

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

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ABSTRACT

SMAST received funding from the Commercial Fisheries Research Foundation to complete an industry-based survey for winter flounder in the waters of southern New England. The survey was conducted between April and July of 2012, and was completed during 20 days of field work. SMAST partnered with the F/V Black Sheep, F/V Lena Pearl, and the F/V Hopefull to complete the survey. The survey area was determined by meeting with members of the southern New England otter trawl fleet, and included waters ranging from roughly 15-40 fathoms south of Martha's Vineyard and Nantucket. The objectives of the survey were to estimate the abundance, distribution and biological characteristics of winter flounder in southern New England.

A total of 160 tows were completed at random locations in the study site over the course of the four survey trips. Winter flounder catch weights increased between April and July. The distribution of winter flounder shifted noticeably from shallow waters in April to deeper, offshore waters in July. Survey tows were used to generate both relative and absolute estimates of winter flounder biomass in the study area. Generalized Additive Models were used to examine the geographic and environmental factors that affect the distribution and abundance of winter flounder in this region. Nearly 8,000 winter flounder were tagged over the four month period, and length information was obtained from almost 10,000 individuals. In addition, scale samples were collected from yellowtail flounder for use in stock assessments. The results of the survey have been presented to fishermen, academic scientists, fishery managers, and government scientists at several 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 species 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, with a survey area ranging 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.

The 2008 stock assessment concluded that the southern New England/Mid-Atlantic (SNE/MA) stock of winter flounder was overfished, and that overfishing was occurring (NEFSC, 2008). The estimate of fishing mortality in 2007 (0.65) was more than twice the overfishing limit, and the estimate of spawning stock biomass (3,368mt) was less than 10% of the rebuilding target. The 2008 assessment model had substantial sources of uncertainty and the peer-review panel was concerned about low sampling intensity and retrospective patterns present in the population estimates (NEFSC, 2008). The most recent assessment conducted in 2011 determined that the stock is still overfished with spawning stock biomass at 16 percent of the target biomass level (NEFSC, 2011). During the two most recent assessments, projections indicated that the stock had less than a 1% chance of rebuilding by the 2014 deadline (NEFSC, 2008; NEFSC, 2011). In response to the 2008 stock assessment, an Interim Rule was implemented in May of 2009. The Interim Rule was designed in part to reduce fishing mortality of the SNE/MA stock of winter flounder. The Interim Rule prohibited the possession of winter flounder throughout the SNE/MA stock area. The prohibition on possessing SNE/MA winter flounder has continued under Amendment 16 to the Northeast multispecies fishery management plan for sectors and the common pool. The regulations have added to the economic hardship of otter trawl fleets throughout southern New England. Winter flounder, which once supported a robust trawl fishery in the waters of southern New England, has become a discard species under the current regulations.

Given the prohibition on landing winter flounder and the limited observer and at-sea monitor coverage, winter flounder samples from commercial fisheries are expected to be minimal. The paucity of available samples may introduce even greater uncertainty into the stock assessment, or may preclude the use of the stock assessment model in the future. In addition, the R/V Albatross was replaced by the RSV Bigelow in 2009. Although calibration experiments have been completed, the calibration may not be precise enough to bridge the time series gap between these two surveys. Therefore, additional fishery-independent data sources are needed to provide information on relative abundance, geographic distribution and demographic information to improve the data available for assessing the SNE/MA stock complex of winter flounder.

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 have proven to be useful platforms for collecting high

resolution fisheries data, and data collected during industry-based surveys have been incorporated into regional stock assessments. In 2000, the assessment for southern New England (SNE) yellowtail flounder was rejected due to low sampling intensity (Cadrin, 2001). In response, an industry-based survey was conducted to improve the sampling of yellowtail flounder in the SNE stock area (Valliere and Pierce, 2007). In 2005, the yellowtail flounder stock assessment used data from the industry-based survey. The consistency of the assessment was improved dramatically and the assessment was accepted as a basis for management advice (Cadrin and Legault, 2005). A cooperative survey run by the NEFSC onboard commercial otter trawl vessels was used to survey monkfish in 2001, 2004 and 2009. The survey was designed to provide better coverage of the depth and range of monkfish, which were not fully covered by the NEFSC survey (Bonzek et al., 2006). Data from the surveys have been used in stock assessments for the species (NEFSC, 2002; NESFC, 2010).

In 2010, scientists at the SMAST worked cooperatively with members of the New Bedford otter trawl fleet to conduct an industry-based survey for winter flounder in the Great South Channel, which is in the SNE/MA stock area. Meetings were held with fishermen from the New Bedford otter trawl fleet with experience targeting winter flounder in the Great South Channel. Input from industry members was used to define the study area, determine the best time of year for the survey, design the survey net, and develop the survey protocols. Five, ten-day trips were completed between June and October of 2010. During the project, 288 survey tows were completed with many of the tows made in areas of the Great South Channel that are not covered by the biannual NEFSC Survey. Approximately 24,000 winter flounder were measured and nearly 17,300 winter flounder were tagged. The survey accurately quantified the seasonal distribution of winter flounder in the Great South Channel, and generated high quality fishery-independent data which was used during the 2011 assessment. In particular, biomass estimates derived from the survey were used to groundtruth the results of candidate stock assessment models during the Working Group meetings.

STATEMENT OF RESEARCH QUESTION

The purpose of the industry-based survey was to collect information which could be used to improve the stock assessment for the SNE/MA stock of winter flounder. Biological data collected during the survey will help to inform the stock assessment during a period when sampling intensity is low. The survey was designed to investigate the seasonal distribution of winter flounder in the study area, and provide estimates of relative abundance which can be compared to other surveys being conducted in the SNE/MA stock area. The research questions we sought to address during the survey included:

- How abundant are winter flounder in the study area, and where are they distributed?
- How does the abundance of winter flounder in the study area compare to estimate of winter flounder biomass from the stock assessment?
- What are the biological characteristics of winter flounder in the region?
- Where do winter flounder migrate to, and how long do they survive?

GOALS AND OBJECTIVES

The primary objective of the winter flounder industry-based survey was to provide information for stock assessments during a period of restricted fishery catches and low sampling intensity. Technical objectives were:

- Collaborate with fishermen from Point Judith, Rhode Island to identify a study area encompassing historical and current concentrations of winter flounder.
- Representatively survey the abundance, density and biological characteristics of winter flounder in the defined study area.
- Document the seasonal distribution of winter flounder in the study area and examine long-term migration patterns through tag recapture data.
- Calculate time-at-large for winter flounder in the study area using tag recapture data.

METHODOLOGY

Survey Design

Meetings were held in Point Judith with otter trawl fishermen to identify fishing grounds that currently, and have historically, contained high concentrations of winter flounder. The time period when fishermen historically fish for winter flounder was identified to determine when the survey should be conducted. The months of April through July were identified as months when winter flounder are most abundant in the study area. During our first meeting, held on 12/7/2010, three potential study areas were developed based on input from trawl fishermen (Figure 1). In particular, an effort was made to conduct the study in regions not currently sampled during other surveys (e.g., NEAMAP). After a SMAST groundfish steering committee meeting was held on 12/15/2010, the study area and time frame were finalized based on comments from attendees (Figure 2). The final study area was again refined after additional comments were received from industry members at a meeting on January 24th, 2012 held by the CFRF (Figure 3).

After the study area was finalized, survey protocols were developed with an emphasis on standardization, measurement of fishing power and effective area swept. Originally, the survey design had 75% of the tow locations selected at random and 25% of the tow locations selected by the captain of that trip. We later requested that the sampling format be modified from a combination of random and fishermen-selected tow locations to 100% random selection of tow locations. This request was made following the 2011 Working Group Meetings for the winter flounder stock assessment, where NEFSC assessment scientists stated that tows made at fishermen selected locations are not acceptable for use in stock assessments.

The final study area was divided into 106 three nautical mile² grids covering 3,258 square kilometers (Figure 3). The random point generation software of the Hawth's Tools extension for ArcGIS was used to generate a series of random points within the study area. When a random point fell within

a grid cell, a survey tow was assigned to that grid cell. For each survey leg, a total of 40 random tow locations (grid cells) were generated. Based on comments from industry members, it was concluded that sampling could be completed over one five day trip per month.

Survey Nets

In 2010, Reidar's Manufacturing Inc designed and built two 4.5 inch mesh 60 x 80 trawl nets that were used to survey winter flounder in the Great South Channel. Because of differences in substrate types and fishing styles between the two fleets and the two study areas, the nets had to be modified prior to the 2012 survey. Input from Point Judith fishermen was used to help redesign the survey nets. The nets were modified using three inch rubber cookie groundgear, 40 fathom of groundcable, and 20 fathom bridles (Figure 4). The nets had a 4.5 inch square codend.

Reidar's Manufacturing Inc. built two cookie sweeps and attached the sweeps to the nets. The company also built one set of groundcables and bridle riggings. Transportation of the nets to and from New Bedford, MA was carried out by Reidar's Manufacturing. The nets were housed at Superior Trawl in Point Judith, RI between trips, and Superior Trawl was responsible for transporting the nets to the various vessels prior to and after each survey trip.

Survey Vessels

Fishing industry collaborators with experience fishing for winter flounder out of Point Judith, RI were contracted for the project. Originally, four vessels were selected, and each vessel was going to complete one survey leg. The four original vessels were the F/V Black Sheep, F/V Conor and Michael, F/V Lena Pearl, and F/V Hopefull. In June, F/V Conor and Michael was unwilling to complete the survey trip as originally planned, and the Work Agreement for the F/V Conor and Michael was terminated. The F/V Black Sheep agreed to complete the June survey trip, and the Work Agreement for the F/V Black Sheep was modified to allow the vessel to make an additional survey trip. This decision was completed in consultation with Peg Parker of the CFRF. All vessels had similar characteristics in terms of length and horsepower (Table 1). Vessel captains communicated with each other and SMAST technicians to work out a schedule for the survey. This schedule was continuously modified throughout the project due to mechanical issues and availability of vessels.

Survey Tows

The captain chose the starting location of each survey tow 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 NEFSC study fleet software, which was connected to a handheld GPS. Net mensuration equipment was placed on the trawl doors, top wing ends, and the headrope to monitor net dimensions and allow for the area swept to be calculated during each tow. 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 when the winches were engaged to retrieve the net. Captains were instructed to complete tows in a straight line, without turning the vessel, whenever possible. Captains were 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 condition, depth, wire out, and other relevant information were recorded in an Access database during each survey tow. A Vemco® Minilogger was attached to a trawl door to record temperature and depth every minute, allowing for the calculation of an average bottom water temperature during each survey tow. Tows were made during the daytime only, following feedback from the captains involved the catch rates of winter flounder in this region decline considerably between sunset and sunrise.

The target tow duration was 30 minutes, and the minimum acceptable tow duration was 20 minutes. Tows less than 20 minutes were repeated within the same grid cell, and multiple attempts were made to complete a tow 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 tow was completed within the replacement grid cell. If the net was damaged during a tow (e.g., hole in the net), then the tow was considered invalid. The tow was repeated after the damage to the net was repaired.

Catch Sampling

After a tow was completed, the catch was dumped into the checker pen. All winter flounder were sorted from the catch by hand. The winter flounder were immediately transferred to a holding tank that was aerated constantly with fresh seawater. 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 winter flounder were placed overboard as quickly as possible to minimize mortality. When yellowtail flounder scale samples were taken, yellowtail flounder were placed in a holding tank until samples could be processed. Yellowtail flounder were measured, sex was identified by candling, and scales were removed from the caudal peduncle using methods similar to those used by the Northeast Fisheries Observer Program. Scales were placed in envelopes along with all identifying information.

The total length of each winter flounder was measured to the nearest centimeter, and any relevant biological information (e.g., scale loss) was also recorded. The condition of each flounder was assessed using the tagging protocols developed for the cooperative yellowtail tagging project conduct by SMAST (Cadrin, 2006). All winter flounder > 19 cm in 'excellent' or 'good' condition were tagged with T-bar anchor tags. Approximately, 50 winter flounder in "poor" condition were retained during each trip and brought back to SMAST for meristic analysis. All winter flounder < 20 cm were not tagged.

ANALYICAL TECHNIQUES

Length-Weight Relationship

The weight of each winter flounder was calculated using the length-weight relationship established for winter flounder captured during the NEFSC annual bottom trawl survey (Wigley et al., 2003) using the following equation.

$$\ln \text{ weight (kg)} = -11.4718 + (3.0431 * \ln \text{ length (cm)})$$

Net Mensuration Data

Net mensuration data were not available for all tows on all trips because of mechanical issues with the system. The data also contained outliers, so the data were audited before area swept calculations were completed. Data for trip one included headline and wing data, but there was no data for trip two. Trips three and four had data for all three sensors (door spread, wing spread, and headline height). Data were trimmed to remove outliers by using the 25th and the 75th quantiles by sensor. For headline and wing data, data were pooled for all trips after looking at the quantiles for each trip separately. Door data were only available for trips three and four, so the 25th and 75th quantiles for the two trips combined were used in data auditing. For missing values, the mean value for each sensor was used after data auditing was complete.

Area Swept Biomass Estimates

Estimates of winter flounder density (kg/km²) and biomass (mt) were calculated using the observed catch of winter flounder and the area swept calculated during each valid tow. The doorspread and wingspread were used to calculate the area swept.

The position of the vessel (latitude and longitude), the vessel speed, and the vessel course were recorded electronically every minute using the GPS polling function of the FLDRS for every tow. 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, tow speed data were 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 actual tow durations ranged from 23 to 35 minutes, tow durations were standardized to a 30 minute tow. The tow durations were standardized as follows:

$$\text{Catch adjustment} = 0.5 \text{ (hr) / reported tow duration (hr)}$$

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

$$\text{Standardized Catch (kg)} = \text{winter flounder catch (kg)} * \text{catch adjustment}$$

$$\text{Standardized Catch Number} = \text{winter flounder number} * \text{catch adjustment}$$

The area swept (km²) by the survey net was calculated for each tow, using the following formula:

$$\text{Area swept (km}^2\text{)} = \text{doorspread (km)} * \text{tow speed (km/hr)} * \text{tow duration (hr)}$$

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

$$\text{Winter flounder density (kg/km}^2\text{)} = \text{winter flounder catch (kg)/area swept (km}^2\text{)}$$

Each of the grid cells within the survey area had an area of 30.74km². The study area contained 106 grid cells, for a total area of 3,258km². Estimates of winter flounder density, which were calculated for each valid tow, were used to estimate the biomass of winter flounder present in the study site. The biomass estimate was also converted to metric tons to allow for a more direct comparison with biomass estimates derived from the NEFSC trawl survey and the stock assessment. The biomass of winter flounder was calculated as follows:

$$\text{Winter flounder biomass (kg)} = \text{winter flounder density (kg/km}^2\text{)} * \text{size of survey area (km}^2\text{)}$$

The catchability of the survey net is unknown, and the calculations of winter 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 (q) 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.

$$\text{Winter flounder density (kg/km}^2\text{)} = \text{winter flounder catch (kg)/area swept (km}^2\text{)} * (1/q)$$

Spatial Distribution of Winter Flounder

An index of dispersion test (Krebs, 1989) was performed to determine whether the catch weights of winter flounder were distributed randomly throughout the study site. The index of dispersion (I) was calculated using the following equation:

$$I = \text{observed variance in catch weight/mean catch weight}$$

The chi-square statistic was calculated for the index of dispersion using the following equation:

$$\chi^2 = I(n-1)$$

The calculated value of the chi-square statistic could not be compared directly against the critical value, because our sample size was large (n > 51). Instead, we calculated the normal approximation to the chi-square value using the following formula:

$$z = \text{squareroot}(2\chi^2) - \text{squareroot}(2V-1)$$

where z is the standard normal deviate, and V is the number of degrees of freedom. The calculated value of z was compared against the range of critical values (-1.96 to 1.96). If the value of z falls outside of the critical range, the null hypothesis that the population conforms to a Poisson (random) distribution is rejected.

Generalized Additive Models

Generalized Additive Models (GAMs) were used to better understand the distribution and biological characteristics of winter flounder in southern New England. Generalized Additive Models are commonly used to understand distribution and abundance data derived from fisheries surveys and commercial catches (Venables and Dichmont, 2004). Generalized Additive Models are well suited for applications to fisheries datasets, because GAMs are designed to model processes that are nonlinear, which are common in fisheries (Xiao, 2004). In general, the form of a GAM is shown in the equation below (Hastie and Tibshirani, 1990):

$$Y = B_0 + f_1(x_1) + f_2(x_2) + f_3(x_3) + \dots + f_p(x_p)$$

Where Y is the response variable, B_0 is a fixed intercept term, and the $f_i(x_i)$ terms are local smoothers that are applied to the explanatory variables.

In the first model, winter flounder catch weights (kg/tow) were chosen as the response variable. The results of a Shapiro-Wilk test indicated that the distribution of winter flounder catch weights was highly non-normal. Therefore, winter flounder catch weights were log transformed. In the second model, the total length (cm) of winter flounder was chosen as the response variable. A number of explanatory variables were available from the data collected during the survey. Eight explanatory variables were considered during model development. The explanatory variables included in the models were: latitude, longitude, depth, temperature, time of day, wind speed, wave height and trip number.

Explanatory factors influencing catch weights and winter flounder length were identified using backward model selection. Explanatory terms were removed from the model based on the results of an ANOVA that tested for significant differences in the deviance explained between models. Explanatory terms were removed from the model if they explained less than 2% of the total deviance even if the variable was significant.

RESULTS

Winter Flounder Catches

The survey was completed over a four month period between April 28th and July 25th, 2012 onboard three different vessels (Table 2). One five day survey trip was completed each month. A total of 164 tows were attempted, with 160 tows completed successfully (Figure 5). Four tows were invalid as a result of problems with sea grass and mud fouling the gear.

A total of 9,852 winter flounder were captured and measured, and 7,845 winter flounder were tagged. The standardized mean winter flounder catches observed for each trip are shown in Table 3. The mean catch generally increased over the course of the survey, with the lowest catches in April and May followed by larger catches in June and July. The overall mean catch for the entire survey was 25.35 kg/tow. Winter flounder were present in the majority of survey tows. Between 85% and 95% of the tows contained winter flounder in the catch, and an only 7% of the tows completed over the entire survey had zero winter flounder catch.

The distribution of winter flounder in the study area shifted southwards over the course of the survey. In April and May, larger catches were primarily closer to Martha's Vineyard in shallow water ranging from 13 to 23 fathoms (Figure 6). In June, catches were greatest in the middle portion of the study area in 19 to 26 fathoms (Figure 6). In July, the highest catches appeared to be condensed in waters ranging from 24 to 27 fathoms in depth (Figure 6). There were relatively low catches of winter flounder in the southern portion of the study area beyond the 30 fathom contour over the course of the survey (Figure 6). Catches inside of the Nantucket Lightship Closed Area were also relatively low with the exception of one area that had consistent moderate catches throughout the survey.

Juvenile and adult winter flounder appear to be aggregated by depth in this portion of southern New England. The percent of legal size (> 32 cm) winter flounder captured in each survey tow is shown in Figure 7. Generally, survey tows made in shallow water had a smaller proportion of legal size winter flounder than tows made in deeper water. This trend was most pronounced in July, when tows in deeper water were dominated by catches of large winter flounder, while juvenile winter flounder were most numerous in tows from shallow portions of the study area.

Winter Flounder Tagging

A total of 7,845 winter flounder were tagged. The majority of fish were double tagged with T-bar tags (Figure 8). One fish was recaptured from a previous trip during the survey. The fish was released on April 29th on the first trip and recaptured on June 29th on the third trip. The fish was re-released after it was measured. The fish was originally measured at 25 cm, and when recaptured was measured at 27 cm. Winter flounder often grow rapidly following spawning in late winter and early spring, and the growth of this individual over the two month period was not atypical.

Length Frequency

The pooled length frequency distribution of winter flounder captured in the study area is shown in Figure 9, and the relative length frequency distributions by trip are shown in Figure 10. There appears to have been a shift in the length distribution of winter flounder over the course of the survey, with smaller fish present in April and May and larger fish present in June and July (Figure 10). The percentage of winter flounder considered exploitable biomass (≥ 30 cm) captured during the survey was 65%. The proportion of exploitable fish present in the study area increased from 52% in April to 68% in July, which is consistent with the shift in length frequency distributions shown in Figure 10.

The length frequency distributions of winter flounder caught during the 2010 and 2012 industry-based surveys were compared (Figure 11). The comparison showed that winter flounder in the Great South Channel (2010) were typically larger than those that were sampled in southern New England. Winter flounder sampled in the Great South Channel ranged from 19 to 52 cm, while winter flounder taken in southern New England were between 13 and 51 cm. The mode of the length frequency distribution of winter flounder in the Great South Channel was 35 cm, while a mode of 29 cm was observed for winter flounder in Southern New England.

Biological Samples and Meristic Analysis

Yellowtail and winter flounder biological samples were taken over the course of the survey. Yellowtail flounder scale samples (n=305) have been archived at SMAST, and will be provided to the NEFSC for age determination prior to the next assessment for SNE/MA yellowtail flounder. The scale samples can be used to inform estimates of catch at age during the assessment.

A total of 188 winter flounder were retained as part of an ongoing, multidisciplinary study to investigate the stock structure of winter flounder in U.S waters. The objective of the study is to investigate differences in meristic characters (fin ray counts) between winter flounder from southern New England, the Great South Channel, and Georges Bank. The number of dorsal and anal fin rays were counted for each flounder collected during the survey. Fin ray counts, which have been used to differentiate between winter flounder stocks, were compared between fish collected in the Great South Channel, Georges Bank and southern New England. Winter flounder from Georges Bank had the highest fin ray counts, fin ray counts were intermediate in flounder taken from the Great South Channel, and lowest from flounder sampled in southern New England. The differences in fin ray counts between the three areas were significant, suggesting that winter flounder from the Great South Channel may comprise a unique group that is discrete from other stocks. The findings could have important implications for the management and assessment of the winter flounder resource, and the stock structure of winter flounder in the Great South Channel merits further investigation using multiple stock identification approaches. A manuscript is being prepared to document the results of the meristic analysis. In addition to the meristic analysis, scale and genetic samples were obtained from each fish, the sex of the fish was recorded, and the fish was weighed.

Area Swept Biomass

The mean density (kg/km²) and biomass (kg and mt) of winter flounder estimated in the study area were calculated and are included in Table 4. When the doorspread is used to calculate area swept, the biomass estimate from the survey (407.5mt) is approximately 6% of the spawning stock biomass estimate from the most recent winter flounder assessment that was completed in 2011 (7,076mt). This estimate includes all size classes of winter flounder from the study area. When the area swept is calculated using the wingspread, the biomass estimate from the current survey (2,295 mt) is approximately 32% of the spawning stock biomass estimate from the assessment. It should be noted that the biomass estimates from the survey 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.

Area swept estimates of the exploitable biomass of winter flounder in the study area were also calculated. All winter flounder ≥ 30 cm were considered to be exploitable by the fishery, and the catch weights of winter flounder ≥ 30 cm were tabulated for each tow and used in the area swept biomass calculations. The results are shown in Table 5. When the doorspread is used to calculate the area swept, the estimate of exploitable winter flounder biomass in the study area is 1480 metric tons.

The catchability (q) of the survey net is unknown. To examine the sensitivity of the winter flounder biomass estimate to the assumed catchability value (q) that was used for the survey net, a

series of calculations were performed using an assumed catchability value that ranged from 0.1 to 1.0 (Tables 6 and 7). These calculations were made for using both the doorspread and wingspread to calculate area swept.

Vessel Effect

A vessel effect can exist when multiple vessels are used during a survey even though the same net is utilized, and vessel characteristics are similar. We tested for a vessel effect by examining differences in tow speed and scope ratio. The mean vessel tow speed was generally around three knots (kts), which was consistent with survey protocols (Table 8). The overall mean tow speed was 3.08 kts. However, there was a significant difference in the mean tow speed between vessels (Figure 12). On the second trip the F/V Lena Pearl had a greater mean tow speed compared to the other two vessels. A ranked ANOVA was used to test for differences in the mean tow speed by vessel after the assumptions of normality and homogeneity of variances were not met (Sokal and Rohlf, 2001). Weinberg and Kotwicky (2008) found a significant difference in tow speed among vessels that participated in the eastern Bering Sea survey.

There were also significant differences in the scope ratio between vessels. Two of the three vessels (trips one - three) followed a similar pattern regarding the amount of warp set relative to depth (Figure 13). On trip four, the vessel had a greater scope ratio with more wire set for the same depths than the other vessels. The larger scope ratio used by vessel four may have increased the herding effect of the trawl, which in turn could have increased the catch rates for this trip. Indeed, the survey catches (kg/tow) are larger on trip four than on trips one, two, and three. While relative estimates of winter flounder biomass (i.e., kg/tow) would be sensitive to the scope ratio used by the vessel, it should be noted that differences in fishing behavior (e.g., tow speed and wire out) between vessels are accounted for in calculations of area swept biomass. An analysis of covariance was used to test for differences in the slope between vessels (Sokal and Rohlf, 2001). The analysis indicated that there was a significant difference between trips.

Spatial Distribution of Winter Flounder

The index of dispersion (I) was calculated to be 139.3. The calculated index of dispersion was used to estimate a chi-square statistic (X^2) and estimate the normal approximation to the chi-square value (z). The value of z was calculated to be 192.7, which fell far outside of the critical range (-1.96 to 1.96). Therefore, the null hypothesis was rejected, and it can be stated that the population of winter flounder in the study area did not conform to a Poisson (random) distribution. Instead, the population of winter flounder in this region is highly aggregated, and exhibits a very patchy distribution between April and July.

Generalized Additive Models- Winter Flounder Catch Weights

A number of candidate models were explored to explain the variation in winter flounder catch weights during the survey. Depth was not included as an explanatory variable because depth was highly

correlated with latitude ($r = 0.72$) and temperature ($r = 0.63$). When depth was included as an explanatory variable the model output was confounded, and produced unrealistic results.

The final model for winter flounder catch weights included four explanatory variables: latitude, temperature, trip number and longitude. Overall, the model performed well, and the deviance explained by the explanatory variables was 64.4%. Figure 14 depicts the response of winter flounder catch weights to the explanatory variables included in the final model. Generally winter flounder catch weights increased with increasing latitude, suggesting that winter flounder were generally distributed closer to shore in the study site. The relationship between catch weight and temperature suggested that catch weights were higher than average when temperatures ranged from 8-12°C and generally declined when bottom water temperatures exceeded 12°C. The relationship between catch weight and longitude suggests that winter flounder were typically more numerous in the eastern portion of the study site. The results of the GAM model indicated that there was substantial variation in catch weights between trips. To explore this variability in more detail, catch weight was modeled independently for each of the four trips.

Depth was the only explanatory variable included in the final model for the first survey trip, which took place in April. The model output (Figure 15) indicates that catch weights were typically larger than average in shallow waters (34-40 m) and that catch weight declined rapidly in waters deeper than 50m. Depth explained 63.6% of the variance in catch weights for the survey in April. It should be noted that depth and latitude are strongly correlated, and latitude was used as an explanatory variable in the models for the other survey trips. When both latitude and depth were included in the model, the results were confounded and unrealistic. Therefore, monthly analyses were completed using either latitude or depth as an explanatory variable.

The final model of winter flounder catch weights from the May trip included three explanatory variables; latitude, temperature, and time. The results of the model output are shown in Figure 16. Overall, catch weights increased with increasing latitude, suggesting that winter flounder were concentrated closer to shore during the month of May. There was little trend in the response of catch weights to temperature. Bottom temperatures were quite stable in May, and temperature ranged from approximately 8 to 12°C. Finally, the model output indicates that catch weights were generally lower in the morning and increased towards sunset during the month of May.

The final model of winter flounder catch weight for June included two explanatory variables: latitude and temperature. The model performed well, with the two explanatory variables explaining 81.8% of the deviance in the catch weights. The output from the model is shown in Figure 17. Generally, catches were smaller in the southern portion of the study area, and catch weights were generally greatest around 41°N. Catch weights began to decline again towards the northern portion of the study site. Catch weights are not very responsive to changes in water temperature, although the model output suggests that the relationship between catch weight and temperature in June was slightly parabolic.

Catch weights in July were also modeled using latitude and temperature as explanatory variables. The model fit was reasonably good, and the model was able to explain 71.6% of the variance in the catch weights. The output from the model is shown in Figure 18. The response of catch weights to latitude is nearly identical to the trends that were observed in June. The response of catch weights to temperature shows a distinctive trend. Catches were generally higher when temperatures ranged from 10 to 13°C. Catch weights decreased sharply as temperatures increased above 13°C. Observed water temperatures in July were more variable (10-18°C) than in the other months of the survey, which may explain why the strong relationship between temperature and catch weights is present.

Generalized Additive Models- Winter Flounder Lengths

A number of models were explored to examine the relationship between the length of winter flounder and geographical and environmental variables. The final model included three explanatory variables: depth, latitude and temperature. The output from the final model is shown in Figure 19. The model results show that catches in shallow waters tended to be dominated by juvenile flounder, while larger fish were more numerous in survey tows made in deeper waters. The model results are consistent with our on the water observations throughout the course of the survey. The relationship between winter flounder length and latitude is noisy, and the trend is not very informative. The relationship between temperature and fish length is roughly parabolic. The results suggest that larger winter flounder were generally present when water temperatures ranged from 8 to 12°C. When temperatures decreased below 8°C, or were greater than 12°C, catches were typically comprised of smaller flounder.

Presentations

The design and results of the survey have been presented at a number of relevant meetings and conferences. On October 27, 2011, Sally Roman gave a presentation at the Northeast Regional Collaborative Research Conference held in Portsmouth, NH. The presentation discussed SMAST's collaboration with stakeholders to conduct industry-based surveys for winter flounder. The presentation discussed both the 2010 industry-based survey conducted in the Great South Channel and the 2012 survey in southern New England.

On January 24, 2012, Greg DeCelles presented the proposed survey methodology and objectives to an audience of fishermen, scientists and fisheries managers at a meeting convened by the CFRF in South Kingston, RI. Feedback received from industry members during the meeting was used to make modifications to the survey design and objectives.

On September 20, 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 the 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.

On December 4, 2012, Greg DeCelles gave a presentation at the 13th Flatfish Biology Conference in Westbrook, CT. The presentation was entitled, “Winter Flounder Distribution in Southern New England- Insights from Industry-Based Trawl Surveys”. The talk included results from the 2010 and 2012 SMAST industry-based surveys for winter flounder.

Finally, on February 26th, 2013 Greg DeCelles presented the results and major findings of the survey to an audience of fishermen, academic scientists, and government scientists at a research meeting in Kingston, RI that was convened by the CFRF. Feedback received during the meeting was used to refine the final report for this project.

DISCUSSION

Seasonal Distribution of Winter Flounder

The results from the survey offer insights into the seasonal distribution of winter flounder in the coastal waters of southern New England. Historical tagging and survey data suggest that adult winter flounder typically leave estuaries and bays in southern New England in the early spring as water temperature begins to increase (DeCelles and Cadrin, 2011). Tagging studies generally show that winter flounder in southern New England generally disperse to the south and east during the summer months, in an effort to find suitable temperatures (Perlmutter, 1947; Saila, 1961; Howe and Coates, 1975). Tag-return data suggests that some adult flounder undertake relatively limited seasonal migrations, while other fish have been observed migrating long distances from estuaries and bays to offshore grounds like Nantucket Shoals and the Great South Channel (e.g., Powell, 1989; Phelan, 1992).

The distribution of winter flounder observed during the present survey is congruent with previous studies. In April, the largest survey catches of winter flounder were generally observed in waters less than 20 fathoms. For example, sizeable winter flounder catches were observed south of Martha’s Vineyard, near Muskeget Channel. In May, large catches of flounder were still observed near Muskeget Channel, but the distribution of winter flounder had shifted slightly to the south. Winter flounder were now present in appreciable quantities in waters ranging from roughly 15 to 25 fathoms. By June and July the distribution of winter flounder had shifted markedly to the south. Catches in water less than 20 fathoms declined substantially, and the largest catches were generally found in water between 22 and 27 fathoms. Winter flounder catches generally declined substantially in the deeper portions of the study site where depths were approximately 30 fathoms.

The seasonal change in distribution generally matched the expectations of the captains that participated in the survey. In retrospect, it would probably have been more appropriate to sample between May and August, rather than between April and July. The captains in the survey reported that

August is typically a strong month for winter flounder fishing in this region. The captains also expected that large flounder catches would likely have been observed between 20 and 30 fathoms in August.

Sampling Intensity

During the course of the survey we were able to sample the entire study site, and attain a high density of survey observations. The results of the Chi-Square Goodness of Fit Test indicated that the distribution of winter flounder within the study site was very patchy. A similar distribution was observed from the industry-based survey for winter flounder in the Great South Channel in 2010. 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 not be sampled representatively when the sample density is inadequate (Powell et al., 2006).

The NEFSC biannual trawl survey is currently the only fishery independent survey conducted in federal waters (> 3 nm) that is considered in the assessment of southern New England/Mid-Atlantic winter flounder. The survey is conducted across a wide geographical area that stretches from Cape Hatteras northwards to the Bay of Fundy. Due to the limited resources available to the survey, and the huge geographic area that needs to be covered, the density of observations from the survey is often sparse. We believe that the sampling density of the NEFSC biannual survey is not sufficient to detect the patches of winter flounder that are present in the Southern New England stock area. As such, the survey may not be a reliable estimator of the size of the winter flounder in this region. Our study site overlapped multiple NEFSC survey strata, although the majority of the study site was in the NEFSC stratum 1090. Since the Chi-Square Goodness of Fit Test indicated that winter flounder are not distributed homogeneously throughout the study area, then relying on the assumption of homogeneity of fish throughout a stratum is not supported. If the NEFSC sampling intensity is limited in stratum 1090, then patches of winter flounder may be missed by the survey.

While the stock assessment of SNE/MA winter flounder suggests that the biomass of the stock is still at very low levels, many fishermen contend that the resource is relatively healthy. Much of this disagreement may be explained by the differences in scale between normal fishing operations and a coast-wide resource survey. Through years of observations, fishermen have developed the ability to locate patches of high fish density with regularity. During the course of our survey trips, captains were almost always able to predict areas where winter flounder catches would be high, and could locate specific, small-scale bathymetric features that consistently support high densities of fish.

Tag Returns

Thus far, we have not received any reports of recaptured winter flounder from the commercial fishery. The lack of tag returns is surprising, as we released nearly 8,000 tagged fish over the four months of the survey. SMAST has developed a good working relationship with members of the New England groundfish fleet, and past tagging projects have been bolstered by strong rates of tag reporting. During the 2010 industry-based survey for winter flounder we tagged and released over 23,000

individuals. Despite extensive outreach efforts, we have only received one report of a tagged flounder being recaptured by the fishery thus far.

It is unclear why so few tagged flounder have been recaptured by the fishery. Since 2009, the possession of winter flounder has been prohibited in federal waters. Therefore, fishermen no longer target this species, which likely reduces the chances of a tagged flounder being recaptured. For example, the fishing mortality rate (F) of winter flounder was estimated to be very low (0.051) in 2010 (NEFSC, 2011). However, winter flounder are still taken as bycatch in many fisheries. Fishermen may overlook tags when winter flounder are recaptured, because they are primarily concerned with retuning the discarded flounder to the sea quickly. In addition, fishermen may be hesitant to report the recapture of a tagged flounder, since the possession of this species is now prohibited.

An alternative explanation is that the post-release survival of tagged flounder may be low, which would reduce the probability of recaptures from the commercial fishery. However, this explanation seems unlikely. Holding studies conducted prior to the 2010 industry-based survey suggest that the tagging process does not affect the survival of winter flounder. Certainly, previous studies have reported high recapture rates (e.g., Howe and Coates, 1975), suggesting that winter flounder typically survive the tagging process. Similarly, some flounder may shed their tags, which would also reduce the likelihood of tag recaptures. Tag shedding is certainly a possibility, but tag shedding was not observed during the holding study for winter flounder prior to the 2010 industry-based survey. Similar t-bar anchor tags were used by SMAST to tag yellowtail flounder in Closed Area II in 2008, and tag returns are still being reported to SMAST, which is evidence that at least some flounder retain the tags for extended periods of time. A previous tagging study (Powell, 1989) also used t-bar anchor tags to track adult winter flounder, and tag reporting rates during the project were 12.9%, which suggests that shedding of t-bar anchor tags is likely minimal.

Another potential explanation is that the abundance of winter flounder is quite large, which would make the likelihood of recapturing a tagged fish very small. For instance, although we tagged nearly 8,000 flounder during the course of the survey, we only recaptured one tagged fish during a survey tow. Given the relatively small size of the study area, and the high density of survey tows, we expected to recapture more tagged flounder during the course of the survey.

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 winter 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 fishermen. Despite the small staff on each vessel, we worked efficiently and were typically able to complete between nine and 12 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 participating 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. Captains were able to indicate where potential survey tows may not be able to be completed because of issues with sea grass. Of the 164 tows attempted during the course of the survey, only four tows (2.4%) were not completed successfully. The expertise of the captains and crew was a valuable asset when problems arose during the surveys. When problems like gear fouling did arise, the experience of the fishermen allowed us to deal with issues quickly to 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.

Many fish species, such as winter 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 winter 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 winter 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 winter flounder. The Point Judith fleet typically uses long groundcables (75-100 fathoms) when they target flatfish in southern New England, and each vessel used 40 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.

During the 2010 survey for winter flounder in the Great South Channel, our survey net was designed with five fathom groundcables. This was similar to the nets used by the New Bedford fleet to fish for winter flounder in the Great South Channel, where the bottom is very rocky, and there are a lot of hangs. In 2010 we used 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. Using the wingspread in calculations will reduce the uncertainty associated with estimates of area swept. Because long groundcables were present on the net, the doorspread was larger and more variable than the wingspread. When the doorspread is used, the estimate of winter flounder biomass is substantially lower, when compared to the biomass estimate that is derived using the wingspread. We suggest that future surveys can avoid this uncertainty by using the shortest possible groundcables on their survey nets, which will allow the use of wingspread 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 conducted in federal waters that is used in the stock assessment of southern New England winter flounder. Many industry members contend that the NEFSC survey is not able to accurately estimate the scale of the winter 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 now being used on the NEFSC survey net is unsuitable for sampling flatfish 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 or changes in survey protocols.

SUMMARY OF CONCLUSIONS- MAJOR RESEARCH FINDINGS

- By forming collaborative partnerships with the fishing industry, we can improve the quality and efficiency of fisheries research.
- Seasonal winter flounder distribution in the study area is influenced by water temperature, month, and fish size.
- Winter flounder are not distributed randomly throughout the study area, but have a patchy distribution.
- The distribution of winter flounder in the study area shifted southwards over the course of the survey.
- A vessel effect was detected for tow speed and scope ratio.
- The average (mean of all four trips) area swept biomass of winter flounder in the study site was estimated to be 407.5 mt when the doorspread was used to calculate area swept, and 2,295mt when the wingspread was used to calculate area swept. The biomass estimates from the current survey are approximately 6% and 22%, respectively, of the SSB estimated for SNE/MA winter flounder in the most recent assessment.

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TABLES

Table 1. Vessel characteristics including captain name, vessels name, horsepower, length (ft), gross registered tonnage (GRT), and US Coast Guard (USCG) documentation number.

Captian	Vessel Name	Horsepower	Length (ft)	GRT	USCG Doc Number
Einar Barlow	Lena Pearl	420	67	95	622589
Niles Pearsall II	Black Sheep	410	71	113	622003
James Jordan	Hopefull	420	67	93	620064

Table 2. Trip dates by vessel.

Trip Number	Vessel	Date Sailed	Date Landed
1	Black Sheep	4/28/2012	5/4/2012
2	Lena Pearl	5/23/2012	5/27/2012
3	Black Sheep	6/26/2012	6/30/2012
4	Hopefull	7/21/2012	7/25/2012

Table 3. Standardized mean catch per tow (kg) by month with the standard deviation of the catch, the maximum catch (kg), and the percentage of tows with no winter flounder. Grand totals are also included.

Month	Number of tows	Mean winter flounder catch (kg)	Standard Deviation	Maximum Catch	% Tows with no winter flounder
April	40	13.87	18.65	92.97	7.50%
May	40	12.14	14.92	76.15	5.00%
June	40	28.61	32.61	124.19	15.00%
July	40	46.76	109.81	690.18	5.00%
Grand Totals	160	25.35	59.61		6.88%

Table 4. Area swept biomass calculations by trip and area swept metric with survey means. Estimates are provided in terms of density (kg/km²), biomass in kilograms, and biomass in metric tons.

Trip	Doorspread			Wingspread		
	Density (kg/km ²)	Biomass (kg)	Biomass (mt)	Density (kg/km ²)	Biomass (kg)	Biomass (mt)
1	73.98	241,065.13	237.21	410.16	1,336,483.17	1,315.10
2	56.31	183,493.17	180.56	330.41	1,076,628.79	1,059.40
3	154.36	502,987.91	494.94	820.66	2,674,079.14	2,631.29
4	231.12	753,090.08	741.04	1,301.04	4,239,358.10	4,171.53
Survey Mean	127.11	414,168.55	407.54	715.57	2,331,637.30	2,294.33

Table 5. Area swept estimates of exploitable biomass (winter flounder >30cm) by trip. Biomass is given by density (kg/km²), and metric tons.

Trip	Doorspread		Wingspread	
	Density (kg/km ²)	Biomass (mt)	Density (kg/km ²)	Biomass (mt)
1	48.16	154.42	267.51	857.70
2	42.88	137.48	237.65	761.99
3	120.44	386.16	628.08	2013.82
4	125.03	400.89	713.05	2286.26
Survey Mean	84.13	269.74	461.57	1479.95

Table 6. Estimates of area-swept biomass under varying assumptions of q. Area swept was calculated for each tow using the wingspread.

	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
Trip 1	237.2	263.6	296.5	338.9	395.3	474.4	593.0	790.7	1186.0	2372.0
Trip 2	180.6	200.7	225.8	258.0	301.0	361.2	451.5	602.0	903.0	1806.0
Trip 3	494.9	549.9	618.6	707.0	824.8	989.8	1237.3	1649.7	2474.5	4949.0
Trip 4	741.0	823.3	926.3	1058.6	1235.0	1482.0	1852.5	2470.0	3705.0	7410.0
Survey Mean	407.5	452.8	509.4	582.1	679.2	815.0	1018.8	1358.3	2037.5	4075.0

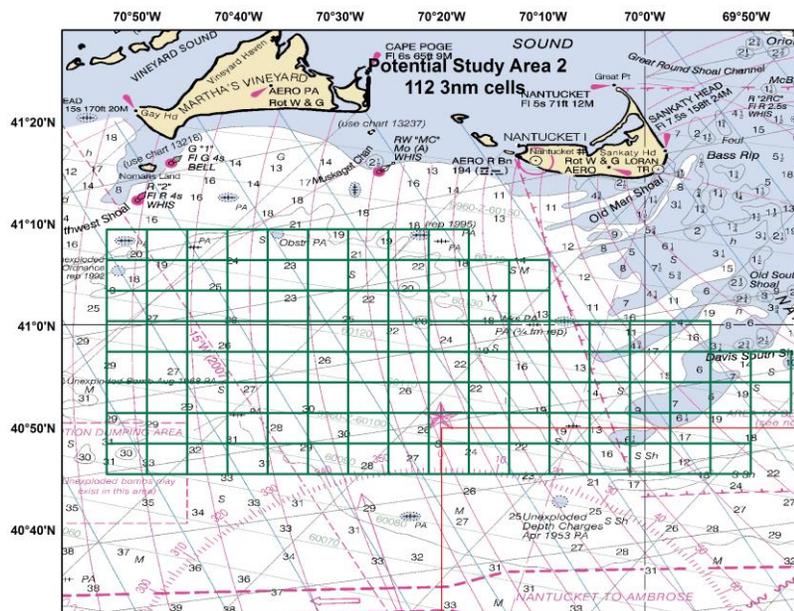
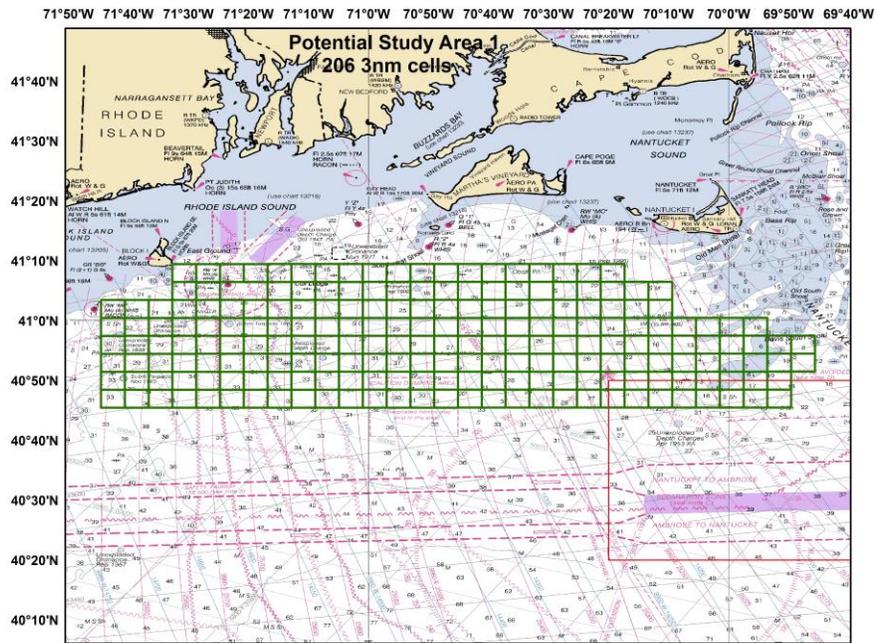
Table 7. Estimates of area-swept biomass under varying assumptions of q. Area swept was calculated for each tow using the doorspread.

	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
Trip 1	1315.1	1461.2	1643.9	1878.7	2191.8	2630.2	3287.8	4383.7	6575.5	13151.0
Trip 2	1059.4	1177.1	1324.3	1513.4	1765.7	2118.8	2648.5	3531.3	5297.0	10594.0
Trip 3	2631.3	2923.7	3289.1	3759.0	4385.5	5262.6	6578.3	8771.0	13156.5	26313.0
Trip 4	4171.5	4635.0	5214.4	5959.3	6952.5	8343.0	10428.8	13905.0	20857.5	41715.0
Survey Mean	2294.3	2549.2	2867.9	3277.6	3823.8	4588.6	5735.8	7647.7	11471.5	22943.0

Table 8. Mean tow speed and standard deviation by trip and vessel.

Trip	Vessel	Mean	Standard Deviation
1	F/V Black Sheep	2.98	0.29
2	F/V Lena Pearl	3.28	0.25
3	F/V Black Sheep	3.06	0.27
4	F/V Hopefull	3.02	0.28

FIGURES



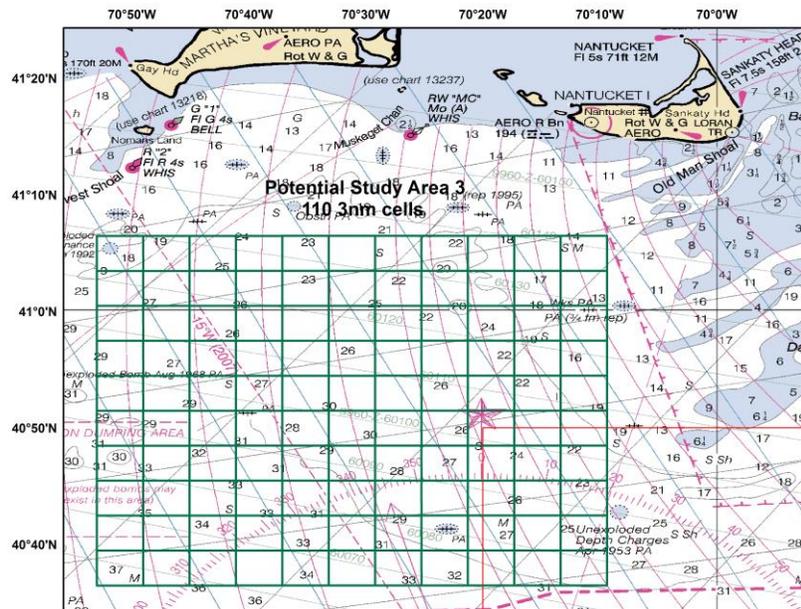


Figure 1. Three potential study areas that were identified with input from trawl fishermen from the port of Point Judith, RI.

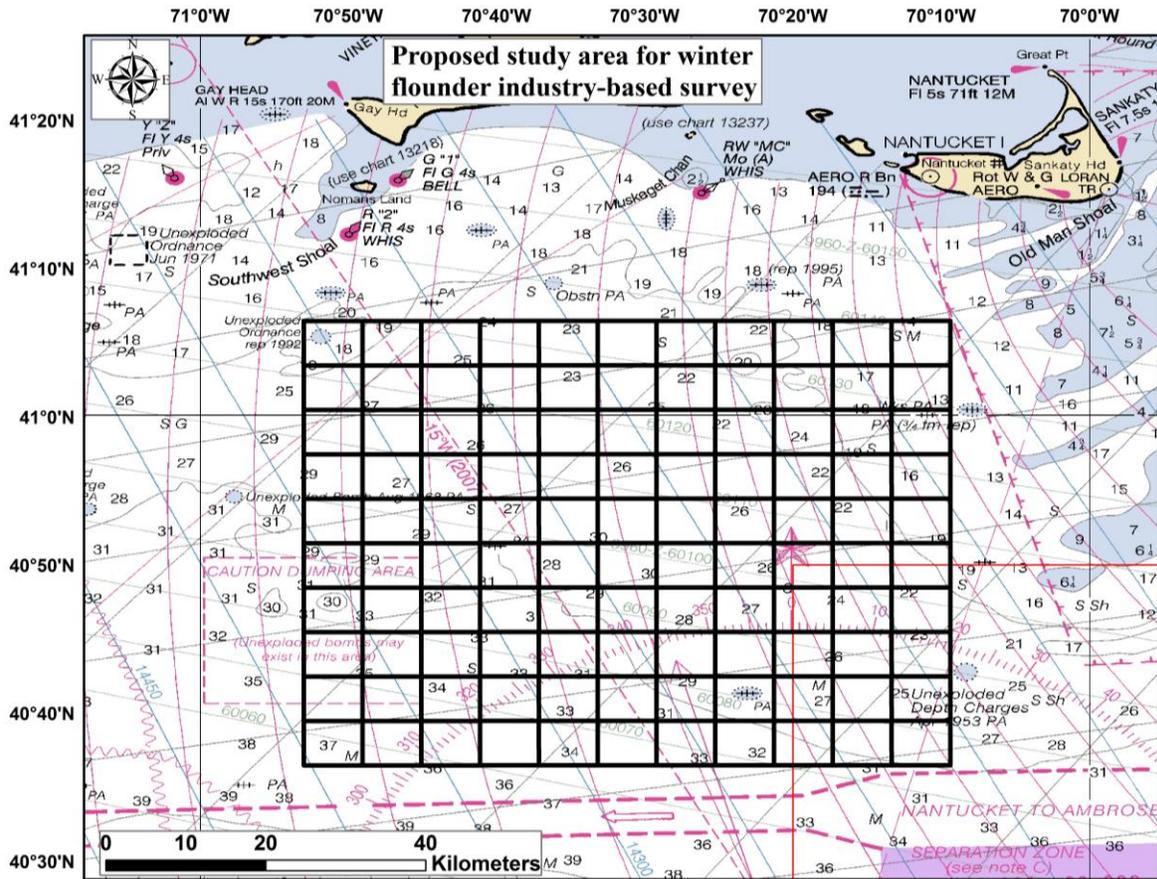


Figure 2. Original final study area as decided at the SMAST Groundfish Steering Committee meeting held on 12/15/2010.

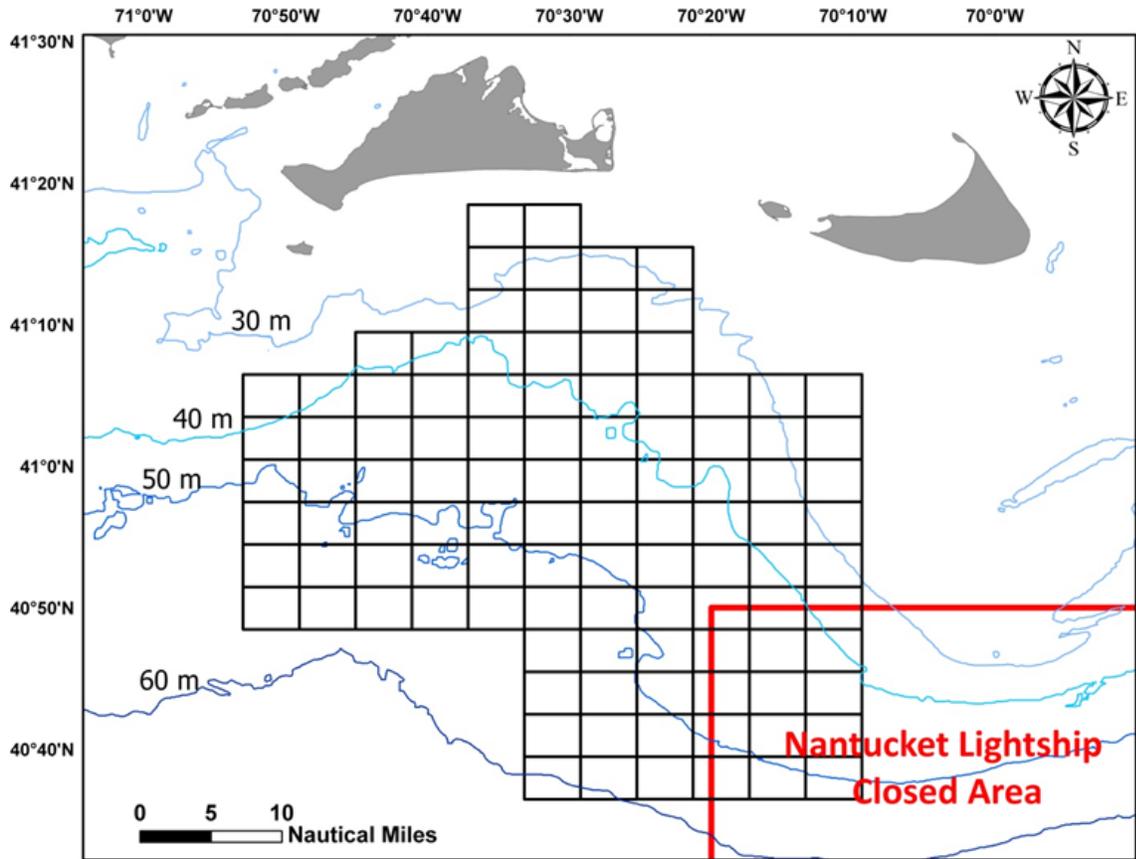


Figure 3. Modified final study area. The study area was modified based on comments received at a Commercial Fisheries Research Foundation meeting on January 24, 2012.

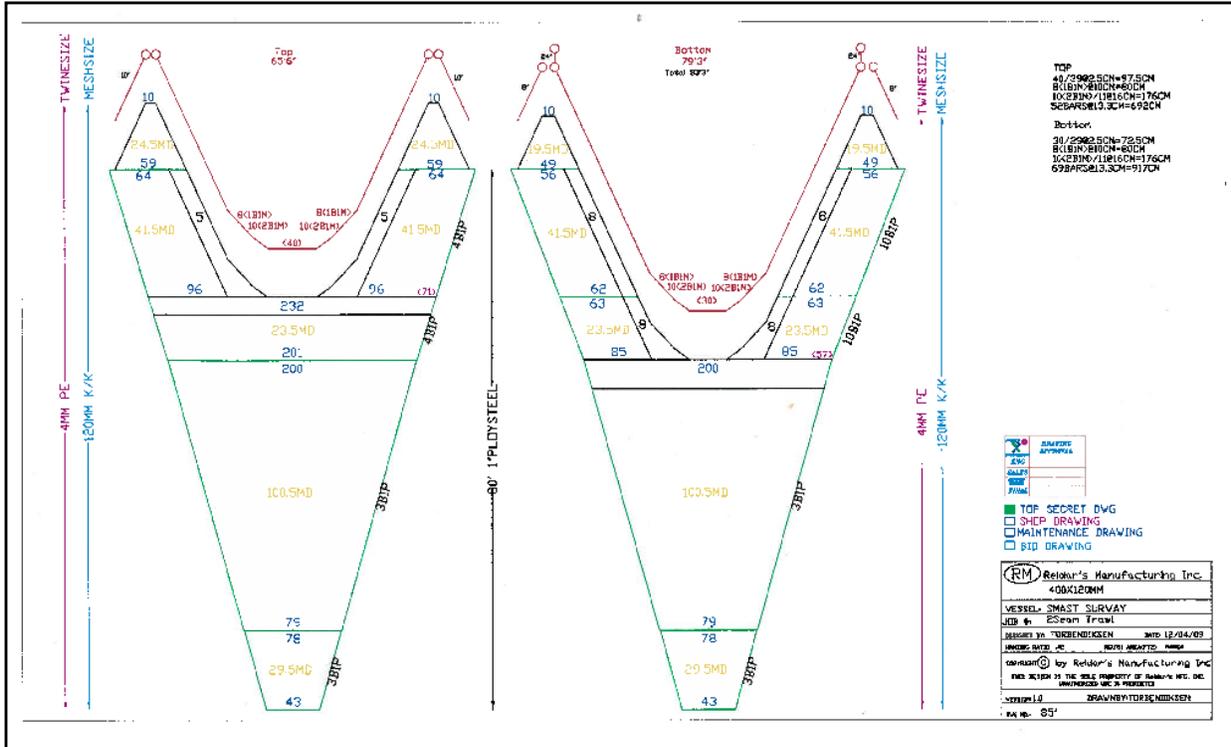


Figure 4. Net diagram from Reidar's Manufacturing Inc. for the survey net.

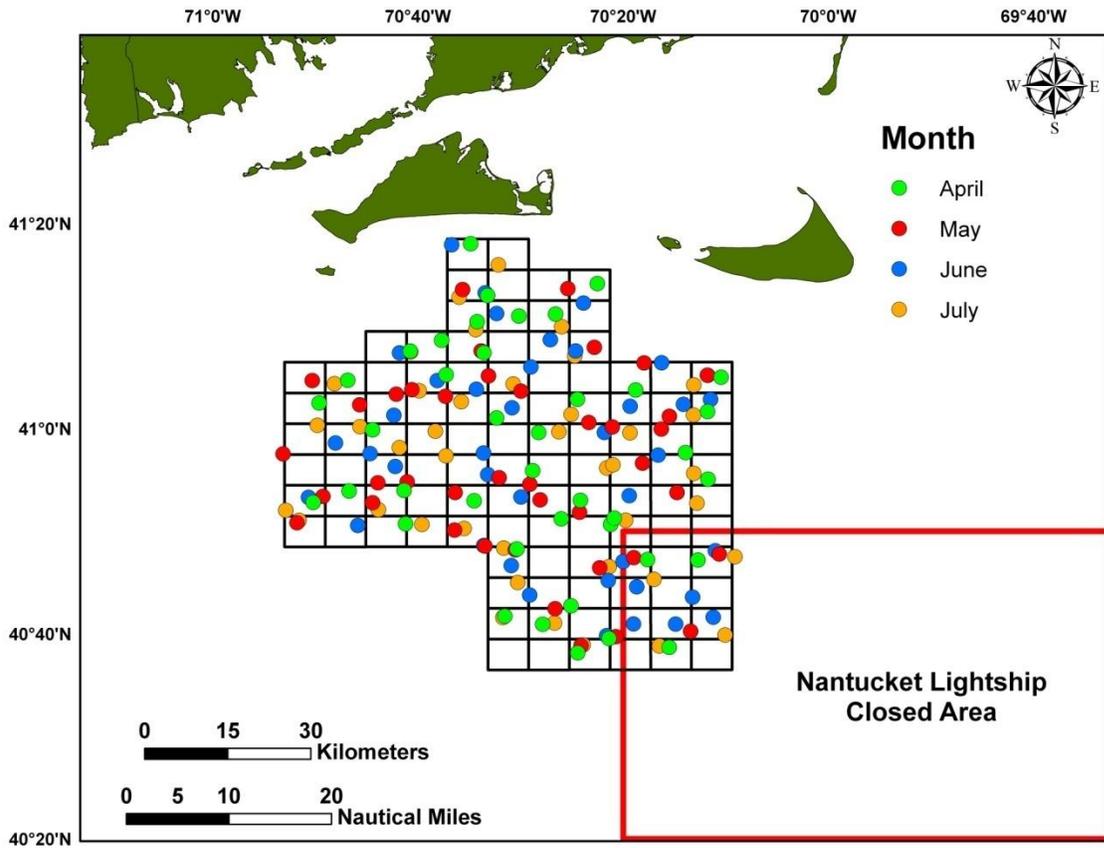


Figure 5. Study area with end locations for all successful tows completed over the course of the survey.

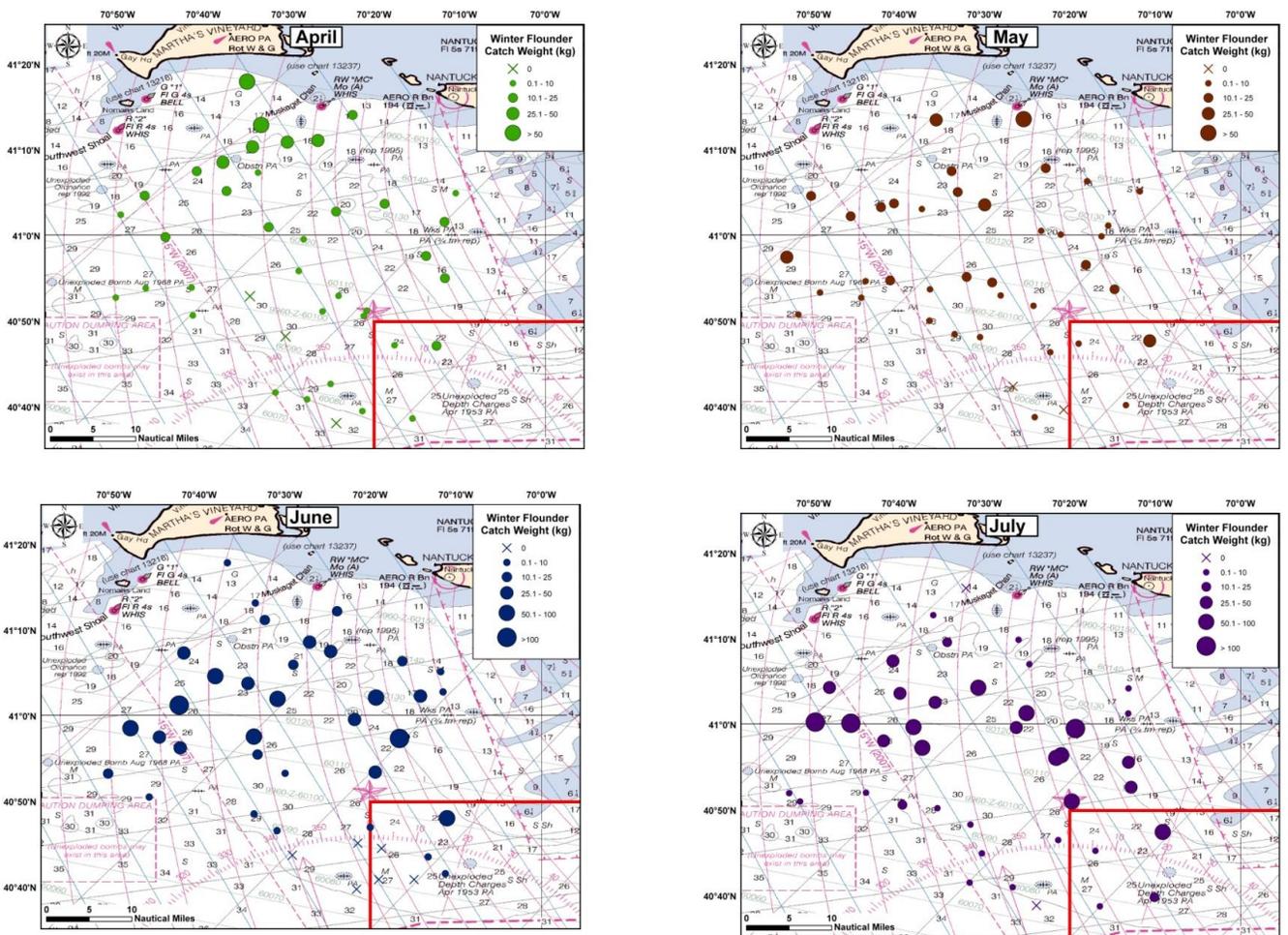


Figure 6. Distribution of winter flounder catches (kg/tow) during each month of the survey.

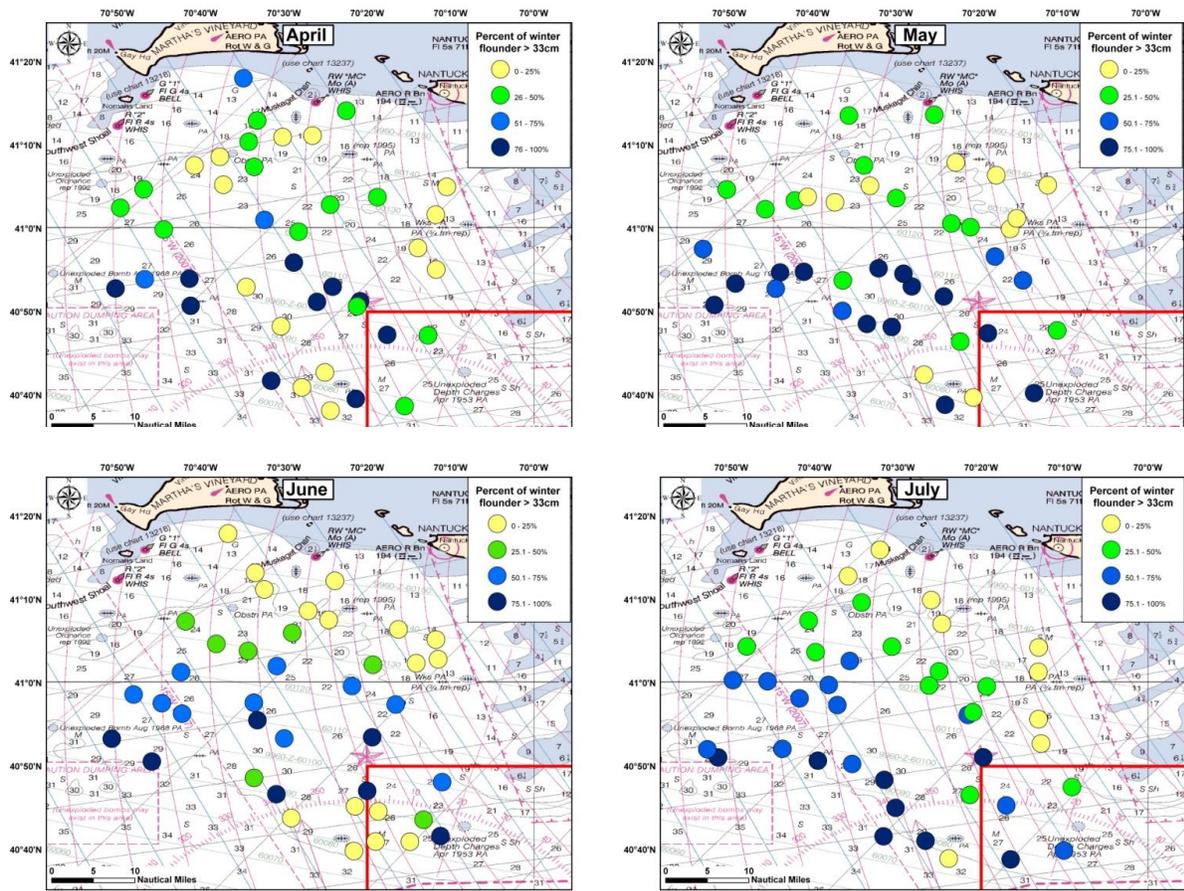


Figure 7. Monthly survey distribution of winter flounder catch by percentage of legal sized fish (> 32 cm).



Figure 8. Picture of a winter flounder that was recaptured with two t-bar tags that had been applied during an earlier survey trip.

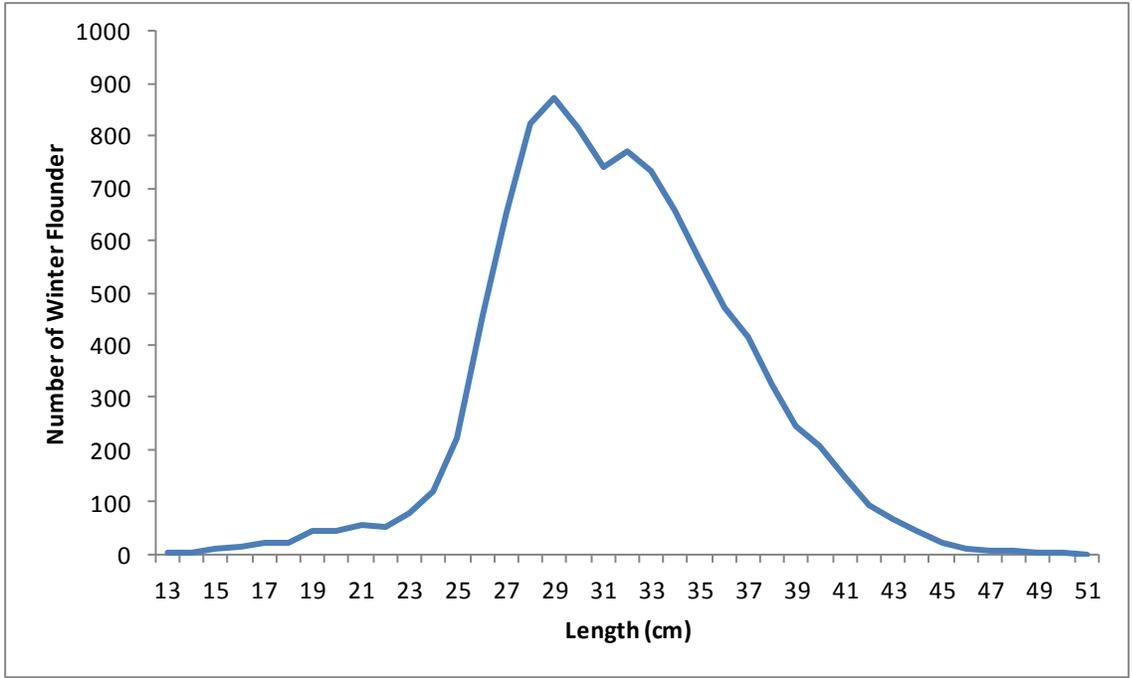


Figure 9. Pooled length frequency distribution for winter flounder measured over the course of the survey.

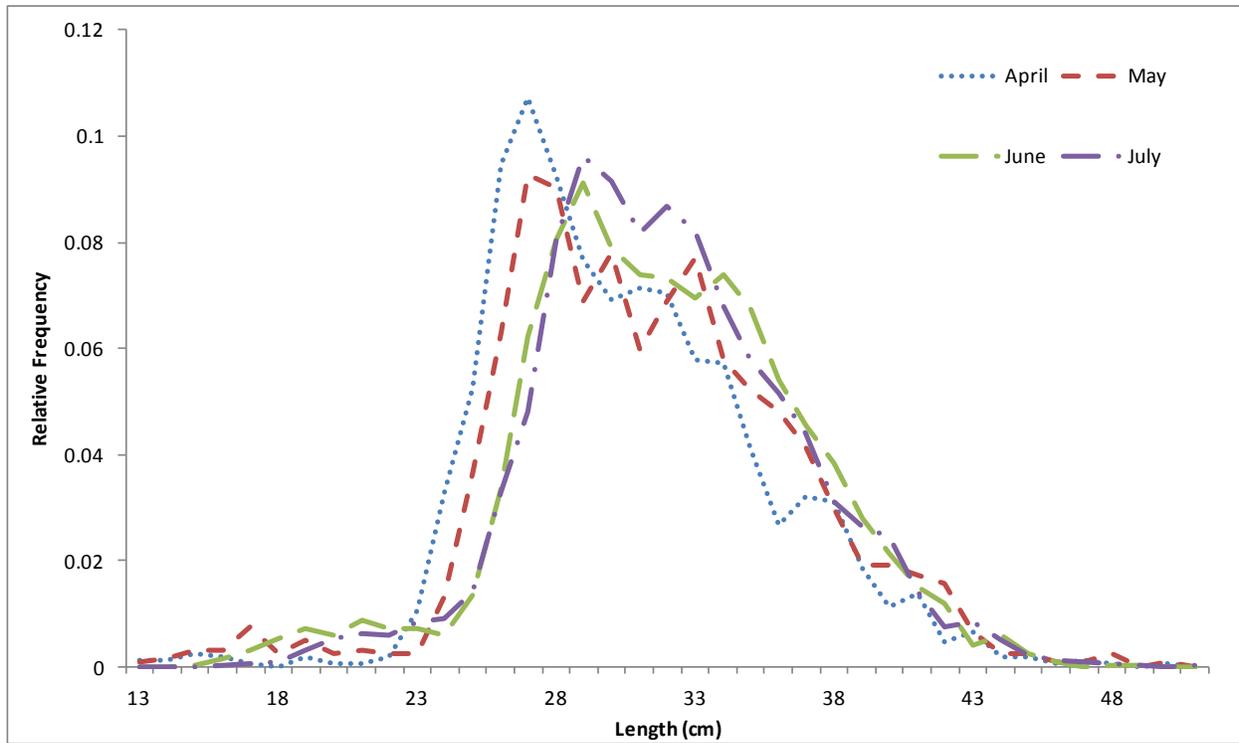


Figure 10. Relative length frequency distribution for winter flounder measured during each of the four survey trips.

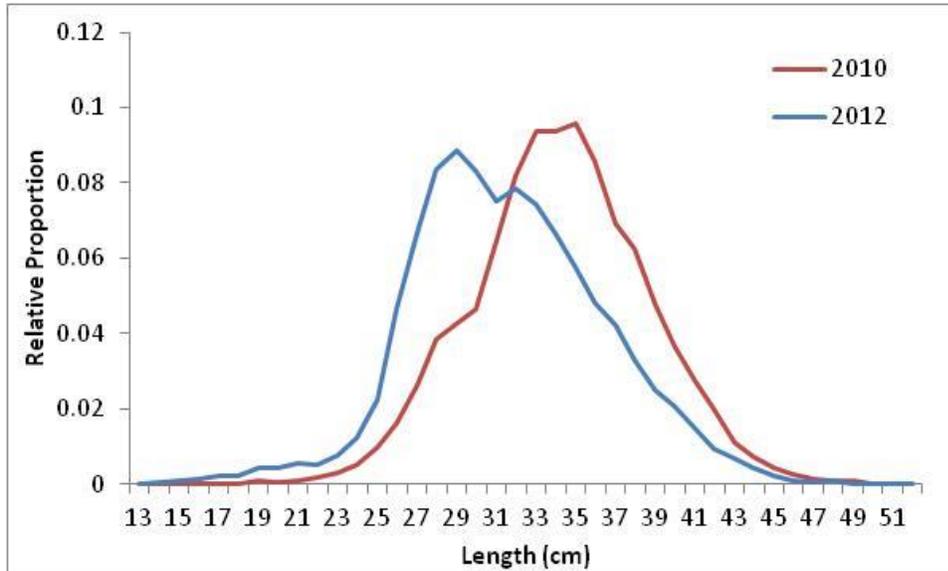


Figure 11. Comparison of the length frequency distributions of winter flounder caught during the 2010 and 2012 industry-based surveys for winter flounder. The 2010 industry-based survey was conducted in the Great South Channel and the eastern portion of Nantucket Shoals, while the 2012 industry-based survey was completed in the waters of southern New England, south of Nantucket and Martha’s Vineyard.

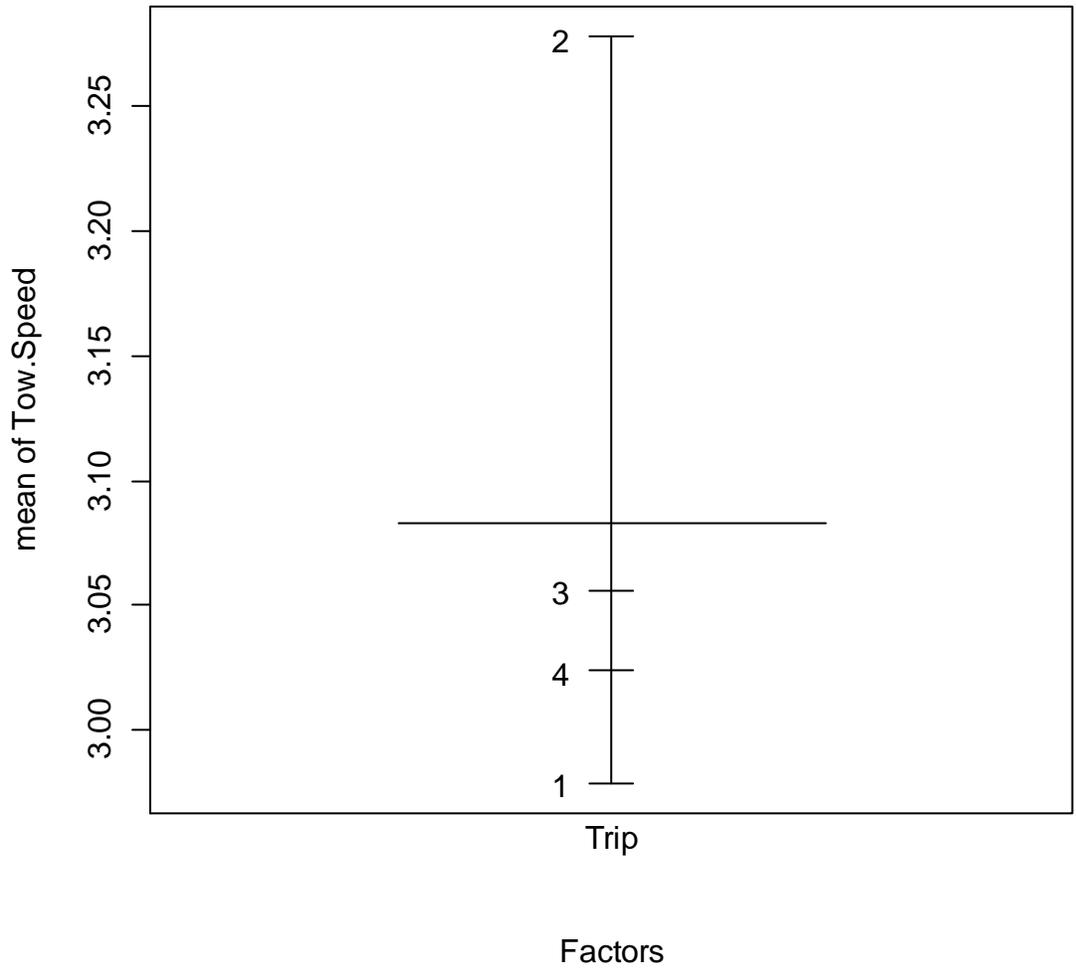


Figure 12. Plot of mean tow speed in knots by trip for survey tows for the winter flounder industry-based survey.

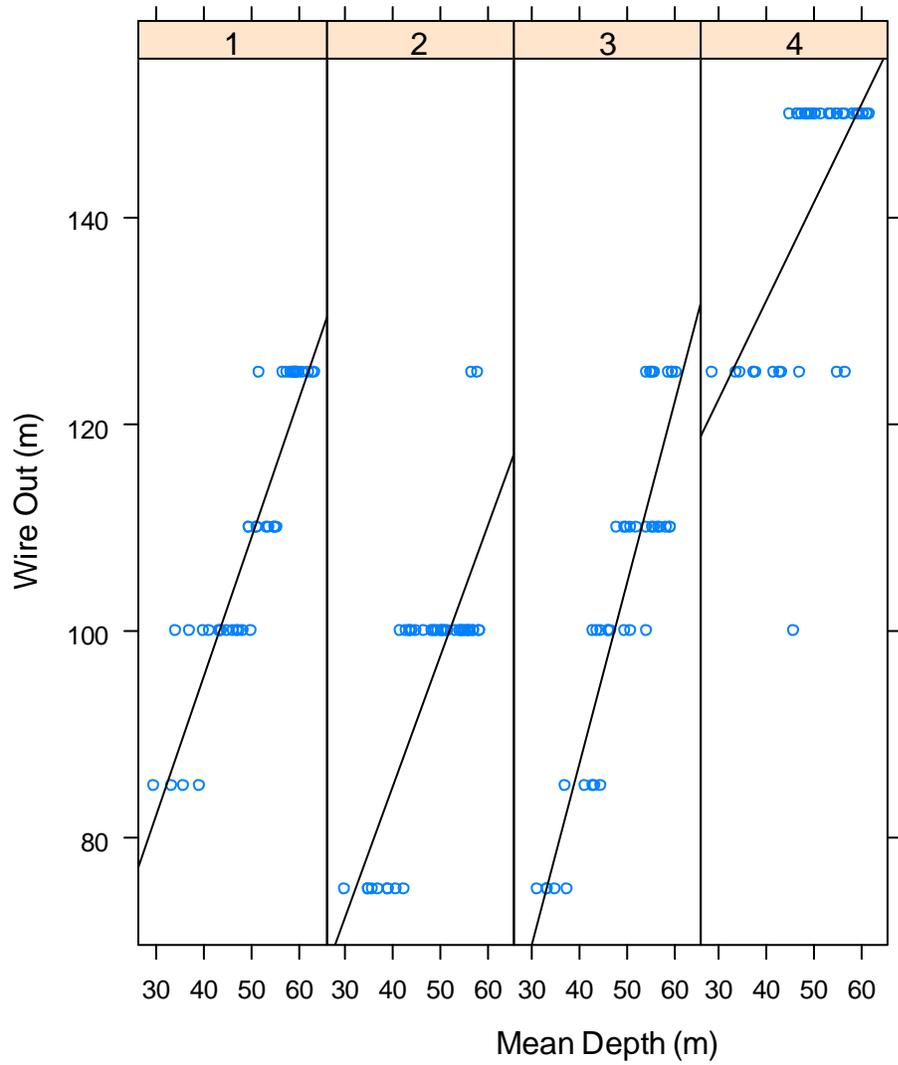


Figure 13. Plot of wire out (meters) against depth (meters) by trip for the survey.

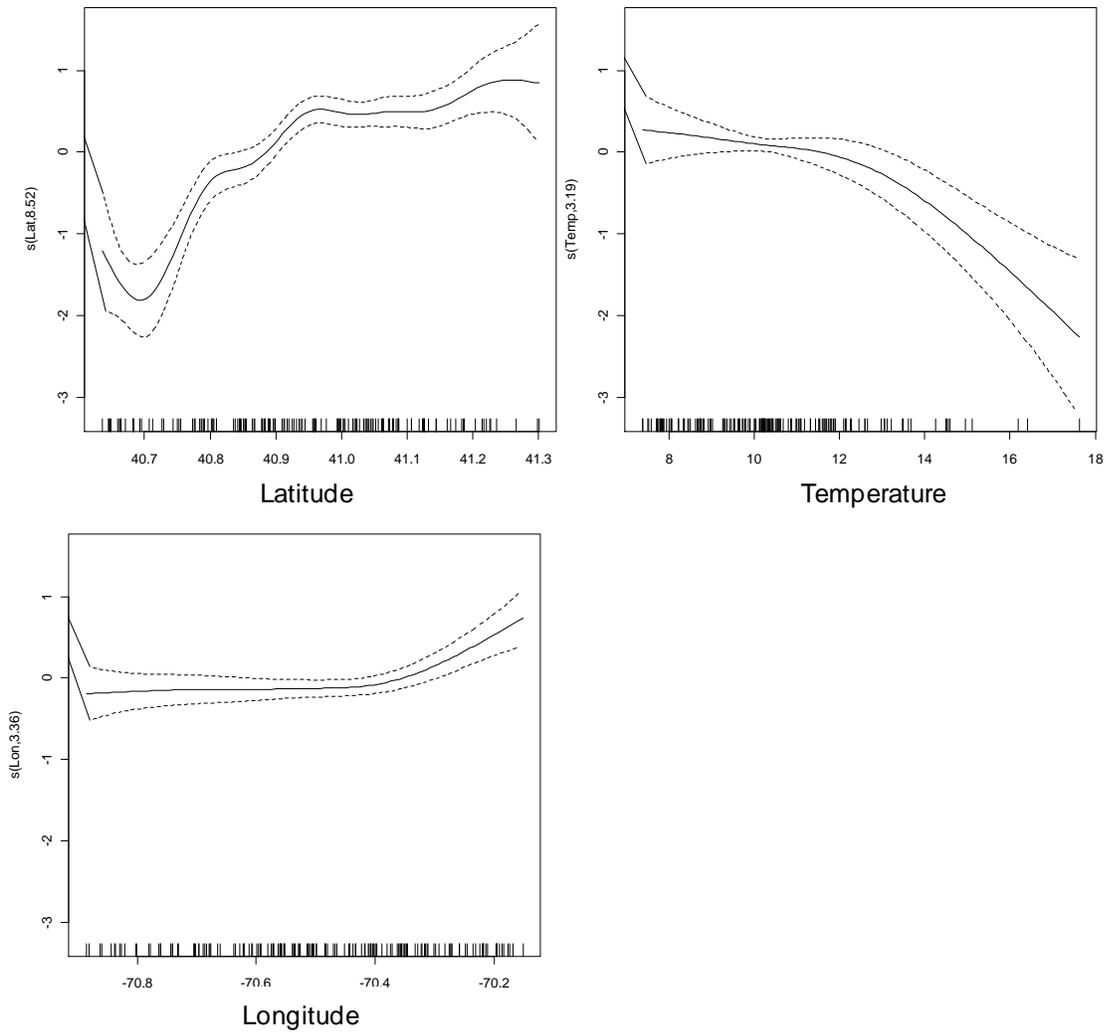


Figure 14. GAM model plots of log transformed winter flounder catch weights plotted against latitude, temperature and longitude. The dashed lines indicate the 95% confidence intervals.

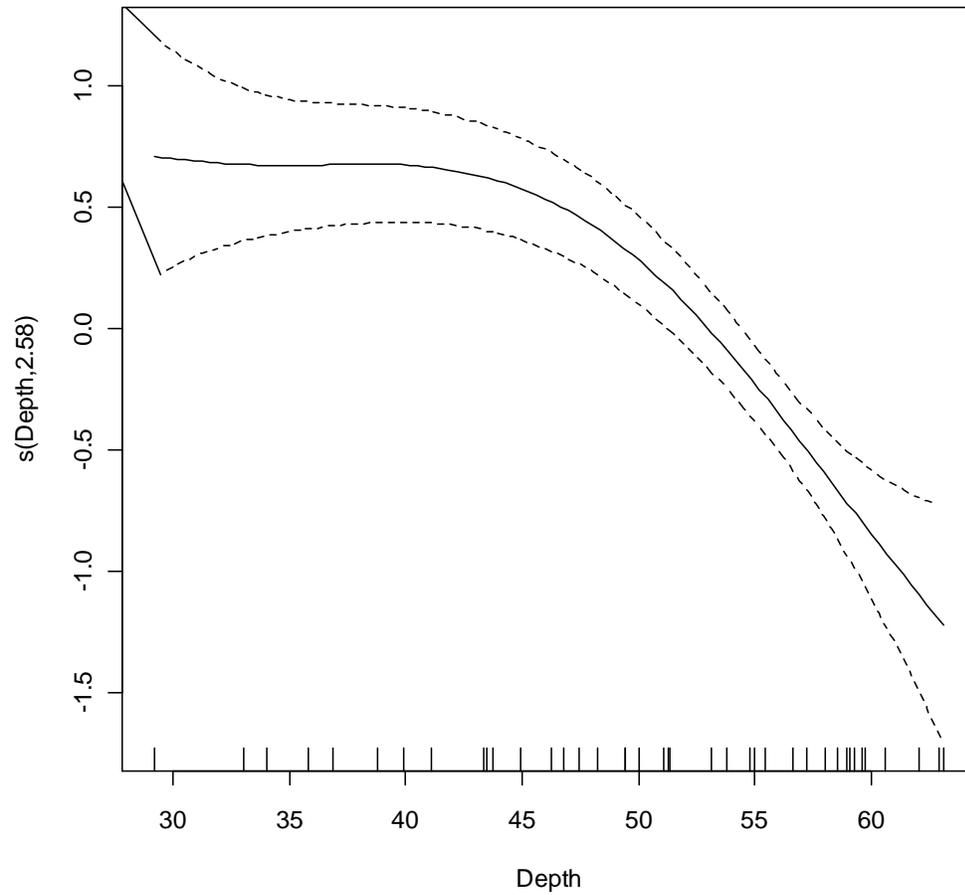


Figure 15. GAM model plot of log transformed winter flounder catch weights plotted against depth for the April survey trip. The dashed lines indicate the 95% confidence intervals.

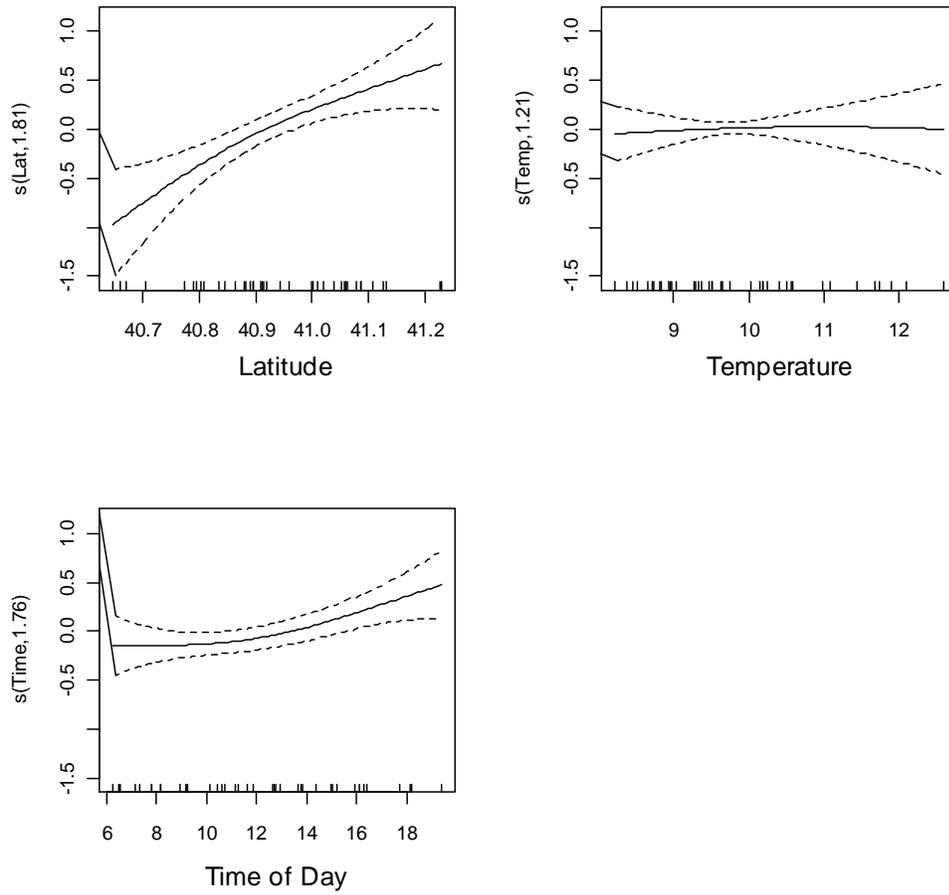


Figure 16. GAM model plots of log transformed winter flounder catch weights plotted against latitude, temperature and time of day for the May survey trip. The dashed lines indicate the 95% confidence intervals.

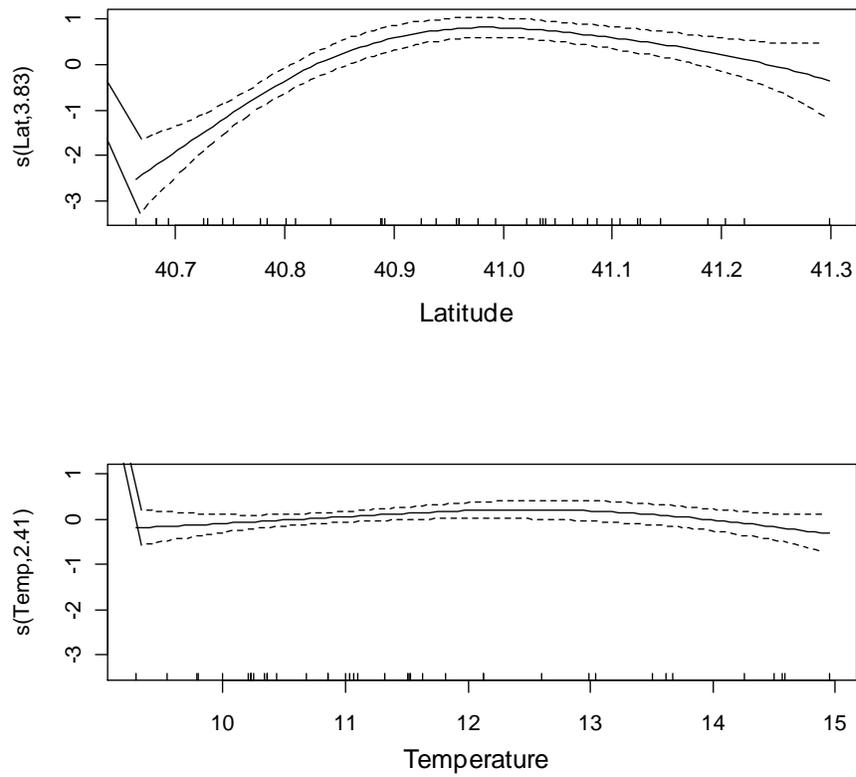


Figure 17. GAM model plots of log transformed winter flounder catch weights plotted against latitude and temperature for the June survey trip. The dashed lines indicate the 95% confidence intervals.

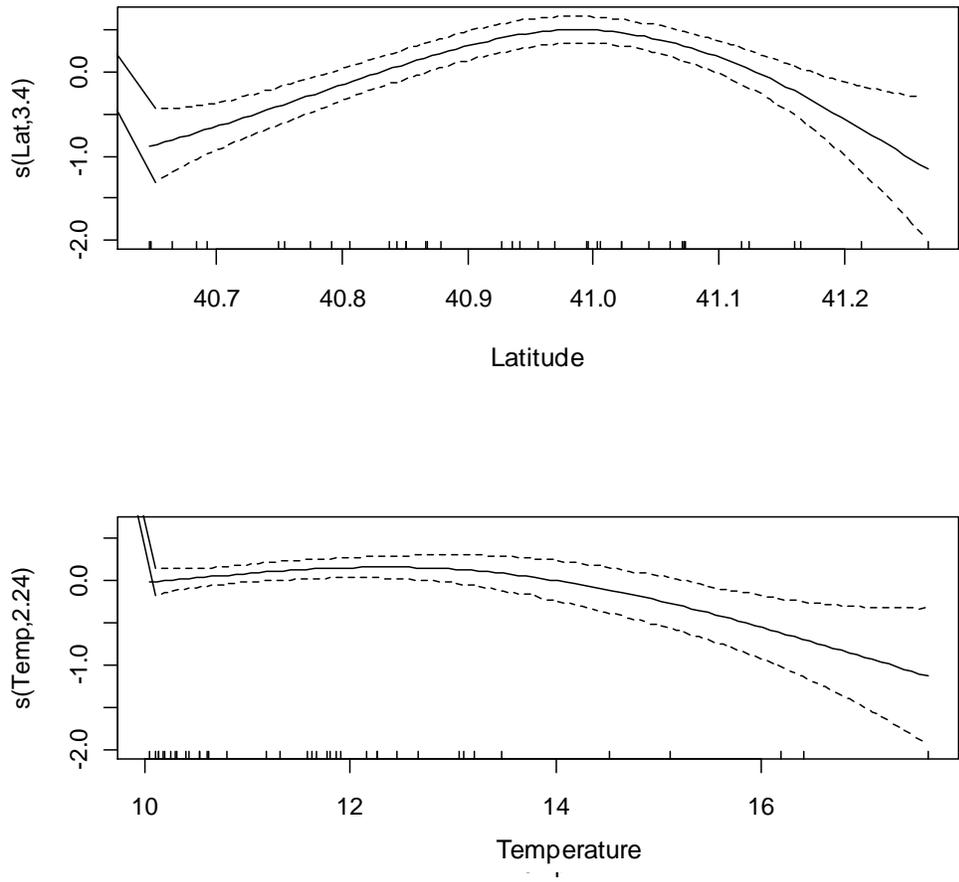


Figure 18. GAM model plots of log transformed winter flounder catch weights plotted against latitude and temperature for the July survey trip. The dashed lines indicate the 95% confidence intervals.

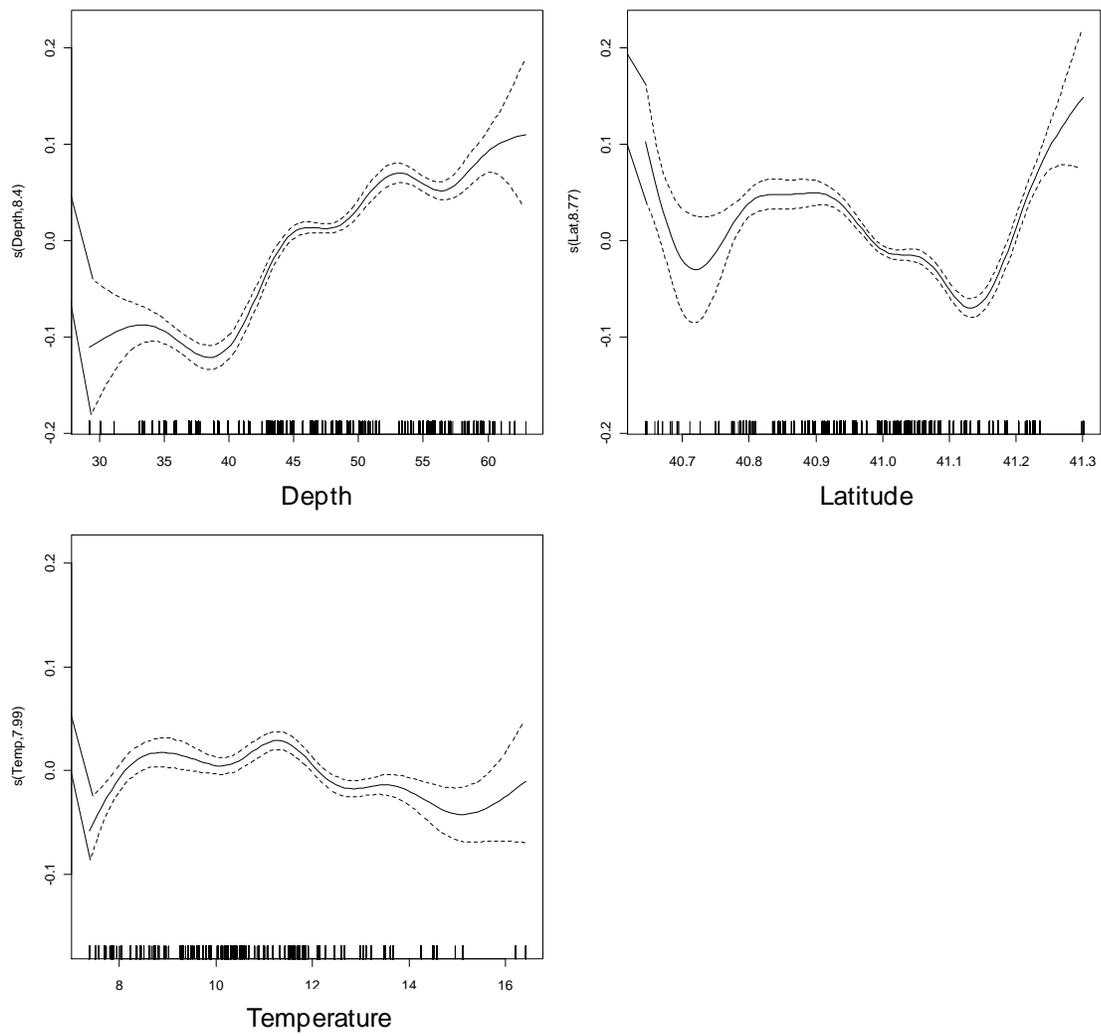


Figure 19. GAM model plots of the length of winter flounder in the survey catch against depth, latitude and temperature.