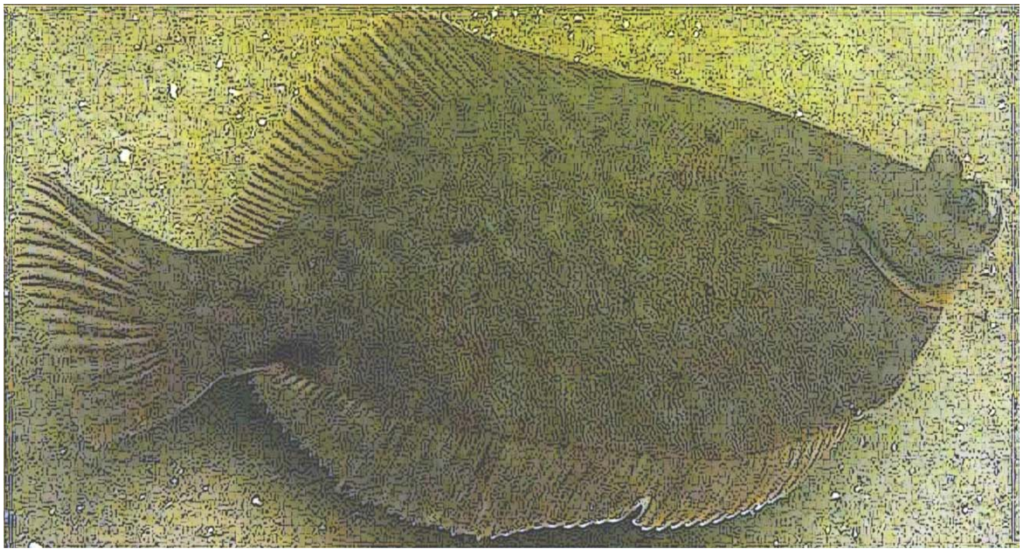
Investigating Offshore Essential Fish Habitat of Southern New England Winter Flounder



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Saltonstall-Kennedy Competitive Research Program Award Number NA15NMF4270266

Award Period: 9/01/2015 – 8/31/2017

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Abbreviations

AIC: Akaike information criterion

BIC: Schwarz Bayesian information criterion

BOEM: Bureau of Ocean Energy Management

CAI: Closed Area I

CFF: Coonamessett Farm Foundation, Inc.

CPUE: Catch per unit effort

NBD: New Bedford dredge

NEAMAP: Northeast Area Monitoring and Assessment Program

NEFMC: New England Fishery Management Council

NEFSC: Northeast Fisheries Science Center

NOAA: National Oceanic and Atmospheric Administration

ROV: remotely operated vehicle

S-K: Saltonstall-Kennedy

SMAST: University of Massachusetts Dartmouth School for Marine Science and Technology

SNE: Southern New England

SNE/MA: Southern New England/Mid-Atlantic

TDD: Turtle deflector dredge

USGS: United States Geological Survey

Executive Summary

The primary objective of this project was to identify non-estuarine spawning locations of winter flounder (*Pseudopleuronectes americanus*) to show that spawning is taking place outside of estuaries in southern New England (SNE) to a substantial extent. The current essential fish habitat (EFH) described for winter flounder are estuarine and riverine habitats. However, more recent data gathered from trawl surveys and acoustic telemetry suggests that groups of winter flounder spawn outside of estuaries. The proposed project addressed S-K priority Theme #1 – maximize fishing opportunities and jobs. Specifically, it will address 1D) by providing information needed to define and protect **essential fish habitat** and **reduce bycatch**.

Initially, the project had multiple goals including: (1) Identification of coastal winter flounder spawning grounds and seasonal distribution patterns, (2) Identification of sympatric species at the various winter flounder habitats, (3) Collection of biological data to improve stock assessments, (4) Winter habitat assessment in the survey area, and (5) Reduction of winter flounder bycatch in the Atlantic sea scallop fishery. One additional goal was added to the project before applying for permits: (6) Collection of winter flounder eggs. Three additional goals were added to the project after the first series of dredge surveys:(7) Comparison of winter flounder catch in scallop dredges to catch in survey trawl dredges, (8) Filming of juvenile winter flounder with a remotely operated vehicle (ROV), (9) Filming of spawning winter flounder with stationary camera array stands.

To meet these objectives, Coonamessett Farm Foundation, Inc. (CFF) completed a series of five winter dredge surveys in southern New England waters between December 2015 and early April 2016. Fish catch data collected during the dredge surveys provided needed information about fish winter presence in the area. Furthermore, because each dredge station was also surveyed at least once with a towed camera sled, the CFF survey provided information about benthic habitat in this area. However, because we caught few winter flounder in our dredge survey and the rocky bottom at some stations damaged our dredges, the project was modified after the fifth dredge survey trip. One trip was conducted to compare winter flounder catch in the Northeast Area Monitoring and Assessment Program (NEAMAP) survey trawl versus a scallop dredge to assess the validity of using a dredge for a flounder survey. Two short day trips focused on searching for juvenile winter flounder using our ROVs in Mount Hope Bay and Point Judith Pond. A final trip was conducted with our stationary camera array stands to film in areas where we previously caught winter flounder or received reports from fishermen about winter flounder presence.

Overall, the project was a moderate success. Because we identified ripe winter flounder in early February and spent flounder in late February, it is likely that winter flounder were spawning offshore in SNE waters because ripe and spent winter flounder swim slowly and therefore could not enter, spawn in, and then leave nearby Narragansett Bay, the closest documented winter flounder spawning location, in 2 ½ weeks. The winter distributions of three important commercial fish species were documented, all in numbers that surpassed winter flounder catch. These included yellowtail flounder, windowpane flounder, and monkfish. Video surveys were conducted at most of the dredge survey stations, and this data was used to create a substrate map of the area with the locations of sandy substrate, mixed gravel substrate, rocks, and areas with high sand dollar concentrations.

Project Overview and Purpose

The primary objective of this project was to identify non-estuarine spawning locations of winter flounder (*Pseudopleuronectes americanus*) to show that, despite historical information, spawning is taking place outside of estuaries in southern New England to a substantial extent. The current essential fish habitat (EFH) described for winter flounder are estuarine and riverine habitats. However, more recent data gathered from trawl surveys and acoustic telemetry suggests that groups of winter flounder spawn outside of estuaries (DeCelles and Cadrin 2010; Fairchild et al. 2013; Gibson 2013; Wuenschel et al. 2009). Additionally, these existing data provide even less information on the deeper water spawning (Decelles and Cadrin 2010; Fairchild et al. 2013, Sagarese and Fisk 2001). The proposed project addressed S-K priority Theme #1 – maximize fishing opportunities and jobs. Specifically, it addressed 1D) by providing information needed to define and protect **essential fish habitat** and **reduce bycatch**.

The Southern New England/Mid-Atlantic (SNE/MA) stock of winter flounder is overfished, yet the stock is not currently being heavily exploited and current landings represent a small fraction of the maximum sustainable yield (MSY) and historical catches (NEFSC 2011). In 2011, 174 metric tons of winter flounder were landed from the SNE/MA stock, a substantial reduction from the 11,176 metric tons that were landed in 1981 (NEFSC 2011). If the SNE/MA winter flounder stocks were rebuilt and annual harvests were equivalent to the MSY (11,728 metric tons), the fishery would produce $55.3 million in annual revenue for the coastal communities of New England (assuming a landed value of $2.14 per pound; BASE New England Seafood Display Auction). However, the landings in 2010 (174 metric tons) generated only $701,000 dollars in revenue to the fishing communities of New England (NEFSC 2011). Given the foregone yield associated with winter flounder, further research is needed to help rebuild populations in southern New England, and revive the once profitable fishery.

In order to restore this stock to past biomass levels, it is important to increase understanding of the basic ecology of this species and decrease winter flounder incidental bycatch in non-target fisheries. This includes understanding habitat utilization during spawning and post-spawning periods. Further research is also needed to better understand the relative importance and prevalence of non-estuary spawning groups of winter flounder in southern New England (Gibson 2013).

Tagging studies on winter flounder

The historical seasonal movements of winter flounder have been examined using conventional tagging studies and analyses of survey data and fishery catches (Howe and Coates 1975; Perlmutter 1947; Saila 1961). These studies have documented that winter flounder in the SNE/MA stock undergo relatively extensive migrations, typically leaving shallow bays and estuaries in the spring and summer months as water temperatures increase above 15ºC. In SNE/MA, tagging studies determined that winter flounder migrate south and east during the summer (Howe and Coates 1975; Perlmutter 1947; Phelan 1992; Saila 1961). During the spring and summer, some flounder in the SNE/MA stock will move short distances to cooler coastal waters, while others undertake long distance migrations. During winter flounder summer migrations, members of localized inshore groups intermix in coastal waters, a phenomenon described by Phelan (1992) as a dynamic assemblage. While these historical tagging studies are informative, most of the research was conducted at a time when winter flounder were relatively abundant. Contemporary research is needed to elucidate the movement patterns and distribution of this species in southern New England during a time when the biomass is relatively low to understand if the habitat utilized during the previous studies is still important for current stock. Furthermore, there is a need to reevaluate seasonal movements of winter flounder given that the geographic ranges of many fish stocks are changing with warmer water temperatures and changing circulation patterns (Nye et al. 2009). Collie et al. (2008) reported that a 1.3° C increase in surface water temperature in Narragansett Bay over a 47-year period correlated with population declines of several fish species, including winter flounder.

The conventional tagging and survey data for winter flounder from southern New England and the Gulf of Maine resulted in winter flounder being classified as obligate estuarine spawners (Bigelow and Schroeder 1953; Crawford and Carey 1985; Saila 1961). However, more recent evidence gathered from trawl surveys and acoustic telemetry suggests that groups of winter flounder spawn outside of estuaries (DeCelles and Cadrin,2010; Fairchild et al. 2013; Gibson 2013; Wuenschel et al. 2009). Using acoustic tagging information of sexually mature winter flounder, DeCelles and Cadrin (2010) reported that 76% of the fish tagged were not in estuaries during the defined peak spawning time (from March through May). This suggests that spawning was occurring in deeper waters throughout the coastal region. Additionally, local fishermen (personal communication, Captain Mike Marchetti and Captain Chris Brown) have reported sizeable catches of spawning winter flounder in Block Island Sound and on Nantucket Shoals. Existing documentation of spawning happening outside of estuaries still has not provided much information on the deeper water spawning in SNE (Decelles and Cadrin 2010; Fairchild et al. 2013, Sagarese and Fisk 2001). It has been recently documented that a majority of the population of the Gulf of Maine stock of winter flounder spawn in deeper colder coastal waters, despite the historical assumption that they were obligate estuarine spawners (DeCelles and Cadrin 2010; Fairchild et al. 2013). While tagging studies were able to confirm that non-estuary spawning was occurring, they were not able to identify specific locations or determine if spawning events were aggregations or localized individuals. Directed research is needed to confirm reports of coastal spawning in SNE and to identify the coastal spawning grounds which are important to this stock. During this study, we will examine the reproductive condition of adult winter flounder in order to gain insight into the distribution of pre-spawning and spawning individuals in SNE.

Current designations of Essential Fish Habitat (EFH) for winter flounder are limited to estuarine and riverine habitats less than 5m deep (NEFSC 1999; Pereira et al. 1999), and do not offer protection to coastal spawning groups of winter flounder. Fairchild et al. (2013) found that the majority of the acoustically tagged fish did not spawn in estuaries. Using trawl surveys, they also determined that mature flounder in the estuaries had already spawned. Their results indicate that, while estuaries are a very important piece of the winter flounder habitat, spawning locations may not be as well understood. There has been documentation of winter flounder utilizing varying habitats during spawning, even though many fish species show a clear habitat preference (Crawford 1990; Stoner et al. 1999).

Winter flounder distribution

Substantial numbers of winter flounder were caught during the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) industry-based yellowtail survey in 2011, and survey catches indicate that the waters south of Cox's Ledge are important fall feeding grounds for winter flounder in southern New England (Cadrin et al. 2012: **Figure 1**). Cox's Ledge is currently an area of interest for habitat-based closures for groundfish (NEFMC 2014). The Northeast Area Monitoring and Assessment Program (NEAMAP) trawl survey is conducted in the waters of Block Island Sound and Rhode Island Sound in the spring and fall. Substantial catches of winter flounder were observed between Block Island and Martha's Vineyard in roughly 30m of water in the spring of 2012 (**Figure 2**). In the spring and summer of 2012, SMAST worked with the Point Judith trawl fleet to conduct an industry-based survey for winter flounder in the waters south of Martha's Vineyard and Nantucket. In the spring, sizeable catches of winter flounder were observed in relatively shallow waters (<60m) south of Nantucket and Martha's Vineyard (**Figure 3**).

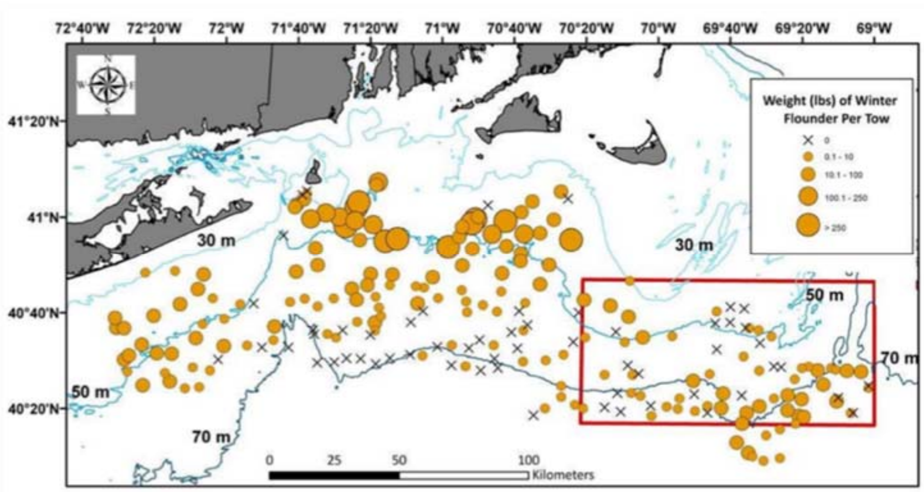

Figure 1. *Catches of winter flounder observed during the 2011 industry-based survey for yellowtail flounder in southern New England.The survey was completed between September and November of 2011. Red box indicates the Nantucket Lightship Closed Area (Cadrin et al. 2012).*

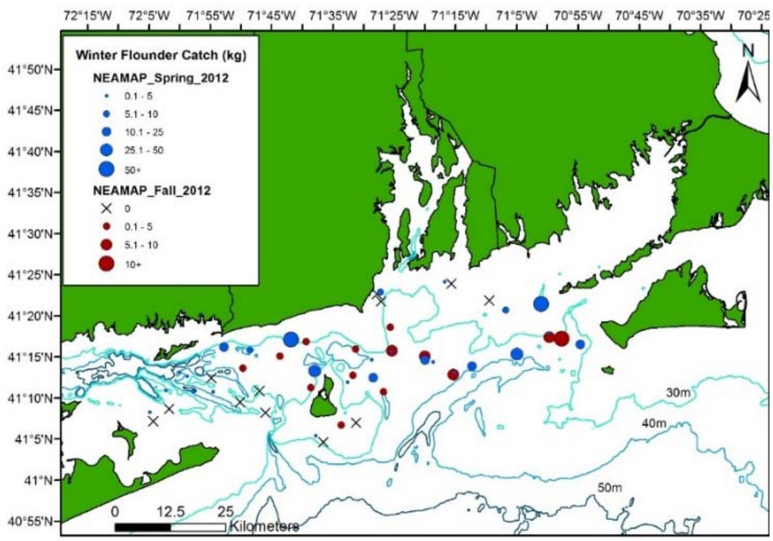

Figure 2*. The distribution of winter flounder catches observed during the 2012 spring and fall NEAMAP trawl surveys in Block Island Sound and Rhode Island Sound. (VIMS Multispecies Research Group. Year, Month, Day. Fishery Analyst Online Catch Data Maps.* http://www.vims.edu/fisheries/mrg/gis*)*

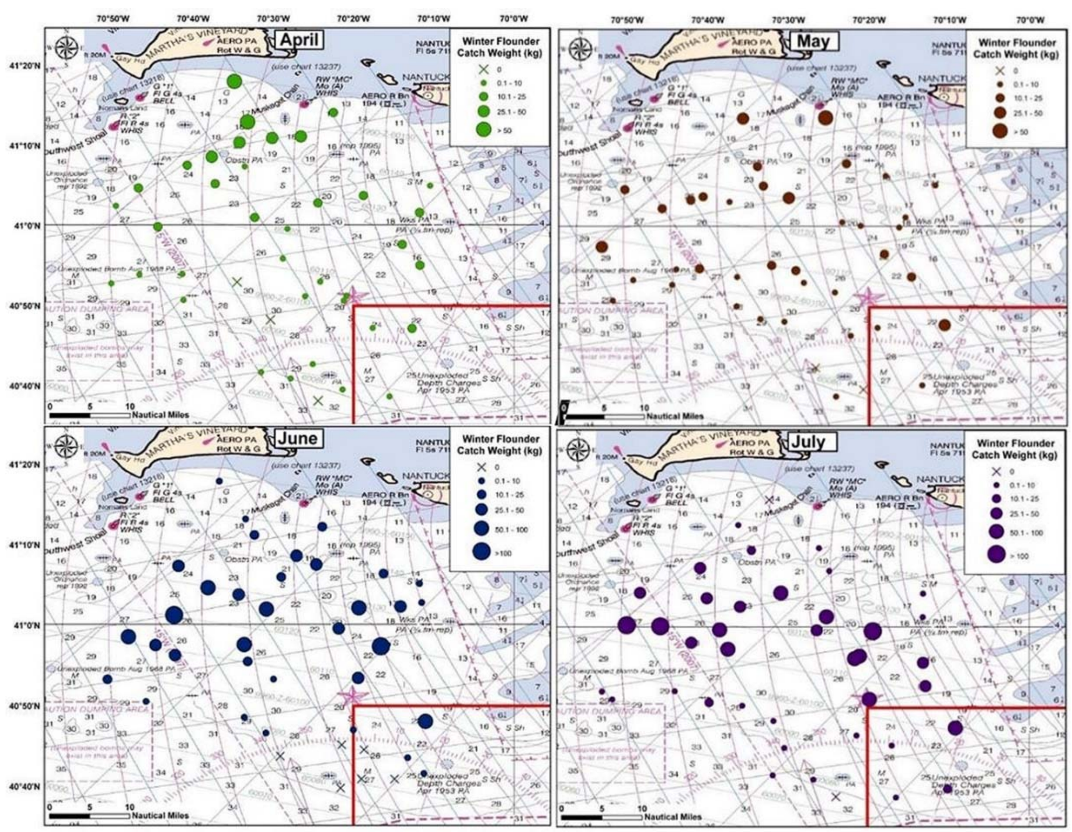

Figure 3*. Winter flounder catches observed in 2012 during each month of the SMAST industry-based survey in southern New England. (Cadrin et al. 2012).*

Project Objectives

Initially, the project had multiple goals including:
(1) Identification of coastal winter flounder spawning grounds and seasonal distribution patterns,
(2) Identification of sympatric species at the various winter flounder habitats,
(3) Collection of biological data to improve stock assessments,
(4) Winter habitat assessment in the survey area, and
(5) Reduction of winter flounder bycatch in the Atlantic sea scallop fishery.

One additional goal was added to the project before applying for permits:
(6) Collection of winter flounder eggs.

Three additional goals were added to the project after the first series of dredge surveys:
(7) Comparison of winter flounder catch in scallop dredges to catch in survey trawl dredges,
(8) Filming of juvenile winter flounder with a remotely operated vehicle (ROV),
(9) Filming of spawning winter flounder with stationary camera array stands.

To meet these objectives, Coonamessett Farm Foundation, Inc. (CFF) completed a series of five winter dredge surveys in southern New England waters between December 2015 and early April 2016 (**Table 1**). Fish catch data collected during the dredge surveys provided needed information about fish winter presence in the area. Furthermore, because each dredge station was also surveyed at least once with a towed camera sled, the CFF survey provided information about benthic habitat in this area.

Because we caught few winter flounder in our dredge survey and the rocky bottom at some stations damaged our turtle deflector dredges (TDDs), the project was modified after the fifth dredge survey trip. One trip was conducted to compare winter flounder catch in the NEAMAP survey trawl versus a scallop dredge to assess the validity of using a dredge for a flounder survey. Two short day trips focused on searching for juvenile winter flounder using our ROVs in Mount Hope Bay and Point Judith Pond. Based on discussions we had at the Flatfish Biology Conference about the need for observations of winter flounder spawning behavior, a final trip was conducted with our stationary camera array stands to film in areas where we previously caught winter flounder (February 2016) or received reports from fishermen about winter flounder presence.

Table 1. *Survey months with trip start and end dates and survey type.*

Month	Start date	End date	Survey type
December	12/07/15	12/11/15	Dredge and video sled
Early February	02/02/16	02/05/16	Dredge and video sled
Late February	02/22/16	02/26/16	Dredge and video sled
March	03/15/16	03/18/16	Dredge and video sled
April	03/29/16	04/01/16	Dredge and video sled
May	05/17/16	05/19/16	Dredge vs NEAMAP survey trawl
February	02/17/17	02/21/17	Stationary camera array survey

Project Approach - Data Collection and Analysis

Scallop dredge tows were conducted at 32 stations during each trip (**Figure 4**). One additional station just south of Martha's Vineyard was surveyed during four of the trips (December, late February, March, and April), while an additional six stations were surveyed in early February. Scallop and fish catch at each station was recorded, with a focus on four species - winter flounder, windowpane flounder, yellowtail flounder, and monkfish. Because the project focused on the identification of offshore winter flounder spawning grounds, we also collected reproductive stage data for every winter flounder taken during the surveys. We conducted video surveys at 33 of the dredge survey stations (**Figure 4**), and each site was categorized based on the bottom type (sand, gravel, or rocks) and amount of shell hash and sand dollars (high, low, or absent). A plankton net was attached to the benthic video survey sled to collect winter flounder eggs. Samples from the net were sorted and examined under a microscope.

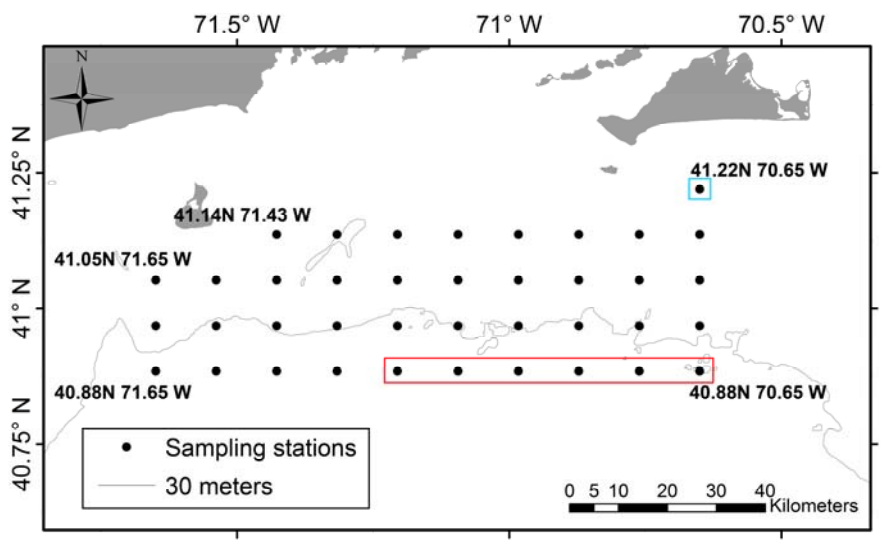

Figure 4. *Location of the dredge and video survey stations. The dredge station outlined in blue was surveyed during four out of five trips and the six stations outlined in red were surveyed during one trip. All other stations were surveyed during all five trips. Video surveys were conducted at all but the six stations outlined in red.*

Dredge Surveys

The dredge surveys used a fixed grid design, with the stations laid out to cover waters from Block Island to south of Martha's Vineyard at depths close to 30 meters. CFF and the commercial fishermen we surveyed had previously caught winter flounder in this area, and some fishermen reported catching ripe winter flounder during February and March. Stations were separated by 9.3 km east to west and north to south. Each tow passed through the center of the pre-determined grid cell, with tow start points, and therefore tow directions, determined randomly for each station prior to the research cruises.

During each survey, two commercially rigged scallop dredges, owned by CFF, were towed from the vessel. The control dredge bag had a typical 7-row apron, while the experimental dredge had a shorter 5-row apron. The dredge bags were not lined because the study was targeting only larger mature winter flounder. Tows were 15 minutes long at 4.8 knots. During the first three trips (December and early and late February), two turtle-deflector dredges were used for the surveys. However, because the dredge headbales were repeatedly damaged by rocks at some of the stations, the control headbale was switched to the stronger New Bedford dredge (NBD) for the last two trips (March and April). The dredge configuration details are shown in **Table 2**.

Start and end coordinates, depth, and temperature were recorded for each tow, with temperature and depth recorded every 30 seconds using Star-Oddi DST milli-TD temperature-depth loggers attached to the dredges. After each tow, scallops and commercially important fish species were sorted, counted, and measured. The reproductive stage of each winter flounder was determined using established sex and reproductive stage guidelines (Brown-Peterson et al. 2011) based on characteristics of the reproductive organs during gross dissections.

To confirm that our dredges catch winter flounder when and where the NEAMAP survey trawl does, we conducted a dredge tow immediately after and near 21 stations surveyed in May 2016.

Table 2. *Dredge configuration details*

Specification	Control TDD	Experimental TDD	Control NBD
Width	4.57 meters	4.57 meters	4.57 meters
Ring size	4 inch	4 inch	4 inch
Apron	7-by-40 ring	5-by-40 ring	7-by-40 ring
Bag	10-by-40 ring	10-by-40 ring	10-by-40 ring
Sides	6-by-18 ring	6-by-20 ring	6-by-18 ring
Skirt	2 ring	2 ring	3 ring
Twine top mesh	10.5 inch	10.5 inch	10.5 inch
Hanging ratio	2-to-1	2-to-1	2-to-1
Turtle mat	Present	Present	Present
Ticklers	9 rows	9 rows	9 rows
Scope	3:1 + 10	3:1 + 10	3:1 + 10

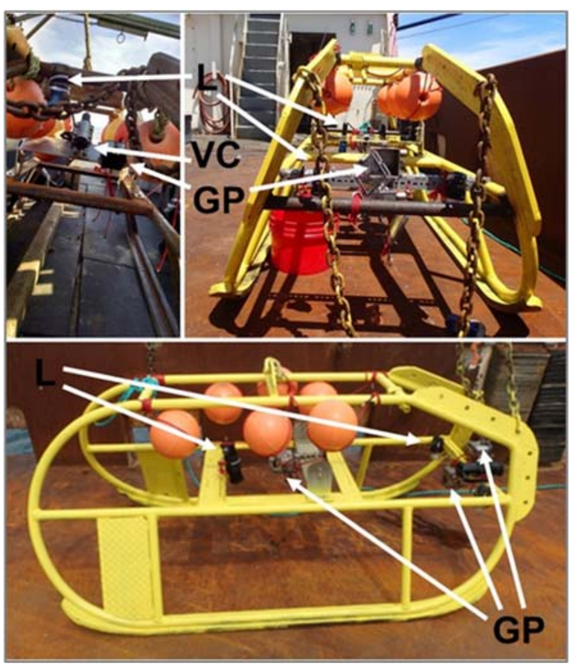

Figure 5. *On-deck photos of the benthic sled with different camera (VC – Outland Technology underwater camera, GP – waterproof GoPro) housings) and light (L – different underwater LED lights) configurations.*

Towed Video Surveys

Towed video surveys were conducted using the CFF benthic sled (**Figure 5**). The sled was configured with two GoPro cameras with 2.97 mm rectilinear lenses (https://www.peauproductions.com/) facing down, one GoPro camera with the stock fisheye lens facing forward at an oblique angle, and two FIX NEO underwater dive lights angled toward the bottom to illuminate the fields of view for the downward-facing cameras. A rectangular plankton net (Watermark steam drift net with 500 µM mesh) was attached inside the benthic sled frame (**Figure 6**) to collect winter flounder eggs. At least one video transect was conducted at the main stations during the project. To obtain clear images in the videos, the sled had to be towed at speeds of less than 2 knots. Because a large scallop vessel cannot travel continuously and consistently at such a slow speed, we completed the video transects by having the vessel move at faster speeds while approaching the designated video analysis areas, coast through each area, and then pick up speed once again. It was difficult to tow the video sled in bad weather or moderately rough seas, so it was not possible to conduct video surveys at each station during each trip. As a compromise, we chose to survey each station at least once, and survey stations with winter flounder present when conditions permitted. Consequently, some stations were surveyed with the video sled two to four times over the course of the study.

Figure 6. *CFF benthic sled with a plankton net attached inside the frame.*

Stationary camera array surveys

Stationary camera array surveys used CFF's drop camera platforms outfitted with a stereo set-up that included two Sony alpha a6000 cameras, four Hartenberger deep water lights, and large high-capacity batteries (**Figure 7**) or an array of GoPro Hero 4 cameras.

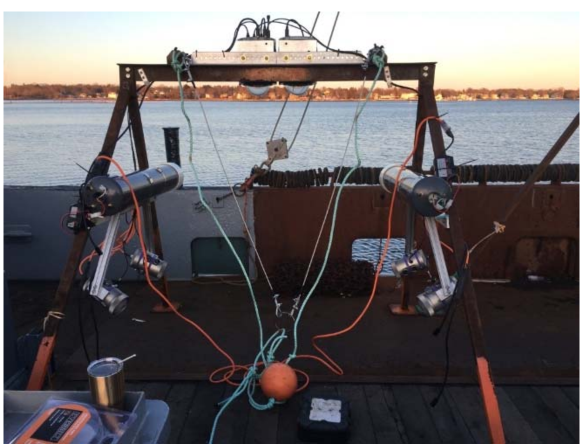

Figure 7. *CFF stationary camera array system.*

Stereo camera frames were deployed in the mid- to late afternoon, and images were taken over 17-24 hours so filming would occur during dusk and night hours when winter flounder are thought to spawn. The cameras were programmed to take images every minute, and the lights were synched to flash when the images were taken. Frames with GoPro cameras were deployed during the day, and video was recorded until the camera batteries died (3-5 hours). Camera stand locations were chosen based on the presence of winter flounder during the February 2016 dredge surveys and fishermen reports (**Figure 8**).

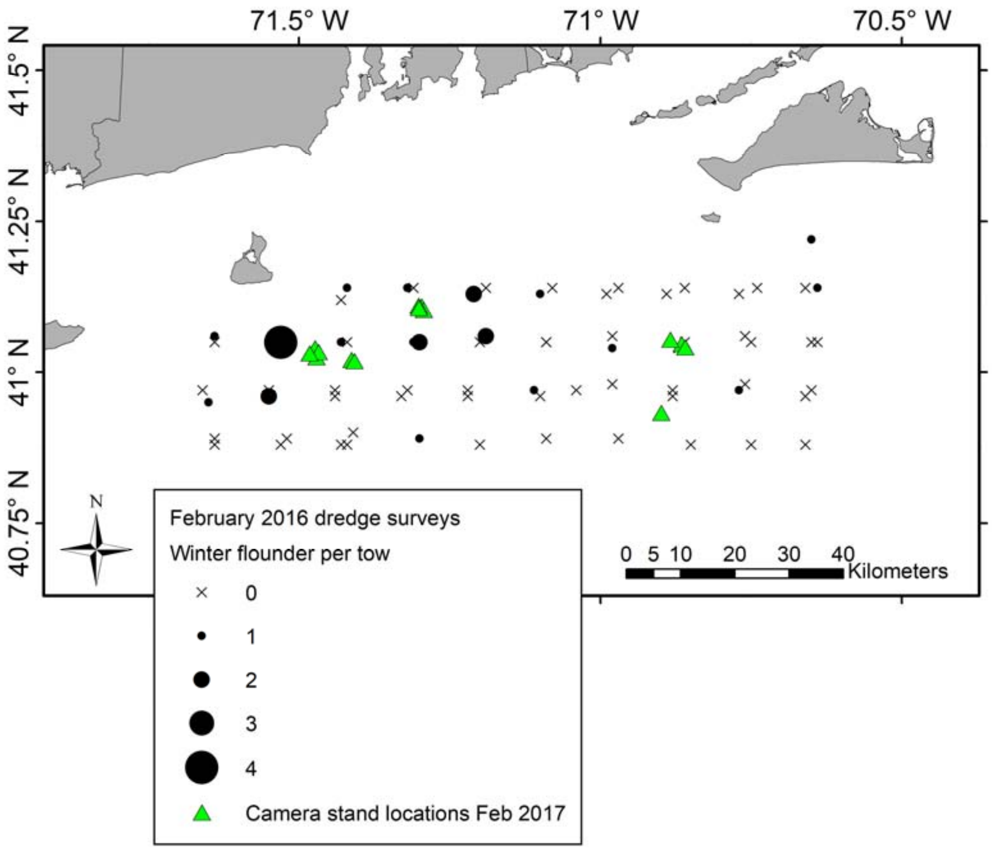

Figure 8. *Locations where the stationary camera stands were deployed in February 2017 and winter flounder catch per dredge tow in February 2016.*

Data Analysis

Video analysis: Videos from the benthic sled tows were analyzed using Behavioral Observation Research Interactive Software event-logging software. All videos were viewed in slow motion by a single trained observer. State and point events were notated according to the scheme in **Table 3**. Equivalent Wentworth scale categories are also listed in **Table 3**.

Mapping in ArcGIS: The substrate types determined from the video analysis were plotted by station, and this layer was included in additional maps for reference. The abundances (number per tow) of winter flounder, windowpane flounder, yellowtail flounder, and monkfish were plotted by station and month. The numbers of winter flounder per reproductive stage were also plotted by station and month. The cumulative abundance of scallops (bushels per tow) was plotted by station. Bureau of Ocean Energy Management (BOEM) wind farm lease area boundaries were also included in the maps.

Statistical analysis: Fish catch by month and substrate type (sand, mixed gravel/sand, and rocky) was summarized using box plots created with the "lattice" package in R (Sarkar 2008). Changes in abundance by trip and substrate preferences were examined using generalized linear models with a negative binomial distribution in the R package "glmmADMB" (Fournier et al. 2012, R Core Team 2015, Skaug et al. 2013). Catch per tow for winter flounder, windowpane flounder, yellowtail flounder, and monkfish was modeled using trip and substrate (sand, mixed, and rocky) as categorical variables. The presence of sand dollars was not included in the models because sand dollar presence was strongly correlated with sandy substrate. The final model was determined based on the Akaike information criterion (AIC) and the Schwarz Bayesian information criterion (BIC) values (Akaike 1973, Schwarz 1978). When the models selected by the two criterion differed, final selection was made by combining the two criteria.

Winter flounder catch numbers and length frequency were compared between the NEAMAP survey trawl and the CFF dredge. CFF results were also plotted with data from the following other surveys to qualitatively compare multiple data sets collected in the same southern New England (SNE) area. In addition, we compared the catch per unit effort (CPUE)7 (fish/km^2) for the CFF surveys in March and April 2016 with the CPUE from the Northeast Fisheries Science Center (NEFSC) spring trawl surveys from 2011 to 2015.

Table 3. *Coding scheme used to annotate video footage. All measurements given are approximate and based on the known size of images taken with a GoPro camera with a 2.97 mm lens mounted on the sled at the known height of the cross bars.*

Variable	Description	Wentworth scale categories
State event (notate start and stop)		
Sand	Grain diameter < 1% of image width (< 75mm)	Sand - small cobble
Gravel	Grain diameter > 1% and < 10% of image width (75 - 600mm)	Cobble
Light shell hash	<= 50% of frame has hash	
Heavy shell hash	> 50% of frame has hash	
Light sand dollars	<= 5 sand dollars per frame	
Heavy sand dollars	> 5 sand dollars per frame	
Point event (notate occurrence)		
Boulder	> 50% of frame (> 290 cm diameter)	Boulder
Cobble	<= 50% of frame	Large cobble - small boulder
Flatfish	Flatfish in frame	
Groundfish	Groundfish in frame	
Skate	Skate in frame	
Sea star	Sea star in frame	
Macroalgae	Macroalgae in frame	

Stationary camera array analysis: Still and videos from the stationary camera arrays were viewed by a single trained observer. All footage was examined for the presence of winter flounder.

Project Management

The project was managed by the staff of CFF, with Carl Huntsberger as the lead researcher for at-sea operations and Liese Siemann as the head of data analysis. CFF is a non-profit organization that has been researching sustainable fisheries operations, and providing resource managers with gear-based solutions for resolving fisheries issues. CFF's purpose is the development and transfer of appropriate technology in support of local communities that are environmentally sound, socially equitable, economically feasible and compatible with a sustainable future.

Results

Substrate Map and the Coastal and Marine Ecological Classification Standard

Substrate with shell hash was rarely observed in the videos, so that category was removed when the video data was summarized for mapping. Therefore, the substrate map shows the locations of sandy substrate, mixed gravel substrate, rocks, and areas with high sand dollar concentrations (**Figures 9 and 10**).

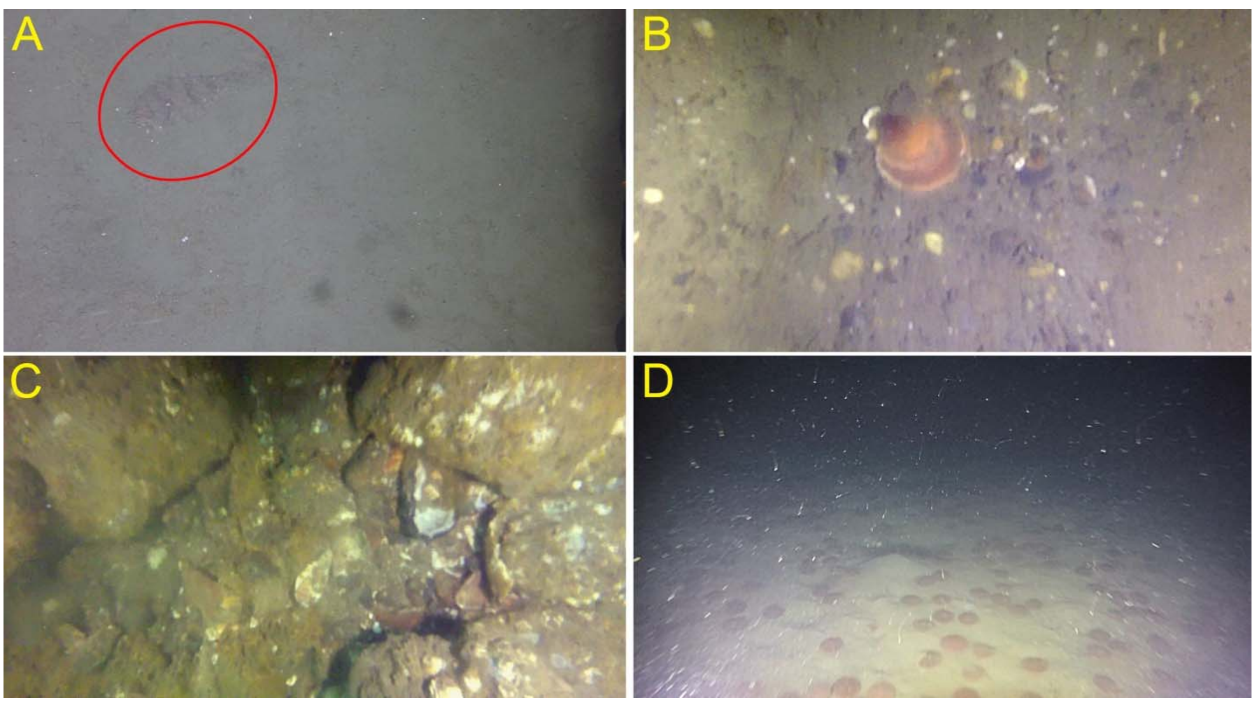

Figure 9. *Examples of substrate types seen in the video survey. A) Sandy substrate with a small ~13 cm summer flounder (circled in red). B) Mixed substrate with a ~102 mm scallop. C) Rocky substrate. D) Area with a high concentration of sand dollars. Images A-C were taken with the downward-facing GoPro camera (field of view ~ 0.23 m^2). Image D was taken with the forward-facing GoPro camera.*

Most of the survey area had sandy substrate, including the majority of the area overlapping the BOEM lease areas (**Figure 10**). High concentrations of sand dollars were found only at the sandy stations (**Figure 10**). Six of the stations in the northwest corner of the survey area had mixed gravel substrate, and rocks (cobble and boulders) were seen in the videos from six stations in the same area (**Figure 10**). The habitat types observed in the CFF video survey were classified according to Coastal and Marine Ecological Classification Standard criteria, and the groups are listed in **Table 4** (NOAA 2012).

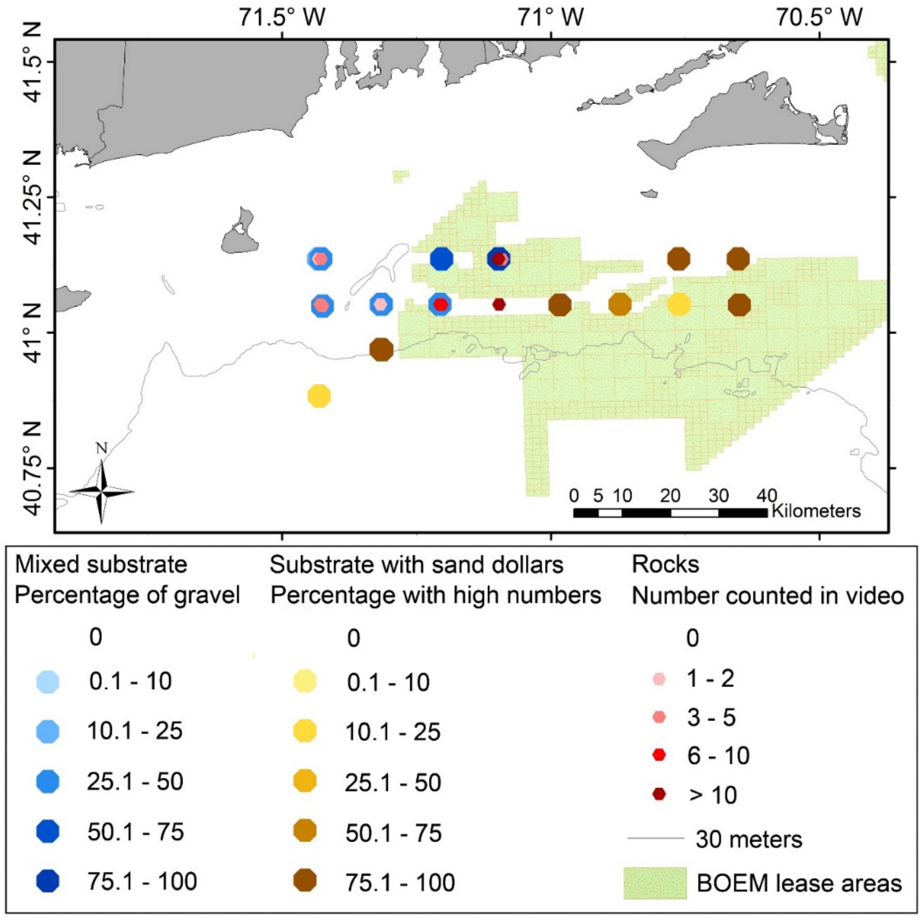

Figure 10. *Map of the habitat categories determined from the video analysis.*

Table 4. *Classifications of geologic and biotic substrates from the CFF video survey in SNE waters in accordance with Coastal and Marine Ecological Classification Standards.*

Component	Origin	Class	Subclass	Group	Subgroup/ Community
Substrate	Geologic substrate	Unconsolidated mineral substrate	Fine unconsolidated substrate	*	*
Substrate	Geologic substrate	Unconsolidated mineral substrate	Coarse unconsolidated substrate	Gravel	Cobble and boulder
Substrate	Biogenic substrate	Shell substrate	Shell hash	*	*
Biotic	Benthic/ attached biota	Benthic/ attached biota	Faunal bed	Soft sediment fauna	Sand dollar bed
* Identification to group and subgroup/community was not possible using benthic sled video					

At one station surveyed in December and March using the video sled, we observed very different benthic substrates (**Figure 11**). Very rocky substrate was observed in December, while sandy substrate was observed only 380 meters to the west in March. This could have been due to mobilization of substrate during the months between the surveys, with sand covering the rocky areas observed in December. Alternatively, bottom substrates could be very patchy in this region.

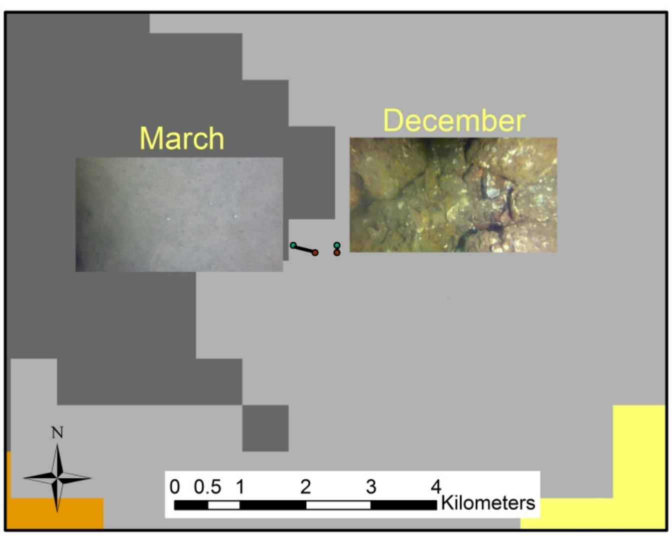

Figure 11. *Substrate types observed during two video surveys at the same Background colors indicate substrate types from the USGS sediment data sets with dark gray indicating gravel and light gray indicating coarse sand.*

Dredge Survey and Fish Catch

The catch per trip and average catch per station by month and by substrate type for winter flounder, windowpane flounder, yellowtail flounder, and monkfish are summarized in **Tables 5 – 7**. Box plots summarizing the catch per station by month and by substrate type are shown in **Figures 11 and 12**. Catch data at each station by month can be found in **Table A1** of **Appendix A**.

The catch at each station was plotted by month for each fish species. The map sets are shown in **Figures 14 - 17**. Winter flounder catches were low overall, with the largest number caught in December (**Figure 12**). They were caught along the northern edge of the survey area in December, while the catch shifted west to the mixed substrate stations in February. Windowpane flounder catch was also highest in December, and while there was no clear shift in the catch distribution by month, catch was significantly lower at the rocky stations (**Figure 13**). Like the other two flounder species, yellowtail flounder catch was highest in December, and the catch distribution shifted from the northern to more southern stations (**Figure 13**). Monkfish catch peaked in March, and catch was highest toward the southwest stations throughout the survey months (**Figure 12**). Monkfish catch was significantly lower at the mixed and rocky stations (**Figure 13**).

Table 5. *Catch per trip (month) for winter flounder, windowpane flounder, yellowtail flounder, and monkfish.*

Month	Total number caught per trip			
	Winter flounder	Windowpane flounder	Yellowtail flounder	Monkfish
December	23	475	50	220
Early February *	16	374	42	244
Late February	9	245	14	257
March	3	184	19	311
April	5	214	18	237

* The early February trip included 6 additional stations

Table 6. *Average catch per station by trip (month) for winter flounder, windowpane flounder, yellowtail flounder, and monkfish.*

Month	Average number caught per station			
	Winter flounder	Windowpane flounder	Yellowtail flounder	Monkfish
December	0.72	14.84	1.56	6.88
Early February	0.48	11.33	1.27	7.39
Late February	0.28	7.66	0.44	8.03
March	0.10	5.94	0.61	10.03
April	0.16	6.69	0.56	7.41

Table 7. *Average catch per station by substrate type for winter flounder, windowpane flounder, yellowtail flounder, and monkfish.*

Substrate	**Average number caught per station**			
	Winter flounder	Windowpane flounder	Yellowtail flounder	Monkfish
Sand	0.31	10.06	0.96	9.02
Mixed	0.89	6.44	0.78	2.33
Rocky	0.40	4.40	0.40	1.40

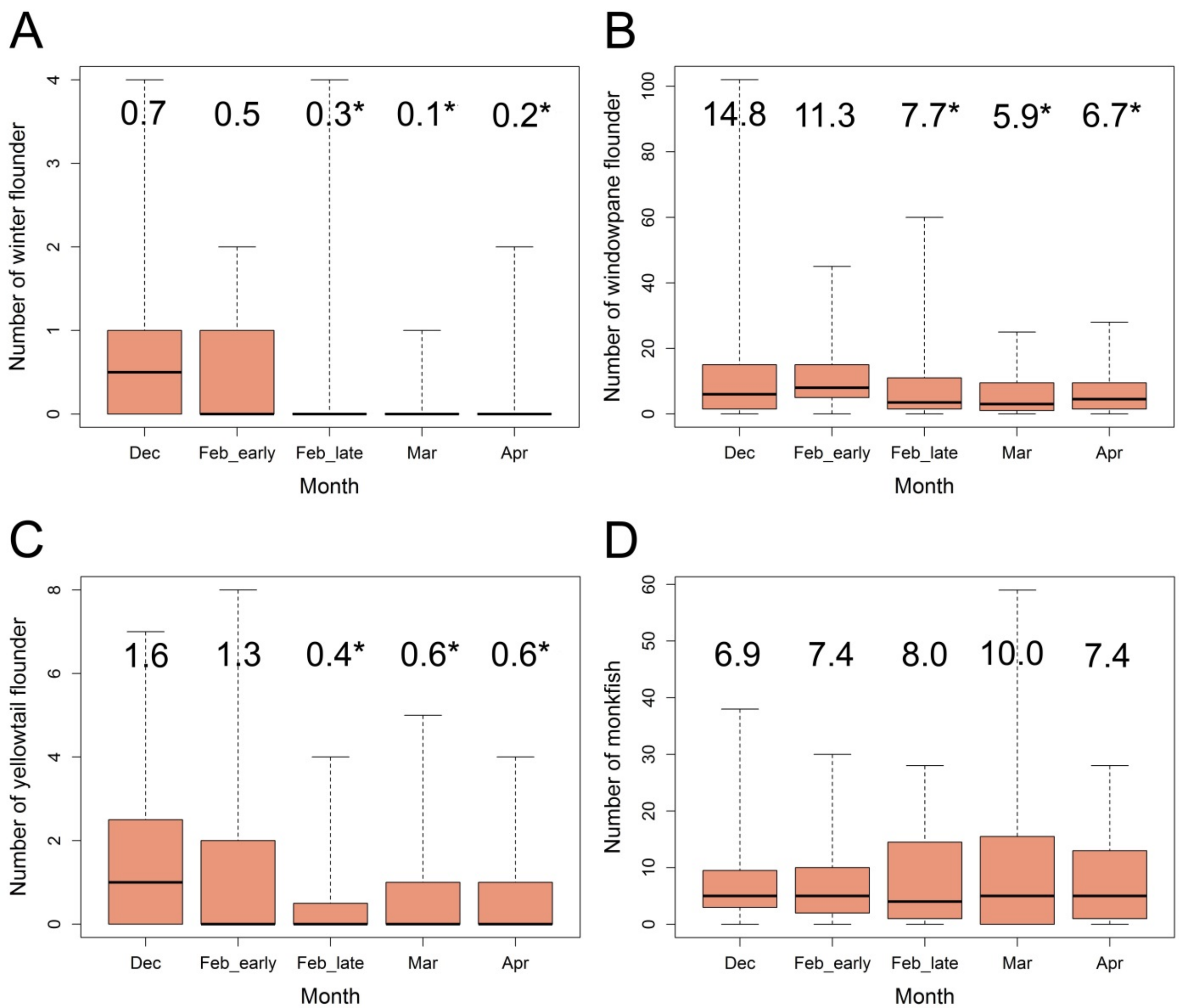

Figure 12. *Box plots showing the catch by month for A) winter flounder, B) windowpane flounder, C) yellowtail flounder, and D) monkfish. Boxes end at the first and third quartiles of the distribution of catches per station, with the whiskers extending to the minimum and maximum catch values. The lines in the boxes are the median catch per station each month. Numbers above each month are the average catch per station each month, and asterisks indicate that the catch was significantly different from the catch in December.*

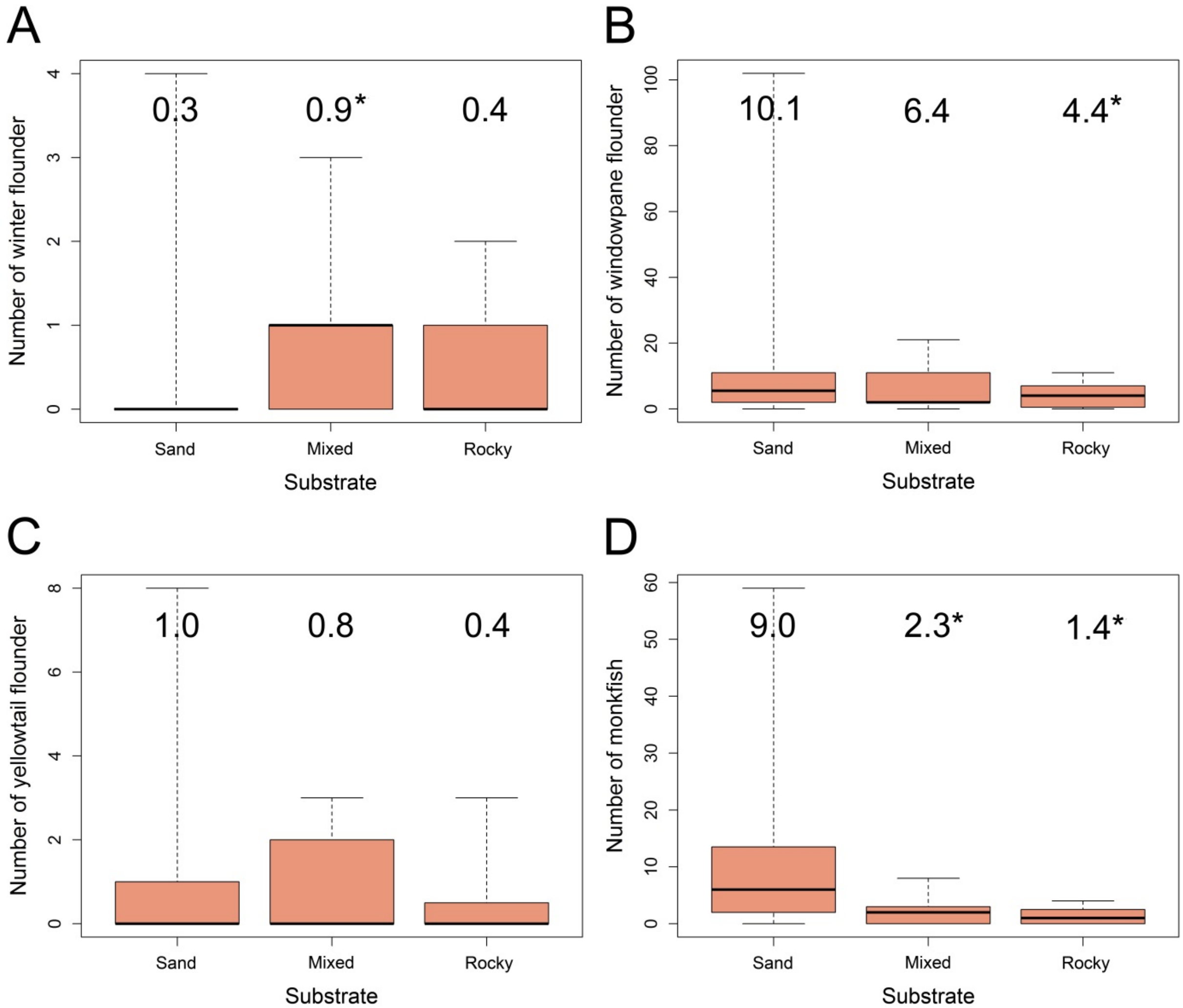

Figure 13. *Box plots showing the catch by substrate type for A) winter flounder, B) windowpane flounder, C) yellowtail flounder, and D) monkfish. Boxes end at the first and third quartiles of the distribution of catches per station, with the whiskers extending to the minimum and maximum catch values. The lines in the boxes are the median catch per station on each substrate type. Numbers above each substrate are the average catch per station, and asterisks indicate the catch was significantly different from the catch on sand.*

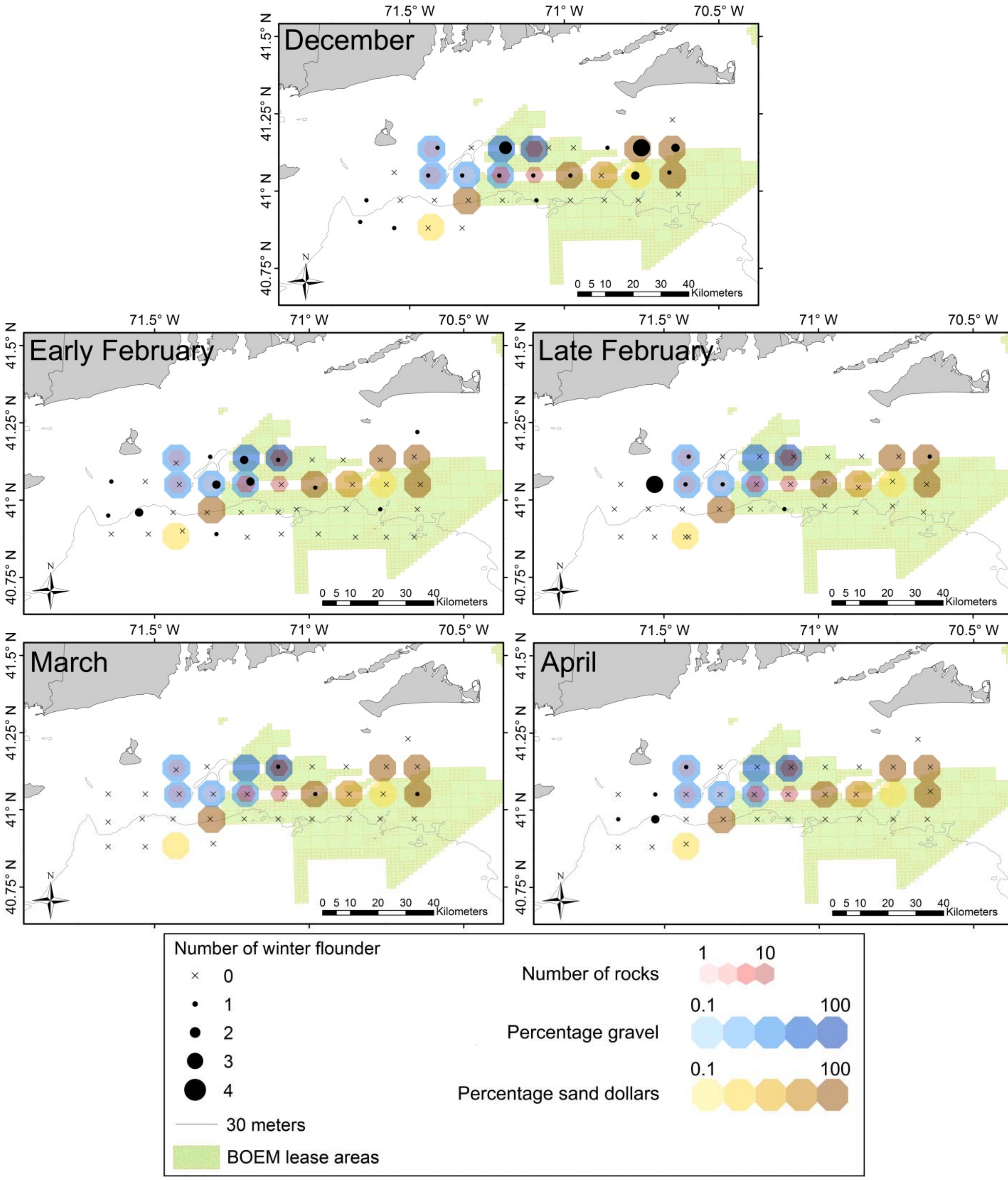

Figure 14. *Winter flounder catch by month*

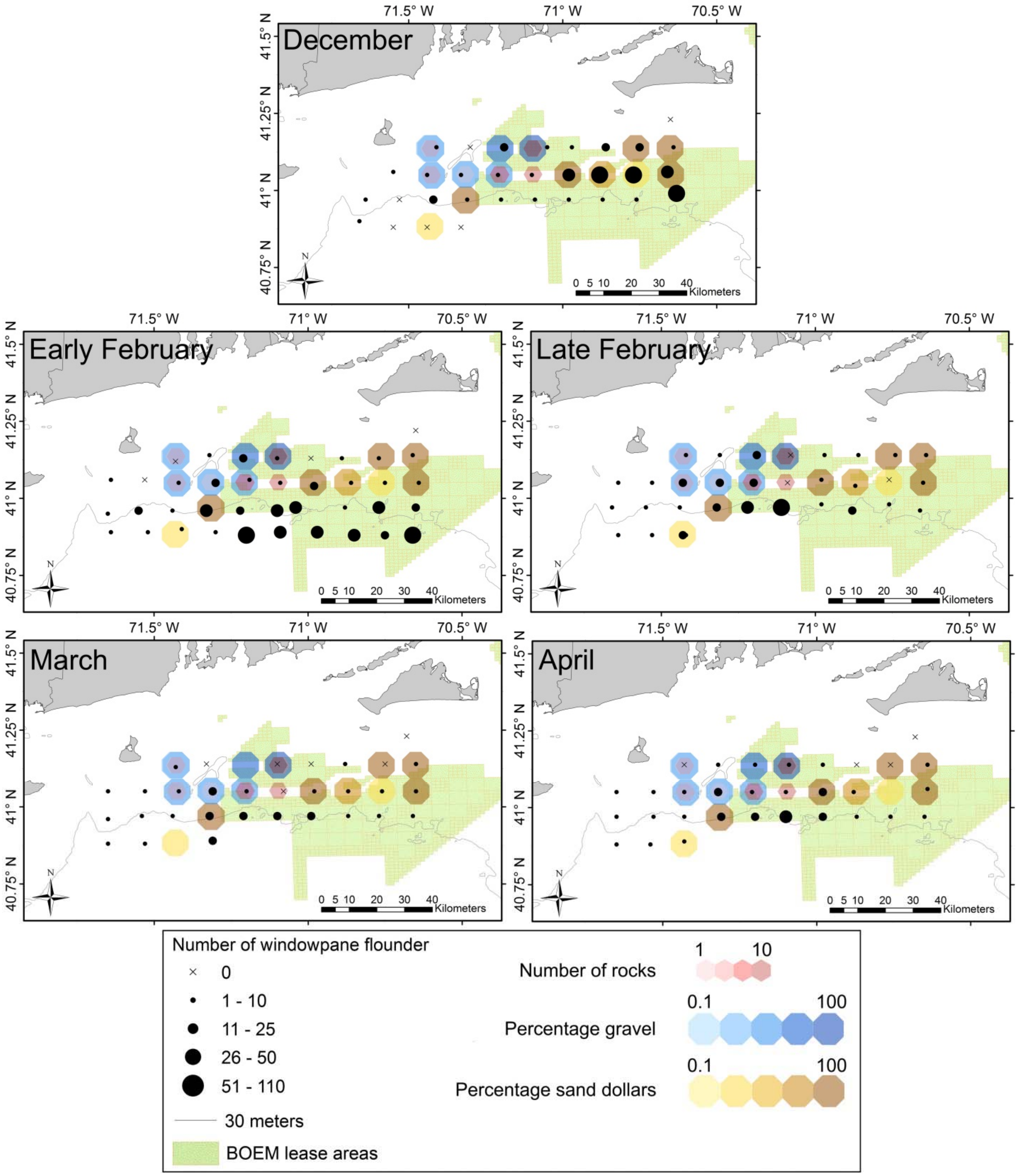

Figure 15. *Windowpane flounder by month*

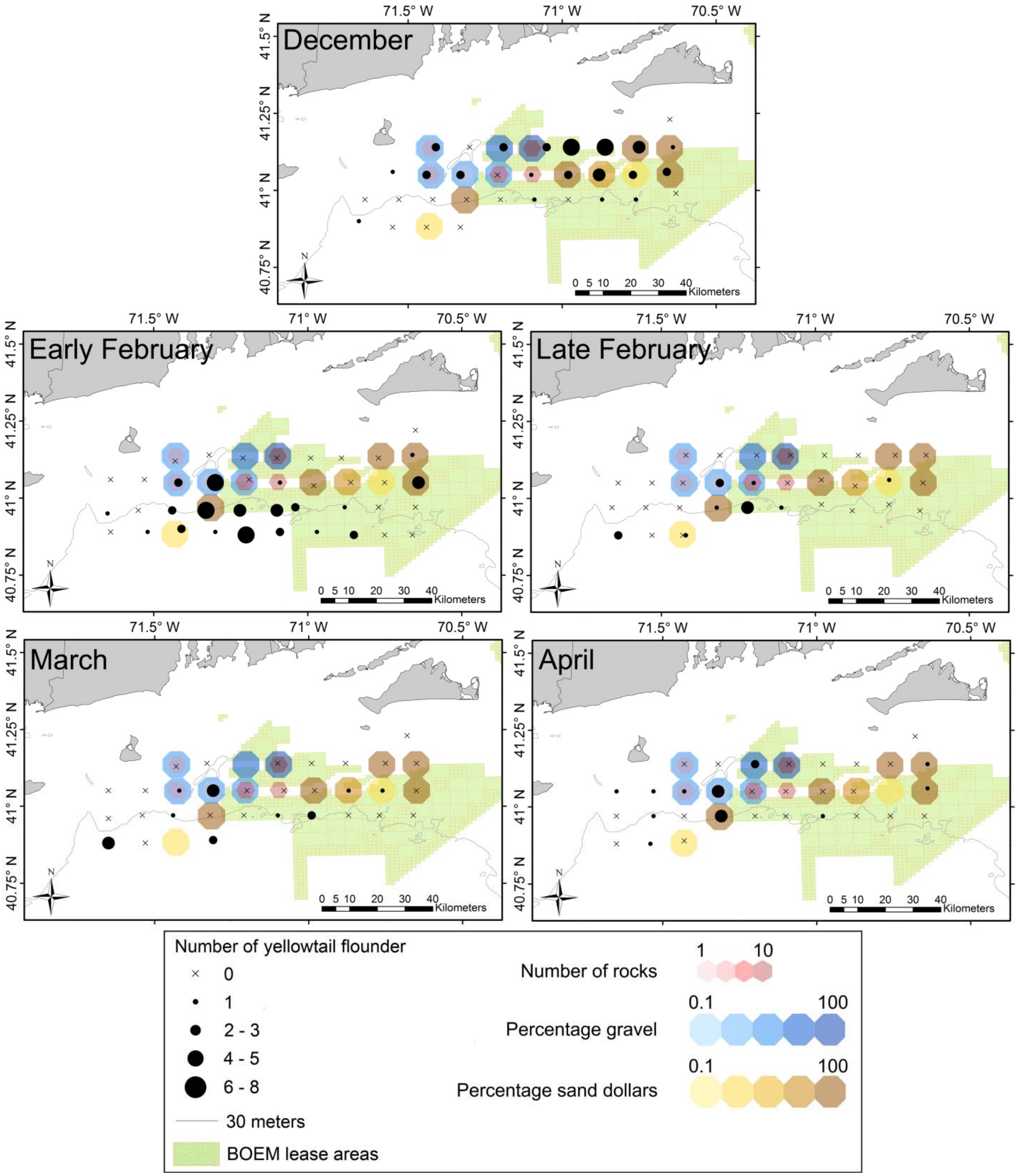

Figure 16. *Yellowtail flounder catch by month*

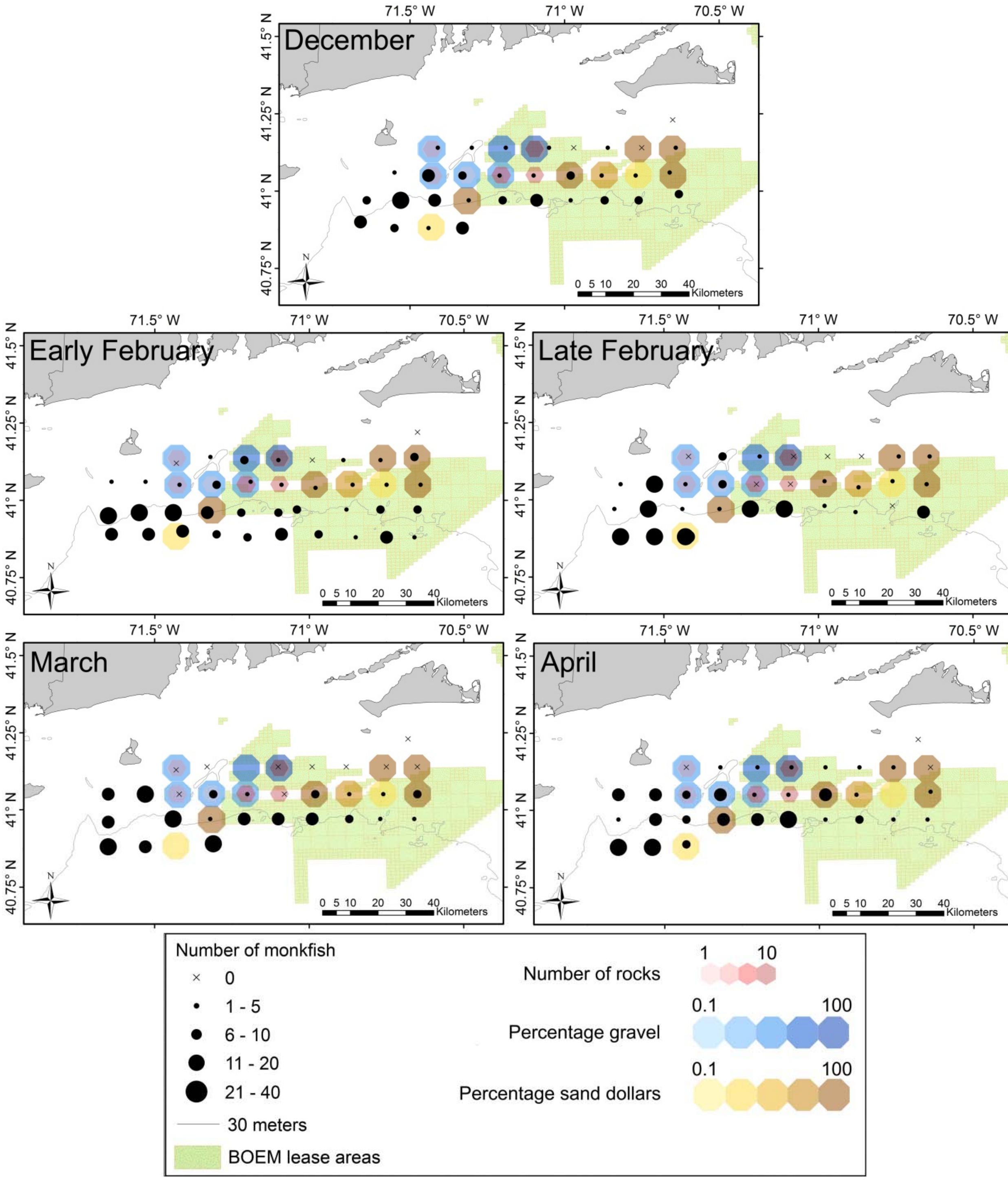

Figure 17. *Monkfish catch by month*

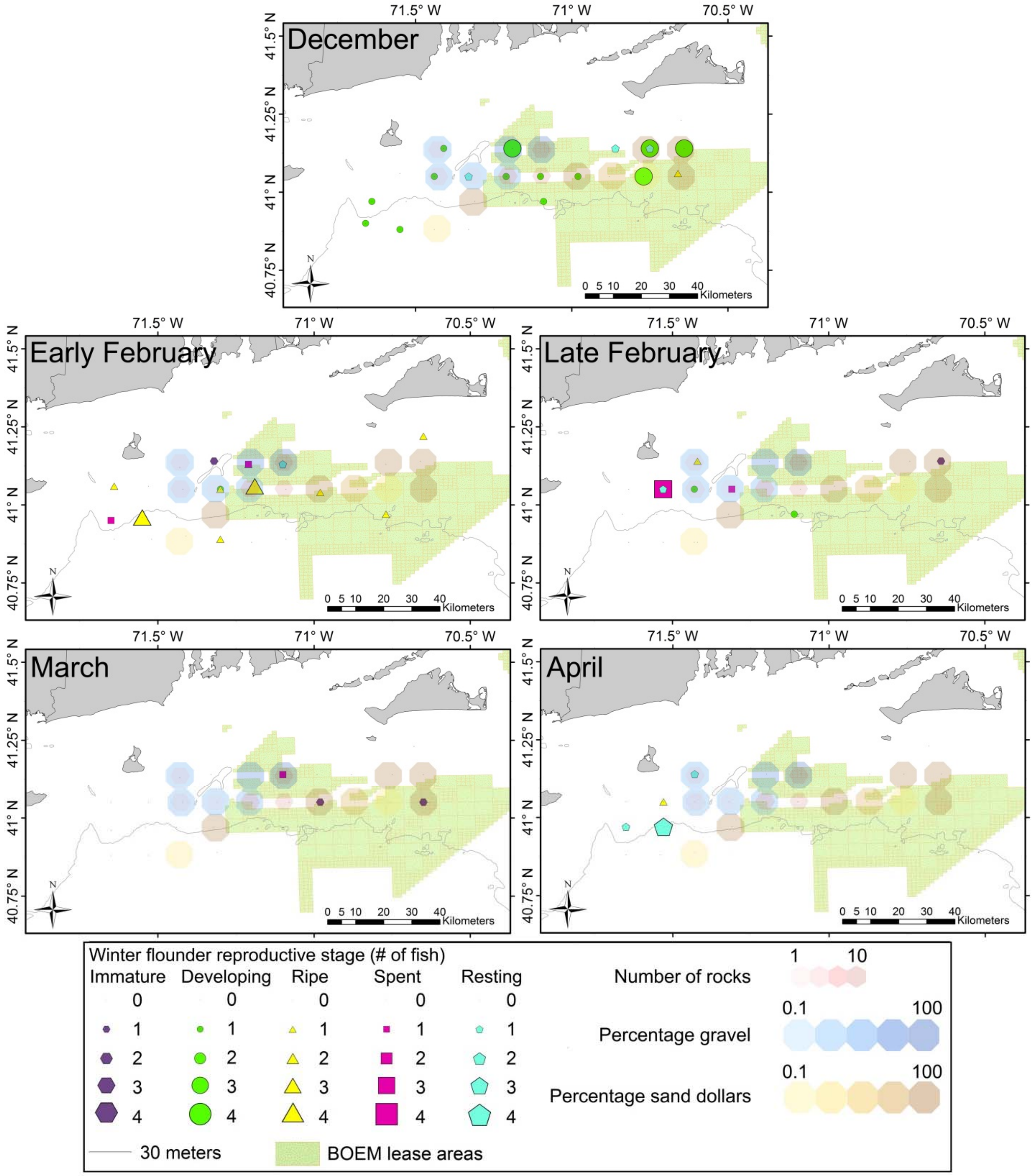

Figure 18. *Winter flounder catch and reproductive stage by month.*

Winter flounder catch was classified by reproductive stage and mapped by month (**Figure 18**). Stage data for each station by month can be found in **Table A2** of Appendix A. The majority of the flounder caught in December were developing, although a few were resting and one was ripe. By early February, most of the flounder were ripe, but a few immature, resting, or spent fish were caught. By late February, the majority of the flounder were spent, and fish in each reproductive stage were caught. In March, the few flounder that were caught were immature or spent. By April, most of the flounder were resting, although one ripe fish was also caught.

Statistical Modeling

The catch numbers for winter flounder, windowpane flounder, yellowtail flounder, and monkfish were modeled with month (trip) and substrate included as fixed effects. Stations with greater than seven rocks observed during the video survey were classified as rocky when defining the modeling categories. Stations with more than 25% of the video footage (by time) classified as gravel were defined as mixed. When stations were surveyed more than once, substrate percentages and rock counts were averaged before categorizing the station. The best fitting models were selected based on the lowest AIC and BIC values combined (**Table 8**). The best fitting model for the three flounder species did not include substrate as a predictor, while only substrate was included in the best fitting model for monkfish. The model outputs, including coefficient estimates, are shown in **Table 9**.

Table 8. *AIC and BIC values for models to predict catch numbers of winter flounder, windowpane flounder, yellowtail flounder, and monkfish using month and substrate or month or substrate alone as predictors. Models with the lowest combined criteria values are highlighted with pale yellow.*

Species	Month and substrate		Month		Substrate	
	AIC	BIC	AIC	BIC	AIC	BIC
Winter flounder	240.7	265.3	240.6	259.0	251.1	263.4
Windowpane flounder	1037.5	1062.1	1039.9	1058.4	1043.3	1055.6
Yellowtail flounder	409.2	433.8	408.4	426.8	414.5	426.8
Monkfish	984.9	1009.5	1006.4	1024.8	977.7	990.0

Table 9. *Final models for catch numbers of winter flounder, windowpane flounder, yellowtail flounder, and monkfish as determined by AIC and BIC values.*

	Coefficient Estimate	Standard error	z-value	p-value
Winter flounder				
(Intercept)	-0.3300	0.2470	-1.3400	0.1806
Early February	-0.3940	0.3740	-1.0500	0.2930
Late February	-0.9380	0.4350	-2.1600	0.0310
March	-2.0050	0.6420	-3.1200	0.0018
April	-1.5260	0.5270	-2.8900	0.0038
Windowpane flounder				
(Intercept)	2.6980	0.2090	12.9000	0.0000
Early February	-0.2700	0.2950	-0.9200	0.3597
Late February	-0.6620	0.2990	-2.2100	0.0269
March	-0.9170	0.3040	-3.0200	0.0025
April	-0.7970	0.3000	-2.6600	0.0079
Yellowtail flounder				
(Intercept)	0.4460	0.2750	1.6200	0.1043
Early February	-0.2050	0.3910	-0.5200	0.6001
Late February	-1.2730	0.4500	-2.8300	0.0047
March	-0.9360	0.4310	-2.1700	0.0298
April	-1.0220	0.4320	-2.3700	0.0180
Monkfish				
(Intercept)	2.1997	0.0951	23.1300	0.0000
Mixed	-1.3524	0.4254	-3.1800	0.0015
Rocky	-1.8632	0.3623	-5.1400	0.0000

CFF dredge versus survey trawl catch

Winter flounder were present in the dredge and NEAMAP surveys at 11/21 stations, present in only the trawl survey at 8/21 stations, present in only the dredge at 1/21 stations, and absent in both surveys at 1/21 stations. When both survey gears caught winter flounder, the trawl caught more at 10/11 stations (**Figures 19 and 20**). The dredge selected for larger fish (**Figure 21**). All winter flounder caught in the dredge were above the L50 size of first maturity for this species. In contrast, 44% of the winter flounder caught in the trawl were below this size (by design, since the trawl has a small-mesh liner). Because this study was focused on catching mature fish, this selectivity difference was advantageous.

For the current project, we compared the CPUE (fish/km^2) for the CFF surveys in March and April 2016 with the CPUE from the NEFSC spring trawl surveys from 2011 to 2015. The resulting maps are shown in **Figure 22**. Overall, the trends match those CFF observed previously. Catch for the trawl (NEFSC) surveys was higher for winter and yellowtail flounder, while catch for the dredge (CFF) surveys was higher for windowpane flounder and monkfish (**Figure 22**).

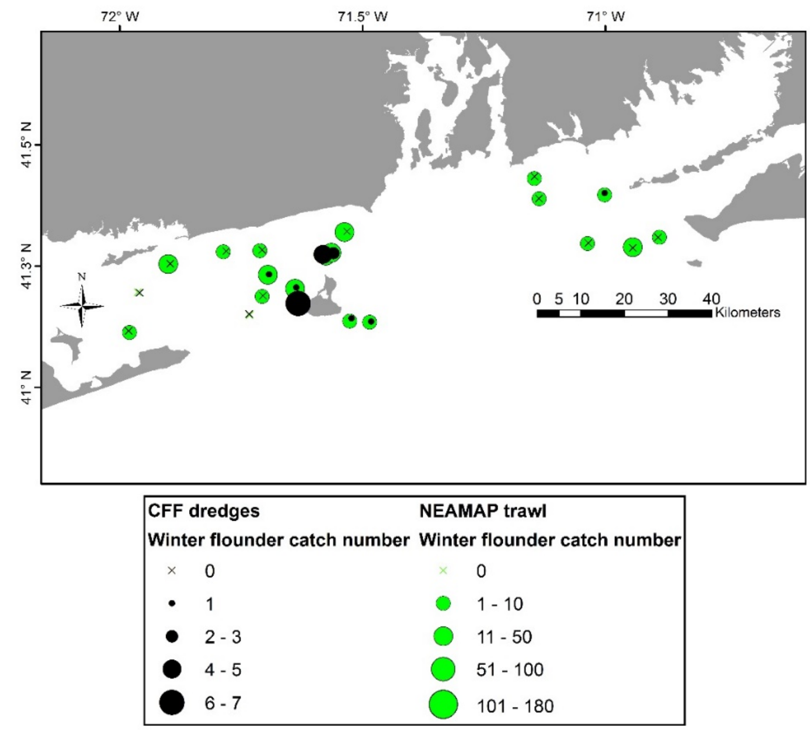

Figure 19. *Locations of the CFF and NEAMAP concurrent survey stations*

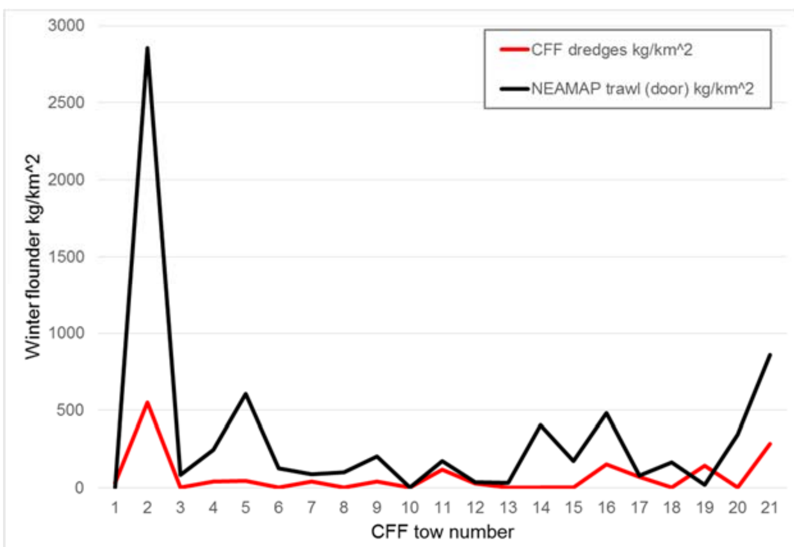

Figure 20. *Winter flounder catch per unit area by station for CFF dredges and the NEAMAP survey trawl*

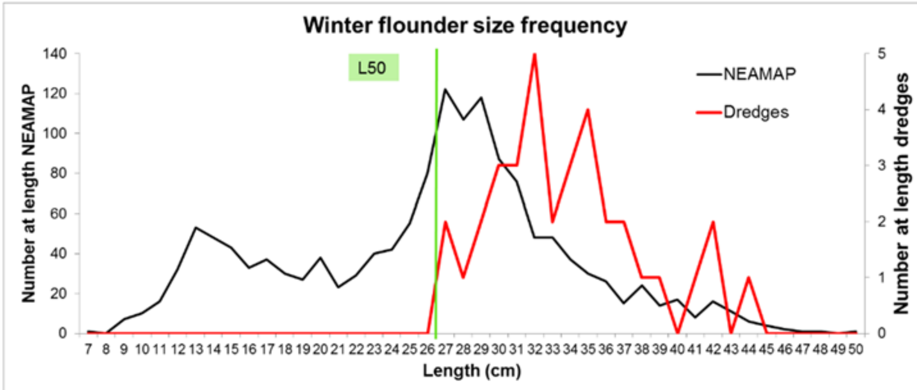

Figure 21. *Winter flounder size-frequency curves for the CFF dredge (right axis) and the NEAMAP trawl (left axis) catches. Winter flounder size at maturity (L50) from NEFMC 2014.*

As was observed with the NEAMAP trawl, catch in the NEFSC trawl surveys was higher for winter flounder. Catch was also higher for yellowtail flounder, while catch for the dredge surveys was higher for windowpane flounder and monkfish (**Figure 21**).

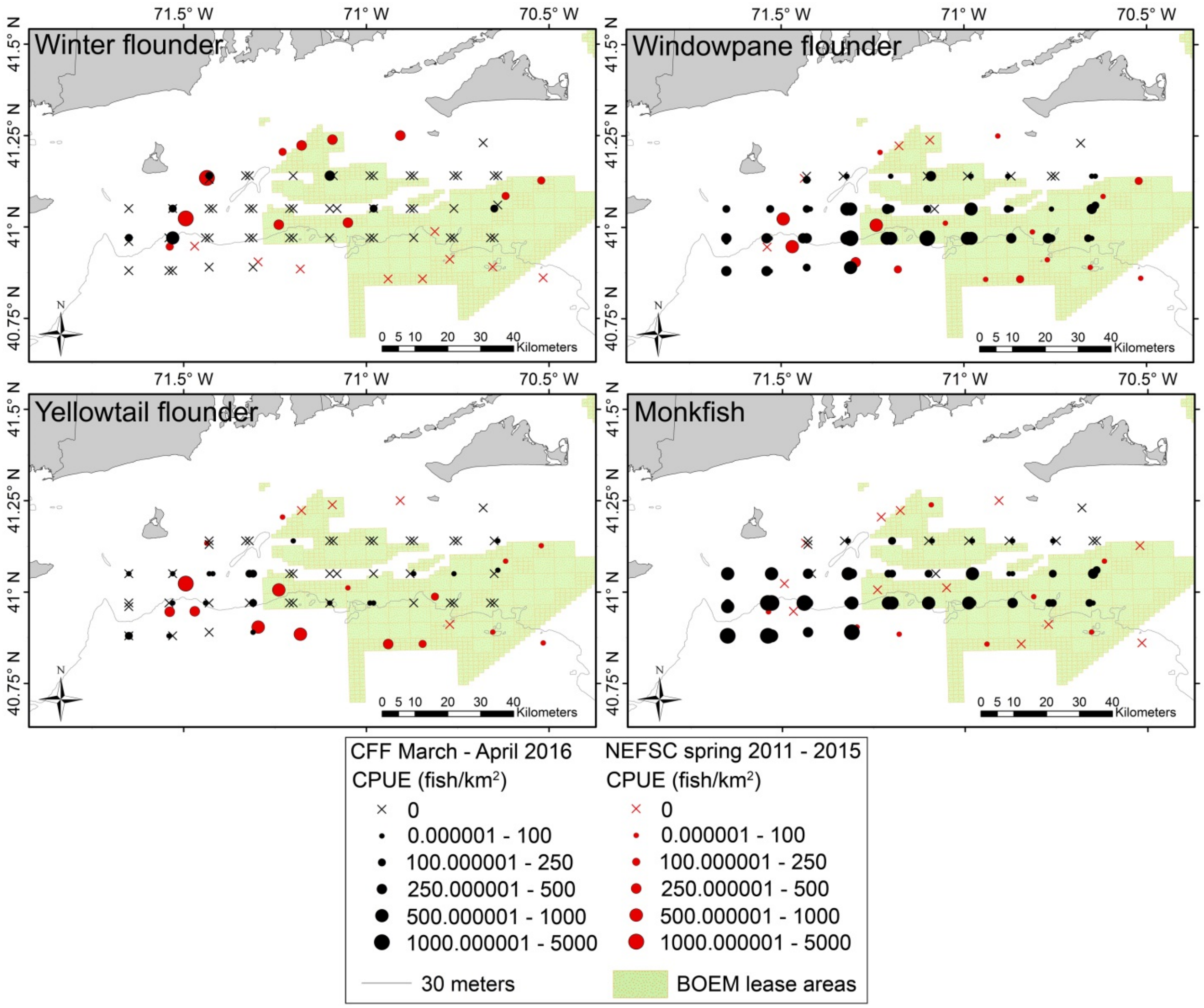

Figure 22. *CPUE of winter flounder, windowpane flounder, yellowtail flounder, and monkfish in the 2015-2016 CFF dredge survey and the 2011-2015 NEFSC spring bottom trawl surveys.*

Video surveys

We did not capture video footage of juvenile flounder during any trips. During our previous research trip using the stationary camera arrays, we recorded scallop dispersal behavior and scallop responses to predators, as well as feeding behavior of multiple fish species and crabs (**Figure 23A**). However, despite building an improved camera system with higher resolution cameras and synchronized strobes, we did not observe any winter flounder. We believe that there were very few fish in the area. Only a few skate, hake, and a seal appeared during our baited video sessions (**Figure 23B-D**), and fishermen we spoke to said during this season they were not seeing winter flounder in their typical areas or in concentrations they observed previously.

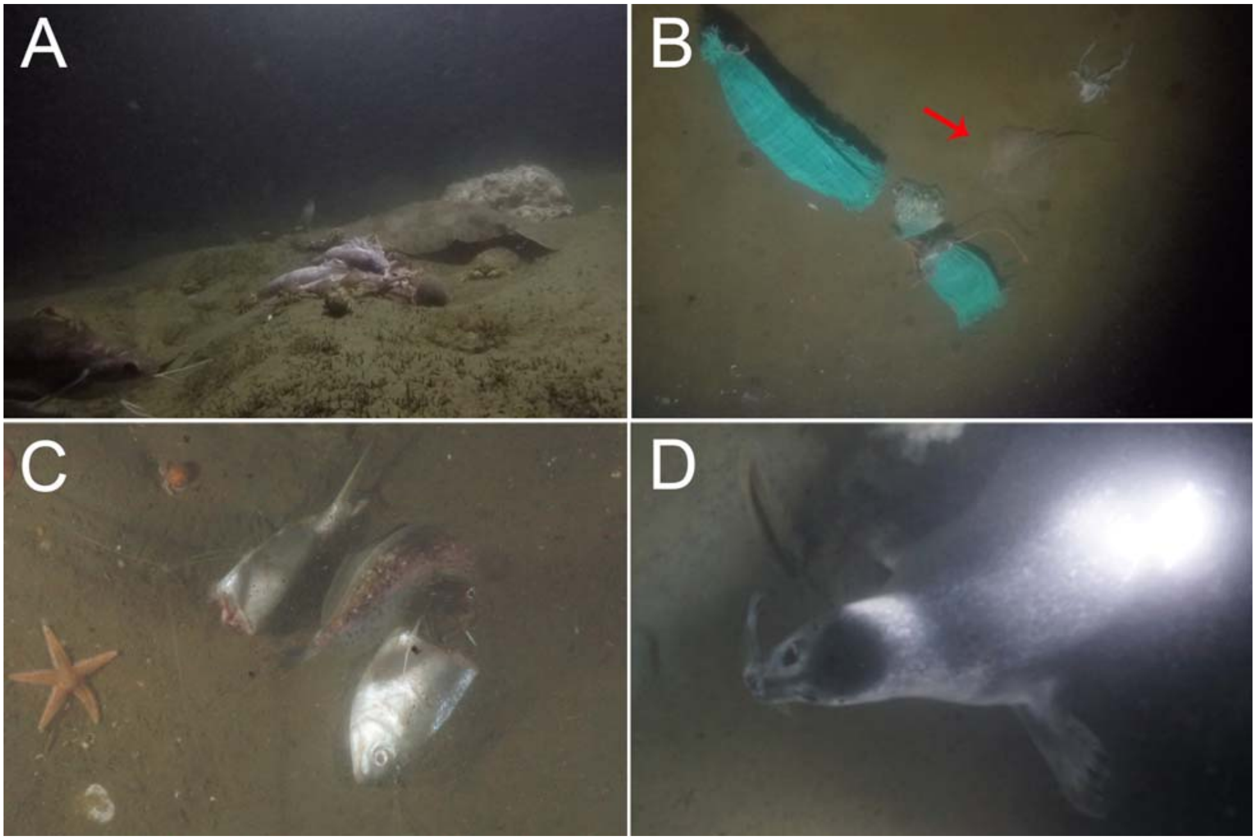

Figure 23. *Stills taken from Go-Pro footage of baited camera stands (A) during deployment in August in the eastern part the Nantucket Lightship Closed Area and (B-D) during deployment in February south of Rhode Island where winter flounder were caught in 2016. (A) A wide variety of fish species were observed in August, including winter flounder, summer flounder, and red hake (shown), as well as monkfish, conger eel, skate, and dogfish (not shown). Only (B) a few skate, (C) hake, and (D) a harbor seal, a known flounder predator, were seen during the February research trip.*

Accomplishments by Objective

(1) Identification of coastal winter flounder spawning grounds and seasonal distribution patterns

We attended the recent 15th Flatfish Biology Conference on December 6th and 7th, 2016 in Westbrook, CT and presented data from this project. Because we identified ripe winter flounder in early February and spent flounder in late February, experts at the conference universally agreed that winter flounder were spawning offshore in SNE waters. The consensus was that ripe and spent winter flounder swim slowly and therefore could not enter, spawn in, and then leave nearby Narragansett Bay, the closest documented winter flounder spawning location, in 2 ½ weeks.

(2) Identification of sympatric species at the various winter flounder habitats

Three important commercial fish species were caught during the dredge surveys, all in numbers that surpassed winter flounder catch. These included yellowtail flounder, windowpane flounder, and monkfish.

(3) Collection of biological data to improve stock assessments

Reproductive stage data was collected for winter flounder catch and mapped by month.

(4) Winter habitat assessment in the survey area

Video surveys were conducted at 33 of the dredge survey stations, and each site was categorized based on the bottom type (sand, gravel, or rocks) and amount of shell hash and sand dollars (high, low, or absent). This data was used to create a substrate map with the locations of sandy substrate, mixed gravel substrate, rocks, and areas with high sand dollar concentrations.

(5) Reduction of winter flounder bycatch in the Atlantic sea scallop fishery.

The project was planned with an assessment of a 5-row apron as a potential dredge modification to reduce flounder bycatch. Yet because towing over rocky bottom destroyed one of our TDDs, this part of the project was abandoned.

CFF has continued assess the 5-row apron in other projects, and this modification is currently being considered as a reactive accountability measure for the sea scallop fishery.

(6) Collection of winter flounder eggs.

We towed a plankton net along the sea floor at all of our survey sites, but we did not collect any winter flounder eggs.

(7) Comparison of winter flounder catch in scallop dredges to catch in survey trawl dredges.

Winter flounder catch in the scallop dredges was compared to catch in the NEAMAP and NEFSC surveys.

(8) Filming of juvenile winter flounder with a remotely operated vehicle (ROV).

Two trips were conducted in coastal ponds where juvenile winter flounder are regularly caught during other surveys. However, we did not observe any winter flounder.

(9) Filming of spawning winter flounder with stationary camera array stands.

Even though the camera stands were deployed in areas where we caught winter flounder during February 2016, we did not observe any winter flounder in the same areas.

Evaluation and Discussion

The goal of the research funded by the S-K grant program was to identify winter flounder offshore spawning habitat in SNE waters. Because we identified ripe winter flounder in early February and spent flounder in late February, it is likely that winter flounder are spawning in the area we surveyed.

Flounder catch was strongly dependent on survey month. Although winter flounder catch was significantly higher at mixed substrate stations, month was a much more important factor for predicting winter flounder catch numbers, and the best model for predicting winter flounder catch included only month. Similarly, although windowpane flounder catch was significantly lower at rocky stations, the best model for predicting windowpane flounder catch only included month as a factor. Yellowtail flounder catch was not significantly different on any substrate type, and substrate type was not a significant factor for predicting yellowtail flounder catch numbers. All three flounder species were caught at stations within the BOEM lease area, with catch numbers highest in the month of December.

This contrasted with the results for monkfish. Substrate type strongly impacted monkfish catch, with the best model for predicting catch including only substrate type but not month. Because the area of overlap between the CFF survey and the BOEM lease areas has primarily sandy substrate, monkfish were present across the BOEM lease areas for all months from December through April.

Some care has to be taken when interpreting the fish catch data from the dredge surveys because the dredge headbale type was changed midway through the project. However, fish catch with the TDD tends to be lower or equal to catch with the NBD (Smolowitz et al. 2012). Because flounder catch declined after the dredge headbale was switched to an NBD and monkfish catch with the NBD in April was within the range of catches with the TDD in December and February, we are comfortable using the catch data from the entire study.

Scallop dredges did catch winter flounder, but in smaller numbers and at fewer sites than the NEAMAP survey trawl. The same trend was observed for winter flounder catch between CFF dredges and the NEFSC survey trawl. This is not surprising since modifications made to commercial dredges in recent years were designed to minimize flatfish bycatch. Furthermore this result was observed in previous work by CFF. We examined the presence of four important commercial species in CFF seasonal dredge surveys and NEFSC bottom trawl surveys that were conducted at stations that were spatially and temporally close (depth ≤ 7 meters apart, distance ≤ 6.5 km apart, sampling date ≤ 7.5 days apart) (Siemann et al. in review). For the 21 stations that met these criteria, the catch was adjusted based on swept area (average swept area for the dredge tows based on tow start and end locations and dredge width, global mean swept area using door spread for the NEFSC trawl tows from Jacobson et al.2014). When catch from these spatiotemporally close scallop-dredge and bottom-trawl tows were compared, the dredge caught more windowpane flounder and monkfish, while the bottom trawl caught more winter and yellowtail flounder.

Dissemination of Project Results

Results from the project were presented at the 15th Flatfish Biology Conference on December

6th and 7th, 2016 in Westbrook, CT and in a recently published report for BOEM (Siemann and Smolowitz 2017).

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Appendix A. Data Tables

Table A1. *Catch number per station for winter flounder (WinterF), windowpane flounder (WPF), yellowtail flounder (YTF), and monkfish, scallop bushels per station, and substrate details for each station.*

Month	Latitude	Longitude	WinterF	WPF	YTF	Monkfish	Scallops (bushels)	Sand	Gravel	Sand dollars	Rocks	Substrate
Dec	41.230	-70.650	0	0	0	0	0	1	0	0	0	sand
Dec	41.138	-70.643	2	9	1	3	0.02	1	0	0.97	0	sand
Dec	41.136	-70.754	4	19	4	0	0.02	1	0	1	0	sand
Dec	41.136	-70.864	1	21	7	1	0.04	1	0	0	0	sand
Dec	41.136	-70.974	0	9	7	0	0.2	1	0	0	0	sand
Dec	41.136	-71.054	0	7	3	2	0.02	0	1	0	11	rocky
Dec	41.136	-71.193	3	21	2	5	1	0.58	0.42	0	0	mixed
Dec	41.136	-71.299	0	0	0	4	0.12	1	0	0	0	sand
Dec	41.136	-71.413	1	4	3	3	0.08	0.74	0.26	0	2	mixed
Dec	41.057	-70.655	1	39	2	2	0.5	1	0	1	0	sand
Dec	41.052	-70.769	2	70	3	4	0.5	1	0	0.21	0	sand
Dec	41.052	-70.881	0	102	5	5	5	1	0	0.72	0	sand
Dec	41.052	-70.982	1	44	3	10	5.25	1	0	1	0	sand
Dec	41.052	-71.103	1	7	1	2	0.05	1	0	0	11	rocky
Dec	41.052	-71.213	1	5	0	4	0.5	0.91	0.09	0	7	rocky
Dec	41.052	-71.326	1	4	2	10	5	0.82	0.18	0	1	sand
Dec	41.052	-71.439	1	6	2	11	2.25	0.84	0.16	0	4	sand
Dec	41.056	-71.545	0	5	1	3	0.2	1	0	0	0	sand
Dec	40.987	-70.630	0	60	0	8	0.4	1	0	0	0	sand
Dec	40.968	-70.760	0	6	1	7	0.55	1	0	0	0	sand
Dec	40.968	-70.869	0	5	1	6	0.5	1	0	0	0	sand
Dec	40.968	-70.976	0	7	0	5	1.1	1	0	0	0	sand
Dec	40.968	-71.087	1	2	1	12	2	1	0	0	0	sand
Dec	40.968	-71.203	0	1	0	9	0.2	1	0	0	0	sand
Dec	40.968	-71.309	0	4	0	5	1	1	0	1	0	sand
Dec	40.968	-71.423	0	11	0	11	2.75	1	0	0	0	sand
Dec	40.968	-71.533	0	0	0	38	1.25	1	0	0	0	sand
Dec	40.968	-71.637	1	6	0	7	3.05	1	0	0	0	sand
Dec	40.884	-71.327	0	0	0	15	0.5	1	0	0	0	sand
Dec	40.884	-71.441	0	0	0	4	1.1	1	0	0.1	0	sand
Dec	40.884	-71.549	1	0	0	8	1.8	1	0	0	0	sand
Dec	40.897	-71.660	1	1	1	16	3.55	1	0	0	0	sand

Month	Latitude	Longitude	WinterF	WPF	YTF	Monkfish	Scallops (bushels)	Sand	Gravel	Sand dollars	Rocks	Substrate
Feb_early	41.218	-70.646	1	0	0	0	0	1	0	0	0	sand
Feb_early	41.137	-70.655	0	6	1	6	1	1	0	0.97	0	sand
Feb_early	41.132	-70.765	0	9	0	1	0.02	1	0	1	0	sand
Feb_early	41.129	-70.885	0	7	0	2	0.03	1	0	0	0	sand
Feb_early	41.130	-70.989	0	0	0	0	0.55	1	0	0	0	sand
Feb_early	41.132	-71.095	1	2	0	3	0.2	0.5	0.5	0	11	rocky
Feb_early	41.130	-71.214	2	16	0	8	1.75	0.58	0.42	0	0	mixed
Feb_early	41.136	-71.321	1	7	0	2	0.35	1	0	0	0	sand
Feb_early	41.124	-71.425	0	0	0	0	0.01	0.74	0.26	0	2	mixed
Feb_early	41.047	-70.640	0	5	4	2	0.8	1	0	1	0	sand
Feb_early	41.054	-70.746	0	8	0	3	0.2	1	0	0.21	0	sand
Feb_early	41.053	-70.858	0	5	0	4	1.5	1	0	0.72	0	sand
Feb_early	41.042	-70.975	1	12	0	1	2	1	0	1	0	sand
Feb_early	41.045	-71.087	0	4	1	1	0.06	1	0	0	11	rocky
Feb_early	41.055	-71.191	2	10	0	1	0.04	0.91	0.09	0	7	rocky
Feb_early	41.047	-71.304	2	21	8	6	4.5	0.82	0.18	0	1	sand
Feb_early	41.050	-71.418	0	6	3	1	0.75	0.84	0.16	0	4	sand
Feb_early	41.058	-71.530	0	0	0	2	0	1	0	0	0	sand
Feb_early	41.056	-71.640	1	8	0	5	0.2	1	0	0	0	sand
Feb_early	40.972	-70.653	0	23	0	10	0.15	1	0	0	0	sand
Feb_early	40.966	-70.772	1	26	0	7	0.5	1	0	0	0	sand
Feb_early	40.965	-70.881	0	10	1	4	0.8	1	0	0	0	sand
Feb_early	40.955	-71.104	0	43	2	7	1.8	1	0	0	0	sand
Feb_early	40.958	-71.216	0	45	4	7	2.5	1	0	0	0	sand
Feb_early	40.959	-71.331	0	17	4	9	0.35	1	0	0	0	sand
Feb_early	40.959	-71.437	0	28	6	16	0.45	1	0	1	0	sand
Feb_early	40.955	-71.547	0	8	3	23	2.9	1	0	0	0	sand
Feb_early	40.953	-71.651	2	15	0	30	1.8	1	0	0	0	sand
Feb_early	40.888	-71.298	1	9	1	21	2.5	1	0	0	0	sand
Feb_early	40.895	-71.411	1	7	1	10	0.8	1	0	0	0	sand
Feb_early	40.893	-71.523	0	4	2	20	1	1	0	0.1	0	sand
Feb_early	40.886	-71.642	0	8	1	14	4	1	0	0	0	sand
Feb_early	40.970	-71.036	0	5	0	18	3	1	0	0	0	sand

Month	Latitude	Longitude	WinterF	WPF	YTF	Monkfish	Scallops (bushels)	Sand	Gravel	Sand dollars	Rocks	Substrate
Feb_late	41.143	-70.635	1	1	0	3	2	1	0	0.97	0	sand
Feb_late	41.136	-70.744	0	2	0	1	0.07	1	0	1	0	sand
Feb_late	41.136	-70.860	0	2	0	0	0.02	1	0	0	0	sand
Feb_late	41.136	-70.966	0	5	0	0	0.04	1	0	0	0	sand
Feb_late	41.136	-71.080	0	0	0	0	0	0.5	0.5	0	11	rocky
Feb_late	41.136	-71.188	0	11	0	2	1.4	0.58	0.42	0	0	mixed
Feb_late	41.136	-71.307	0	2	0	7	0.06	1	0	0	0	sand
Feb_late	41.136	-71.419	1	2	0	0	0.12	0.74	0.26	0	2	mixed
Feb_late	41.045	-70.649	0	1	0	5	0.45	1	0	1	0	sand
Feb_late	41.062	-70.764	0	0	1	1	1.1	1	0	0.21	0	sand
Feb_late	41.044	-70.871	0	1	0	1	2.7	1	0	0.72	0	sand
Feb_late	41.059	-70.982	0	1	0	1	2	1	0	1	0	sand
Feb_late	41.050	-71.090	0	0	0	0	0	1	0	0	11	rocky
Feb_late	41.053	-71.201	0	11	1	0	0.15	0.91	0.09	0	7	rocky
Feb_late	41.052	-71.309	1	18	2	7	2.2	0.82	0.18	0	1	sand
Feb_late	41.052	-71.427	1	11	0	4	0.75	0.84	0.16	0	4	sand
Feb_late	41.052	-71.530	4	3	0	23	1.2	1	0	0	0	sand
Feb_late	41.053	-71.638	0	2	0	2	0.07	1	0	0	0	sand
Feb_late	40.960	-70.657	0	4	0	12	0.03	1	0	0	0	sand
Feb_late	40.978	-70.761	0	4	0	0	0.07	1	0	0	0	sand
Feb_late	40.957	-70.875	0	13	0	5	0.4	1	0	0	0	sand
Feb_late	40.975	-70.983	0	10	0	4	0.7	1	0	0	0	sand
Feb_late	40.968	-71.106	1	60	1	27	2.25	1	0	0	0	sand
Feb_late	40.968	-71.215	0	31	4	24	0.35	1	0	0	0	sand
Feb_late	40.968	-71.324	0	13	1	5	1.2	1	0	1	0	sand
Feb_late	40.968	-71.435	0	4	0	4	1.6	1	0	0	0	sand
Feb_late	40.968	-71.550	0	6	0	23	0.4	1	0	0	0	sand
Feb_late	40.965	-71.659	0	3	0	3	0.38	1	0	0	0	sand
Feb_late	40.884	-71.434	0	13	0	28	0.8	1	0	0	0	sand
Feb_late	40.884	-71.420	0	1	1	17	0.65	1	0	0.1	0	sand
Feb_late	40.884	-71.527	0	2	0	23	1.5	1	0	0	0	sand
Feb_late	40.884	-71.642	0	8	3	25	1.3	1	0	0	0	sand

Month	Latitude	Longitude	WinterF	WPF	YTF	Monkfish	Scallops (bushels)	Sand	Gravel	Sand dollars	Rocks	Substrate
Mar	41.234	-70.682	0	0	0	0	0	1	0	0	0	sand
Mar	41.137	-70.652	0	1	0	0	0.01	1	0	0.97	0	sand
Mar	41.135	-70.753	0	0	0	0	0.01	1	0	1	0	sand
Mar	41.137	-70.878	0	1	0	0	0.15	1	0	0	0	sand
Mar	41.136	-70.986	0	0	0	0	0.06	1	0	0	0	sand
Mar	41.136	-71.097	1	0	0	0	0	0.5	0.5	0	11	rocky
Mar	41.135	-71.325	0	0	0	0	0.07	1	0	0	0	sand
Mar	41.132	-71.434	0	2	0	0	0.02	0.74	0.26	0	2	mixed
Mar	41.048	-70.650	1	9	0	8	0.35	1	0	1	0	sand
Mar	41.053	-70.757	0	1	1	3	0.4	1	0	0.21	0	sand
Mar	41.053	-70.866	0	1	1	2	1.25	1	0	0.72	0	sand
Mar	41.053	-70.979	1	7	0	9	0.9	1	0	1	0	sand
Mar	41.052	-71.082	0	0	0	0	0.02	1	0	0	11	rocky
Mar	41.053	-71.199	0	1	0	1	0.1	0.91	0.09	0	7	rocky
Mar	41.051	-71.311	0	20	5	10	3.25	0.82	0.18	0	1	sand
Mar	41.052	-71.423	0	2	1	0	0.9	0.84	0.16	0	4	sand
Mar	41.053	-71.530	0	3	0	22	0.16	1	0	0	0	sand
Mar	41.051	-71.646	0	5	0	16	0.2	1	0	0	0	sand
Mar	40.970	-70.656	0	5	0	5	0.02	1	0	0	0	sand
Mar	40.968	-70.765	0	10	0	4	0.35	1	0	0	0	sand
Mar	40.967	-70.871	0	3	0	8	0.5	1	0	0	0	sand
Mar	40.968	-70.986	0	16	2	15	2.5	1	0	0	0	sand
Mar	40.967	-71.099	0	25	1	13	2	1	0	0	0	sand
Mar	40.967	-71.208	0	14	0	13	0.35	1	0	0	0	sand
Mar	40.969	-71.322	0	18	0	5	1.3	1	0	1	0	sand
Mar	40.968	-71.436	0	10	1	33	2.4	1	0	0	0	sand
Mar	40.967	-71.544	0	8	0	59	0.85	1	0	0	0	sand
Mar	40.962	-71.651	0	2	0	16	1.9	1	0	0	0	sand
Mar	40.885	-71.308	0	13	2	27	0.5	1	0	0	0	sand
Mar	40.884	-71.533	0	1	0	19	2	1	0	0	0	sand
Mar	40.884	-71.645	0	6	5	23	5.5	1	0	0	0	sand

Table A2. *Catch number per station for winter flounder in each reproductive stage and substrate details for each station.*

Month	Latitude	Longitude	Immature	Developing	Ripe	Spent	Resting	Sand	Gravel	Sand dollars	Rocks	Substrate
Dec	41.230	-70.650	0	0	0	0	0	1	0	0	0	sand
Dec	41.138	-70.643	0	2	0	0	0	1	0	0.97	0	sand
Dec	41.136	-70.754	0	3	0	0	1	1	0	1	0	sand
Dec	41.136	-70.864	0	0	0	0	1	1	0	0	0	sand
Dec	41.136	-70.974	0	0	0	0	0	1	0	0	0	sand
Dec	41.136	-71.054	0	0	0	0	0	0	1	0	11	rocky
Dec	41.136	-71.193	0	3	0	0	0	0.58	0.42	0	0	mixed
Dec	41.136	-71.299	0	0	0	0	0	1	0	0	0	sand
Dec	41.136	-71.413	0	1	0	0	0	0.74	0.26	0	2	mixed
Dec	41.057	-70.655	0	0	1	0	0	1	0	1	0	sand
Dec	41.052	-70.769	0	2	0	0	0	1	0	0.21	0	sand
Dec	41.052	-70.881	0	0	0	0	0	1	0	0.72	0	sand
Dec	41.052	-70.982	0	1	0	0	0	1	0	1	0	sand
Dec	41.052	-71.103	0	1	0	0	0	1	0	0	11	rocky
Dec	41.052	-71.213	0	1	0	0	0	0.91	0.09	0	7	rocky
Dec	41.052	-71.326	0	0	0	0	1	0.82	0.18	0	1	sand
Dec	41.052	-71.439	0	1	0	0	0	0.84	0.16	0	4	sand
Dec	41.056	-71.545	0	0	0	0	0	1	0	0	0	sand
Dec	40.987	-70.630	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-70.760	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-70.869	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-70.976	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-71.087	0	1	0	0	0	1	0	0	0	sand
Dec	40.968	-71.203	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-71.309	0	0	0	0	0	1	0	1	0	sand
Dec	40.968	-71.423	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-71.533	0	0	0	0	0	1	0	0	0	sand
Dec	40.968	-71.637	0	1	0	0	0	1	0	0	0	sand
Dec	40.884	-71.327	0	0	0	0	0	1	0	0	0	sand
Dec	40.884	-71.441	0	0	0	0	0	1	0	0.1	0	sand
Dec	40.884	-71.549	0	1	0	0	0	1	0	0	0	sand
Dec	40.897	-71.660	0	1	0	0	0	1	0	0	0	sand

Month	Latitude	Longitude	Immature	Developing	Ripe	Spent	Resting	Sand	Gravel	Sand dollars	Rocks	Substrate
Feb_early	41.218	-70.646	0	0	1	0	0	1	0	0	0	sand
Feb_early	41.137	-70.655	0	0	0	0	0	1	0	0.97	0	sand
Feb_early	41.132	-70.765	0	0	0	0	0	1	0	1	0	sand
Feb_early	41.129	-70.885	0	0	0	0	0	1	0	0	0	sand
Feb_early	41.130	-70.989	0	0	0	0	0	1	0	0	0	sand
Feb_early	41.132	-71.095	0	0	0	0	1	0.5	0.5	0	11	rocky
Feb_early	41.130	-71.214	0	0	1	1	0	0.58	0.42	0	0	mixed
Feb_early	41.136	-71.321	1	0	0	0	0	1	0	0	0	sand
Feb_early	41.124	-71.425	0	0	0	0	0	0.74	0.26	0	2	mixed
Feb_early	41.047	-70.640	0	0	0	0	0	1	0	1	0	sand
Feb_early	41.054	-70.746	0	0	0	0	0	1	0	0.21	0	sand
Feb_early	41.053	-70.858	0	0	0	0	0	1	0	0.72	0	sand
Feb_early	41.042	-70.975	0	0	1	0	0	1	0	1	0	sand
Feb_early	41.045	-71.087	0	0	0	0	0	1	0	0	11	rocky
Feb_early	41.055	-71.191	0	0	2	0	0	0.91	0.09	0	7	rocky
Feb_early	41.047	-71.304	0	1	1	0	0	0.82	0.18	0	1	sand
Feb_early	41.050	-71.418	0	0	0	0	0	0.84	0.16	0	4	sand
Feb_early	41.058	-71.530	0	0	0	0	0	1	0	0	0	sand
Feb_early	41.056	-71.640	0	0	1	0	0	1	0	0	0	sand
Feb_early	40.972	-70.653	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.966	-70.772	0	0	1	0	0	1	0	0	0	sand
Feb_early	40.965	-70.881	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.955	-71.104	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.958	-71.216	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.959	-71.331	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.959	-71.437	0	0	0	0	0	1	0	1	0	sand
Feb_early	40.955	-71.547	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.953	-71.651	0	0	2	0	0	1	0	0	0	sand
Feb_early	40.888	-71.298	0	0	0	1	0	1	0	0	0	sand
Feb_early	40.895	-71.411	0	0	1	0	0	1	0	0	0	sand
Feb_early	40.893	-71.523	0	0	0	0	0	1	0	0.1	0	sand
Feb_early	40.886	-71.642	0	0	0	0	0	1	0	0	0	sand
Feb_early	40.970	-71.036	0	0	0	0	0	1	0	0	0	sand

Month	Latitude	Longitude	Immature	Developing	Ripe	Spent	Resting	Sand	Gravel	Sand dollars	Rocks	Substrate
Feb_late	41.143	-70.635	1	0	0	0	0	1	0	0.97	0	sand
Feb_late	41.136	-70.744	0	0	0	0	0	1	0	1	0	sand
Feb_late	41.136	-70.860	0	0	0	0	0	1	0	0	0	sand
Feb_late	41.136	-70.966	0	0	0	0	0	1	0	0	0	sand
Feb_late	41.136	-71.080	0	0	0	0	0	0.5	0.5	0	11	rocky
Feb_late	41.136	-71.188	0	0	0	0	0	0.58	0.42	0	0	mixed
Feb_late	41.136	-71.307	0	0	0	0	0	1	0	0	0	sand
Feb_late	41.136	-71.419	0	0	1	0	0	0.74	0.26	0	2	mixed
Feb_late	41.045	-70.649	0	0	0	0	0	1	0	1	0	sand
Feb_late	41.062	-70.764	0	0	0	0	0	1	0	0.21	0	sand
Feb_late	41.044	-70.871	0	0	0	0	0	1	0	0.72	0	sand
Feb_late	41.059	-70.982	0	0	0	0	0	1	0	1	0	sand
Feb_late	41.050	-71.090	0	0	0	0	0	1	0	0	11	rocky
Feb_late	41.053	-71.201	0	0	0	0	0	0.91	0.09	0	7	rocky
Feb_late	41.052	-71.309	0	0	0	1	0	0.82	0.18	0	1	sand
Feb_late	41.052	-71.427	0	1	0	0	0	0.84	0.16	0	4	sand
Feb_late	41.052	-71.530	0	1	0	2	1	1	0	0	0	sand
Feb_late	41.053	-71.638	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.960	-70.657	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.978	-70.761	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.957	-70.875	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.975	-70.983	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.968	-71.106	0	1	0	0	0	1	0	0	0	sand
Feb_late	40.968	-71.215	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.968	-71.324	0	0	0	0	0	1	0	1	0	sand
Feb_late	40.968	-71.435	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.968	-71.550	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.965	-71.659	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.884	-71.434	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.884	-71.420	0	0	0	0	0	1	0	0.1	0	sand
Feb_late	40.884	-71.527	0	0	0	0	0	1	0	0	0	sand
Feb_late	40.884	-71.642	0	0	0	0	0	1	0	0	0	sand

Month	Latitude	Longitude	Immature	Developing	Ripe	Spent	Resting	Sand	Gravel	Sand dollars	Rocks	Substrate
Mar	41.234	-70.682	0	0	0	0	0	1	0	0	0	sand
Mar	41.137	-70.652	0	0	0	0	0	1	0	0.97	0	sand
Mar	41.135	-70.753	0	0	0	0	0	1	0	1	0	sand
Mar	41.137	-70.878	0	0	0	0	0	1	0	0	0	sand
Mar	41.136	-70.986	0	0	0	0	0	1	0	0	0	sand
Mar	41.136	-71.097	0	0	0	1	0	0.5	0.5	0	11	rocky
Mar	41.135	-71.325	0	0	0	0	0	1	0	0	0	sand
Mar	41.132	-71.434	0	0	0	0	0	0.74	0.26	0	2	mixed
Mar	41.048	-70.650	1	0	0	0	0	1	0	1	0	sand
Mar	41.053	-70.757	0	0	0	0	0	1	0	0.21	0	sand
Mar	41.053	-70.866	0	0	0	0	0	1	0	0.72	0	sand
Mar	41.053	-70.979	1	0	0	0	0	1	0	1	0	sand
Mar	41.052	-71.082	0	0	0	0	0	1	0	0	11	rocky
Mar	41.053	-71.199	0	0	0	0	0	0.91	0.09	0	7	rocky
Mar	41.051	-71.311	0	0	0	0	0	0.82	0.18	0	1	sand
Mar	41.052	-71.423	0	0	0	0	0	0.84	0.16	0	4	sand
Mar	41.053	-71.530	0	0	0	0	0	1	0	0	0	sand
Mar	41.051	-71.646	0	0	0	0	0	1	0	0	0	sand
Mar	40.970	-70.656	0	0	0	0	0	1	0	0	0	sand
Mar	40.968	-70.765	0	0	0	0	0	1	0	0	0	sand
Mar	40.967	-70.871	0	0	0	0	0	1	0	0	0	sand
Mar	40.968	-70.986	0	0	0	0	0	1	0	0	0	sand
Mar	40.967	-71.099	0	0	0	0	0	1	0	0	0	sand
Mar	40.967	-71.208	0	0	0	0	0	1	0	0	0	sand
Mar	40.969	-71.322	0	0	0	0	0	1	0	1	0	sand
Mar	40.968	-71.436	0	0	0	0	0	1	0	0	0	sand
Mar	40.967	-71.544	0	0	0	0	0	1	0	0	0	sand
Mar	40.962	-71.651	0	0	0	0	0	1	0	0	0	sand
Mar	40.885	-71.308	0	0	0	0	0	1	0	0	0	sand
Mar	40.884	-71.533	0	0	0	0	0	1	0	0	0	sand
Mar	40.884	-71.645	0	0	0	0	0	1	0	0	0	sand

Month	Latitude	Longitude	Immature	Developing	Ripe	Spent	Resting	Sand	Gravel	Sand dollars	Rocks	Substrate
Apr	41.233	-70.681	0	0	0	0	0	1	0	0	0	sand
Apr	41.137	-70.643	0	0	0	0	0	1	0	0.97	0	sand
Apr	41.137	-70.758	0	0	0	0	0	1	0	1	0	sand
Apr	41.137	-70.871	0	0	0	0	0	1	0	0	0	sand
Apr	41.136	-70.980	0	0	0	0	0	1	0	0	0	sand
Apr	41.137	-71.092	0	0	0	0	0	0.5	0.5	0	11	rocky
Apr	41.136	-71.203	0	0	0	0	0	0.58	0.42	0	0	mixed
Apr	41.136	-71.315	0	0	0	0	0	1	0	0	0	sand
Apr	41.137	-71.428	0	0	0	0	1	0.74	0.26	0	2	mixed
Apr	41.055	-70.643	0	0	0	0	0	1	0	1	0	sand
Apr	41.719	-70.761	0	0	0	0	0	1	0	0.21	0	sand
Apr	41.052	-70.876	0	0	0	0	0	1	0	0.72	0	sand
Apr	41.053	-70.983	0	0	0	0	0	1	0	1	0	sand
Apr	41.052	-71.095	0	0	0	0	0	1	0	0	11	rocky
Apr	41.053	-71.206	0	0	0	0	0	0.91	0.09	0	7	rocky
Apr	41.054	-71.320	0	0	0	0	0	0.82	0.18	0	1	sand
Apr	41.054	-71.428	0	0	0	0	0	0.84	0.16	0	4	sand
Apr	41.051	-71.531	0	0	1	0	0	1	0	0	0	sand
Apr	41.052	-71.647	0	0	0	0	0	1	0	0	0	sand
Apr	40.967	-70.647	0	0	0	0	0	1	0	0	0	sand
Apr	40.968	-70.760	0	0	0	0	0	1	0	0	0	sand
Apr	40.967	-70.868	0	0	0	0	0	1	0	0	0	sand
Apr	40.967	-70.983	0	0	0	0	0	1	0	0	0	sand
Apr	40.967	-71.102	0	0	0	0	0	1	0	0	0	sand
Apr	40.968	-71.204	0	0	0	0	0	1	0	0	0	sand
Apr	40.969	-71.314	0	0	0	0	0	1	0	1	0	sand
Apr	40.969	-71.425	0	0	0	0	0	1	0	0	0	sand
Apr	40.969	-71.534	0	0	0	0	2	1	0	0	0	sand
Apr	40.969	-71.649	0	0	0	0	1	1	0	0	0	sand
Apr	40.885	-71.427	0	0	0	0	0	1	0	0	0	sand
Apr	40.884	-71.541	0	0	0	0	0	1	0	0	0	sand
Apr	40.884	-71.648	0	0	0	0	0	1	0	0	0	sand