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Estimates of Yellowtail Flounder Biomass on Georges Bank Derived from a Seasonal Dredge Survey

Greg DeCelles[1], Katherine Thompson[2], and Steve Cadrin[1]

[1]University of Massachusetts, Dartmouth
School for Marine Science & Technology
Department of Fisheries Oceanography
200 Mill Road, Suite 325
Fairhaven, MA 02719 USA

[2]Coonamessett Farm Foundation Inc.
277 Hatchville Road
East Falmouth, MA 02536 USA

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ABSTRACT

A seasonal dredge survey was completed in Closed Area 1, Closed Area 2, and on the southwest portion of Georges Bank in 2013. Eight survey trips were made over the course of the year, and 75 to 91 survey tows were completed during each trip. Each Yellowtail Flounder caught during the survey was measured to the nearest centimeter, and the total weight of Yellowtail Flounder observed during each survey tow was calculated. Estimates of Yellowtail Flounder density and area swept biomass were calculated for each trip. Each of the eight survey trips produced an area swept biomass estimate of adult-sized Yellowtail Flounder (range = 872 to 3462 mt) that was greater than the estimate of adult biomass (826 mt) derived from the most recent stock assessment (Legault et al. 2013). The results of the survey suggest that the stock assessment for Yellowtail Flounder on Georges Bank is underestimating the biomass of the resource.

RÉSUMÉ

En 2013, un relevé saisonnier à la drague a été réalisé dans la zone interdite 1, dans la zone interdite 2 et sur la partie sud-ouest du banc de Georges. Huit sorties en mer liées au relevé ont été faites durant l'année, et de 75 à 91 traits de relevé ont été faits pendant chaque sortie. Chaque limande à queue jaune capturée durant le relevé a été mesurée au centimètre près, et le poids total des limandes à queue jaune observées durant chaque trait de relevé a été calculé. Les estimations de la densité de la limande à queue jaune et de la biomasse de la superficie balayée ont été calculées pour chaque sortie. Chacune des huit sorties en mer liées au relevé a produit une estimation de la biomasse des limandes à queue jaune de taille adulte (fourchette = de 872 à 3 462 tm) dans la superficie balayée qui était supérieure à la biomasse des adultes (826 tm) dérivée de la plus récente évaluation du stock (Legault *et al.* 2013). Les résultats du relevé laissent supposer que l'évaluation du stock de la limande à queue jaune du banc de Georges sous-estime la biomasse de la ressource.

INTRODUCTION

A seasonal dredge survey was completed on Georges Bank to investigate spatial and temporal patterns of bycatch in the scallop fishery, and to examine the seasonal meat yield of scallops. The seasonal dredge survey is a cooperative effort between scientists from the Coonamessett Farm Foundation, the School for Marine Science and Technology, and the Virginia Institute of Marine Science. The seasonal dredge survey is conducted in coordination with members of the scallop fleet, and the project is funded under the Scallop Research Set-Aside (RSA) Program.

The survey began in 2011, and survey trips are completed throughout the year with each trip spaced approximately six weeks apart. Eight survey trips were completed in 2013, and between 75 and 91 standardized survey tows were completed at fixed locations in Closed Areas 1 and 2, and on the southwest part of Georges Bank during each trip. The survey collects high resolution, fisheries-independent information on the distribution and abundance of Yellowtail Flounder on Georges Bank, which could help inform the assessment of Yellowtail Flounder.

The most recent assessment for Georges Bank Yellowtail Flounder concluded that Yellowtail Flounder was overfished, and that overfishing was occurring (Legault et al. 2013). Spawning stock biomass was estimated to be 869 mt in 2012, which was the weakest value in the time series. Recent estimates of recruitment (2009-2011) were estimated to be the smallest in the time series. Following the assessment results, the 2014 Georges Bank Yellowtail Flounder quota was set to 400 mt, a record low for this stock. Within the 400 mt transboundary quota, 328 mt was apportioned to the United States, of which 50.9 mt were allocated to the Limited Access scallop fishery. There is concern amongst the scallop industry that the allocation of Georges Bank Yellowtail Flounder to the scallop fishery will be too low to avoid Accountability Measures from being triggered.

The Georges Bank Yellowtail Flounder stock assessment uses a calibrated Virtual Population Analysis (VPA) model (Legault et al. 2013). Three fishery-independent survey indices are included in the VPA model; the National Marine Fisheries Service (NMFS) spring and fall bottom trawl surveys, and the Department of Fisheries and Oceans (DFO) Georges Bank bottom trawl survey. The time series of the three surveys are “split” in the assessment model, and catchability coefficients are estimated independently before and after 1994. Observations from the DFO and NMFS trawl surveys between 2002 and 2012 suggest that the distribution of Yellowtail Flounder on Georges Bank is aggregated (Figures 13a and 13b, in Legault et al. 2013). For each of the three fishery-independent surveys, the density of observations on Georges Bank is limited, particularly in Closed Area 2 where Yellowtail Flounder are often concentrated during the fall (Figures 13a and 13b, in Legault et al. 2013). The transition from the former National Oceanic and Atmospheric Administration (NOAA) ship *Albatross IV* to the NOAA ship *Henry B. Bigelow* may also introduce a source of uncertainty to the NMFS survey indices, as substantial changes were made to the survey net and protocols. Biomass and length-based calibration coefficients were applied in the assessment to convert *Henry B. Bigelow* estimates into *Albatross IV* units. Given the importance of the Yellowtail Flounder resource to both the groundfish and scallop fleets, and the uncertainty associated with the most recent stock assessment, additional fishery-independent data sources should be considered in the assessment of Georges Bank Yellowtail Flounder.

This report provides fisheries-independent estimates of Yellowtail Flounder density (kg/km^2) and biomass (mt) on a portion of Georges Bank that were obtained from the seasonal dredge survey in 2013. This report also provides information on a comparative fishing experiment that was completed in September 2012 to examine the relative catchability of the standard dredge that is used during the seasonal dredge survey on Georges Bank.

METHODS

COMPARATIVE FISHING EXPERIMENT TO EXAMINE DREDGE CATCHABILITY

In September 2012, a comparative fishing experiment was conducted on board the *F/V Celtic* to estimate the catchability of a standardized New Bedford style commercial fishing dredge (hereafter referred to as the "standard dredge") that is used on the seasonal dredge survey relative to the Northeast Fisheries Science Center (NEFSC) scallop survey dredge. Eighty paired tows were made on Georges Bank (Figure 1), and both dredges were fished side by side at a target speed of 4.0 knots, and a target tow duration of 15 minutes. After each tow the catches of scallops, Yellowtail Flounder, Winter Flounder, Windowpane Flounder, and Fourspot Flounder were compared between the standard dredge and the NMFS scallop survey dredge. Each Yellowtail Flounder was measured to the nearest centimeter, and estimates of Yellowtail Flounder density (kg/km^2) and area swept biomass (kg) were calculated for each dredge [see equations below]. The relative catchability of the standard dredge was estimated by using linear regression to compare the Yellowtail Flounder catch rates and density estimates that were observed during the 80 paired tows. Comparing the density estimates observed between the two dredges allowed us to account for the differences in dredge width between the standard dredge (4.57 m) and the NMFS scallop survey dredge (2.44 m).

Alternatively, the length-specific relative efficiency of the standard dredge for Yellowtail Flounder could by calculated using the methods proposed by Walsh et al. (1992), where it is assumed that the small mesh dredge (NMFS scallop survey dredge) represents the population size composition. Walsh defined the length specific relative efficiency as follows:

$$efficiency_{length} = {CL}/{(CL + CS)}$$

where CL is the catch in the large mesh gear (standard dredge) and CS is the catch in the small mesh gear (NMFS scallop survey dredge) at 2 cm intervals. However, the Walsh et al. (1992) method does not provide a method to correct for differences in width (and area swept) between the gears that are being tested. While the Walsh et al. (1992) method is informative for exploring the relative catchability of the standard dredge for Yellowtail Flounder, this approach fails to account for the differences in dredge width and area swept (and hence, efficiency) that exist between the two dredges.

SURVEY DESIGN AND GEAR FOR THE SEASONAL DREDGE SURVEY

Eight survey trips were completed using seven vessels in Closed Areas 1 and 2, and on the southwest portion of Georges Bank in 2013 (Table 1; Figure 2). Sampling locations were determined using a fixed grid systematic design (Figure 2), and all of the survey tows were completed within the Georges Bank Yellowtail Flounder stock area. The study area was divided into three a-priori defined strata for analysis; Closed Area 1 (stations 101-138), Closed Area 2 (stations 204-240) and the southwest part of Georges Bank (stations 273 and greater), and Yellowtail Flounder catch rates and biomass estimates were compared between the three strata. Survey stations in Closed Area 1 were spaced 5.40 km apart from east to west and 7.17 km apart from north to south. Survey stations in Closed Area 2, and on the southwest part of Georges Bank were spaced 8.54 km apart from east to west and 11.1 km apart from north to south. The tow direction and tow path was left to the discretion of the captain depending upon the environmental conditions (waves, tides etc.), substrate, and presence of fixed gear at the station. However, the captain was instructed to tow through the center point of the survey station at some point during the tow.

Two different 15 foot scallop dredges were towed side by side at each station. Each survey trip used both a standard dredge, and a Coonamessett Farm turtle deflector dredge. Only Yellowtail Flounder catches from the standard dredge were included in this analysis. The standard dredge was 15 feet (4.57 m) wide, and had an 8 by 40 ring apron, a 10 by 40 ring bag, 6 by 18 ring sides and a two-ring skirt. The standard dredge had 14 ring diamonds and 121 link sweeps made from 5/8 inch grade 70-link-long chain attached to the bag and diamonds with ¼ inch dog chain. The twine tops for the standard dredge had a stretched mesh length of 10.5 inches (26.7 cm), and the hanging ratio was 3 meshes to one ring. The standard dredge was also equipped with turtle mats made from 3/8 inch grade 70 chain, with 9 rows of ticklers and 13 rows of up and downs.

Seventy-five stations were sampled using the standard dredge during the survey trips completed in January and March (Figure 2, Table 2). Ninety one stations were sampled using the standard dredge during the six survey trips completed from April through December (Figure 1, Table 2). The same stations were sampled during each of the eight surveys, with the exception of stations 301-317. Stations 301-317 were not sampled in January or March, but were sampled during survey trips that occurred from April through December.

The target tow duration at each station was 30 minutes, with a minimum acceptable tow duration of 20 minutes. If a problem occurred during the tow or if a problem was noted after the dredges were brought on deck, (e.g., dredges hanging down, interactions with fixed gear, flipped dredge, etc.) another tow was attempted at that station. The dredge tows were repeated at the same station until an acceptable tow was completed. The acceptability of a survey tow was left to the discretion of the captain, crew, and scientists on deck. In order for a tow to be consider acceptable, the dredge must have been fished for at least 20 minutes at the station with no problems noted by the captain, and without any damage occurring to the gear that would affect the retention of scallops or bycatch species in the dredge (e.g., hole in twine top, broken dredge component, etc.). Ultimately, the validity of a survey tow was determined by the chief scientist on board, and the chief scientist (Carl Huntsberger) was present for all of the trips included in this analysis.

The target speed for survey tows was 8.89 km/hr (4.8 knots), although the actual average tow speed varied slightly between the vessels in the survey (Table 1). Each vessel towed the standard dredge with a scope ratio of 3:1. *In situ* measurements of temperature and depth were obtained from data loggers (Vemco Minilog and one Star-Oddi milli-TD) that were attached to the standard dredge.

The total length of each Yellowtail Flounder was measured to the nearest centimeter. The weight of each Yellowtail Flounder was calculated using the seasonal length-weight relationship for Yellowtail Flounder (Wigley et al. 2003) and the total weight of Yellowtail Flounder caught in the standard dredge was calculated for each survey tow as follows:

$$\ln W = \ln a + b \ln L$$

where W = weight (kg), L = length (cm), a = y-intercept, and b = slope.

No length-weight relationship for Yellowtail Flounder is available for the summer, so the weight-at-length of Yellowtail Flounder captured during survey trips in June and July were calculated using the average y-intercept and slope from the spring and autumn length-weight relationships (a = -12.0981 and b = 3.1329).

For each survey trip, mean Yellowtail Flounder catch weights were calculated for each stratum. The variance in Yellowtail Flounder catch weights of the entire sample (across all strata) was also calculated for each trip. A stratified random variance (Brust and Belcher 2000) was used to approximate variance of the systematic design. The coefficient of variation in mean Yellowtail Flounder catch weights was also calculated for each survey trip (Sokal and Rohlf 2001).

Estimates of Yellowtail Flounder density (kg/km^2) and area swept biomass (mt) were calculated by examining the observed catch of Yellowtail Flounder and the area swept by the standard dredge during each valid tow. The area swept by the standard dredge during each tow was calculated using the width of the dredge, the average speed of the vessel during the tow, and the tow duration. Tow speed was converted from knots to km/hr for area swept estimation. Tow duration started when the dredge was on bottom with the winches locked, and ended when the winches were engaged to pull the dredge from the bottom. Bottom contact sensors were not used. The duration of each tow was converted from minutes to fraction of an hour for area swept calculations.

$$\textbf{Area swept (km2)} = \textbf{dredge width (km)} * \textbf{tow speed} \left(\frac{\textbf{km}}{\textbf{hr}}\right) * \textbf{tow duration (hr)}$$

The density of Yellowtail Flounder observed during each survey tow was calculated:

$$\textbf{Yellowtail flounder density} \left(\frac{\textbf{kg}}{\textbf{km2}}\right) = \frac{\textbf{yellowtail flounder catch (kg)}}{\textbf{area swept (km2)}} * \left(\frac{\textbf{1}}{\textbf{q}}\right)$$

Where, q (0.248) is the catchability coefficient that was estimated for the standard dredge during the comparative fishing experiment in September 2012. Estimates of Yellowtail Flounder density and biomass are sensitive to the value of q that is used for the standard dredge. To address this sensitivity, density and biomass estimates were generated for each survey trip using a range of catchability coefficients. The area-swept biomass of Yellowtail Flounder was calculated in each of the three survey strata (Closed Area 1, Closed Area 2, and the southwest part of Georges Bank) using the following formula.

$$\textbf{Yellowtail Flounder Biomass (kg)} = \textbf{Yellowtail Flounder density (kg/km2)} * \textbf{Survey Area (km2)}$$

Each station in Closed Area 1 represented an area of 38.74 km^2, while survey stations in Closed Area 2 and on the southwestern part of Georges Bank represented an area of 94.82 km^2. During each survey trip, 31 stations were sampled in Closed Area 1 and 30 stations were sampled in Closed Area 2 (Table 2). The sampling intensity was more variable on the southwestern part of Georges Bank. During survey trips in January and March, only 14 stations were sampled in this stratum, but the sampling coverage on the southwest portion of Georges Bank increased to 30 stations for all 6 trips completed between April and December of 2013. The total area sampled differed between survey trips and ranged from 5373 km^2 in January and March of 2013 to 6890 km^2 during all trips completed from April to December (Table 2).

Area-swept biomass estimates of Yellowtail Flounder were calculated for each survey trip. For each trip, the mean estimate of area-swept biomass was calculated for the three survey strata (Closed Area 1, Closed Area 2, and the southwest part of Georges Bank), and the biomass estimates from the three strata were then summed to obtain the total biomass estimate for that survey trip.

RESULTS

COMPARATIVE FISHING EXPERIMENT TO EXAMINE DREDGE CATCHABILITY

An independent analysis estimated the catchability of the NMFS scallop survey dredge to be 0.46 (95% confidence intervals (CI) 0.32-0.60) for Yellowtail Flounder across all size classes (Shank et al. unpublished manuscript[1]). Catches of Yellowtail Ffounder in the NMFS scallop survey dredge in 2010 and 2012 were compared to abundance estimates for Yellowtail Flounder that were estimated using an image based survey method (HabCam2) in the southern

[1] Shank, B., Hart, D., Gallager, S., York, A., and Stokesbury, K. 2013. Abundance and spatial distribution of Yellowtail Flounder in Closed Area II South, 2010 vs. 2012, from an image-based survey. Working Paper presented to the 2013 Transboundary Resource Assessment Committee.

portion of Closed Area 2. The comparisons were used to derive an efficiency estimate of the NMFS scallop survey dredge.

Eighty paired tows were completed on Georges Bank in September 2012, and the NMFS scallop survey dredge and the standard dredge were fished side by side during each tow. The catch rates of five species (scallops, Yellowtail Flounder, Winter Flounder, Windowpane Flounder, and Fourspot Flounder) observed during the comparative fishing experiment are shown in Table 3. The average catch rates of Yellowtail Flounder, Fourspot Flounder, and Windowpane Flounder were greater in the NMFS scallop survey dredge, while the standard dredge had greater average catches of scallops and Winter Flounder. The average catch of Yellowtail Flounder was 2.4 individuals/tow in the NMFS scallop survey dredge, and 1.4 individuals/tow in the standard dredge. However, it is somewhat misleading to compare the catch rates directly, because the standard dredge was nearly twice as wide (4.57m) as the NMFS scallop survey dredge (2.44 m). The area swept by the standard dredge during each tow (0.0085km^2) was 87.5% larger than the area swept by the NMFS scallop survey dredge (0.0045 km^2).

To account for the difference in the area sampled by the two dredges, a conversion factor was applied to the catches from the NMFS scallop survey dredge. The average catch observed in the NMFS scallop survey dredge was multiplied by 1.875, and the converted catch rates were compared (Table 4). When the catch rates are converted to account for the width of the dredges, the average catch rates of scallops were more similar between the two dredges, although the mean catch of scallops was greater in the NMFS scallop survey dredge than the standard dredge. The converted catch rates of the four flounder species were greater in the NMFS scallop survey dredge than in the standard dredge, suggesting that the NMFS scallop survey dredge may have a greater catchability for flatfish than the standard dredge.

The length frequency distribution of Yellowtail Flounder differs markedly between the two dredges (Figure 3). The size range of Yellowtail Flounder caught in the NMFS scallop survey dredge (4-48 cm) was much larger than the standard dredge (31-48 cm). The length distributions suggest that the NMFS scallop survey dredge has a higher catchability for Yellowtail Flounder <34 cm, while the relative catchability of both dredges appears to be similar for yellowtail >35 cm. The difference in size selectivity observed between the two dredges is likely due to differences in the configuration of the two dredges. The NMFS scallop survey dredge is designed to retain small scallops, and the NMFS scallop survey dredge uses 2 inch rings, and a 1.5 inch (3.8 cm) liner.

The difference in size selectivity for Yellowtail Flounder between the two dredges is important, and needs to be considered in order to accurately compare the relative catchability of the two dredges. In order to account for the differing size frequency of Yellowtail Flounder caught in the two dredges, density (kg Yellowtail Flounder/km^2) estimates calculated for both dredges were compared. For the 80 paired tows that were completed in September 2012, the average density of Yellowtail Flounder estimated from the NMFS scallop survey dredge (185.8 kg/km^2) is greater than the average density estimated from the standard dredge (81.6 kg/km^2). Estimates of Yellowtail Flounder density from the comparative fishing experiment suggested that the NMFS scallop survey dredge has a greater catchability for Yellowtail Flounder than the standard dredge. In addition, the NMFS scallop survey dredge appears to catch a larger proportion of scallops, Windowpane Flounder and Fourspot Flounder than the standard dredge.

The catchability of the standard dredge relative to the NMFS scallop survey dredge was estimated from a regression of Yellowtail Flounder density estimates derived from both dredges (Figure 4). The estimated slope through the origin, 1.86 (95% CI = 1.62-2.10), was then used to estimate the catchability of the standard dredge with the following equation:

$$\boldsymbol{q\ (standard\ dredge) = \frac{q\ (NMFS\ survey\ dredge)}{1.86}}$$

Using the formula shown above, assuming the catchability of the NMFS scallop survey dredge is 0.46 (95% CI = 0.32-0.60), the catchability of the standard dredge was estimated to be 0.25 for Yellowtail Flounder. Using the 95% lower and upper confidence limits for the slope of the regression line yields a catchability value for the standard dredge of 0.22 and 0.28, respectively. The estimated catchability value of 0.25 was used to calculate the density and area swept biomass of Yellowtail Flounder that was observed during the 8 bycatch survey trips in 2013. Because estimates of density and biomass are sensitive to the value of q that is chosen, area swept biomass estimates were calculated using a range of catchability values. The density and biomass estimates are also sensitive to the length-weight relationships that were used to convert Yellowtail Flounder catches at length to catch weights. If the length-weight relationship has changed substantially from that calculated by Wigley et al. (2003), it may introduce a source of uncertainty into the biomass estimates.

Using the methods of Walsh et al. (1992), it was observed that the standard dredge was relatively less efficient that the NMFS dredge across nearly all length categories that were sampled (Figure 5), and the disparity was most evident for Yellowtail Flounder <30 cm. However, this method fails to account for the differences in width between the two dredges, and thus, may overestimate the relative efficiency at length of the standard dredge.

YELLOWTAIL FLOUNDER CATCHES AND BIOMASS ESTIMATES FROM THE SEASONAL DREDGE SURVEY

The mean catch rates (kg/tow) of Yellowtail Flounder differed between the three strata over the course of the survey. Catch rates were generally greatest in Closed Area 2, intermediate on the southwest part of Georges Bank, and lowest in Closed Area 1 for survey trips completed in 2013 (Table 2, Figure 6). In Closed Area 2 and on the southwest part of Georges Bank there was a strong seasonal pattern to Yellowtail Flounder catch rates, suggesting that Yellowtail Flounder migrate to and from these areas during the course of the year. Yellowtail Flounder catch rates in Closed Area 2 were relatively low in the spring and early summer (March through June). Catch rates began to increase in the middle of the summer (July) and reached a maximum in September. Mean catch rates remained relatively high in October before declining to moderate levels in December, and increasing again in January. A similar seasonal pattern was observed in 2012, when the greatest Yellowtail Flounder catch rates in Closed Area 2 were recorded during the September survey trip (Barkley et al. unpublished manuscript[2]). The seasonal movement of Yellowtail Flounder into Closed Area 2 has also been documented using observer data (Scallop PDT 2012), and has been observed in reports received by the SMAST Bycatch Avoidance Program.

Mean Yellowtail Flounder catch rates were more variable on the southwest part of Georges Bank (Table 2). The largest mean catches were observed on the southwest portion in January, while the smallest catch rates were observed in March and July. It should be noted that only 14 tows were completed on the southwest portion of Georges Bank in January and March, while 30 tows were completed in this area during all other surveys in 2013. In Closed Area 1, the largest mean catches of Yellowtail Flounder were observed in the summer and early fall, and catch rates were lowest in January and March. The mean Yellowtail Flounder catches were also calculated across all strata, along with an estimate of variance and the coefficient of variation, for each survey trip (Table 5).

[2] Barkley, A., Cadrin, S., and Smolowitz, R. 2013. Results of the Seasonal Bycatch Survey of the Georges Bank scallop Fishery-Yellowtail Flounder Biomass Estimation. Working Paper presented to the 2013 Transboundary Resource Assessment Committee.

Estimates of Yellowtail Flounder density (kg/km^2) and area swept biomass (mt) were derived assuming that the catchability of the standard dredge is 0.248, which was the catchability value that was calculated during the comparative fishing experiment conducted in September 2012 (Table 2 and Figure 4). Because the area swept biomass estimates of Yellowtail Flounder are sensitive to the assumed catchability value that is used, area swept biomass was calculated for each survey trip using a range of catchability values (Table 6).

Area swept biomass estimates of Yellowtail Flounder derived from each survey trip range from 872 mt to 3462 mt (Table 2). The largest area swept biomass estimates were observed in September, while the March survey produced the smallest biomass estimate. Yellowtail flounder captured by the standard dredge ranged from 23 to 50 cm in total length, but the majority of yellowtail captured in the standard dredge were >31 cm (Figure 7). The L50 for Georges Bank Yellowtail Flounder is 21 cm and 26 cm for males and females respectively (O'Brien et al. 1993). Therefore, the standard dredge appears to select almost entirely for adult Yellowtail Flounder. The low selectivity of juvenile Yellowtail Flounder is likely due to the large mesh (26.7 cm) that is used on the dredge.

DISCUSSION

Area swept biomass estimates from the seasonal dredge survey suggest that the most recent stock assessment underestimates the adult biomass of Yellowtail Flounder on Georges Bank. The area swept biomass estimates of Yellowtail Flounder derived from the 8 survey trips (range = 872-3462 mt) were all greater than the estimate of adult biomass (826 mt) produced by the most recent stock assessment (Legualt et al. 2013).

The total area sampled during each seasonal dredge survey trip (range = 5,373 to 6,890 km^2) represents a small portion (14.4 to 18.4%) of the entire Georges Bank stock area for Yellowtail Flounder (37,334 km^2; Larry Alade, pers. comm.). The area swept biomass estimates calculated from each survey trip only include the Yellowtail Flounder that were estimated to be present within the study area, and do not make any assumptions about the density or biomass of Yellowtail Flounder on the portions of Georges Bank that were not sampled during the survey. Therefore, biomass estimates derived from the seasonal dredge survey are conservative, because these biomass estimates do not account for the Yellowtail Flounder which inhabit the areas of Georges Bank that were not sampled during the survey.

The comparative fishing experiment completed in September 2012, represented a first attempt to estimate the relative catchability of the standard dredge. It should be noted that the standard dredge was towed at 4.0 knots during the comparative fishing experiment, while a target speed of 4.8 knots is used during the seasonal dredge survey. It is unknown how the change in speed from 4.0 to 4.8 knots affects the catchability of the standard dredge for Yellowtail Flounder. The catchability estimate of the standard dredge (0.25) derived from the comparative fishing experiment assumes that the catchability of the standard dredge is constant at 4.0 and 4.8 knots.

A single dredge is typically towed during the NMFS scallop survey, and the independent estimate of Yellowtail Flounder catchability for the NMFS survey dredge (0.46) was derived from observations made during the 2010 and 2012 NMFS scallop surveys, when only a single survey dredge was being towed. However, during the comparative fishing experiment in September 2012, two dredges (the NMFS scallop survey dredge and the standard dredge) were fished simultaneously. It is unknown whether fishing two dredges simultaneously affects the catchability of the NMFS scallop survey dredge for Yellowtail Flounder. Towing two dredges at once may increase or decrease the catchability of Yellowtail Flounder in the dredges, but at present, sufficient data are not available to investigate this possibility. Therefore, for the purpose of examining data from the comparative fishing experiment it was assumed that the presence of a second dredge (the standard dredge) did not affect the catchability of the NMFS scallop survey dredge for Yellowtail Flounder. Because the estimates of Yellowtail Flounder density and biomass from the seasonal dredge survey depend upon the assumed catchability value for the standard dredge, we estimated area swept biomass for Yellowtail Flounder in the study area assuming a range of catchability values for the standard dredge. Bottom contact sensors were not used on the survey, and relied on the experience of the captain to ensure that the dredge was on bottom. If the dredge was not tending bottom equally well amongst the vessels used during the survey, it may introduce some uncertainty to the estimates of area swept and the resultant density estimates.

A limited amount of fishery-independent data is currently included in the Georges Bank Yellowtail Flounder stock assessment. For example, only three fishery-independent surveys (NMFS spring and fall trawl survey, and the DFO trawl survey) were included in the most recent assessment model for 2011 and 2012 (Legault et al. 2013). There is high variability in the surveys, and the survey indices have been converted to account for changes to the survey vessel and gear (NMFS spring and fall), and down-weighted (DFO spring) to account for large survey tows (Legault et al. 2013). In addition, the time series of survey indices have been split, although “splitting the survey time series between 1994 and 1995 could not be justified based on changes in the survey design or implementation.” (Legault et al. 2013).

During the NMFS spring and fall surveys, the majority of Yellowtail Flounder are captured in NMFS survey strata 13 and 16, and survey observations suggest that Yellowtail Flounder on Georges Bank exhibit a patchy distribution (Legault et al. 2013). Figure 13b from the 2013 TRAC report depicts the spatial distribution of Yellowtail Flounder catches observed during the fall 2012 and spring 2013 NMFS bottom trawl surveys. During both surveys, the density of survey observations in both strata 16 and 13 was limited, and it appears that less than 20 survey tows were completed in each stratum during each survey. Given the patchy distribution of Yellowtail Flounder on Georges Bank, a sufficient density of observations is needed to ensure that the magnitude of the population is sampled adequately.

A total of 696 standardized survey tows were completed during the scallop dredge survey in 2013. Approximately 2/3 of the surveys tows made during each trip were made in Closed Area 2, and on the southwest part of Georges Bank (corresponding to NMFS survey strata 13 and 16), which are areas where Yellowtail Flounder are seasonally abundant on Georges Bank. The scallop dredge survey offers high resolution information on the distribution and abundance of Yellowtail Flounder on Georges Bank. In addition, the survey is conducted throughout the year, which improves the temporal resolution of survey observations that are available to assess the Yellowtail Flounder resource on Georges Bank.

Given the importance of the Georges Bank Yellowtail Flounder resource to both the groundfish and scallop fisheries, and the magnitude of diagnostic issues associated with the stock assessment model, additional sources of information should be considered in the assessment of this resource. The spatial and seasonal resolution of the scallop dredge survey is superior to the three surveys that are currently used in the assessment. Therefore, it is recommend that future TRAC assessments incorporate additional survey information directly into the assessment, or use survey based area-swept biomass estimates to groundtruth the output from candidate assessment models.

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TABLES

Table 1. Sampling dates and participating vessels for the seasonal dredge survey in 2013.

Trip #	Sampling Dates	Vessel	Mean Vessel Speed (km/hr)	Mean Tow Duration (hr)	Tow Duration Range (hr)
1	1/29 - 2/2	Polaris	8.85	0.52	0.43 - 0.58
2	3/16 - 3/22	Vanquish	8.76	0.47	0.30 - 0.67
3	4/28 - 5/3	Endeavor	8.91	0.512	0.33 - 0.57
4	6/15 - 6/20	Zibet	8.83	0.5	0.33 - 0.53
5	7/27 - 8/1	Venture	8.89	0.49	0.33 - 0.67
6	9/10 - 9/15	Atlantic	8.89	0.5	0.42 - 0.58
7	10/27 - 11/1	Regulus	8.85	0.54	0.43 - 0.87
8	12/7 - 12/12	Vanquish	8.67	0.5	0.38 - 0.52

Table 2. Summary of sampling locations and the size of the area surveyed during each trip in 2013. The mean Yellowtail Flounder catches (kg/tow), and the resulting estimates of Yellowtail Flounder density and biomass are also provided for each survey trip. CA1 = Closed Area 1, CA2 = Closed Area 2, and SWP = southwest part of Georges Bank.

Sampling Dates	Area	# of Stations	Area Sampled (km2)	Mean Yellowtail Flounder Catch (kg/tow)	Yellowtail Flounder Density (kg/km2)	Yellowtail Flounder Biomass (mt)
1/29 - 2/2 Trip 1	CA1	31	1201.1	0.18	34.5	40.8
	CA2	30	2844.6	4.04	786.3	2201.0
	SWP	14	1327.5	3.56	676.3	883.3
	Sum	**75**	**5373.2**			**3125.1**
3/16 - 3/22 Trip 2	CA1	31	1201.1	0.09	18.5	21.8
	CA2	30	2844.6	1.34	281.2	787.1
	SWP	14	1327.5	0.19	48.1	62.7
	Sum	**75**	**5373.2**			**871.6**
4/28 - 5/3 Trip 3	CA1	31	1201.1	0.27	53.0	62.7
	CA2	30	2844.6	1.33	263.9	738.7
	SWP	30	2844.6	1.13	213.7	598.2
	Sum	**91**	**6890.3**			**1399.6**
6/15 - 6/20 Trip 4	CA1	31	1201.1	0.62	124.6	145.6
	CA2	30	2844.6	0.95	189.2	529.7
	SWP	30	2844.6	0.78	154.3	431.9
	Sum	**91**	**6890.3**			**1107.2**
7/27 - 8/1 Trip 5	CA1	31	1201.1	0.42	87.1	102.9
	CA2	30	2844.6	2.3	452.3	1265.8
	SWP	30	2844.6	0.13	24.9	69.6
	Sum	**91**	**6890.3**			**1438.4**
9/10 - 9/15 Trip 6	CA1	31	1201.1	0.65	129.8	153.4
	CA2	30	2844.6	5.57	1104.0	3090.5
	SWP	30	2844.6	0.4	78.0	218.3
	Sum	**91**	**6890.3**			**3462.1**
10/27 - 11/1 Trip 7	CA1	31	1201.1	0.27	54.3	64.2
	CA2	30	2844.6	4.44	826.5	2313.3
	SWP	30	2844.6	1.46	273.7	766.2
	Sum	**91**	**6890.3**			**3143.6**
12/7 - 12/11 Trip 8	CA1	31	1201.1	0.45	92.7	109.6
	CA2	30	2844.6	1.71	347.0	971.4
	SWP	30	2844.6	0.86	174.2	487.4
	Sum	**91**	**6890.3**			**1568.4**

Table 3. Mean and maximum catch rates (unconverted data) of five species observed during the comparative fishing experiment on the F/V Celtic in September 2012.

Catch per Tow	NMFS scallop survey dredge	Standard Dredge	Ratio NMFS Dredge/Standard Dredge
Mean Yellowtail (n)	2.4	1.4	**1.7**
Maximum Yellowtail (n)	30.0	17.0	
Mean Scallop (bushels)	1.0	1.7	**0.6**
Maximum Scallops (bushels)	4.8	14.8	
Mean Winter Flounder (n)	0.2	0.3	**0.9**
Maximum Winter Flounder (n)	6.0	6.0	
Mean Windowpane Flounder (n)	1.4	1.2	**1.2**
Maximum Windowane Flounder (n)	14.0	15.0	
Mean Fourspot Flounder (n)	5.0	0.2	**21.2**
Maximum Fourspot Flounder (n)	20.0	4.0	

Table 4. Mean and maximum catch rates of five species observed during the comparative fishing experiment on the F/V Celtic in September 2012. The catch rates observed in the NMFS scallop survey dredge have been multiplied by 1.875 to account for the difference in the width of the NMFS scallop survey dredge and the standard dredge.

Catch per Tow (Converted)	NMFS scallop survey dredge	Standard Dredge	Ratio NMFS Dredge/Standard Dredge
Mean Yellowtail (n)	4.5	1.4	**3.2**
Maximum Yellowtail (n)	56.3	17.0	
Mean Scallop (bushels)	1.9	1.7	**1.1**
Maximum Scallops (bushels)	8.9	14.8	
Mean Winter Flounder (n)	0.4	0.3	**1.6**
Maximum Winter Flounder (n)	11.3	6.0	
Mean Windowpane Flounder (n)	2.6	1.2	**2.2**
Maximum Windowane Flounder (n)	26.3	15.0	
Mean Fourspot Flounder (n)	9.4	0.2	**39.7**
Maximum Fourspot Flounder (n)	37.5	4.0	

Table 5. The mean Yellowtail Flounder catch (kg/tow) across all three survey strata. The variance of Yellowtail Flounder catches across all strata is also provided, along with an estimate of the coefficient of variation for each trip.

Trip #	Sampling Dates	n	Mean Yellowtail Catch (kg/tow)	Variance	CV
1	1/29 - 2/2	75	3.06	0.432	0.141
2	3/16 - 3/22	75	0.78	0.050	0.065
3	4/28 - 5/3	91	1.07	0.012	0.011
4	6/15 - 6/20	91	0.82	0.020	0.024
5	7/27 - 8/1	91	1.08	0.049	0.045
6	9/10 - 9/15	91	2.58	0.134	0.052
7	10/27 - 11/1	91	2.48	0.247	0.100
8	12/7 - 12/12	91	1.14	0.017	0.015

Table 6. Estimates of area swept biomass for Yellowtail Flounder using a range of catchability values. The catchability of the standard dredge was estimated to be 0.248 during the comparative fishing experiment in September 2012, and area swept biomass estimates calculated using q = 0.248 are shown in bold.

Sampling		Assumed value of q							
Dates	Area	1	0.8	0.6	0.5	0.4	0.3	**0.248**	0.1
	CA1	10.1	12.6	16.9	20.2	25.3	33.7	40.8	101.1
1/29 - 2/2	CA2	545.9	682.3	909.8	1091.7	1364.6	1819.5	2201.0	5458.6
Trip 1	SWP	219.1	273.8	365.1	438.1	547.7	730.2	883.3	2190.7
	Sum	775.0	968.8	1291.7	1550.1	1937.6	2583.5	**3125.1**	7750.4
	CA1	5.4	6.8	9.0	10.8	13.5	18.0	21.8	54.1
3/16 - 3/22	CA2	195.2	244.0	325.3	390.4	488.0	650.6	787.1	1951.9
Trip 2	SWP	15.6	19.4	25.9	31.1	38.9	51.9	62.7	155.6
	Sum	216.2	270.2	360.3	432.3	540.4	720.5	**871.6**	2161.6
	CA1	15.5	19.4	25.9	31.1	38.8	51.8	62.7	155.4
4/28 - 5/3	CA2	183.2	229.0	305.3	366.4	458.0	610.7	738.7	1832.0
Trip 3	SWP	148.4	185.5	247.3	296.8	371.0	494.7	598.4	1484.0
	Sum	347.1	433.9	578.6	694.3	867.8	1157.1	1399.7	3471.4
	CA1	36.1	45.1	60.2	72.2	90.2	120.3	145.6	361.0
6/15 - 6/20	CA2	131.4	164.2	219.0	262.7	328.4	437.9	529.7	1313.7
Trip 4	SWP	107.1	133.9	178.5	214.2	267.8	357.0	431.9	1071.1
	Sum	274.6	343.2	457.6	549.2	686.5	915.3	**1107.2**	2745.9
	CA1	25.5	31.9	42.5	51.1	63.8	85.1	102.9	255.3
7/27 - 8/1	CA2	313.9	392.4	523.2	627.8	784.8	1046.4	1265.8	3139.2
Trip 5	SWP	17.3	21.6	28.8	34.5	43.2	57.6	69.6	172.7
	Sum	356.7	445.9	594.6	713.5	891.8	1189.1	**1438.4**	3567.3
	CA1	38.0	47.6	63.4	76.1	95.1	126.8	153.4	380.5
9/10 - 9/15	CA2	766.4	958.0	1277.4	1532.9	1916.1	2554.8	3090.5	7664.3
Trip 6	SWP	54.1	67.7	90.2	108.3	135.3	180.4	218.3	541.3
	Sum	858.6	1073.3	1431.0	1717.2	2146.5	2862.0	**3462.1**	8586.1
	CA1	15.9	19.9	26.5	31.8	39.8	53.1	64.2	159.2
10/27 - 11/1	CA2	573.7	717.1	956.2	1147.4	1434.2	1912.3	2313.3	5736.9
Trip 7	SWP	190.0	237.5	316.7	380.0	475.0	633.4	766.2	1900.1
	Sum	779.6	974.5	1299.4	1559.2	1949.0	2598.7	**3143.6**	7796.2
	CA1	27.2	34.0	45.3	54.4	67.9	90.6	109.6	271.8
12/7 - 12/11	CA2	240.9	301.1	401.5	481.8	602.3	803.1	971.4	2409.2
Trip 8	SWP	120.9	151.1	201.5	241.8	302.2	402.9	487.4	1208.8
	Sum	389.0	486.2	648.3	778.0	972.4	1296.6	**1568.4**	3889.8

FIGURES

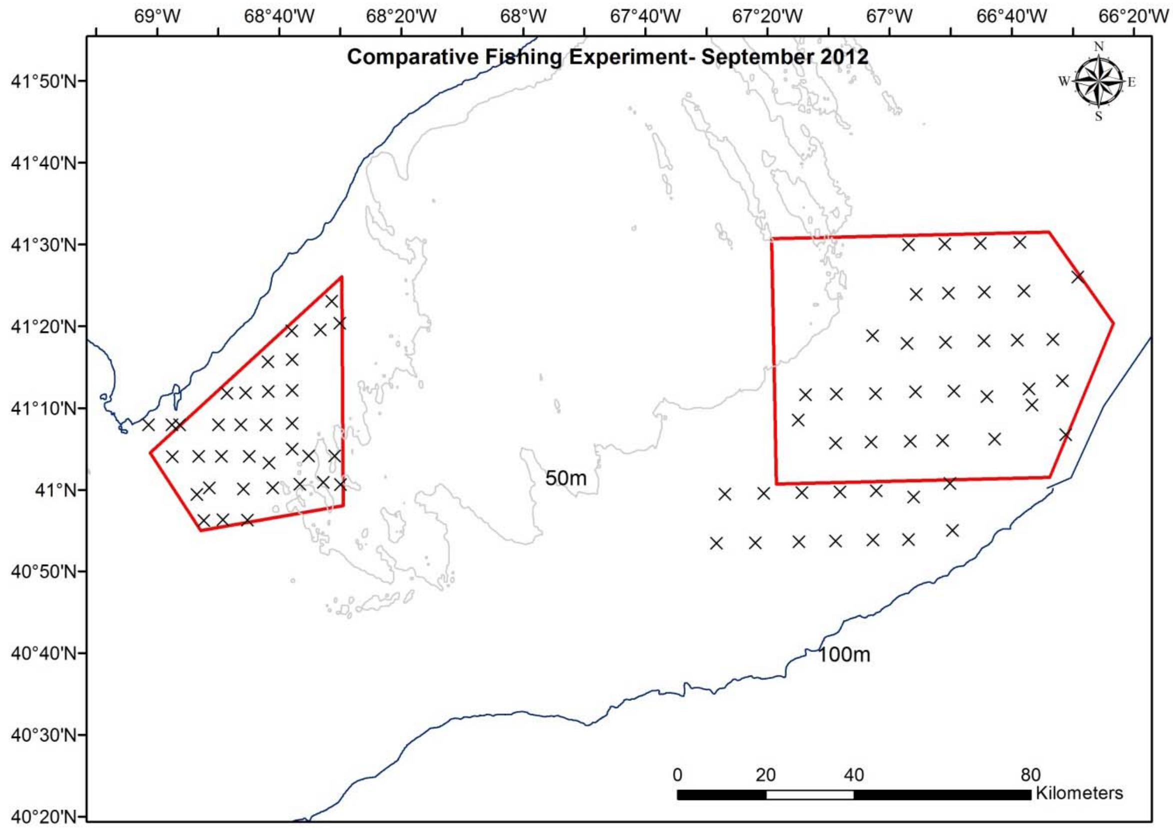

Figure 1. End locations of survey tows completed during the comparative fishing experiment on the F/V Celtic in September 2012. The NMFS scallop survey dredge and the standard dredge were fished simultaneously at 80 locations on Georges Bank at a speed of 4.0 knows for a duration of 15 minutes.

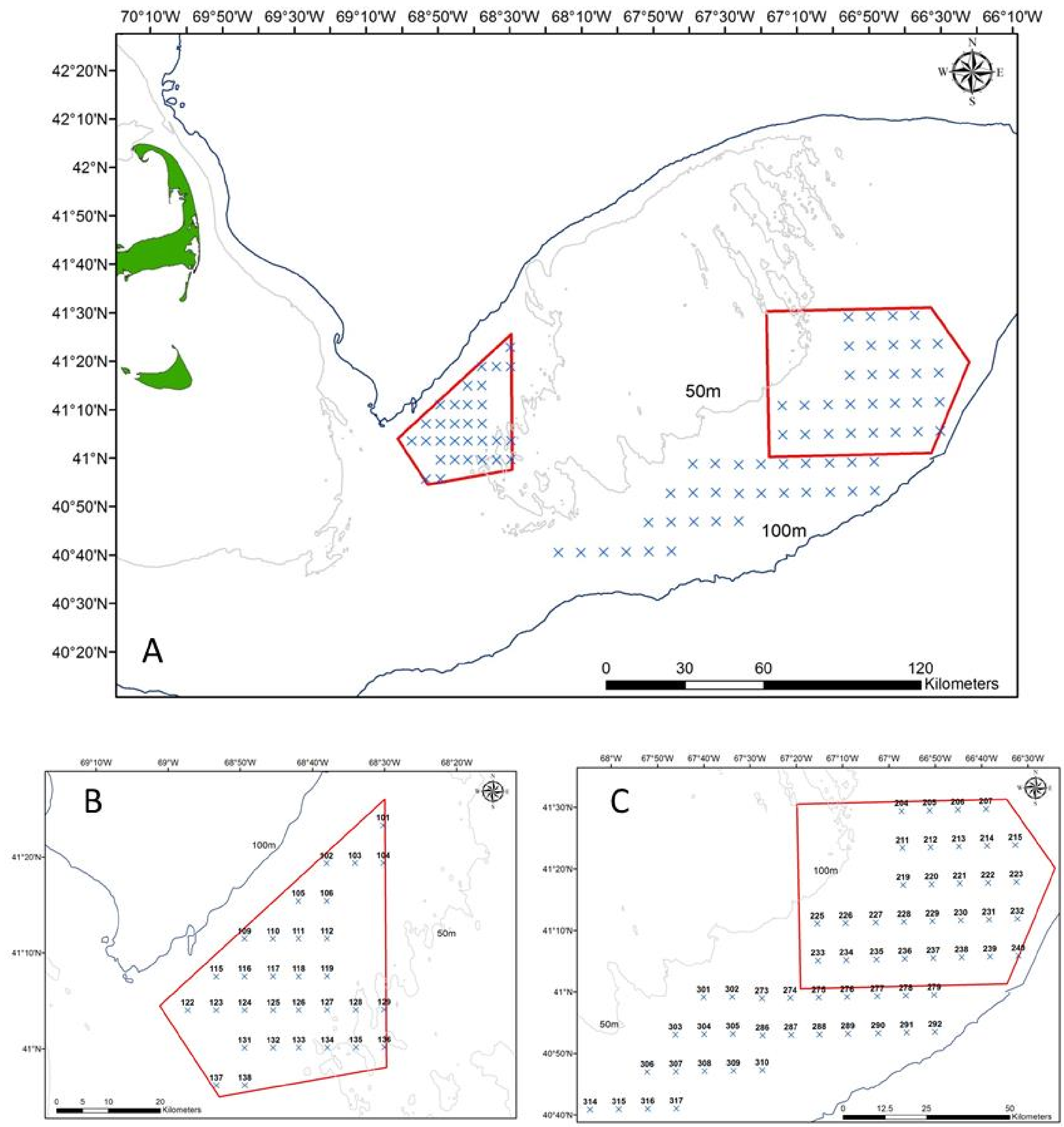

Figure 2. Locations of the survey stations that were sampled during the 2013 seasonal dredge survey on Georges Bank (A). Survey tow locations were allocated using a fixed grid systematic design in Closed Area 1 (B), and in Closed Area 2 and on the southwest portion of Georges Bank (C). Stations 301-317 were not sampled during the January and March survey trips in 2013.

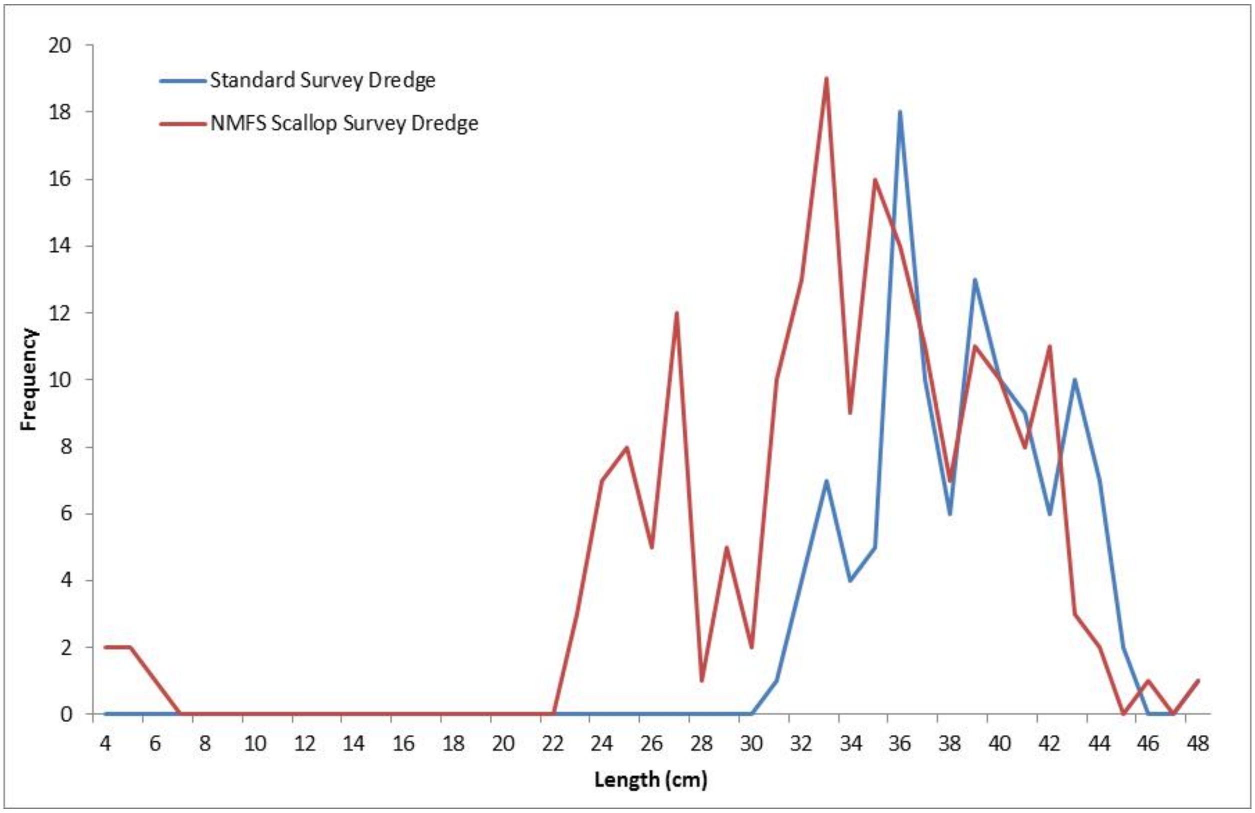

Figure 3. Length frequency distribution of Yellowtail Flounder observed in the standard dredge and the NMFS scallop survey dredge during the comparative fishing experiment on board the F/V Liberty in September 2012.

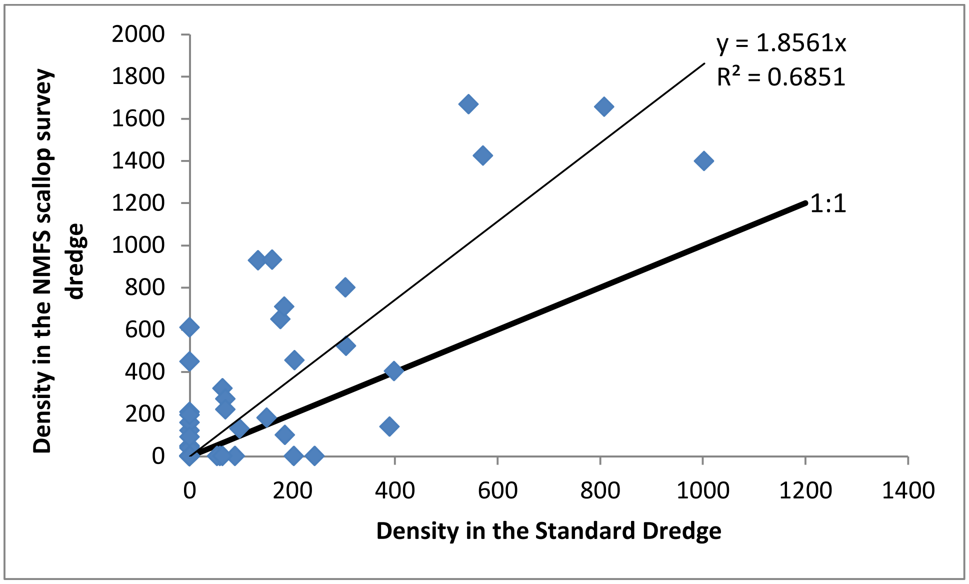

Figure 4. Regression through the origin of the Yellowtail Flounder density (kg/km^2) estimates derived during the comparative fishing experiment using the standard dredge and the NMFS scallop survey dredge. A 1:1 line is shown for reference.

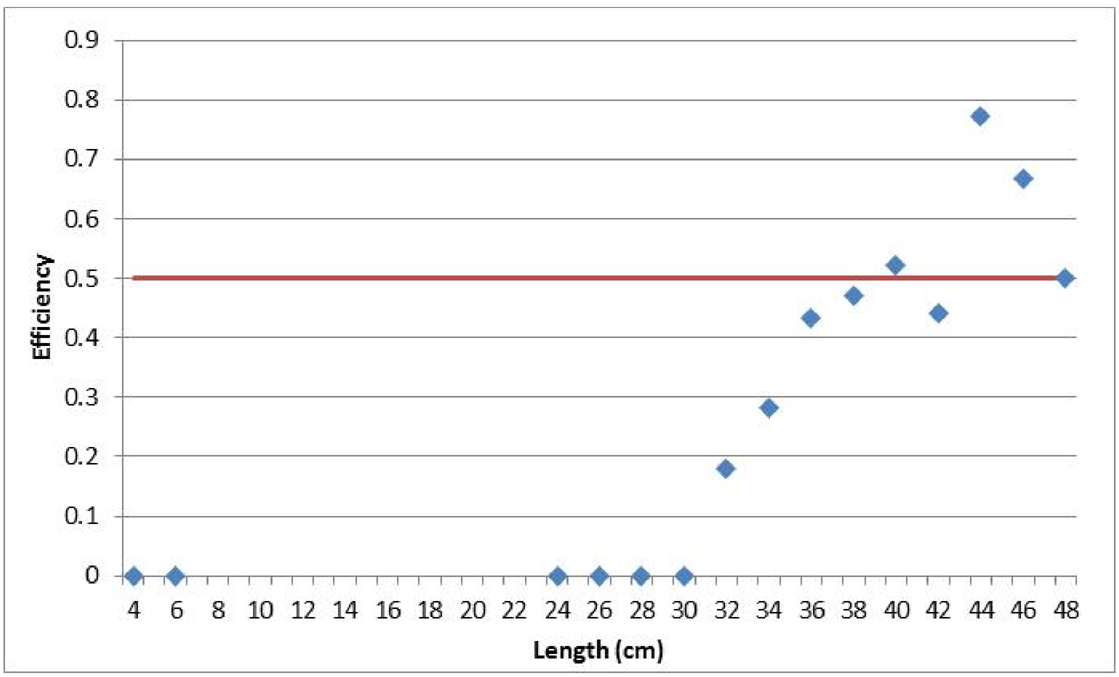

Figure 5. Length-based efficiency (2 cm intervals) of the standard dredge relative to the NMFS scallop survey dredge following the methods of Walsh et al. (1992). The proportion of the catch in each 2 cm length class is plotted as a function of the catch in the NMFS scallop survey dredge. An efficiency value of 0.5 would indicate that both gears were equally efficient at that length class.

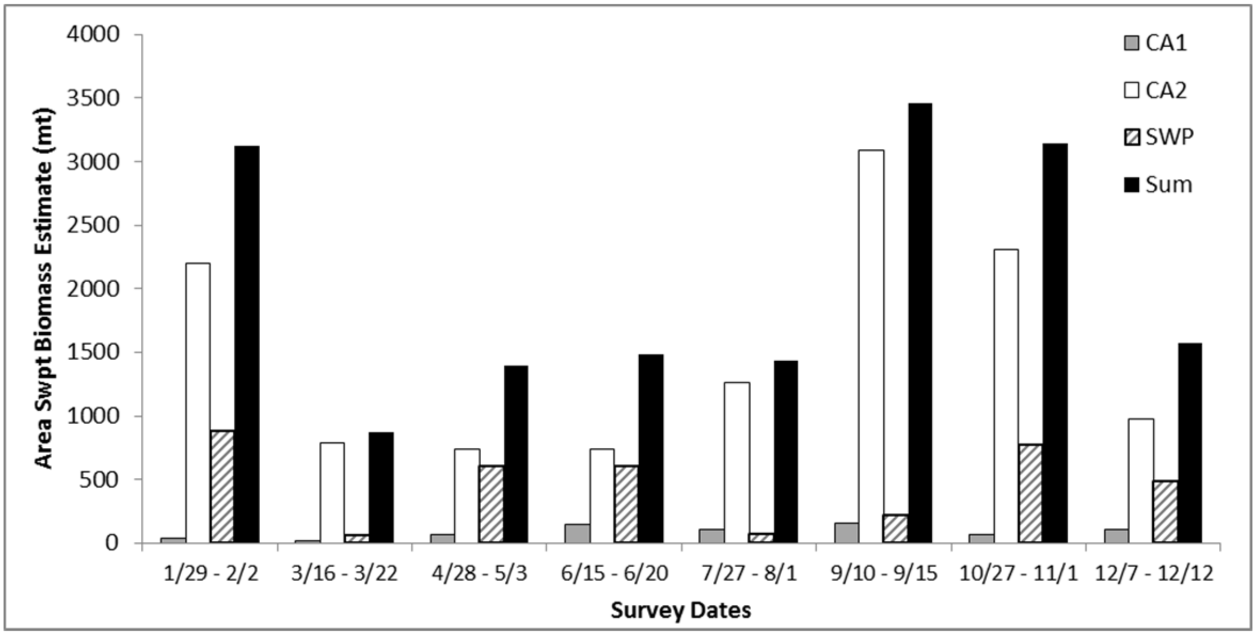

Figure 6. Area swept biomass estimates for Yellowtail Flounder. Biomass estimates are provided for the three strata covered during the seasonal bycatch survey, and a total biomass estimate is provided for each of the eight survey trips. CA1 = Closed Area 1, CA2 = Closed Area 2, and SWP = southwest part of Georges Bank.

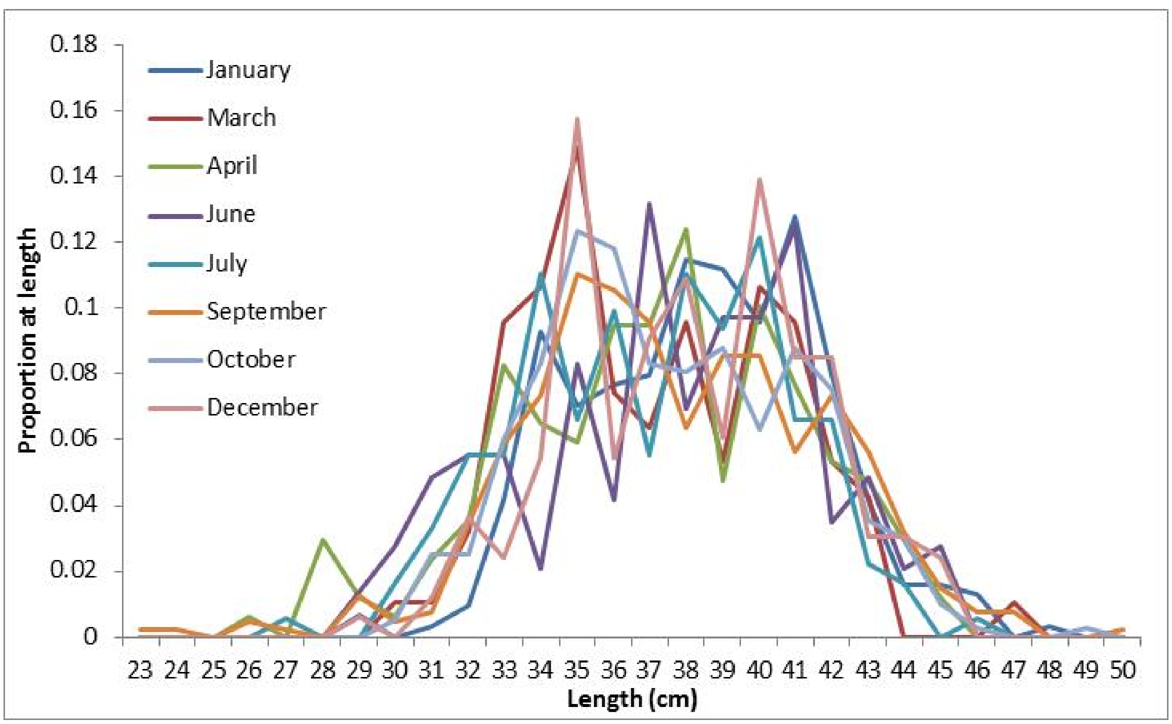

Figure 7. Proportional length frequency distribution of Yellowtail Flounder observed in the standard dredge during each dredge survey trip in 2013. The L50 for male and female Yellowtail Flounder is 21 cm and 26 cm, respectively (O'Brien et al. 1993).