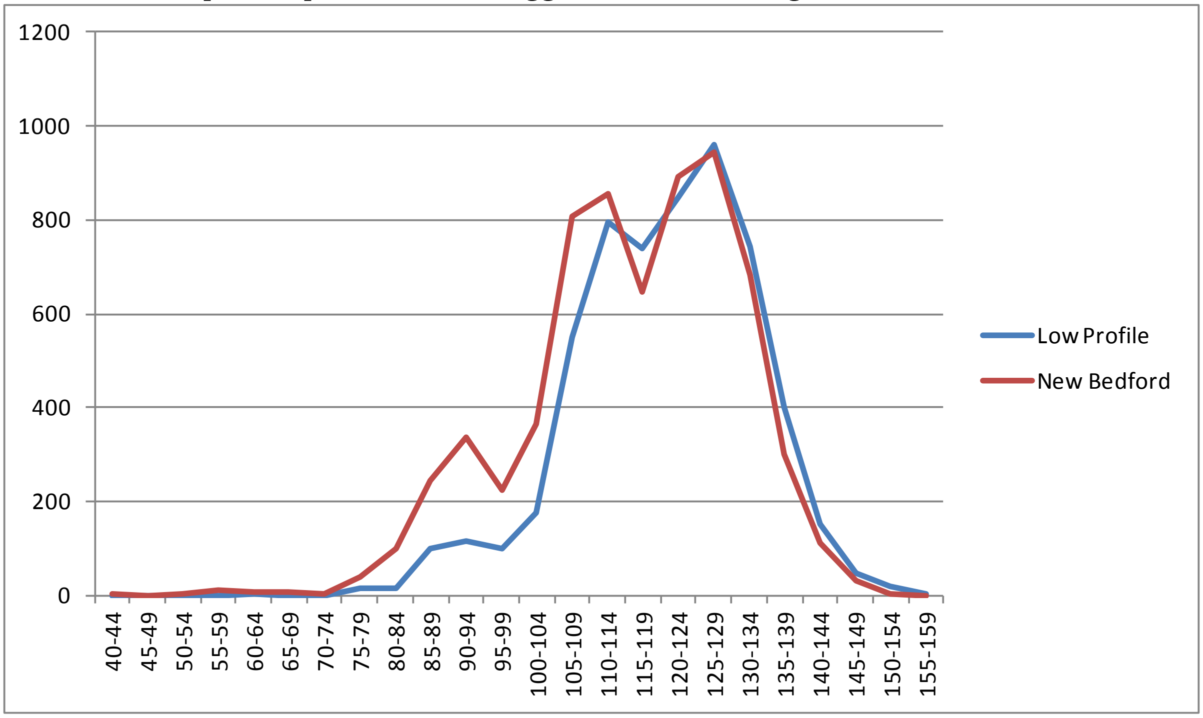
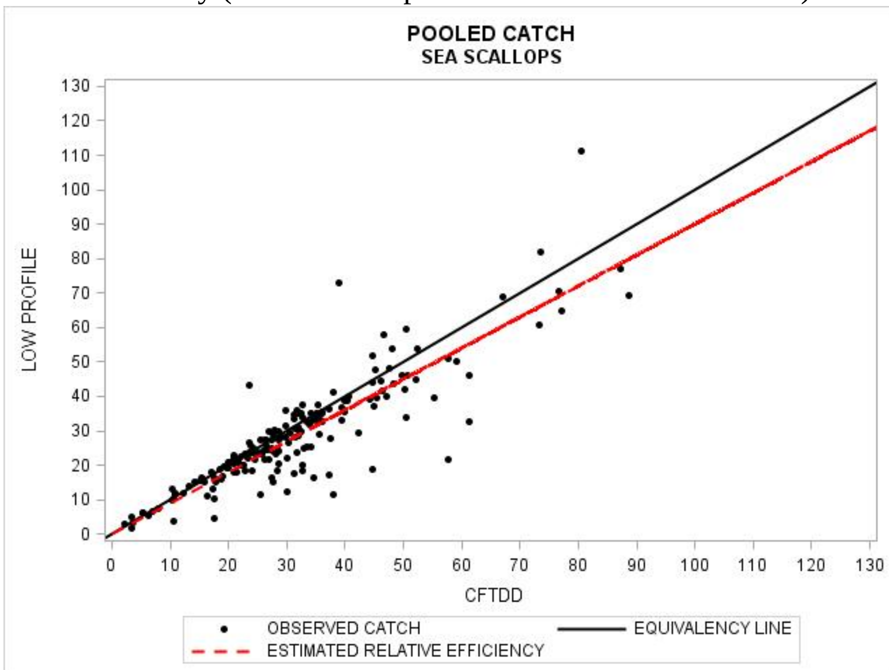


Figure 9: Total pooled catches for Sea Scallops for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).



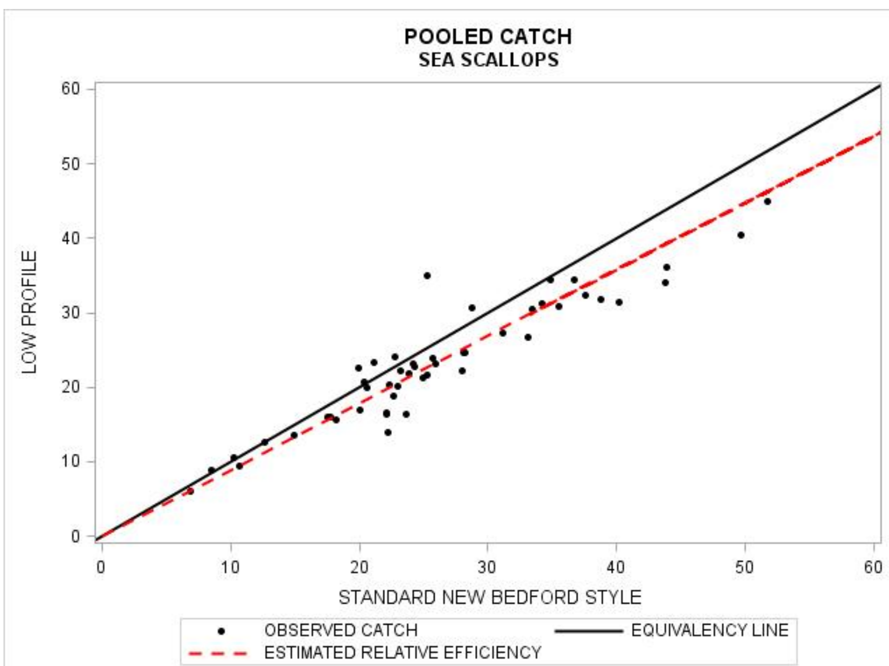


Figure 10: Total pooled catches for Barndoor Skates for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

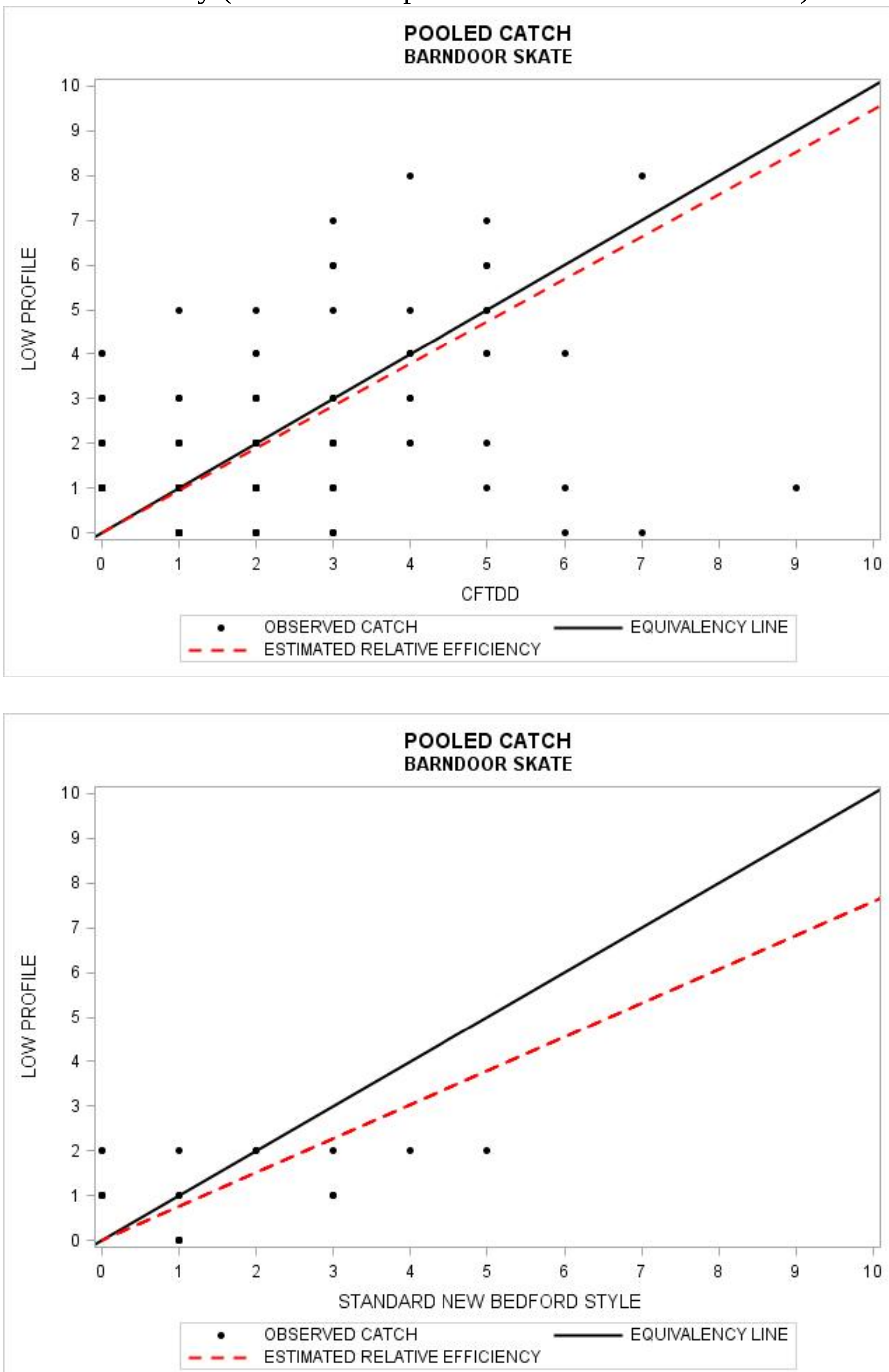
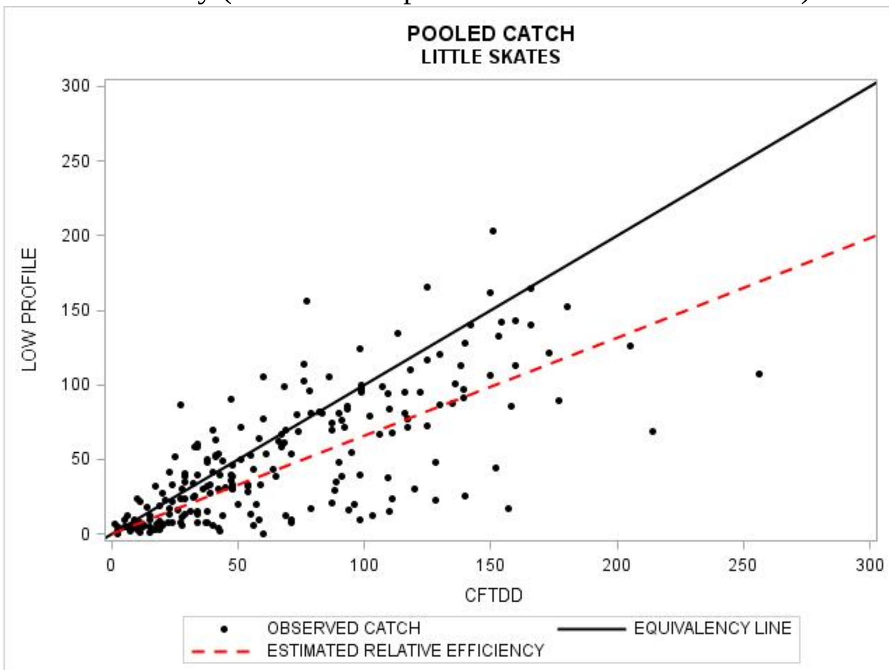


Figure 11: Total pooled catches for Little Skates for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).



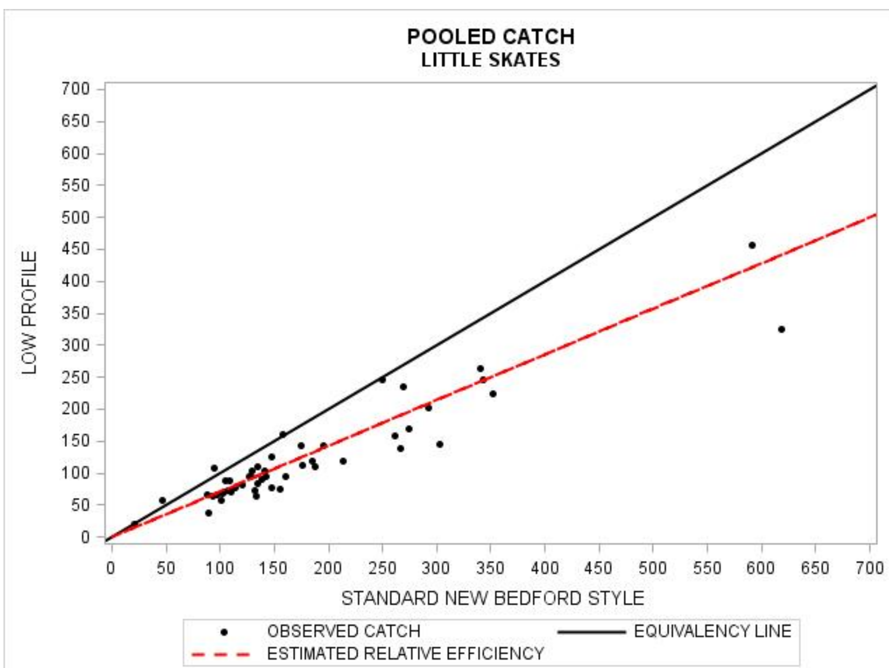


Figure 12: Total pooled catches for Winter Skates for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

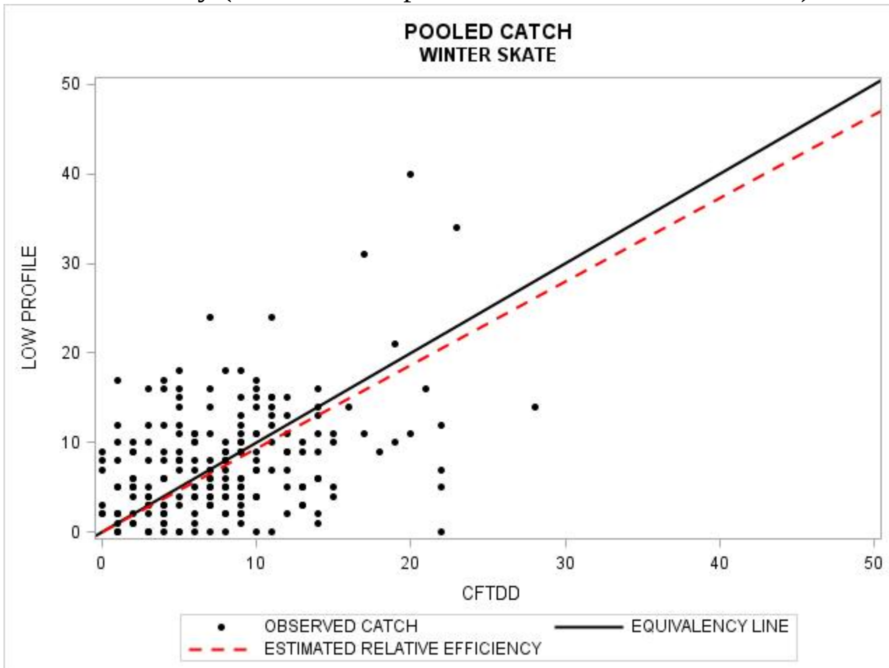
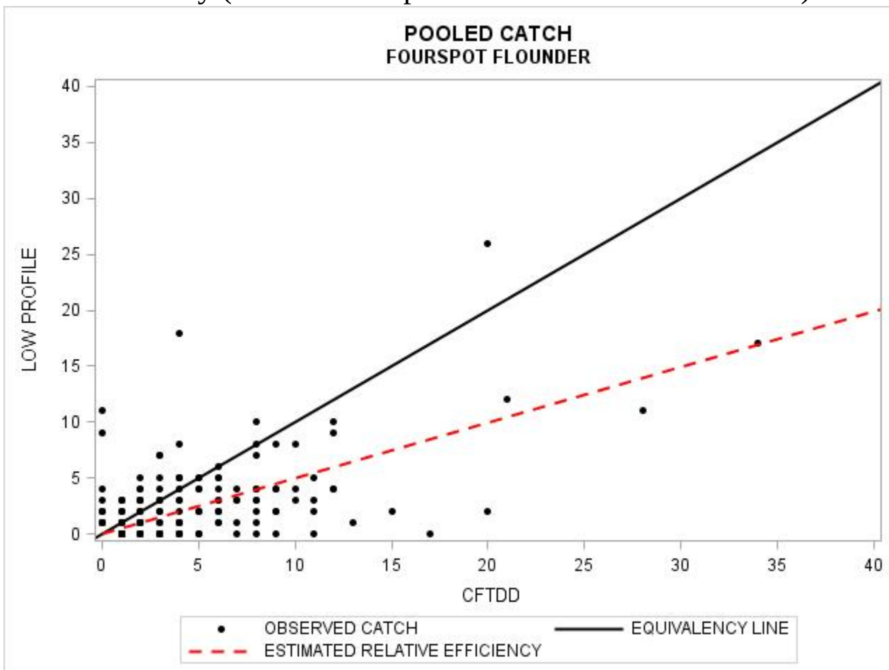


Figure 13: Total pooled catches for Fourspot Flounder for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).



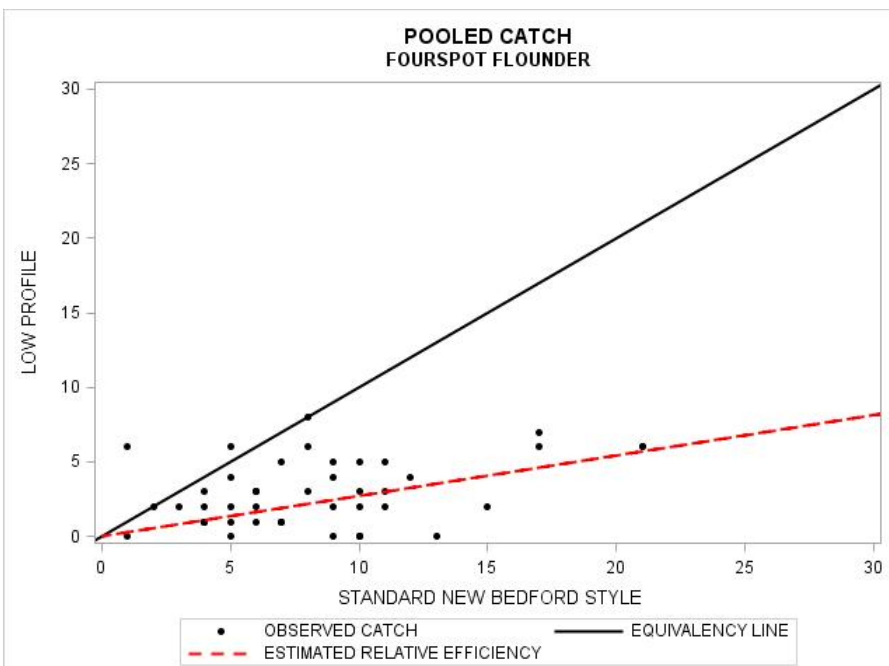
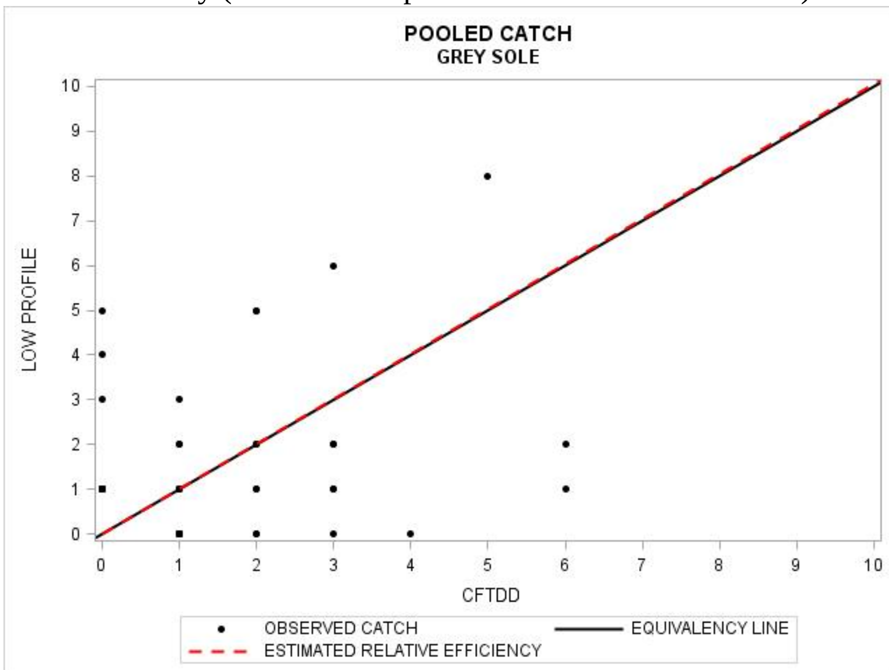
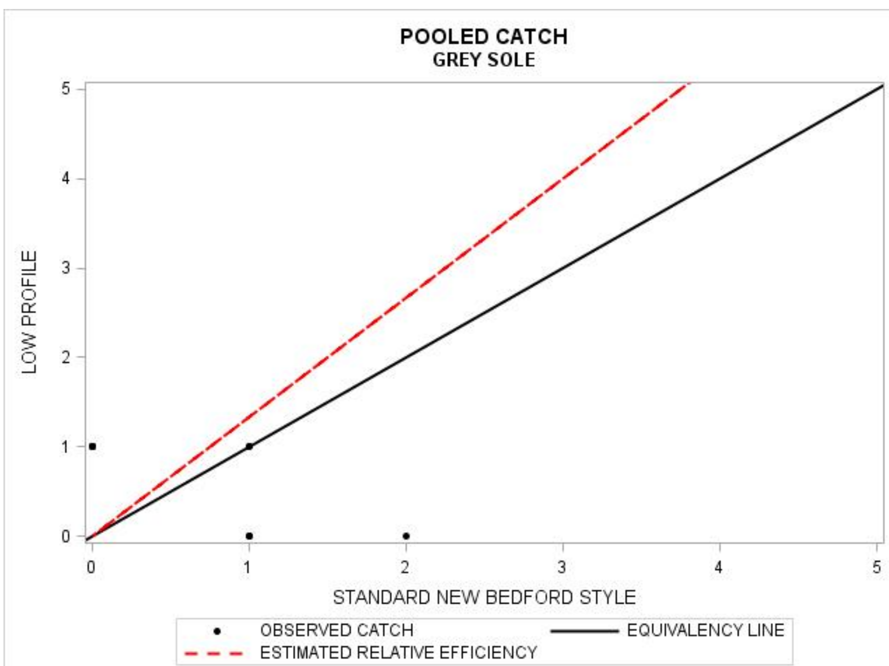


Figure 14: Total pooled catches for Grey Sole for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).





<u>Figure 15:</u> Total pooled catches for American Plaice for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. There were insufficient American Plaice captured on the WES-2-12 cruise to estimate relative efficiency. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

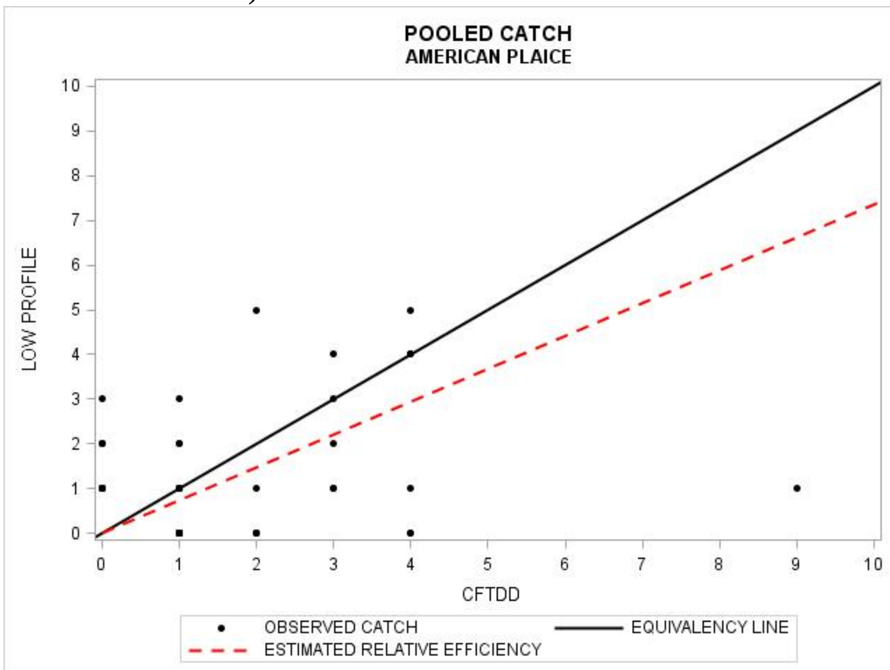
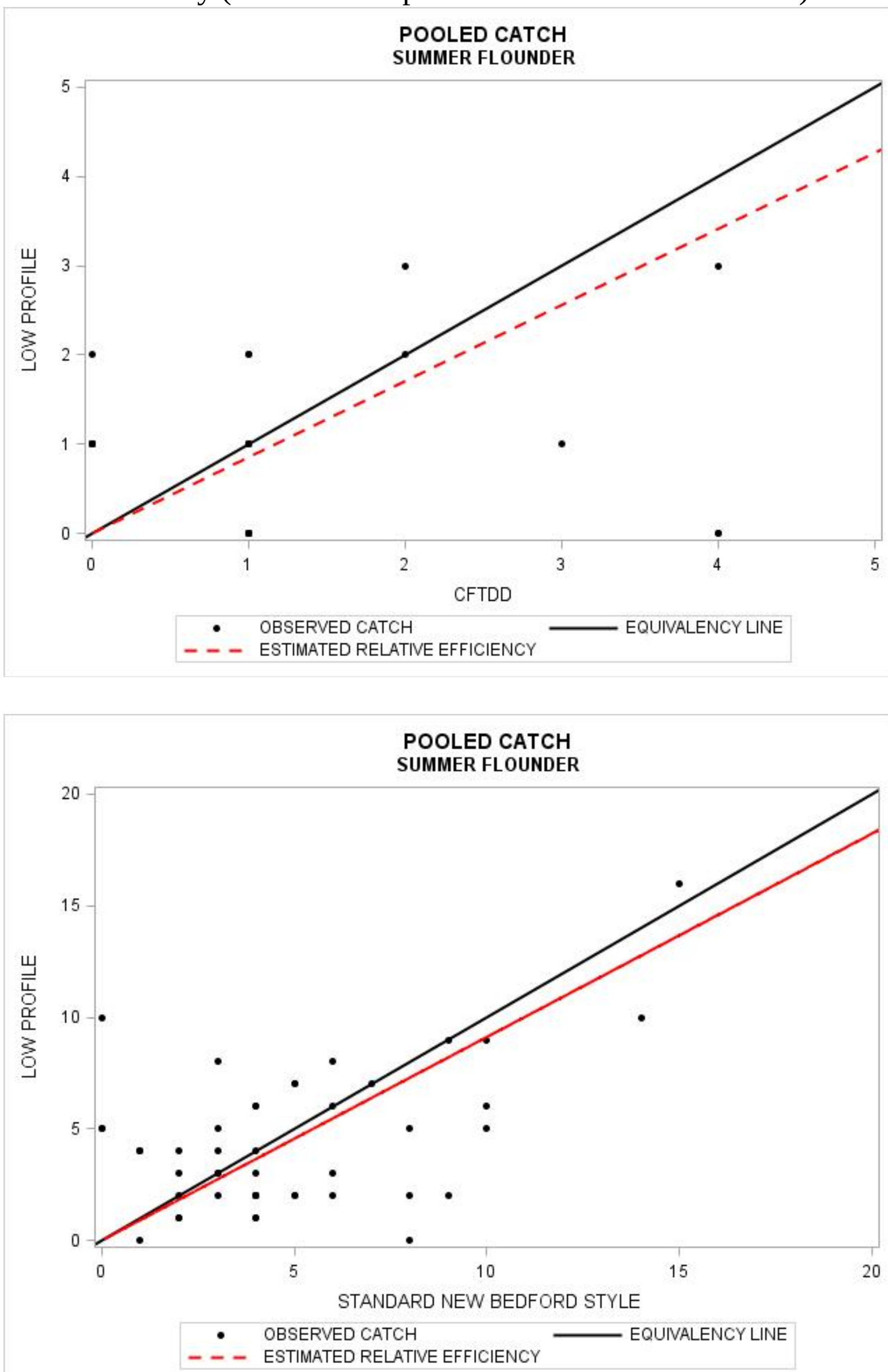
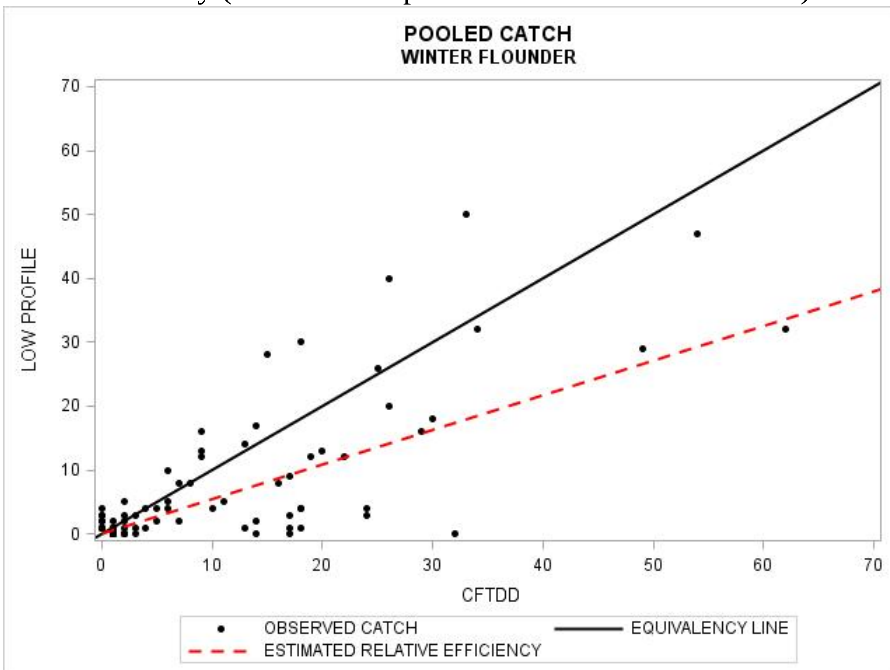


Figure 16: Total pooled catches for Summer Flounder for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).



<u>Figure 17:</u> Total pooled catches for Winter Flounder for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).



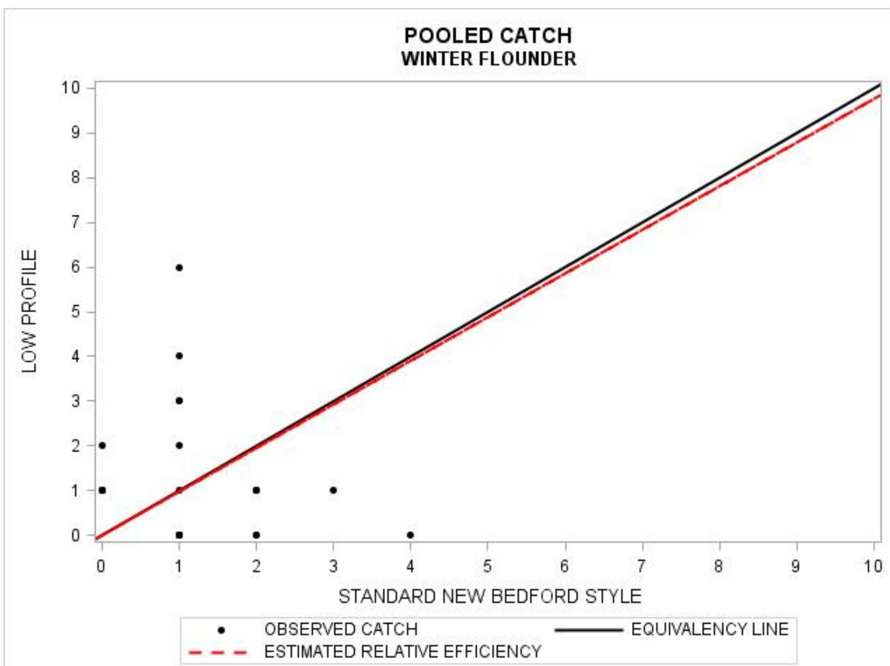


Figure 18: Total pooled catches for Windowpane Flounder for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

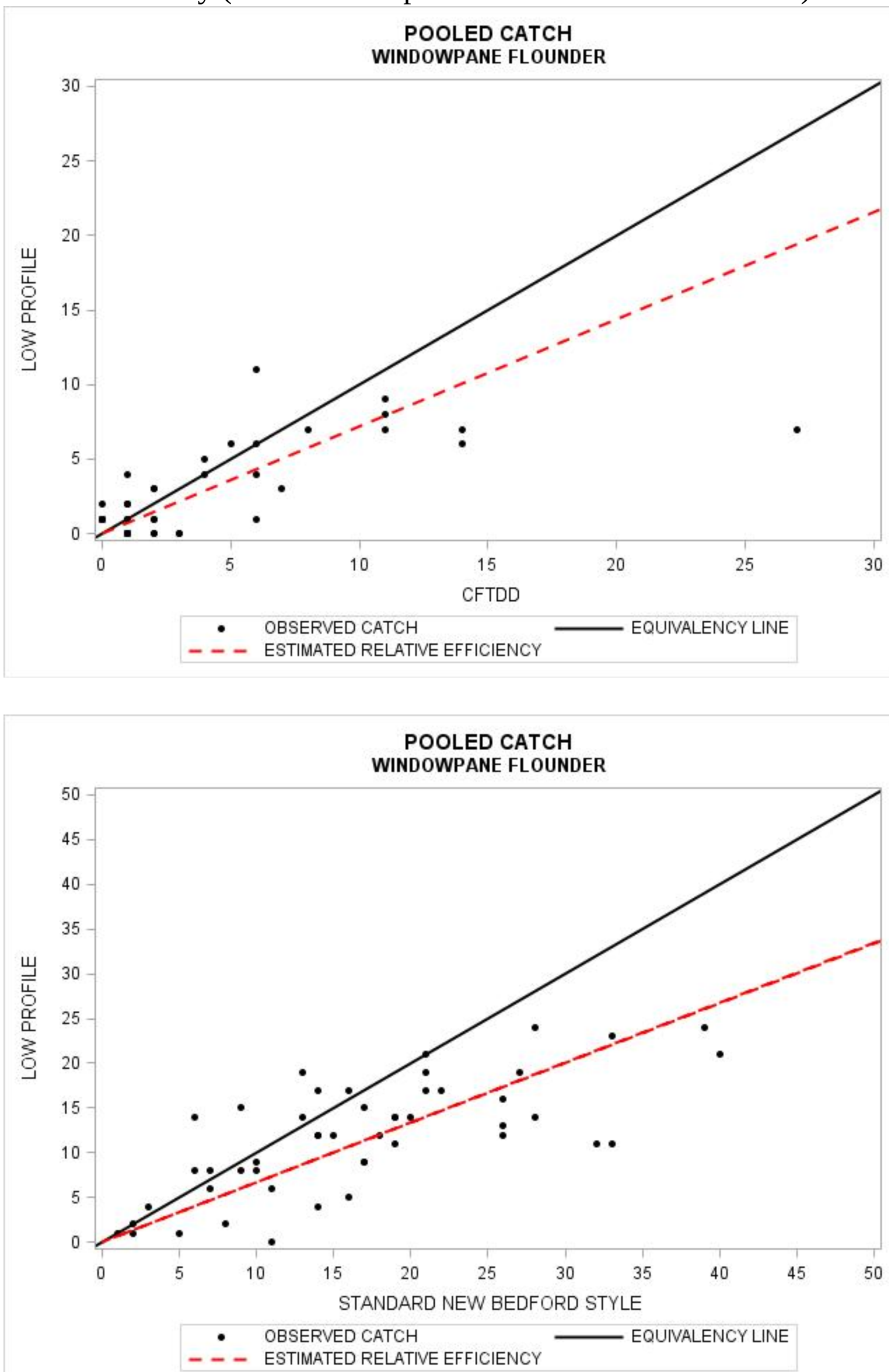


Figure 19: Total pooled catches for Yellowtail Flounder for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

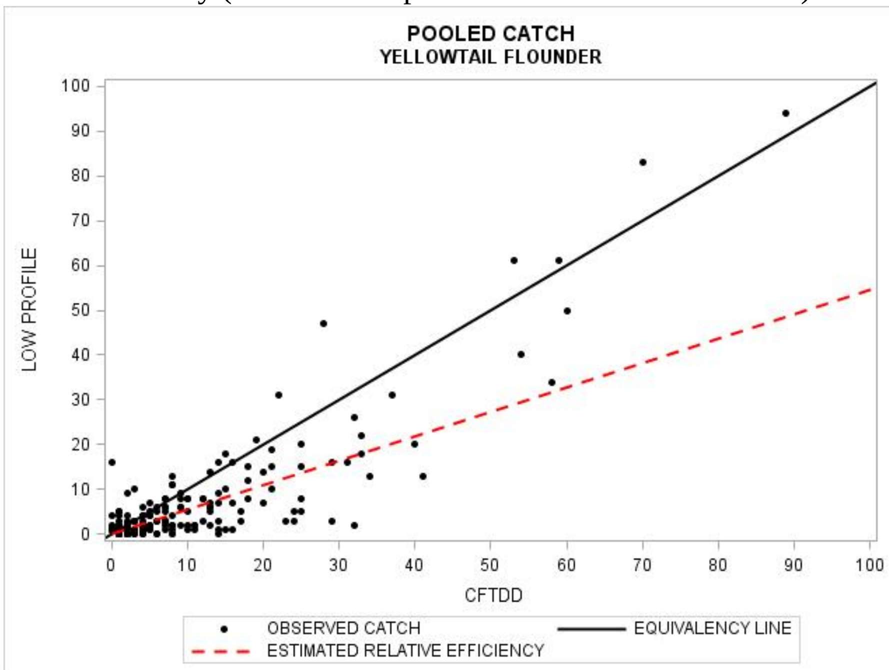


Figure 20: Total pooled catches for Atlantic Cod for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. There were insufficient Atlantic cod captured during WES-2-12 to estimate relative efficiency. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

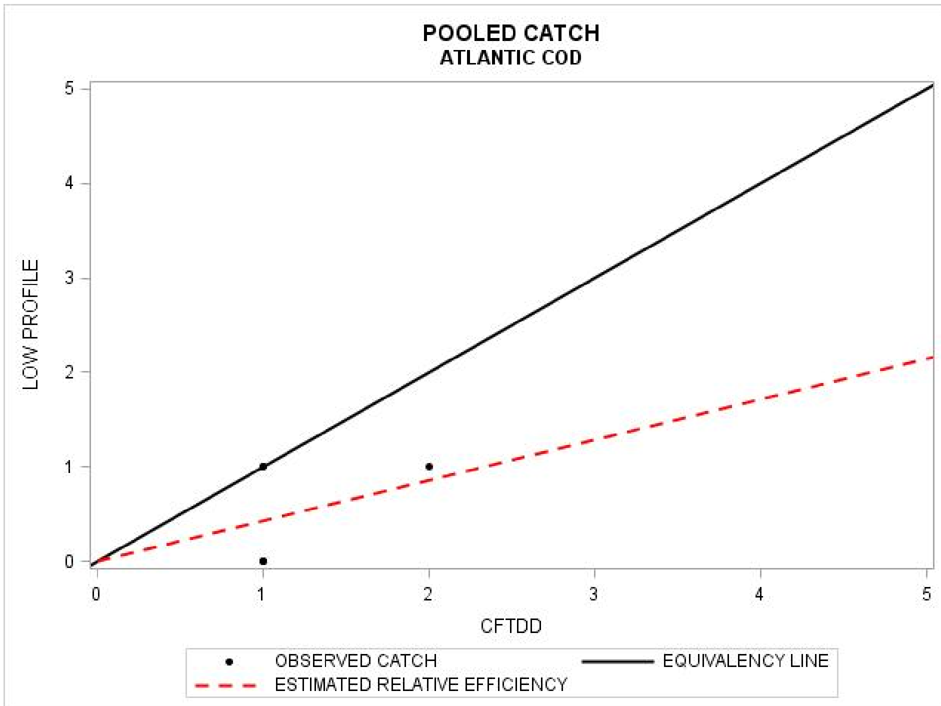


Figure 21: Total pooled catches for Haddock for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. There were insufficient Atlantic cod captured during WES-2-12 to estimate relative efficiency. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).

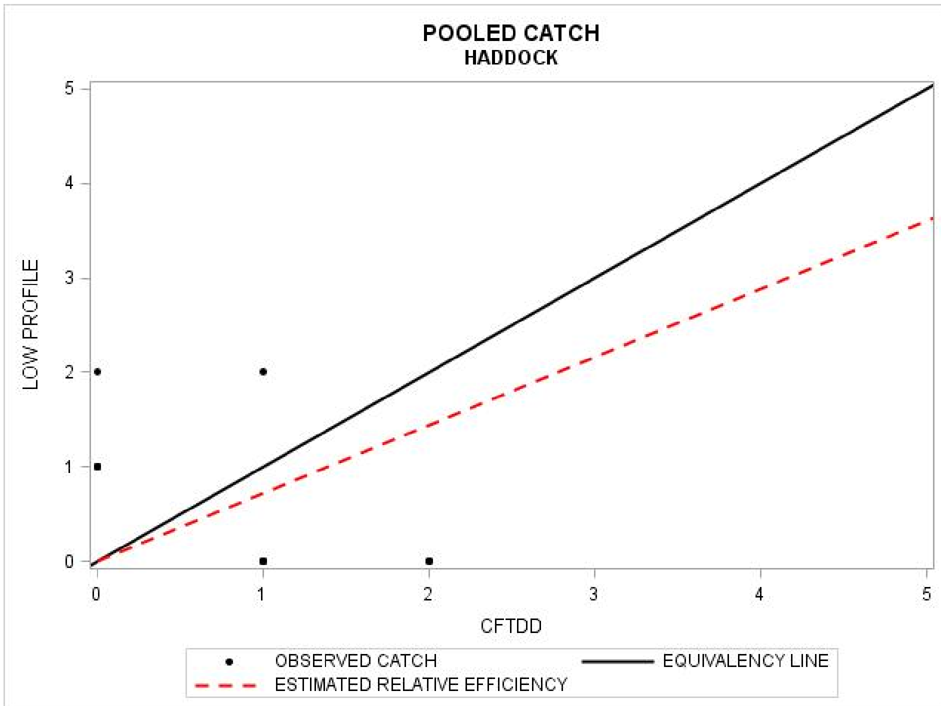
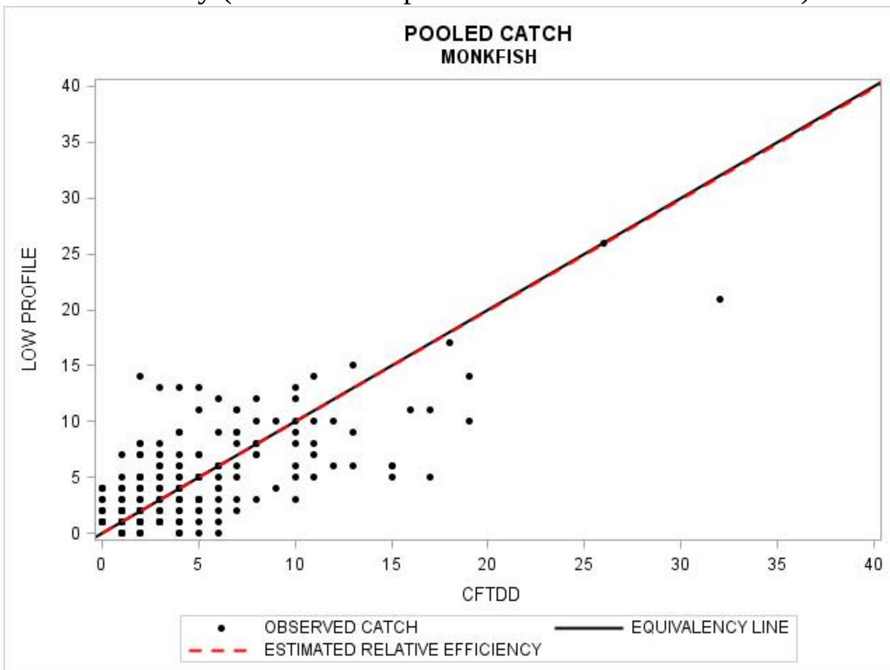


Figure 22: Total pooled catches for Monkfish for the Low Profile Dredge vs. the control dredge (Coonamessett Farm Turtle Deflector Dredge or Standard New Bedford Style Sea Scallop Dredge). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12. The black line has a slope of one. The dashed line has a slope equal to the estimated relative efficiency (from the one parameter mixed effects model).



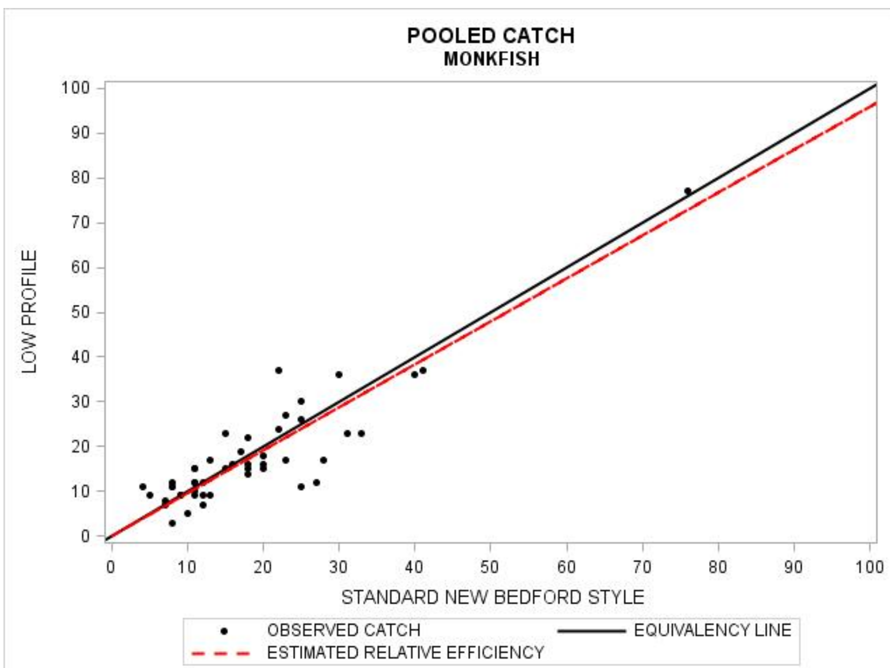
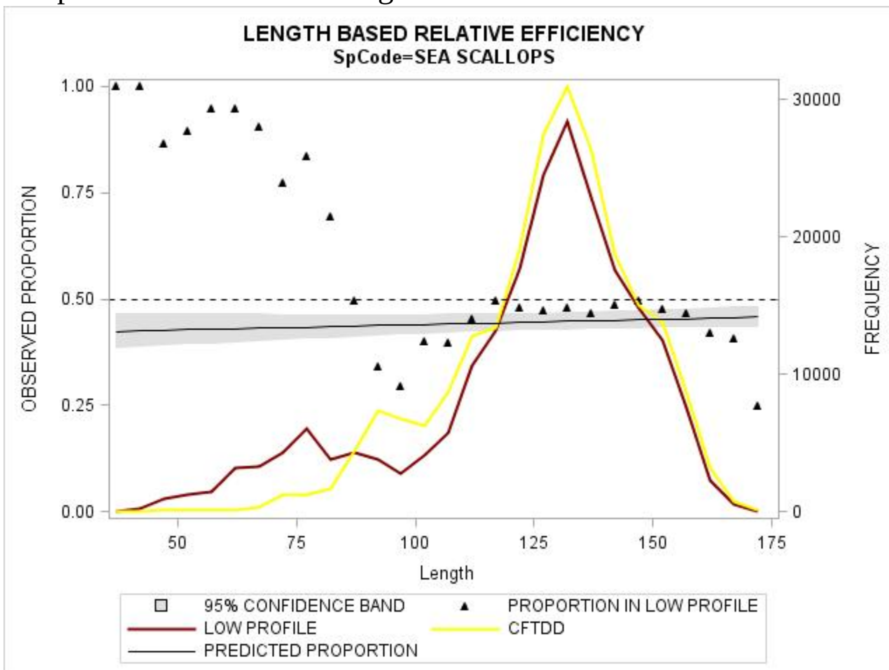


Figure 23: Relative Sea Scallop catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$), with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



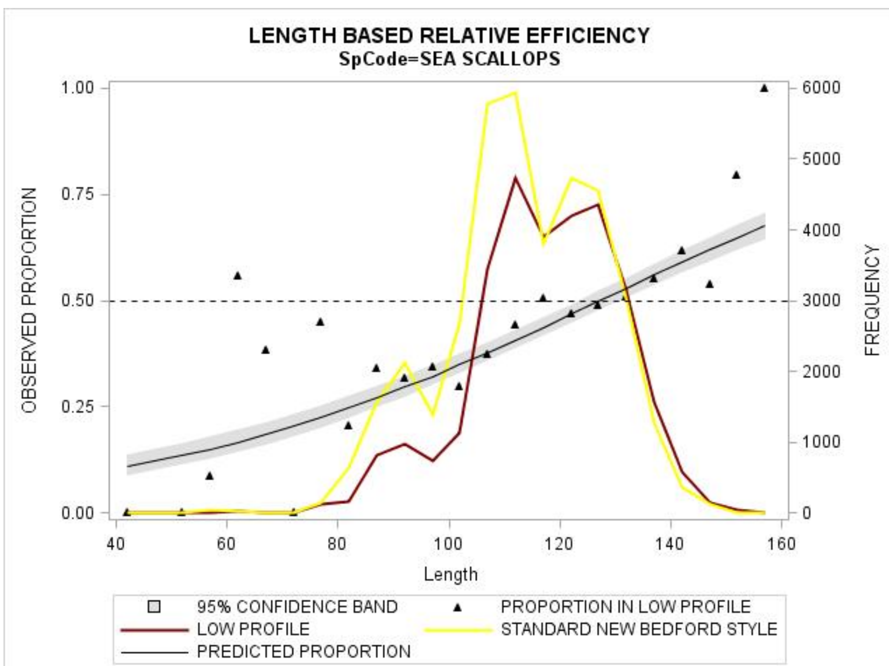
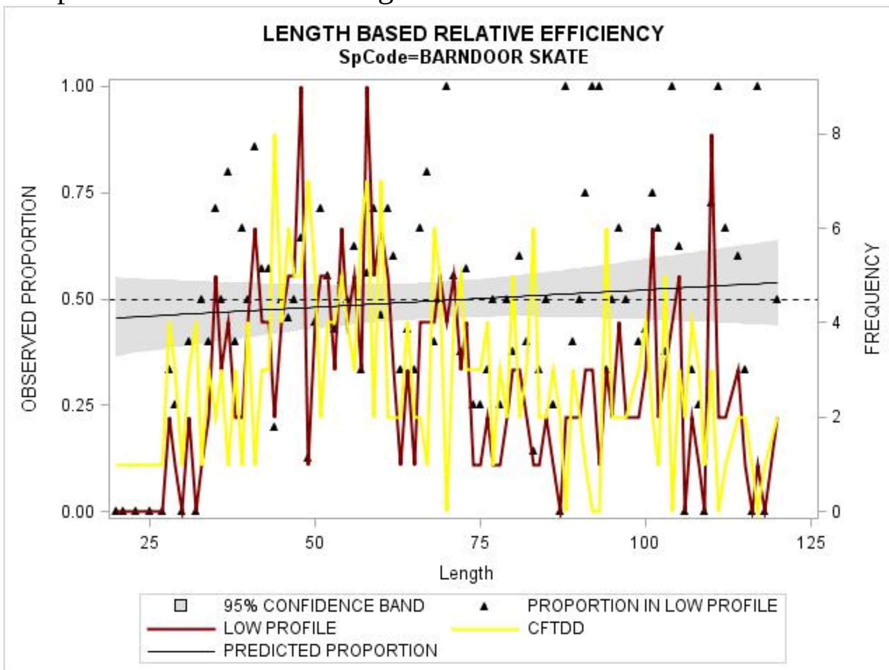


Figure 24: Relative Barndoor Skate catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$, with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



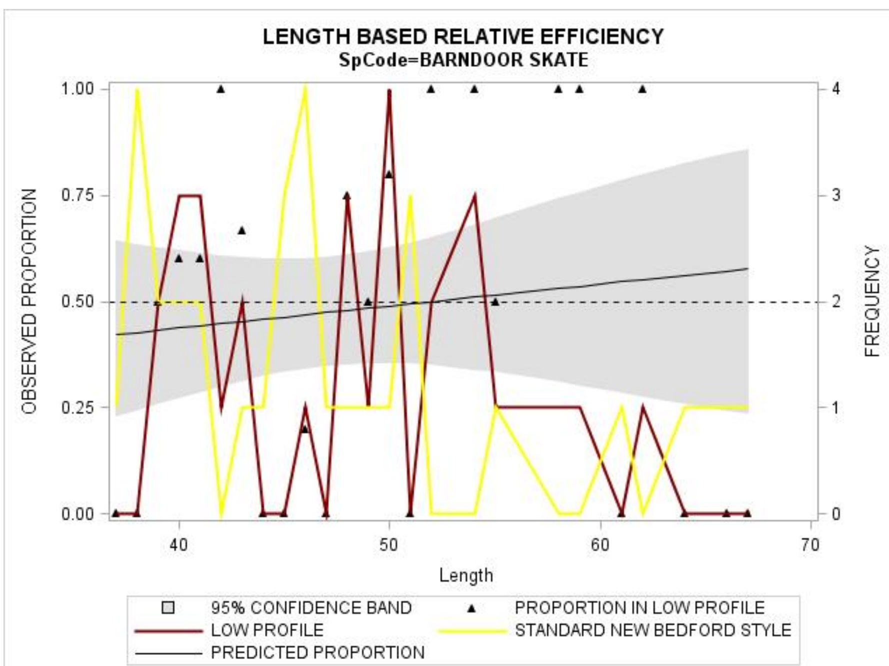
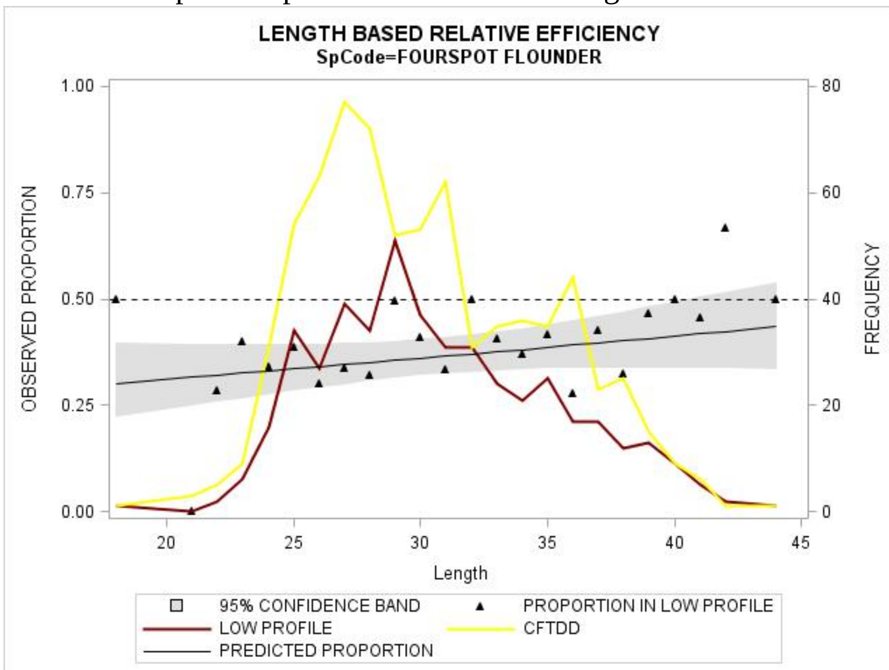


Figure 25: Relative Fourspot Flounder catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$), with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



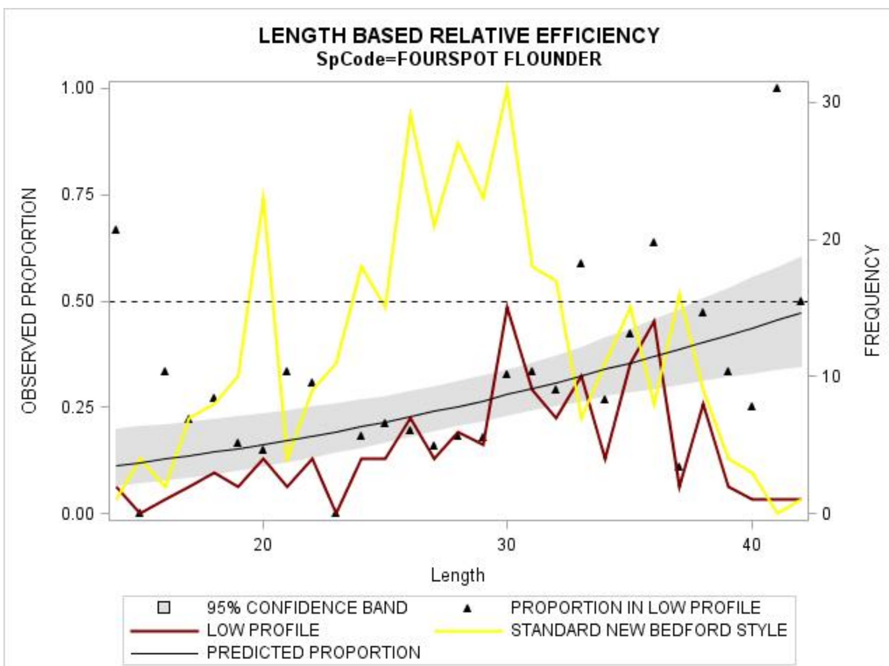


Figure 26: Relative Grey Sole catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$), with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. There were insufficient Grey Sole captured during WES-2-12 to return a stable solution for length based relative efficiency.

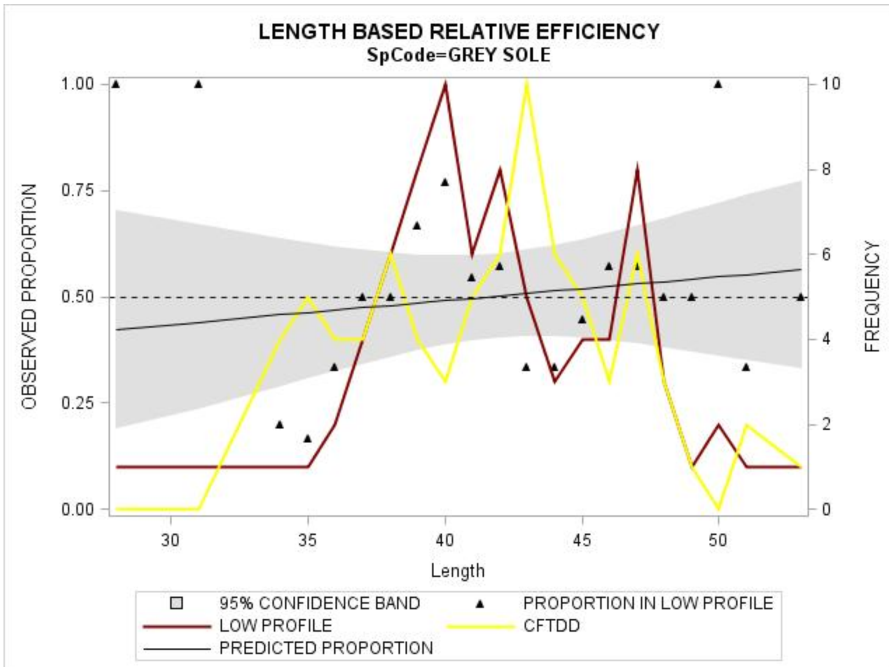


Figure 27: Relative American Plaice catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$, with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. There were insufficient American Plaice captured during WES-2-12 to return a stable solution for length based relative efficiency.

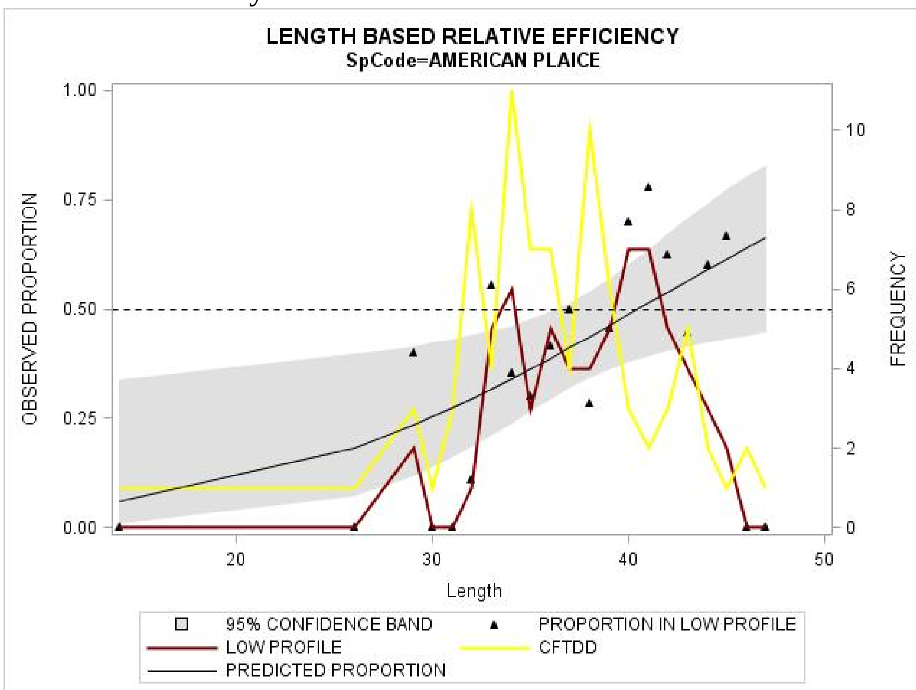
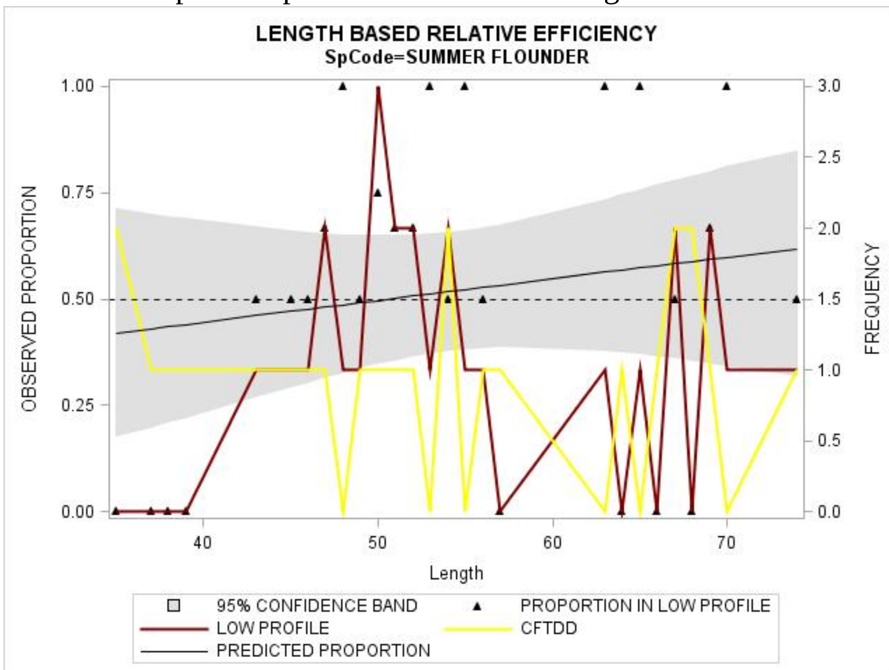


Figure 28: Relative Summer Flounder catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$, with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



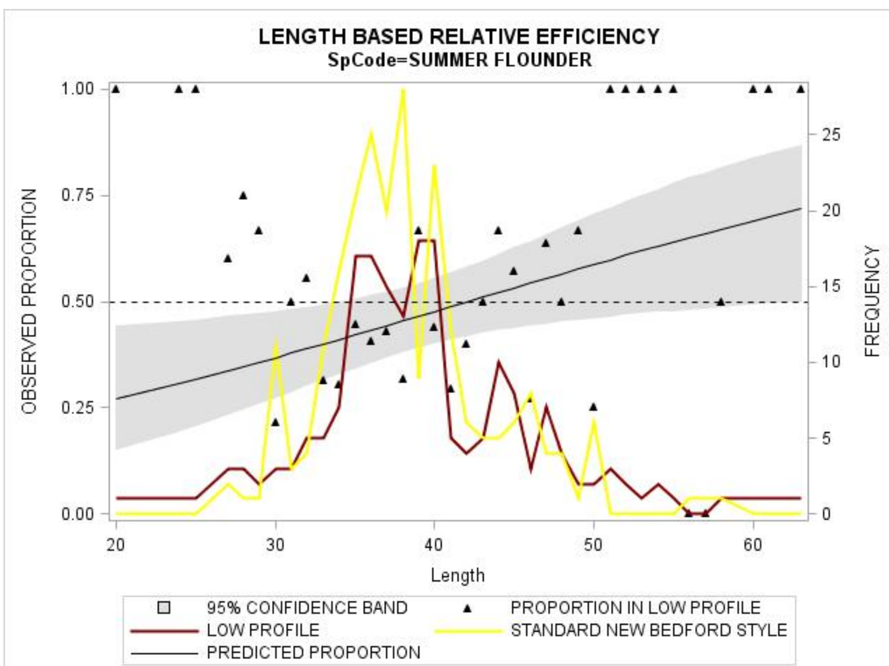
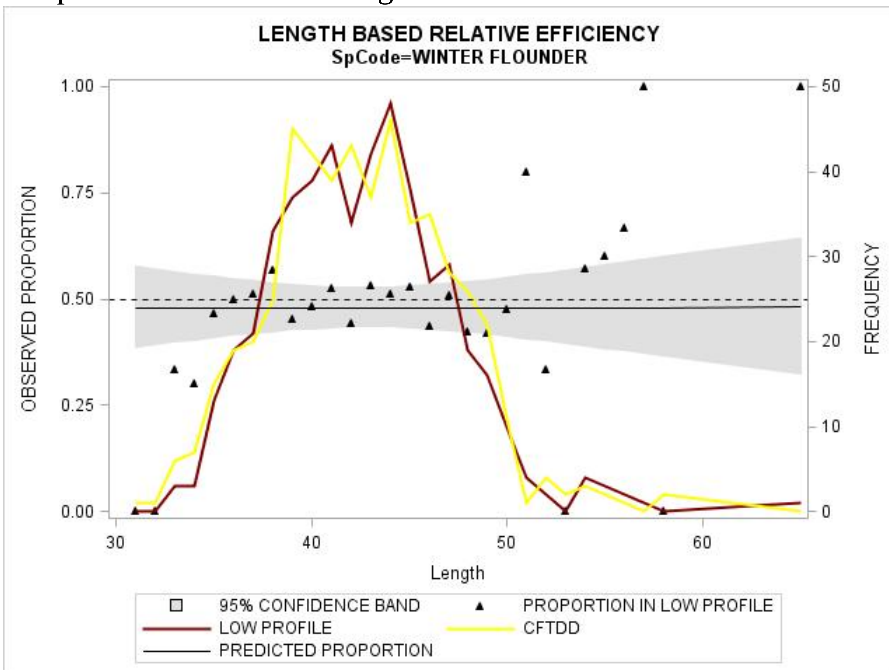


Figure 29: Relative Winter Flounder catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$), with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



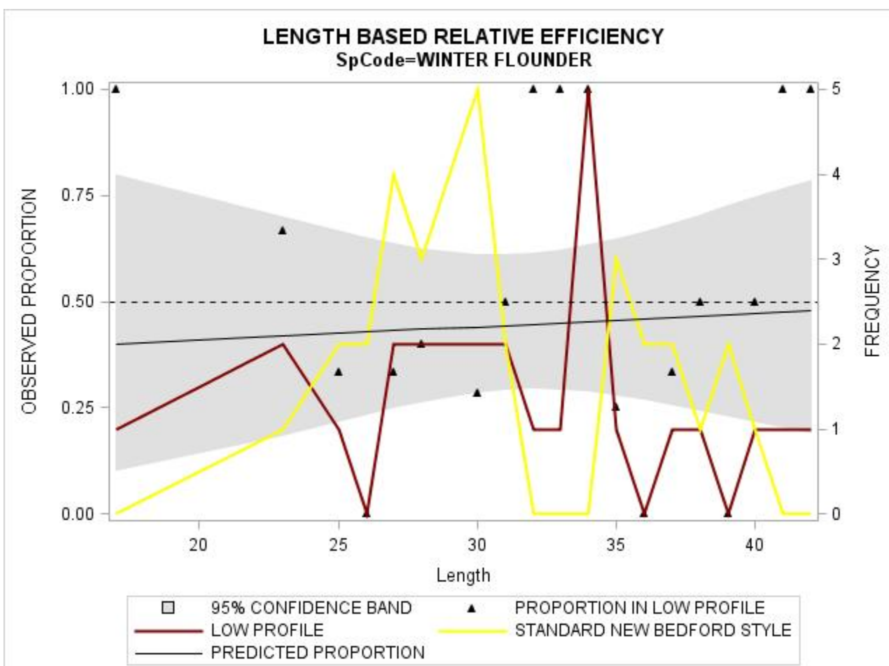


Figure 30: Relative Windowpane Flounder catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$, with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.

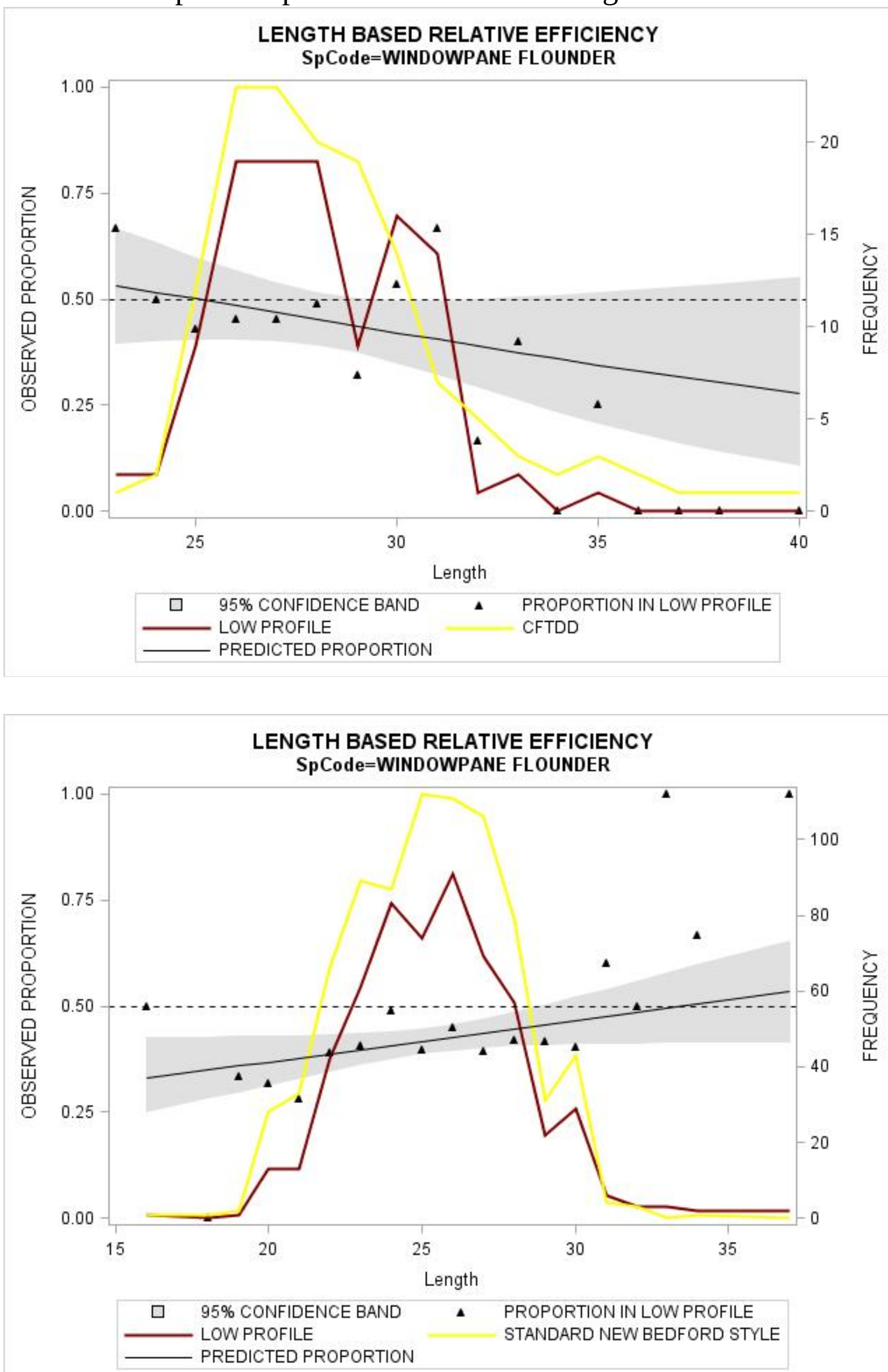
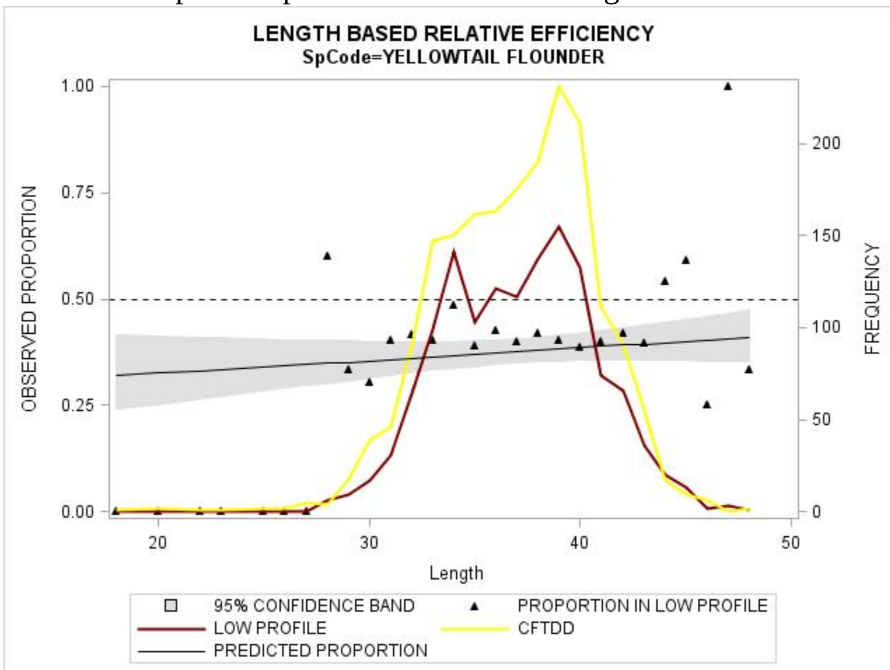


Figure 31: Relative Yellowtail Flounder catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$), with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



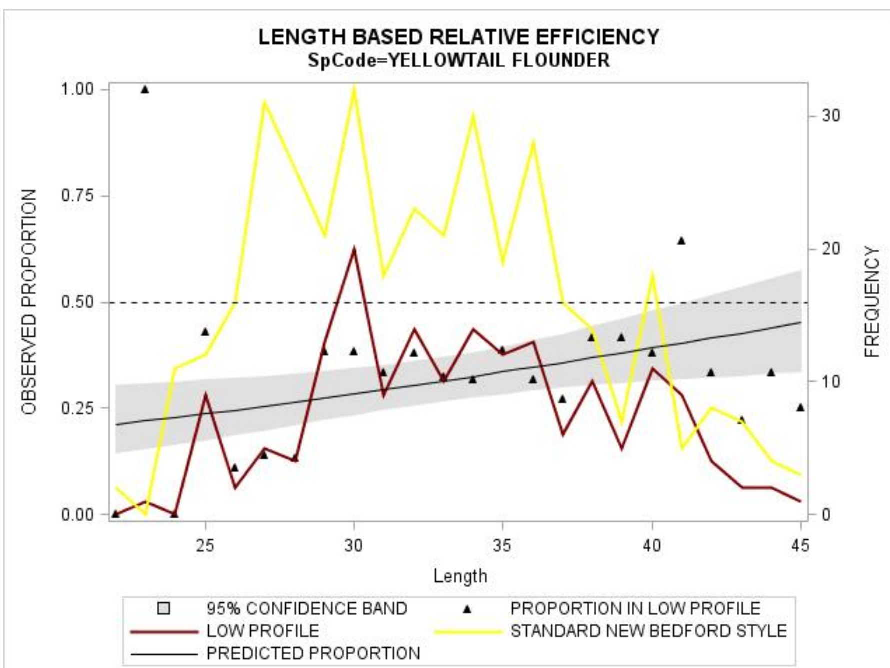
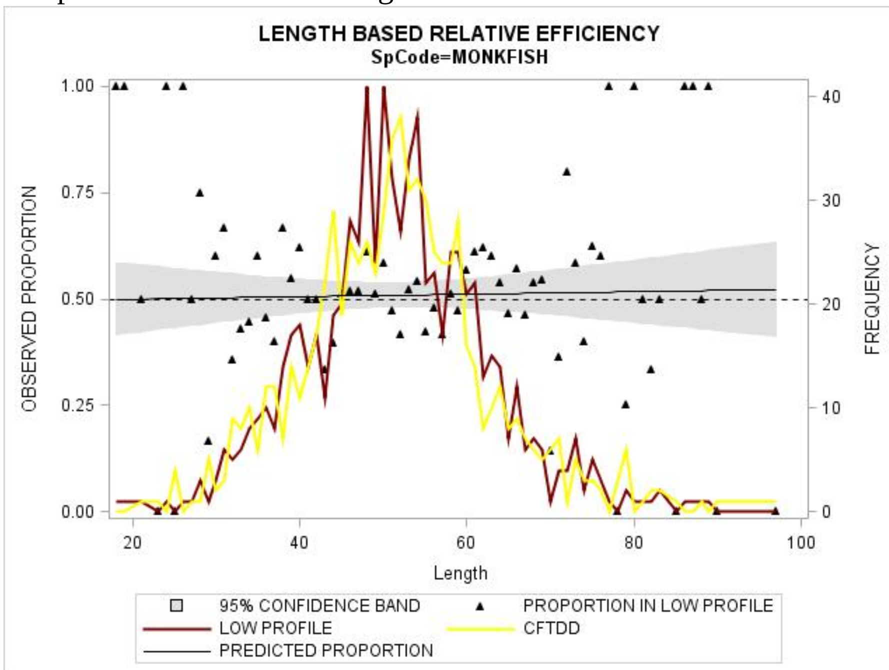


Figure 32: Relative Monkfish catch by the two dredge designs. The triangles represent the observed proportion at length ($Catch_{LPD}/(Catch_{LPD} + Catch_{control})$), with a proportion >0.5 representing more animals at length captured by the LPD. The grey area represents the 95% confidence band for the modeled proportion (solid black line). The top panel depicts data collected on the grouping of cruises that included DIL-1-11, FRE-1-11 and MON-1-11. The bottom panel depicts data collected during WES-2-12.



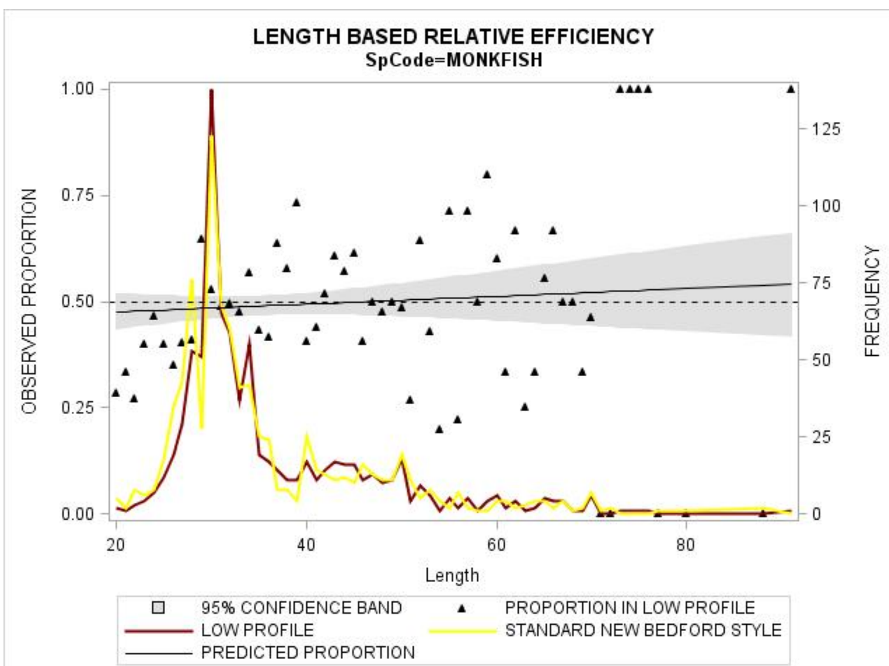


Table 1: General gear specifications

	Turtle	Low-profile	Westport NBD
Bag (Belly)	10 x 40	9 x 40	9 x 40
Apron	8 x 40	8 x 40	8 x 40
Side Piece	6 x 17	5 x 16	6 x 17
Diamond	14	15	14
Skirt	3 x 38	3 x 38	2 x 36
Sweep link #	143	151	121 long
Standard Twine Top	8.5 x 60	8.5 x 60	8.5 x 60

Table: 2: Summary of the first three trips into CAI and CAII

	Scallops (bu)	Little Skate	Window pane	YT	Winter Flounder	Barndoor	Grey Sole	Monk	Fluke	4 Spot	
F/V Diligence		**CAI**	Tows 62-78								
% Low-P	122%	90%	80%	96%	75%	74%	100%	97%	55%	122%	
F/V Diligence		**CAII**	Tows 1-61								
% Low-P	80%	70%	57%	51%	10%	98%	88%	106%	20%	49%	
F/V Diligence		**CAII**	Tows 15-61*		*Added a row of mesh on tow 15						
% Low-P	86%	72%	60%	53%	10%	105%	97%	101%	20%	53%	
	Scallops (bu)	**Little Skate**	**Window pane**	**YT**	**Winter Flounder**	**Barndoor**	**Grey Sole**	**Monk**	**Fluke**	**4 Spot**	
F/V Freedom		**CAI**	Tows 64-73		Laced						
% Low-P	96%	103%	0%	63%	103%	123%		118%		109%	
F/V Freedom		**CAI**	Tows 74-81		Windows						
% Low-P	76%	70%		25%	53%	92%		82%		70%	
F/V Freedom		**CAII**	Tows 1-57		Combined various pressure plates						
% Low-P	85%	90%		79%	64%	113%	85%	101%	233%	63%	
	Scallops (bu)	**Little Skate**	**Window pane**	**YT**	**Winter Flounder**	**Barndoor**	**Grey Sole**	**Monk**	**Fluke**	**4 Spot**	**TRASH**
F/V Monomoy		**CAI**	Tows 1-18		1:1 Twine						
% Low-P	57%	25%	0%	40%	16%	69%		72%		10%	42%
F/V Monomoy		**CAI**	Tows 67-82		2:1 Twine						
% Low-P	92%	111%	67%	57%	87%	105%	0%	92%	100%	75%	38%
F/V Monomoy		CAII	Tows 19-31		1:1 Twine						
% Low-P	48%	22%	30%	11%	75%	108%		109%	22%	14%	35%
F/V Monomoy		CAII	Tows 32-66		2:1 Twine						
% Low-P	62%	75%	96%	37%	175%	63%		105%	117%	14%	34%
	Scallops (bu)	**Little Skate**	**Window pane**	**YT**	**Winter Flounder**	**Barndoor**	**Grey Sole**	**Monk**	**Fluke**	**4 Spot**	**TRASH**
All Vessels		CAI & CAII			2:1 Twine		no windows				
% Low-P	85%	84%	69%	65%	91%	102%	90%	102%	64%	53%	36%

Table 3: Catch by areas for the first three trips where the gear was fished without significant modifications (used 2:1 hanging ratio and had no windows). Scallop catch is in bushels and fish catch is in numbers caught. CAI=41 tow comparisons; CAII=148 tow comparisons.

CAI	Common Name	Scientific Name	LPD	CFTDD	% Difference
	Sea Scallops	*Placopecten magellanicus*	639	595	7%
	Winter Skate	*Raja ocellata*	364	202	45%
	Little skate	*raja erinacea*	3470	3489	-1%
	Barndoor skate	*Raja laevis*	140	90	36%
	American Plaice	*Hippoglossoides platessoides*	17	12	29%
	Summer Flounder	*Paralichtys dentatus*	11	16	-45%
	Fourspot Flounder	*Paralichtys oblongotus*	38	40	-5%
	Yellowtail Flounder	*Limanda ferruginea*	36	43	-19%
	Winter Flounder	*Psuedopleuronectes americana*	463	487	-5%
	Windowpane Flounder	*Scophthalmus aquasus*	81	104	-28%
	Monkfish	*Lophius americanus*	260	261	0%

CAII	Common Name	Scientific Name	LPD	CFTDD	% Difference
	Sea Scallops	*Placopecten magellanicus*	1,456	1,857	-28%
	Winter Skate	*Raja ocellata*	1240	1287	-4%
	Little skate	*raja erinacea*	6861	8470	-23%
	Barndoor skate	*Raja laevis*	210	207	1%
	American Plaice	*Hippoglossoides platessoides*	41	82	-100%
	Summer Flounder	*Paralichtys dentatus*	16	19	-19%
	Fourspot Flounder	*Paralichtys oblongotus*	380	743	-96%
	Yellowtail Flounder	*Limanda ferruginea*	1332	2026	-52%
	Winter Flounder	*Psuedopleuronectes americana*	24	39	-63%
	Windowpane Flounder	*Scophthalmus aquasus*	63	95	-51%
	Monkfish	*Lophius americanus*	514	496	4%

Both	Common Name	Scientific Name	LPD	CFTDD	% Difference
	Sea Scallops	*Placopecten magellanicus*	2,095	2,452	-17%
	Winter Skate	*Raja ocellata*	1,604	1,489	7%
	Little skate	*raja erinacea*	10,331	11,959	-16%
	Barndoor skate	*Raja laevis*	350	297	15%
	American Plaice	*Hippoglossoides platessoides*	58	94	-62%
	Summer Flounder	*Paralichtys dentatus*	27	35	-30%
	Fourspot Flounder	*Paralichtys oblongotus*	418	783	-87%
	Yellowtail Flounder	*Limanda ferruginea*	1,368	2,069	-51%
	Winter Flounder	*Psuedopleuronectes americana*	487	526	-8%
	Windowpane Flounder	*Scophthalmus aquasus*	144	199	-38%
	Monkfish	*Lophius americanus*	774	757	2%

Table 4: Catch of the F/V Westport trip comparing the LPD with a 20-inch wide depressor plate to a NBD; both dredges rigged with similar bags.

	Scallops (bu)	Little Skate	Winter Skate	Windowpane Flounder	Yellowtail Flounder	Winter Flounder	Barndoor Skate	Monk	Summer Flounder	4 Spot	Benthos (bu)
Low Profile	246	6434	43	594	190	27	30	884	232	148	152
New Bedford	281	9456	80	833	413	31	36	920	244	397	456
# diff	-35	-3022	-37	-239	-223	-4	-6	-36	-12	-249	-303
% diff	-14%	-47%	-86%	-40%	-117%	-15%	-20%	-4%	-5%	-168%	-199%

Table 5: Scallop catch by area for the first three trips where the gear was fished without significant modifications (used 2:1 hanging ratio and had no windows. CAI=41 tow comparisons; CAII=148 tow comparisons.

	Three GB trips combined							
	SUM CAI				SUM CAII			
	Turtle		Low Profile		Turtle		Low Profile	
Shell Height	#	gms	#	gms	#	gms	#	gms
(mm)								
35-39	0	0	1	2	0	0	0	0
40-44	0	0	5	12	0	0	0	0
45-49	8	26	20	64	0	0	0	0
50-54	2	8	26	108	0	0	0	0
55-59	4	21	31	162	0	0	0	0
60-64	13	84	65	420	1	5	0	0
65-69	28	220	70	551	0	0	0	0
70-74	24	226	93	878	9	63	0	0
75-79	12	134	120	1344	30	249	25	211
80-84	32	419	69	905	90	877	64	645
85-89	45	683	74	1121	252	2883	121	1428
90-94	40	697	52	908	394	5200	128	1727
95-99	29	563	43	832	380	5724	113	1717
100-104	50	1099	70	1525	316	5348	143	2406
105-109	112	2731	98	2395	460	8791	318	6132
110-114	208	5630	194	5181	680	14711	621	13512
115-119	237	7118	243	7217	746	18161	802	19398
120-124	351	11564	332	10922	1051	28589	1072	29408
125-129	539	19445	507	18265	1508	46187	1448	44251
130-134	552	21746	546	21538	1653	55968	1715	58134
135-139	469	20101	446	19076	1422	53093	1345	50512
140-144	334	15739	304	14257	1106	45891	1129	46708
145-149	284	14288	307	15454	1040	47421	1132	51420
150-154	298	15815	260	13781	1008	49922	1083	53592
155-159	228	12936	206	11691	617	33017	577	31152
160-164	93	5618	84	5125	227	12911	160	9144
165-169	27	1728	18	1168	47	2856	29	1816
170-174	1	69	2	137	10	676	0	0
175-	0	0	0	0	0	0	0	0
TOTAL #	4020		4286		13047		12025	
Total weight (g)		158708		155040		438544		423311
Totals <110 mm	399	6911	837	11226	**1932**	29140	**912**	14265
Totals >110 mm	3621	151796	3449	143814	**11115**	409403	**11113**	409047

Table 6: The scallop length frequencies from the F/V Westport trip comparing the LPD with a 20-inch wide depressor plate to a NBD; both dredges rigged with similar bags. The LPD frame clearly reduces the amount of smaller scallops caught.

SNE	New Bedford		Low Profile			
	#	gms	#	gms		g/scallop
Shell Height						
(mm)						
35-39						
40-44	2	5	0	0		2.30
45-49	0	0	0	0		3.11
50-54	2	8	0	0		4.09
55-59	10	53	0	0		5.25
60-64	8	53	2	13		6.60
65-69	5	41	0	0		8.15
70-74	4	40	0	0		9.90
75-79	39	464	13	155		11.89
80-84	98	1383	16	226		14.11
85-89	246	4077	100	1657		16.57
90-94	338	6522	115	2219		19.30
95-99	223	4970	100	2229		22.29
100-104	366	9353	175	4472		25.56
105-109	808	23524	551	16042		29.11
110-114	857	28257	797	26279		32.97
115-119	648	24067	740	27484		37.14
120-124	891	37090	846	35217		41.63
125-129	943	43797	958	44494		46.44
130-134	682	35192	741	38237		51.60
135-139	300	17132	400	22843		57.11
140-144	110	6927	150	9446		62.97
145-149	33	2284	48	3322		69.21
150-154	4	303	20	1516		75.82
155-159	0	0	1	83		82.82
160-164	0	0	0	0		90.22
165-169	0	0	0	0		98.02
170-174	0	0	0	0		106.24
175-	0	0	0	0		114.88
TOTAL #	6617		5773			
Total weight (g)		245541		235933		
Totals <110 mm	**2149**	50491	**1072**	27013		
Totals >110 mm	**4468**	195050	**4701**	208921		

Table 7: Mixed effects model using the pooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11. Results are from species where the intercept only model provided the best fit to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	**Effect**	**Estimate**	**SE**	**DF**	**t-value**	**p-value**	**LCI**	**UCI**
Winter Skate	Intercept	-0.068	0.064	209	-1.064	0.289	-0.195	0.058
Summer Fl.	Intercept	-0.159	0.253	30	-0.629	0.534	-0.675	0.357
Winter Fl.	Intercept	-0.613	0.137	93	-4.468	0.000	-0.885	-0.341
Grey Sole	Intercept	0.005	0.199	59	0.027	0.979	-0.393	0.404
Windowpane Fl.	Intercept	-0.329	0.135	52	-2.446	0.018	-0.599	-0.059
Monkfish	Intercept	-0.003	0.052	215	-0.053	0.957	-0.106	0.100

Table 8: Mixed effects model using the pooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11. Results are for the species where the model that provided the best fit (intercept, area) to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	**Effect**	**Area**	**Estimate**	**SE**	**DF**	**t-value**	**p-value**	**LCI**	**UCI**
Little Skate	Intercept		-0.404	0.059	218	-6.861	0.000	-0.520	-0.288
	Area	CAI	-0.037	0.105	218	-0.354	0.723	-0.245	0.170
	Area	CAII	0.000						
Haddock	Intercept		-0.534	1.477	18	-0.361	0.722	-3.638	2.570
	Area	CAI	0.442	2.150	18	0.205	0.840	-4.076	4.960
	Area	CAII	0.000						
Yellowtail Fl.	Intercept		-0.634	0.075	190	-8.460	0.000	-0.782	-0.486
	Area	CAI	0.406	0.277	190	1.468	0.144	-0.139	0.952
	Area	CAII	0.000						

Table 9: Mixed effects model using the pooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11. Results are for the species where the model that provided the best fit (intercept, cruise) to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	Effect	Cruise	Estimate	SE	DF	t-value	p-value	LCI	UCI
Atl. Cod	Intercept		-1.099	1.15	4	-0.951	0.395	-4.305	2.107
	CRUISE	DIL-1-11	0.405	1.44	4	0.281	0.793	-3.602	4.413
	CRUISE	FRE-1-11	0.000						
Am. Plaice	Intercept		-0.129	0.35	52	-0.366	0.716	-0.837	0.579
	CRUISE	DIL-1-11	-0.249	0.42	52	-0.596	0.554	-1.087	0.589
	CRUISE	FRE-1-11	0.000						

Table 10: Mixed effects model using the pooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11. Results are for the species where the model that provided the best fit (intercept, area, cruise) to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	Effect	Area	Cruise	Est.	SE	DF	t-val.	p-val.	LCI	UCI
Winter Skate	Int.			-0.417	0.129	206	-3.239	0.001	-0.671	-0.163
	Area	CAI		0.422	0.148	206	2.850	0.005	0.130	0.714
	Area	CAII		0.000						
	Cruise		DIL-1-11	0.335	0.166	206	2.013	0.045	0.007	0.662
	Cruise		FRE-1-11	0.357	0.155	206	2.303	0.022	0.051	0.662
	Cruise		MON-1-11	0.000						
Fourspot Fl.	Int.			-2.127	0.284	186	-7.476	0.000	-2.688	-1.566
	Area	CAI		0.604	0.279	186	2.164	0.032	0.053	1.154
	Area	CAII		0.000						
	Cruise		DIL-1-11	1.639	0.307	186	5.332	0.000	1.032	2.245
	Cruise		FRE-1-11	1.637	0.305	186	5.371	0.000	1.036	2.238
	Cruise		MON-1-11	0.000						
Sea Scallop	Int.			-0.619	0.077	179	-7.996	0.000	-0.772	-0.466
	Area	CAI		0.358	0.091	179	3.940	0.000	0.179	0.537
	Area	CAII		0.000						
	Cruise		DIL-1-11	0.523	0.095	179	5.532	0.000	0.337	0.710
	Cruise		FRE-1-11	0.383	0.095	179	4.024	0.000	0.195	0.571
	Cruise		MON-1-11	0.000						

Table 11: Mixed effects model using the pooled catch data for the grouping that included cruise WES-2-12. Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	Effect	Estimate	SE	DF	t-value	p-value	LCI	UCI
Barndoor Skate	Intercept	-0.159	0.253	26	-0.629	0.535	-0.679	0.361
Winter Skate	Intercept	-0.595	0.190	38	-3.135	0.003	-0.980	-0.211
Little Skate	Intercept	-0.380	0.030	48	-12.626	0.000	-0.440	-0.319
Summer Fl.	Intercept	-0.098	0.117	47	-0.843	0.403	-0.333	0.136
Fourspot Fl.	Intercept	-1.109	0.125	46	-8.852	0.000	-1.361	-0.857
Yellowtail Fl.	Intercept	-0.813	0.101	47	-8.068	0.000	-1.015	-0.610
Winter Fl.	Intercept	0.004	0.331	27	0.013	0.990	-0.675	0.684
Grey Sole	Intercept	0.000	0.535	10	0.000	1.000	-1.191	1.191
Windowpane Fl.	Intercept	-0.352	0.061	47	-5.732	0.000	-0.475	-0.228
Monkfish	Intercept	-0.038	0.048	47	-0.795	0.430	-0.135	0.059
Sea Scallops	Intercept	-0.220	0.037	48	-5.894	0.000	-0.295	-0.145

Table 12: Mixed effects model using the unpooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11.Results are for from the model that provided the best fit (intercept and length) to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	Effect	Estimate	SE	DF	t-value	p-value	LCI	UCI
Barndoor Skate	Intercept	-0.243	0.257	147	-0.946	0.346	-0.752	0.265
	Length	0.003	0.004	356	0.927	0.355	-0.004	0.010
Grey Sole	Intercept	-0.935	1.663	59	-0.562	0.576	-4.263	2.393
	Length	0.022	0.039	75	0.569	0.570	-0.056	0.101
Winter Fl.	Intercept	-0.090	0.639	64	-0.142	0.888	-1.367	1.186
	Length	0.000	0.015	341	0.014	0.989	-0.029	0.029
Windowpane Fl.	Intercept	1.610	1.378	44	1.168	0.249	-1.168	4.387
	Length	-0.064	0.049	97	-1.322	0.189	-0.161	0.032
Monkfish	Intercept	-0.024	0.263	180	-0.092	0.927	-0.544	0.496
	Length	0.001	0.005	1056	0.237	0.813	-0.009	0.011

Table 13: Mixed effects model using the unpooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11.Results are for from the model that provided the best fit (intercept and length, cruise) to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

Species	**Effect**	**Cruise**	**Estimate**	**SE**	**DF**	**t-val**	**p-val**	**LCI**	**UCI**
Am. Plaice	Intercept		-4.086	1.684	53	-2.426	0.019	-7.464	-0.708
	Length		0.103	0.043	77	2.385	0.020	0.017	0.188
	Cruise	DIL-1-11	-0.095	0.435	77	-0.219	0.828	-0.962	0.771
	Cruise	FRE-1-11	0.000						
Summer Fl.	Intercept		-0.700	1.556	23	-0.450	0.657	-3.918	2.518
	Length		0.018	0.028	22	0.625	0.538	-0.041	0.076
	Cruise	DIL-1-11	-0.865	0.652	22	-1.327	0.198	-2.218	0.487
	Cruise	FRE-1-11	0.533	0.809	22	0.659	0.517	-1.145	2.211
	Cruise	MON-1-11	0.000						

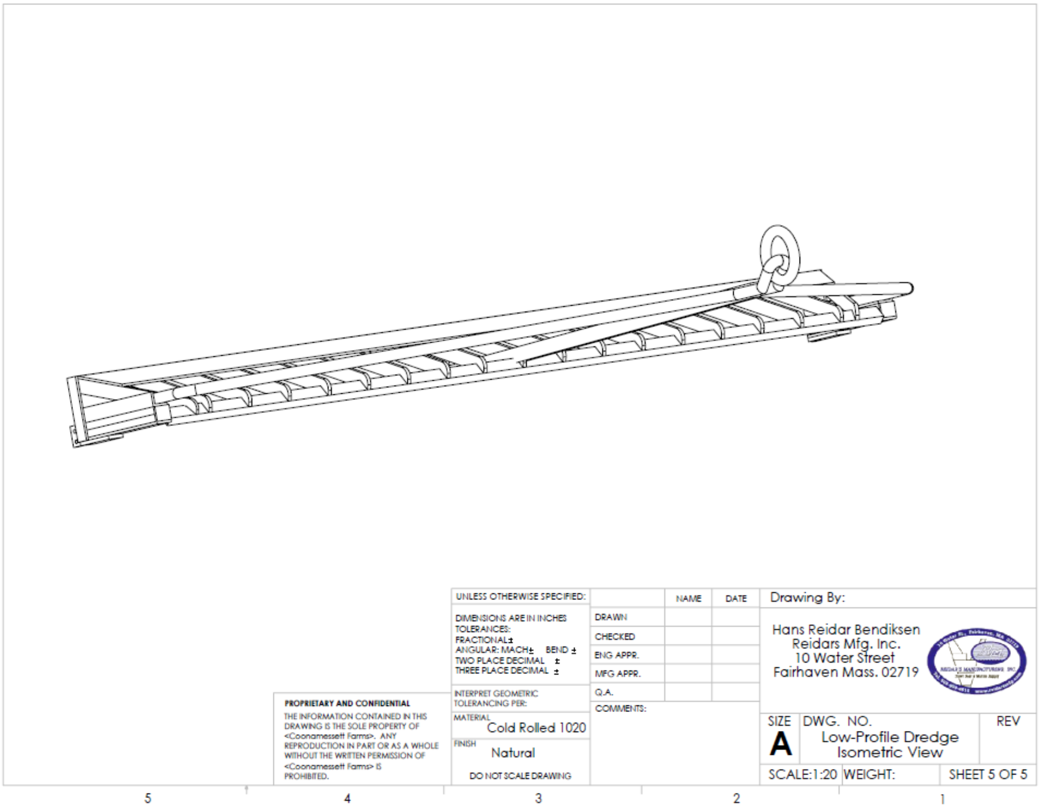
Table 14: Mixed effects model using the unpooled catch data for the grouping that included cruises DIL-1-11, FRE-1-11 and MON-1-11.Results are for from the model that provided the best fit (intercept, length, area and cruise) to the data as supported by model comparison (minimum AIC value). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

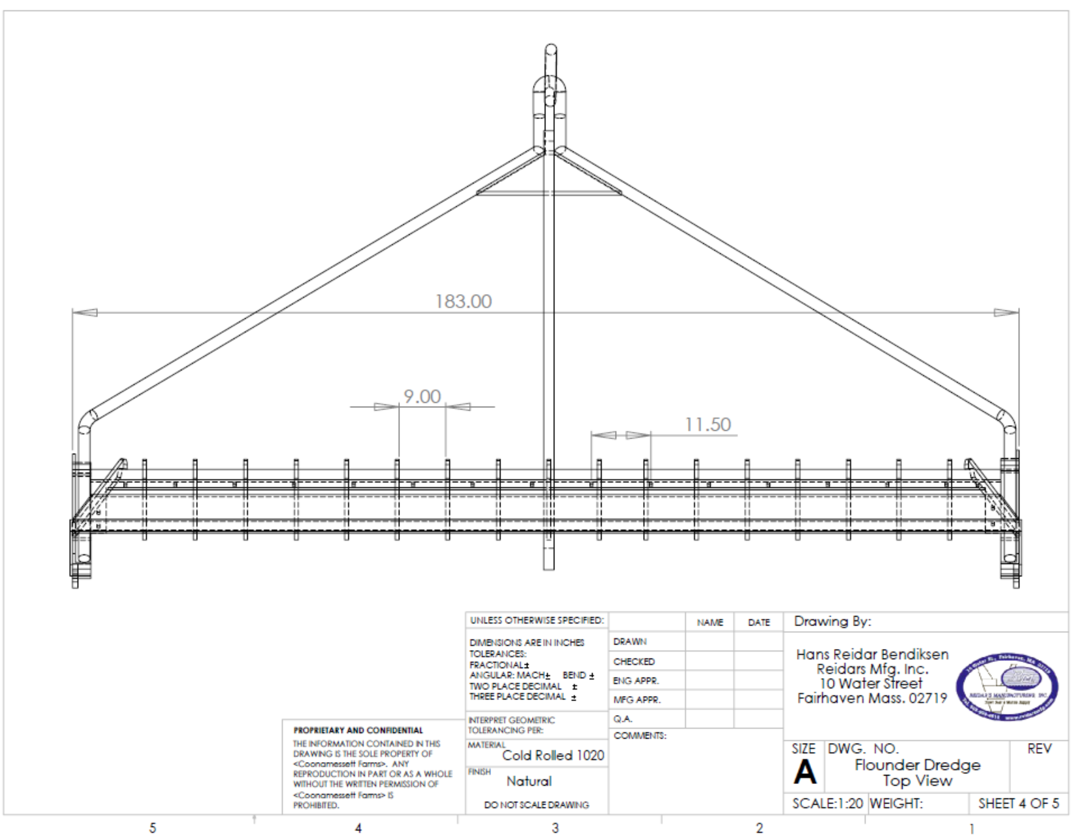
Species	**Effect**	**Cruise**	**Area**	**Est.**	**SE**	**DF**	**t-val**	**p-val**	**LCI**	**UCI**
Fourspot	Int.			-2.434	0.573	156	-4.244	0.000	-3.56	-1.30
	Length			0.019	0.015	658	1.277	0.202	-0.01	0.04
	Area		CAI	0.857	0.332	658	2.587	0.010	0.20	1.50
	Area		CAII	0.000						
	Cruise	DIL-1-11		1.343	0.356	658	3.778	0.000	0.64	2.04
	Cruise	FRE-1-11		1.361	0.359	658	3.794	0.000	0.65	2.06
	Cruise	MON-1-11		0.000						
YT	Int.			-1.527	0.416	169	-3.673	0.000	-2.34	-0.70
	Length			0.015	0.010	1085	1.434	0.152	-0.00	0.03
	Area		CAI	0.274	0.283	1085	0.968	0.333	-0.28	0.82
	Area		CAII	0.000						
	Cruise	DIL-1-11		0.558	0.183	1085	3.054	0.002	0.20	0.91
	Cruise	FRE-1-11		0.608	0.154	1085	3.946	0.000	0.30	0.91
	Cruise	MON-1-11		0.000						
Sea Scallop	Int.			-0.782	0.133	181	-5.874	0.000	-1.04	-0.51
	Length			0.001	0.001	2260	1.461	0.144	0.00	0.00
	Area		CAI	0.365	0.093	2260	3.925	0.000	0.18	0.54
	Area		CAII	0.000						
	Cruise	DIL-1-11		0.534	0.097	2260	5.517	0.000	0.34	0.72
	Cruise	FRE-1-11		0.389	0.097	2260	4.023	0.000	0.19	0.57
	Cruise	MON-1-11		0.000						

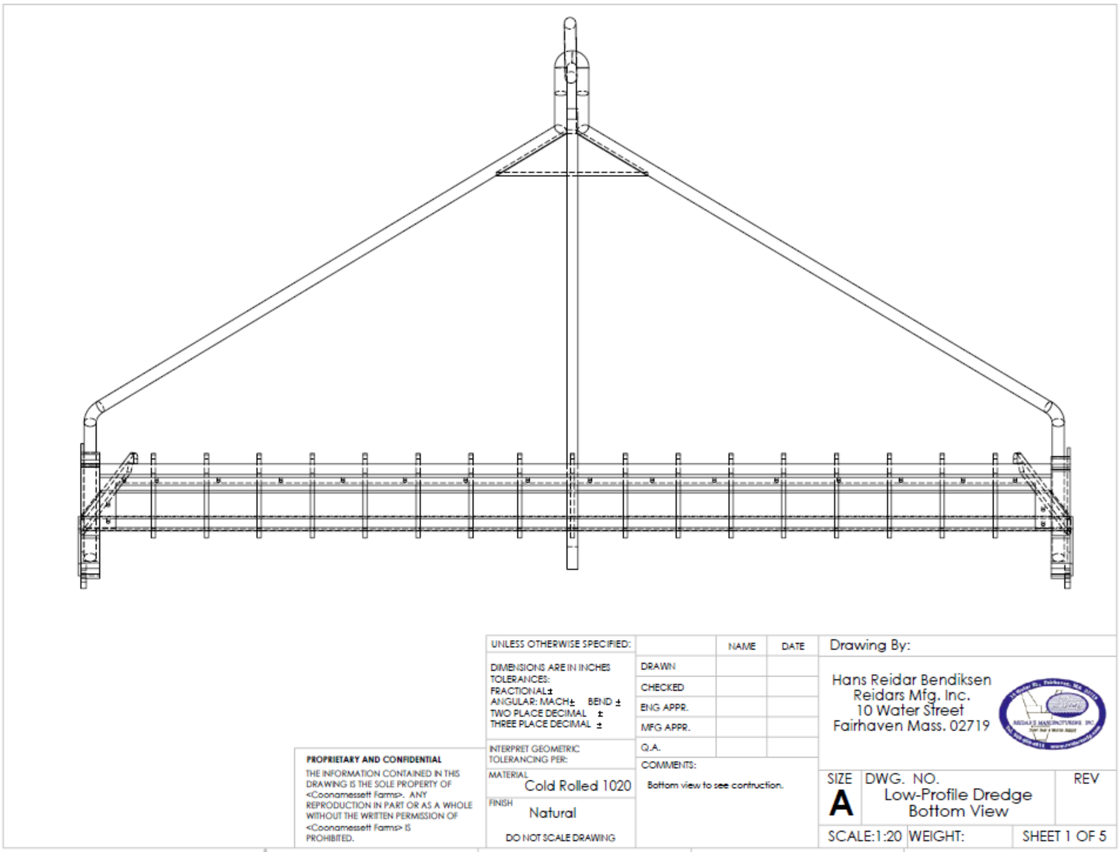
<u>Table 15:</u> Mixed effects model with the unpooled catch data from cruise WES-2-12. Results are for from the model that included the explanatory variables (intercept and length). Confidence limits are Wald type confidence intervals. Parameter estimates are on the logit scale.

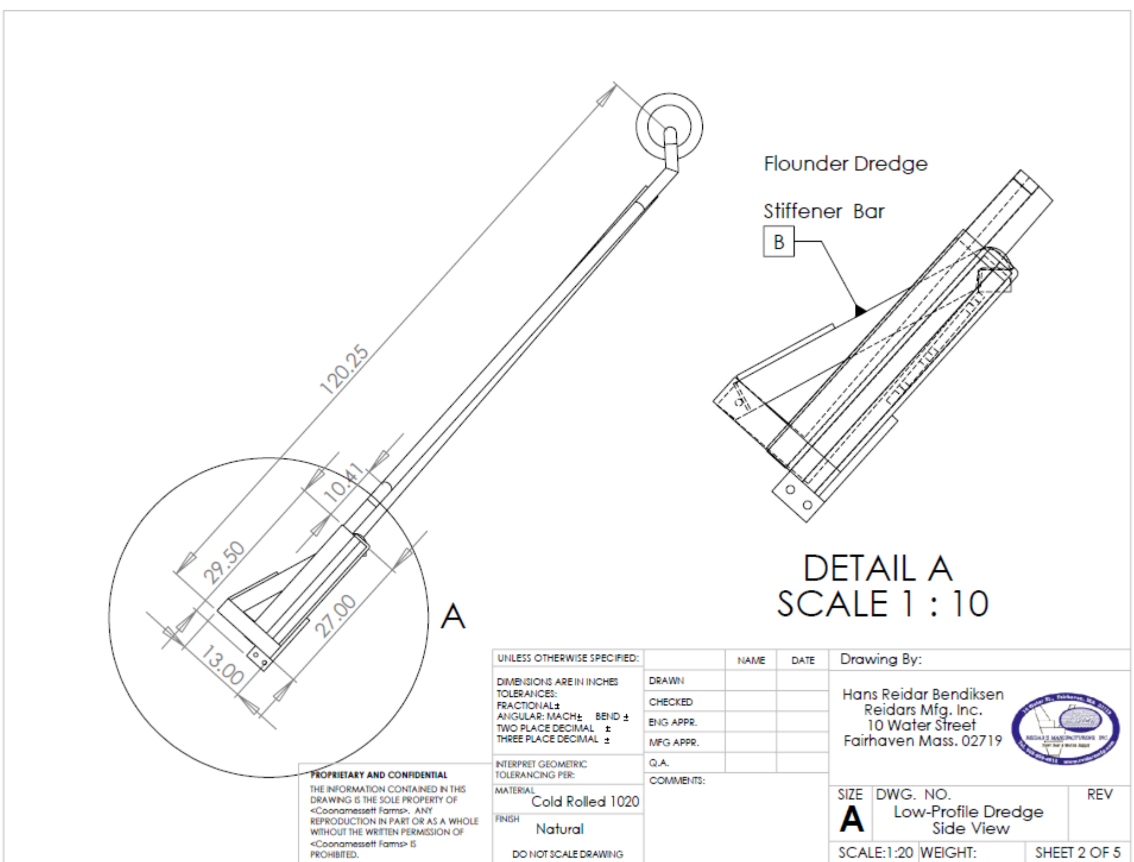
Species	**Effect**	**Estimate**	**SE**	**DF**	**t-value**	**p-value**	**LCI**	**UCI**
Barndoor Skate	Intercept	-1.081	1.662	25	-0.650	0.521	-4.504	2.342
	Length	0.021	0.035	28	0.599	0.554	-0.050	0.092
Summer Fl.	Intercept	-1.883	0.740	47	-2.546	0.014	-3.370	-0.395
	Length	0.045	0.019	269	2.401	0.017	0.008	0.081
Fourspot Fl.	Intercept	-3.026	0.591	46	-5.121	0.000	-4.215	-1.836
	Length	0.069	0.019	303	3.610	0.000	0.032	0.107
Yellowtail Fl.	Intercept	-2.384	0.649	47	-3.675	0.001	-3.690	-1.079
	Length	0.049	0.019	328	2.545	0.011	0.011	0.086
Winter Fl.	Intercept	-0.626	1.779	24	-0.352	0.728	-4.297	3.046
	Length	0.013	0.056	25	0.232	0.818	-0.102	0.127
Windowpane Fl.	Intercept	-1.337	0.533	47	-2.509	0.016	-2.409	-0.265
	Length	0.040	0.021	389	1.911	0.057	-0.001	0.081
Monkfish	Intercept	-0.170	0.173	47	-0.986	0.329	-0.518	0.177
	Length	0.004	0.005	790	0.795	0.427	-0.005	0.013
Sea Scallop	Intercept	-3.134	0.185	48	-16.932	0.000	-3.506	-2.762
	Length	0.025	0.002	604	16.222	0.000	0.022	0.028

Appendix A: Dredge Drawings






UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
INTERPRET GEOMETRIC TOLERANCING PER:
COMMENTS:
Bottom view to see contruction.
MATERIAL
Cold Rolled 1020
FINISH
Natural
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <Coonamessett Farms>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <Coonamessett Farms> IS PROHIBITED.
Drawing By:
Hans Reidar Bendiksen
Reidars Mfg. Inc.
10 Water Street
Fairhaven Mass. 02719
SIZE
A
DWG. NO.
Low-Profile Dredge
Bottom View
REV
SCALE:1:20
WEIGHT:
SHEET 1 OF 5


120.25
10.41
29.50
27.00
13.00
A
Flounder Dredge
Stiffener Bar
B
DETAIL A
SCALE 1 : 10
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
INTERPRET GEOMETRIC TOLERANCING PER:
COMMENTS:
MATERIAL
Cold Rolled 1020
FINISH
Natural
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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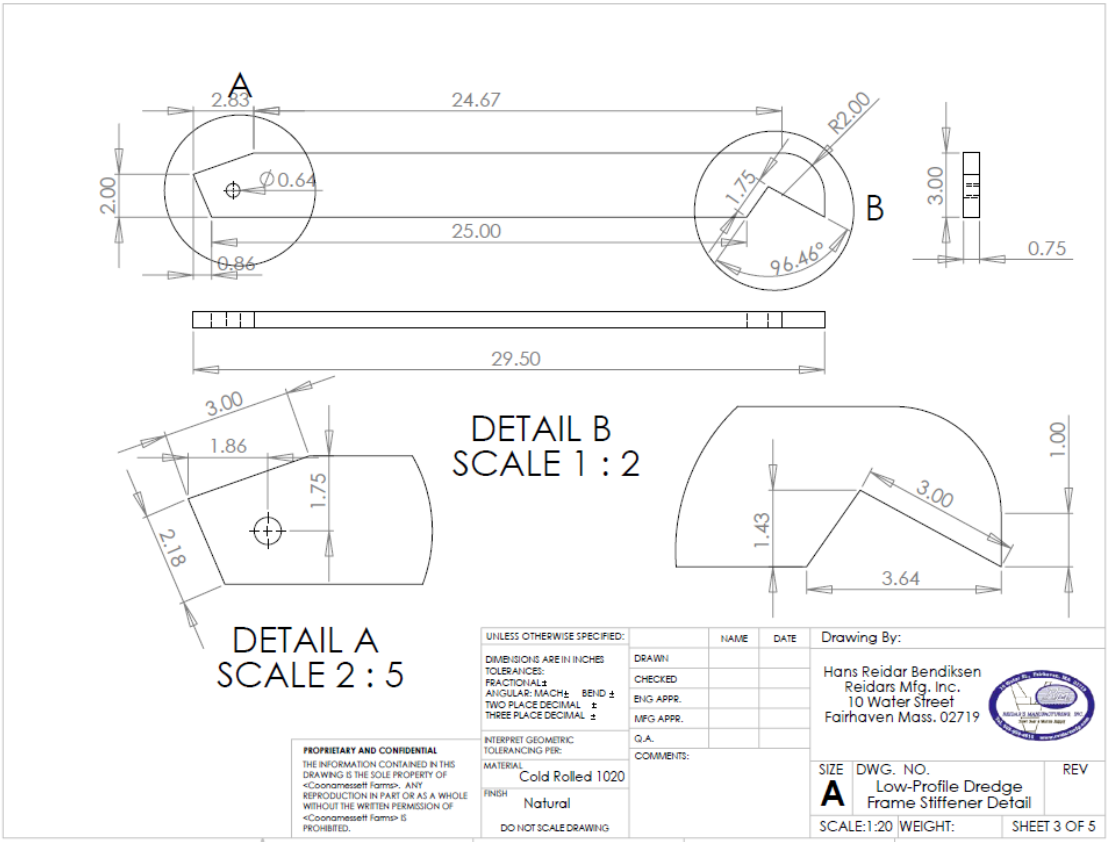
Drawing By:
Hans Reidar Bendiksen
Reidars Mfg. Inc.
10 Water Street
Fairhaven Mass. 02719
SIZE
A
DWG. NO.
Low-Profile Dredge
Side View
REV
SCALE:1:20
WEIGHT:
SHEET 2 OF 5


A
2.83
24.67
R2.00
2.00
Ø0.64
1.75
B
3.00
25.00
0.86
96.46°
0.75
29.50
3.00
1.86
1.75
2.18
DETAIL B
SCALE 1 : 2
3.00
1.00
1.43
3.64
DETAIL A
SCALE 2 : 5
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
Drawing By:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Hans Reidar Bendiksen
Reidars Mfg. Inc.
10 Water Street
Fairhaven Mass. 02719
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Cold Rolled 1020
FINISH
Natural
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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SIZE
A
DWG. NO.
Low-Profile Dredge
Frame Stiffener Detail
REV
SCALE:1:20
WEIGHT:
SHEET 3 OF 5