Coonamessett Farm Foundation

Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

June 7, 2019

Mr. Michael Pentony
NOAA Regional Administrator
55 Great Republic Drive
Gloucester, MA 01930

Dear Mr. Pentony,

Coonamessett Farm Foundation, Inc. would like to request an Exempted Fishing Permit (EFP) to conduct a habitat impact analysis of clam and mussel harvesting by dredge gear in the least complex clam grounds of the Great South Channel Habitat Management Area (GSC HMA). This project will be conducting a seasonal survey, using cameras mounted on dredges, to map habitat types impacted by dredging. During the same period, using fixed camera platforms, we would monitor substrate changes in adjoining areas that have been recently closed to fishing. The fixed camera platforms, along with Baited Underwater Video (BUV) camera platforms, will be used to assess the use of these areas by cod, forage species, and structure building organisms.

Proposed Research Program under this EFP Request

<u>During fishing trips</u>

Dredge mounted cameras (clam and mussel dredges)

- Characterize substrate types where fishing occurs
- Estimated tow tracks to be mapped: 3000 linear nautical miles
- These trips also provide the source of funding for the research (other than in-kind contributions) via compensation fishing

<u>During fishery-independent trips</u>

Camera Stand

- To assess species habitat use and substrate movement
- Number of deployments by area and season: 3 winter, 5 summer
- Estimated amount of video and time-lapse: ~400 hrs video; 512 hrs time-lapse

BUV Cameras

- To assess spatiotemporal species occurrence
- Both small prey species and commercial species
- On all habitats and in reference areas: Total time 384 hours

Drift Camera Stand

- Downward facing camera for more detailed quantifiable assessment of substrate types and habitat features
- Amount of area to be covered by areas and season: TBD by PDT

Coonamessett Farm Foundation

Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

This EFP request contains the research plan with the methods and objectives explained in greater detail. Please see the next pages for additional application information. The five fishing vessels in the following list will collect video for one year from the EFP issue date to conduct this research:

Vessel Name	Permit #	Doc #	Operator	Owner	Owner Phone
F/V Sea Fox	321114	1107736	Steven Wood	Allen Rencurrel	508-951-3137
F/V Miss Kara	251778	919001	Mike O'Brien	Allen Rencurrel	508-951-3137
F/V Miss Iris		1153176	Allen Rencurrel	Allen Rencurrel	508-951-3137
F/V Mariette	410204	608020	Alexander Lagace	Louis Lagace	401-480-2090
F/V Redemption	MS6095BG		Domenic Santoro	Domenic Santoro	

The project coordinator and point of contact for this project is:

Stephen Davies
Coonamessett Farm Foundation, Inc.
277 Hatchville Road
East Falmouth, MA 02536
sdavies@cfarm.org
TEL: 508-356-3601
FAX: 508-356-3603

Exemptions Requested

Coonamessett Farm Foundation, Inc. is requesting the following exemptions:

i. Temporary possession of fish with exemption from possession limits and minimum size requirements in 50 CFR 648 subsections B and D through 0.
ii. Select samples will be returned to land for further sampling following our research plan
iii. An exemption from 50 CFR 648.370(h), which defines this HMA.

Catch Information

a. A species list for the project can be found below. Surf clams and mussels are the target species and all others listed are potential incidental species.
b. Estimated catch volume by species based on previous clam dredge catches from this area (**Table 1** and **Table 2**).
c. Catch will be retained for sale. With the exception of samples retained for further processing, non-target catch will be returned to the sea once sampling is complete.
d. Ronald Smolowitz is the Principal Investigator (PI) on the Coonamessett Farm Foundation ESA Sea Turtle Permit and has been trained in sea turtle handling/sampling. Any sea turtles brought aboard that are comatose or inactive shall be handled in accordance with Sea Turtle Resuscitation Regulations at 50 CFR 223.206(d)(1).

Coonamessett Farm Foundation
Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Table 1: Experimental trips made to the HMA to collect data for this EFP request.

Date	Vessel	Clam bushels (total)	Clam bushels per tow	Tows	Tow (Mi)	Distance/Tow (Mi)
12/27/2018	Seafox	384	13	30	6	0.2
1/18/2019	Seafox	384	13	30	4	0.1
2/3/2019	Tom Slaughter	325	11	29	5	0.2
2/10/2019	Tom Slaughter	663	11	59	25	0.4
4/5/2019	Seafox	388	8	46	28	0.6
	Total	2,144	56	194	68	1.5

Table 2: Estimated catch data based on the HMA experimental trips for this EFP. Catch rates for winter flounder, windowpane flounder, and skates are extrapolated to the total expected clam catch of 200,000 bu based on bycatch rates during the December 2018-April 2019 trips in Tbl 1.

Common Name	Scientific Name	Estimated catch
Atlantic Surf Clam	*Spisula solidissima*	200,000 bu
Mussel, Nk	*Mytilus edulis, Modiolus modiolus*	5,000 bu
Winter Flounder	*Pseudopleuronectes americanus*	540 ea
Windowpane Flounder	*Scophthalmus aquosus*	540 ea
Unclassified Skate	*Leucoraja erinacea, Leucoraja ocellata*	1000 ea

Fishing Effort Specifications
Areas to be harvested: Sub-area of the Rose and Crown

Estimated bushels per clam boat: 10,000 bushels, ~370 bushels/trip avg
Fishing effort distribution per clam boat: 20 summer trips (Apr-Oct), 10 winter trips (Nov-Mar)
Total clam fishing trips for EFP: 120
Total clam harvest: 40,000 bushels
Estimated miles towed per clam trip: 7 nm
Total distance towed all trips: 840 nm
Total swept area clam trips: 840 nm x 4-foot dredge width (.00066 nm) = 0.55 nm^2
Ex-vessel value of harvest: 40,000 x $23/bushel = $230,000 per boat x 4 boats = $920,000
Research value generated: $1 per bushel x 40,000 bushels = $40,000

Estimated bushels for mussel boat: 10,000 bushels, ~370 bushels/trip avg
Fishing effort distribution for mussel boat: 20 summer trips (Apr-Oct), 7 winter trips (Nov-Mar)
Total mussel fishing trips for EFP: 27
Total mussel harvest: 10,000 bushels

Coonamessett Farm Foundation
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Estimated miles towed per mussel trip: 1 nm
Total distance towed all trips: 35 nm
Total swept area mussel trips: 35 nm x 7-foot dredge width (.00066 nm) = .02 nm^2
Ex-vessel value of harvest: 10,000 x $11/bushel = $110,000 per boat x 1 boat = $110,000
Research value generated: $1 per bushel x 10,000 bushels = $10,000
$1 per bushel set aside determined with collaborating vessel owners

Coonamessett Farm Foundation
Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Background

As the GSC HMA borders were being selected during Omnibus Habitat Amendment 2 (OHA2) development, the Council examined a wide range of variables including dominant currents, bottom type, sediment stability, and the presence of clusters of hard bottoms with cobble and boulders (NEFMC 2013a). Fishing effort, specifically by the Limited Access and General Category scallop fleets and the groundfish fleet, was also considered (NEFMC 2013a). Yet as the draft OHA2 was showcased at public meetings, it became clear that the favored GSC HMA alternative included bottom that had been historically targeted by the surf clam hydraulic dredge fishery (NEFMC 2015a, b). The clam fishery requested an exemption to continue fishing in the proposed GSC HMA if it was approved, and the fishery was given a temporary exemption to fish throughout most of the GSC HMA through April 9, 2019 (NEFMC 2018a, b). The hydraulic clam fishery, however, is highly disruptive and significantly impacts the seafloor (NRC 2002, NEFMC 2011). Recognizing this, but also cognizant of the value of the Nantucket Shoals clam fishery, in December 2018 the Council recommended three clam dredge exemption areas that would allow the fishery to continue at a reduced capacity (**Figure A1**; NEFMC 2018b). The Council also recommended that research be allowed in two additional sub-areas of the HMA, subject to EFP approval. As of May 2019, rulemaking and review of the framework document and associated environmental assessment are underway at NMFS GARFO. At present, the entire GSC HMA is closed to all types of mobile bottom-tending gear, including both surf clam and mussel dredges, but the three exemption areas should reopen to these gear types upon implementation of the clam framework during summer 2019.

Through development of the underlying OHA2, the trailing clam framework, and conversations with the surfclam industry, a detailed summary of fishing activity in the GSC HMA has been established.

- Number of vessels fishing each identified clam area within the HMA- last two years: 13
- Number of bushels harvested from the HMA area: approx. 600,000
- Bushels per hour: Approximately 1 cage (32 bushels) per hour
- Value per bushel: $22-$23 per bushel very high quality and high yield per clam of meat per cage owing to hand sorting of catch

Fishing history of vessels that work primarily in the GSC HMA (yield per year from the HMA)

1	Mariette (Lou Lagace)	90,000 bushels
2	Seafox (Allen)	50,000
3	Miss Kara (Allen)	25,000
4	Miss Iris (Allen)	35,000
5	Tom Slaughter 1 (Monte)	50,000
6	Tom Slaughter 2 (Monte)	50,000
7	Lori Ann (ACF)	75,000
8	Enterprise (ACF)	50,000

9	Lauren (ACF)	35,000
10	Silver Fox (ACF)	25,000
11	Madison III (ACF)	40,000
12	Mandy Lynn (ACF)	40,000
13	Bing Bing (Monte)	25,000
		Total: **590,000 bushels**

Proposed EFP Fishing effort = 211,968/590,000 = 36% of past HMA effort

A large part of the Council's rationale for protecting the habitats of Nantucket Shoals with mobile bottom-tending gear restrictions centers on the desire to protect habitat for juvenile cod within the GSC HMA. The Northeast Fisheries Science Center (NEFSC) seasonal trawl surveys have caught juvenile cod in all of the recommended areas during the last 30 years, but the importance of these areas for young cod are not fully understood. There is a critical need for additional information about juvenile cod habitat associations in this area because exemptions to mobile gear restrictions are currently in effect and the potential impacts of fishing on juvenile cod populations are not fully understood. Yet the NEFSC seasonal trawl surveys have not included stations across most of the HMA since 2010, and the survey has never included stations along the western boundary (**Figure A2**). The GSC HMA was put in place as part of the OHA2 to protect sensitive habitat for juvenile cod (NEFMC 2016), but the surf clam fishery has traditionally operated in the same area (NEFMC 2015a, b). Difficult decisions have been made to balance the continued vitality of two different fishing communities (NEFMC 2018a, b). Habitat protection for juvenile cod will benefit the New England groundfish fleet, while continued access to areas in the GSC HMA will benefit the clam dredge fishery. This project may identify areas within the GSC HMA where juvenile cod do not occur at certain times of the year, thereby making those locations safer for the clam dredge fishery to continue to operate during certain months.

Beyond addressing this specific data need, the study will also incorporate a new survey method to obtain fishery-independent data for juvenile Atlantic cod and other groundfish species occurrence that are not adequately surveyed using other methods. Although BUV systems have been used to survey Pacific cod in relatively protected coastal areas (Stoner *et al*. 2008), baited video surveys have not been conducted in more energetic environments with strong tidal currents like the GSC HMA. If the project is successful, it will open up new survey options for other areas where juvenile groundfish are not being adequately assessed, including regions on Georges Bank that are currently designated as, or have been considered for, protecting cod (NEFMC 2016). Furthermore, because BUV systems collect information about animal behavior, including intra- and interspecific interactions and habitat usage, this survey could provide data needed to further improve EFH designations and improve the New England Fisheries Management Council's (NEFMC) understanding of the importance of the GSC HMA to managed species, including Atlantic cod.

This research will improve the NEFMC's understanding of the distribution of living and nonliving habitat features within the GSC HMA, while it is actively fished, and in the areas closed to fishing starting April 9th, 2019. Dredge mounted cameras will allow for a unique mensurative fishery-dependent habitat survey that will track spatiotemporal habitat change and benthic macrofauna distribution in an active fishing ground. Additionally, dredge mounted cameras can inform on the measurement and extrapolation errors associated with doing visual habitat surveys in an area as highly variable and dynamic as the GSC HMA. Three thousand nautical miles of bottom will be recorded, informing on patchiness and approximate size of soft, hard, and mixed habitat types on a fragmented seafloor.

The research conducted will encompass hydraulic clam dredge fishing activities in two subareas of the Rose and Crown and Zone D (**Figure A3**, **Table A1**). Dredge mounted cameras (**Appendix B**) will be used during fishing trips to assess the habitat types affected by clam dredging on a tow and trip basis. A CFF scientist will be on 10% (54 trips) of the fishing trips to corroborate data collected by fishers with more intensive biological sampling. Additionally, camera stands and BUVs will be used to assess various fish species and habitat types. The results of this research will lay the groundwork for assessing the function of a HMA and inform on the balance that must be struck between clam/mussel harvest and habitat protection.

Research Program

Addendum

This proposal will use a phased approach per habitat PDT comments, the proposed work will be conducted in phases to limit potential deleterious effects to essential fish habitat. All parts of the proposal will be conducted in a manner commensurate with the smaller research area outlined by the Habitat PDT for phase I. Phase I (**Figure A23**) will be conducted until clam harvest proves untenable and the resulting data begins to answer Council research priorities. The transition to Phase II would be predicated on how well the collected data addresses Council priorities and furthers industry, Council, and Habitat PDT knowledge on the Rose and Crown's viability as an access area. The ideal Phase II area would be a doubling of the Phase I area into Rose and Crown and allow research into Zone D. This would start a time series to monitor recovery from anthropogenic disturbance and assess episodic surficial sediment transport over hard bottom habitats in the Phase I area while expanding research and mapping efforts to a larger area. Given vessel maneuverability in the smaller area, Phase I will feature a north and south reference area rather than a grid as outlined in the proposal.

I. Research objectives/goals

The overall goal of this project is to develop an ecological survey that assesses habitat types in high and low dredge impact areas and determine spatiotemporal occurrence of Atlantic cod and other species in these habitats that are subjected or adjacent to commercial fishing activities. This goal will be met through specific objectives: 1) Develop juvenile cod habitat associations in this area and identify areas where juvenile cod do not occur at certain times of year. 2) Use BUVs for assessing occurrence of juvenile cod and other species. 3) Characterize habitat types in which dredging does and does not occur. 4) Establish areas of high clam CPUE and low habitat complexity.

This goal and concurrent objectives are driven by these research questions: 1) How much does cod occurrence overlap with high and low dredge impact areas over time in a variety of habitat types? 2) How do high and low dredge impact area habitat types and species occurrence compare? 3) How much structure do dredges remove relative to contact? 4) How frequently do sandy habitat types shift in the HMA? 5) How can dredge mounted cameras optimize fishing decisions to reduce habitat impact?

II. Methods

a. Fishing trips

These trips serve to fund the research habitat research in this area. Additionally, the GSC HMA is a dynamic shoal area, characterized by strong bottom currents, high energy sandy environments, essential fish habitat, and historically productive fishing grounds. This is an area where site-specific, fishery-dependent and independent data needs to be gathered to assess fishing interactions with the habitat.

Compensation fishing trips will occur in sub-areas of the Rose and Crown (191.2 km^2) and Davis Bank East (Zone D; 83.7 km^2) research areas identified by NEFMC (**Figure A3, Table A1**). The proposed Rose and Crown sub-area is 68.9 km^2 and the proposed Zone D sub-area is 39.5 km^2 (**Figure A3**). Both sub-areas are based off approximately ten years of clam tow track data, provided by members of the research fleet (**Figure A4**). Historically, Rose and Crown and Zone D have boasted high revenues, bottom contact time, and hours fished. Further, defining subareas helps ensure that the areas fished and not fished over the course of the study exhibit similar habitat types. Fishermen would be allowed to select their tow locations anywhere in the grey and crosshatched areas and avoid the pink areas that will serve as low impact reference sites (**Figure A5)**.

Target species catch and bycatch will be documented during each trip. CFF staff will be unable to go on every fishing trip that occurs in the proposed fishing areas, however a crew member(s) from each vessel will be trained to take pictures of the deck pile from a specified angle for every tow (**Figure A6**). As all crew members pick they will attempt to visually estimate the volume of bycatch by bushel (1.47 ft^3), weight for individual fish species, or counts for cobble and rocks. To corroborate visual estimates with a quantifiable estimate the deck will be measured as rail height (ft), deck width (ft) and length (ft) (**Figure A6**). A total volume will be measured by following volume-to-volume based estimates from the observer program. Further, a camera with a rectilinear lens will be set up to take video and time lapse frames of the deck pile as it is picked (**Figure A7**). This camera will be set up as a safeguard for when the crew gets too busy or forgets to take pictures. Camera set up and deck measurements will be considered for the unique layout of each boat and every attempt will be made to incorporate deck pictures, video, and time lapse video preferably from the angles shown in **Figures A6 and A7**. Protocols and logs (**Appendices B** and **C**) will be given to each participating vessel for use on fishing trips to track trip level data, kept and discarded catch, and operate the camera systems.

On trips staffed by CFF, additional biological sampling will occur. Before fishing begins, the dredge will be stripped of all benthic flora (e.g., macroalgae, bryozoans, and hydrozoans) caught on the bars of the dredge. Accumulation of these algae and invertebrates will be noted during the trip and samples will be collected for classification. A high/low habitat vulnerability score will be developed to assess the tows with high/low scores combined with high/low target species catch. CFF scientists will utilize the volume-to-volume approach and weigh subsamples of captured bycaught species, shell hash, cobble and rock. A subsample of cobble and rock will be photographed to capture presence of attached bionts and will be recorded as absent, present, and predominant. A lotek sensor will be attached to the dredge to measure depth and temperature.

Volume-to-Volume assessment of catch per tow

Clam dredge catch (clams plus bycatch, substrate) will be dumped directly onto the deck. Depending on the width of the deck from the rail to the fish hold (**Figure A6**), catch will fall into a rounded oval shape and will slope to zero. The deck and the rail of each vessel will be measured, marked, and gridded in order to estimate the volume of the total catch. Depth will be calculated from pictures based on the tallest height (ft) of the pile using rail height as a proxy. Once the tallest height is determined, an additional 8 heights taken throughout the pile can be measured falling within the range of 0 to the tallest height. Further, the length and width of the pile will be determined from the picture. A portion of the pile's volume will always be known because clam bushels are tracked for each tow. Using the estimated volume of the entire pile and the known volume of clam catch a rough estimate of bycatch species weight or volume can be recorded on fishing trips using a combination of captain and crew visual estimates, and picture estimates.

Example:

Total volume = 5.2 ft (length) x 2.7 ft (width) x 1.4 ft (avg depth) = 19.67 ft^3, approximately 13 bushels of volume.
Kept clam volume = 8 bushels x 1.47ft^3= 11.76 ft^3. Captain's estimate of clam bushel weight ~80 pounds. 640 pounds of clam.
Visual estimate for mussels = 2 bushel x 1.47ft^3= 2.94 ft^3. Captain's estimate of mussel bushel weight 70 pounds. 140 pounds of mussel
Visual estimate for winter flounder = 1 fish~ 2 pounds
Visual estimate for crabs = 1 bushel x 1.47ft^3=1.47ft^3 ~ 50 crabs. Estimate of crab weight 50 pounds

Visual estimate for moon snails = 10 snails ~ 3 pounds
Visual estimate for cobble = 2 bushels x 1.47ft^3 = 2.94 ft^3. Estimate of cobble weight 100 pounds.

Dredge Mounted Cameras

We plan to outfit all dredges with at least one forward viewing GoPro camera (see **Appendix C**) and lights to video the substrate in front of the dredge (**Figures A8, A9, and A10**). The images will then be made into substrate maps as demonstrated in **Figure A11** to track disturbance changes in the high impact areas. The proposed trips and tows should generate a minimum of 3000 linear nautical miles of video mapped transects. Information on preliminary dredge mounted camera data collection can be found in **Appendix E.**

Each vessel will be equipped with: one laptop, external hard drive, dredge mounted camera stand; multiple lights, GoPro Hero 4 action cameras, extended life battery backs, SD cards, and waterproof housings; and all applicable reference materials. During the day, 6 hours of uninterrupted video will be collected, and at night approximately 3 hours will be collected due to lighting constraints before batteries need to be changed. The goal is to have 75% of every trip recorded. This camera system offers clammers the ability to record on-bottom during fishing trips with minimal interruption to their routine and easy troubleshooting.

Video analysis

Recorded dredge-mounted video will be analyzed with the Behavioral Observation Research Interactive Software (BORIS) (http://penelope.unito.it/boris), an open-source event logging software that utilizes VLC media player (http://www.videolan.org/vlc). BORIS provides a simple interface to capture and time-stamp both state (duration) and point (no duration) events from video. The annotation image analysis can be found in **Appendix D**. Using the start and end time and location for each tow, sediment type, species, cobbles, rocks, boulders, and dredge interactions with a rock or boulder can be plotted along a straight-line tow path in ArcMap. For example, pilot Trip 1 (**Figure A11**) has an approximate tow area of 0.13 km^2 compared to the entire Rose and Crown area mi^2, and 7.6 km of tow track were recorded. The fishing duration of this trip was approximately 12 hrs and landed 384 bushels of clam. Preliminary analysis suggests the dredge hit rocks or boulders 117 times or .02 rock/boulders per meter, however only nine rocks were visible in the video during these interactions with a total of 14 rocks/boulders seen, suggesting the majority of rocks or boulders hit are buried. Unseen dredge/rock hits are interpolated from how the dredge reacts when it hits a visible rock. Habitat types were classified as state events and a linear distance (m) was determined for each type e.g., (200 m of sand/shellhash). Thiessen polygons were generated from the point data, the start and stop of each state event determines the extent of each habitat type. The dominant substrate for Trip 1 was a silt/sand/shell hash/mussel cover type for ~8 acres and there was approximately 7 acres of

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

mussel bed (**Figure A11**, **Table A2**). Point events included species visible in the recordings, 83 moon snails, 200 clams, 101 crabs, and 31 fish (sculpin, skate, flatfish).

b. Camera stands, BUVs, and drift cameras

Camera stands, BUVs, and drift cameras will be used on dedicated survey trips to observe shifting sand environments, assess the occurrence of groundfish species over different habitat types, and further characterize habitat types in the disturbed fishing areas and the not-fished reference sites. These methods will follow an adaptive sampling design, and initial data will be reviewed and consulted with the Council and PDT to determine future sampling locations and areas of interest. **Figures A12-A18** show a variety of past CFF camera projects and image analysis deliverables.

Eight two day (48 hr) cruises will be conducted in the Rose and Crown subareas and Zone D during April through October (5 trips) and December through March (3 trips). Video survey locations in each subarea will be broken up into 4 km^2 grids, 18 in the Rose and Crown subarea and nine in Zone D. Each grid contains 3 km^2 of high impact area and 1 km^2 of low impact reference site. Sampling locations for each survey trip will be determined using a random stratified sampling design weighted by area, with strata based on depth, bottom type, and fishing effort. Certain grids may be targeted or ignored depending on associated habitat types derived from CFF video footage and existing data from other institutions. Further, fewer grids may be selected in order to track seasonal and fishing effort changes in discrete areas.

Cameras on BUVs and stationary camera stands will be calibrated and fish lengths will be measured using OpenCV, an open-source computer vision package (http://opencv.org/). The OpenCV package includes functions for calibrating stereo cameras (stereoCalibrate), projecting points in three dimensions (triangulatePoints), and measuring lengths to the nearest centimeter. If necessary, we will develop additional programs for video or image analysis. L. Siemann (CFF) has extensive experience writing custom image analysis programs to analyze cephalopod behavior and body patterns (Chiao *et al*. 2013, Ulmer *et al*. 2013), fish and other coloration patterns (Hepfinger *et al*. 2012, Watson *et al*. 2014, Tyrie *et al*. 2015), and benthic animal distributions (Siemann *et al*. 2015a).

The habitat use of fish recorded by the video system will be analyzed using BORIS. CFF has used this program and the similar program Noldus Observer XT to analyze scallop behavior (Siemann *et al*. 2015b), sea turtle behavior (Patel *et al*. 2016), and dredge-mounted camera footage (unpublished data), and similar programs are customarily used to analyze baited video system footage (Langlois *et al*. 2012, Letessier *et al*. 2013, Santana-Garcon *et al*. 2014, Bouchet &Meeuwig 2015, McLean *et al*. 2015). We will develop a coding system for the BORIS software appropriate to the footage we obtain to ensure we are accounting for all filmed events of cod and sympatric species along with important abiotic features of the environment.

The annotations from BORIS will be used to estimate cod relative abundance as 1) MaxN, the maximum number of cod counted in a frame at once per defined interval of recording (e.g. maximum number of fish per hour of video) and 2) MeanCount, the mean number of cod per frame for a defined number of frames per deployment (e.g. mean number of fish per frame extracted every minute from a one hour recording) (Ellis & DeMartini 1995, Conn 2011, Schobernd *et al*. 2013, Campbell *et al*. 2015). Recording and frame intervals for the analysis will be chosen after viewing our initial recordings to maximize the collection of useful data. MaxN gives a conservative estimate of abundance, avoids repeat counts of the same fish, and is the commonly used measure of relative abundance in baited video surveys (Ellis & DeMartini 1995, Conn 2011, Langlois *et al*. 2012, Letessier *et al*. 2013, Schobernd *et al*. 2013, Santana-Garcon *et al*. 2014, McLean *et al*. 2015). Furthermore, relative abundance estimates derived from MaxN may be more precise than those derived from other video count measures when applied to surveys of species that do not aggregate in large numbers in the camera field of view (Campbell *et al*. 2015). However, MeanCount may have a better linear relationship to true fish abundance than MaxN in some cases (Schobernd *et al*. 2013), so we will use both methods to derive relative abundance estimates during these surveys.

Size-specific habitat preferences will be quantified using a Habitat Index of Relative Importance (HIRI), with the HIRI defined as the relative proportion of fish found in a given habitat relative to all habitats surveyed (Laurel *et al*. 2007). If sample size is sufficient, the relationship between cod relative abundance and environmental variables (benthic habitat classifiers and Hydrolab data) will be modeled using generalized additive mixed models. Cod MaxN will be modeled using an appropriate distribution function in the R package “mgcv” (R Core Team 2017, Wood 2011). Random effects for survey station will be added to account for differences in MaxN due to any consistent differences between survey stations. The final model was selected based on generalized cross validation scores after eliminating variables and interaction terms (Wood 2011).

Baited Stationary Camera Stands

Two stationary camera systems will be used for eight-hour deployments in four grids, two in the Rose and Crown and two in Zone D per trip. One stand will be deployed in a high impact area and the other stand will occur in the corresponding low impact reference site. After 8 hours, cameras will be collected and redeployed in the next grid. These systems will be used mainly to observe shifting sand when dropped in sandy areas and longerterm observations of the species utilizing the habitat types in the camera images. These camera systems are equipped with two stereo-mounted Sony alpha 5000 digital single lens reflex (DSLR) cameras in deep-sea housings that are rigged with an intervalometer and mounted near the center of the top of each stand with approximately 30 cm separating the two camera lenses to allow for stereo images to be captured **(Figure A19**). Light-emitting diode (LED) puck lights are mounted on either side of the camera array and programmed to flash in sync with the cameras to minimize the effect of light on animal behavior. Two large external batteries mounted on the sides of the stand power the lights and the cameras. This configuration will allow high-resolution images of approximately 2.6 m2 of the seafloor to be taken once a minute for up to 55 hours (note the maximum expected deployment for this project will be 8 hours).

High-definition action cameras are mounted on the top and legs of the frame to allow 1080p video to be taken for up to 8 consecutive hours. A Hydrolab DS5X sonde located on the top of the frame will collect conductivity, temperature, depth, luminescent dissolved oxygen (LDO), pH, turbidity, and chlorophyll a concentration data which will be embedded into the images to allow for a better understanding of habitat types. Finally, a modified Maryland crab trap will be used to deploy bait, live organisms, and other fish attraction devices below the image frame to bring fish into the field of view. Tilt current meters will be deployed at each station near the stationary frames to collect data on current speed and direction (**Figure A20**).

BUV survey of HMA

This part of the proposed EFP will utilize video survey methods to derive occurrence indices for juvenile Atlantic cod (*Gadus morhua*) over a broad spatial area in the GSC HMA. The BUV survey will provide preliminary data on the feasibility of conducting a more rigorous dedicated survey incorporating BUVs and physical measurement of the cod population (hook and line, fish pots).

Two BUV frames will be deployed four times in each sampling grid for 50 minute soak times, one in the high impact area and one in the reference site, for a total of 8 deployments in each grid (**Figure A5**). The video systems will be optimized for high-quality images and each frame will have a stereo camera system for accurate estimates of fish size (**Figure A21**). A Lotek temperature-depth logger will be attached to each frame to collect baseline environmental data. All filming will be done using ambient light, so cod will not be deterred from approaching the frame. We will try a variety of bait options to determine which will be the most effective for attracting juvenile cod. CFF has determined that dangling bait, attached outside the bait box (**Figure A21**), was needed to attract tilefish (unpublished results); therefore, we will try bait configurations with and without dangling bait.

Drift camera tows

A lighter drift camera frame (**Figure A22**) will be used to conduct drift surveys while BUVs are deployed. The vessel and camera system will drift with the tide for 10 minutes. 8 drifts will be conducted in the high impact area and 8 drifts will be conducted in the reference site, for each of the four grids sampled during a trip. A live-view video camera will be use to ensure the stand is upright and collecting habitat video. Further, additional cameras will be used to collect high-resolution stills. Benthic habitat classification will be adapted from methods developed by Bethoney and Stokesbury 2018. These classifications include habitat details, like benthic substrate and epifauna presence, which have been used for habitat classification by NEFMC. Methods will differ in that a linear distance of habitat type will be classified while Bethoney and Stokesbury 2018 utilized a drop camera approach with 4 drops per station.

A drift camera frame will enable comparisons with dredge mounted camera video (both linear), and drift camera frames will allow for tracking disturbance changes in the high impact areas compared with the low impact reference sites. Further, the drift cameras will allow for accurate sediment classification and a better ability to annotate microhabitat features (<1m) occurring in high and low impact areas.

Coonamessett Farm Foundation
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

References

Armstrong, M.J., H.D. Gerritsen, M. Allen, W.J. McCurdy, and J.A.D. Peel. 2004. Variability in maturity and growth in a heavily exploited stock: cod (*Gadus morhua* L.) in the Irish Sea. ICES Journal of Marine Science 61: 98-112.

Bax, N.J. 1997. The Significance and Prediction of Predation in Marine Fisheries. ICES Journal of Marine Science 55: 997-1030.

Bethony, N.D. and K.D.E. Stokesbury. 2018. Methods for image-based surveys of benthic macroinvertebrates and their habitat exemplified by the drop camera survey for the Atlantic sea scallop. Journal of Visualized Experiments 137. doi:10.3791/57493.

Bouchet, P.J. and J.J. Meeuwig. 2015. Drifting baited stereo-videography: a novel sampling tool for surveying pelagic wildlife in offshore marine reserves. Ecosphere 6. DOI: 10.1890/ES14-00380.1.

Brooks, E.J., K.A. Sloman, D.W. Sims, and A.J. Danylchuk. 2011. Validating the use of baited remote underwater video surveys for assessing the diversity, distribution, and abundance of sharks in the Bahamas. Endangered Species Research 13: 231-243.

Brown, S.K., P.J. Auster, L. Lauck, and M. Coyne. 1998. Ecological Effects of Fishing. NOAA State of the Coast Report. http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/IEF.PDF.

Campbell, M.D., K.R. Rademacher, M. Hendon, P. Felts, B. Noble, M. Felts, J. Salisbury, and J. Moser. 2014. SEAMAP reef fish video survey: relative indices of abundance of red grouper. SEDAR42-DW-11. 25 pp.

Campbell, M.D., A.C. Pollack, C.T. Gledhill, T.S. Switzer, and D.A. DeVries. 2015. Comparison of relative abundance indices calculated from two methods of generating video count data. Fisheries Research 170: 125-133.

Cappo, M., E. Harvey, and M. Shortis. 2007. Counting and measuring fish with baited video techniques - an overview. Proceedings of the Australian Society for Fish Biology Workshop Proceedings: 101-114.

Chiao, C.C., K.M. Ulmer, L.A. Siemann, K. Buresch *et al*. 2013. How visual edge features influence cuttlefish camouflage patterning. Vision Research 83: 40-47.

Conn, P.B. 2011. An evaluation and power analysis of fishery-independent reef fish sampling in the Gulf of Mexico and U.S. south Atlantic. NOAA/NMFS/SEFSC Technical Memorandum NMFS-SEFSC-610. 38 pp.

da Silva, P.P. and A. Kitts. 2006. Collaborative fisheries management in the Northeast US: emerging initiatives and future directions. Marine Policy 30: 832-841.

DeCelles, G.R., D. Martins, D.R. Zemeckis, and S.X Cadrin. 2017. Using fishermen's ecological knowledge to map Atlantic cod spawning grounds on Georges Bank. ICES Journal of Marine Science 74: 1587-1601.

Dunn, D.C., A.M. Boustany, J.J. Roberts, E. Brazer. M. Sanderson, B. Gardner. and P.N. Halpin. 2013. Empirical move-on rules to inform fishing strategies: a New England case study. Fish and Fisheries 15: 359-375.

Ellis, D.N. and E.E. DeMartini. 1995. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. Fisheries Bulletin 93: 67-77.

FGDC. 2012. Coastal and Marine Ecological Classification Standard. Federal Geographic Data Committee document FGDC-STD-018-2012. 353 pp.

Gallager, S.M., J. Howland, A.D. York, N.H. Vine, and R. Taylor. 2008. Adaptive characterization of scallop populations using high resolution optical imaging. Final Report for 2006 Sea Scallop RSA Program. Award NA06NMF4540264. 21 pp.

Gibson, R.N. 1994. Impact of habitat quality and quantity on the recruitment of juvenile flatfishes. Netherlands Journal of Sea Research, 32: 191-206.

Harris, B.P., G.W. Cowles, and K.D.E. Stokesbury. 2012. Surficial sediment stability on Georges Bank, in the Great South Channel and on eastern Nantucket Shoals. Continental Shelf Research 49: 65-72.

Hepfinger, L., M. Coughlin, L. Siemann, and R.T. Hanlon. 2012. Digital camouflage processing: A 21st century solution to a 20th century problem. Military Sensing Symposia, Washington DC, October 2012.

King, J.R., M.J. Camisa, and V.M. Manfredi. 2010. Massachusetts Division of Marine Fisheries trawl survey effort, lists of species recorded, and bottom temperature trends, 1978-2007. MA DMF Technical Report TR-38. 166 pp.

Langlois, T.J., B.R. Fitzpatrick, D.V. Fairclough, C.B. Wakefield *et al*. 2012. Similarities between line fishing and baited stereo-video estimations of length-frequency: novel application of kernel density estimates. PLOS One 7: e45973.

Laurel, B.J., A.W. Stoner, C.H. Ryer, T.P. Hurst, and A.A. Abookire. 2007. Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. Journal of Experimental Marine Biology and Ecology 315: 42-55.

Letessier, T.B., J.J. Meeuwig, M. Gollock, L. Groves *et al*. 2013. Assessing pelagic fish populations: the application of demersal video techniques to the mid-water environment. Methods in Oceanography 8: 41-55.

Lindholm, J. B., J.A. Peter, and L.S. Kaufman. 1999. Habitat-mediated survivorship of juvenile (0-year) Atlantic cod, *Gadus morhua*. Marine Ecology Progress Series 180: 247-255.

Lough, R.G., P.C. Valentine, D.C. Potter, P.J. Auditore, J.R. Bolz, *et al*.1989. Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. Marine Ecology Progress Series 56: 1-12.

Lough, R.G. 2010. Juvenile cod (*Gadus morhua*) mortality and the importance of bottom sediment to recruitment on Georges Bank. Fisheries Oceanography. 19:159-181.

Martinez, I., E.G. Jones, S.L. Davie, F.C. Neat *et al*. 2011. Variability in behaviour of four fish species attracted to baited underwater cameras in the North Sea. Hydrobiologia 670: 23-34.

McLean, D.L., M. Green, E.S, Harvey. A. Williams *et al*. 2015. Comparison of baited longlines and baited underwater cameras for assessing the composition of continental slope deepwater fish assemblages off southeast Australia. Deep-Sea Research 98: 10-20.

Myers, R.A., J.A. Hutchings, and N.J. Barrowman. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecological Applications 7: 91-106.

National Research Council (NRC). 2002. Effects of trawling and dredging on seafloor habitat. National Academies Press. Washington, D.C. 136 pp.

Neuman, M.J. and K.W. Able. 2003. Inter-cohort differences in spatial and temporal settlement patterns of young-of-the-year windowpane (*Scophthalmus aquosus*) in southern New Jersey. Estuarine, Coastal and Shelf Science 56: 527-538.

NEFMC. 2011. The Swept Area Seabed Impact (SASI) approach: a tool for analyzing the effects of fishing on Essential Fish Habitat. Appendix D Omnibus Habitat Amendment 2. 257 pp.

NEFMC. 2013a. Great South Channel Habitat Management Area analysis. http://www.nefmc.org/habitat/cte_mtg_docs/130319/(5)%20Great%20South%20Channel%20Analysis.pdf.

NEFMC. 2013b. Synopsis of Closed Area Technical Team analysis of groundfish habitats and groundfish spawning areas. Appendix E Omnibus Habitat Amendment 2. 67 pp.

NEFMC. 2014. EFH designation methodologies. Appendix A Omnibus Habitat Amendment 2. 57 pp.

NEFMC. 2015a. Omnibus Essential Fish Habitat Amendment 2 public comment summary. https://s3.amazonaws.com/nefmc.org/150218-OHA2-Public-comments-summary-report-corrected.pdf.

NEFMC. 2015b. Omnibus Essential Fish Habitat Amendment 2 public hearing summaries. https://s3.amazonaws.com/nefmc.org/2-OHA2-Hearing-summaries.pdf.

NEFMC. 2016. Omnibus Essential Fish Habitat Amendment 2 Volume 1. 490 pp.

NEFMC. 2018a. Clam dredge framework update: industry-suggested alternative and Committee recommendations. https://s3.amazonaws.com/nefmc.org/2a-Potential-exemption-area-alternatives.pdf.

NEFMC. 2018b. Council forwards clam dredge framework alternatives for analysis; proposed Great South Channel HMA exemptions. https://s3.amazonaws.com/nefmc.org/NEFMC-Forwards-Clam-Dredge-FW-Alternatives-for-Analysis.pdf.

NEFSC. 2013. 55th Northeast Regional Stock Assessment Workshop. NOAA/NMFS/NEFSC Reference Document 13-11. 849 pp.

NEFSC. 2014. 59th Northeast Regional Stock Assessment Workshop. NOAA/NMFS/NEFSC Reference Document 14-09. 786 pp.

NEFSC. 2015. Georges Bank Atlantic cod. Assessment Update Report. https://www.nefsc.noaa.gov/saw/sasi/uploads/Georges_Bank_Atlantic_Cod_Update_2015_09_15_094952.pdf

NEFSC. 2017. Georges Bank Atlantic cod. Assessment Update Report. https://www.nefsc.noaa.gov/saw/sasi/uploads/2017_COD_GB_RPT_Georges_Bank_Atlantic_cod_Update_2017_08_18_164915.pdf.

NOAA. 2012. Coastal and Marine Ecological Classification Standard. Marine and Coastal Spatial Data Subcommittee, Federal Geographic Data Committee. FGDC-STD-018-2012. 353 pp.

Patel, S., Dodge, K., Haas, H., Smolowitz, R. 2016. Detailed assessment of loggerhead turtle (*Caretta caretta*) at-sea behavior through in-water videography. Frontiers in Marine Science 10.3389/fmars.2016.00254.

Politis, P.J., J.K. Galbraith, P. Kostovick, and R.W. Brown. 2014. Northeast Fisheries Science Center bottom trawl survey protocols for the NOAA ship Henry B. Bigelow. NEFSC Ref. Doc. 14-06. 138 pp.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Santana-Garcon, J., M. Braccini, T.J. Langlois, S.J. Newman *et al*. 2014. Calibration of pelagic stereo-BRUVs and scientific longline surveys for sampling sharks. Methods in Ecology and Evolution 5: 824-833.

Schobernd, Z.H., N.M. Bacheler, and P.B. Conn. 2014. Examining the utility of alternative video monitoring metrics for indexing reef fish abundance. Canadian Journal of Fisheries and Aquatic Science 71: 464-471.

SEDAR 2015. SEDAR 42 – Gulf of Mexico red grouper. 612 pp.

Siemann, L.A., C. Huntsberger, J. Leavitt, F. Davis *et al*. 2015a. Estimating incidental mortality in the sea scallop fishery. Final Report for 2014 Sea Scallop RSA Program. Award NA14NMF4540082. 27 pp.

Siemann, L.A., C.J. Parkins, and R.J. Smolowitz. 2015b. Scallops caught in the headlights: swimming escape behavior of the Atlantic sea scallop (*Placopecten magellanicus*) reduced by artificial light. ICES Journal of Marine Science 72: 2700-2706.

Smolowitz, R.J., Patel, S.H., Haas, H.L., and Miller, S.A. 2015. Using a remotely operated vehicle (ROV) to observe loggerhead sea turtle (*Caretta caretta*) behavior on foraging grounds off the mid-Atlantic United States. Journal of Experimental Marine Biology and Ecology 471: 84-91.

Stokesbury, K.D.E. 2001. Examination of population biology and dynamics of the sea scallop, *Placopecten magellanicus*, in discrete areas of Georges Bank. Final report for 2000 Sea Scallop RSA Program. Award NA06FM1001. 82 pp.

Stoner, A.W., B.J. Laurel, and T.P. Hurst. 2008. Using a baited camera to assess relative abundance of juvenile Pacific cod: field and laboratory trials. Journal of Experimental Marine Biology and Ecology 354: 202-211.

Stoner, A.W., J.P. Manderson, and J.P. Pessutti. 2001. Spatially explicit analysis of estuarine habitat for juvenile winter flounder: combining generalized additive models and geographic information systems. Marine Ecology Progress Series 213: 253-271.

Tupper, M. and R.G. Boutilier. 1995. Effects of habitat on settlement, growth, and postsettlement survival of Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences 52: 1834-1841.

Truesdell, S. 2013. Modeling juvenile Atlantic cod and yellowtail flounder abundance on Georges Bank and in the Gulf of Maine using 2-stage generalized additive models. Final report to the Closed Area Technical Team of the New England Fisheries Management Council. Appendix F Omnibus Habitat Amendment 2. 65 pp.

Tyrie, E.K., R.T. Hanlon, L.A. Siemann and M.C. Uyarra. 2015. Peacock flounders, *Bothus lunatus*, selectively choose substrates on which they can achieve camouflage with their limited pattern repertoire. Biological Journal of the Linnean Society 14: 629-638.

Coonamessett Farm Foundation

Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Ulmer, K.M., K.T. Buresch, M. Kossodo M, L.M. Mäthger, L.A.Siemann, *et al*. 2013. The importance of vertical cues for cuttlefish camouflage. Biological Bulletin 224: 110-118.

Watson, A.C., L.A. Siemann, and R.T. Hanlon. 2014. Dynamic adaptive camouflage by Nassau groupers on a coral reef. Journal of Fish Biology 85:1634-1639.

Wood, S.N., 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society Series B Statistical Methodology 73: 3-36.

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Appendix A: Figures and Tables

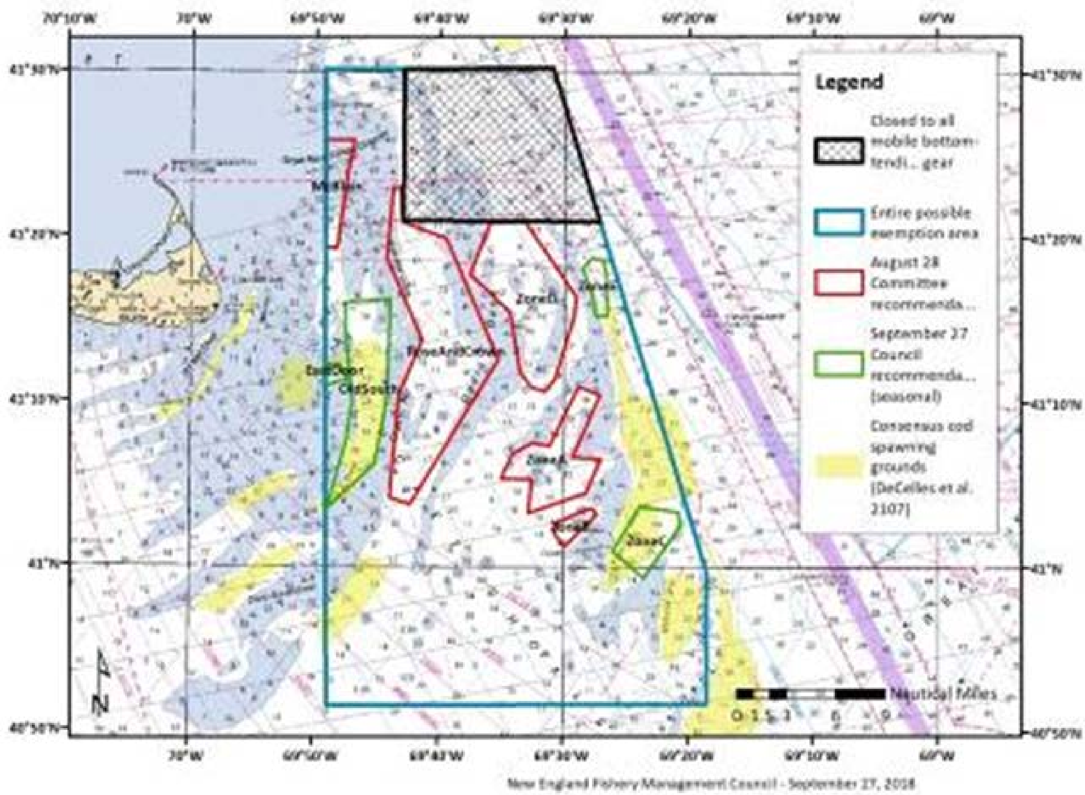


Figure A1. *Clam dredge exemptions considered for the Great South Channel Habitat Management Area, as proposed by the surf clam industry (from NEFMC 2018b).*

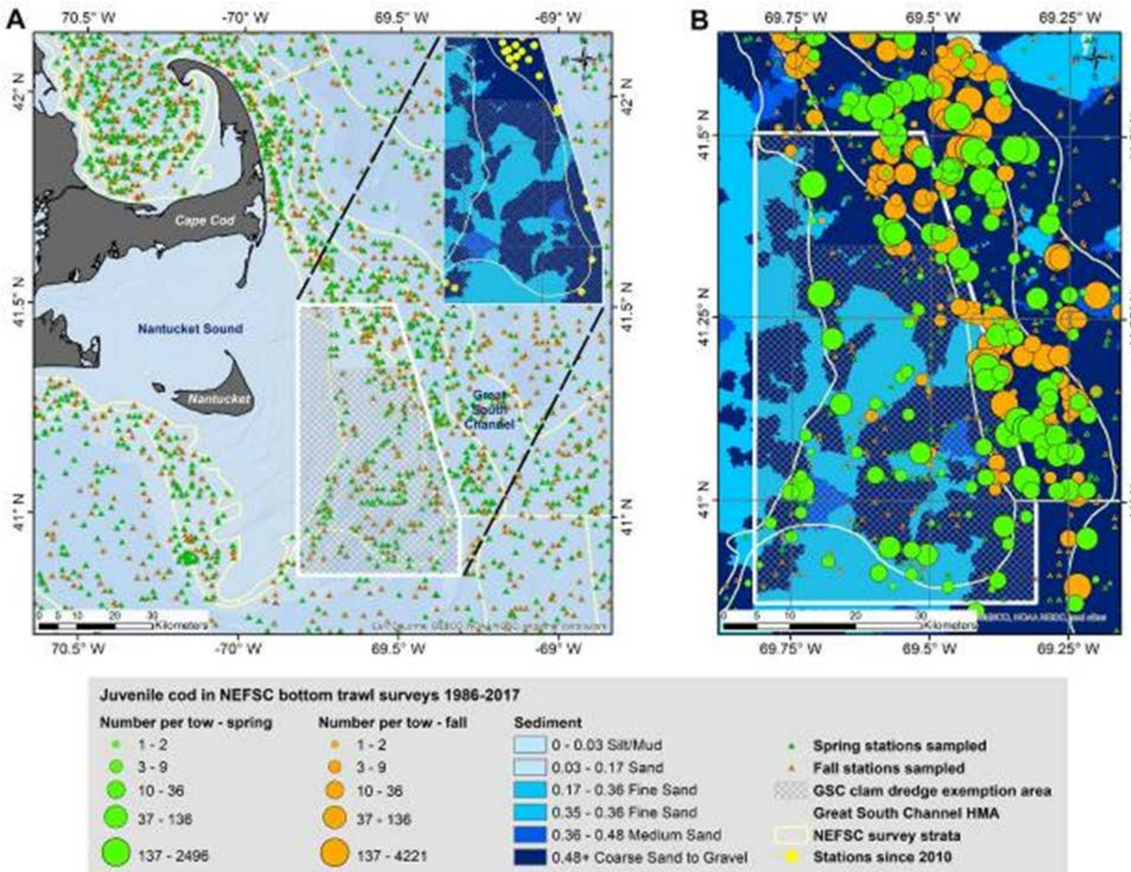


Figure A2. *A) The location of the GSC HMA relative to Cape Cod and Nantucket, with the locations of all NEFSC trawl survey stations since 1986 and the locations of stations since 2010 (inset). B) The numbers of juvenile Atlantic cod caught during the NEFSC fall and spring bottom trawl surveys since 1986 in and around the Great South Channel Habitat Management Area overlaid on map layers of sediment type. Catch data downloaded from* [*https://catalog.data.gov*](https://catalog.data.gov)*. Benthic map layers downloaded from the Northeast Ocean Data Portal at https://www.northeastoceandata.org/.*

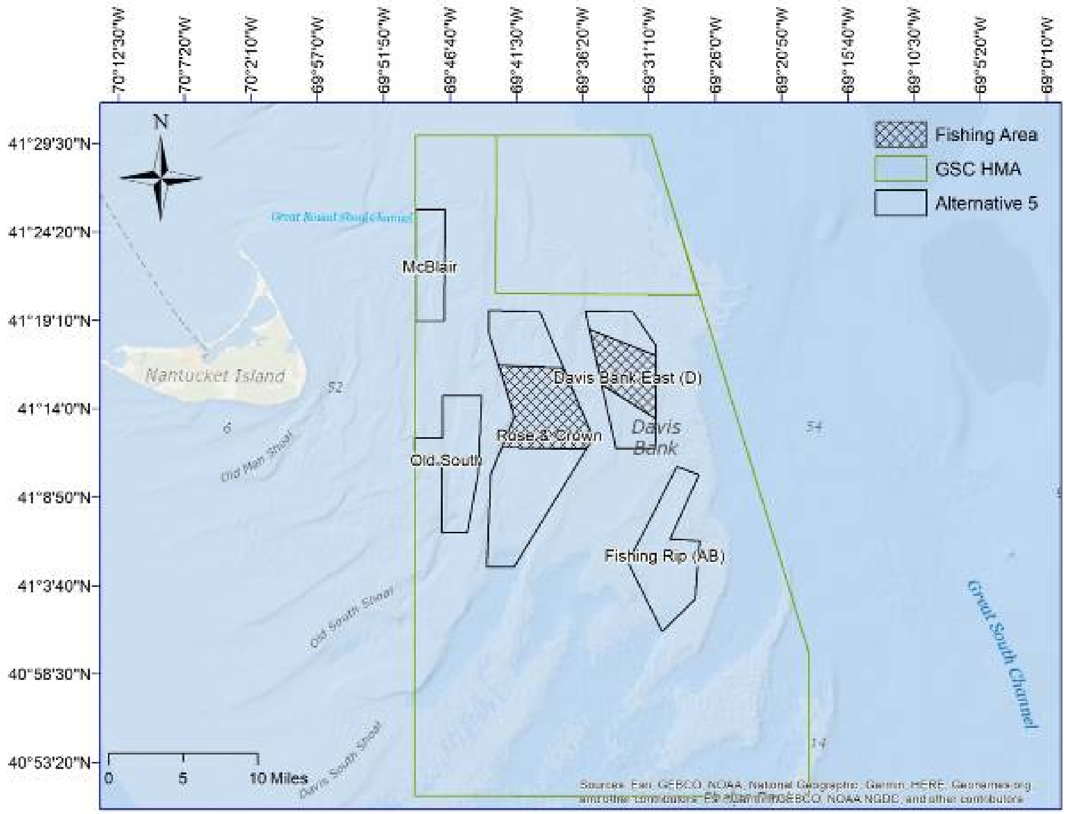


Figure A3. *The five proposed exemption areas (preferred alternative) are shown with cross-hatched areas in the Rose and Crown and Zone D (Davis Bank East) denoting fishing area for the exempted fishing permit. The Rose and Crown area is 74 mi*^{2} *with a proposed fishing area of 26 mi*^{2}*, and Zone D is 32 mi*^{2} *with a proposed fishing area of 15 mi*^{2}*.*

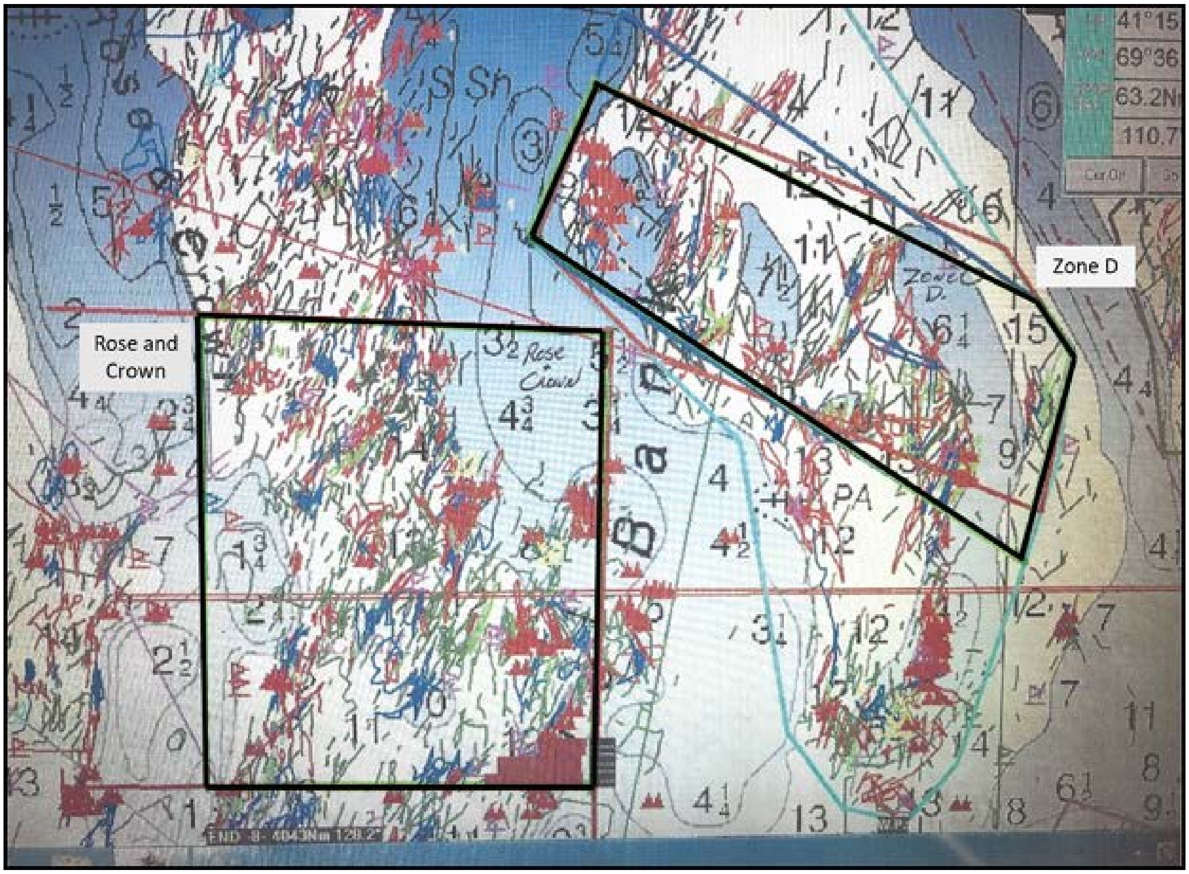


Figure A4. *Tow tracks from a period of ten years for two hydraulic clam dredge fishing vessels*

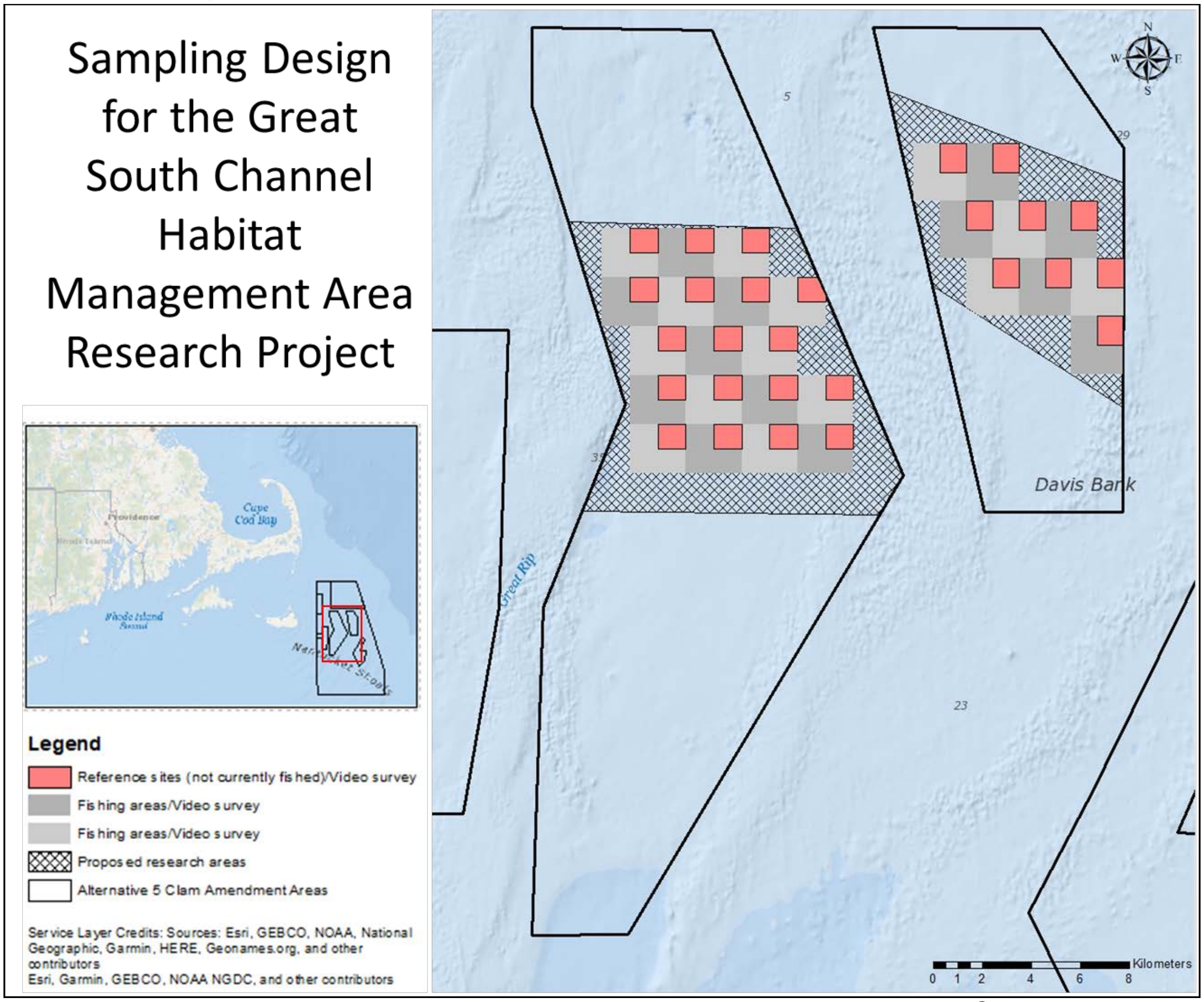


Figure A5. *Subareas of Rose and Crown and Zone D gridded out in 4 km^2 grids. Grey and crosshatched represent total fishing area, and pink represent reference sites, that will have experienced no fishing after April 9th 2019.*

Figure A6. *Example of the preferred angle for taking pictures and filming the pile during fishing. The deck will be measured and gridded in order to quantify volume from pictures.*

Coonamessett Farm Foundation
Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Figure A7. *Preferred angle for filming the pile, to get a more accurate representation of pile depth, and to observe bycatch, rocks and boulders.*

Figure A8. *A, Boulder, encrusted with mussels and other epibionts. B, Rock and mussels. C, Typical gravel, shell hash, cobble, mussel substrate for the December 27th trip in the Rose and Crown area.*

Coonamessett Farm Foundation
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

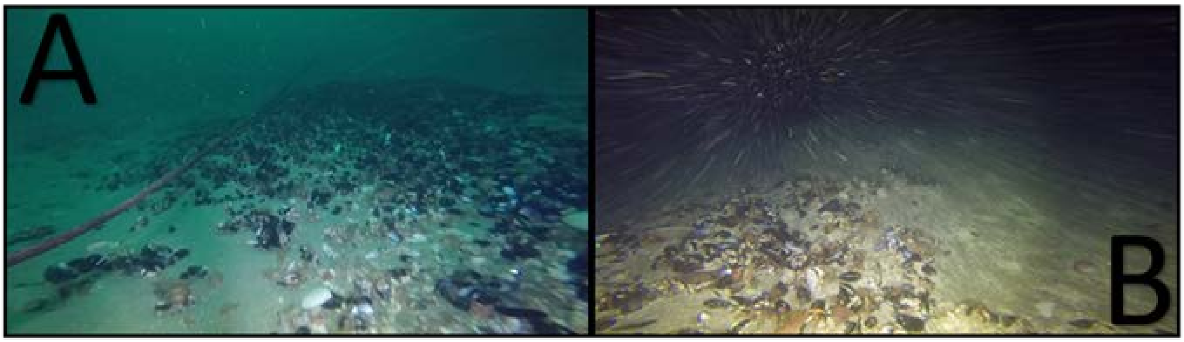


Figure A9. *A, Example of a large mussel bed encountered on December 27th. B, Example of a small mussel bed.*

Figure A10. *Example of a silty/sandy substrate with individual mussels strewn about. Note the sand wave in the forefront of the picture the depression that appears filled with shell hash/mussel/cobble and the following sand wave.*

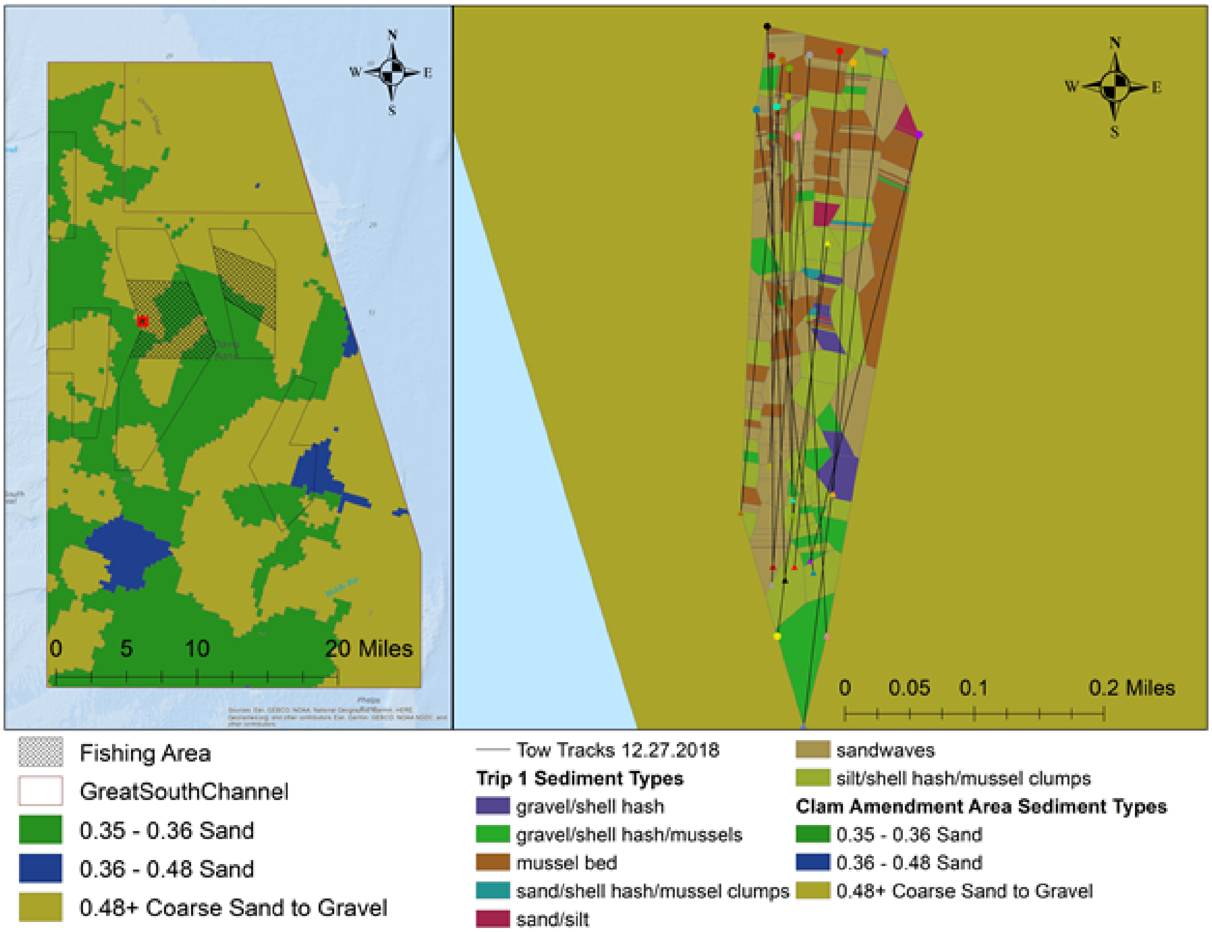


Figure A11. *GSC HMA (left) with sediment types from the Nature Conservancy. The red box shows the location of Trip 1 (Right), December 27th 2018 aboard F/V Seafox. Sediment and habitat types determined from BORIS annotations, 13 tow tracks shown with start (triangle) and end (circle) tow points.*

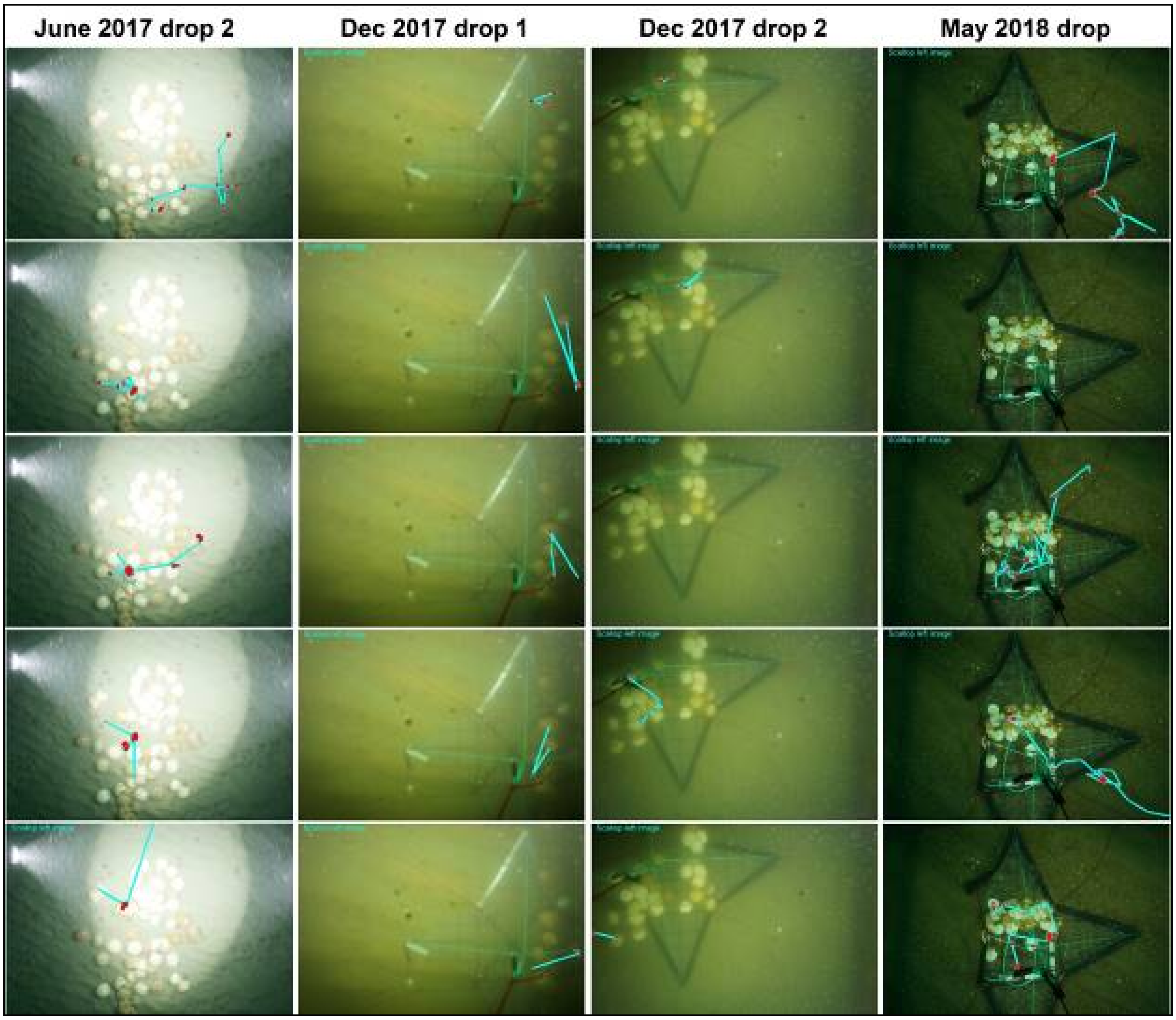


Figure A12. *Movement paths of five tracked scallops for four drops*

.

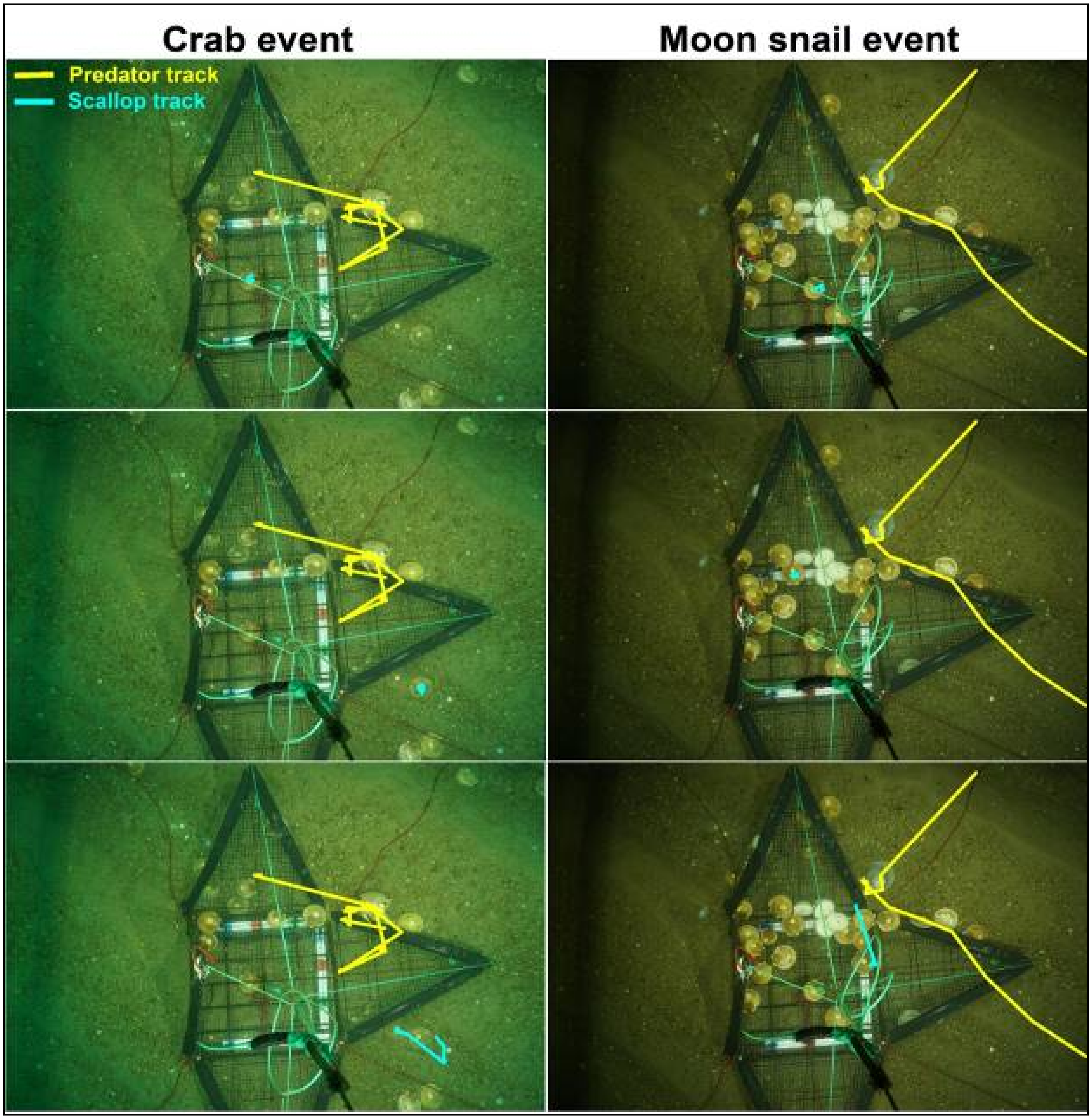


Figure A13. *Examples of predator tracks and scallop responses for crab (left) and moon snail (right) predation events. Each image within a set shows a different scallop track and the same predator track. The crab predation event spanned 24 minutes, and the moon snail predation events spanned 17 minutes.*

Figure A14. *Image from May 2018 showing multiple predation events; a Jonah crab and a black sea bass feeding on a scallop. This scallop was previously preyed upon by a small moon snail.*

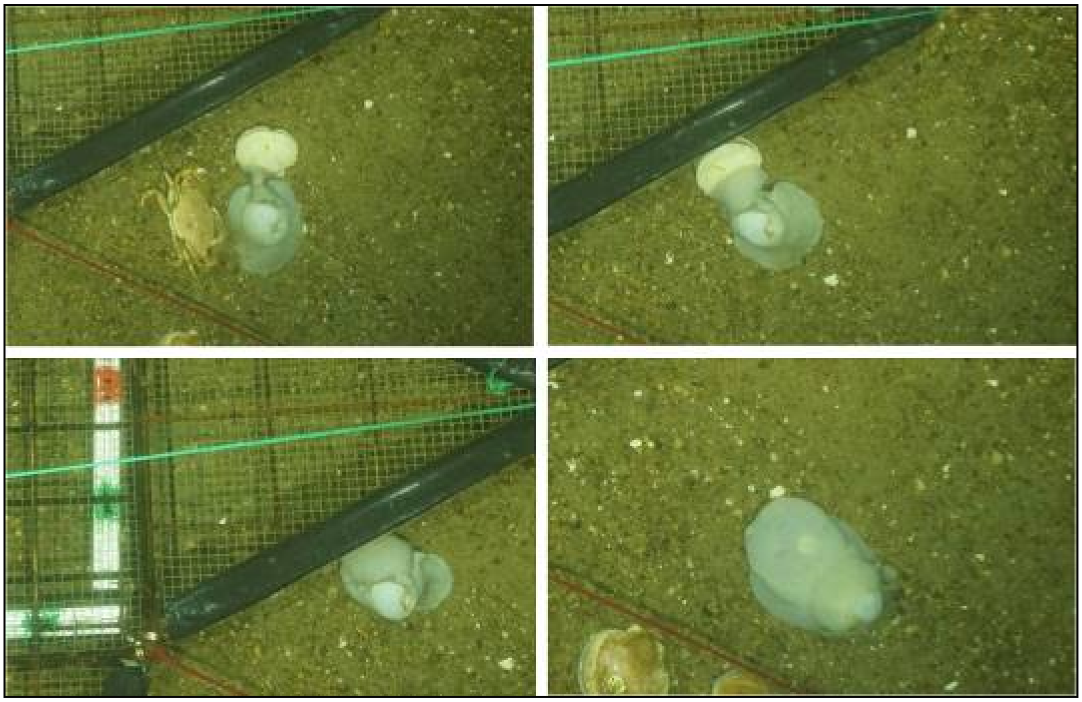


Figure A15. *Example of typical large moon snail predation*

Figure 16. *Monkfish (left) and red hake (center, left, and bottom) attracted to transplanted scallop pile.*

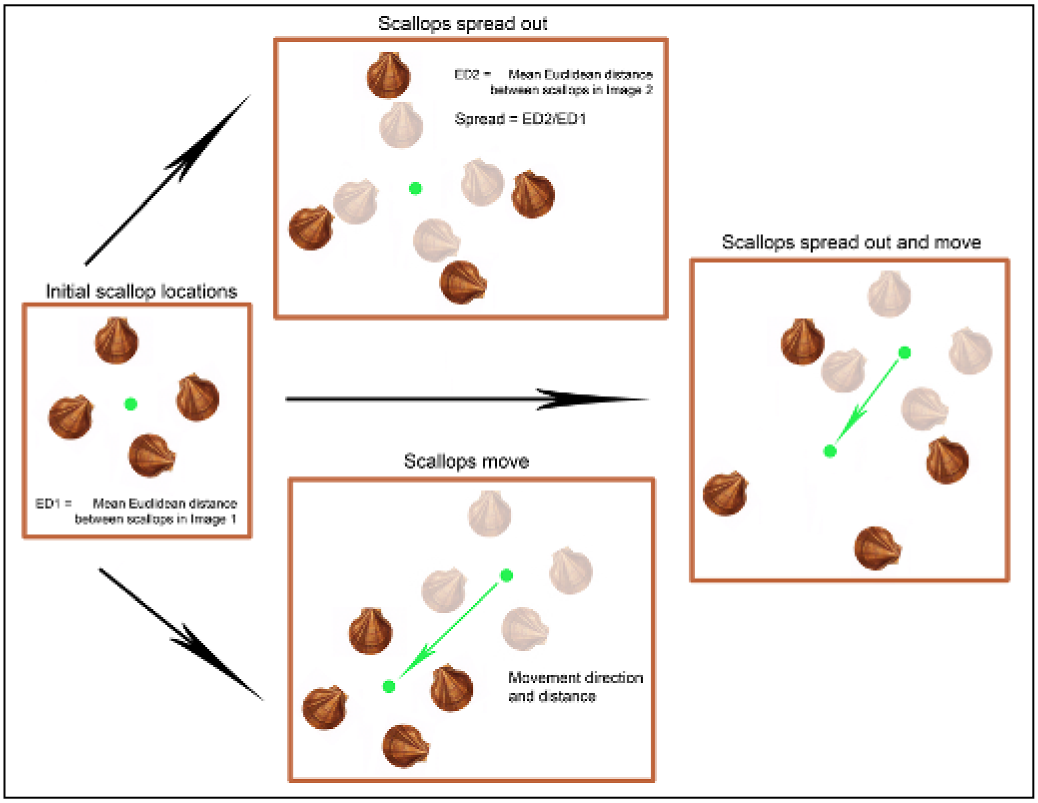


Figure A17. Summary of statistics used to summarize scallop movement.

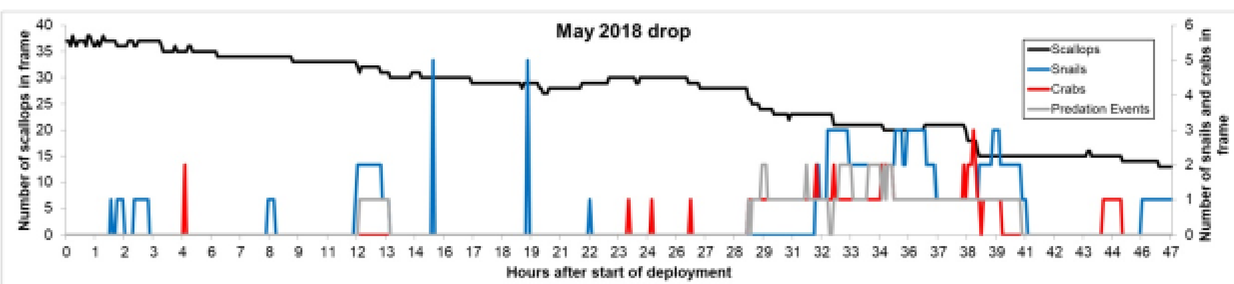


Figure A18. *Sample of data capabilities of animal tracking; The black line represents number of scallops deployed below image frame, blue and red lines represent predators (moon snails and crabs, respectively), and grey lines indicate active predation events.*

Figure A19. *CFF camera stand. Upper image: Sony Alpha 5000 DSLR stereo cameras and intervalometers housed in deep sea housings (black cylinders), integrated Hydrolab DS5X data sonde (yellow cylinder), and integrated LED pucks (off side of frame: one to the right of the sonde, one to the right of blue-gloved hand). Lower image: two large external batteries (grey tubes) and modified crab trap (pyramid to right of battery).*

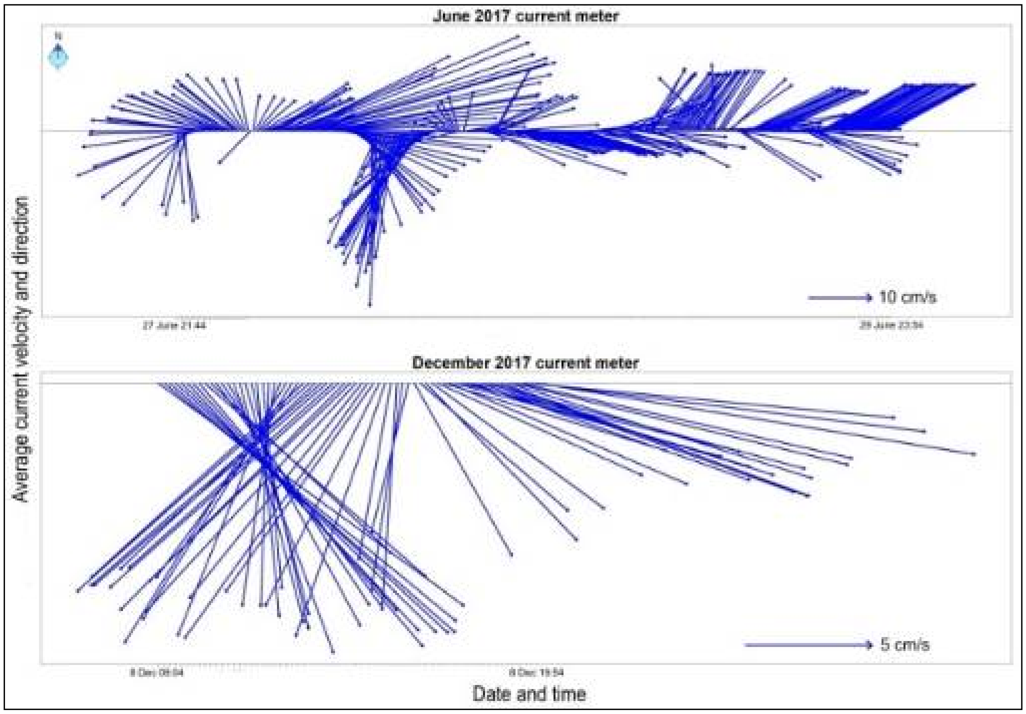


Figure A20. *Examples of feather plots derived from data collected by tilt current meters showing current direction and velocity at CFF research sites.*

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

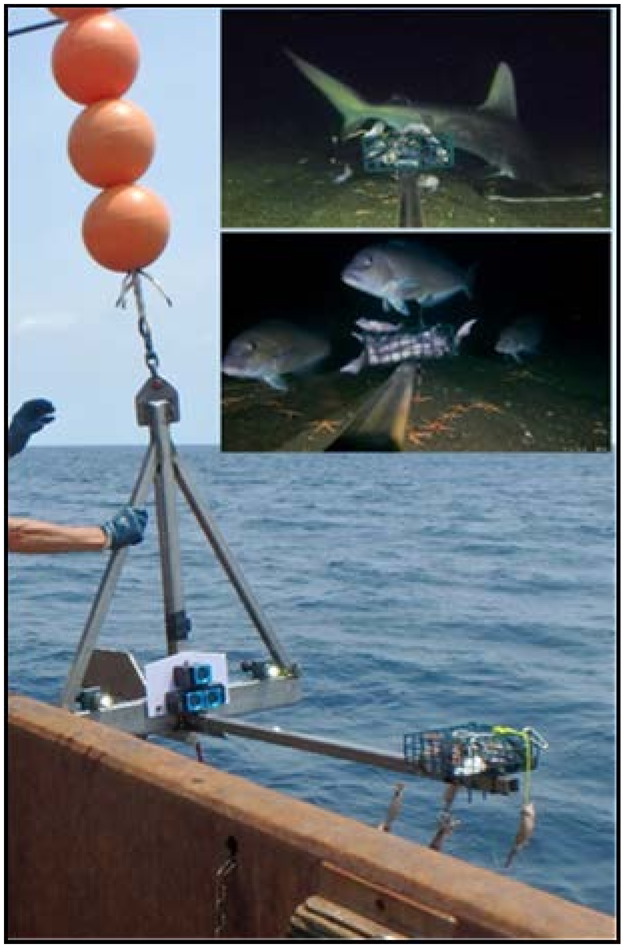


Figure A21. *The CFF BUV frame going over the side with dangling squid bait. (Insets) Screenshots from the video footage taken during a recent CFF research trip.*

Figure A22. *CFF camera stand (light frame) has been used successfully with a live feed underwater camera while drifting*

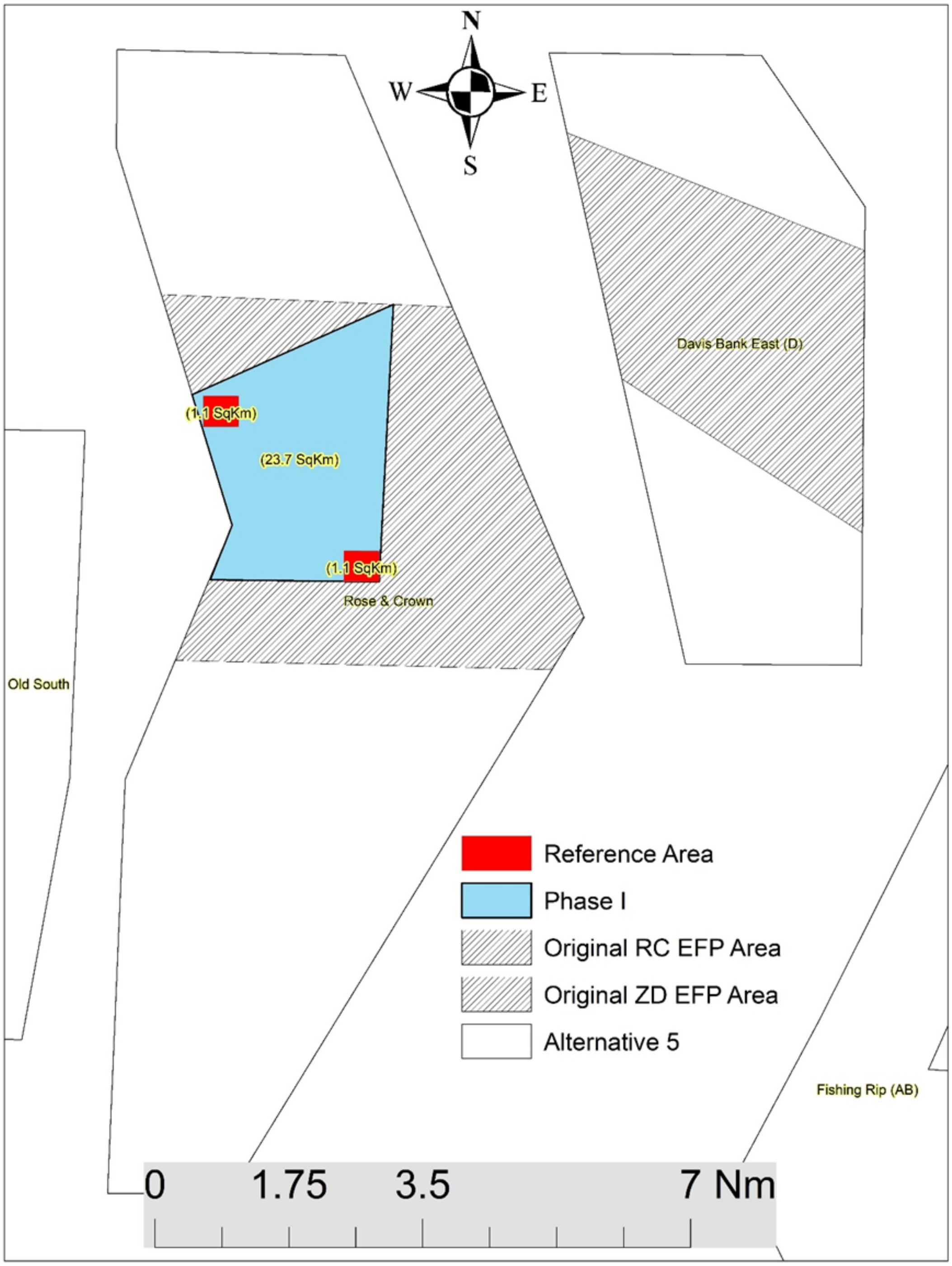


***Figure A23*:** Phase I research area, 23.7 km^2 (~7 nm^2). Two unfished reference areas at 2.2 km^2. Total fishing area 21.5 km^2 (~6.3 nm^2).

Table A1. *Coordinates in degrees, decimal minutes for Zone D and Rose and Crown and their respective EFP fishing areas.*

Area Name	Point	Longitude	Latitude
Zone D	1	-69°35.999' W	41°20' N
	2	-69°32.311' W	41°18.988' N
	3	-69°30.493' W	41°18.009' N
	4	-69°30.508' W	41°11.997' N
	5	-69°33.561' W	41°12' N
Rose and Crown	1	-69°43.5' W	41°20' N
	2	-69°39.54' W	41°19.949' N
	3	-69°35.324' W	41°12.601' N
	4	-69°41.436' W	41°13.773' N
	5	-69°43.5' W	41°18.711' N
	6	-69°35.324' W	41°12.601' N
	7	-69°32.311' W	41°5.009' N
	8	-69°43.5' W	41° 5' N
	9	-69°43.254' W	41°10.431' N
	10	-69°41.436' W	41°12' N
Zone D fishing area	1	-69°34.703' W	41°15.733' N
	2	-69°35.681' W	41°18.944' N
	3	-69°30.490' W	41°17.429' N
	4	-69°30.497' W	41°13.750' N
Rose and Crown fishing area	1	-69°42.699' W	41°16.793' N
	2	-69°41.436' W	41°13.773' N
	3	-69°42.383' W	41°12.021' N
	4	-69°35.857' W	41°11.949' N
	5	-69°35.323' W	41°12.595' N
	6	-69°37.654' W	41°16.678' N

Table A2. Dominant sediment/habitat types observed from the 13 recorded tows on Trip 1, December 27th 2019, aboard the F/V Seafox.

Observation	Count Observation	Mean sq ft	Total sq ft	Acres
gravel/shell hash	8	5817.732301	46541.85841	1.068454
gravel/shell hash/mussels	22	6122.038078	134684.8377	3.091938
mussel bed	108	2680.409656	289484.2429	6.645644
sand/shell hash/mussel clumps	3	1916.593143	5749.779429	0.131997
sand/silt	5	3211.444566	16057.22283	0.368623
sandwaves	111	3832.756344	425435.9542	9.766666
silt/shell hash/mussel clumps	48	7485.808345	359318.8005	8.248825

Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Appendix B: Field protocol for catch estimation

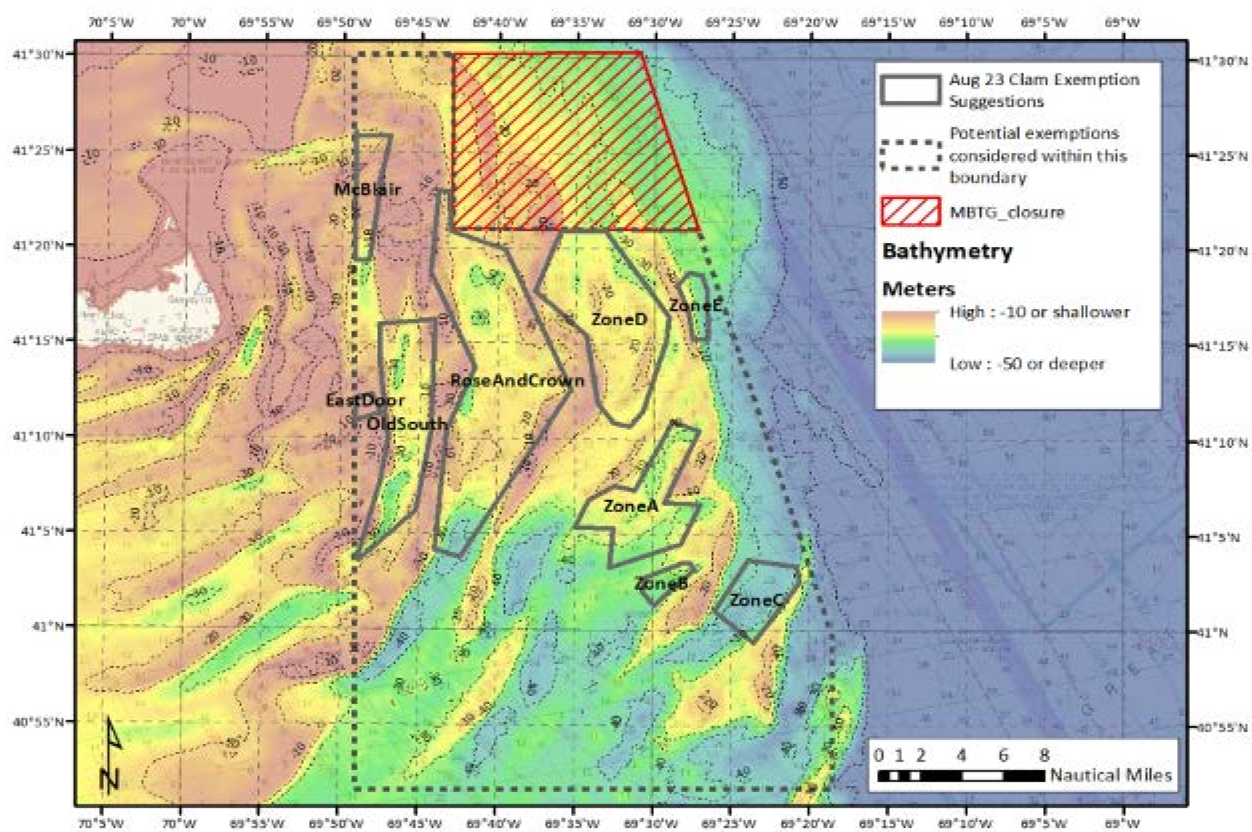
Coonamessett Farm Foundation

Coonamessett Farm Foundation
Conducting scientific research projects that support sustainable fisheries, aquaculture, and agriculture
277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Field Protocols for Captain's Log

Introduction:

This document is a field manual intended for visual catch estimation on clam dredge trips where dredge-equipped cameras are used to record tow tracks. This manual is meant to be used by vessel captains and/or crew. These steps should be followed to produce quality data that can be used to demonstrate various habitat types observed on fishing grounds in the Great South Channel HMA, specifically in the proposed clam dredge exemption areas (see map below). There is a data sheet at the end of this document that can be used by captains to keep track of information gathered during a trip.



Tow Tracks:

An important aspect of this work is accurate timing and location of haul starts and ends. A haul start is defined as the clam dredge hitting the bottom. A haul end is defined as starting to haul wire onto the winch. Because this data will be synced with video data by time stamp, it is important to be accurate when recording/marking start/end haul locations/times. If you regularly record tow tracks on your plotter, please be sure you are familiar with how to extract this information so that it can be shared with CFF. If you are not comfortable using your plotter in this way, a laptop capable of recording GPS can be provided with training on how to use the program.

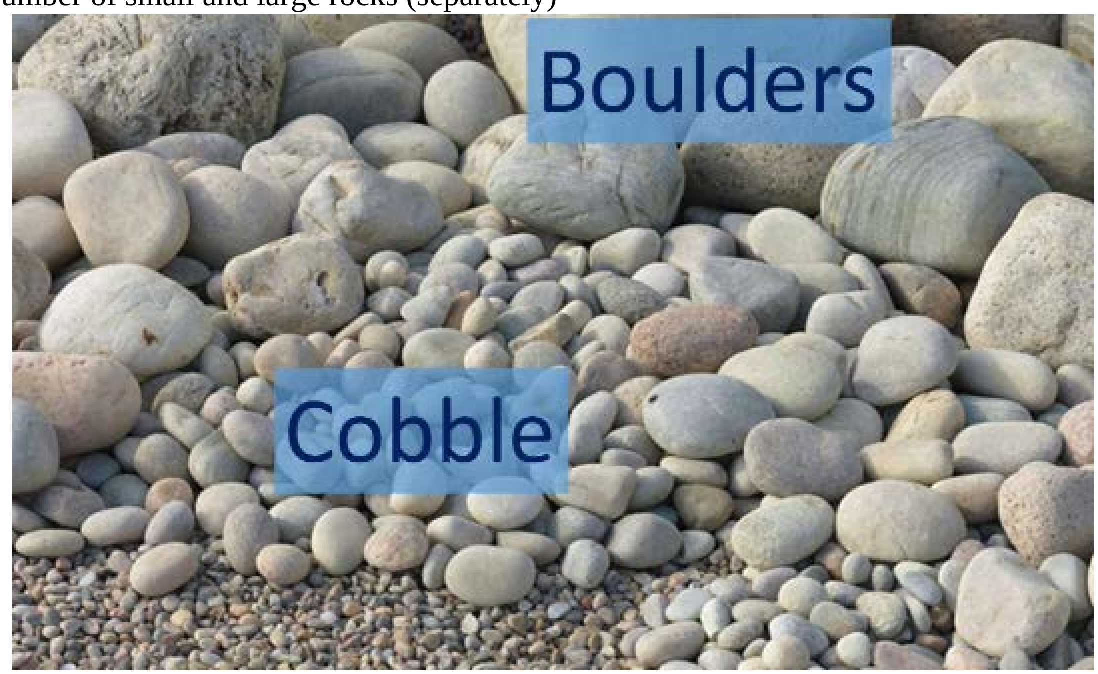
Catch estimation:

CFF requests that you keep track of catch volume (by bushel) on a tow-by-tow basis so that we can corroborate what we see on film with what comes up in the dredge. There is no need to weigh anything, simply make your best educated guess. Animals to document will include:

- Bushel counts and total estimated weight of surf clams

- Bushel counts and total estimated weight of mussels
- Fraction of mussels that appear damaged (broken shells)

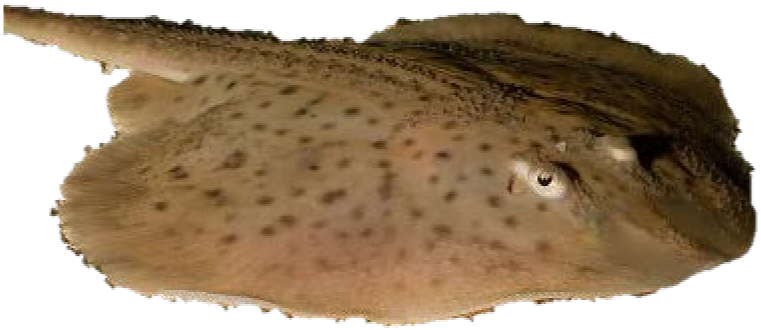
- Number of small and large rocks (separately)



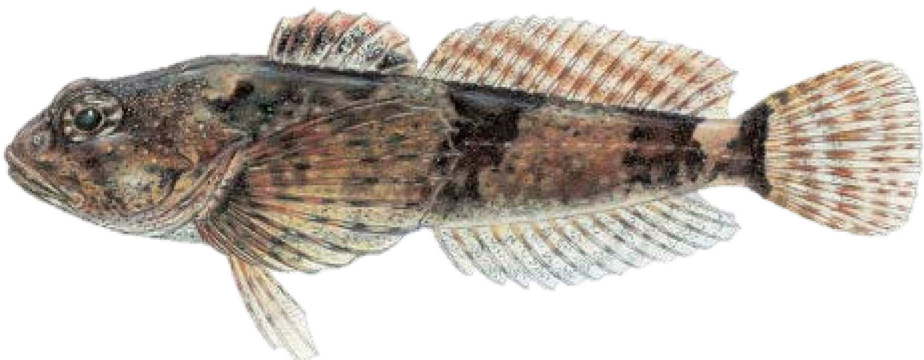
- Total estimated volume of moon snails

- Total volume and estimated number of crabs

- Total estimated weight of fish (all species combined)



Winter/Little Skate



Sculpin

Sea Raven

Winter Flounder

- Total volume of whelks

- Estimated volume of benthos (sand dollars, sponge, algae) and etc.

277 Hatchville Road • East Falmouth, MA 02536
Tel: (508) 356-3601 • Fax: (508) 356-3603
Website: www.coonamessettfarmfoundation.org

Vessel Name:					Trip Start Date:			
Hull Number:					Trip End Date:			
Tow Number	Haul Date	Start Time	Start Lat	Start Long	End Time	End Lat	End Long	Camera Used (y/n)?
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

Tow Number	Bushels clam	Weight clam	Bushels mussel	Weight Mussel	% Crushed Mussel	Weight Moonsnail	Weight Whelks	Weight Fish	Number Cobble	Num Boulders	Weight crabs	Number crabs	Weight benthos
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

Appendix C: Field protocol for camera and strobe use

Coonamessett Farm Foundation

Field Protocols for camera use

Table of Contents

GoPro Use

This section describes the proper maintenance, operation, and memory storage for GoPro Hero4s.

To operate the GoPro Hero4, you will need:

- GoPro Hero4 action camera
- External BacPac battery (for extended use)
- SD card (32-128 GB micro SD cards work; use larger cards for longer deployments)
- GoPro Hero4 charging cable
- Waterproof GoPro Hero4 housing

On the steam out, charge the GoPro camera(s) with the BacPac attached. The charging cable fits into the port on the BacPac because you can charge them separately. Do not insert the cable into this port, as this will only charge the BacPac. Plug the charging cable directly into the camera as shown:

When you are ready to use the camera, unplug the charging cable. Most often, this will make the GoPro turn on, if it isn't already. If not, hold the "Mode" button down for a few seconds:

If no SD card has been inserted, the camera display will read “NO SD”:

The GoPro has no internal memory, so you must use an SD card. For shorter deployments of ~2-3 hrs, a 32 GB card will suffice. For longer deployments, a 64 or 128 GB card is necessary. Insert the card, face up, into the slot below the charging port on the camera. If the card does not slide in easily, do not force it. Flip the card and try it the other way. Note the battery charge level. If not fully charged, the filming period will be reduced.

Prior to filming, ensure the camera is in video mode by looking at the upper left hand corner of the display. A film camera icon should be displayed as shown here:

If the film camera icon is not shown as above, scroll using the Mode button on the front of the camera. When the video camera icon appears on the display, along with the word “video”, simply stop scrolling. After three seconds, the display should revert back to normal with the video icon displayed, as shown above. GoPro has three modes; video, single, and burst (multi-shot). Single mode can be used to capture deck shots of camera configurations, catches, etc. Multi-shot mode should not be used.

Setting the date/time:

The date and time can be set up using the Go Pro 4 camera. Simply click the front button that has the power symbol and the word “mode”. This allows you to scroll through the cameras modes and allows you to get to the Set Up menu. When you arrive on the Set Up menu you then need to press the shutter button, located on the top of the camera and has a red circle on it. This button lets you select the mode, category, or sub-category within each set up option. Now you are in the Set Up menu. Use the front power button and scroll down to Date/Time. Again press the shutter button. Date will be displayed at the top and you should see a date and time. Hit the shutter once more and now you will be able to change the date. The shutter button will allow you to change the Month/ Day/ and Year and the mode button will let you scroll amongst the Month/Day/Year and allow you to scroll to Done. Once the date is set, scroll to Done and press the shutter button. Repeat these steps for time. After changing out batteries, ensure the right date and time are displayed on the camera.

Filming:

When you are ready to film, press the Start button on top of the camera:

You should see a red light flashing on the front and top of the camera indicating that the camera is filming. Occasionally, the video will stop shortly after it begins due to an SD card error. Generally, simply turning the camera off and back on will resolve this issue (the camera will restore the file or delete it and re-format the SD card). Once the camera is filming, insert the camera into the waterproof housing, then secure the camera into the camera stand or GoPro mount.

To operate the GoPro Hero4, you will need:

Battery, different from the Go Pro 4

Battery charger adapter, can charge two Git Up 2 batteries at once.

Waterproof housing, specific to Git Up cannot be used with GoPro

SD Cards.

Filming

Filming occurs similar to a GoPro 4, be sure to select video mode and press the shutter button on top of camera with a red circle to begin filming, making sure to have an SD card in the camera.

Setting Date/Time

The settings button, outlined in the red circle shown below will open up different menus when the camera is in different modes. To set the date and time you must use the Power/ mode button and scroll to System Settings, on the git up, this is the same procedure as selecting the camera for a single shot or the selecting the camcorder for filming. When on System Settings click the shutter button. Press the mode button until you select the clock, you will need to scroll through one screen and you will get to the second screen with the clock. Once on the clock click the shutter button again. Now use the mode button (front of camera to change the date and time) and use the shutter button to scroll through the date and time settings. The button on the side of the camera will act as your back/exit button. Press this button once you have the date and time set and press it again to get back to

the camera view.

Fix NEO Strobe Use

Underwater cameras work best when used in combination with light, due to the loss of color and light attenuation with water depth. This section describes the use of Fix NEO underwater strobes. These strobes can be used with the supplied mount, which is a bolt-on stainless steel tapered cylinder with a threaded grey plastic cap for the wide end (back end of strobe). Basic operation consists of turning on the strobe, selecting the correct light setting, locking the strobe, placing it light-first into the wide end of the cylinder, and screwing on the plactic endcap.

To operate the Fix Neo strobe you will need:

- Fix Neo Light DX strobe
- Fix Neo strobe battery charger

- Fix Neo strobe batteries (plus extra)

On the steam out, remove the battery from the strobe by twisting the top of the strobe. The strobe will come apart as shown:

To charge, plug the charging cable into a wall outlet and insert the DC end into the battery as shown:

When you are ready to use the strobe, unplug the battery, and insert it into the back end of the strobe. The battery will only fit into the strobe one way. Screw the top back onto the strobe. Replace batteries on charger with extra batteries so they are ready when the current batteries are depleted.

Turn the strobe on by pressing the circular button on the bottom of the strobe (circled in yellow):

The display will turn on, along with the strobe (make sure you’re not looking at the lens when you turn it on, the lights are very bright). The display will consist of a percentage and number of minutes, as shown:

You can adjust the percentage, which is a scale of relative brightness, by pressing the circular button again. This will adjust the brightness in intervals of 25%. You can use the arrow buttons, shown below (yellow circle), to adjust brightness to individual percentage points:

To turn the strobe off, hold the circular button for three to five seconds.

Prior to deployment, turn the strobe on and adjust to desired brightness. Select brightness based on time of day (you won't need as bright a light during high noon as you will at night) and battery conservation (the battery will last longer at lower brightness levels). When you are happy with the brightness level, slide the lock button (in blue circle above) to prevent water pressure from depressing buttons during deployment, turning off the strobe mid-video.

Insert strobe, light end first, into the wide end of the cylinder. Screw on grey plastic cap to secure strobe in cylinder.

BigBlue Strobe Use

This section describes the proper use of BigBlue strobes.

To operate the BigBlue strobe, you will need:

- BigBlue strobe
- BigBlue strobe charger
- Batteries for BigBlue strobe (plus extra)

On the steam out, place batteries (2) on chargers (above), making sure the positive end (shown below) aligns with the + side of the charger.

When you are ready to use the strobe, remove the battery from the charger and place into the strobe as shown correctly (- end goes in towards the bottom end and + end goes towards the top):

Screw the top (left) and bottom (right) together. Replace batteries on charger with extra batteries so they are ready when the current batteries are depleted.

Prior to deployment, test the strobe to be sure you put the batteries in by pressing the power button (the only button). Be careful not to look directly at the LEDs on the strobe, as the light is very intense and could damage your vision. Brightness can be adjusted down in 25% intervals by pressing the power button (one step of brightness per click). Select brightness based on time of day (you won't need as bright a light during high noon as you will at night) and battery conservation (the battery will last longer at lower brightness levels). To turn the strobe off, press and hold the power button for 3-5 seconds.

When ready to deploy, carefully remove the endcap from the white strobe mount on the CFF dredge-mounted camera stand, being mindful not to drop/lose the plastic gasket (ring) inside the mount. Insert strobe, light end first, into white cylinder on CFF camera stand. Screw on the white endcap, with the angled side of the gasket facing forward, to secure strobe in cylinder. Move wire cable from strobe mount to the bracket on the back end of the strobe.

CFF Dredge-Mount Camera Stand Use

This section describes the proper installation of camera and strobes into the CFF dredge-mounted camera stand. This will not cover installation of the stand onto the dredge; the placement of the camera on the dredge may be variable between dredges. Installation will require welding a base plate into place on the dredge. Please work with CFF scientists prior to camera trips to determine the best location in terms of camera protection, structural integrity, and camera angle.

To use the CFF dredge-mounted camera stand, you will need:

- CFF dredge-mounted camera stand
- GoPro Hero4
- GoPro Hero4 BacPac external battery
- BigBlue strobes (x2)
- 11 mm wrench

1. Basic Use:

The CFF dredge-mounted camera frame is a ruggedized steel and aluminum frame designed to bolt onto a base plate that has been welded to the dredge. Two bars and an aluminum housing protect the GoPro from rocks and other debris; however it is very important to 1. make a strong, continuous weld along all four sides of the base plate as well as 2. ALWAYS use a tether (aka leash) to catch the frame in the event a weld breaks. Preferably, use two leashes, one on each side. This can be accomplished by simply tying a line around an arm of the frame and some part of the dredge. This will ensure that the frame comes up with the dredge, in the event of a structural failure.

In the photo above, the circular, silver colored mount with a square hole is the camera mount. This is custom milled to accommodate a GoPro Hero4 with a waterproof housing. The two cylinders on either side are custom built to accommodate BigBlue strobes. Not shown; a bundle of wire cables are attached to the back of the frame. These are for tethering (leashing) the camera mount and both strobes mounts to the frame, as well as the frame to the dredge. Always use these leaches when deploying the camera frame, in addition to the primary leash(es) (around the arm(s) of the frame.

2. Adjusting angles:

The camera mount and both strobe mounts can be adjusted to get a better field of view in the video footage. To adjust the camera angle up or down, loosen the bolts on either side of the camera mount, adjust as necessary, then retighten bolts. To adjust the light angle, loosen the bolts on either side of the strobe mount (inside and out), adjust as necessary, then retighten bolts.

3. Inserting the camera into the mount:

Circular camera mount.

Four 11 mm bolts hold the face of the camera mount on. Remove these bolts to open the GoPro Hero4 camera mount. The waterproof housing fits into the mount one way – forward facing and top-up. Prior to placing the camera (within its housing) into the mount, turn the camera on and begin recording. Insert the cameras into the mount and carefully replace the front cover. Be mindful that when the mount is angled downward, gravity will push the camera forward; be careful not to drop the camera. Re-insert the bolts and tighten. Check that the camera is recording by looking through the access panel on top of the camera mount; you should see a red light flashing. If you do not, the camera was turned off when you put the plate on. Re-open the mount, turn the camera on, begin recording, place the camera into the mount, and replace the cover. Check again. If the problem persists, insert washers between the cover and the mount, or, if you absolutely need to, try tightening the bolts less. This last suggestion is risky, as bolts may vibrate loose, and could result in the loss of a camera and the mount cover, so avoid if possible.

Square camera mount

The cover for these mounts are secured with wing-nuts on bolts attached to the mount. There are three slots and one hole milled into the cover. To remove the cover, loosen the wingnuts and slide off the three that correlate with slots, then slide the cover off the remaining post. To attach the cover, reverse these instructions. Unlike the circular cover, these mounts can be used with virtually any HD action camera (and generation of GoPro, GitUp, Garmin Verv, etc.). To use, turn the camera on and start recording. Remove the cover, place the camera in, again being mindful not to drop the camera, then replace the cover.

Appendix D: BORIS image analysis approach

<u>State Events</u>

Sediment Type (Sand through heavy shellhash needs to have a threshold of 30 seconds to be considered as a sediment type)

Sand- make notes on if the sand appears coarse or smooth

Silt- can be mucky or a layer of silt/sediment on top of sand

Gravel- pavement, densely packed gravel

Light Mussels (Strewn about the bottom mainly as individual mussels (living or dead)) can still see other sediment types easily.

Heavy Mussels (Strewn about the bottom mainly as clumps of mussels with individuals dispersed amongst the clumps (living or dead)) more difficult to see other sediment types relative to light mussels

Mussel Bed (Dense congregation of mussels). Mussels dominate the sediment difficult to see other sediment types

Light Shell Hash

Heavy Shell Hash

Light Macroalgae/Bryozoans/Hydrozoans –Used when intermittently spaced individuals are in the field of view.

Heavy Macroalgae/Bryozoans/Hydrozoans (Dense aggregations "fields" of M/B/H) must have a threshold of 5 seconds.

Clam Vein- Probably a rare occurrence, at times long sections of exposed clam are visible annotate these for any time interval.

Sandwaves- must have a 30 second threshold, note small or large sandwaves

Tow related

Start Tow- Dredge is on the bottom and moving forward.

End Tow- Dredge begins to lift of the bottom, stop annotating as soon as you notice this, at times this can be subtle so you may have to go back and find the time the dredge begins ascending.

Dredge Ascending- Dredge is moving up in the water column.

Dredge Descending- Dredge is descending down through water column.

Surface/Steaming- Dredge is at surface and vessel is steaming for next tow.

Bottom- Dredge is on bottom. This field is here because many times the dredge will sit stationary for a few seconds and then begin moving forward. Be sure to end bottom when you end the tow.

Point Events

Inorganic

Boulder- (> ½ frame) > 12”

Rock- (>1/2 frame) = 6”-12”

Cobble- (1/10 < x < ½ frame) <= to 6”

Tow path- Make a note of suspected tow paths

Organic

Flatfish- Any species, if you can ID make a comment

Groundfish- “”

Skate-“”

Sea Stars-“”

Sponge-“”

Snail-“”

Crab-“”

Fish, NK

Mussel- only use for a single mussel in field of view

Clam- To be used for individual surf clams

Macroalgae/Bryozoans/Hydrozoans

The camera is mounted on the right side of the dredge. Most likely 100% of the area that the dredge interacts with is visible. Annotate 75% of the screen to account for this, annotations made on the sides of the field of view should be noted.

Also note when there are clearly demarcated sediment types i.e. the left side of the screen is sand and the right side is a mussel bed.

Appendix E: Preliminary data collection

To test research approaches a series of commercial clam trips were conducted before the closures went into effect. A trip aboard the F/V Seafox occurred on December 27th to the 28th 2018 with all fishing occurring on the 27th. Approximately 30 tows were made during the fishing period. 13 tows had fully recorded front facing video for the entire duration of the tow (**Table E1**). One tow, Tow 15 had a partial recording and tow ten was not recorded. Approximately 7.6 kilometers of bottom were recorded, occurring in an approximately 0.13 square kilometer area. The longest tow was approximately 850 meters long from tow start to tow end and the shortest tow was approximately 460 meters.

Table E1. *13 tows from the December 27th 2018 trip aboard the F/V Seafox. These 13 tows had fully recorded front facing video.*

Tow	Tow Track Length (m)	Tow Duration (sec)	Meters/Second
1	493.0197954	523.021	0.943
2	536.821887	544.197	0.986
3	643.951855	591.224	1.089
4	845.260592	572.129	1.477
5	547.232414	565.44	0.968
6	621.428419	621.644	1.000
7	580.650045	608.527	0.954
8	489.234398	511.537	0.956
9	556.843849	610.369	0.912
11	459.456041	600.55	0.765
12	565.064451	616.46	0.917
13	635.292768	697.855	0.910
14	689.118275	709.902	0.971

During these test trips the camera set-up with the most success utilized a GoPro Hero 4 with a 128 gb sd card and a Re-Fuel 6 hr Action Pack Extended Battery. The company offers 6, 12, and 24 hr batteries. This recorded continuously for 4 hrs before being taken down, while still recording, and filled 40 gbs of the 128 gb SD card. Newer GoPros are unable to utilize these battery packs and getting continuous power for the lights and camera would be cost prohibitive. During the day lights can be reliably used for four to six hours, at night lights should be changed every 2 hours to obtain the highest quality video. This camera system offers clammers the ability to record on-bottom during fishing trips with minimal interruption to their routine and easy troubleshooting.