Testing of a Low Profile Excluder Dredge For Winter Flounder Bycatch Reduction

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Abstract

A low profile scallop dredge frame (CFLP) was constructed in two sizes: a 9-foot wide version for the Limited Access General Category (LAGC) fleet and a 15-foot wide version for the Limited Access (LA) offshore fleet. The objective was to gather comparison fishing data on the CFLP design for both inshore and offshore fleets. A remotely operated vehicle (ROV) was used to of gather behavioral data on winter flounder to ascertain how winter flounder can be encouraged to avoid capture, or to escape once caught, in scallop dredges and other gear types. The dredge was taken to sea on dedicated research trips: 15 DAS for the small dredge and 21 DAS for the larger dredge, and 3 DAS were dedicated to ROV operations. The gear was tested in areas of high concentrations of winter flounder. Results indicate that the LP design has the potential to reduce flatfish bycatch while maintaining the catch of larger sized scallops compared to the traditional New Bedford style dredge.

Background

A new concept for construction of a New Bedford style sea scallop (*Placopecten magellanicus*) dredge frame has recently been 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 (Milliken et al, 2007; Smolowitz et al, 2010, 2012). The modifications to the dredge frame smoothly guide turtles over the top of the dredge primarily by moving the cutting bar forward and eliminating most of the bale bars.

The final dredge frame design, the Cfarm turtle deflector dredge (CFTDD), 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 CFTDD 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. Flume tank tests and video observations suggest some advantages to widening the pressure plate in the forward cutting bar design in that increased lift is created behind the cutting bar. A wider pressure plate may also decrease the amount of fish entering the dredge above the cutting bar by blocking that opening.

Our objective in this project was to lower the profile of the CFTDD 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 New Bedford dredge (NBD) shoe of 15 inches. We maintained the CFTDD strut spacing of 9 inches, the reduced number of bale bars, the doubled outer bale, and the 45° cutting bar angle.

Under the CFRF Challenge Grant Program Part I, a four day research trip onboard the F/V Tradition was conducted using dredge mounted video cameras to ascertain how winter flounder react to a scallop dredge. Two dredges were utilized: a standard New Bedford dredge (NBD) and the new low-profile dredge (CFLP). In addition the catches from 32 paired tows by the two dredges were compared. The dredges caught similar amounts of scallops but the low profile dredge significantly reduced the bycatch of winter flounder, *Pseudopleuronectes americanus*, (122%), little skate, *Leucoraja erinace*, (88%), summer flounder, *Paralichthys dentatus*, (55%), and sand dab, *Scophthalmus aquosus*, (116%). On a commercial fishing trip conducted by the F/V Celtic, the new CFLP caught about the same amount of scallops as the CFTDD in an area with few fish present. Appendix A contains photographs of the dredge design and fish reactions to the dredge.

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 CFLP (with 20-inch depressor) and a standard NBD where both dredges were rigged with the same bag (only the side pieces differed). The CFLP 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). In this area, with large amounts of sand dollars, the CFLP caught 67% less trash (152 bu vs. 455 bu).

A closer examination of the scallop length frequency data from the three scallop RSA trips into CAII on George's Bank shows that the CFTDD caught smaller scallops than the CFLP 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 CFLP (1932 vs. 912; $P(T<=t)$, 0.009) but were almost equal 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 CFLP.

The F/V Westport trip demonstrates significant scallop size selection differences between the CFLP with a 20-inch depressor plate and a NBD with a standard 8-inch depressor plate. The CFLP caught 5773 scallops vs. 6617 for the NBD. For scallops below 110 mm shell height the catch was 1072 vs. 2149; for greater than 110 mm shell height the CFLP caught 4701 vs. 4468 for the NBD. The report can be found at the following link:

http://www.nefsc.noaa.gov/coopresearch/pdfs/FR-11-0021_Testing_CFF.pdf

Based on the F/V Westport results we used the wider depressor plate version of the 15-foot wide CFLP for the testing in this project.

Methods LAGC vessels:

In a period from September 20, 2011 through May 20, 2012, 16 day paired day-trips comparing the Coonamessett Farm Low Profile Dredge (CFLP, Figure 1) against a standard dredge (Provincetown-style, Figure 2) were completed on the LAGC scallop boat F/V Mister G from Point Judith, RI. Of the 16 days, 8 of the days were spent fishing the CFLP, and 8 days were spent fishing a standard "Provincetown" 9-foot dredge (supplied by Captain Mike Marcetti) as a comparison dredge. While the proposed project incorporated multiple vessels in the LAGC fleet, due to quota restrictions, vessel availability and mechanical limitations, the F/V Mister G was the only vessel available, willing to participate, and able to fulfill the objectives of the proposal. Subsequent gear projects have sought to increase vessel participation, though additional vessels must be able to fish the modified dredge on subsequent days, which eliminates many vessels in the LAGC fishery.

Figure 1: Upper and under side of the Coonamessett Farm Low Profile 9-foot dredge.

Figure 2: Provincetown-style control dredge, supplied by Mike Marcetti, captain F/V Mr. G.

The proposed project was to employ an “alternate tow strategy to minimize fish availability bias in the area.” In order to alternate tows, the participating vessels must be able to carry two dredges on the boat, and by definition, the LAGC fishery is a one-dredge fishery. Therefore the “alternate tow strategy” employed was to fish one day using one dredge, and the next day (or as soon as possible afterward; within 3 days) use the other modified dredge. All General Category research DAS comprised of between 8-10, 50 minute tows. The sampling procedure for the inshore LAGC study comprised of fishing 8-10 tows in a particular spot which may have high rates of bycatch using one of the dredges (Figure 3). All bycatch was enumerated, and subsequently sampled for length. All scallop catch was picked into bushel baskets, and enumerated, and for each tow one entire basket was sampled for shell height frequencies. Statistical analysis for all catch data includes paired t-tests and all summary statistics for all species collected, including differences in shell height frequencies between the two different dredges.

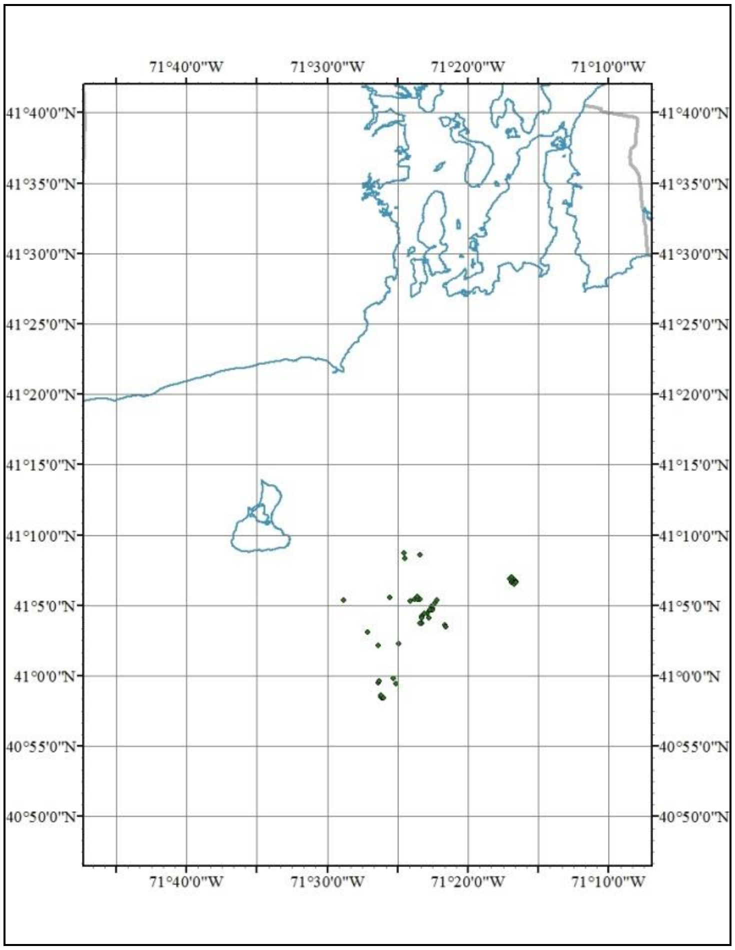

Figure 3: Inshore tow locations for the LAGC boat F/V Mister G, southeast of Block Island.

Results LAGC Vessels:

Throughout the entire comparison between dredges, the CFLP always caught less bycatch species than the control dredge (Table 1). The reduction in bycatch ranged from 53.5% (Barndoor skate) to 18.9% (yellowtail flounder), though none of the results were statistically significant due to high variability (paired t-test, df=7, α=0.05). Although not statistically significant, reductions in commercially important species such as yellowtail and winter flounder were large (31.4% and 37.0%, respectively) and for every tow the LP dredge caught many less fish than the standard control dredge. While the bycatch retention rate was much lower for the CFLP compared to the control, overall the kept scallop rate was lower as well (Table 1). When averaged across all tows, the CFLP dredge caught 23.9% less scallops than the control, but due to high variability, this is not a statistically significant reduction. Bycatch rates showed no significant differences as well (Table 2), probably due to the low number of tows. It is inherent in fishery science that it is difficult to show statistical significance without many, many trips and tows to reduce variability. The LA portion of this project had similar standard deviations with many more tows compared to the LAGC aspect of this project. In addition, on the second day using the modified dredge, the same area was fished using the same coordinates, same tow time and same fishing strategy. However, given the dredge is 9' wide, and oceanic conditions vary day-to-day, there is no way that the same exact tow path was followed. The intent was to sample the same area of ocean bottom, and therefore, with the limited amount of tows, and the limited amount of time between tows, any variability would not be due to significant depletion of the resource at that particular site. Given the limited number of vessels in this fishery, the limited number of vessels operating in that area, and the limited time between sampling each dredge (typically hours and not days), it is not possible that the resource was depleted between comparison tows. Therefore, more research is needed in this area to show statistical significance.

Table 1: Average catch per tow of each bycatch species and kept scallops LAGC trips.

	Fish caught per tow						
	Windowpane Flounder	Winter Flounder	Yellowtail Flounder	Summer Flounder	Four Spot Flounder	Barndoor Skate	Bushels of scallops per tow
Control	8.94	0.97	3.04	2.85	1.10	0.35	4.99
CFLP	6.97	0.61	2.09	2.31	0.81	0.16	3.80
% Reduction	22.04	36.95	31.36	18.91	26.93	53.48	23.9

Table 2: Bycatch rates for key species showed no significant differences most likely due to the limited number of tow comparisons.

LAGC Bycatch Rates		Windowpane Flounder	Winter Flounder	Yellowtail Flounder	Summer Flounder	Barndoor Skate	Four spot Flounder
Control	Total fish weight	353.1	83.5	188.9	384.7	57.6	34.6
Control	Total scallop meat weight	3754.2	3754.2	3754.2	3754.2	3754.2	3754.2
CFLP	Total fish weight	263.5	47.2	142.4	275.8	26.8	20.7
CFLP	Total scallop meat weight	2751.2	2751.2	2751.2	2751.2	2751.2	2751.2
D/K	Control	0.094	0.022	0.050	0.102	0.015	0.009
D/K	CFLP	0.096	0.017	0.052	0.100	0.010	0.008

There was a trend for increased catch of larger scallops (>130mm shell height) with the CFLP, and a trend towards retention of smaller scallops (<130mm shell height) with the control dredge. However, variability in shell height averages was high, so the difference was not statistically significant (Figure 4).

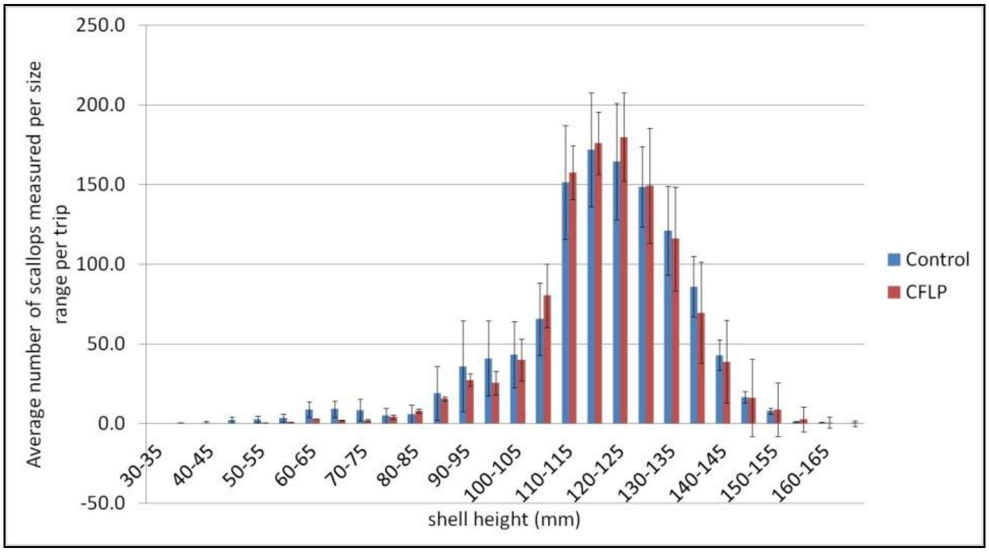

Figure 4: Average number of scallops in each size range per trip (mean±s.e.m.).

Methods LA Vessels:

Tow parameters for the CFLP dredge were standardized as using a 3:1 wire scope and a tow speed of 4.8 knots for 30 minutes. Tows less than 20 minutes or longer than 40 minutes as well as tows with gear malfunctions were not considered valid tows and were excluded from the analysis. The goal of this project was to design a dredge that would reduce flatfish bycatch while maintaining scallop catch. When preliminary results indicated reduced scallop catch in the CFLP, the dredge design and tow parameters were modified to improve the dredge's efficiency. Additional tows were conducted with modified tow parameters to determine if dredge performance could be improved.

On the first of the three planned trips, the F/V Arcturus towed the 15-foot CFLP frame with a bag design similar to the bag attached to the NBD. The CFLP bag varied from the NBD bag in two ways: a two ring skirt on the CFLP bag instead of three rings on the NBD bag, and a sweep of 125 links for the CFLP sweep instead of 121 links for the NBD sweep. After 55 tows and inconsistent catches with this bag design, the bag was rehung to be as identical as possible to the bag on the NBD for the 43 remaining tows completed during the trip. The first 55 tows were excluded from the statistical analysis of the findings because the experimental dredge was not standardized.

For the second of the LA directed research trips, scope was the main focus. Data were collected using 90 paired tows, 45 tows for each compared scope (3:1 or 4:1) aboard the F/V Weatherly. The odd numbered tows tested a short scope of 3:1 (wire out to depth) and the even numbered tows were conducted at a 4:1 scope. Additionally, a forward tickler chain was welded onto the frame of the CFLP and both dredges were towed at a 4:1 scope for the last 20 tows aboard the F/V Weatherly (Figure 5). A total of 110 tows were performed on this trip. The CFLP catches were compared to the catches of the NBD. Tows with a 4:1 scope and tickler chains were excluded from the statistical analysis because they were an attempt to increase the efficiency of the dredge and did not follow standardized tow parameters.

Figure 5: The Forward Tickler Chain design that was tested aboard the F/V Weatherly. (Note the wide depressor plate at the top of the photo.)

The final LA trip was completed aboard the F/V Ranger with 98 paired tows made in September. On this final trip, the sampling area was limited to a small area south of Martha's Vineyard (Figure 6) where catches of winter flounder and yellowtail had been consistently large on previous tows made in the area.

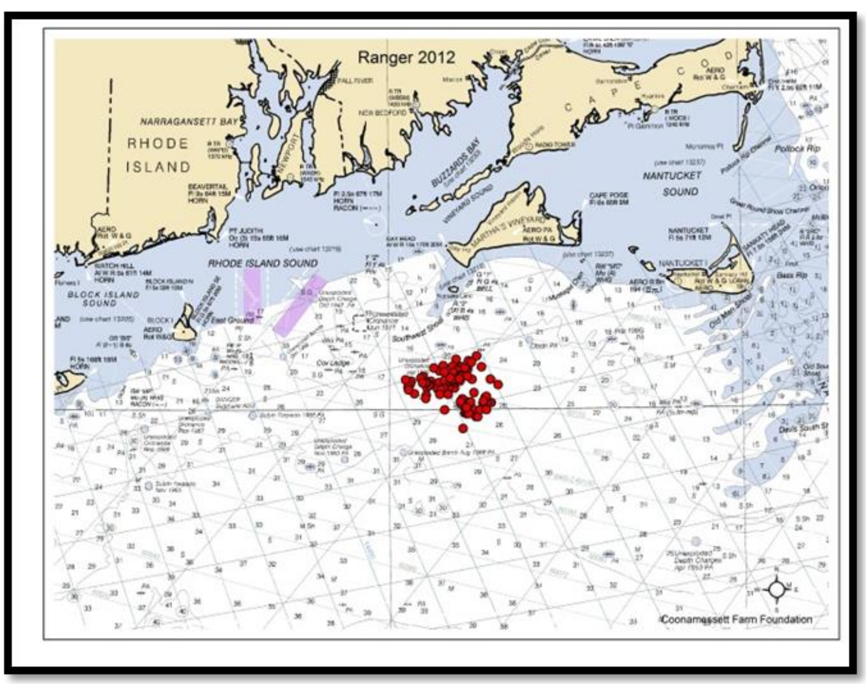

Figure 6: Locations of the tows for the final LA trip aboard the F/V Ranger.

Results LA Vessels:

Data were recorded on 279 paired tows comparing the CFLP and the New Bedford dredge (NBD) for the LA portion of the project. Of those, 186 were valid tows using the standardized tow parameters and scallops were measured on 179 of those tows. The combined standardized tow data from all three trips shows a reduction in flatfish bycatch for the CFLP dredge compared to the control dredge. Demersal species bycatch reduction ranged from 10.89% for barndoor skate to 63.12% for fourspot flounder (Table 3). The data from the 186 tows failed the Shapiro-Wilk Test for normality and therefore all statistical values were obtained using the Mann-Whitney Test (Table 3). The observed catch reductions for yellowtail, winter, windowpane and four spot flounder were statistically significant. There was no statistical difference in summer flounder or barndoor skate catch between gear types (Table 3). There was a significant reduction of scallop catch (18.75%) in the CFLP dredge as compared with the dredge (Table 3). A comparison of the scallop size frequency distribution is shown in Figure 7. Although the CFLP appears to catch more scallops greater than 110 mm than the control dredge, the difference was not shown to be statistically significant (Table 4).

Table 3: Average catch per tow of each flatfish species and scallops with standard deviation in parenthesis for all 186 standardized tows. Statistical values were obtained using a Mann-Whitney Rank Sum Test. (*) indicates a statistically significant difference.

	Comparison of CFLP and Control (Standardized Tows)							
	Windowpane Flounder	*Winter Flounder*	*Yellowtail Flounder*	*Summer Flounder*	*Fourspot Flounder*	*Barndoor Skate*		*Bushels of scallops per tow*
Control	**9.102 (11.339)**	**2.183 (2.118)**	**7.22 (9.597)**	**4.086 (5.231)**	**1.559 (2.605)**	**0.387 (0.877)**		**2.574 (2.442)**
CFLP	**5.71 (7.393)**	**1.382 (1.66)**	**4.511 (6.881)**	**3.005 (3.005)**	**0.575 (1.017)**	**0.349 (0.976)**		**2.097 (2.174)**
Difference of Means	**-3.39**	**-0.80**	**-2.71**	**-1.08**	**-0.98**	**-0.04**		**-0.48**
% Difference	**-37.27%**	**-36.69%**	**-37.52%**	**-26.46%**	**-63.12%**	**-10.89%**		**-18.53%**
n	**186**	**186**	**186**	**186**	**186**	**186**		**186**
U Statistic	**15141**	**13430**	**14401**	**16205**	**16205**	**17163**		**15020**
P Value	**0.033***	**<0.001***	**0.005***	**0.276**	**<0.001***	**0.858**		**0.028***

Table 4: Difference in scallop weights of the measured bushels by dredge type using approximately a 20 meat count scallop as the cull point.

	Scallop Weight Comparison			
	<110 mm	***>110 mm***		***Total***
Control	**116.270**	**1406.686**		**1522.955714**
CFLP	**86.148**	**1456.457**		**1542.604926**
Difference	**-30.12**	**49.77**		**19.65**
% difference	**-25.91%**	**3.54%**		**1.29%**
n	**179**	**179**		**179**
P Value	**0.284**	**0.78**		**0.272**

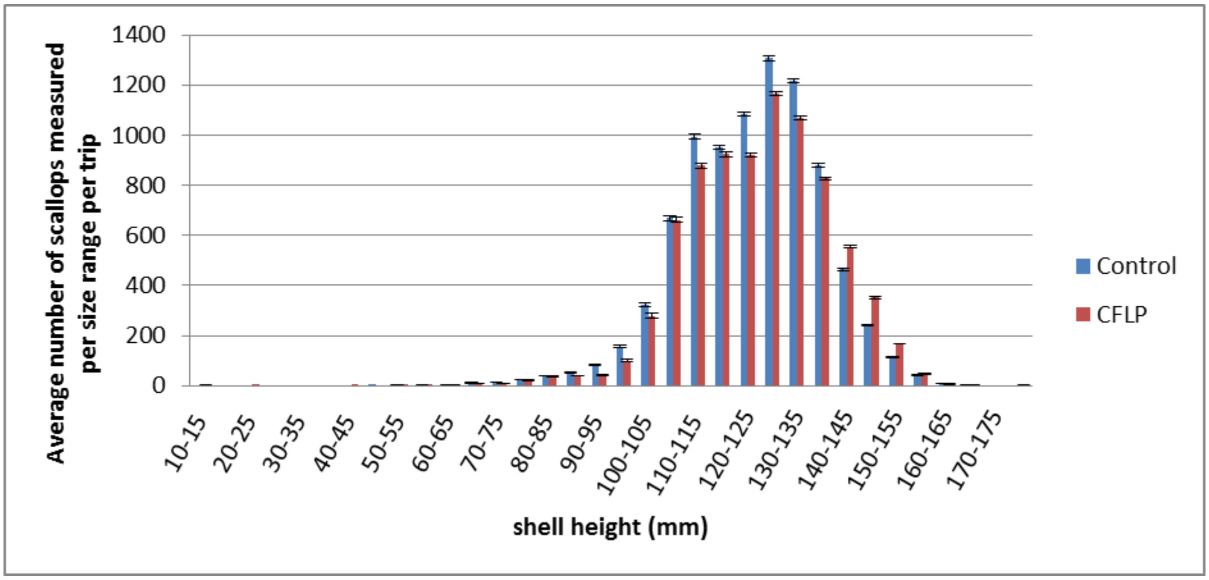

Figure 7: Average number of scallops in each size range per trip (mean±s.e.m.).

Using a seasonal length-weight relationship, the yellowtail flounder and winter flounder weights were calculated from the size frequency data collected aboard all three trips. The scallop weights per tow were collected using shell height to meat weight ratios supplied by the Virginia Institute of Marine Science (VIMS). With the weight data, a bycatch rate for both the CFLP and the control dredge can be calculated by dividing the pounds of yellowtail flounder or winter flounder by the pounds of scallops. The bycatch rate serves as a relative measurement of the dredges efficiency at bycatch reduction. The calculated average yellowtail bycatch rate for the CFLP was lower than the control NBD (CFLP=0.137637; Control=0.167298). The winter flounder bycatch rate for the CFLP was also lower than the control NBD (CFLP=0.058536; Control=0.063515). A lower bycatch rate means that at the same amount of effort, measured as pounds of scallops, the CFLP will catch less yellowtail and winter flounder than the traditional New Bedford dredge (Table 5; Figure 8).

Table 5: Bycatch Rates (lbs. of fish/lbs. of scallops).

Yellowtail Flounder	Control	CFLP
Combined Weight	1522.95	999.8
Expanded Scallop Weights	9892.136433	7785.754
Bycatch Rate	0.15395562	0.128414

Winter Flounder	Control	CFLP
Combined Weight	628.3	455.75
Expanded Scallop Weights	9892.136433	7785.754
Bycatch Rate	0.063515096	0.058536

Figure 8: Winter flounder bycatch (in pounds) by trip.

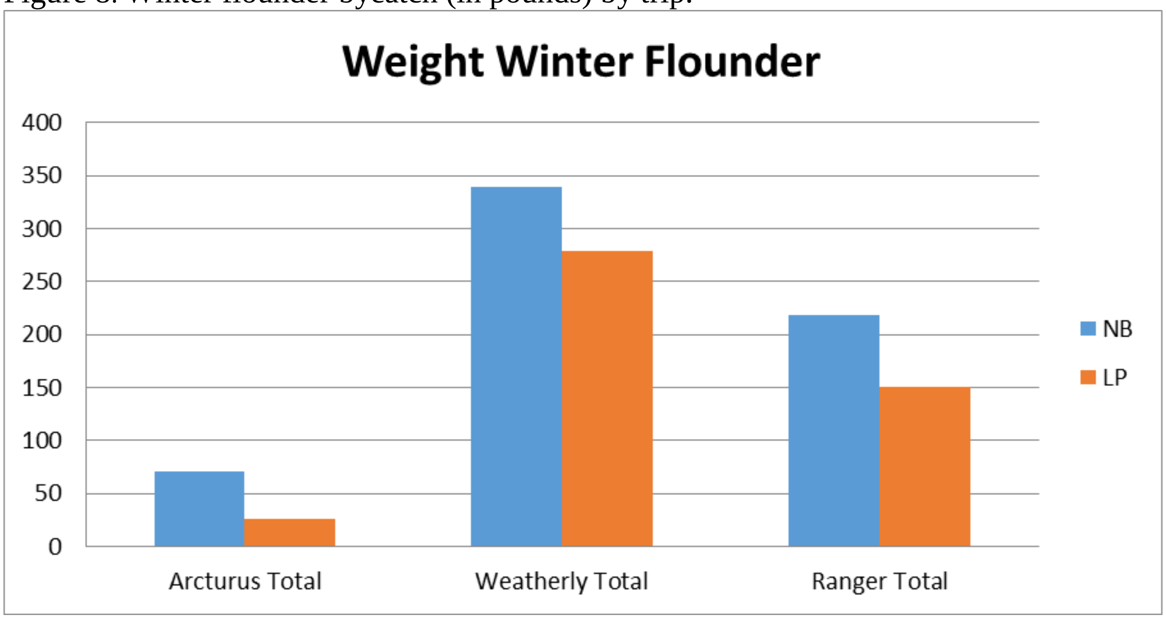

Table 6: During the testing aboard the F/V Weatherly, a forward tickler chain was attached to the frame of the CFLP (Figure 5). Twenty tows were done with the forward tickler chain.

Tickler Chains	*Windowpane Flounder*	*Winter Flounder*	*Yellowtail Flounder*	*Summer Flounder*	*Fourspot Flounder*	*Barndoor Skate*		*Bushels of scallops per tow*
Control	**5.56**	**1.25**	**7.55**	**0.22**	**0.89**	**0.56**		**0.435565**
CFLP	**3.56**	**0.9**	**3.4**	**0.11**	**0.44**	**0.33**		**0.250335**
Diffference	**-2.00**	**-0.35**	**-4.15**	**-0.11**	**-0.45**	**-0.23**		**-0.19**
% Difference	**-36.05%**	**-28.00%**	**-54.97%**	**-50.00%**	**-50.56%**	**-41.07%**		**-42.53%**
*** Average of tows 91-110**								

ROV Operations

In February 2013, three days at sea (DAS) were dedicated to ROV (remotely operated vehicle) work in an effort to explore potential winter flounder spawning grounds in areas of high scallop dredging effort in SNE. Ideally, the goal was to record video footage of winter flounder spawning, winter flounder eggs, and/or skate preying upon winter flounder eggs. On February 13 and 14, 2013, the F/V Edgartown was chartered out of New Bedford, MA. Three Coonamessett Farm Foundation (CFF) scientists were aboard, as well as the captain, the mate, a crewmember, and a groundfisherman with considerable knowledge of the areas in which the vessel was operating.

The ROV utilized is a MiniRover ROV that is owned and operated by CFF. It is outfitted with both a 10X zoom TV camera and a low light black and white TV camera, which are mounted on a tilt mechanism inside an optically clear cast acrylic pressure housing on the bow of the vehicle. The tilt mechanism can tilt at 33 degrees per second up to 90 degrees up and down from horizontal. This tilt function allows for adjustment for the optimum "gazing angle" to represent objects and features in the water column as well as on the sea floor. It also enhances the ROV pilot's ability to collect detailed video of fish, objects, and seafloor features. The color zoom camera provides 470 lines of resolution using a single chip CCD and includes auto iris and gain; the black and white TV camera provides 600 lines of resolution. The bow is also equipped with a total of six LED light sources, three per side, each positioned 45 degrees apart, to provide a 240 degree wide fixed beam of light. The lights can be turned on and off, or can be dimmed from the ROV operational hand box.

All video footage was recorded directly to a hard drive using the Roxio Easy VHS to DVD program and then subsequently burned onto DVDs, while the sonar footage was recorded using its own self-recording program, and then burned to DVDs as well. A total of eight ROV dives were completed in six different locations (Table 7). When the vessel approached the desired area, the ROV was lowered into the water by a crewmember. The CFF scientist in charge of ROV operation, Dan Ward, would then slowly fly the ROV through the water column until reaching the bottom. The second CFF scientist was in charge of recording significant events that occurred during the dive.

A total of four hours and thirteen minutes of footage was recorded throughout the eight dives, and many different species of flora and fauna were viewed. A vast majority (almost 40%) of the noted species were skate. Others noted were sea anemone, swimming larvae, snails, hermit crabs, scallops and other bivalves, sea robin and hake, shrimp, starfish, and a four spot flounder. The visibility was relatively clear most of the time, despite the fact that there had been a heavy storm passing through the area in the days before the cruise. All efforts were made to travel to areas where we expected to see winter flounder, and other fishing boats were even spotted at the same time launching gear in close proximity to the dive locations. Unfortunately, no winter flounder were observed. Therefore, although the intent was to film winter flounder and all reasonable effort and timing was directed at finding winter flounder, none were found throughout any of the dives. Subsequent video analysis was directed at quantifying predators in the area (skate and starfish), and evaluated substrate to inform future dives targeting winter flounder.

Table 7: List of dives completed on the F/V Edgartown cruise with corresponding locations, and latitudinal and longitudinal beginning and ending coordinates.

Date	Dive	Location	Lat Beg (N)	Long Beg (W)	Lat End (N)	Long End (W)
2/13/13	1	1	41° 10.717’	71° 15.816’	41° 10.729’	71° 17.778’
2/13/13	2	1	41° 10.745’	71° 15.667’	41° 10.786’	71° 15.520’
2/13/13	3	1	41° 10.793’	71° 15.476’	41° 10.828’	71° 15.318’
2/13/13	4	2	41° 01.591’	71° 11.899’	41° 01.558’	71° 11.951’
2/13/13	5	3	41° 01.470’	71° 14.914’	41° 01.869’	71° 14.966’
2/14/13	6	4	41° 02.660’	71° 21.017’	41° 02.339’	71° 20.726’
2/14/13	7	5	40° 56.771’	71° 20.516’	40° 56.667’	71° 20.398’
2/14/13	8	6	41° 05.449’	71° 35.303’	41° 05.445’	71° 35.037’

During each of the ROV dives, observational notes were taken about the images displayed by the ROV’s camera. These notes and videos were reviewed on multiple occasions once back on land. One species that was frequently observed by the ROV was little skate (*Raja erinacea*), and we were interested in finding a density for this species using our ROV data. Throughout the three hours and five minutes the ROV spent on the sea floor, a total of twenty-nine little skate were observed, counted, and verified from the video footage. The calculations in Table 8 show how we arrived at our density estimate of fewer than 29,000 skate per square nautical mile.

Table 8. Calculations to estimate skate density per square nautical mile.

Area Swept: Camera Width (km) * ROV Speed (km/hr) * Bottom Duration (hr) = Area Swept (km^2) 0.00122 * 0.926 * 3.083 = 0.00348
Density: Catch (# skate) / Area Swept (km^2) = Density (skate/km^2) 29 / 0.00348 = 8330.94
Density Conversion to squared Nautical Miles: Density (skate/ km^2) * Conversion (km^2/0.291 nm^2) = Density (skate/nm^2) 8330.94 * 1/0.291 = 28,629

We wanted to compare the density we found from our ROV data to other density examples in an effort to prove that the ROV can be a valid tool to estimate density in absolute abundance. To evaluate this, we first compared our ROV estimate to two other estimates from our April 2012 F/V Westport cruise and September 2012 F/V Ranger cruise. Both cruises were completed in the same area as the F/V Edgartown ROV cruise.

We also looked into other research involving skate abundance estimates (MacDonald et al.; 2010) which used the SMAST video pyramid to evaluate skate abundance from 2003-2009 throughout the Middle Atlantic Bight and Georges Bank. We compared our ROV skate estimate to their 2009 results from the Middle Atlantic Bight. A summary of the compared skate per square kilometer density estimates from the Coonamessett Farm Foundation cruises and MacDonald et al. results is shown in Table 9 and Figure 9.

There are adjustments we could make to improve the quality of the results. By creating a set of transects to fly the ROV along, similar to the set grid system used by MacDonald et al., we could find more consistent data. In addition, we would need to calibrate the width of an ROV transect. In this instance, we estimated the width to be 4 feet (0.00122 km). The width of the dredges that we towed on the F/V Westport and F/V Ranger were all 15 feet (0.00457 km). The density results that we retrieved from each cruise, though different, are in the same order of magnitude, and speak to the validity of utilizing the ROV to estimate density in absolute abundance.

Table 9. Skate density table comparing the estimates from the three Coonamessett Farm Foundation cruises (F/V Edgartown (ROV), F/V Westport, and F/V Ranger), and results from MacDonald et al. 2010.

Vessel	Start Date	End Date	# Tows	Average Tow Time (hr)	*n* skate	Average Area Swept (km2)	Density (skate/km2)
F/V Edgartown	7/12/13	7/14/13	8	3.5	29	0.0035	8331
F/V Westport	4/10/12	4/12/12	55	0.5	15960	0.0203	21013
F/V Ranger	9/15/12	9/19/12	98	0.5	25750	0.0203	13050
MacDonald et al.		*2009*	*924*			*28523*	*7222*

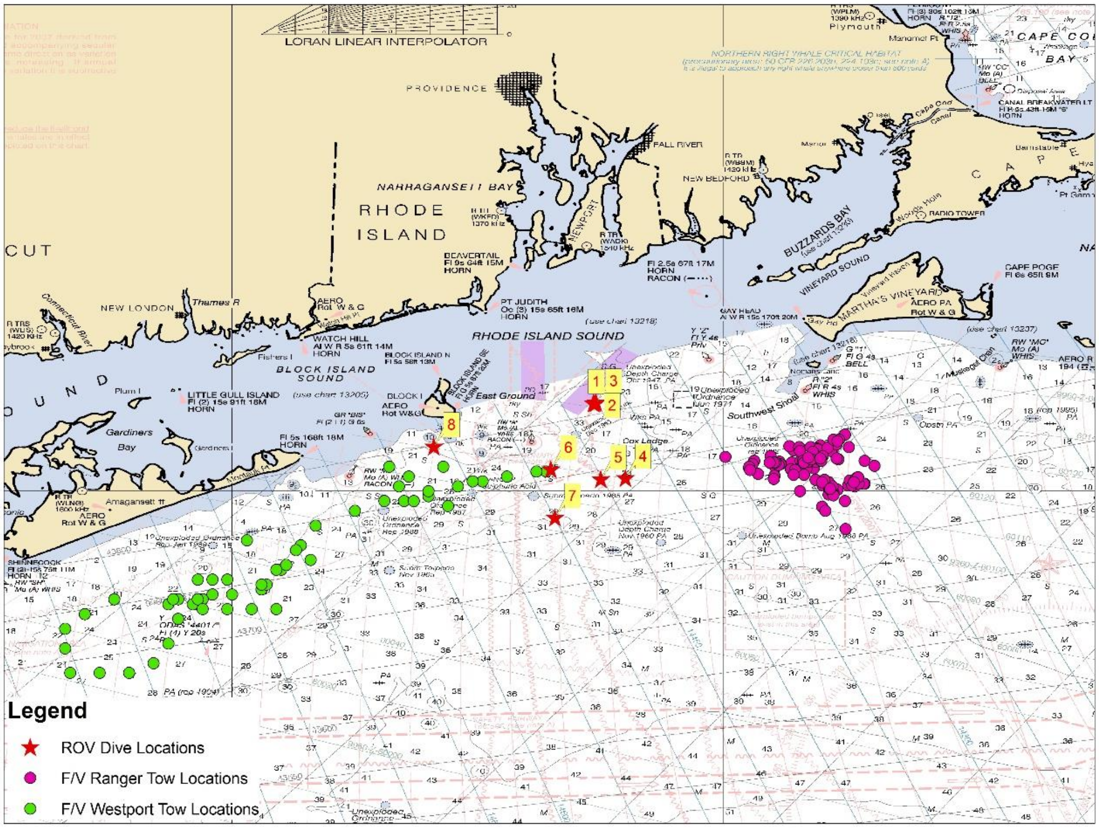

Figure 9: The location of the ROV tows in relationship to scallop dredge gear tests. The millions of skates occupying this area may explain the paucity of winter flounder but much more research is needed to understand the complex inter-relationships.

Discussion

Based on data collected from both the LAGC and LA fleets, the LP dredge can reduce flatfish bycatch and, with further gear testing and modifications, the lower kept scallop rate may be overcome. Aboard the F/V Weatherly, different scope lengths were tested to observe if there are differences between a short and long wire scope. The difference in the kept scallop rate was shown to not be significant while still reducing bycatch, suggesting that the CFLP has the potential to maintain scallop catch while reducing bycatch with low sensitivity to changes in scope. Also, the increased scallop size selectivity of the CFLP could further mitigate the lower kept scallop rate because scallops with a larger shell height have heavier meats. The fishermen aboard the vessels participating preferred the larger scallops because of the increased value for "U10's" and "10-20's" (meats per pound), which is the size of the meats typically found in sea scallops greater than 110 mm. Another benefit the crew found with the CFLP was the smaller benthos or "trash" piles observed. The reduced amount of trash meant less time was devoted to sorting the catch and the piles could often be shoveled rather than picked by hand.

While the quantitative comparison between LAGC dredges showed a reduction in kept scallops (23.9%), the captain of the fishing vessel utilized for this comparison (Mike Marcetti) has expressed advantages to fishing the low profile design which were not captured by the current comparison. He has explained how he likes to fish the CFLP more than the standard dredge even with the lower catch rate, due to the experimental lower profile being much easier to maneuver on deck and in the water when setting out. The 9-foot CFLP can also be towed at the same speed with much lower RPMs compared to the 9-foot Provincetown dredge, thereby lowering fuel costs and realizing savings in spite of the lower retention rates. Therefore, even after noting the retention rates following the conclusion of this project, Mr. Marcetti continues to use the CFLP due to the additional benefits.

There is a continuing need to further develop the dredge frame design, especially design efforts focused on the relationship of the cutting bar to the depressor plate in developing a strong lifting stream to improve efficiency on scallop capture. An analogy would be the relationship of a jib and main sail on a sailing vessel. We do not have comparisons between the two different depressor plate widths (Appendix A1-3) at this time to understand the impact on catch. There is also great room for other improvements in the hydrodynamic characteristics of the dredge frame. The depressor plate is of poor hydrodynamic design with lift to drag ratio of approximately one in the NBD. This ratio was adjusted in the CFLP by changing the angle from the 45 degree angle of attack to 22.5 degrees, giving a lift to drag ratio of 2.4, which should save fuel as observed by the LAGC vessel. However, on the larger CFLP and CFTDD designs there is a resulting shift of the center of gravity aft compared to the NBD due to the removal of the bale bars. This may result in the shoes digging deeper and thus requiring more energy to pull.

Though there was an observed reduction in bycatch during the tows with tickler chains, whether the tickler chain lead to a further reduction in bycatch than prior tows without the tickler chain cannot be determined because only a small number of tows were done with the tickler chains (Table 6). More testing is needed to determine whether the attachment of a tickler chain to the CFLP frame leads to a further reduction in bycatch. Further the experimental scope of 4:1 appeared to increase the CFLP's scallop catch while still reducing the bycatch of flatfish. This is important because if the CFLP can catch scallops as efficiently as a commercial dredge while reducing bycatch it will be more widely used and accepted by the industry. The current reduction in scallop catch using the standardized tow parameters with the CFLP is not commercially viable. Further research is needed in order to effectively reduce bycatch without a loss in scallop catch.

Our operating hypothesis is that the excluder dredge reduces flatfish bycatch in that the forward cutting bar design encourages the fish to swim upwards and over the dredge (see Appendix A4). Additionally, the scallop bag was slightly modified to accompany the reduced height of the frame. Interestingly, the lower height of the frame and bag might aid in the escapement of fish and smaller scallops that enter the dredge. To prevent a loss of scallops, adjustments may have to be made to the bag design.

References:

MacDonald, Alussa M., Charles F. Adams, and Kevin D. E. Stokesbury. 2010. Abundance Estimates of Skates (Rajidae) on the Continental Shelf of the Northeastern United States Using a Video Survey. *Transactions of the American Fisheries Society.* 139:1415-1420.

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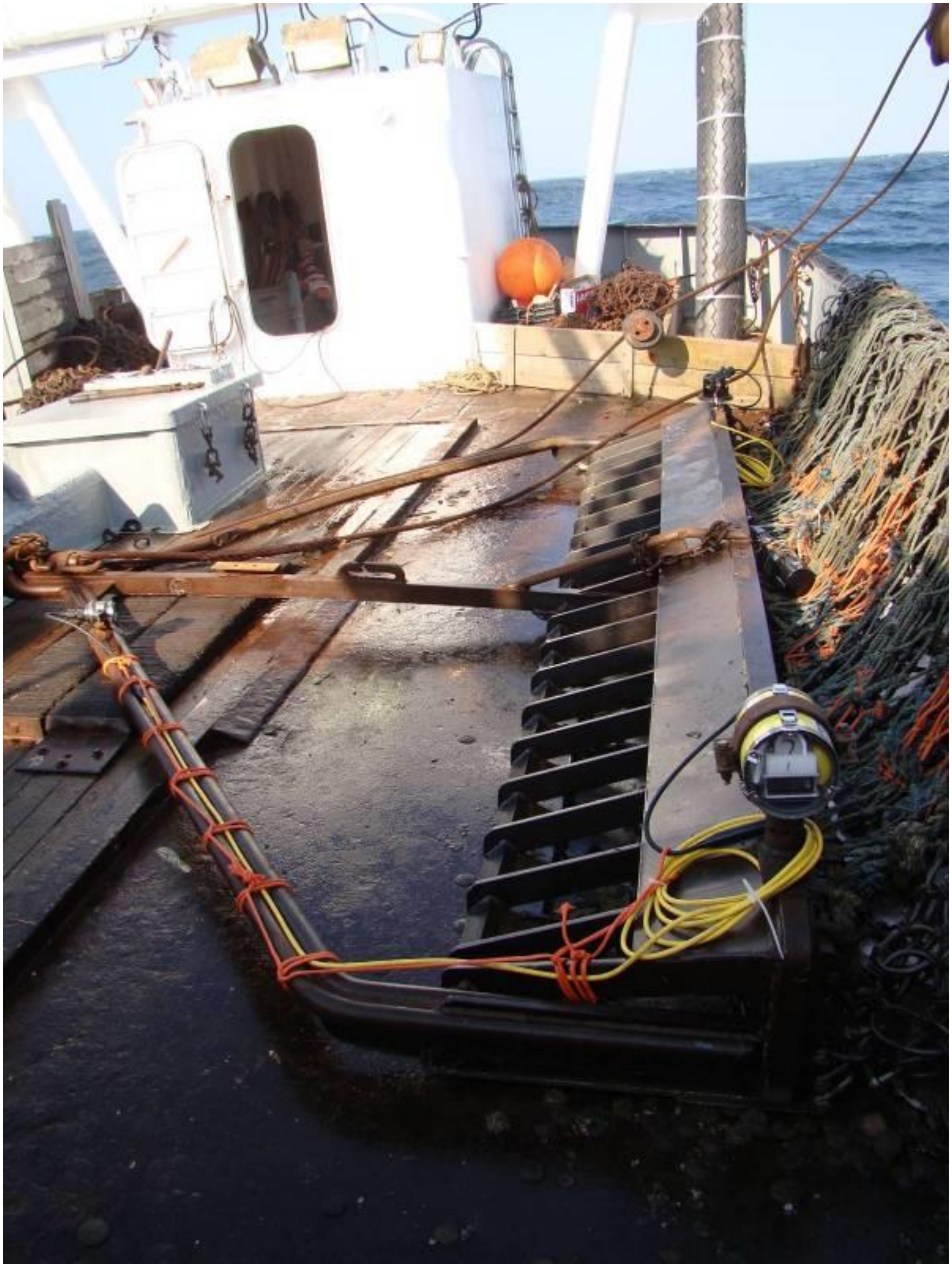
Smolowitz, R., H. Haas, H.O. Milliken, M. Weeks, and E. Matzen. 2010. Using Sea Turtle Carcasses to Assess the Conservation Potential of a Turtle Excluder Dredge. N. Amer. J. Fish. Manage. 30: 993-100.

Smolowitz, R.J., H.O. Milliken, and M. Weeks. 2012. Design, Evolution, and Assessment of a Sea Turtle Deflector Dredge for the U.S. Northwest Atlantic Sea Scallop Fishery: Impacts on Fish Bycatch. N. Amer. J. Fish. Manage. 32: 65–76.

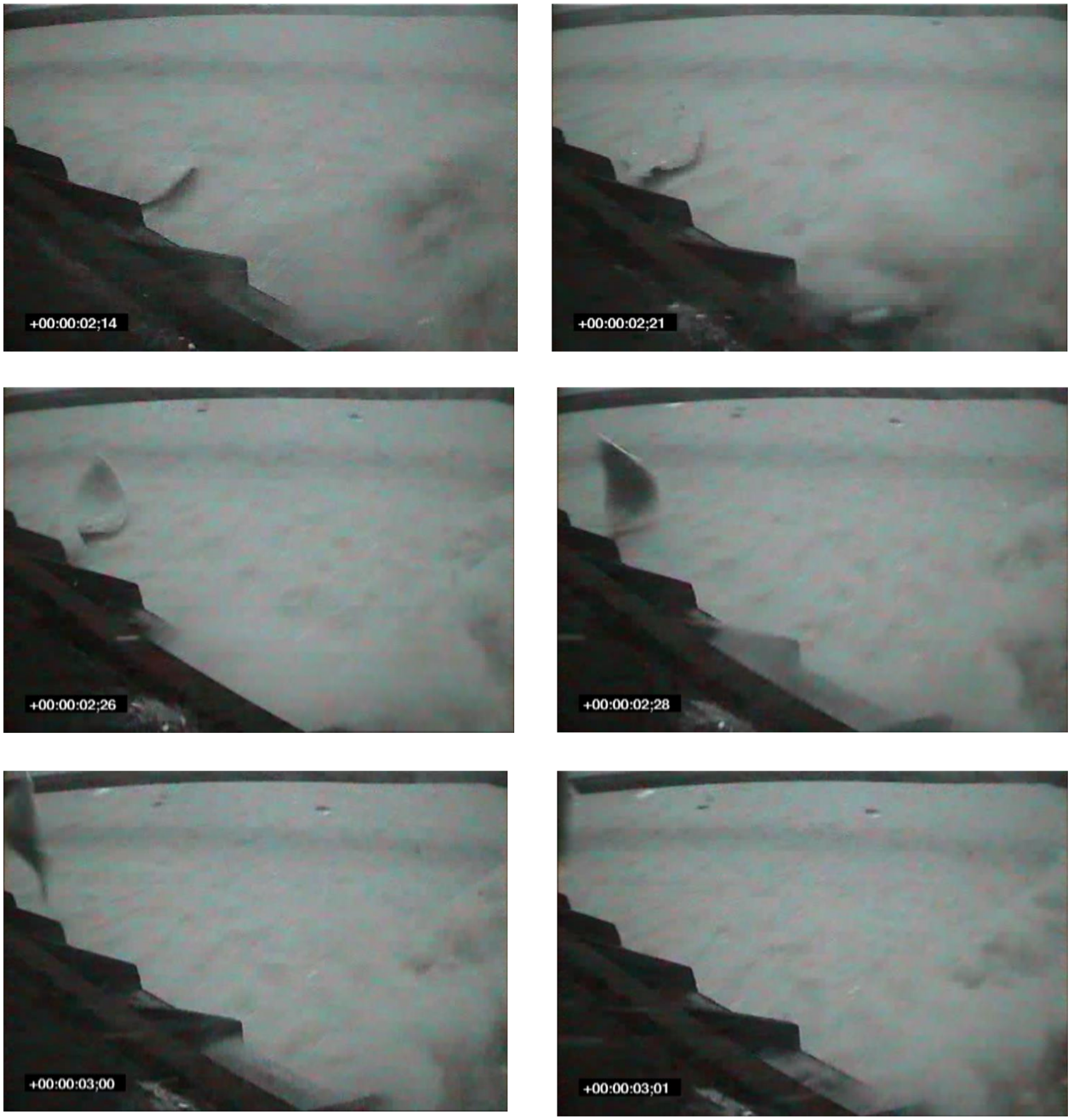
Appendix A1: Comparison of the 15-foot low profile dredge CFLP(Left) to the Cfarm Turtle Excluder Dredge (Right) (8 inch wide depressor plates).

Appendix A2: Low-profile dredge showing the placement of cameras during CFRF Challenge Grant video trials.



Appendix A3: Low-profile dredge showing the wider (20-inch) depressor plate used in the LA research trips.

Appendix A4: A yellowtail flounder going up and over the Cfarm turtle excluder dredge frame; this escape pathway should be easier on the low profile dredge.



Appendix A5: Summary Statistics of Fish Catch Data from the Standardized Tows used for Statistical Analysis.

Species (Dredge)	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
Fluke (Control)	186	0	4.086	5.231	0.384	0.757
Fluke (LPD)	186	0	3.005	3.694	0.271	0.534
4 Spot (Control)	186	0	1.559	2.605	0.191	0.377
4 Spot (LPD)	186	0	0.575	1.017	0.0746	0.147
YT (Control)	186	0	7.220	9.597	0.704	1.388
YT (LPD)	186	0	4.511	6.881	0.505	0.995
BB (Control)	186	0	2.183	2.118	0.155	0.306
BB (LPD)	186	0	1.382	1.660	0.122	0.240
Grey Sole (Control)	186	0	0.118	0.576	0.0422	0.0833
Grey Sole (LPD)	186	0	0.0753	0.382	0.0280	0.0552
WP (Control)	186	0	9.102	11.339	0.831	1.640
WP (LPD)	186	0	5.710	7.393	0.542	1.070

Species (Dredge)	Range	Max	Min	Median	25%	75%
Fluke (Control)	23.000	23.000	0.000	2.000	0.000	7.000
Fluke (LPD)	14.000	14.000	0.000	1.000	0.000	5.000
4 Spot (Control)	28.000	28.000	0.000	1.000	0.000	2.000
4 Spot (LPD)	5.000	5.000	0.000	0.000	0.000	1.000
YT (Control)	43.000	43.000	0.000	3.000	1.000	10.000
YT (LPD)	50.000	50.000	0.000	1.000	0.000	6.250
BB (Control)	8.000	8.000	0.000	2.000	0.000	3.000
BB (LPD)	10.000	10.000	0.000	1.000	0.000	2.000
Grey Sole (Control)	5.000	5.000	0.000	0.000	0.000	0.000
Grey Sole (LPD)	3.000	3.000	0.000	0.000	0.000	0.000
WP (Control)	55.000	55.000	0.000	3.000	0.000	16.000
WP (LPD)	37.000	37.000	0.000	2.000	0.000	10.000

Species (Dredge)	Skewness	Kurtosis	K-S Dist.	K-S Prob.	SWilk W	SWilk Prob
Fluke (Control)	1.370	1.158	0.217	<0.001	0.790	<0.001
Fluke (LPD)	1.236	0.689	0.212	<0.001	0.802	<0.001
4 Spot (Control)	6.098	57.207	0.275	<0.001	0.535	<0.001
4 Spot (LPD)	2.114	4.623	0.386	<0.001	0.628	<0.001
YT (Control)	1.716	2.252	0.264	<0.001	0.746	<0.001
YT (LPD)	2.989	13.218	0.256	<0.001	0.667	<0.001
BB (Control)	0.972	0.184	0.190	<0.001	0.873	<0.001
BB (LPD)	1.654	3.822	0.225	<0.001	0.795	<0.001
Grey Sole (Control)	6.170	42.203	0.522	<0.001	0.213	<0.001
Grey Sole (LPD)	5.488	31.235	0.535	<0.001	0.198	<0.001
WP (Control)	1.379	1.623	0.211	<0.001	0.803	<0.001
WP (LPD)	1.604	2.627	0.220	<0.001	0.783	<0.001

Species (Dredge)	Sum	Sum of Squares
Fluke (Control)	760.000	8168.000
Fluke (LPD)	559.000	4205.000
4 Spot (Control)	290.000	1708.000
4 Spot (LPD)	107.000	253.000
YT (Control)	1343.000	26737.000
YT (LPD)	839.000	12545.000
BB (Control)	406.000	1716.000
BB (LPD)	257.000	865.000
Grey Sole (Control)	22.000	64.000
Grey Sole (LPD)	14.000	28.000
WP (Control)	1693.000	39197.000
WP (LPD)	1062.000	16176.000

Appendix A6: Results testing the experimental scope aboard the FV Weatherly.

	Comparison of Control with Different Scopes			
	Winter Flounder	*Yellowtail Flounder*		*Bushels of scallops per tow*
Control (3:1 Scope)	2.702 (2.653)	9.125 (9.484)		3.212 (3.317)
Control (4:1 Scope)	2.854 (2.690)	8.878 (9.782)		4.048 (3.610)
Difference of Means	0.15	-0.25		0.84
% Difference	5.63%	-2.71%		26.03%
n	48	48		48
P Value	0.729	0.945		0.217

	Comparison of CFLP with Different Scopes			
	Winter Flounder	*Yellowtail Flounder*		*Bushels of scallops per tow*
CFLP (3:1 Scope)	1.872 (1.963)	6.521 (7.232)		2.672 (3.218)
CFLP (4:1 Scope)	2.708 (3.038)	4.857 (5.180)		3.824 (3.808)
Difference of Means	0.84	1.66		1.15
% Difference	44.66%	25.52%		43.11%
n	48	48		48
P Value	0.729	0.945		0.057

	Comparison of CFLP and Control (Standardized Tows)			
	Winter Flounder	*Yellowtail Flounder*		*Bushels of scallops per tow*
CFLP (3:1 Scope)	1.872 (1.963)	6.521 (7.232)		2.672 (3.218)
Control (3:1 Scope)	2.702 (2.653)	9.125 (9.484)		3.212 (3.317)
Difference of Means	-0.83	-2.60		-0.54
% Difference	-30.72%	-28.54%		-16.81%
n	48	48		48
P Value	0.175	0.172		0.194

	Comparison of CFLP and Control (4:1 Scope)			
	Winter Flounder	*Yellowtail Flounder*		*Bushels of scallops per tow*
CFLP (4:1 Scope)	2.708 (3.038)	4.857 (5.180)		3.824 (3.808)
Control (4:1 Scope)	2.854 (2.690)	8.878 (9.782)		4.048 (3.610)
Difference of Means	-0.15	-4.02		-0.22
% Difference	-5.12%	-45.29%		-5.53%
n	48	48		48
P Value	0.44	.026*		0.577
* Denotes a statistically significant difference.				