Quantifying the Selectivity Characteristics of an Extended Link Apron using a Dredge Cover Net

Final Report

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Executive Summary

Small mesh covers are routinely used to estimate the selectivity or the length-based retention probability of trawl gear, the use of small mesh covers to assess the retention and escapement from scallop dredges is far less common. Covers are not routinely applied to dredges because they can frequently tear, reducing the overall amount of sampling that can be achieved during a research trip. Beginning in 2015, Coonamessett Farm Foundation (CFF) started developing extended link aprons in response to overlapping densities of small sea scallops and larger, more desirable sea scallops. Results from traditional paired dredge gear trials indicated that this bag modification was very promising, but a new approach was required to understand more precisely how an extended link apron affects the retention of sea scallops and facilitates the escapement of flatfish. To accomplish this, development of a cover net to retain fish and scallops that pass through the top of the dredge bag started in late 2016.

The objectives of this project were to (1) develop a durable small mesh dredge cover net and standardized protocols for its application in gear research and (2) demonstrate the application of a small mesh cover net for assessing the escapement of sea scallops and non-target species from standard and one-way extended link apron. Through an iterative design process involving CFF scientists and collaborators from the fishing industry, we designed a cover net that is durable, can be fished using commercially representative methods, is easy to handle, and is safe to operate. This small mesh cover net was used to assess the sea scallop and bycatch species retention properties of sea scallop dredges at commercially representative tow speeds using two versions of the SELECT model. Our estimated commercial sea scallop retention parameters and coefficients are comparable to published estimates and those used in sea scallop stock assessments. We predict the sea scallop length of 50% retention (L50) and selection range (SR) for a commercial dredge to be 103.11 mm and 28.86 mm. Furthermore, our covered dredge does not cause “bulldozing” observed using a lined survey dredge. Analysis of catch using a cover net on a one-way extended link apron confirmed our observations from previous work, demonstrating that the extended link apron has different retention properties than a standard apron. Based on the results of this project we are confident in the application of a dredge cover net for the assessing modifications to the top of the dredge bag.

To our knowledge, this project is the first to estimate non-target species retention properties of sea scallop dredges. These retention properties can be used to more precisely understand how sea scallop dredges impact flatfish populations. By developing more selective dredge bags, conservation engineers can ensure that the sea scallop fishery is catching a narrow segment of a flatfish population, minimizing impacts on juvenile fish and more easily accounting

for fishing impacts during stock assessments. Furthermore, the value of incorporating the use of cover nets to assess gear designs goes beyond the modification tested in this project. Adjustments to our cover net and protocol could be used to assess relative impacts of changes to the twine top and apron. Moreover, by incorporating the use of a cover net into seasonal surveys, a covered dredge could be used to examine the seasonal abundance and distributions of species and demographics that are not normally observed in scallop dredges.

Project timeline

Funding period: March 1, 2017 – May 29, 2018

Field Testing and Data Collection: September 9, 2017 – May 3, 2018

Background

Retention and escapement are two sides of the same coin; animals that are not retained by the dredge escape from it. Maintaining the retention of the target species while facilitating the escape of non-target species is the primary goal of gear modifications. Small mesh covers are the most straightforward method to estimate the selectivity or the length-based retention probability of a mobile fishing gear (Wileman et al. 1996; Millar 2009). While this approach is standard for investigating how modifications influence codend selectivity, the use of small mesh covers to assess the retention and escapement of sea scallop (*Placopecten magellanicus*) dredges is limited and has not been standardized (Caddy 1971; Millar and Naidu 1991; Millar 1993; Salerno et al. 2008; Bochenek et al. 2015). Covers are not routinely applied to dredges because they can frequently tear, reducing the overall amount of sampling that can be achieved during a research trip (Millar and Naidu 1991). However, traditional paired gear comparisons require hundreds of tows to determine how a dredge modification influences escapement when bycatch species like yellowtail flounder (*Limanda ferruginea*) are in low abundance. The retention properties of modified sea scallop dredges can be assessed with much fewer tows using a cover net. As a result, Coonamessett Farm Foundation, Inc. (CFF) developed and tested a durable dredge cover net in 2018/2019 and demonstrated its application using the extended link apron.

Caddy (1971) was the first to use a cover net to assess the selectivity of Canadian offshore sea scallop dredge. A 38-mm mesh net covered both the twine top and apron of a New Bedford dredge with a 3” ring chain bag, and sea scallop catches from the codend and dredge were compared to generate a length at 50% retention (L50) estimate (Caddy 1971). Tagged scallops were also used to quantify escapement through the belly (Caddy 1971). Using this experimental design, Caddy (1971) was able to estimate an L50 for both the top of the dredge (twine top and apron) and the whole dredge (belly, twine top, and apron). The L50 for the whole dredge was higher than for the top of dredge and was assumed to be the result of higher escapement through the belly of the chain bag (Caddy 1971). However, a more recent study demonstrated that the effect of escapement through the belly is minor relative to the top of the dredge (Millar and Naidu 1991).

A cover net was used to assess the retention properties of a dredge used for biomass surveys of Iceland scallops (*Chlamys islandica*) on St. Pierre Bank in Newfoundland, Canada (Millar and Naidu 1991; Millar 1993). The net was made of 35-mm mesh and covered the entire back portion of the dredge (Millar and Naidu 1991; Millar 1993). A belly cover, made using the same 35-mm mesh, was protected by chafing gear made of larger mesh (Millar and Naidu 1991). The covered dredge was paired with a standard dredge, and a comparison of the standard dredge catches to those in just the dredge bag of the covered dredge indicated that the efficiency of the covered dredge was reduced (Millar and Naidu 1991). It was also determined that for pre-recruit Iceland scallops (< 58 mm), the covered dredge retained proportionally more scallops as shell height decreased (Millar and Naidu 1991; Millar 1993). Despite these caveats, representative retention properties of the Iceland scallop survey dredge were estimated, and a selectivity curve was generated (Millar and Naidu 1991; Millar 1993).

These previous dredge cover-net studies focused on the escapement and retention of the target species, sea scallops (Caddy 1971) and Iceland scallops (Millar and Naidu 1991; Millar 1993). Covered dredges are suitable for evaluating the retention properties of sea scallop dredges, but the lined survey dredge is the predominate method for evaluating dredge selectivity in the United States sea scallop fishery (Serchuk and Smolowitz 1980; Yochum and DuPaul 2008; SAW 2018). However, the lined survey dredge is towed at a slower speed (3.8 knots) relative to tow speeds currently observed in the commercial fishery (4.5-5 knots). Tow speed significantly impacts the probability that a flatfish in the path of the dredge will enter it (He et al. 2018). Also, underwater observations of the lined survey dredge reveal that a mound of trash and scallops are pushed ahead of the sweep chain, resulting in matter being swept to the side of the dredge and under the dredge belly (Serchuk and Smolowitz 1980). This "bull-dozing" effect was not observed for the standard dredge (Serchuk and Smolowitz 1980). The reduced tow speed and "bull-dozing" effect of the lined survey dredge make it unsuitable for evaluating the escapement of non-target species. The use of a covered dredge avoids these issues (Millar and Naidu 1991).

As the sea scallop resource recovered, concern shifted from optimizing harvesting gear to developing gear to mitigate the impacts of sea scalloping on non-target and protected species. At the time of its collapse in 1994, the regulated minimum twine-top mesh size was 5.5" and the minimum ring size was 3.25" (50 CFR Part §650.21(b)(2)(i) 1994; 50 CFR Part §650.21(b)(3)(i) 1994). The minimum ring size and twine-top mesh size was gradually raised to a 4" ring and 10" mesh over a ten year period following the collapse of the sea scallop fishery. While the retention properties of the 4" inch ring were thoroughly investigated, the implementation of the 10" minimum mesh size for the reduction of bycatch relied on a single formal study (NEFMC 2004; Salerno et al. 2008). To assess the escapement of fish through a 10" mesh twine top, a 3.5" mesh cover was used aboard Limited Access General Category (LAGC) vessels (Salerno et al. 2008). The net only covered the twine-top portion of the dredge bag, where previous dredge cover studies covered the entire top portion of the dredge (Caddy 1971; Millar and Naidu 1991; Salerno et al. 2008). Sea trials using the twine-top cover revealed that fewer fish are passing through the twine top than are retained by the dredge (Salerno et al. 2008). These findings suggest that more fish are contacting the apron portion of the bag rather than the twine top. However, it is unlikely that the cover net in this study was retaining a sample representative of the population's length distribution. Smaller fish (<15 cm) are more likely to be entrained in the flow of water created by towing the dredge and expelled through dredge apron rather than through the twine top (unpublished results). Therefore, covering the entire top portion of the dredge would be a better approach for assessing the escapement of fish from sea scallop dredges.

The most recent application of dredge cover nets investigated the condition of sea scallops passing through the twine top and apron of the dredge bag, highlighting the application of covers for assessing the fate/survival of escaped animals (Bochenek et al. 2015). The estimation of biomass is more sensitive to assumptions about incidental mortality when large recruitment events occur (Hart and Rago 2006). Observations of high recruitment in the Mid-Atlantic region in 2015 led to the need for testing of assumptions about incidental mortality (Hart and Rago 2004). A dredge with a 1-7/8" mesh cover net was simultaneously towed with an uncovered dredge for five minutes (Bochenek et al. 2015). The condition of sea scallops retained in the net was recorded and cages were used to investigate the delayed mortality of sea scallops passing through the dredge bag (Bochenek et al. 2015). This study indicated that the incidental mortality rate of sea scallops escaping from the dredge bag is <1% (Bochenek et al. 2015). To determine whether the covered dredge was fishing in a commercially representative manner, a comparison of the standard and covered-dredge sea scallop catches was done (Bochenek et al. 2015). It was determined that the cover did not significantly impact the total catch of scallops, but the covered dredge appeared to retain a higher proportion of smaller scallops (Bochenek et al. 2015). It was hypothesized that the increase in small scallops was a result of the net laying over some of the apron rings preventing the small scallops from passing through the rings (Bochenek et al. 2015). Nonetheless, the sea-scallop selectivity curve generated from the data was similar to previously published results using lined dredges (Yochum and DuPaul 2008; NEFSC 2014; Bochenek et al. 2015).

Previous research at CFF

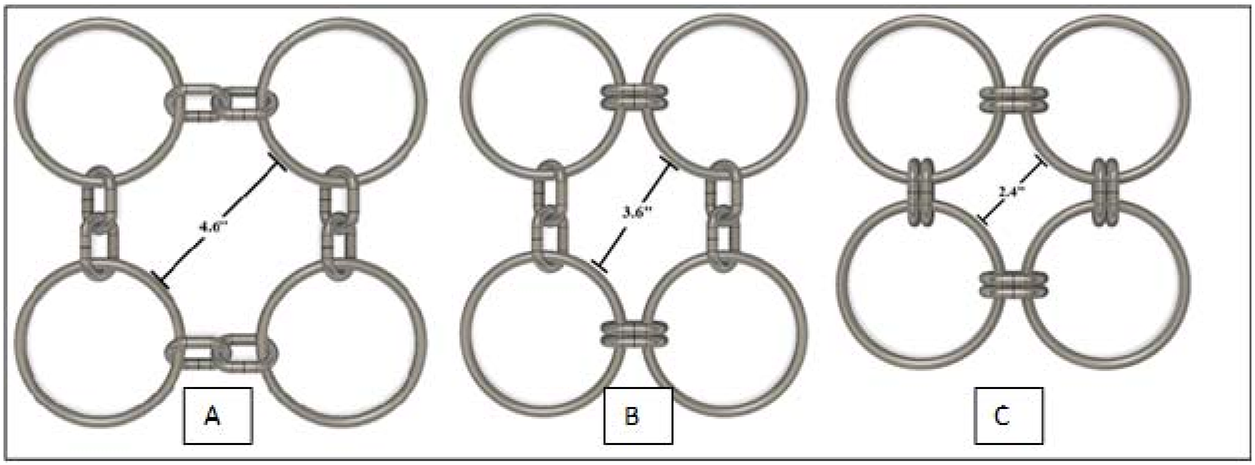

Figure 1: A comparison of the extended link aprons to a standard apron.

Starting in 2015, CFF began developing extended link aprons in response to overlapping densities of small sea scallops and larger, more desirable sea scallops in the Mid-Atlantic region (**Figure 1**; Davis et al. 2017; Davis et al. 2018). Using two connected links (extended links) increases the inter-ring spacing of the dredge and is hypothesized to improve the sorting efficiency of the apron (Davis et al. 2017; Davis et al. 2018). Initially, a more radical apron design was tested, with extended links incorporated in horizontal and vertical directions to create the two-way extended link apron (**Figure 1A**; Davis et al. 2017). Testing of the two-way extended link apron was done exclusively in the Mid-Atlantic region, in areas where both high densities of small and large scallops overlapped (Davis et al. 2017). Four trips compared the two-way extended link apron to control dredges with standard aprons, and the modification improved relative sea scallop catch efficiency with increasing shell height; however there was still a significant reduction of total sea scallop catch with this gear (Davis et. al 2017). In addition to using a traditional gear comparison, we also conducted a fifth trip using a lined survey dredge to further evaluate the hypothesis that an extended link apron improves sea scallop selection (Davis et al. 2017). The two-way extended link apron was found to have a higher L50 and broader selection range (L75 – L25) than a standard dredge apron (Davis et al. 2017). These findings validated our hypothesis that extended links alter the retention properties of the dredge apron, but the significant reduction in sea scallop catch (~20 %) meant that the two-way extended link apron was not a viable management solution.

The 2015/2016 testing of two-way extended links indicated we were on the right track for developing a dredge apron with improved selection, but the design needed to be less extreme (Davis et al. 2017; Davis et al. 2018). A new design, with extended links only in the vertical direction (one-way extended link apron), was chosen and tested in 2016/2017 (**Figure 1B**) (Davis et al. 2018). Pooled trip results demonstrated that this configuration marginally reduced sea scallop catch (~4%) and that a majority of this loss was sea scallops smaller than 75 mm (Davis et al. 2018). However, individual trip analysis found that the impact of the one-way extended link apron on sea scallop catches varied between vessels with no consistent trend in the predicted sea scallop length-based efficiency (Davis et al. 2018). The location of testing and sea scallop densities observed during each trip may account for some of the differences between trips. The one-way extended link apron appeared to have greater sorting efficiency at high sea scallop densities (Davis 2019).

The one-way extended link apron was also investigated for its bycatch-reduction capabilities (Davis et al 2017). The bycatch of yellowtail flounder and windowpane flounder (*Scopthalmus aquosus*) is a continuous concern for the sea scallop fishery. It was hypothesized that increasing the inter-ring spacing might also improve the escapement of these species (Davis et al. 2017). During field trials of the one-way extended link apron, there was an observed reduction in catch of most species despite low bycatch rates overall (Davis et al. 2017). Windowpane flounder and unclassified skates were the only species with a sufficient pooled sample size to determine if the observed reduction was significant (**Table 1**; Davis et al. 2017).

Table 1: Results from the 2017 project testing the extended link apron (Davis et al. 2017)

Species	Extended Link Dredge	Control Dredge	Percent Difference	Model Estimate	Significance
Uncl. Skates	19,253	21,761	-11.53%	-11.46%	**YES**
Barndoor Skate	197	159	23.90%	34.16%	NO
Summer Flounder	107	122	-12.30%	-12.29%	NO
Fourspot Flounder	141	151	-6.62%	-10.32%	NO
Yellowtail Flounder	46	66	-30.30%	-30.30%	NO
Windowpane Flounder	2,003	2,861	-29.99%	-34.47%	**YES**
Monkfish	933	996	-6.33%	-7.82%	NO

A new approach was required to understand more precisely how an extended link apron affects the retention of sea scallops and facilitates the escapement of flatfish. To accomplish this, development of a cover net to retain fish and scallops that pass through the top of the dredge bag started in late 2016 (Davis et al. 2016). Our first net was built to be non-selective using 45-mm (inside opening) diamond-mesh netting. We designed the net to retain fish and scallops that would have passed through the top portion of the dredge bag (apron, twine top, skirt, and sides). It extended the full length and width of the dredge bag, from the headbale to the clubstick and over both sidepieces. A pilot trip tested the net in both open access area and the Nantucket Lightship Access Area, and the covered dredge was fished using commercially representative tow parameters. Use of video to observe the gear in situ and analysis of catch data suggested that a cover net is a suitable tool for evaluating the retention properties of non-target species in sea scallop dredges and how modifications to the top of the dredge influence those properties.

One of the most surprising findings from this pilot trip was how many animals appear to be passing through the top of the dredge (**Table 2**). Over 70% of the windowpane flounder and skate catch was retained in the cover net, and therefore passed through the dredge bag at some point during the tow. Assuming that the sum of the catch in the dredge bag and the cover net is a conservative estimate of the biomass in the dredge tow path (conservative because it does not account for animals in the dredge path that avoid the dredge), we estimated the upper bound of dredge efficiency for windowpane flounder was 0.17 ± 0.13 (average ± standard deviation). The SELECT model (Millar 1992) for estimating gear selectivity was also used to estimate a windowpane flounder 50% retention size of L50 = 23.36 cm in the dredge bag. Given the observed potential of this tool, we decided to develop a durable cover net to assess the escapement of non-target species.

Table 2: Results from testing the first dredge cover net in 2016.

Species	Dredge	Codend	N	n_{Dredge}/N
Unclassified Skates	465	1137	1602	0.710
Windowpane Flounder	62	393	455	0.864
Sea Scallop (Baskets)	36	17	53	0.321

Objectives

The project objectives included:

(1) Develop a durable small mesh dredge cover net and standardized protocols for its application in gear research.

(2) Demonstrate the application of a small mesh cover for assessing the escapement of sea scallops and non-target species from standard and one-way extended link apron.

Methods by Objective

Develop a Durable and Easy-to-Operate Small Mesh Dredge Cover Net

To design a durable and easy-to-operate small mesh dredge cover net, CFF worked in close collaboration with Reidar's Manufacturing Inc. and our fishing industry collaborators. In order to ensure a progressive development of the cover net, criteria for durability and ease of handling were developed in collaboration with our collaborators. The criteria for durability and ease of handling were:

(1) The net must be able to withstand **at least ten sequential valid tows** before requiring significant repairs or becoming compromised.

(2) Setting, towing, and hauling a covered dredge should be as representative of commercial fishing practices as possible.

(3) Handling and operating the net must be safe, repeatable, and transferable across different commercial vessels.

Upon designing and building each net prototype, testing was carried out aboard one of our industry collaborator's vessel. Following each research cruise, a meeting was held to evaluate the performance of the cover net, and if it failed to meet the criteria, we discarded the design and a new design was created based on observations from the trip and collaborator input. Out final cover net design, which satisfied all the criteria, was used to assess the retention of sea scallops and the escapement of non-target species.

<u>Demonstrate the Application of a Small Mesh Cover</u>

All cover net testing was done aboard Limited Access (LA) scallop vessels capable of towing two dredges simultaneously. The first four research trips paired an uncovered a standard linked apron (the control dredge) with a covered control dredge to assess how the cover net effects dredge performance. Both dredges were supplied by our industry collaborators, and the only modification was the addition of the cover net. During the final research trip, a dredge with a standard apron was compared to a dredge with an extended link apron. Both of these dredges were fitted with a cover net but an alternate paired-tow method was chosen because it is not feasible to simultaneously tow both covered dredges. Tow parameter and data collection was standardized for each trip; however tow time was shortened from 15 minutes to 10 minutes for the fourth and fifth trips to reduce the likelihood of overfilling the net.

The tow started when the winch was locked, and the dredge was fished for a target duration of 10 or 15 minutes before being hauled back. If tow parameters were not followed or if the gear malfunctioned (e.g. dredges fished upside down), the tow was declared invalid and a new tow was initiated. Vessel speed, heading, and position during the tow was recorded for each tow using GPS recorded directly from the vessel or by an external GPS unit. An average depth and a Beaufort number (a semi-quantitative measure of sea and wind conditions) was also recorded for each tow.

Bringing the codend aboard the vessel required the greatest deviation from normal dredge handling practices. If not done properly, the dredge bag and codend samples become mixed, resulting in an invalid tow. The dredge or dredges were brought aboard before the codend to ensure that the loss of catch at the side of the vessel was minimized. First, the cargo hook from the opposite side of the boat was used to pull the covered dredge to the middle of the deck. With the frame in the middle of the deck, the second cargo hook was attached to the bull rope and the codend was lifted on board. When the codend was not very full or was light, it was maneuvered by hand towards the stern of the vessel and dumped. To manipulate a heavier codend, a snatch block was required. The snatch block was rigged near the top of the gallus frame where the stay wires attach, and a 5 to 10 m rope with an eye splice at either end was looped around the codend and placed in the snatch block. This allowed the codend to be maneuvered towards the stern with the cargo hook from the opposite side of the boat. Once in position, away from the dredge bag, the codend was dumped for sorting. As the last step, the contents of the dredge bag was emptied using routine commercial practices.

Scallops, commercially important finfish species, and lobsters were sorted, counted, and measured following each tow. Scallop catch, for the control dredge bag, experimental dredge bag, and cover-net codend were evaluated by the number of baskets, the number of scallops within a single basket subsample, and total unshucked scallop basket weight to the nearest 0.2 kilograms. Scallops within the single basket subsample were measured in 5-mm increments. Bycatch species were individually measured to the nearest centimeter, and finfish bycatch weights were measured to the nearest 0.01 kilogram.

Data collected from each tow included:

- Scallop catch rates (bushel(s)/tow/gear)
- Scallop catch weight (sum of bushel(s) weight/tow/gear)
- Scallop shell height frequency (one bushel/tow/gear)
- Finfish catch rates (# of individuals/tow/gear)
- Finfish weight (species weight/tow/gear)
- Finfish and invertebrate length frequency (by species and species groups (i.e. controlled groundfish species, other groundfish species, pelagic species, and shellfish))
- Skate catch rates (# of individuals/tow/gear)
- Skate weight (total weight/tow/gear)
- Weight, volume, and composition assessment of trash (i.e. sea star and crab species)

Detailed dredge cover net deployment and sampling protocols can be found in Appendix XX.

<u>Data Analysis</u>

To estimate the retention properties, the catch-at-length data for each tow were analyzed with the SELECT model (Millar 1992; Yochum and DuPaul 2008).This model defines the proportion of an animal of length *l* that is caught in the uncovered dredge out of the total catch from both dredges ($\Phi_c(l)$) as:

$$\Phi_c(l) = \frac{p_c r_c(l)}{p_c r_c(l) + (1 - p_c)}$$

The probability that an animal of length *l* contacts the uncovered dredge is $r_c(l)$ and a split-parameter, p_c, describes the relative efficiency of the uncovered dredge. For most species selectivity tends to reflect a logistic function which equates to:

$$\mathrm{r}_c\,(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)}$$

For some species a Richard curve provided a better fit to the data (Tokai et al. 1995):

$$\mathrm{r}_c\,(l) = \left\{\frac{\exp(a+bl)}{1+\exp(a+bl)}\right\}^{\frac{1}{\delta}}$$

When substituted into the SELECT model it yields:

$$\Phi_c\,(l) = \frac{p_c \exp(a+bl)}{(1-p_c)+\exp(a+bl)}$$

Estimates for a and b (the logistic parameters) and the split-parameter p_c were generated by maximizing the likelihood:

$$L(a,b,pc|data) = \prod_{l=22}^{167}\left(\frac{p_c \exp(a+bl)}{(1-p_c)+\exp(a+bl)}\right)^{C_{cov}}\left(\frac{p_c \exp(a+bl)}{(1-p_c)+\exp(a+bl)}\right)^{C_{ctrl}}$$

C_{cov} is the number of length l animals in the covered dredge and C_s is number of length l animals in uncovered dredge. The selection parameters L50 and the selection range (SR) are calculated with the following equations:

$$L50 = \frac{-a}{b} \text{ and } SR = \frac{2\ln(3)}{b}$$

Uncontrollable factors like wind speed, sea state, animal density etc. result in variation in selectivity from tow to tow. To determine if the variation is exceeding the model predictions (overdisperion) a test is necessary when combining tows. This can be done using the replication estimate of between-haul variation (REP) combined-hauls approach (Millar et al. 2004). REP is the Pearson chi-square statistic for model goodness of fit divided by the degrees of freedom, the number of terms in summation minus the number of fitted parameters. The REP provides an estimate of overdispersion and the standard errors of the parameters are multiplied by the square root of REP if the null hypothesis that there is no extra variation is rejected (Millar et al. 2004). This approach has been used to estimate selectivity parameters of commercial sea scallop dredges paired with lined survey dredges (Yochum and DuPaul 2008).

The R-Statistical Program was used to evaluate the data (R Core Team 2015). The "trawlfunction" package was used to estimate the selectivity coefficients and parameters (Millar 2009).

Project management and participation

Project management: Farrell Davis
Data Collection and Management: Farrell Davis
Statistical Analysis: Farrell Davis
Technical Support: Liese Siemann, Ronald Smolowitz, and Ricky Alexander

Results

Five LA vessels conducted research trips to develop and test the cover net. It took three design iterations before we developed a net that that satisfied the criteria of (1) durability, (2) representative of commercial fishing, and (3) easy and safe to operate. All versions of the net were built with 45-mm (inside opening) mesh. To assess the cover net's transferability or its ability to be applied fleet wide, our industry collaborators provided both dredges used for each research trip. We were able to use same method with ½" shackles to attach the cover net to each of the dredge bag variants, and none of the dredge bags required modifications to accommodate the cover net. Initially, a standardized tow time of 15 minutes was used during the first three trips, but a 10-minute tow time was adopted for the fourth and fifth trips to reduce the likelihood of overfilling the net. We tested the final version of the cover net extensively during the fourth research trip and used it during the fifth trip focusing on the extended link apron. Data from the fourth and fifth trips were analyzed using the SELECT model, while data from the first three trips are presented only in summary tables (**Tables 3-5**).

F/V Diligence – Design #1

The first design iteration was tested from 11/28 – 11/30/2019 off of Provincetown, MA (42º 09' N and 70º 05' W) in an area where fisheries independent surveys and commercial fishermen identified as a hotspot for small (< 20 cm) yellowtail flounder. Sampling of any kind was not possible during the first day of the trip due to severe sea conditions. Once the seas subsided, two valid 15-minute tows were completed using commercially representative tow parameters before the structural integrity of the net was compromised. After a post-trip evaluation of the net design, it was rejected for failing to meet the criteria of durability and safe and easy to operate. An inspection of the gear showed that a majority of the damage was done to the belly panel of the net. The addition of chaffing gear to protect the belly was suggested to increase the durability of the net. This trip also highlighted the need to shorten the length of the net. An initial concern when designing the net was that if it was too short, catch in the codend could spill back into the dredge bag. However, having a net that was too long made bringing the codend aboard difficult and unsafe in inclement weather. The overall lack of tows was a disappointment, but a summary of the data highlighted that many more yellowtail flounder were passing through the top of the dredge than being retained (**Table 3**).

Table 3: A summary of the results from the first cover net trip aboard the F/V Diligence.

	F/V Diligence											
	Control Dredge				*Covered Dredge*				*Codend*			
	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.
FOURSPOT FLOUNDER	0	0.00	0.00	0.00	0	0	0	0	7	3.5	0.7071	0.5
MONKFISH	0	0.00	0.00	0.0	3	1.5	0.7071	0.5	13	6.5	0.7071	0.5
SEA SCALLOP (RETAINED)	201	201.00			249	249			34	34		
WINDOWPANE FLOUNDER	19	9.50	13.44	180.50	10	5	2.8284	8	20	10	1.4142	2
WINTER FLOUNDER	1	0.50	0.71	1	3	1.5	0.7071	1	31	15.5	10.607	112.5
YELLOWTAIL FLOUNDER	3	1.50	0.71	0.50	8	4	2.8284	8	213	106.5	36.062	1300.5

F/V Concordia – Design #2

Following the first research trip, we built a second shorter cover net with large mesh chaffing gear on the belly panel of the net. Testing of this design took place in the same area as the previous trip from 12/12 – 12/14/2018. Six commercially representative tows were completed, five of which were valid. On the seventh tow, the net snagged the bottom and when it was retrieved, the entire codend was missing. Although this net was significantly easier and safer to operate than the previous net, this design was rejected due to its inability to fulfill the criteria of durability. The captain of the vessel suggested that the addition of a reinforcing rope to the gore seam of the net would both make the net more durable and easier to repair when a panel is damaged. It was also suggested that further shortening the net would reduce the time it takes to bring the codend aboard. Analysis of tow data demonstrated that this cover net was still effectively retaining fish escaping from the dredge (**Table 4**).

Table 4: A summary of the results from the second cover net trip aboard the F/V Concordia.

	F/V Concordia											
	Control Dredge				*Covered Dredge*				*Codend*			
	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.
FOURSPOT FLOUNDER	0	0.00	0.00	0.00	0	0	0	0	6	1.5	0.5774	0.3333
MONKFISH	0	0.00	0.00	0.0	1	0.25	0.5	0.25	6	1.5	0.5774	0.3333
SEA SCALLOP (RETAINED)	187	46.75	14.93	222.92	104	26	22.906	524.67	30	7.5	9.9833	99.667
WINDOWPANE FLOUNDER	61	12.20	6.22	38.70	32	6.4	5.5045	30.3	55	11	13.874	192.5
WINTER FLOUNDER	2	0.40	0.55	0	5	1	1.2247	2	38	7.6	9.0719	82.3
YELLOWTAIL FLOUNDER	43	8.60	11.35	128.80	14	2.8	5.1672	26.7	363	72.6	32.944	1085.3

F/V Incentive – Design #3

The third design of the net incorporated the suggestions of our industry collaborators from the previous trip. The gore seams were reinforced with 5/8" polysteel rope, additional chaffing gear was added to the codend, and the net was further shortened. We also decided to add a trip line along the bottom portion of the cover net. When pulled, the belly of the net separates from the bottom of the dredge and large codend catches can be easily dumped by lifting the codend. We tested this design in the spring of 2019 (4/6 – 4/8/2019) in the same area off of Provincetown, MA as the previous trips. Only three valid tows were completed before the entire net was lost. **Table 5** summarizes the results from this trip.

Table 5: A summary of the results from the third cover net trip aboard the F/V Incentive.

	F/V Incentive											
	Control Dredge				*Covered Dredge*				*Codend*			
	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.
MONKFISH	0	0.00			1	1			0	0		
SEA SCALLOP (RETAINED)	357	178.50	252.44	63724.5	349	174.5	70.004	4900.5	55	27.5	19.092	364.5
WINDOWPANE FLOUNDER	3	1.00	0.00	0.00	1	0.3333	0.5774	0.3333	0	0	0	0
WINTER FLOUNDER	2	0.67	1.15	1.33	5	1.6667	1.1547	1.3333	94	31.333	14.468	209.33
YELLOWTAIL FLOUNDER	2	0.67	0.58	0	10	3.3333	2.5166	6	273	91	29.816	889

Two factors were believed to have contributed to the catastrophic failure of this cover net design. First, during the second day the rope holding the codend closed got caught in the vessel's wheel when setting the dredge. This caused an extensive but repairable tear in area of the net attached to the bottom of the dredge, weakening the overall integrity of the net. The second factor was excessive catches of sand dollars in the cover net. During the final tow, the vessel started to slow down and turn toward the side with the covered dredge, indicating the cover dredge had become full. When it came time to haul the dredges back to the vessel, the cover net had accumulated so much material that the vessel was unable to lift the dredge off the seafloor. Eventually, the weakest point of the cover net gave out and the dredge was retrieved. Only the headrope and framing used to attach the cover net to the dredge bag remained, further validating our hypothesis that the cover had become overfilled.

F/V Edgartown – Final Design

Due to the setbacks from the previous trips, emphasis was placed on developing a cover net that increased durability for the fourth trip. After a final design meeting with the net builders, we increased the size of the rope reinforcing the seams of the net to 3/4" polysteel rope and added a blowout panel into the belly portion of the net. Previous net designs had not considered the possibility of the cover net overfilling, and the net needed to be modified to account for this. Light twine or zip ties were used to hold the panel closed. With this design, when the weight of material in cover net exceeds the breaking strength of the twine or zip ties, the panel opens up and dumps the contents upon haulback. While a tow that triggers the blowout panel would be declared invalid, the ability to avoid loss of the cover net and continue sampling outweighs the loss of a tow. Having confidence in this design, we decided to build two cover nets so that a spare net was available during the final research trip. A schematic of the final cover net design can be found in **Appendix A**.

The final design of the cover net fulfilled the three design criteria of 1) durable, 2) representative of commercial fishing, and 3) safe and easy to handle. Thirty-eight valid tow pairs were completed from 5/12 – 5/18/2019, with testing started in the area where the previous trips occurred and moved to other fishing grounds on Georges Bank and Southern New England (**Figure 2**). Due to the success of this trip, further analysis of the data were carried out to determine if the covered dredge was fishing similar to the control dredge. **Table 6** provides a summary of the catch data from this trip.

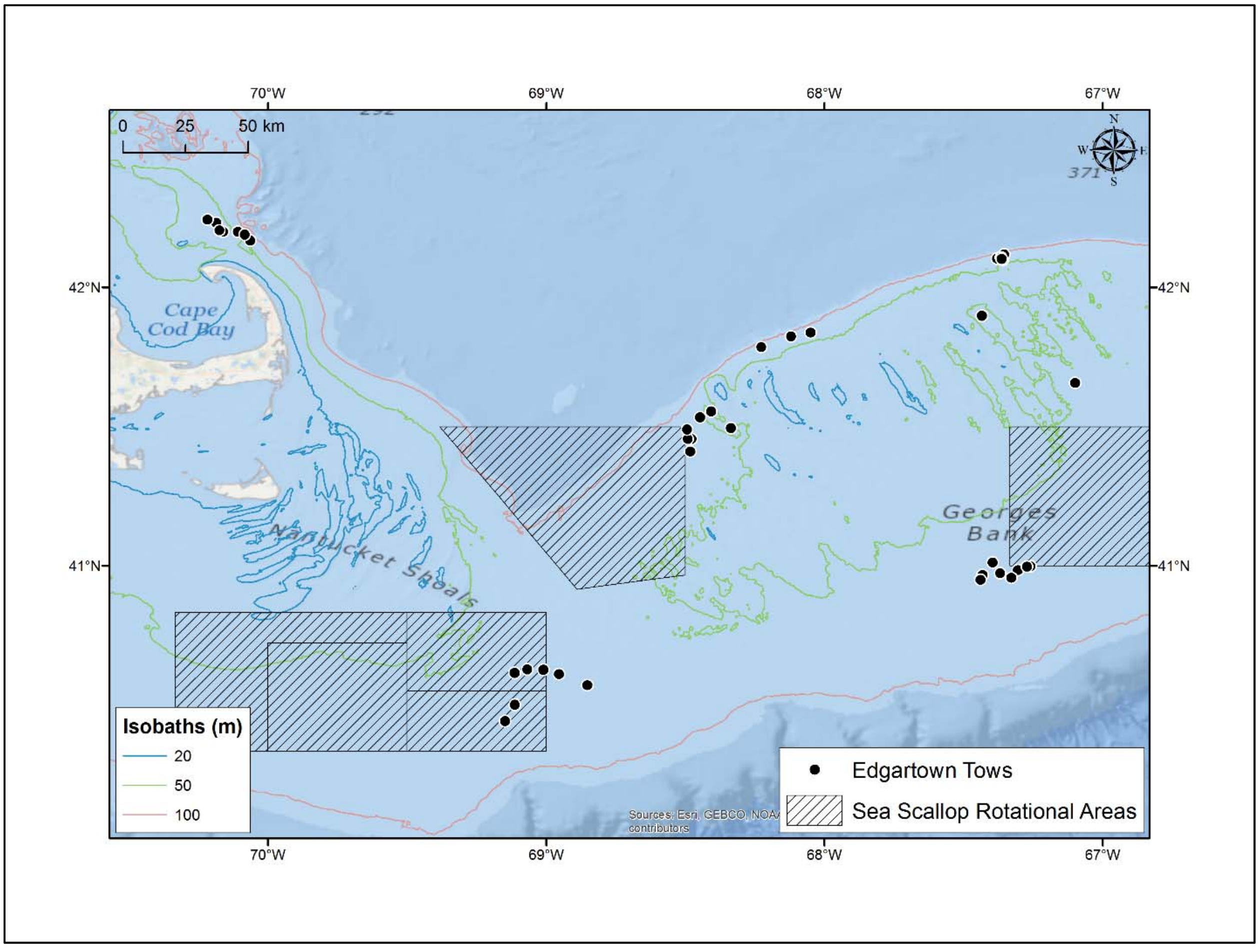

Figure 2: A map of the tow locations from the fourth research trip.

Table 6: A summary of the catch from the fourth research trip aboard the F/V Edgartown.

	F/V Edgartown											
	Control Dredge				*Covered Dredge*				*Codend*			
	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.	N	Mean	St. Dev.	Var.
AMERICAN PLAICE	25	1.00	1.15	1.33	33	1.32	1.1804	1.3933	95	3.8	3.4881	12.167
BARNDOOR SKATE	93	3.58	5.42	29.4	109	4.1923	6.5849	43.362	76	2.9231	5.8851	34.634
FOURSPOT FLOUNDER	5	0.28	0.57	0.33	4	0.2222	0.4278	0.183	56	3.1111	3.7241	13.869
MONKFISH	75	2.34	3.67	13.46	102	3.1875	3.9303	15.448	51	1.5938	2.9823	8.8942
SEA SCALLOP (RETAINED)	8631	308.25	643.16	413660	9576	342	698.46	487851	5499	196.39	500.12	250116
WINDOWPANE FLOUNDER	107	4.86	11.02	121.46	108	4.9091	10.023	100.47	84	3.8182	5.404	29.203
WINTER FLOUNDER	1	0.17	0.41	0.17	1	0.1667	0.4082	0.1667	10	1.6667	1.2111	1.4667
WITCH FLOUNDER	10	0.91	0.94	0.89	18	1.6364	2.2923	5.2545	7	0.6364	1.206	1.4545
YELLOWTAIL FLOUNDER	7	0.33	0.73	0.53	17	0.8095	1.6619	2.7619	287	13.667	20.173	406.93

Sea Scallop Selectivity Analysis

Analysis of the sea scallop catch was only done for tows where the total combined scallop catch of all three gears was greater than twenty scallops (n = 33). A comparison of the total sea scallop catches in the control dredge and the covered dredge indicates that the covered dredge is not impacting the overall efficiency of the dredge ($p = 0.7843$; **Table 7 and Figure 3**). However, when comparing the size frequencies and proportions of the sea scallop catch-at-length, it appeared that the covered dredge was catching more scallops <102 mm (**Figure 4**). A paired t-test was used to determine the significance of this observation (**Table 7**). By plotting the proportion of scallops in each length class in the control dredge (Control/Total), we determined that the control gear was behaving selectively, validating proceeding with an analysis of selective properties of the dredge.

Table 7: A comparison of the proportion per size class retained in each dredge bag. Significance was determined using a paired t-test.

Shell Height	Control Dredge (n_{Ctrl})	Covered Dredge (n_{Cov})	N	Control n_{Ctrl}/N	Covered n_{Cov}/N	difference	df	p-value
< 107 mm	2984	3745	6729	0.443	0.557	-0.113	33	0.280
107-127 mm	3152	2752	5904	0.534	0.466	0.068	33	0.286
> 127 mm	5202	5363	10565	0.492	0.508	-0.015	33	0.671
Total Catch	11338	11860	23198	0.48874903	0.51125097	-0.0225	33	0.7843

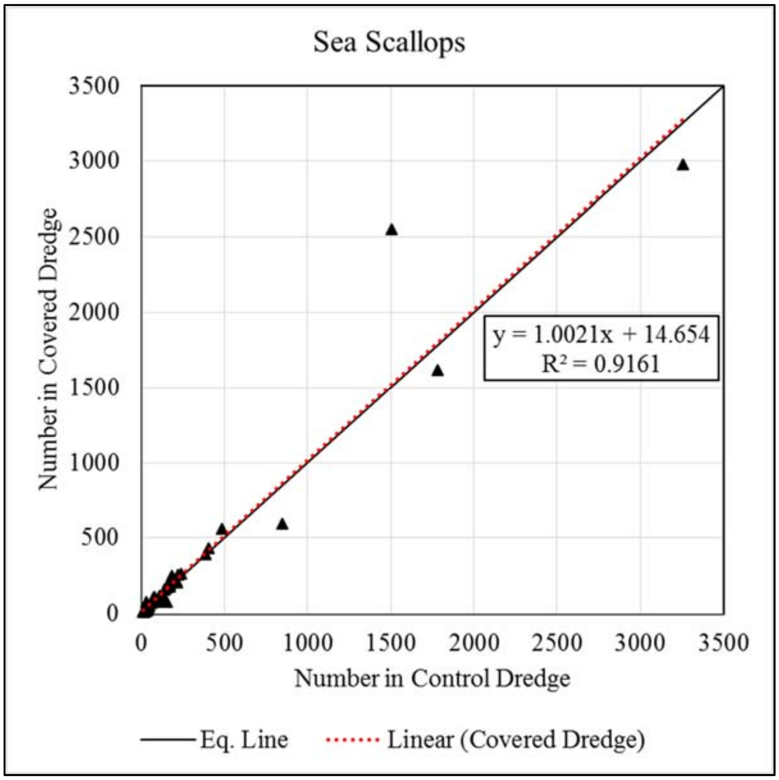

Figure 3: A comparison of the total sea scallop catches of the control and covered dredge.

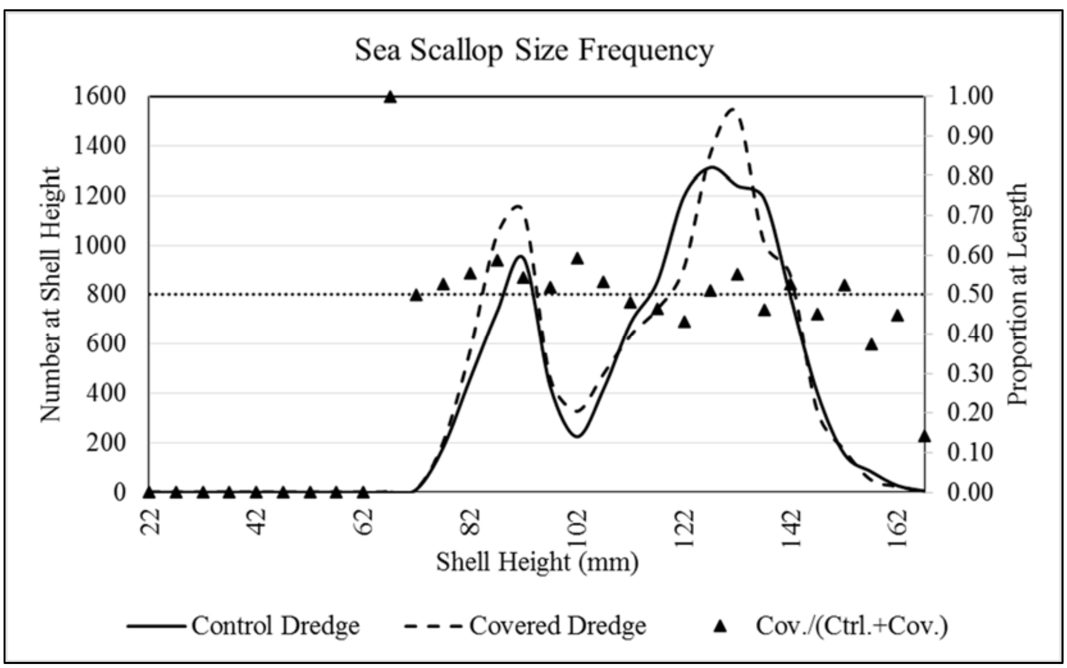

Figure 4: The length frequency distribution of sea scallops in the control and covered dredge bags. Proportion of the catch-at-length is plotted for the covered dredge.

The catch-at-length data for each tow was analyzed with the trouser trawl SELECT model (Millar 1992). For this analysis, the catch-at-length data for the control dredge were compared to catch-at-length data for the covered dredge (bag + codend). The covered dredge is assumed to be nonselective, retaining a sample that is representative of the sea scallop population available to the gear. We estimated the L50 for a standard dredge apron to be 103.11 mm with an SR of 28.86 mm (**Table 8 and Figure 5**). The model-estimated split parameter *p* was 0.53 ± 0.03, indicating that the uncovered dredge was fishing with a slightly higher efficiency. Since the width of both the covered and control dredges was the same, the split parameter would have been 0.5 if the two gears were fishing equivalently. We also generated a retention curve for sea scallops using the cover SELECT model (Millar 1992; Tokai et al. 1995). Unlike the trouser trawl model, this model compares the catch-at-length data for the dredge bag to the codend data. The predicted the L50 for the covered portion of the dredge bag to be 95.43 mm with a SR of 23.72 mm using this method (**Table 8 and Figure 5**).

Table 8: The estimated sea scallop retention parameters from the trouser trawl and codend cover models.

	Trouser Trawl Model		Cover Model	
	Estimate	*S.E.*	*Estimate*	*S.E.*
L25 =	88.68	2.46	83.57	0.26
L50 =	103.11	4.11	95.43	0.20
L75 =	117.54	6.18	107.29	0.27
SR =	28.86	4.57	23.72	0.36
Split parameter *p* =	0.53	0.03	N/A	N/A
REP	6.888		N/A	N/A

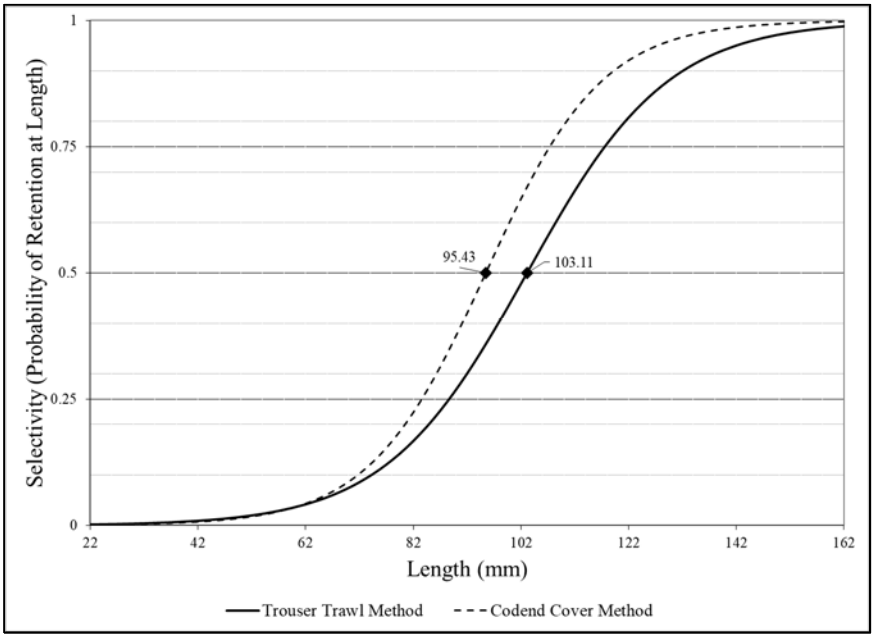

Figure 5: The sea scallop selectivity curves as generated by the trouser trawl and codend cover models.

Fish Selectivity Analysis

We plotted the proportion of fish in each length class in the control dredge, to determine if the control gear was behaving selectively for each species. For many species, there were too few observations in either the control or covered dredge bags to conduct a trouser trawl or cover selectivity analysis. The cover method (Millar 1992; Tokai et al. 1995) was used to analyze the pooled covered dredge catch-at-length data for yellowtail, windowpane, American plaice (*Hippoglossoides platessoides*), and barndoor skate (*Dipturus laevis*). A logistic curve provided the best fit for all species except barndoor skate, which was fit best using a Richard curve. Retention parameters for each species can be found in **Table 9** and the each species curve in **Figure 6**.

Table 9: The estimated selection curve coefficients and parameters for the four species analyzed.

	American Plaice		Barndoor Skate		Windowpane		Yellowtail	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
a =	-12.00		-7.70		-9.47		-5.51	
b =	0.34		0.25		0.42		0.13	
δ =	N/A		0.91		N/A		N/A	
L25 =	31.84	0.84	26.99	1.36	20.06	0.78	32.81	3.87
L50 =	35.05	0.85	31.22	1.24	22.69	0.44	40.99	6.09
L75 =	38.26	1.21	35.52	1.05	25.33	0.52	49.17	8.42
SR =	6.42	1.22	8.53	1.26	5.27	0.99	16.36	4.84

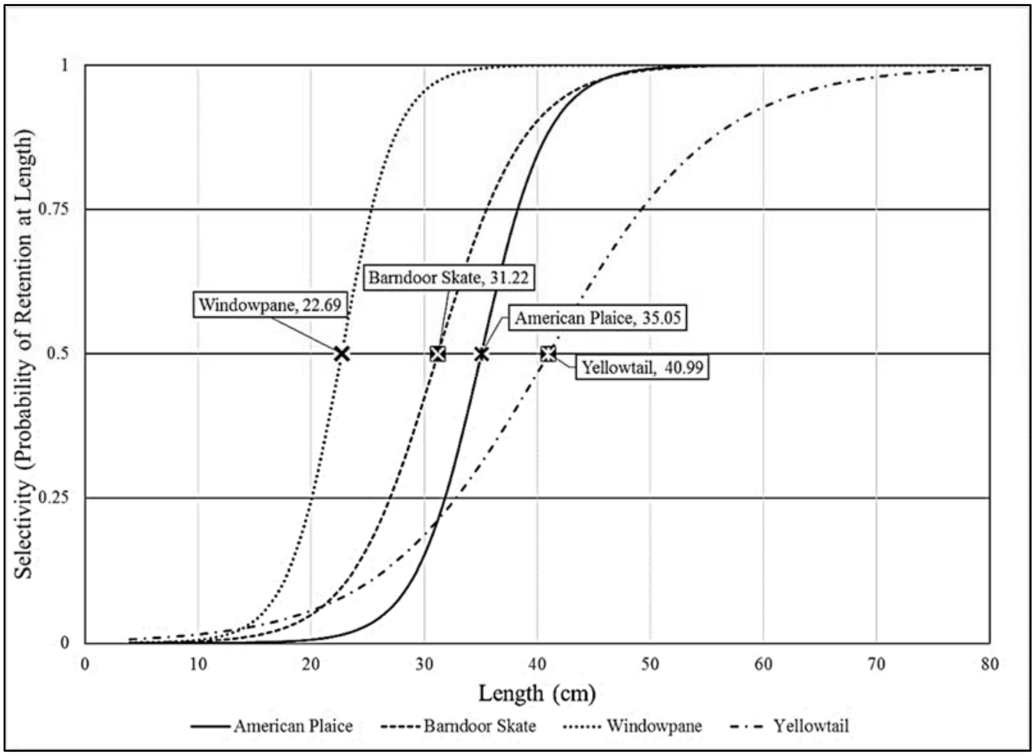

Figure 6: The selectivity curves of the four analyzed species.

Extended Link Analysis

A final research trip for this project took place from 6/17-6/19/2019. Unlike the previous trips, two covered dredges were used: one with a control apron and one with an extended link apron. Using an alternating paired towed design, six tows or three gear pairs were completed. Selectivity parameter estimates and curves for sea scallops and combined flatfish (American plaice, Yellowtail flounder, and Witch flounder (*Glyptocephalus cynoglossus*)) of both the control apron and extended link apron dredges were generated and compared (**Table 10 and Figures 7-8**). A comparison of the curves demonstrates that the extended link apron has different retention properties (a higher L50 and broader SR) than the standard apron (**Table 10 and Figures 7-8**).

Table 10: A comparison of the estimated selection curve coefficients and parameters for flatfish and sea scallops caught in control apron and extended link apron.

	Flatfish				**Sea Scallops**			
	Control		Extended Link		Control Apron		Extended Link	
	Estimate	*S.E.*	*Estimate*	*S.E.*	*Estimate*	*S.E.*	*Estimate*	*S.E.*
a =	-15.89		-10.18		-8.93		-6.77	
b =	0.43		0.25		0.10		0.07	
L25 =	34.55	0.84	36.48	0.84	77.13	6.75	83.61	6.29
L50 =	37.11	0.85	40.89	0.85	87.94	5.42	99.80	4.13
L75 =	39.68	1.21	45.31	1.21	98.76	4.37	115.99	2.71
SR =	5.13	1.22	5.13	1.22	21.63	3.47	32.38	5.05

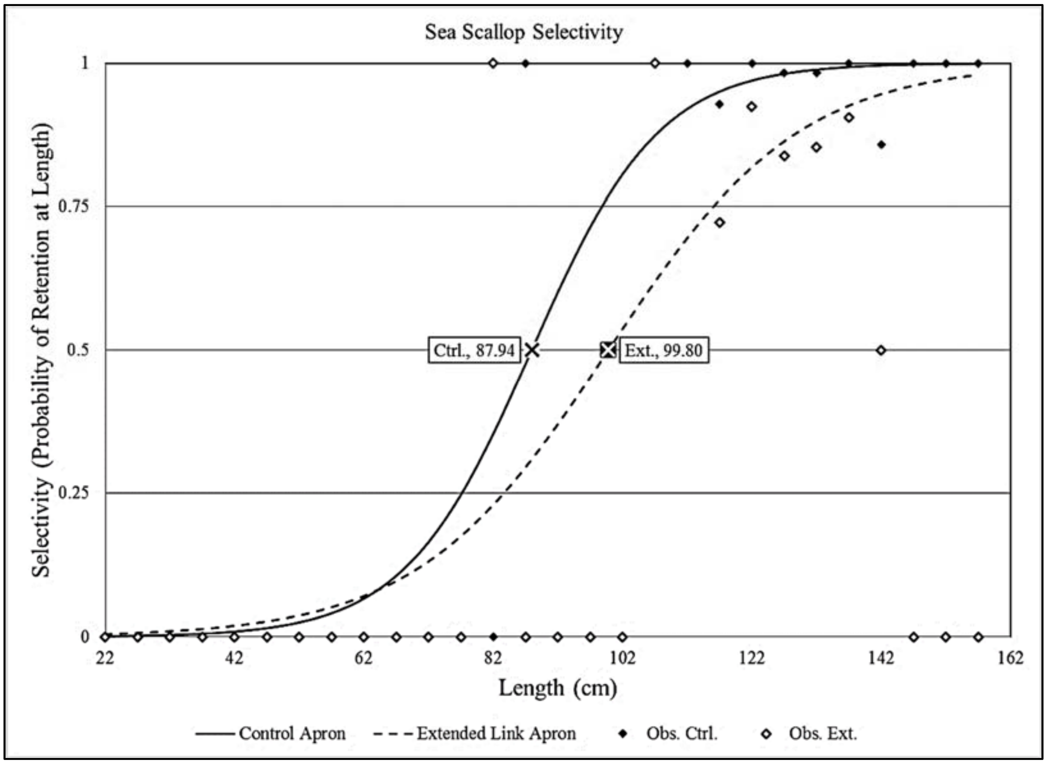

Figure 7: The sea scallop selectivity curves for the control and extended link aprons.

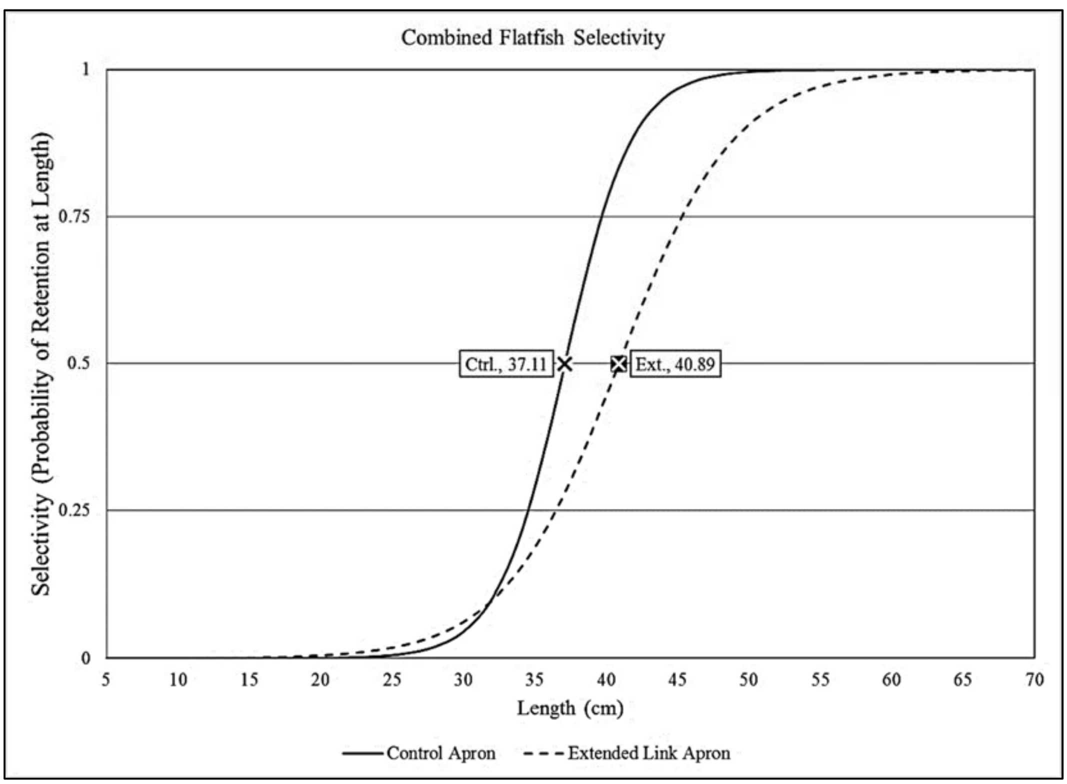

Figure 8: The flatfish selectivity for the control and extended link aprons.

Evaluation

Accomplishments by objective

All objectives were accomplished with few modifications. Accomplishments by objective are described below.

(1) Develop a durable small mesh dredge cover net and standardized protocols for its application in gear research.

Developing the cover net was more challenging than anticipated, but nonetheless we were still able to accomplish this objective by designing a net that met the design criteria of 1) durability, 2) commercially representative of fishing, and 3) easy to handle and safe to operate. Three iterative cover designs were tested aboard collaborating LA vessels before we were able to create a net that satisfied the design criteria. Feedback and input from our industry collaborators proved to be essential in the development of the cover net itself as well as protocols for its deployment aboard sea scallop vessels. The final cover net design plans and protocols for its use aboard commercial sea scallop vessels can be found in **Appendix A**.

(2) Demonstrate the application of a smell mesh cover for assessing the escapement of sea scallops and non-target species from a standard and a one-way extended link apron.

We fulfilled the proposed objective of demonstrating the application of small mesh covers for the development of dredge modifications. Once the first objective of designing, building, and testing of durable cover net was met, focus shifted toward its application as a tool for assessing the retention properties of a standard apron and an extended link apron. During the fourth trip aboard the F/V Edgartown, we were able to collect data from 38 valid tow pairs, and analysis of the data showed that the sea scallop catches in the cover net were similar to uncovered dredge ($p = 0.7843$; **Table 6**). With the data from this fourth trip, we used a standard statistical approach to assess the retention properties of the top portion of the control dredge bag (**Tables 7-8 and Figures 5-6**). A fifth trip then used an alternate paired-tow method to compare the retention properties of the one-way extended link apron (**Table 9 and Figures 7-8**).

Discussion

Our results demonstrate that a durable and easy-to-handle small mesh cover net can be used to assess the sea scallop and bycatch species retention properties of sea scallop dredges at commercially representative tow speeds. Our estimated commercial sea scallop retention parameters (L50 and SR) and coefficients (a and b) are comparable to published estimates and those used in sea scallop stock assessments (**Table 11**; Yochum and DuPaul 2008; SAW 2018). The estimated split-parameter $p = 0.53$ is greater than the expected value of 0.5, indicating that the control dredge was fishing slightly more efficiently than the covered dredge. However, the differences between the estimated and the expected split-parameter from lined dredge studies is much higher, suggesting there is a greater difference in the relative efficiencies between a commercial dredge and the lined dredge. The bulldozing effect may be one explanation for this greater difference (Serchuk and Smolowitz 1980; NEFSC 2004; Yochum and DuPaul 2008). A covered dredge is not susceptible to bulldozing (Millar and Naidu 1991), and based on the results from this project, we are confident in the application of a dredge cover net for assessing modifications to the top of the dredge bag.

Table 11: A comparison of the estimated sea scallop selection curve coefficients and parameters generated from this study and published commercial dredge parameters.

	Trouser Trawl Model	Cover Model	Yochum & DuPaul 2008 (All Areas)	2018 SAW (MAB Turtle Dredge)
L50	103.11	95.43	100.11	98.15
S.R.	28.86	23.72	23.61	28.19
a =	-7.85	-8.84	-9.32	-0.76
b =	0.08	0.09	0.09	0.08
Split parameter p =	0.53	N/A	0.77	0.83
REP	6.888	N/A	7.98	34.749

With the exception of a minimum ring size, sea scallop dredge regulations implemented since 2004 have been designed to reduce the impact of sea scalloping on non-target and protected species (**Figure 9**). A majority of the regulations to reduce bycatch require modifications to the twine top and dredge apron, specifically 10" minimum mesh size (50 CFR Part §648.51(b)(2)), the windowpane flounder Reactive Accountability Measure (50 CFR Part §648.65(b)(3)) and 7-row maximum apron width (50 CFR Part §648.51(b)(4)(iv)). Intensive, multi-year research was conducted before fisheries managers were confident these dredge regulations would achieve conservation goals without significantly impacting the fishery. With a cover net, conservation engineers can more efficiently assess how modifications to the apron and twine top influence the escapement of non-target species with less intensive sampling. To our knowledge, this project is the first to estimate non-target species retention properties of sea scallop dredges. These retention properties can be used to more precisely understand how sea scallop dredges impact flatfish populations. For example, based on a comparison of our estimated windowpane L50 value from the SELECT model (22.69 cm) to length of 50% maturity for the species (Northern stock = 22.5 cm and Southern stock = 21 cm; O'Brien et al. 1993), we expect that a majority of the animals caught by a scallop dredge are sexually mature. By developing more selective dredge bags, conservation engineers can ensure that the sea scallop fishery is catching a narrow segment of a flatfish population, minimizing impacts on juvenile fish and more easily accounting for fishing impacts during stock assessments.

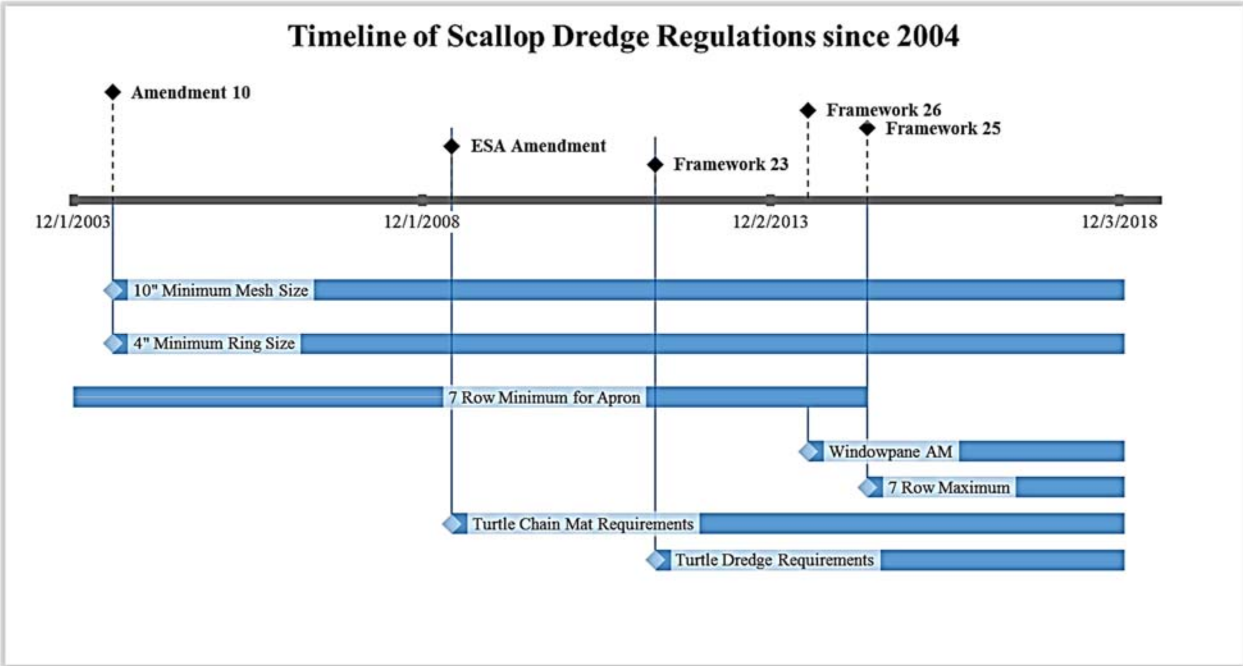

Figure 9: A timeline a sea scallop dredge regulations since 1994.

Another application of the dredge cover net is the assessment of the seasonal distribution and abundance of juvenile flatfish. While the finding that small flatfish (<30 cm) are passing through the dredge bag was not surprising, the numbers of small flatfish passing through was more than expected. A conservative estimate of swept area relative abundance of juvenile yellowtail (# of yellowtail per km^2) from the covered dredge tows predicts that the covered dredge catches two to ten times as many juvenile fish per unit area than the bottom trawl used in the NEFSC seasonal spring and fall surveys (**Figure 10**), suggesting that juvenile fish abundance may be higher than previously estimated. The differences between the relative abundance estimates for the covered dredge and bottom trawl survey data was significant (Provincetown tows $p = 0.045$; Georges Bank tows $p < 0.001$). A higher relative abundance of juvenile yellowtail coupled with low levels of spawning stock biomass indicate that juvenile mortality may be significantly impacting the recovery of this overfished stock.

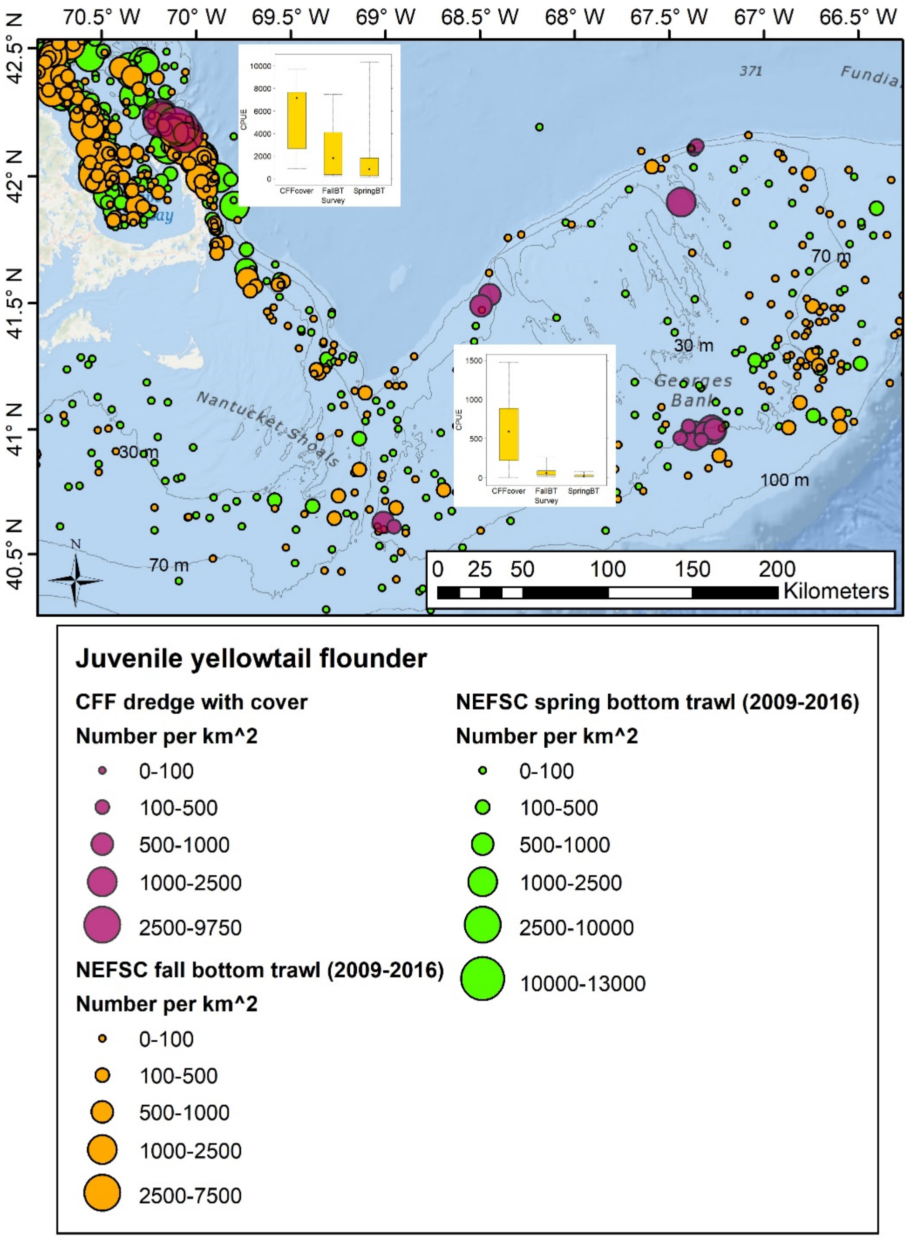

Figure 10: A comparison of the relative abundance estimates of juvenile (<30 cm) yellowtail flounder.

Additional work

Seasonal bycatch surveys could deploy the cover net in order to better understand the temporal and spatial distribution of juvenile flatfish. Having confidence in the cover net designed by this project, CFF is planning to incorporate the cover net into its 2019 Seasonal Survey. This tool will expand the dataset to species and demographics that are not normally observed in scallop dredges. Use of the cover net in the seasonal survey also serves as an opportunity to improve the selection parameter estimates generated from this project. In time, CFF's seasonal survey has the ability to generate a robust time series of seasonal abundance and distribution of juvenile flatfish on Georges Bank.

More tows will improve our understanding of how the one-way extended link apron influences the retention properties of the dredge bag, but based on our findings we can assume that this modification has improved selectivity relative to a standard apron. Yet the value of incorporating the use of cover nets to assess gear designs goes beyond the modification tested in this project. For instance, using a small mesh panel to block escapement through the twine top, we may be able to assess the independent selective properties of the apron and twine top. This could be used to determine if the observed bycatch reduction in a dredge with 5-row apron and 1.5:1 is the result of the shortening the apron and/or decreasing the twine top hanging ratio. Because this combined modification is currently being considered to reduce flatfish bycatch, better understanding of the relative impacts of each change would have immediate management implications.

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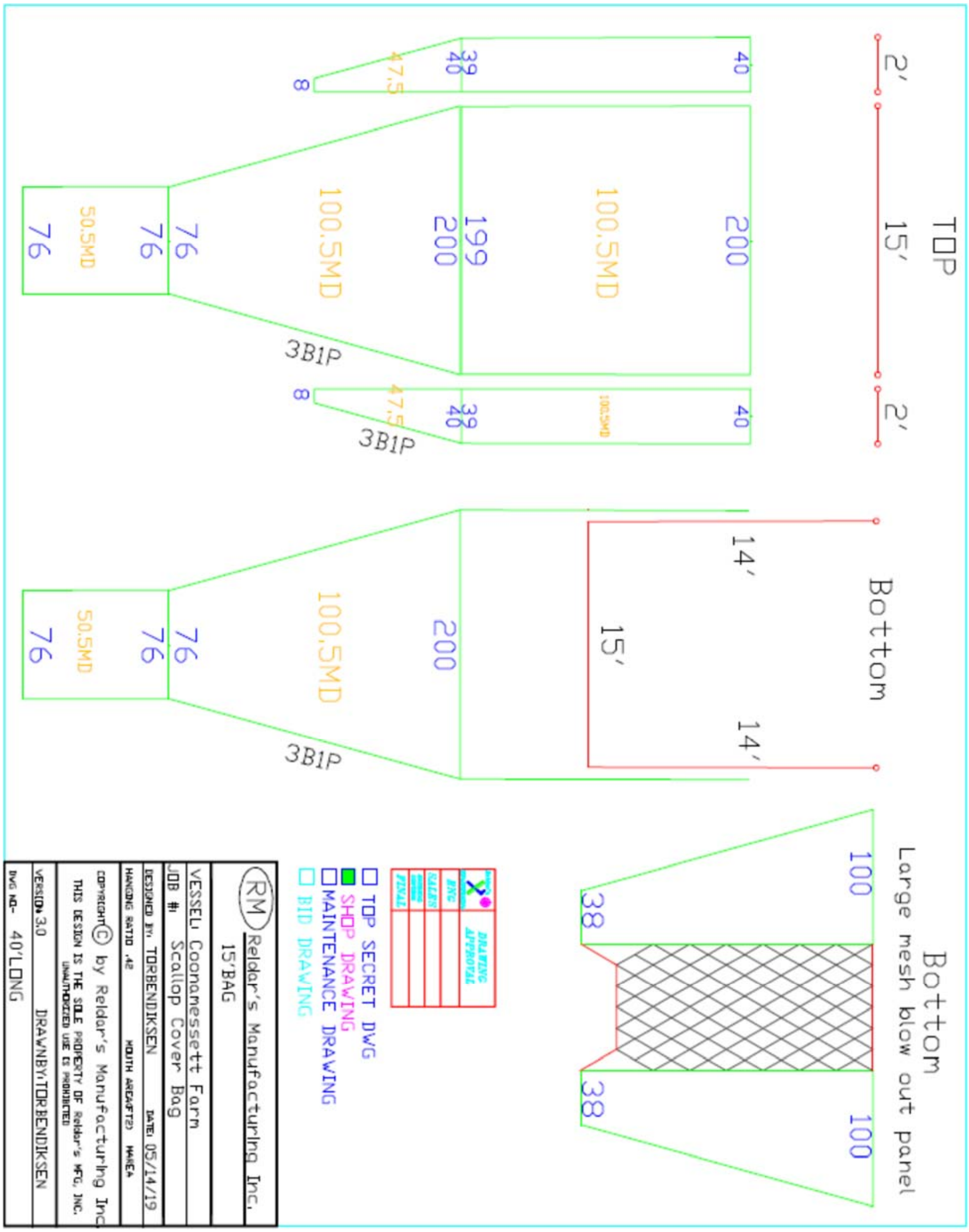
Appendix A

45 mm Sea Scallop Dredge Cover Net Plans



The blowout panel and gore seam reinforcing of the final cover net.

Scallop Dredge Cover Net Study Protocols for Commercial Fishing Vessels

Contents

Executive Summary

This document describes the standard operational protocols for conducting a study using a scallop dredge cover net aboard a commercial fishing vessel. This manual documents the protocols implemented during the development of the dredge cover net and is intended to serve as a reference manual to ensure that cover net studies are standardized and repeatable.

1.0 Overview

The development of gear-based reduction strategies can be cost prohibitive especially if bycatch species are in low relative abundance and the differences between the catches are subtle. For these reasons, researchers developing gear modifications can be left with inconclusive results about the efficacy of a gear modification. One strategy that gear researchers can employ to investigate more thoroughly the efficacy of a gear modification is to compare the experimental gear to a non-selective gear. While non-selective gears for otter trawls have been extensively developed and studied, this method was not applied to scallop dredges until recently. Since the use of non-selective methods is a novel approach to developing gear modifications for scallop dredges it is necessary to develop standardized protocols to ensure repeatability of cover net studies.

1.1 Calibration Sampling Design

A paired-tow experimental design is used to evaluate the impact of a cover net on the performance of a control dredge. A Limited Access Full-Time commercial sea scallop vessels must be used for this experimental design, as they are capable of towing two dredges simultaneously. For this experimental design, two dredges with identical ring bags are used and the experimental treatment is simply the addition of the cover net to either of the dredges. The covered dredge should be alternated each day to account for a "side" effect. Alternating the cover net may not be possible every day to weather conditions. A comparison of the dredge bag catches will enable for the researcher to determine if the addition of a dredge cover net is impacting the performance of a sea scallop dredge. A calibration coefficient can be derived if there is predictable relationship in catch differences between a covered and uncovered dredge allowing for comparability of datasets.

1.2 Gear Development Sampling Design

A Limited Access Full-Time commercial sea scallop vessel is also required when using a cover net to evaluate the efficacy of modifications to top portion of the dredge (skirt, twine top, and apron). For this type of experimental design, two cover nets are required so that both the control and experimental dredges will be covered. Comparing the catches of the codends enables researchers to evaluate how a modification to the top of the dredge impacts escapement.

1.3 Relative Abundance

This method cannot be used to estimate absolute abundance because the efficiency of the gear is less than 100% i.e. animals escaping under/over the dredge are not sampled. A dredge cover net can be used to estimate a relative abundance of a sampled species and this estimate can be comparable through time if catchability is held constant through standardization of gear and methodology.

2.0 Predeparture

Communication between the researchers and the vessel captains are critical to maximize the efficiency of the organization and planning of cruises utilizing a dredge cover. Delivery of the dredges must be done in coordination with the vessel captain and the shore side crane operator.

2.1 Exempted Fishing Permit

An Exempted Fishing Permit (EFP) is required when using the cover net in federally managed waters. The EFP process can take a minimum of 45 days and therefore the researchers must apply for an EFP immediately upon receiving an award for a cover net study to ensure that it is received before the study begins. When applying for an EFP for a cover net project, the researcher needs to specifically request the following exemptions:

i. Days at sea (DAS) utilized to conduct this research are not counted against the participating vessel's allocated DAS for the fishing season. (§ 648.53(b))
ii. Exemption for crew size restriction (§648.53(b))
iii. Exemption from dredge gear restrictions (§648.51(b)), specifically exemption of the minimum mesh size (§648.51(b(2))) and regulations involving chafing gear and other gear obstructions (§648.51(b(4)))
iv. Temporary possession of fish with exemption from possession limits and minimum size requirements in 50 CFR 648 subsections B and D through 0.

In addition to these exemptions it is also important that researcher requests an exemption to fish in areas not open to the sea scallop fishery if sampling in those areas is required by the project.

2.2 Cruise Scheduling

Cruises should be schedule at least two months prior to the proposed departure date. It is recommended that the vessel owner/captain be periodically called in the two month period between the departure date and initial contact to solidify the departure date and time as well as coordinate the delivery of the dredges and/or cover net.

2.3 Cruise Staffing

A minimum of three researchers including the chief scientist are required for a cover net trip. This enables the Chief Scientist to assign one scientist to monitor the sorting of the catch for each side, thereby ensuring that catches are kept separate. The scientific crew roster should be finalized 1 week prior to the departure.

3.0 Sampling Operations

Upon arriving at the fishing grounds or at the start of each day-at-sea, the Chief Scientist must assess conditions including depth contours, vessel traffic, navigational hazards, fixed gear, wind speed, and sea conditions and then determine if a valid tow can be done. A standard cover net sampling tow is 10 minutes long (on-bottom) and towed at speeds between 4.5 and 5.2 kts. Targeting a speed over ground of 4.8 kts ensures that tow speeds fall within this range. The scope, ratio of warp length to depth, should be 3 (warp):1 (depth) plus 10 fathoms e.g. a depth of 30 fathoms requires a warp length of 100 fathoms. A tow begins when the winches are braked and ends when the winches are reengaged at haul back.

3.1 Determination of Tow Path and Direction

The chief scientist is encouraged to work with the vessel captain to scout out optimal tow paths prior to sampling. Tows should be along consistent depth contours and all tows must be planned to be on-bottom for the full 15 minute duration.

3.1.1 Factors Affecting Tow Path and Direction

a. Hazards or obstructions. Before towing, the vessel command will identify any obstructions or navigational hazards that may affect tow direction, location, or duration.
b. Conditions at the station. Conditions at the station may affect tow direction. These include the presence of fixed fishing gear, vessel traffic, sonar targets indicating significant bottom obstructions, weather, and sea surface conditions. In some cases, i.e., the presence of fixed gear or significant sonar targets, the vessel may be required to scout a towable path.
c. Presence of protected species.

3.2 Standardized Towing Procedures

A standardized haul is 10 minutes long at 4.8 knots and begins when the winches are braked and ends when the winches are reengaged at haul back. For the start and end of each haul it is fundamental to record the date, time, and geographic location. Hauls that deviate significantly from standardized parameters should be declared invalid.

3.2.1 Setting the Dredge

a. The Chief Scientist will select the tow location.
b. Vessel traffic and fixed gear will be identified and avoided to ensure that it is safe to deploy the dredges for the full tow duration.
c. Once a tow location is judged to be clear, both dredges will be brought to the gallus and flared. A fishermen at each gallus will ensure that the cover net is safely away for the vessel's propeller during flaring.
d. After the dredges are flared, the brakes on the winches will be disengaged and the vessel speed will increase to 5.5-6 knots for wire payout.
e. When the 3:1 scope is achieved the winches will be braked and towing will commence. At this time the Chief Scientist must record the date, time, and geographic location.

3.2.2 Standardized Towing

a. Towing commences once both winch brakes are engaged and at this time the Chief Scientist must record the date, time, and geographic location of the tow start.

b. The vessel must tow at speed between 4.5 and 5.2 knots, targeting an average speed of 4.8 knots.
c. The tow duration will be exactly 15 minutes from the time recorded at the start of a tow. Tows times should always be planned for the full 15 minutes.
d. The captain and Chief Scientist are responsible for monitoring the gear and its performance throughout the tow.
e. At exactly 15 minutes, the winches will be reengaged and the dredges hauled back to the vessel.

3.2.3 Dredge On-Deck Post Tow

a. Catch will be emptied on deck by the vessel crew.
b. Bringing the codend aboard the vessel required the greatest deviation from normal dredge handling practices. If not done properly, the dredge bag and codend samples could become mixed, resulting in an invalid tow.
    i. The dredge or dredges were brought aboard before the codend to ensure that the loss of catch at the side of the vessel was minimized. First, the cargo hook from the opposite side of the boat was used to pull the covered dredge to the middle of the deck (See Above Photo). With the frame in the middle of the deck, the second cargo hook was attached to the bull rope and the codend was lifted on board. When the codend was not very full or was light, it can be maneuvered by hand towards the stern of the vessel and dumped. However, to manipulate a heavier

codend, a snatch block was required. The snatch block is rigged near the top of the gallus frame where the stay wires attach, and a 5 to 10-m rope with an eye splice at either end was looped around the codend and placed in the snatch block. This allows the codend to be maneuvered towards the stern with the cargo hook from the opposite side of the boat. Once in position, away from the dredge bag, the codend is dumped for sorting. As the last step, the contents of the dredge bag is emptied using routine commercial practices

a. It may be necessary to sort the cod-end catch prior to dumping the dredge. In these cases, the Chief Scientist must be sure that all the cod-end catch is clear of the deck prior to dumping out the dredge.
b. Subsampling may also be necessary and its implementation is up to the discretion of the chief scientist.

c. The Chief Scientist and vessel crew will inspect both the cover net and dredge bag after each tow for damage/malfunction and record, as descriptive as possible, observations of damage/malfunction.
d. Required repairs to the gear will be made by the vessel crew.
e. Once the dredges and/or cover nets are dumped and inspected the cod-end will be retied and the dredges will be set over the side in preparation for the next tow.
    i. It is not recommended to conduct a tow until the catch from the previous tow has been fully sampled.

3.3 Tow Evaluation and Tow Validity

All standardized tows are evaluated for validity before sampling begins. The following can deemed invalid for any of the following reasons:

a. **For paired tow experiments any tow where one of the sampling gears experiences a malfunction the tow is deemed invalid.** Gear malfunctions include but are not limited to fouling of the clubstick, a “back job” (the dredge lands upside down), a “rider” (one dredge rides on top of the other), hanging down within the first 30 minutes or one of the dredges being lost.
b. **For alternate tow experiments any gear malfunction results in an invalid tow.**
c. Tows can only be deemed invalid if it is apparent beyond a reasonable doubt that a gear malfunction took place or there was a complete failure to maintain standardized towing parameters. **A visual comparison of catch quantities of the two dredges is not appropriate to declare a tow invalid.**
d. **There is an excessive catch (>50 bushels) of sand dollar (“buttons”), sand, and/or shell hash in the dredge bag or cod-end.**
e. **Ghost gear or fixed gear was intercepted by one or both dredges.**

All invalid tows must be recorded by the Chief Scientist. Catch from the invalid tow may still be sampled by the scientific party at the discretion of the PI or Chief Scientist.

3.4 Cessation of Operations Due to Weather or Sea Surface Conditions

Survey operations should cease any time the Chief Scientist believes the safety of personnel or the vessel is compromised. In certain instances, dredge performance is significantly affected before any safety concerns of the vessel are identified. Sampling operations should be ceased any time the Chief Scientist and/or captain believes dredge performance is significantly altered by weather or sea conditions. During marginal weather conditions, dredge performance should be closely monitored by the Chief Scientist and captain.

d. 4.0 Data Collection

Catch data from scallop dredge cover net studies are collected using standardized procedures to ensure accuracy, comparability, and repeatability between other studies. The Chief Scientist has the primary responsibility for proper collection of data during the research cruise.