AN INDUSTRY-BASED SURVEY FOR YELLOWTAIL FLOUNDER IN SOUTHERN NEW ENGLAND

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ABSTRACT

SMAST received funding from the Commercial Fisheries Research Foundation and the Massachusetts Marine Fisheries Institute to conduct an industry-based survey for yellowtail flounder in the waters of southern New England. The survey was completed between September and November of 2011. The F/V Heather Lynn and the F/V Travis and Natalie served as the industry partners during the survey. The study location was chosen to cover a large portion of the area sampled during the 2003-2005 Rhode Island Division of Fish and Wildlife industry-based survey for yellowtail flounder. The objectives of the survey were to examine the abundance, distribution and biological characteristics of yellowtail flounder in the southern New England stock area.

All tow locations were chosen at random within the study site, and a total of 232 valid tows were completed over the course of nine survey trips. The largest mean yellowtail flounder catches were observed in the western portion of the study area, while the smallest catches were observed in the Nantucket Lightship Closed Area. A greater proportion of large (>32cm) yellowtail flounder were captured in the open areas, while the majority of yellowtail captured in the Nantucket Lightship were sublegal size. A total of 9,766 yellowtail flounder were measured during the survey, and 5,014 yellowtail were tagged. Survey tows were used to generate relative and absolute abundance estimates, and biological data collected during the survey was provided to the Northeast Fisheries Science Center for inclusion in the yellowtail flounder stock assessment. The results of the survey have been presented to fishermen, academic scientists, fishery managers, and government scientists at a number of meetings and conferences.

INTRODUCTION

Indices of abundance and biomass derived from fisheries independent surveys are critical inputs to stock assessment models for many groundfish species in New England. Surveys also serve as a valuable platform for collecting the demographic information needed to inform stock assessment models. The Northeast Fisheries Science Center (NEFSC) conducts a biannual trawl survey for groundfish in the spring and autumn. Abundance indices derived from the NEFSC survey are used in the assessment of many fish species in New England. The NEFSC survey utilizes a stratified random design, and the area covered by the survey ranges from the Cape Hatteras, North Carolina northward to the Gulf of Maine (Grosslein, 1969). Because of the vast area covered by the survey, and the large number of stocks that need to be sampled, the sampling density and spatial resolution is limited in some regions of the survey.

Yellowtail flounder is managed as three stocks in the coastal waters of the United States: Cape Cod-Gulf of Maine, Georges Bank, and Southern New England/Mid-Atlantic (Cadrin, 2010). Yellowtail flounder is a commercially important species that has been targeted by the southern New England groundfish fleet for decades. This species formerly supported a robust commercial fishery, but landings have been reduced dramatically in recent years following the collapse of the stock in the mid 1990s and subsequent fishery restrictions. During the 1940's, annual landings of yellowtail flounder from the Southern New England area were approximately 10,000 metric tons. Recent annual landings are only approximately 200 metric tons. Yellowtail flounder is an important bycatch species in the scallop fishery, and the low yellowtail flounder allocations have constrained the harvest of the valuable sea scallop resource in certain years (O'Keefe et al., 2010). The 2008 stock assessment concluded that the Southern New England-Mid Atlantic yellowtail flounder stock was overfished, and that overfishing was occurring (Alade et al., 2008). The peer review panel also concluded that more age and length data was needed to support the continued use of the assessment model. The most recent stock assessment for yellowtail flounder (SAW 54) found that overfishing is no longer occurring for this stock, but the model was unable to determine if the stock was overfished (NEFSC, 2012). Following the results of the most recent stock assessment, yellowtail flounder remain in a rebuilding plan (NEFSC, 2012).

To assess fish stocks accurately, adequate biological data is needed. Demographic information such as length frequency, age structure, abundance and distribution are critical elements to age-based stock assessments. Industry-based surveys provide useful platforms to collect this high resolution fisheries data. Further, industry-based surveys allow fishermen and scientists to work cooperatively to address critical problems.

The Southern New England yellowtail flounder stock has been assessed using a calibrated Virtual Population Analysis (VPA) since the late 1980's (Cadrin 2003). The stock assessment in 2000 was rejected by the Stock Assessment Review Committee (SARC), because catch-at-age data could not be estimated accurately due to a lack of biological samples. The assessment had severe retrospective patterns, which underestimated fishing mortality and overestimated stock size. An industry-based survey was started in 2003 to provide increased biological sampling of the yellowtail flounder resource (Valliere and Pierce, 2007). The industry-based survey was conducted by the Rhode Island Division of Fish and Wildlife (RIDFW) from 2003 through 2005, and input from commercial fishermen was used to design the survey net (Figure 1) and define traditional areas of yellowtail flounder abundance (Figure 2). Biological data collected during the survey was included in the 2005 assessment, the inclusion of this data reduced the retrospective patterns and lead to the stock assessment being accepted as a basis for management (Cadrin and Legault, 2005).

STATEMENT OF RESEARCH QUESTION

We sought to expand upon the findings of a previous industry-based survey for yellowtail flounder, which was conducted by the RIDFW between 2003 and 2005. In particular, we wanted to examine the abundance and distribution of yellowtail flounder in southern New England. We also wanted to learn more about the biological characteristics of yellowtail flounder in the southern New England area, and conduct a tagging experiment to examine the long-term movements and survival of this species.

GOALS AND OBJECTIVES

The specific objectives that we outlined for the yellowtail flounder industry-based survey were as follows:

1) Sample the relative abundance of yellowtail flounder in and around the Nantucket Lightship Closed Area in the fall of 2011.
2) Compare the relative densities of yellowtail flounder observed during the 2003-2005 survey and the 2011 survey, and compare the relative density of yellowtail flounder inside the closed area to the density in open areas that are adjacent to the closed area.
3) Compare the size distribution of yellowtail flounder inside the closed area to the size distribution in open areas that are adjacent to the closed areas.
4) Provide biological samples that can be used in the stock assessment of this species.
5) Allow fishermen to be actively involved in the research that guides the assessment and management of fisheries resources.

METHODOLOGY

Survey Design

The 2011 industry-based survey for yellowtail flounder was a collaboration between SMAST, the F/V Heather Lynn, and the F/V Travis and Natalie. The survey was completed between September and November of 2011, and a total of nine trips were made during the survey. The F/V Heather Lynn was a participant during the 2003-2005 survey, and the captain, Steve Follet, has participated in numerous cooperative research projects during his career. Both vessels have similar characteristics, and the captains of both vessels have extensive experience fishing for yellowtail flounder in southern New England.

The Rhode Island Division of Fish and Wildlife completed a biannual industry-based survey for yellowtail flounder in the waters of southern New England between 2003 and 2005 (Figure 2). The area chosen for the 2011 industry-based survey contained a subset of the area sampled during the 2003-2005 survey (Figure 3). Depth within the study site ranged from approximately 10-45 fathoms, and the study site include regions where yellowtail flounder have historically been abundant. The study site was divided into three regions for the purpose of survey planning (Figure 3). The area furthest to the west was defined as the SNECRI area, because the funds needed to survey this area were awarded to SMAST by the Southern New England Collaborative Research Initiative. The area to the east of the SNECRI area, and a small area south of the Nantucket Lightship was labeled as the MFI Open area. Finally, the Nantucket Lightship Closed Area was labeled as the MFI Closed Area.

Prior to the selection of tow locations, the study area was divided into a series of nine square nautical mile grid cells. Each of the three regions within the survey area were almost identical in size. The SNECRI area and the MFI Open area each contained 201 grid cells, and had an area of 6178.7 km^2. The MFI Closed area contained 200 grid cells, and had an area of 6148 km^2. Two sets of randomly selected tow locations were chosen for each of the survey regions. The random point generation software of the Hawth's Tools extension for ArcGIS was used to generate a series of random points within each study region. When a random point fell within a grid cell, a survey tow was assigned within that grid cell. Two series of 48 random tow locations (grid cells) were generated for each of the study regions. For the SNECRI area, the captain of the F/V Heather Lynn was instructed to complete the first set of 48 randomly selected tows, then proceed on to the second set of randomly selected tows. Each vessel was assigned 48 randomly selected tow locations in the MFI Open and Closed Areas.

The location of every tow completed during the 2011 survey was selected at random. This is in contrast to the 2003-2005 survey, during which 50% of the tow locations were chosen at random, and 50% of the tow locations were selected by the captain.

Netmind and E-Sonar net mensuration equipment were used to monitor the performance of the survey nets. Problems with the new mensuration equipment were frequent during the survey. Problems with the Netmind software occurred during survey trips on the F/V Heather Lynn. The Netmind software was not able to record the doorspread data within the Netmind software program. Instead, doorspread values were recorded manually by the scientists and captain during each tow when the door sensors worked properly. Similar problems occurred with the E-Sonar net mensuration sensors on the F/V Travis and Natalie. During tows when the door sensors worked properly, the observed door spread values were recorded manually by the captain and scientific crew, and a mean doorspread value was calculated for that tow. Captains typically set three discrete amounts of wire out during survey tows, depending on the depth (100, 125 or 150 fathoms). For each vessel, the mean observed doorspread was calculated for each of the three values of wire out (100, 125 or 150 fathoms). That doorspread value was then used in the calculation of area swept during each survey tow.

Survey Nets

The nets used during the 2011 survey were provided to SMAST by the RIDFW. The nets were originally designed and built for the 2003-2005 yellowtail flounder industry-based survey. The RIDFW allowed us to use the nets in 2011, which greatly reduced the overall costs associated with the survey.

The survey nets were originally designed as part of a collaborative effort between industry members, the RIDFW, Trawlworks Inc., and Superior Trawl. The nets are 360 x 6" two-seam trawls with a 3" cod end (Figure 1; Valliere and Pierce, 2007). The nets are designed to target yellowtail flounder in the soft bottom substrates of southern New England. The nets were designed using the results of a previous cod end selectivity study for yellowtail flounder (Skrobe et al., 2003). The cod end was chosen to retain sublegal size yellowtail flounder, while avoiding excessive amounts of bycatch of small fish. Four survey nets were built between 2003 and 2005, and the four survey nets were provided to SMAST for use in the 2011 survey.

Superior Trawl transported the survey nets from the RIDFW storage facility to their workshop in Point Judith, RI. Prior to the start of the survey, the nets were inspected by the staff at Superior Trawl, and repairs were made to each of the nets as needed before the start of the survey.

Survey Vessels

The F/V Heather Lynn and the F/V Travis and Natalie served as our industry partners on the survey. Both are otter-trawl vessels based out of Point Judith, RI. Each vessel is 84' in length, and the horsepower of the two vessels are nearly identical. The captain of the Heather Lynn, Steve Follet, has extensive experience participating in cooperative research.

Survey Tows

The captain chose the starting location of each of the survey tows within the designated grid cell, and the direction of the tow was left to the discretion of the captain. The tow time, duration, and vessel position were recorded using FLDRS, the Northeast Fisheries Science Center study fleet software, which was connected to a handheld GPS. The start of the tow was marked when the net was fully deployed and the winches were locked. The end of the tow was recorded immediately when the winches were engaged to retrieve the net. The captains were instructed to complete tows in a straight line, without turning the vessel, whenever possible. The captain was also instructed to maintain a tow speed of approximately three knots, and to complete the tow within the boundaries of the assigned grid cell. The captain determined the amount of wire set during each tow, depending upon the depth at the tow location. The tow number, weather conditions, depth, wire out, and other relevant information were recorded in an Access database during each survey tow. A Vemco® Minilogger was attached to each of the trawl doors on the survey net. The Miniloggers recorded temperature and depth every 30 seconds during the survey tow, allowing us to calculate an average bottom water temperature for each survey tow.

The target duration for survey tows was 30 minutes, and the minimum acceptable tow duration was 20 minutes. All catches were standardized to a 30-minute tow (e.g. catch from a 20 minute tow was multiplied by 30/20=1.5). Some of the survey tows were terminated prematurely, due to interactions with fixed gear, excessive catches of spiny dogfish, or due to the net hanging down on the bottom. Survey tows that were less than 20 minutes were repeated within the same grid cell, and multiple attempts were made to complete each of the survey tows in the designated grid cell. If a valid tow could not be completed within the designated grid cell, an adjacent grid cell was chosen as a replacement, and the survey tow was completed within the replacement grid cell. If the survey net was damaged during a tow (e.g., hole in the net), that tow was considered to be invalid, and the tow was repeated after the damage to the net had been repaired.

Excessive amounts of spiny dogfish bycatch (>10,000 pounds) was a problem during some of the survey tows. In many instances, the net had to be opened in the water to release some of the dogfish before the net could be safely brought back on board. When this occurred, the tow was considered invalid, because the yellowtail flounder catch could not be quantified exactly. Of the 263 tows that were attempted during the survey, 31 tows were deemed to be invalid, and the data from these tows was not included in the calculation of yellowtail flounder density, distribution, or biomass.

Catch Sampling

After a survey tow was completed, the net was brought onboard and the catch was dumped into the checker pen. All of the yellowtail flounder and winter flounder were sorted from the catch by hand. The yellowtail flounder were immediately transferred to a holding tank that was aerated constantly with fresh seawater. On the F/V Heather Lynn, winter flounder were transferred to baskets and weighed using an electronic, motion compensating scale. The weight of all other species was estimated by the scientists, captain, and crew, and recorded electronically in an Access database. All species except for yellowtail flounder were placed overboard as quickly as possible to minimize mortality.

The total length of each yellowtail flounder was measured to the nearest centimeter, and any relevant biological information (e.g., scale loss) was recorded for each yellowtail flounder. Scales samples were taken from a subsample of yellowtail flounder, and the scales were provided to the Northeast Fisheries Science Center for age determination. The weight of each yellowtail flounder was calculated using the length-weight relationship established for yellowtail flounder captured during the fall NEFSC annual bottom trawl survey (Wigley et al., 2003) using the following equation.

$$\ln \text{weight (kg)} = -11.8381 + (3.0559 * \ln \text{length (cm)})$$

A two-way ANOVA (Sokal and Rohlf, 2001) was performed to test for significant differences in the catch rates of yellowtail flounder between the two survey vessels.

2003-2005 IBS Data

The raw yellowtail flounder catch and station data from the 2003-2005 yellowtail industry-based survey was provided to SMAST by the Northeast Fisheries Science Center. The raw data was edited to allow for more direct comparisons between the 2003-2005 surveys and the 2011 survey. The measures that were taken to edit the 2003-2005 survey data are discussed below.

The 2003-2005 industry-based survey was completed biannually, with a survey in the spring and a survey in the fall. To allow for a more direct comparison to the SMAST survey which was completed in the fall of 2011, we limited our comparisons to yellowtail flounder catches that were observed during the fall surveys between 2003 and 2005.

Only tows that had a reported SHG (Set-Haul-Gear) code of 135 (randomly selected stations, and tows that were representative with no major gear damage) or less were included in the analysis. During the 2003-2005 survey, 50% of the tow locations were selected at random, and 50% were selected by the captain. However, during the 2011 survey, all tow locations were selected at random. Using the SHG value as a quality control criteria ensured that only randomly selected tow locations from the 2003-2005 survey were included in our analysis. In addition, using this SHG criteria ensured that no problems (e.g., gear damage) occurred during the survey tow.

The location of each tow completed during the 2003-2005 survey was plotted using ArcGIS. Tows that occurred outside of the study area used for the 2011 survey were excluded from the analysis.

This reduced the number of observations, but ensured that the results of the two surveys could be compared more directly.

The 2003-2005 survey used a tow distance of 1.9km as their target, rather than using a target tow duration. As a result, the tow durations that were reported for the 2003-2005 survey were highly variable. To reduce some of this variability, the data were edited, and only tows that were between 18 and 51 minutes in duration were included in the analysis.

A number of problems were encountered with the data from the 2003 fall survey. For example, the tow speed was not reported on a number of tows. In addition, the tow duration, and the tow distance was also not recorded for a number of the tows. Due to these missing values, catch data from the 2003 fall survey was not included in the analysis, and comparisons were limited to yellowtail flounder catches observed during the 2004 and 2005 RIDFW fall surveys.

Finally, the actual doorspread values that were observed during the 2003-2005 survey were not available. We contacted the Rhode Island Division of Fish and Wildlife to obtain the doorspread data, but the doorspread data could not be located. In the Valliere and Pierce (2007) report, it is stated that the observed door spreads were 65-72 fathoms during the survey. Therefore, we used the mid-point of that range (68.5 fathoms) to calculate area swept for tows completed during the 2004 and 2005 fall surveys.

After the 2004 and 2005 catch data had been edited, as described above, the dataset included 163 survey tows.

Area Swept Estimates

Estimates of yellowtail flounder density (kg/km^2) and biomass (mt) were calculated by examining the observed catch of yellowtail flounder and the area swept by the survey net during each valid tow. The doorspread of the survey net was used to calculate the area swept by the survey net during each valid tow completed in 2011.

During each survey trip in 2011, the position of the vessel (latitude and longitude), the vessel speed, and the vessel course were recorded electronically every 30 seconds using the GPS polling function of the FLDRS fishery monitoring software. Fishing activity was assumed to occur when the vessel maintained a speed between 2.0 and 4.0 knots, based on the results of Palmer and Wigley (2007), which found that 99.2% of trawl fishing activity takes place at this range of speeds. Therefore, the tow speed data was trimmed, and observations <2.0 or >4.0 knots were excluded from the analysis. The trimmed data were used to calculate the mean speed (km/hour) of the vessel during each survey tow. The duration of each tow was converted from minutes to fraction of an hour for area swept calculations.

Because the tow durations reported during the 2004 and 2005 industry-based surveys were so variable, the tow durations were standardized to allow for a more direct comparison to the 2011 survey. The tow durations were standardized as follows:

Catch adjustment = 0.5 (hrs)/reported tow duration (hr)

The catch weights and catch numbers per tow were then standardized to a 30 minute tow as follows.

Standardized Catch (kg) = yellowtail flounder catch (kg) * catch adjustment

Standardized Catch Number = yellowtail flounder number * catch adjustment

The area swept (km^2) by the survey net was calculated for each tow, using the following formula. A constant doorspread value of 125.3 meters (68.5 fathoms) was used for survey tows completed in 2004 and 2005.

Area swept (km^2) = doorspread (km) * tow speed (km/hr) * tow duration (hr)

After the area swept during each tow was calculated, we were able to calculate the density of yellowtail flounder observed during each survey tow. The density of yellowtail flounder was calculated for each survey tow as follows.

Yellowtail flounder density (kg/km^2) = yellowtail flounder catch (kg)/area swept (km^2)

Each of the grid cells within the survey area had an area of $30.74km^2$. The SNECRI and MFI Open study regions each contained 201 grid cells, and each of these survey regions had an area of $6179km^2$. The SNECRI Closed study region contained 200 grid cells, and had an area of $6148km^2$. Estimates of standardized yellowtail flounder density, which were calculated for each valid survey tow, were used to estimate the biomass of yellowtail flounder present in each of the three regions using the following formula. The biomass estimate was later converted from kilograms to metric tons to allow for comparison with biomass estimates derived from the NEFSC annual trawl survey and the stock assessment.

Yellowtail flounder biomass (kg) = yellowtail flounder density (kg/km^2) * size of survey subarea (km^2)

The catchability of the survey net is unknown, and our calculations of yellowtail flounder density and biomass are conservative because they assume that the survey net is able to catch 100% of the flounder that are within the path of the trawl. To investigate the effect of catchability on the estimates of biomass, a series of calculations were performed with assumed catchability values ranging from 0.1 to 1.0. The following equation was used to examine the sensitivity of the biomass estimate to the assumed survey catchability that was used.

Yellowtail flounder density (kg/km^2) = yellowtail flounder catch(kg)/area swept (km^2) * (1/q)

Where, q is the catchability coefficient.

We also compared the area swept biomass estimates obtained from the two industry-based surveys to the area swept biomass estimates calculated from the Northeast Fisheries Science Center (NEFSC) fall trawl survey. Data from the NEFSC bottom trawl survey was obtained from Larry Alade and Lisa Kerr. The NEFSC bottom trawl survey strata were plotted in ArcGIS, and overlaid with the study area used during the 2011 SMAST industry-based survey (Figure 4). Nearly all of the 2011 industry-based survey study area is contained within four NEFSC survey strata: 1050, 1060, 1090 and 1100. Therefore, observed yellowtail flounder catches from these four strata were included in the analysis of area swept biomass. The total area covered by the four NEFSC strata is 28,412km^2.

Area swept biomass estimates of yellowtail flounder for the NEFSC survey were calculated using the formula shown below. The area swept by a standard Albatross tow (0.0112nm^2; 0.04189km^2) was used in the calculations. Yellowtail flounder catch data from the 2011 survey had already been converted from Bigelow to Albatross units, and the converted catch weights were used in the analysis.

Area Swept Biomass (kg) = Yellowtail Flounder Catch (kg) * (size of survey strata (km^2)/Area Swept (km^2)

A mean estimate of area swept biomass was calculated for each of the four survey strata. The sum of the four estimates was then calculated to obtain a single estimate of yellowtail flounder biomass for the 2004, 2005 and 2011 NEFSC fall surveys.

Before-After-Control-Impact Analysis

A before-after- control-impact (BACI) analysis was used to compare the catch numbers and catch weights of yellowtail flounder that were observed inside and outside of the Nantucket Lightship Closed Area during the 2004-2005 and 2011 industry-based surveys. The distribution of catch weights observed during the 2011 survey was characterized as having a large number of zero observations and was positively skewed (Figure 5). Kerr et al (2012) found that a generalized linear model with a zero adjusted inverse Gaussian distribution was appropriate for modeling a data set with this type of distribution.

The standardized catch number and catch weights from all valid survey tows, for the 2011 and 2004-2005 surveys were used in a BACI model to examine the spatial and temporal effects of the Nantucket Lightship closed area. We adopted the methods of Kerr et al. (2012), with some adjustments to account for differences in input data. In this analysis, the main effects of each model included time period (2004-2005 vs. 2011), and location (MFI Open area vs. MFI Closed Area). The interaction term (period*location) was used to test for significant changes in the catches of yellowtail flounder in the closed area over the time period.

This analysis included all valid tows from the 2004-2005 (n=106) and 2011 (n=151) industry-based surveys that took place in the MFI open and MFI closed survey areas. All tows that were within the MFI open area were labeled as “OUTSIDE” and all tows within the MFI closed area were labeled as “INSIDE.” Survey tows that took place during the 2004-2005 industry-based survey were included in the “BEFORE” group and all tows during the 2011 survey were included in the “AFTER” group.

RESULTS

Yellowtail Flounder Catches

The survey was completed over the course of nine sampling trips between September 27th and November 9th, 2011. A total of 263 tows were attempted during the course of the survey. Thirty one tows were considered to be invalid, due to a number of factors (e.g., excessive bycatch, net damage, etc…). Ultimately, data from 232 survey tows were used in the final analysis (Figure 6). Some regions of the study site could not be sampled with the trawl gear that we were using. For example, we were not able to sample in the northeast portion of the Nantucket Lightship Closed Area, or on certain portions of Cox's Ledge (Figure 6). The captains did not feel comfortable trying to tow the survey nets in these locations, because there are a number of hangs and sections of hard bottom in both areas. We also could not sample in the area just to the southeast of Block Island, due to the large amount of fixed gear that was present in this region. There are also a few smaller regions of the study site where a valid tow could not be completed due to excessive amounts of spiny dogfish bycatch.

The standardized mean yellowtail flounder catch weights that were observed in each study area are shown in Table 1. The largest mean yellowtail flounder catches were observed in the SNECRI area, while the smallest average yellowtail catches were observed in the Nantucket Lightship closure. The single largest catch of yellowtail flounder was observed in the MFI Open area, where 224.1 kg of yellowtail flounder were captured in a single survey tow (Figure 7). Generally, the largest yellowtail flounder catches were observed between 40 and 60 meters in the SNECRI and MFI Open areas. Catches were typically larger in the southeast portion of the Nantucket Lightship, in roughly 70 meters of water. Interestingly, very few yellowtail flounder were present in the southwest corner of the Lightship.

The catches of yellowtail flounder that were observed in the MFI Open and MFI Closed survey areas were compared between the two survey vessels (Table 2). The mean catch weights of yellowtail flounder were greater on the F/V Heather Lynn in the MFI Open area, but smaller in the MFI Closed area. Results from a two-way ANOVA (Sokal and Rohlf, 2001) indicated that there was no significant difference in the catch weights between the two survey vessels ($p = 0.29$).

Length Frequency

The length frequency of yellowtail flounder captured during the industry-based survey was examined to gain a better understanding of the size structure of yellowtail flounder present in southern New England. The observed length frequency of yellowtail flounder captured during the industry-based survey is shown in Figure 8 and Table 3. Two modes appeared to be present in the length frequency data, with the first mode appearing around 24cm and the second mode appearing around 33cm.

The length frequency of yellowtail flounder captured in the MFI Open and MFI Closed Area was compared, and is shown in Figure 9. Overall, it appears that there is a greater proportion of large yellowtail flounder present in the MFI Open study area. A Kolmogorov-Smirnov test (Sokal and Rohlf, 2001) was used to test for significant differences in the length frequency of yellowtail flounder in the two survey areas. There was a significant difference ($p<0.001$) in the size structure of yellowtail flounder between the two areas, and on average, yellowtail flounder in the MFI Open area were larger than yellowtail flounder in the MFI Closed area (Figure 9).

A large number of recruits were observed in the SNECRI area (Figure 9). A greater proportion of large (>32cm) yellowtail flounder were observed in the SNECRI and MFI Open areas than were observed in the Closed area. In the SNECRI area, 43.4% of the yellowtail flounder captured during the survey were sublegal size (<33cm). In the MFI Open area, only 31.8% of the yellowtail were sublegal size, while in the Closed area, the majority of yellowtail flounder that were captured were sublegal size (56.8%).

Biological Samples

Yellowtail flounder scale samples (n=242) collected during the 2011 industry-based survey were provided to the Northeast Fisheries Science Center for age determination. The scale samples were processed, and the age was determined for 192 of the samples. The age information obtained from the scale samples was used to inform estimates of catch at age during the 2012 yellowtail assessment.

Area Swept Biomass

The mean density (kg/km^2) and biomass (mt) of yellowtail flounder estimated to be present in each of the three survey regions was calculated. It should be noted that these biomass estimates are conservative, since a catchability (q) of 1 was assumed for the survey net. This assumed catchability value is likely to be an overestimation of the true catchability of the survey net.

For the 2011 survey, the estimates of yellowtail flounder biomass in the MFI Open and SNECRI survey regions are nearly identical (Table 4). However, the survey results indicate that the biomass of yellowtail flounder in the MFI Closed area is substantially lower than the biomass estimated to be present in the SNECRI area and the MFI Open area.

The catchability (q) of the survey net is unknown. To examine the sensitivity of the yellowtail flounder biomass estimate to the assumed catchability value (q) that was used for the survey net, a series of calculations were performed, using a catchability value that ranged from 0.1 to 1.0 (Table 5).

The area swept biomass estimates calculated from the 2004-2005 industry-based survey area shown in Table 6. The estimates of biomass in the SNECRI area and the MFI Open area are nearly identical, while the biomass estimated to be present in the MFI Closed area is lower. Overall, the total biomass estimate that was observed during the 2004-2005 survey (258.2mt) is much lower than the yellowtail flounder biomass that was estimated from the 2011 survey (1042.2mt). Catch weights from the 2004-2005 RIDFW survey suggest that 29% of the yellowtail flounder biomass was present in the Nantucket Lightship. However, in 2011, only 15% of the biomass was estimated to be present in the Nantucket Lightship. These results suggest that yellowtail flounder appear to be rebuilding in this portion of the SNE/MA stock area. However, it is interesting to note that rebuilding appears to be much slower in the Nantucket Lightship closed area, when compared to adjacent areas that are open to fishing.

Area swept estimates of yellowtail flounder biomass were calculated for the 2004, 2005, and 2011 NEFSC Autumn bottom trawl survey. The results are shown in Table 7.

The results of the NEFSC survey indicate that the biomass of yellowtail flounder in the four survey strata has increased since 2004.

Estimates of yellowtail flounder density and biomass were compared between the NEFSC bottom trawl survey and the RIDFW industry-based survey for 2004 and 2005. The results are shown in Table 8.

The results of both surveys indicate that the biomass of yellowtail flounder increased between 2004 and 2005. In 2004, the density and biomass of yellowtail flounder observed on the RIDFW survey was much greater than was observed on the NEFSC trawl survey. However, in 2005, the estimates of biomass derived from the NEFSC trawl survey are greater than the biomass estimates calculated from the RIDFW survey. It should be noted that the area covered by the four NEFSC trawl survey strata used in this analysis (28,412km^2) is much greater than the area that covered by the RIDFW survey (18,506km^2). Therefore, it may be more appropriate to compare the estimates of yellowtail flounder density, rather than biomass. The results show that the density of yellowtail flounder observed during the 2004 NEFSC survey is much lower than was observed during the RIDFW survey. In 2005, the density estimates from the two surveys was nearly identical. Estimates of yellowtail flounder biomass and density were compared between the SMAST industry-based survey and the NEFSC trawl survey for the fall of 2011. The results of the two surveys are shown in Table 9.

Estimates of yellowtail flounder density and biomass from the 2011 SMAST industry based survey are much greater than the biomass and density estimates calculated from the 2011 NEFSC trawl survey. The density estimates derived from the SMAST survey are nearly three times larger than the estimates of yellowtail flounder density observed on the NEFSC fall survey in 2011. It should be noted that the number of observations on the SMAST survey is nearly an order of magnitude greater than the NEFSC trawl survey. The variance associated with the biomass estimates is quite large for both surveys.

Winter Flounder Catches

The distribution of winter flounder catch weights is shown in Figure 10. The largest catches of winter flounder were typically observed in waters less than 30 meters. For example, sizeable winter flounder catches were observed to the south and east of Block Island, and in the vicinity of Cox's Ledge. Catch weights generally decreased with increasing depth, and winter flounder were commonly absent from survey tows made in the deeper portions of the study site. Winter flounder catches were generally small in the Nantucket Lightship Closed Area. Interestingly, the largest winter flounder catches were observed in the southwest portion of the Nantucket Lightship, in waters ranging from roughly 65 to 75 meters.

BACI Analysis

The effect of the closed area on yellowtail flounder catch weight was fit using a generalized linear model with an inverse Gaussian distribution. The likelihood ratio test for the standardized catch weight suggested that the model fit was strong and that the model explained a significant amount of the variability in the data (p=0.0001). The results of the BACI analysis (Figure 11; Table 10) on standardized catch weights indicated that there were significantly higher standardized catch weights outside of the closed area. There was an increase in the standardized mean catch weights in both areas over time, but the increase in catch weights over the time period was not significant (p=0.085). The relative increase in yellowtail flounder catch weights was greater in the open areas than in the closed area (Figure 11). The interaction term was also not significant (P = 0.212), indicating that there was not a significant closed area effect over the time period.

A generalized linear model with a zero adjusted inverse Gaussian distribution was fit to the data to investigate the probability of occurrence and the yellowtail catch numbers. The likelihood ratio test indicated that this model was not explaining a significant amount of the variability in the data, and the results were suggestive of a poor model fit (p=0.59). Because using the generalized linear model could not adequately explain the variability in the data, the results of this model were not considered further in the analysis.

Presentations

The results of the survey were presented at a number of relevant meetings and conferences. On January 24th, 2012 Greg DeCelles presented the survey methodology and the results of preliminary data analysis at a research meeting convened by the Commercial Fisheries Research Foundation in South Kingston, RI. The meeting was attended by regional fishermen, academic and government scientists, and fishery managers.

On February 27th, 2012 Greg DeCelles presented the results of the survey to the Groundfish Plan Development Team (PDT) in Mansfield, MA. The presentation was focused primarily on the results of the BACI analysis. The PDT was very interested in this information as they consider making changes to the fishery closed areas in southern New England and on Georges Bank. In the presentation, we concluded that the Nantucket Lightship Closed Area has not been effective at helping to rebuild the yellowtail flounder population in southern New England.

On February 27th, 2012 Adam Barkley presented the methods and results of the industry-based survey to an audience of fishermen and scientists at the SMAST campus in Fairhaven, MA. The meeting was held ahead of the yellowtail flounder stock assessment in April. Feedback received at the meeting was used to improve the analysis and interpretation of data collected during the survey.

On April 2nd, 2012 Greg DeCelles presented the results of the survey to the Southern Demersal Working Group at the Stock Assessment Workshop (SAW 54) for yellowtail flounder in southern New England. Scale samples that were provided to the NEFSC for age determination were used during the model meetings to help inform estimates of yellowtail flounder catch at age. Area swept biomass estimates that were calculated from the 2011 industry-based survey were considered as “minimum biomass estimates” as candidate stock assessment model runs were being explored. A number of candidate stock assessment models were explored during the meeting, and each assessment model estimated a different biomass for the yellowtail flounder stock. It was agreed that any model would be rejeceted immediately if the biomass estimate produced by the model was less than the area swept biomass calculated from the industry based survey (1042.3 mt).

On September 20th, 2012 Greg DeCelles presented results from the survey to an audience of academic scientists at the International Council for the Exploration of the Sea’s Annual Science Conference (ICES ASC), which was held in Bergen, Norway. The title of the theme session for this presentation was “Consequences of improved survey performance on assessments and management advice? Do innovations in survey and sampling design and in technology make any difference?”. The presentation focused on the benefits of forming collaborative partnerships with fishermen, and how these partnerships can improve the quality of fisheries research. Experiences gained from this survey, and other SMAST industry-based surveys, were discussed in the context of efficient and effective research designs.

DISCUSSION

Nantucket Lightship Closed Area

The Nantucket Lightship was closed to commercial fishing in 1994, primarily to help rebuild depleted stocks of yellowtail flounder. Since 1994, yellowtail flounder biomass has increased inside the Closed Areas on Georges Bank (Murawski et al., 2000; TRAC, 2009), but similar increases in biomass have not been noted inside the Nantucket Lightship area. The results of the current survey provide further evidence that the Nantucket Lightship Closed Area has not been effective at helping to rebuild the yellowtail flounder population in southern New England.

Following the 2003-2005 industry-based survey, it was estimated that less than 3% of the total yellowtail flounder biomass was present in the Nantucket Lightship Closed Area (Valliere and Pierce, 2007). Differences in the design of the two surveys makes direct comparison of catch weights between the RIDFW and SMAST surveys very difficult. However, the design of the BACI analysis allows for more direct comparisons to be made between the results of the two surveys. The results of the BACI analysis showed that yellowtail flounder catch weights were significantly smaller inside the closed area, when compared to catches in adjacent open areas. The results also suggest that yellowtail flounder biomass has increased since the 2003-2005 survey, although the magnitude of this increase is not significant (Figure 11, Table 10). The findings of the analysis match the perceptions of our industry partners, who also believe that the yellowtail flounder stock has increased in recent years. These findings are also in line with the most recent stock assessment, which also suggests that spawning stock biomass has increased in the southern New England/Mid-Atlantic yellowtail stock since 2003-2005 (NEFSC, 2012).

The length frequency distributions of yellowtail flounder (Figures 9a and 9b) reveal some interesting patterns. A large number of juvenile yellowtail flounder were noted in the SNECRI area, and most recruits were between 20 and 24 cm. To the east, in the MFI Open Area, far fewer recruits were present, and the yellowtail flounder population in this region was represented primarily by adult fish. There appeared to be fewer large yellowtail present in the Nantucket Lightship Closed Area, when compared to the adjacent open areas. The observed dearth of adult fish in the Closed Area was surprising, since this area has been closed to groundfishing activities since 1994.

There are several potential reasons why few adult fish were present in the Closed Area. A proportion of adult flounder may migrate out of the Closed Area once they reach a certain size (i.e., spillover effect). Alternatively, there may be differential survival of yellowtail within the regions of the stock area, and survival may be lower in the Nantucket Lightship than in other areas. We are hopeful that long-term tag recaptures from the commercial fishery will help address this question. However, we have not received any tag returns from the commercial fishery to date. We have maintained outreach efforts with regional fishing fleets, and have encouraged fishermen to return tags. We will continue these outreach efforts moving forward, and will analyze tag recapture information as it is received.

The Benefits of Working with Fishermen to Conduct Research

The benefits of working closely with the fishing industry were evident throughout each stage of the survey. By forming a cooperative partnership, we were able to efficiently collect large amounts of high quality data that can be used to better inform the assessment and management of yellowtail flounder in southern New England. Due to the limited space available on each vessel, survey trips were completed with a crew of only two scientists and three or four fishermen. Despite the small staff on each vessel, we worked efficiently and were typically able to complete between nine and 14 survey tows per day. The vessels that participated in the project served as a cost effective platform for performing the research, allowing us to complete these surveys within the constraints of our operating budget.

The benefits of working with the industry were most evident while we were completing the field work of the survey. The practical experience of the captains that participated in the survey allowed us to complete each project in a timely manner. For example, the captains were very familiar with the study area, which allowed us to sample effectively in a region where fixed gear and wrecks are common. The expertise of the captains and crew was a valuable asset when problems arose during the surveys. For example, large catches of dogfish (>10,000kg) were common throughout the survey. The experience of the fishermen allowed us to deal with these large catches quickly and minimize the amount of sampling time that was lost. Throughout each survey, we were focused on maximizing the sampling intensity and density of samples within the study site. A sufficient sampling density is required to ensure that patches of fish are sampled adequately. Occasionally large survey catches can contribute heavily towards estimates of abundance and biomass, and these patches of fish may be overlooked when sample density is inadequate (Powell, 2006).

Many fish species, such as yellowtail flounder exhibit diel differences in catchability (Casey and Myers, 1998; Petrakis et al., 2001; Adlerstein and Elrich, 2002). If these diel changes in catchability are not accounted for during a survey, it can introduce considerable bias into abundance indices and assessment results (Walsh, 1988). The captains that we worked with during this survey informed us that catch rates of yellowtail flounder typically decrease substantially between sunset and sunrise. In response to this information, we structured our survey to sample only during the daylight hours. In contrast, the NEFSC trawl survey samples 24 hours a day. Sampling at night may artificially reduce the survey catches for yellowtail flounder in the southern New England stock area. As a result, the NEFSC survey index of abundance may underestimate the true scale of the population.

Survey Nets

The true catchability (q) of the survey nets is unknown, which is problematic because the estimates of area swept biomass derived from the survey are directly proportional to the assumed value of q. The survey nets were designed to be similar to the trawl nets that are commonly used by the Point Judith fleet to target yellowtail flounder. The Point Judith, RI trawl fleet typically uses long groundcables (75-100 fathoms) when they target flatfish in southern New England, and each vessel used 75 fathom groundcables with their survey net. In retrospect, we probably should have designed the net with much shorter groundcables, to reduce the potential amount of herding between the doors of the trawl. For example, in 2010 when we surveyed for winter flounder in the Great South Channel, our survey net was designed without groundcables. This allowed to use the wingspread values to calculate area-swept biomass, because we could assume that there was very little herding of flatfish between the doors and the wings of the net. Using the wingspread to calculate area swept is advantageous, because the wingspread is less variable, and the use of the wingspread can reduce the uncertainty associated with area swept estimates. Because long groundcables were present on the net, the doorspread was larger and more variable than the wingspread. Obviously, the area swept biomass estimates are sensitive to whether the doorspread, or wingspread, is used to calculate the area swept by the trawl. When the doorpsread is used, the estimate of yellowtail flounder biomass is substantially lower, when compared to the biomass estimate that is derived using the wingspread. We suggest that future surveys avoid this uncertainty by using the shortest possible groundcables on their survey nets, which will allow the use of the wingspread to be used to calculate area swept per tow.

The Utility of Industry-Based Surveys

Surveys serve two important roles in the stock assessment process; they allow scientists to estimate the scale (abundance) of fish populations and to measure trends in the productivity of the resource over time (Powell et al., 2006). Scale is typically harder to measure than trend, but accurately quantifying the scale of fish populations is critical for effective management (Powell et al., 2006). The NEFSC Bottom trawl survey is the only fishery independent survey used in the stock assessment for southern New England yellowtail flounder. Many industry members contend that the NEFSC survey is not able to accurately estimate the scale of the yellowtail flounder population in southern New England. This criticism has become more prevalent following the transition from the R/V Albatross to the R/V Bigelow. In particular, fishermen are concerned that the rockhopper groundgear that is now being used on the NEFSC survey net is unsuitable for sampling yellowtail flounder in southern New England.

We feel that industry-based surveys are well suited to assess the scale of fish populations. Industry-based surveys can be designed to target species in particular regions and times of year that may be undersampled by existing resource surveys. By using standardized protocols, electronic data collection, and net mensuration equipment, industry-based surveys can generate accurate biomass estimates that offer insight into the scale of fish populations. These surveys may be most useful in the period immediately preceding new stock assessments. For example, results from this survey were considered during the benchmark yellowtail flounder assessment (SAW 54). The biomass estimate generated from this survey was considered as a “minimum biomass” as candidate assessment models were being explored. During the meeting it was agreed that a candidate assessment model should be rejected if the biomass estimate from the model was lower than the biomass estimate from the industry-based survey.

Industry-based surveys are also very useful for collecting the demographic information (e.g., length frequency, maturity, etc…), that is needed for stock assessments. For example, biological data collected during an industry-based survey for yellowtail flounder between 2003 and 2005 was included in the 2005 stock assessment for yellowtail flounder (Valliere and Pierce, 2007), and this biological data helped eliminate the retrospective pattern that had been plaguing the assessment (Cadrin and Legault, 2005). During the current survey, we were able to gather a large amount of information on the size and age structure of yellowtail flounder in southern New England which was considered during the 2012 stock assessment workshop (SAW 54)

SUMMARY OF CONCLUSIONS- MAJOR RESEARCH FINDINGS

- Mean yellowtail flounder catch weights were much larger in open areas that are adjacent to the Nantucket Lightship when compared to the catch weights of yellowtail flounder inside of the Nantucket Lightship Closed Area.
- The results of the BACI analysis indicate that the abundance of yellowtail flounder in southern New England has increased since 2004-2005.
- While yellowtail flounder appears to be rebuilding in southern New England, the population seems to be rebuilding much faster in the open areas when compared to the Nantucket Lightship Closed Area.
- The majority of yellowtail flounder inside of the Nantucket Lightship Closed Area are sublegal size, and there is a noticeable lack of adult yellowtail flounder in the Closed Area. While recruitment in the SNECRI area appeared to be very strong, the majority of flounder captured in the SNECRI area and the MFI Open area were larger than the minimum landings size (33cm).
- By forming collaborative partnerships with the fishing industry, we can improve the quality and efficiency of fisheries research.

ACKNOWLEDGEMENTS

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We would like to thank the captains and crews of the F/V Heather Lynn and the F/V Travis and Natalie. Their hard work and expertise allowed this project to succeed. We are grateful to Doug Zemeckis and Dave Martins for helping to complete the field work. We would also like to thank Jon Knight and his crew at Superior Trawl for their help in repairing and transporting the survey nets. April Valliere and her staff at the RIDFW were kind enough to lend us the survey nets for use during the project. Without their generosity, this survey may not have been possible. We would also like to thank Fred Mattera for helping us to organize meetings, and for providing us with a meeting space to discuss the project with fishermen. Lisa Kerr provided us with a tremendous amount of help on the use of BACI analysis for fisheries datasets. Finally, we would like to thank Robert Johnston, Larry Alade and Chris Legault at the NEFSC for providing us with survey data and for answering questions about the analysis of the NEFSC survey data.

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TABLES

Table 1. Mean standardized yellowtail flounder catches observed in each of the three regions of the study area during the 2011 industry-based survey.

	Number of tows	Mean standard. catch (kg)	St. Dev.	Maximum Catch (kg)	% of tows with no yellowtail flounder
SNECRI	81	20.3	37.91	174.7	18.5%
MFI Open	77	19.35	36.81	224.1	15.6%
MFI Closed	74	7.32	11.48	50.1	18.9%
	232	15.84	31.93		17.6%

Table 2. Mean yellowtail flounder catches observed on each of the survey vessels in the MFI Open and MFI Closed survey areas during the 2011 industry-based survey.

Area	Vessel	n	Mean yellowtail catch (kg)	St. Dev.
MFI Open	Heather Lynn	40	21.10	44.97
MFI Open	Travis and Natalie	37	13.08	15.98
MFI Closed	Heather Lynn	35	7.25	10.26
MFI Closed	Travis and Natalie	39	7.35	12.82

Table 3. Length frequency data for yellowtail flounder that were captured during the 2011 industry-based survey.

Length (cm)	Frequency
17	5
18	11
19	61
20	129
21	200
22	221
23	316
24	367
25	332
26	225
27	186
28	159
29	266
30	424
31	496
32	686
33	750
34	698
35	667
36	590
37	541
38	485
39	417
40	447
41	330
42	322
43	200
44	105
45	67
46	31
47	17
48	8
49	6
50	1

Table 4. Area swept estimates of yellowtail flounder density and biomass in each of the three regions of the study area.

Area	# of Tows	Area swept/tow (km^2)	Density (kg/km^2)	Biomass (mt)
SNECRI	81	0.27	72.41	440.23
MFI Open	77	0.25	73.17	444.88
MFI Closed	74	0.28	25.98	157.18
Total	**232**			**1042.29**

Table 5. Estimates of area swept biomass that were calculated using a range of catchability (q) assumptions.

Area	q=1	q=0.9	q=0.8	q=0.7	q=0.6	q=0.5	q=0.4	q=0.3	q=0.2	q=0.1
SNECRI	440.2	489.1	550.3	628.9	733.7	880.5	1100.6	1467.4	2201.1	4402.3
MFI Open	444.9	494.3	556.1	635.5	741.5	889.8	1112.2	1482.9	2224.4	4448.8
MFI Closed	157.2	174.6	196.5	224.5	262.0	314.4	393.0	523.9	785.9	1571.8
Total	**1042.3**	**1158.1**	**1302.9**	**1489.0**	**1737.2**	**2084.6**	**2605.7**	**3474.3**	**5211.5**	**10422.9**

Table 6. Estimates of yellowtail flounder area swept biomass that were calculated from tows made during the RIDFW industry-based survey in the fall of 2004 and 2005.

Area	# of tows	Density (kg/km^2)	Biomass (mt)
SNECRI	57	15.1	91.6
MFI Open	43	15.3	92.9
MFI Closed	63	12.2	73.7
	163		**258.2**

Table 7. Estimates of yellowtail flounder biomass (mt) that were calculated for the four NEFSC bottom trawl survey strata in the fall of 2004, 2005 and 2011.

Strata	2004	2005	2011
1050	13.4	307.0	11.8
1060	47.4	105.6	509.9
1090	12.8	31.4	4.5
1100	9.3	6.6	65.1
Total	**82.9**	**450.6**	**591.4**

Table 8. Comparisons of yellowtail flounder density and biomass observed on the RIDFW and NEFSC trawl surveys during the fall of 2004 and 2005.

	RIDFW Trawl Survey				NEFSC Trawl Survey			
	# Tows	Density (kg/km2)	Biomass (mt)	Variance	# Tows	Density (kg/km2)	Biomass (mt)	Variance
2004	85	11.9	216.9	162345	26	3.0	82.9	3988
2005	78	16.3	296.6	246280	26	17.0	450.6	42012

Table 9. Comparisons of yellowtail flounder density and biomass observed on the SMAST and NEFSC trawl surveys during the fall of 2011.

	SMAST Trawl Survey				NEFSC Trawl Survey			
	# Tows	Density (kg/km2)	Biomass (mt)	Variance	# Tows	Density (kg/km2)	Biomass (mt)	Variance
2011	232	57.9	1053.3	4558938	27	20.4	591.4	460716.5

Table 10. Output from the generalized linear model that was fit to the catch weight data for yellowtail flounder observed during the 2004-2005 and 2011 industry-based surveys for yellowtail flounder.

		Estimate	P value
Catch (weight)	Location:Inside	-0.65	0.011
	Period:After	0.5	0.085
	Interaction:Inside:After	0.51	0.212

FIGURES

Figure 1. Diagram of the survey nets that were used during the 2011 industry-based survey for yellowtail flounder. The nets were originally used during the 2003-2005 RIDFW industry-based survey. Figure taken from Valliere and Pierce (2007).

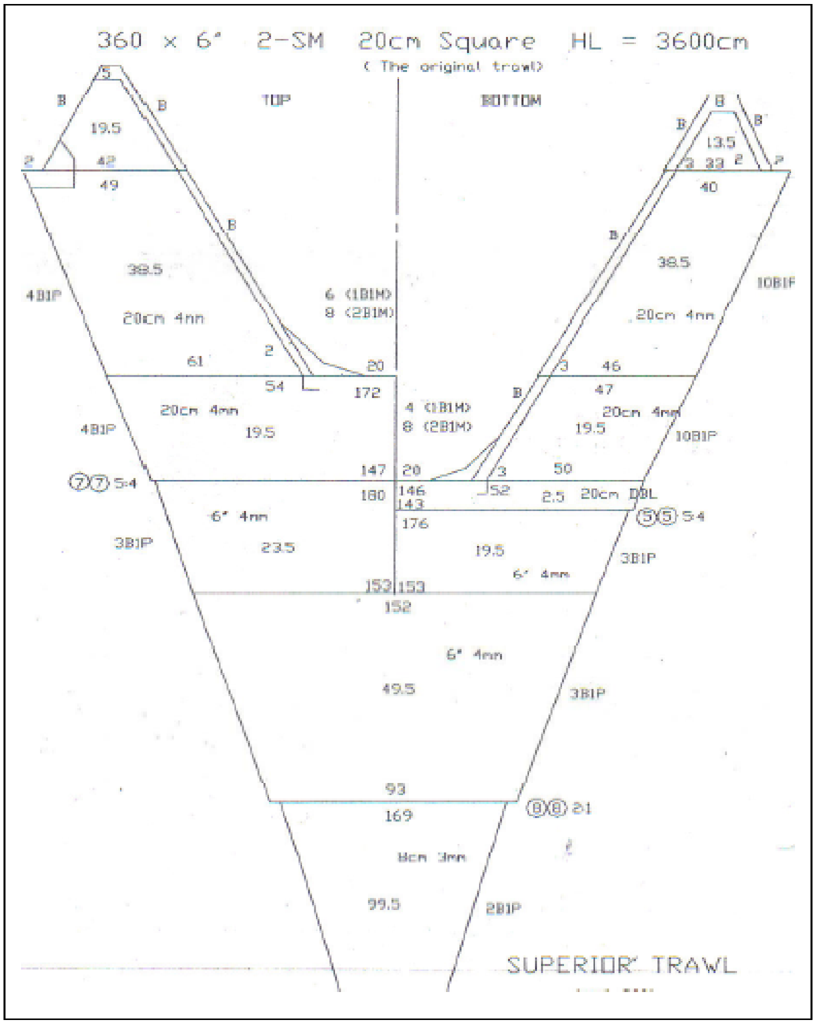

Figure 2. Map of the area that was sampled by the Rhode Island Division of Fish and Wildlife during the 2003-2005 industry-based survey for yellowtail flounder. The survey area is outlined in dark blue, and the Nantucket Lightship Closed Area is shown in light blue. Figure taken from Valliere and Pierce (2007).

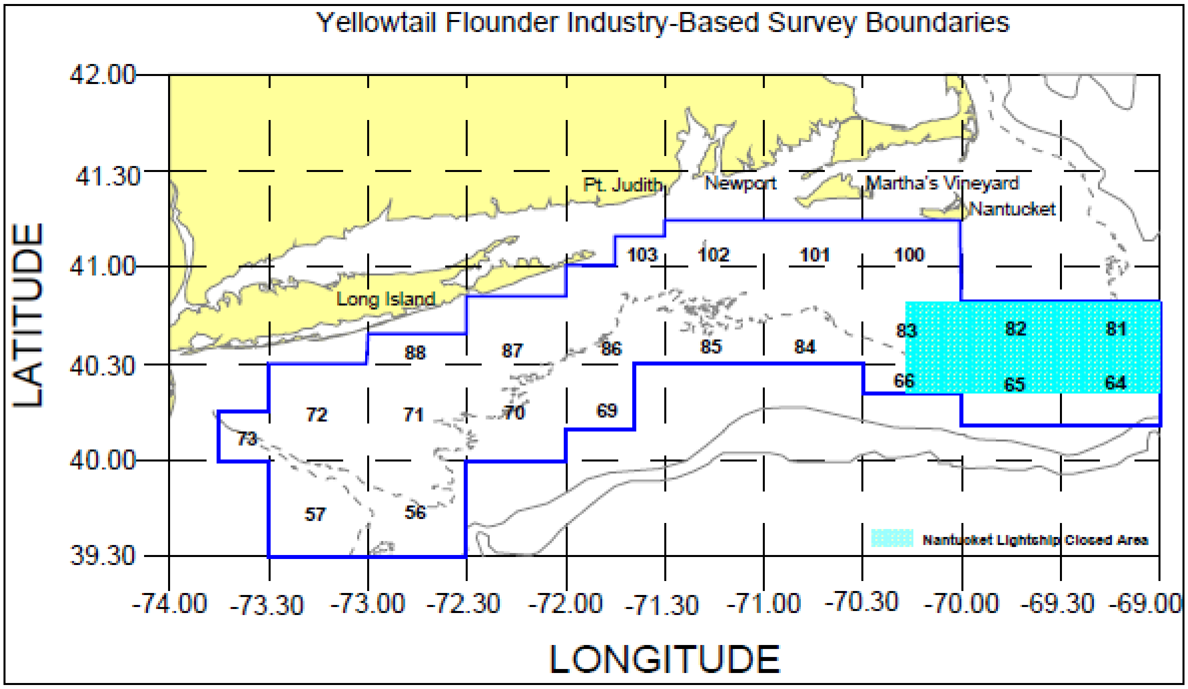

Figure 3. Study area for the 2011 SMAST industry-based survey for yellowtail flounder. The study area is outlined in black, and the Nantucket Lightship Closed Area is outlined in red. The survey area was divided into three regions; the SNECRI study area, the MFI Open area and the MFI Closed area.

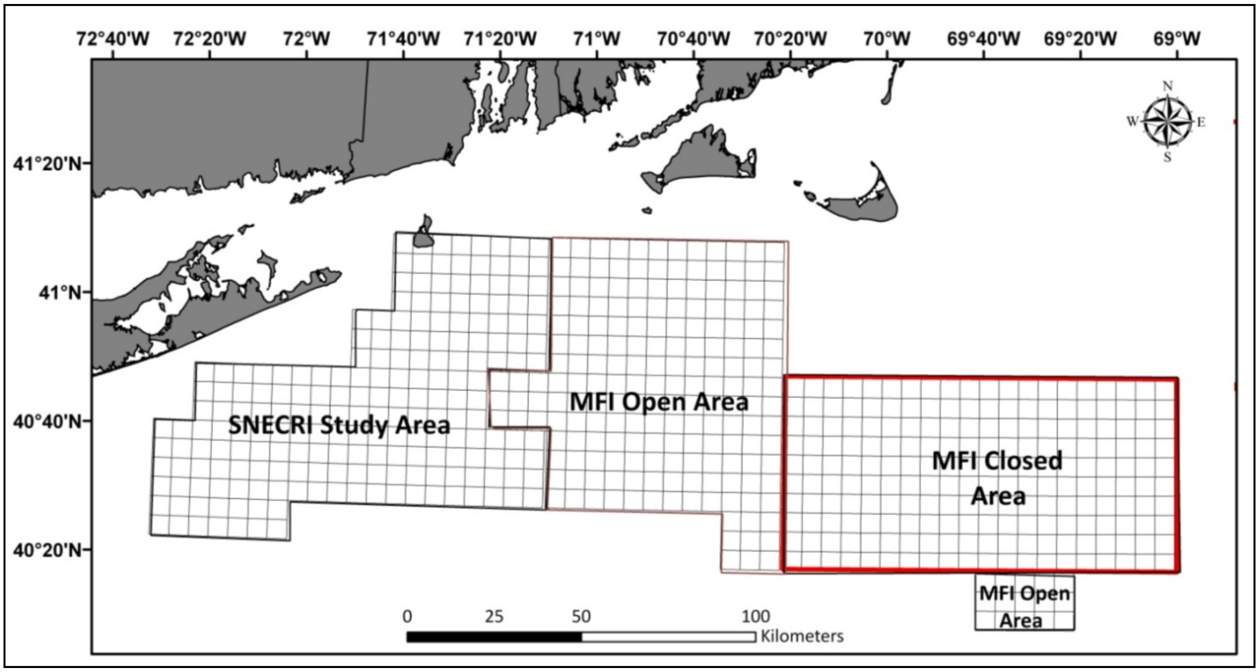

Figure 4. The study areas for the 2004-2005 RIDFW and the 2011 SMAST industry-based surveys are shown in grey. NEFSC bottom trawl survey strata are also shown. Strata 1050, 1060, 1090 and 1100 were included in the analysis.

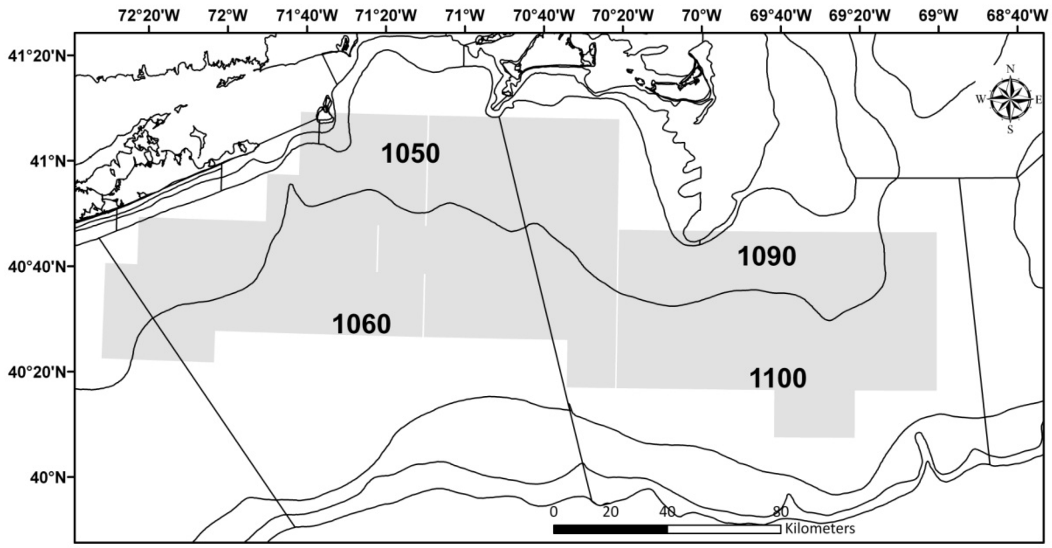

Figure 5. Histogram showing the distribution of yellowtail flounder catch weights that were observed during the 2011 industry-based survey. The catch weights are characterized by a large number of zero observations and are positively skewed.

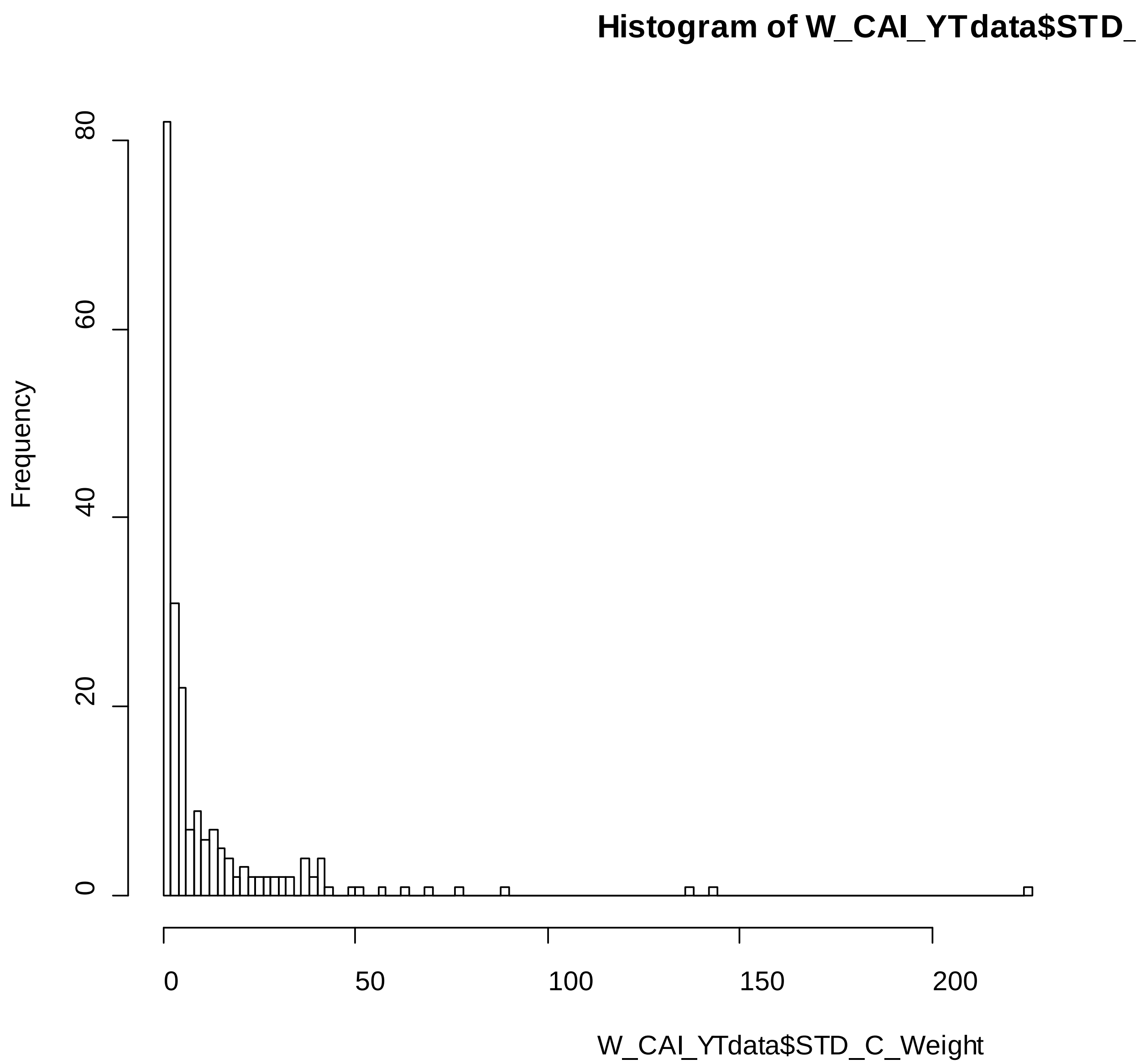

Figure 6. Map showing the location of the 232 valid survey tows that were completed during the 2011 yellowtail flounder industry-based survey. The tows are color-coded by vessel. Tows completed by the F/V Heather Lynn are shown in red, and tows completed by the F/V Travis and Natalie are shown in blue. The Nantucket Lightship Closed Area is outlined in red.

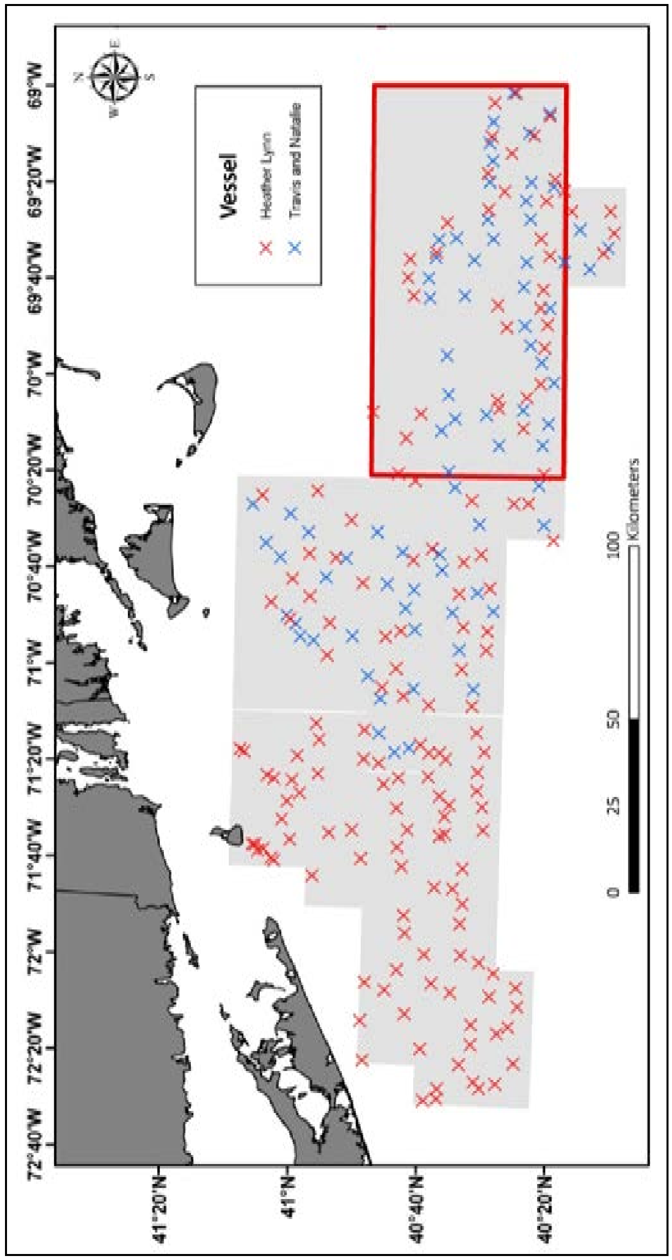

Figure 7. Geographic distribution of yellowtail flounder catch weights (kg/tow) observed during the 2011 industry-based survey. The Nantucket Lightship Closed Area is outlined in red.

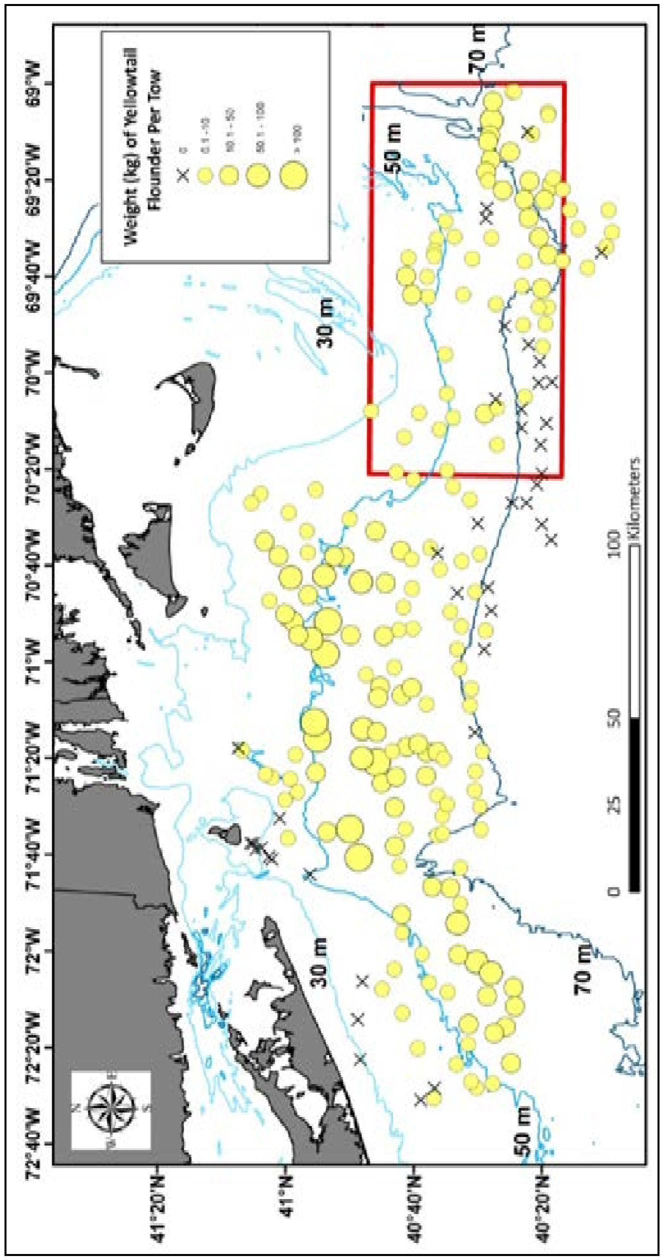

Figure 8. Length frequency distribution of yellowtail flounder captured in the three regions of the study area during the 2011 industry-based survey.

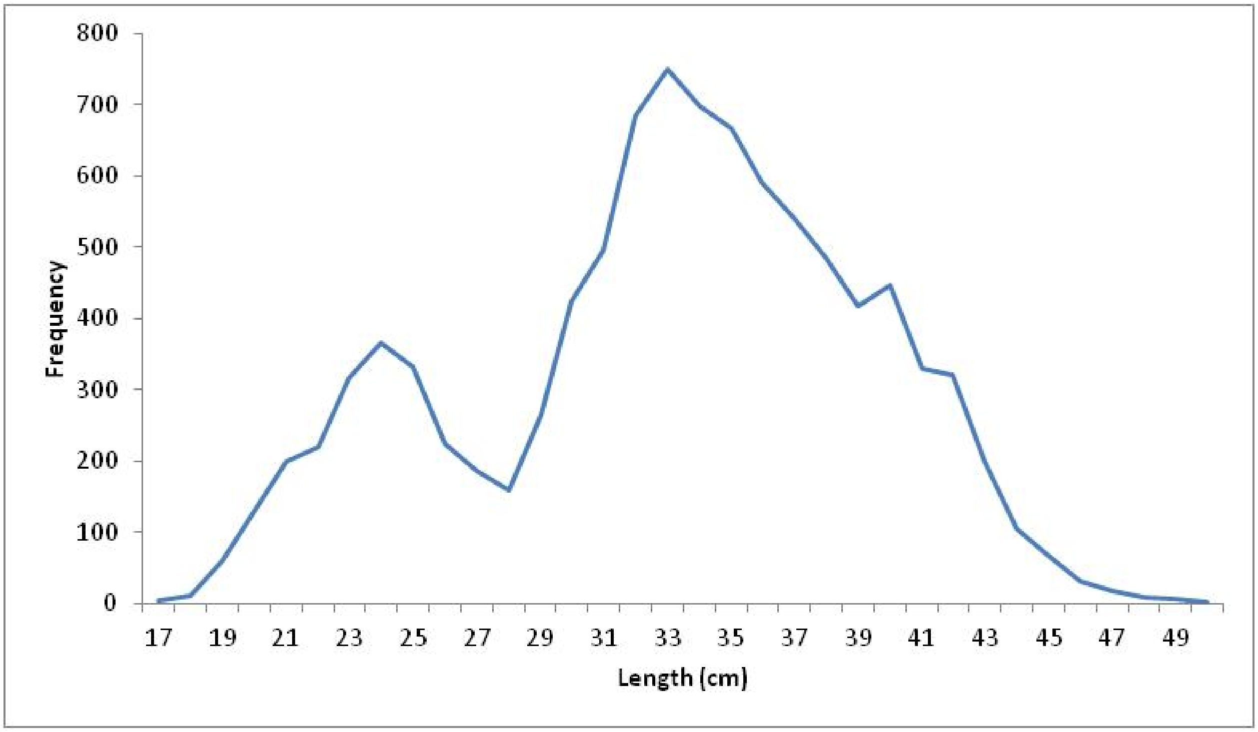

Figure 9. The length frequency distribution of yellowtail flounder observed in each of the three regions sampled during the industry-based survey (top panel). The relative proportion of yellowtail flounder observed at each size class in each regions covered during the industry-based survey (lower panel).

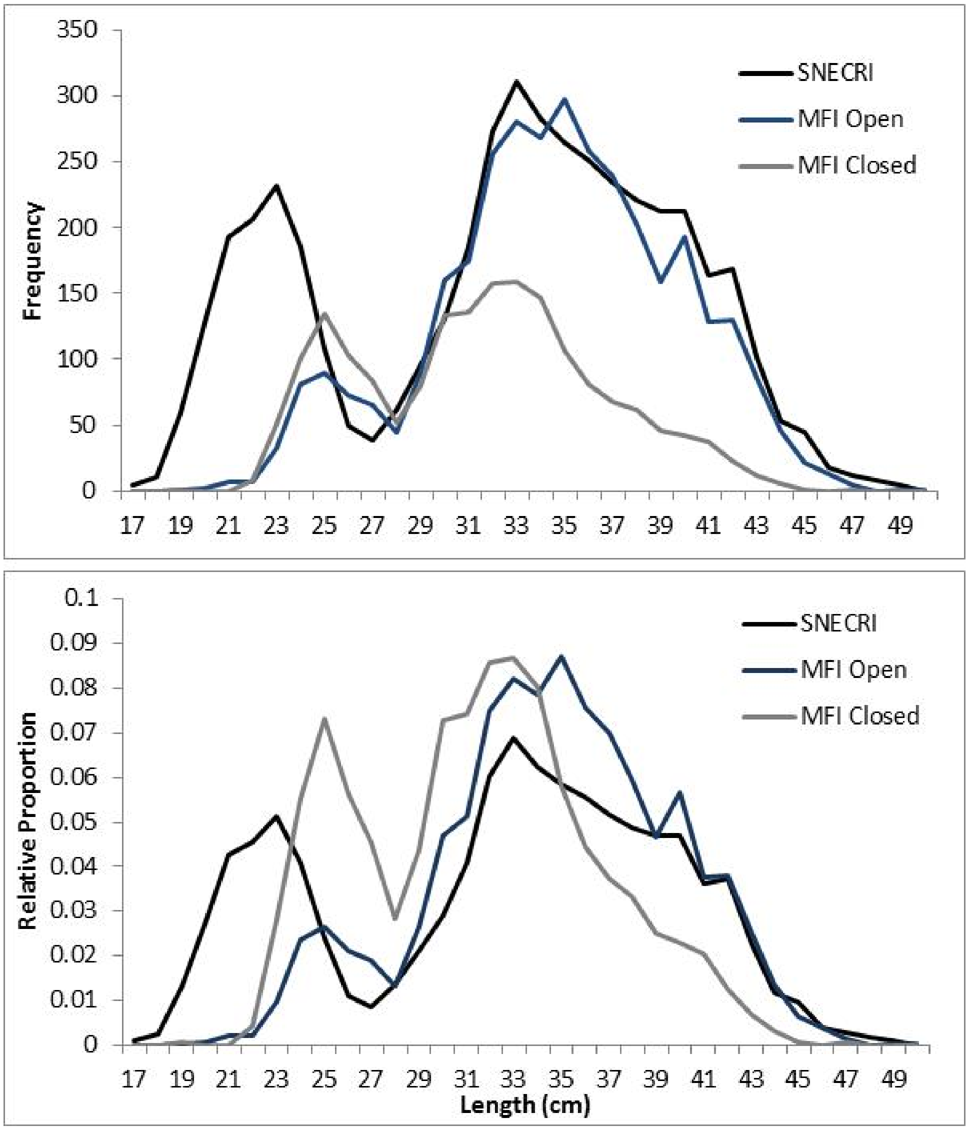

Figure 10. Geographic distribution of winter flounder catch weights (kg/tow) observed during the 2011 industry-based survey. The Nantucket Lightship Closed Area is outlined in red.

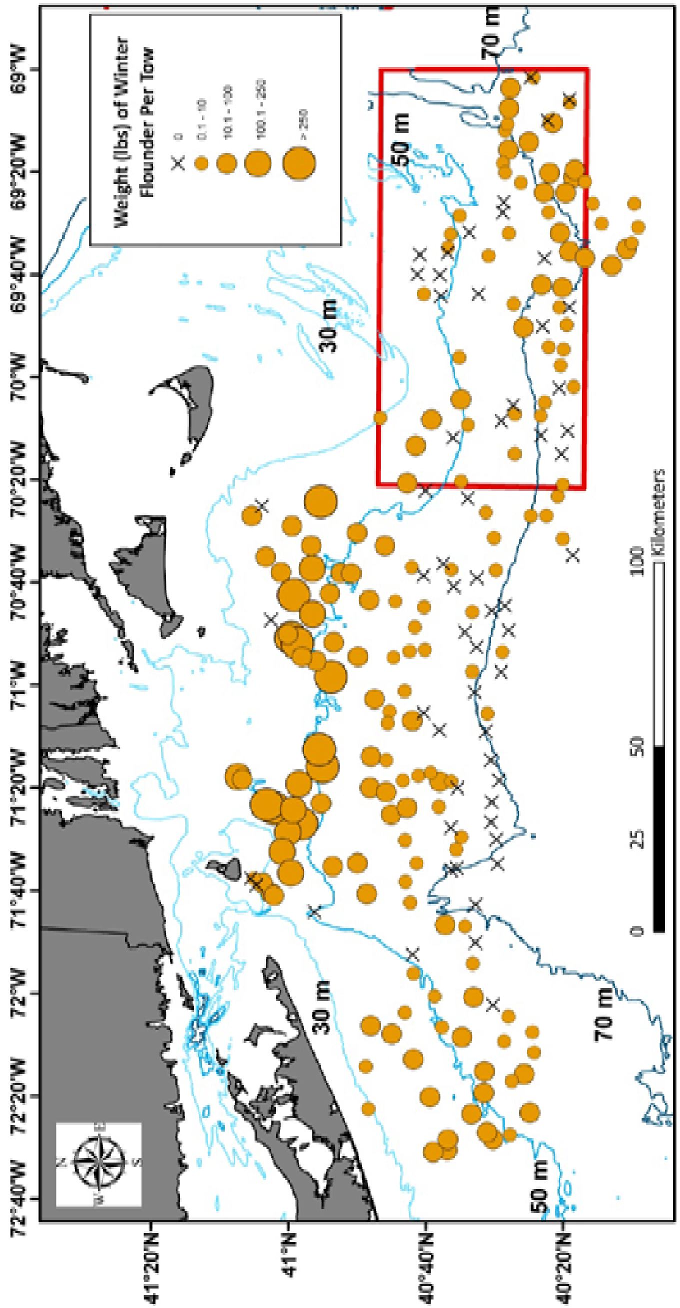

Figure 11. Mean catch weight of yellowtail flounder inside and outside of the Nantucket Lightship Closed Area observed during the 2004-2005 and 2011 industry-based surveys. Mean catch weights are shown with standard errors.