Relative Catch Efficiencies of Georges Bank Yellowtail Flounder and Fourspot Flounder in National Marine Fisheries Service Research Surveys

Brian C. Linton

National Marine Fisheries Service
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543

ABSTRACT

Catchability is an important stock assessment quantity, because it scales the absolute abundance of the stock in the assessment model. Catchability can be difficult to estimate in an assessment model, because it is not a process that can be easily observed and measured in the field. Some information about catchability can be obtained by estimating the relative catch efficiency of a species caught in two different gears. Georges Bank yellowtail flounder (*Limanda ferruginea*) are caught more frequently in the National Marine Fisheries Service (NMFS) bottom trawl surveys than fourspot flounder (*Hippoglossina oblonga*), while fourspot flounder are caught more frequently than yellowtail flounder in the NMFS sea scallop survey. This observation points to potential differences in catchability of the two species in the bottom trawl and sea scallop surveys. Therefore, some insight into the catchability of yellowtail flounder in the NMFS surveys may be gained by estimating relative catch efficiencies based on the ratios of yellowtail flounder to fourspot flounder caught in each of the surveys. Examination of the survey data suggests there is limited spatial overlap between yellowtail and fourspot flounder in the NMFS research surveys, which makes it difficult to infer anything meaningful about the relative catchability of the two species.

Introduction

The Georges Bank yellowtail flounder (*Limanda ferruginea*) stock is a transboundary resource in Canadian and US jurisdictions. This paper describes an attempt to estimate relative catch efficiencies based on the ratios of Georges Bank yellowtail flounder to fourspot flounder (*Hippoglossina oblonga*) caught in four research surveys conducted by the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC): the fall bottom trawl survey, winter bottom trawl survey, spring bottom trawl survey, and sea scallop survey.

Catchability is an important stock assessment quantity, because it scales the absolute abundance of the stock in the assessment model. Catchability can be difficult to estimate in an assessment model, because it is not a process that can be easily observed and measured in the field. Some information about catchability can be obtained by estimating the relative catch efficiency of a species caught in two different gears. Relative catch efficiency normally is thought of as the ratio of the expected catches of a species in two gears from a paired-gear study (Miller et al. 2010):

(1) $$\rho = \frac{E[C_{A,1}]}{E[C_{A,2}]} = \frac{q_{A,1}D_A}{q_{A,2}D_A} = \frac{q_{A,1}}{q_{A,2}},$$

where ρ is the relative catch efficiency, C is the catch of species A in gear 1 or 2, q is the catchability of species A in gear 1 or 2, and D is the available density of species A. If the available density is the same for both gears, then the ratio of the expected catches simplifies to the ratio of the catchabilities of the gears.

Georges Bank yellowtail flounder are caught more frequently in the NMFS bottom trawl surveys than fourspot flounder, while fourspot flounder are caught more frequently than yellowtail flounder in the NMFS sea scallop survey (Table 1). This observation points to potential differences in catchability of the two species in the bottom trawl and sea scallop surveys. Therefore, some insight into the catchability of yellowtail flounder in the NMFS surveys may be gained by estimating relative catch efficiencies based on the ratios of yellowtail flounder to fourspot flounder caught in each of the surveys. The objective of this analysis is to explore 1) whether or not relative catch efficiencies can be estimated reliably using this approach, and 2) if any inference can be made from those relative catch efficiencies.

Methods/Results

This analysis was conducted using data from the NMFS fall, winter, and spring bottom trawl surveys, and the NMFS sea scallop survey. The same strata were used to define Georges Bank as were used to derive the research survey indices of abundance in the 2013 Transboundary Resource Assessment Committee (TRAC) assessment for Georges Bank yellowtail flounder (Legault et al. 2013). NMFS strata 13-21 were used to represent Georges Bank for the bottom trawl surveys (Figure 1), while NMFS scallop strata 54, 55, 58-72, and 74 were used for the sea scallop survey (Figure 2). Bottom trawl tows from other NMFS surveys conducted in the winter in the 1960s and 1970s were included with

the NMFS winter bottom trawl survey for this analysis. Only tows which caught yellowtail or fourspot flounder were used in this analysis.

Proportions of Georges Bank yellowtail to fourspot flounder were used in this analysis, rather than ratios of yellowtail to fourspot flounder:

(2) $\qquad P = \dfrac{E[C_Y]}{E[C_Y + C_F]}$,

where P is the proportion of yellowtail flounder, and C is the survey catch in numbers of either yellowtail (Y) or fourspot (F) flounder. Proportions rather than ratios were used to prevent division by zero in cases where no fourspot flounder were caught. Proportions were calculated by year and stratum, because it would be difficult to pair individual tows between surveys due to the stratified random sampling design used in the NMFS surveys. The variances associated with those proportions were calculated as:

(3) $\qquad Var(P) = \dfrac{E^2[C_Y]}{E^2[C_Y + C_F]}\left(\dfrac{Var(C_Y)}{E^2[C_Y]} - 2\dfrac{Cov(C_Y, C_Y + C_F)}{E[C_Y]E[C_Y + C_F]} + \dfrac{Var(C_Y + C_F)}{E^2[C_Y + C_F]}\right)$,

which is the variance of a ratio.

Relative catch efficiencies were estimated by year and stratum using a ratio estimator:

(4) $\qquad \rho_{1,2} = \dfrac{P_1}{P_2}$,

where ρ is the relative catch efficiency between surveys 1 and 2, and P is the proportion of yellowtail from survey 1 or 2 from Equation 2. In theory, the variances of the relative catch efficiencies could be estimated as the variance of a ratio:

(5) $\qquad Var(\rho_{1,2}) = \dfrac{E^2[P_1]}{E^2[P_2]}\left(\dfrac{Var(P_1)}{E^2[P_1]} - 2\dfrac{Cov(P_1, P_2)}{E[P_1]E[P_2]} + \dfrac{Var(P_2)}{E^2[P_2]}\right)$.

In reality, the covariance of the proportions from the two surveys (i.e., P_1 and P_2) cannot be estimated, because the survey tows are not paired.

Overall relative catch efficiency (i.e., including all years and strata) was estimated as:

(6) $\qquad \rho'_{1,2} = \dfrac{P'_1}{P'_2}$,

where $\rho'_{1,2}$ is the overall relative catch efficiency between surveys 1 and 2, and P' is the proportion of yellowtail calculated across all years and strata for survey 1 or 2. The variance of the overall relative catch efficiency could not be calculated for the same reason that the year/stratum-specific variances could not be calculated. Overall relative catch efficiency was estimated between the NMFS spring and winter bottom trawl surveys as a test case.

The year/stratum-specific proportions of Georges Bank yellowtail flounder for the NMFS fall, winter, and spring bottom trawl surveys show that in most cases either only yellowtail ($P = 1$) or only fourspot flounder ($P = 0$) were caught in a given year/stratum (Figures 3-5). The NMFS sea scallop survey shows a similar pattern in the year/stratum-specific

proportions of yellowtail flounder, though there are more instances in which both yellowtail and fourspot flounder are caught in the same year and stratum (Figure 6).

The number of fish caught by stratum shows that Georges Bank yellowtail and fourspot flounder are caught primarily in strata 13 and 16 in the NMFS fall bottom trawl survey (Figure 7). The spatial and temporal distribution of yellowtail flounder proportions in the fall bottom trawl survey reveals that yellowtail flounder have been caught primarily in stratum 16 since the mid 1990s (Figure 8). The spatial and temporal distribution of yellowtail flounder in the NMFS winter bottom trawl survey is similar to the fall survey distribution, with yellowtail flounder concentrated in strata 13 and 16 (Figures 9 and 10). The distribution of fourspot flounder caught in the winter bottom trawl survey differs from the fall bottom trawl survey distribution. Fourspot flounder were distributed more widely in strata 13-15 of the winter bottom trawl survey (Figures 9 and 10). The spatial and temporal distribution of yellowtail flounder in the NMFS spring bottom trawl survey is similar to the distribution in the fall and winter surveys, with yellowtail flounder concentrated in strata 13 and 16 (Figures 11 and 12). The distribution of fourspot flounder caught in the spring bottom trawl survey is similar to the winter bottom trawl survey distribution. Though, fourspot flounder are caught in relatively substantial numbers in strata 17 and 18 in the winter, in addition to strata 13-15 (Figures 11 and 12). Yellowtail flounder are caught primarily in scallop strata 61 and 621 in the NMFS sea scallop survey, while fourspot flounder are caught primarily in scallop strata 55, 58, 60, 61, and 621 (Figures 13 and 14).

Differences exist in the depths at which Georges Bank yellowtail and fourspot flounder are caught in the NMFS research surveys (Table 2; Figures 15-18). Fourspot flounder are caught in waters that are 17-70 m deeper on average than those in which yellowtail flounder are caught in the NMFS bottom trawl surveys. There is a slight difference (i.e., 4 m) in the average depth of capture between yellowtail and fourspot flounder in the NMFS sea scallop survey.

The overall relative catch efficiency of Georges Bank yellowtail and fourspot flounder between the NMFS spring and winter bottom trawls is estimated to be 0.886 (Table 3). While no uncertainty estimate could be obtained for the relative catch efficiency estimate (see explanation above), the overall yellowtail flounder proportions for the spring and winter bottom trawl surveys both had coefficients of variation (CVs) around 200%. Therefore, it is likely that the relative catch efficiency estimate has a relatively high level of uncertainty associated with it.

Discussion/Conclusions/Summary/Recommendations

The spatial distribution of Georges Bank yellowtail and fourspot flounder survey catches reveals that there is limited spatial overlap between the two species in the NMFS bottom trawl surveys (Figures 7-12). Yellowtail flounder are concentrated in the southeast portion of Georges Bank (i.e., stratum 16), while fourspot flounder appear to be distributed in deeper water along the western and southern edges of Georges Bank (i.e., strata 13-15, 17, and 18). These differences in spatial distribution are supported by the

differences in average depth of capture between the two species in the bottom trawl surveys (Table 2; Figures 15-17). Differences in average depth of capture (Table 2; Figures 18) appear to be less pronounced in the NMFS sea scallop survey, which might explain the higher frequency of year/stratum-specific yellowtail flounder proportions that are greater than zero and less than one (i.e., where both species are caught together) for the sea scallop survey compared to the bottom trawl surveys (Figures 3-6). The greater similarity in depth of capture between the species in the sea scallop survey may be explained by the fact that the sea scallop survey does not operate as deep as the bottom trawl surveys. Regardless, these spatial differences between yellowtail and fourspot flounder make it difficult to infer anything meaningful about the relative catchability of the two species, which is reflected in the relatively high CVs associated with the overall yellowtail flounder proportions for the winter and spring bottom trawl surveys (Table 3).

Additional difficulties exist in making inferences about the relative catchability of Georges Bank yellowtail and fourspot flounder, when relative catch efficiency is estimated using two proportions. The available densities of the target species cancel out in conventional single-species relative catch efficiency estimates, leaving only the relative catchability of that species in the two surveys (Equation 1). Catchability remains confounded with density when proportions based on two species are used to estimate relative catch efficiency:

$$(7) \qquad \rho_{1,2} = \frac{P_1}{P_2} = \frac{\dfrac{q_{Y,1}D_Y}{q_{Y,1}D_Y + q_{F,1}D_F}}{\dfrac{q_{Y,2}D_Y}{q_{Y,2}D_Y + q_{F,2}D_F}} = \frac{\dfrac{q_{Y,1}}{q_{Y,1}D_Y + q_{F,1}D_F}}{\dfrac{q_{Y,2}}{q_{Y,2}D_Y + q_{F,2}D_F}},$$

where ρ is the relative catch efficiency between surveys 1 and 2, q is the catchability of yellowtail (Y) or fourspot flounder (F) in survey 1 or 2, and D is the available density of yellowtail (Y) or fourspot flounder (F). This issue is complicated by the fact that the two surveys generally occur at different times of year, which means the available densities of the two species may differ between the surveys.

Options exist for dealing with some of the issues associated with this analysis of Georges Bank yellowtail and fourspot flounder. Estimating relative catch efficiencies using the ratio of yellowtail flounder survey catch to fourspot flounder survey catch could remove the confounding of density with catchability that arises when proportions are used, but an approach to dealing with situations in which no fourspot flounder are caught would need to be developed. A field study pairing gear from the NMFS bottom trawl surveys and sea scallop survey would provide the paired-tows needed to estimate the variances associated with estimates of relative catch efficiency.

Given the issues that exist, the NEFSC staff concluded that this analysis is not useful for comparing catches of Georges Bank yellowtail and fourspot flounder in different survey gears at this time.

Literature Cited

Legault, C.M., L. Alade, W.E. Gross, and H.H Stone. 2013. Stock assessment of
    Georges Bank yellowtail flounder for 2013. TRAC Ref. Doc. 2013/XX. 138p.

Miller, T.J., C. Das, P.J. Politis, A.S. Miller, S.M. Lucey, C.M. Legault, R.W. Brown, and
    P.J. Rago. 2010. Estimation of Albatross IV to Henry B. Bigelow calibration
    factors. NEFSC Ref. Doc. 10-05. 233p.

Tables

Table 1. Number of yellowtail flounder (YT) and fourspot flounder (FS) caught on Georges Bank in the NMFS fall, winter, and spring bottom trawl surveys, and the NMFS sea scallop survey. Also includes number of survey tows which caught yellowtail flounder and/or fourspot flounder.

Survey	Number of		
	Tows	YT	FS
Fall	1,703	26,157	14,330
Winter	331	12,816	10,327
Spring	1,586	19,860	19,442
Scallop	1,429	5,024	8,329

Table 2. Average depth of capture (m) of Georges Bank yellowtail flounder (YT) and fourspot flounder (FS) in the NMFS fall, winter, and spring bottom trawl surveys and the NMFS sea scallop survey.

Survey	Average Depth (m)	
	YT	FS
Fall	77.4	94.5
Spring	74.3	144.6
Winter	80.5	118.0
Scallop	65.4	69.7

Table 3. Overall proportions (P') of Georges Bank yellowtail flounder in the NMFS spring (s) and winter (w) bottom trawl surveys, and the overall relative catch efficiency between the spring and winter bottom trawl surveys ($\rho'_{s,w}$). Means and associated coefficients of variation (CV) are reported.

	Mean	CV
P'_w	0.550	1.88
P'_s	0.487	2.02
$\rho'_{s,w}$	0.886	-

Figures
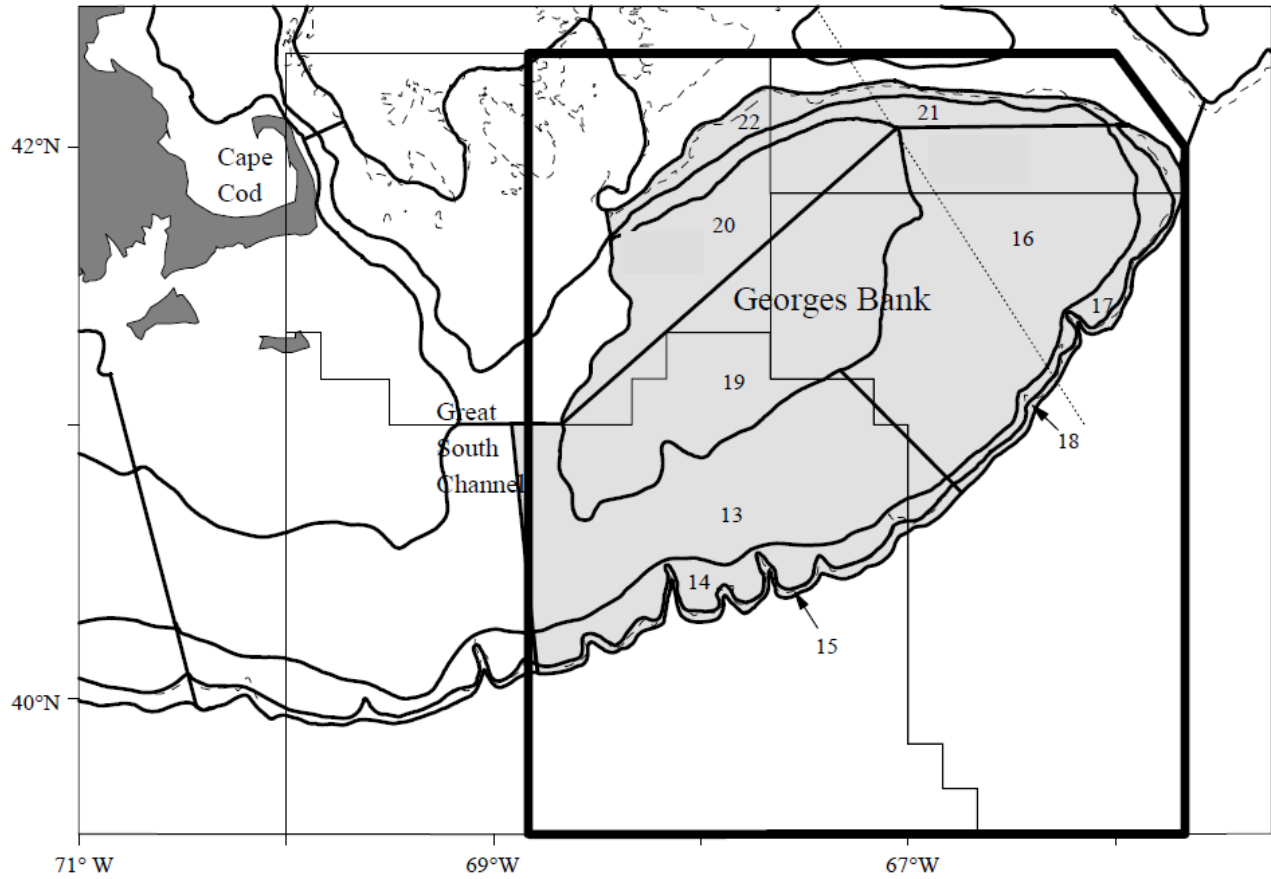
Figure 1. NMFS strata used to represent Georges Bank for the NMFS bottom trawl surveys. Stratum 22 is not used in this analysis.
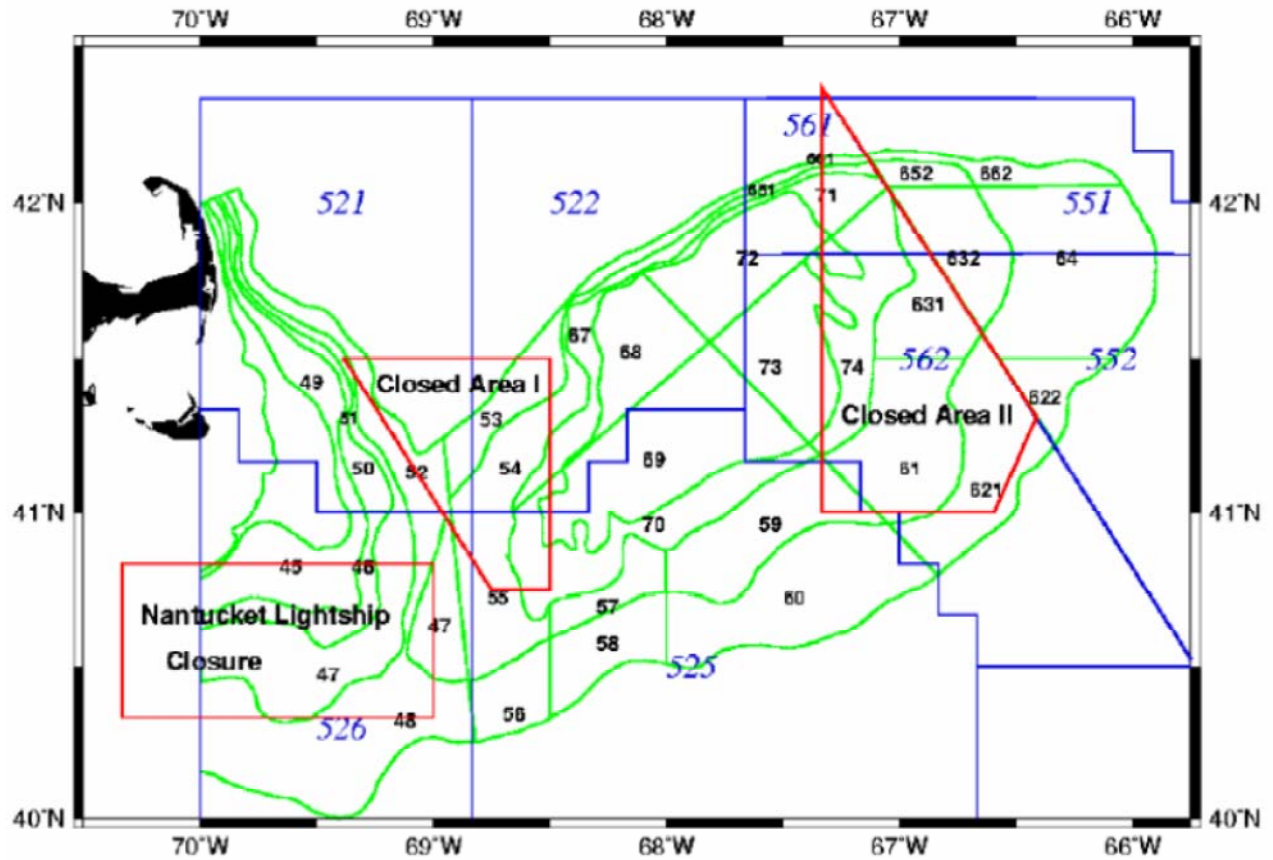
Figure 2. NMFS scallop survey strata used to represent Georges Bank for the NMFS sea scallop survey. Strata 54, 55, 58-72, and 74 are used in this analysis.

YT Proportions from Fall Survey by Year/Strata
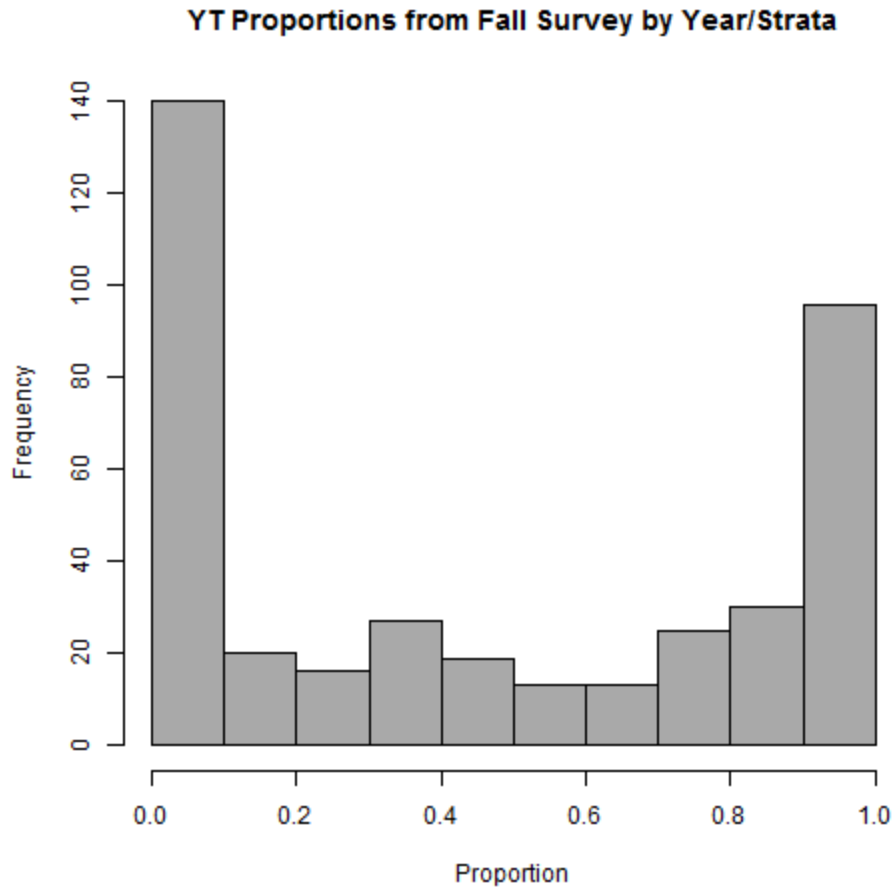
Figure 3. Frequency distribution of the proportion of Georges Bank yellowtail flounder caught in the NMFS fall bottom trawl survey by year and stratum. A proportion of 0 means only fourspot flounder were caught in a given year/stratum, while a proportion of 1 means only yellowtail founder were caught in a given year/stratum.

YT Proportions from Winter Survey by Year/Strata
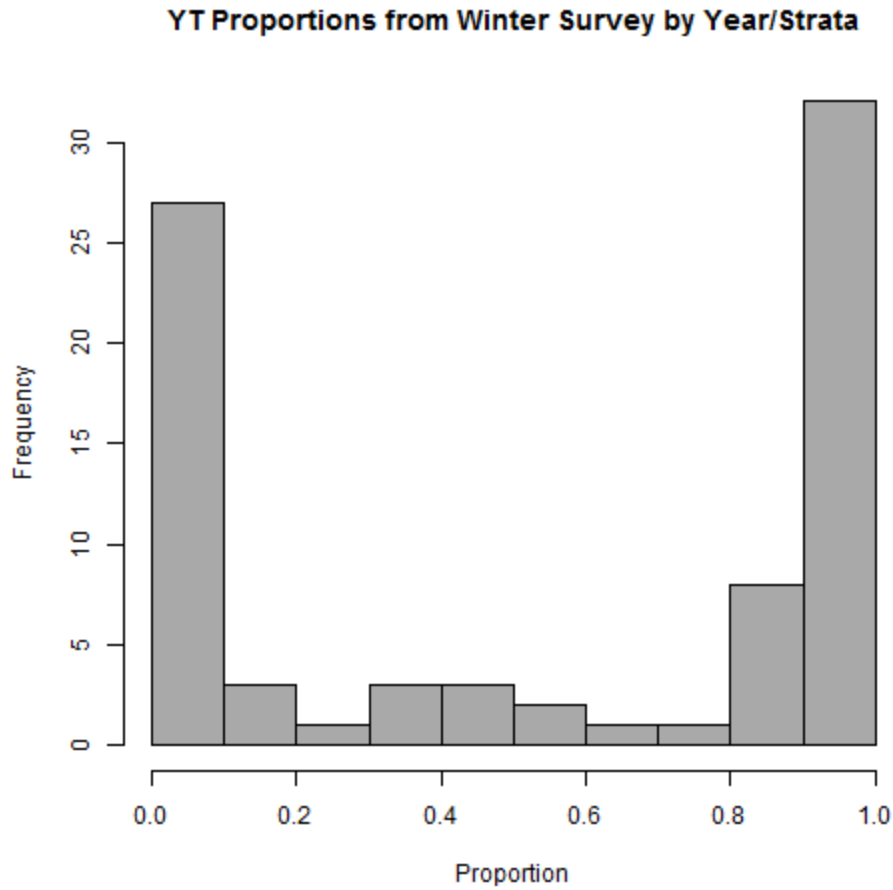
Figure 4. Frequency distribution of the proportion of Georges Bank yellowtail flounder caught in the NMFS winter bottom trawl survey by year and stratum. A proportion of 0 means only fourspot flounder were caught in a given year/stratum, while a proportion of 1 means only yellowtail founder were caught in a given year/stratum.

YT Proportions from Spring Survey by Year/Strata
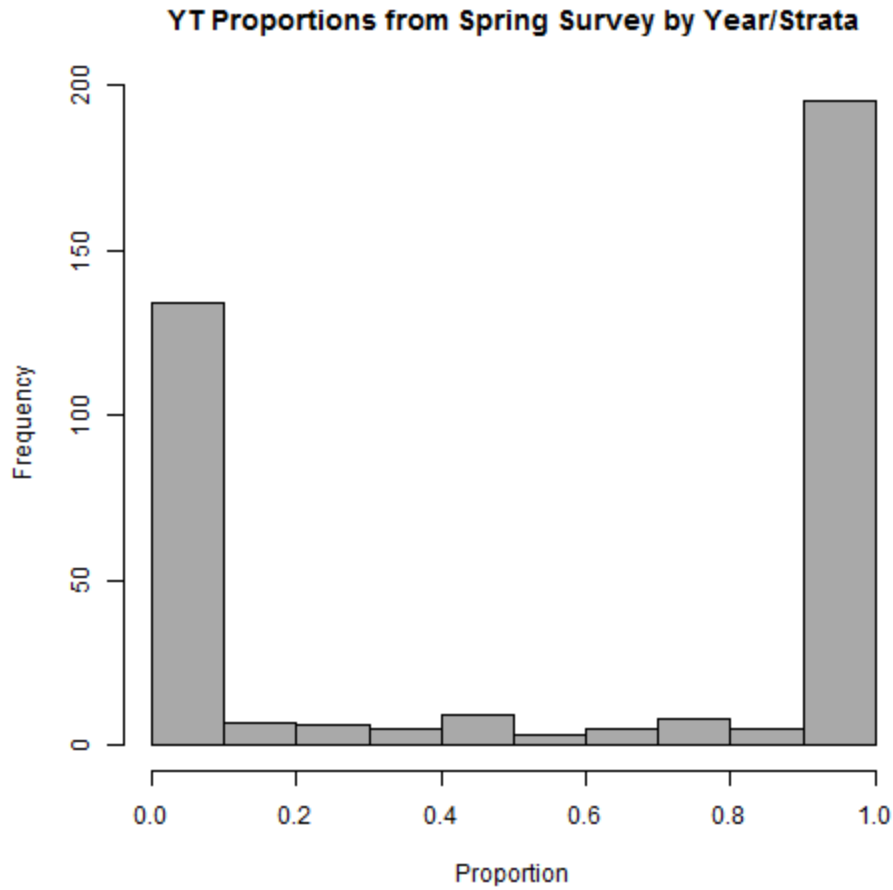
Figure 5. Frequency distribution of the proportion of Georges Bank yellowtail flounder caught in the NMFS spring bottom trawl survey by year and stratum. A proportion of 0 means only fourspot flounder were caught in a given year/stratum, while a proportion of 1 means only yellowtail founder were caught in a given year/stratum.
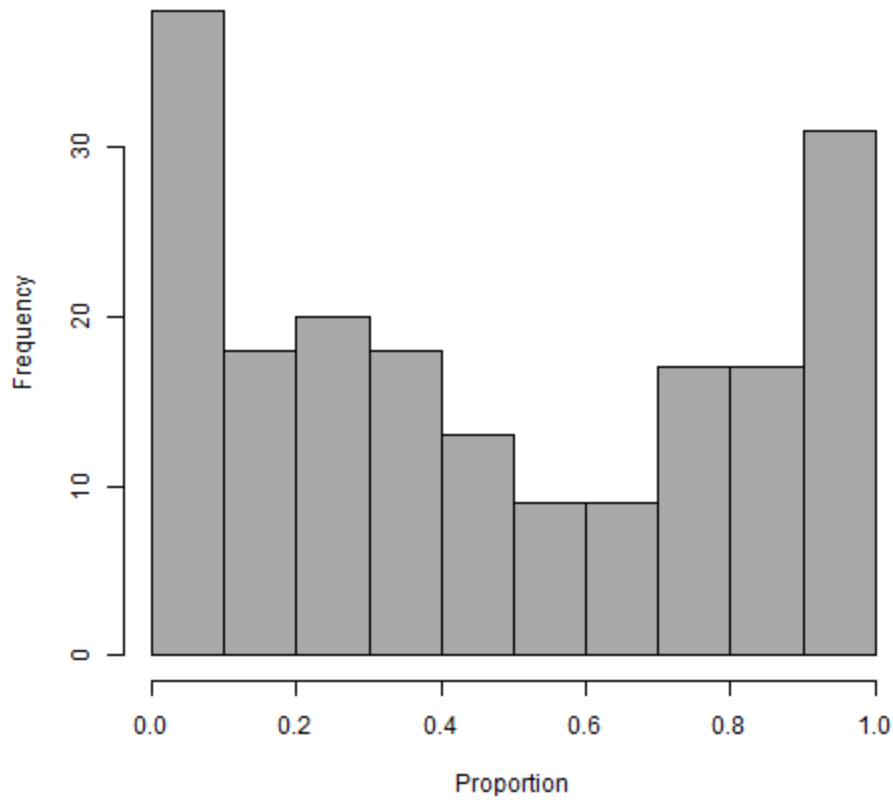
Figure 6. Frequency distribution of the proportion of Georges Bank yellowtail flounder caught in the NMFS sea scallop survey by year and stratum. A proportion of 0 means only fourspot flounder were caught in a given year/stratum, while a proportion of 1 means only yellowtail founder were caught in a given year/stratum.
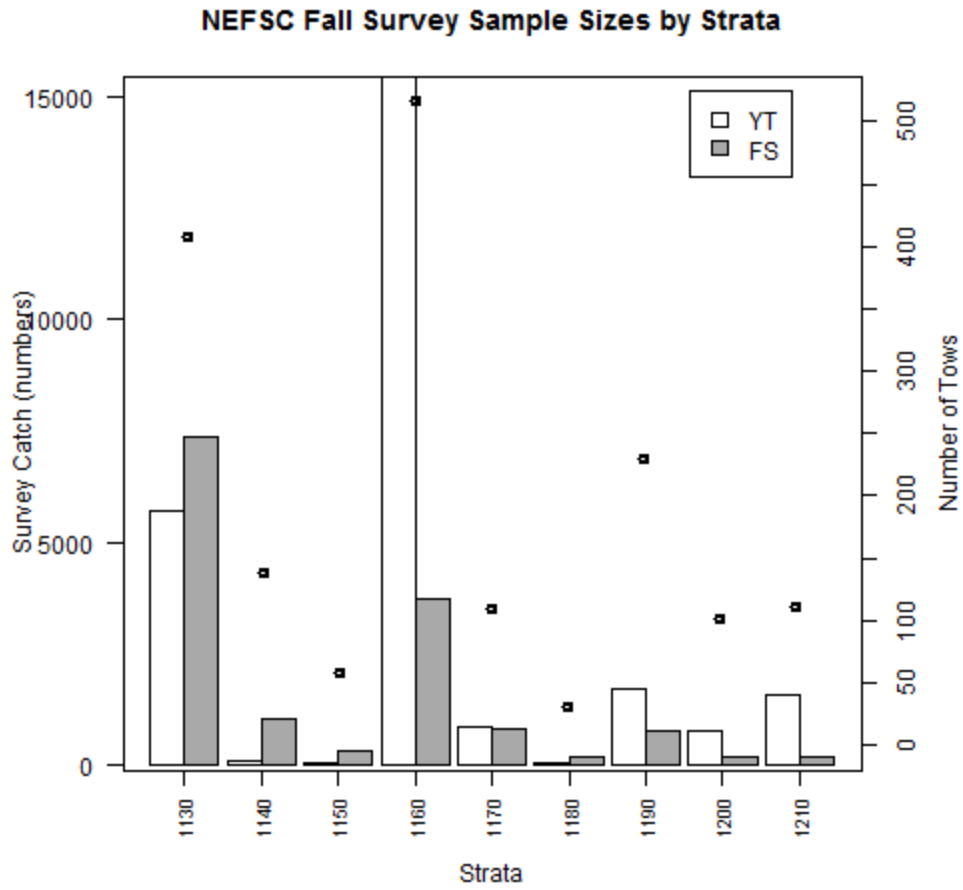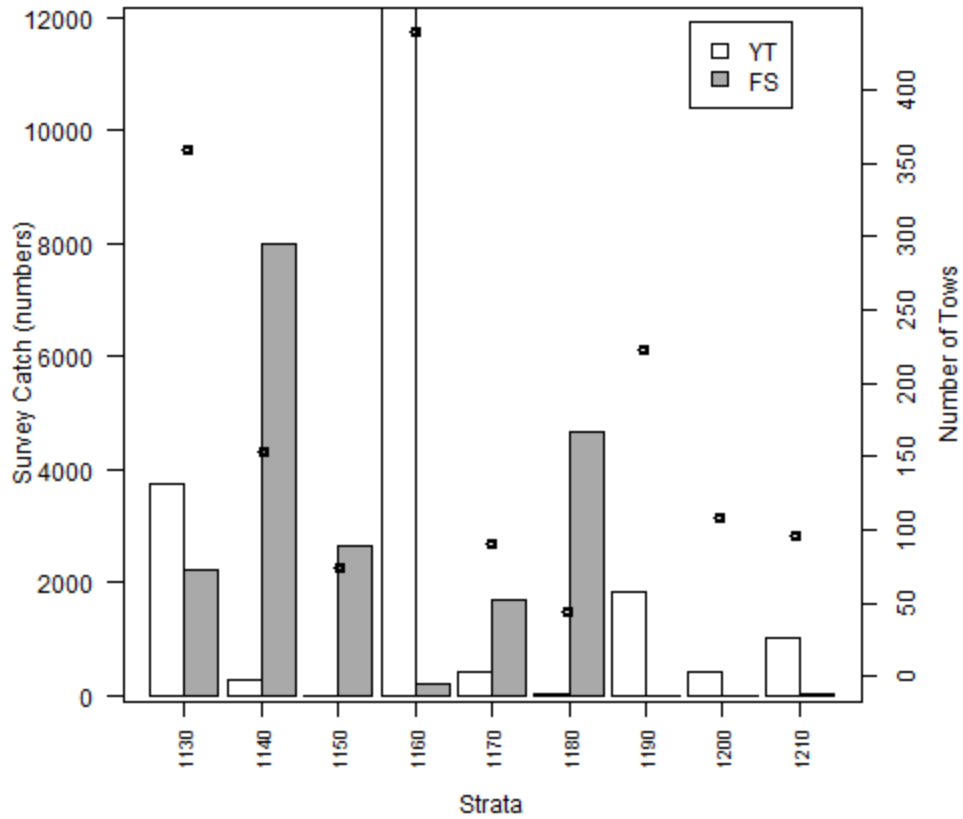
Figure 7. Number of Georges Bank yellowtail (YT) and fourspot (FS) flounder (bars) caught in the NMFS fall bottom trawl survey by stratum. Number of survey tows (circles) conducted in each stratum during the NMFS fall bottom trawl survey.
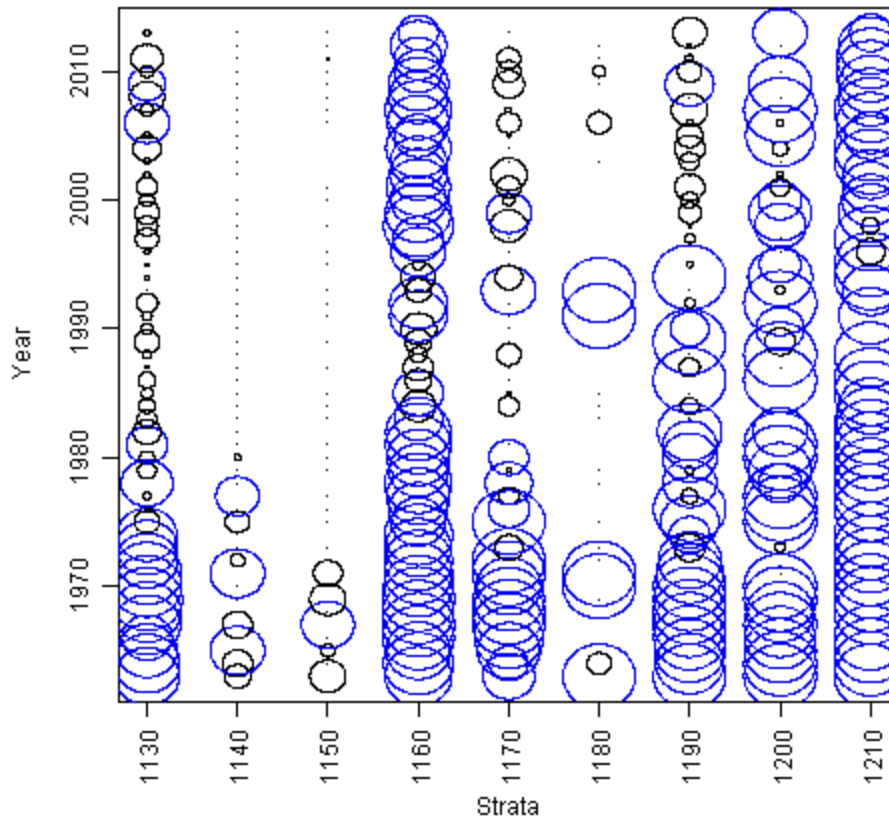
Figure 8. Bubble plot of the proportion of Georges Bank yellowtail flounder by year and stratum in the NMFS fall bottom trawl survey. Blue bubbles indicate when the proportion of yellowtail flounder is greater than 0.5, while black bubbles indicate when the proportion of yellowtail flounder is less than or equal to 0.5.
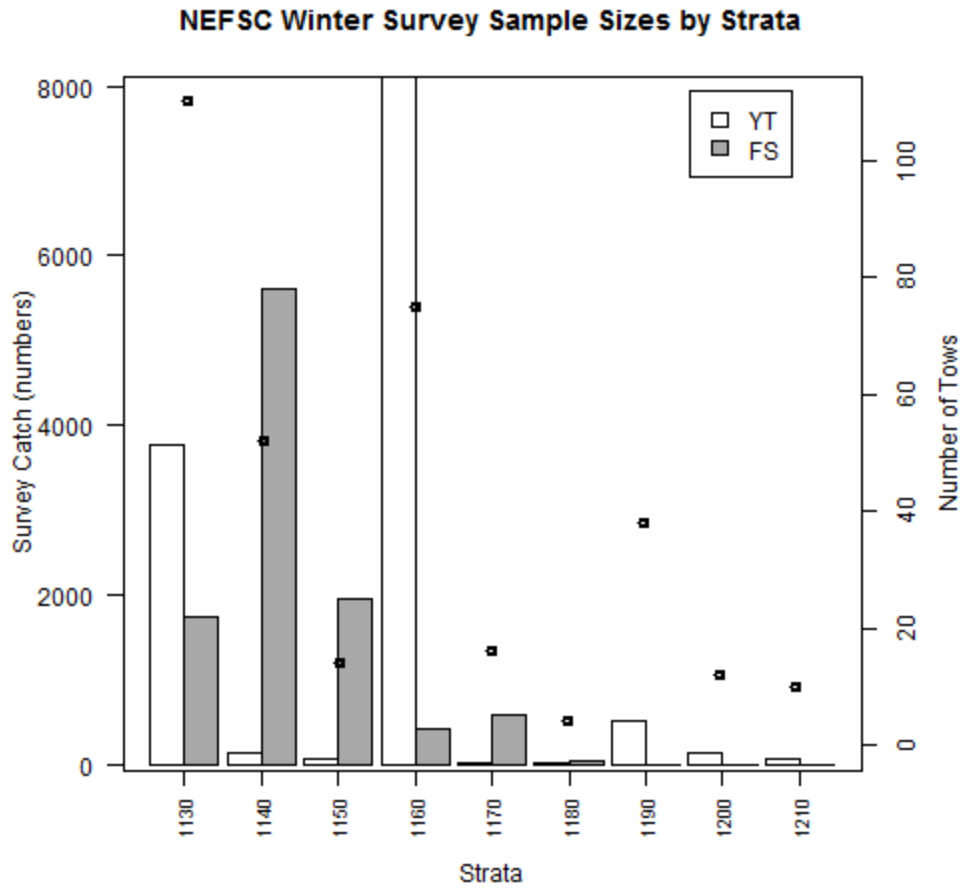
Figure 9. Number of Georges Bank yellowtail (YT) and fourspot (FS) flounder (bars) caught in the NMFS winter bottom trawl survey by stratum. Number of survey tows (circles) catching yellowtail and/or fourspot flounder in each stratum during the NMFS winter bottom trawl survey.
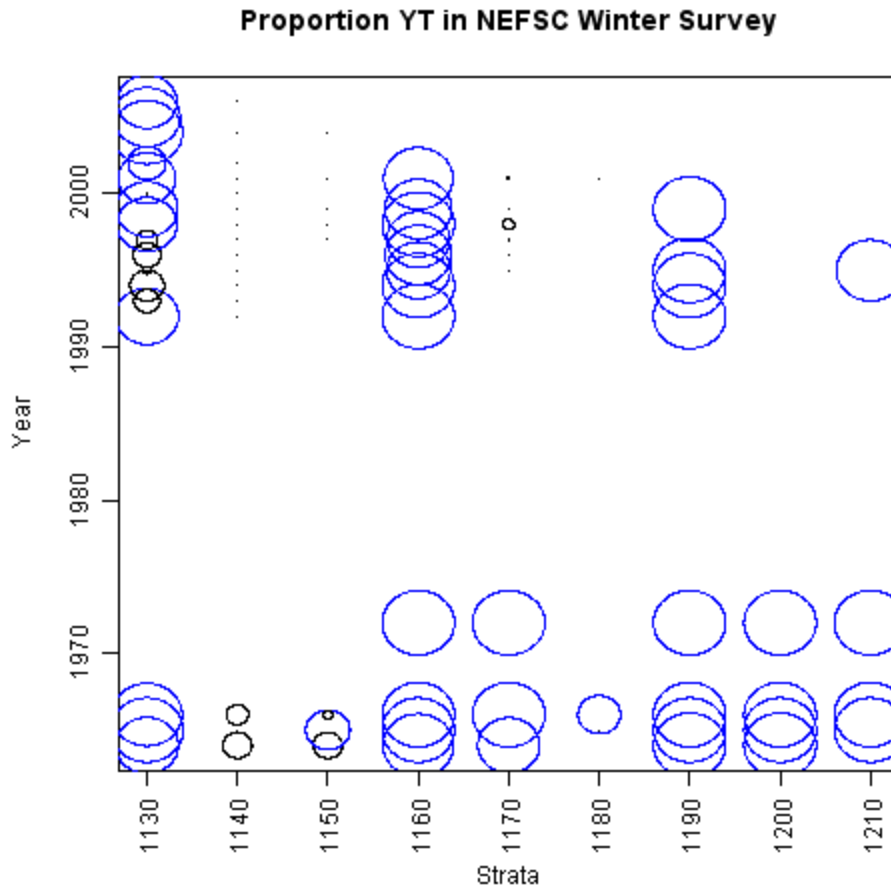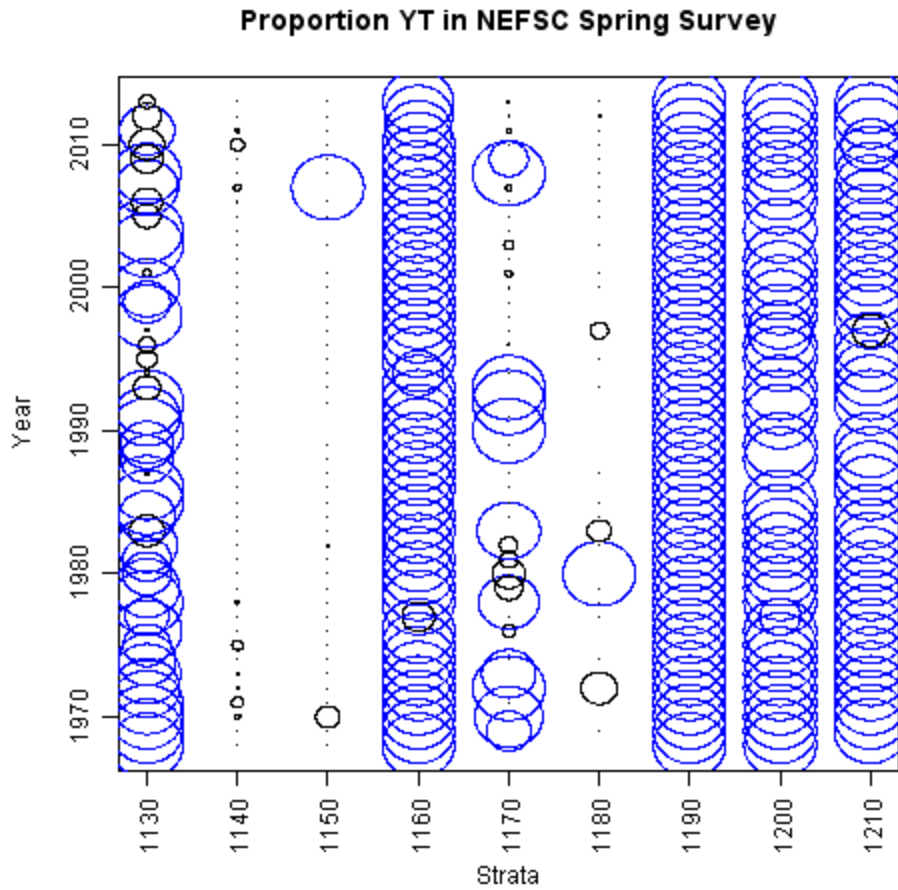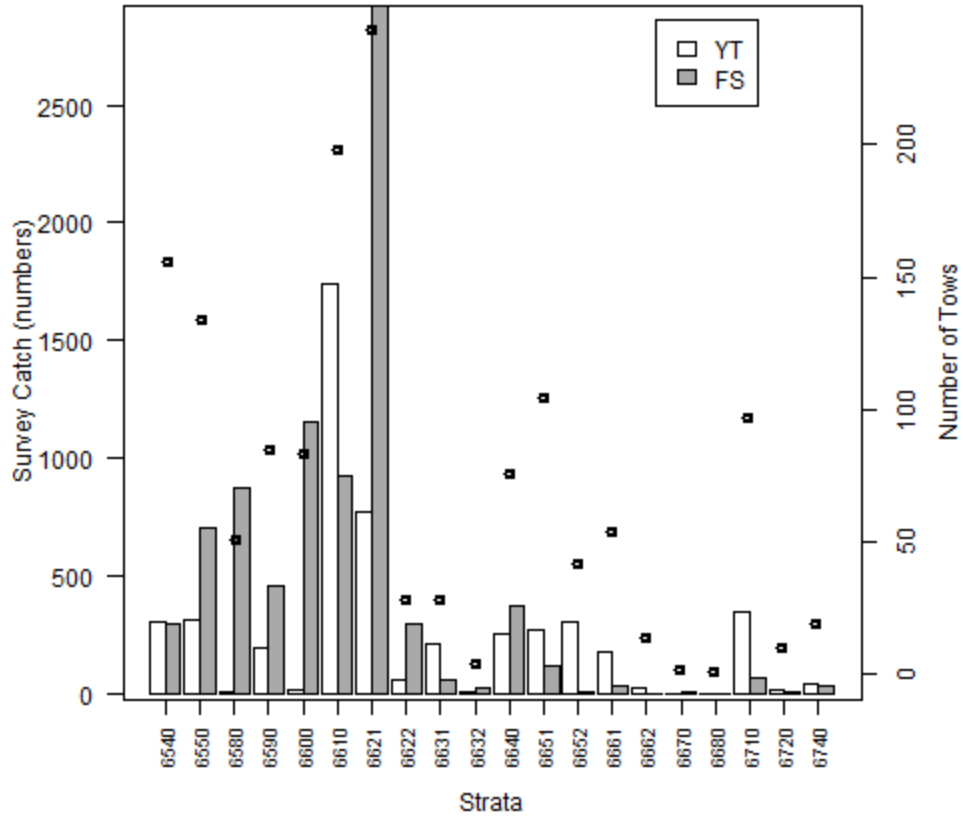
Figure 10. Bubble plot of the proportion of Georges Bank yellowtail flounder by year and stratum in the NMFS winter bottom trawl survey. Blue bubbles indicate when the proportion of yellowtail flounder is greater than 0.5, while black bubbles indicate when the proportion of yellowtail flounder is less than or equal to 0.5.

Figure 11. Number of Georges Bank yellowtail (YT) and fourspot (FS) flounder (bars) caught in the NMFS spring bottom trawl survey by stratum. Number of survey tows (circles) catching yellowtail and/or fourspot flounder in each stratum during the NMFS spring bottom trawl survey.
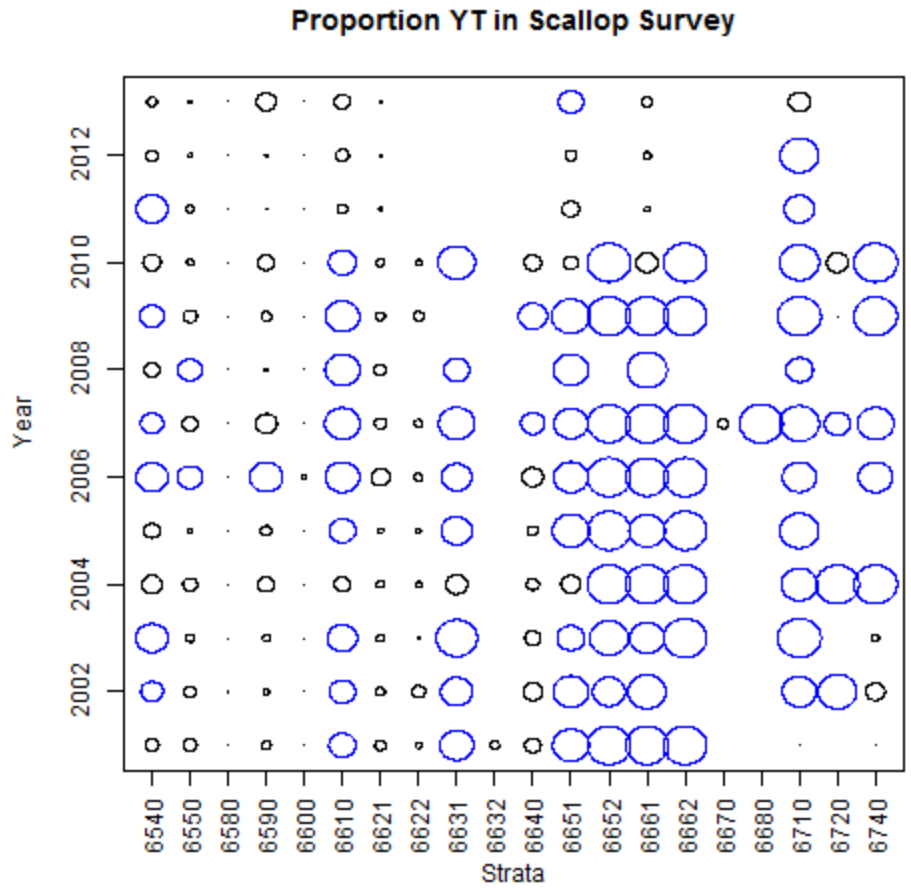
Figure 12. Bubble plot of the proportion of Georges Bank yellowtail flounder by year and stratum in the NMFS spring bottom trawl survey. Blue bubbles indicate when the proportion of yellowtail flounder is greater than 0.5, while black bubbles indicate when the proportion of yellowtail flounder is less than or equal to 0.5.
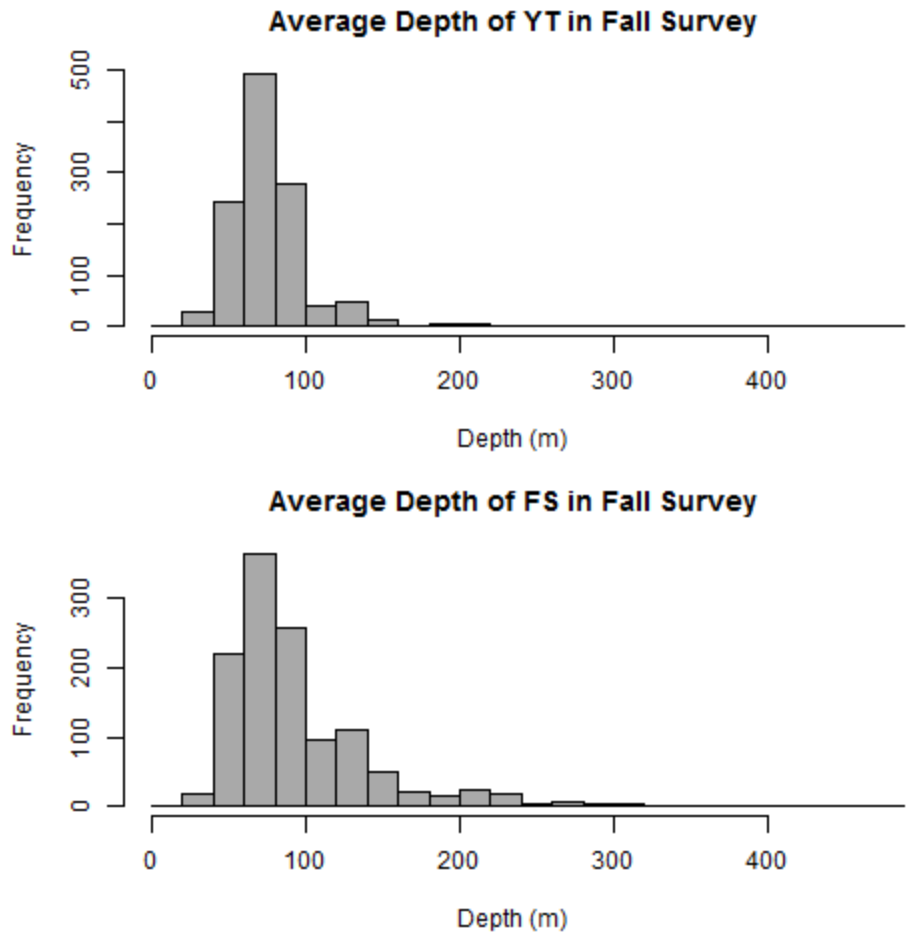
Figure 13. Number of Georges Bank yellowtail (YT) and fourspot (FS) flounder (bars) caught in the NMFS sea scallop survey by stratum. Number of survey tows (circles) catching yellowtail and/or fourspot flounder in each stratum during the NMFS sea scallop survey.

Figure 14. Bubble plot of the proportion of Georges Bank yellowtail flounder by year and stratum in the NMFS sea scallop survey. Blue bubbles indicate when the proportion of yellowtail flounder is greater than 0.5, while black bubbles indicate when the proportion of yellowtail flounder is less than or equal to 0.5.

Average Depth of YT in Fall Survey

Average Depth of FS in Fall Survey

Figure 15. Average depths (m) of tows catching Georges Bank yellowtail (YT) and fourspot (FS) flounder in the NMFS fall bottom trawl survey.
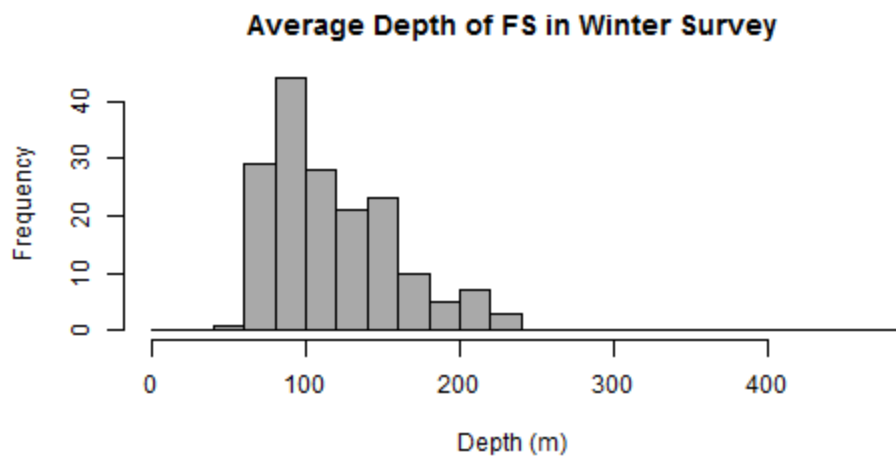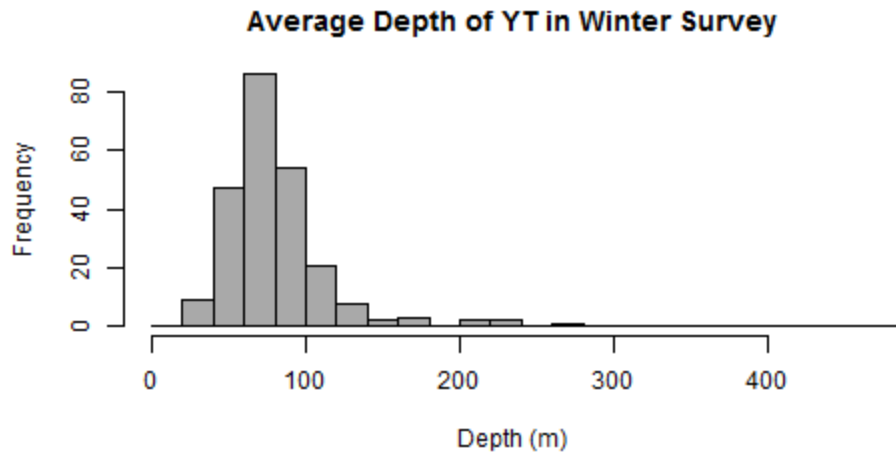
Figure 16. Average depths (m) of tows catching Georges Bank yellowtail (YT) and fourspot (FS) flounder in the NMFS winter bottom trawl survey.
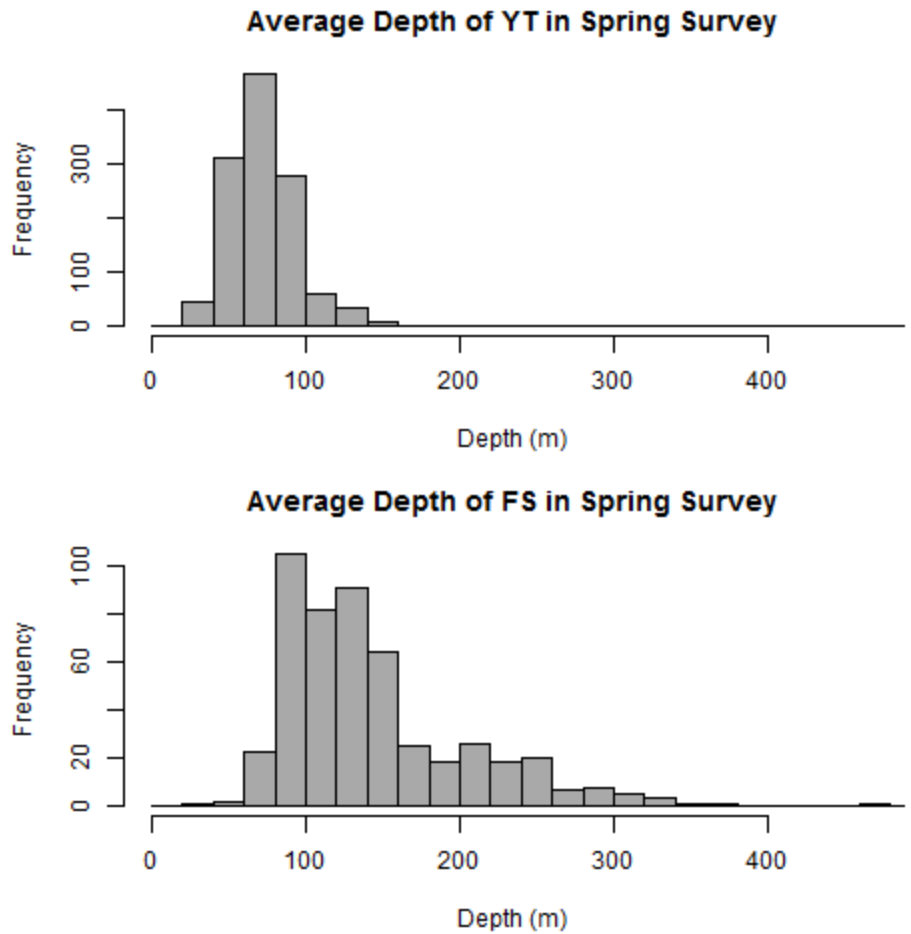
Figure 17. Average depths (m) of tows catching Georges Bank yellowtail (YT) and fourspot (FS) flounder in the NMFS spring bottom trawl survey.
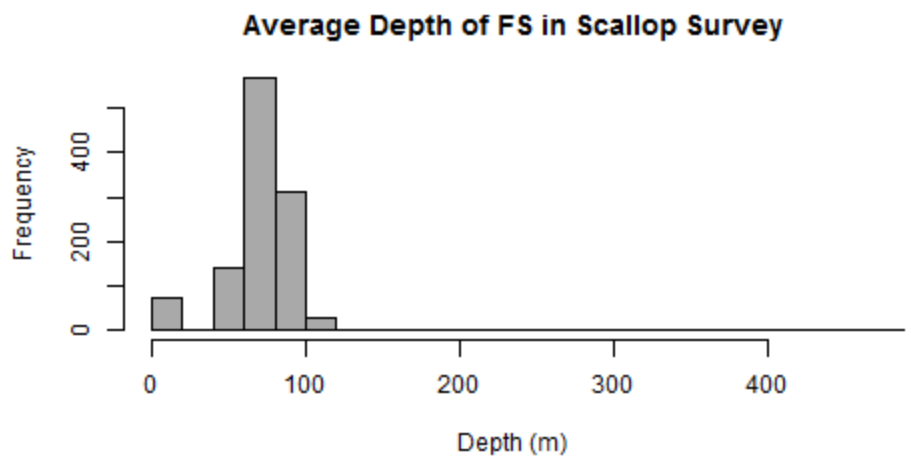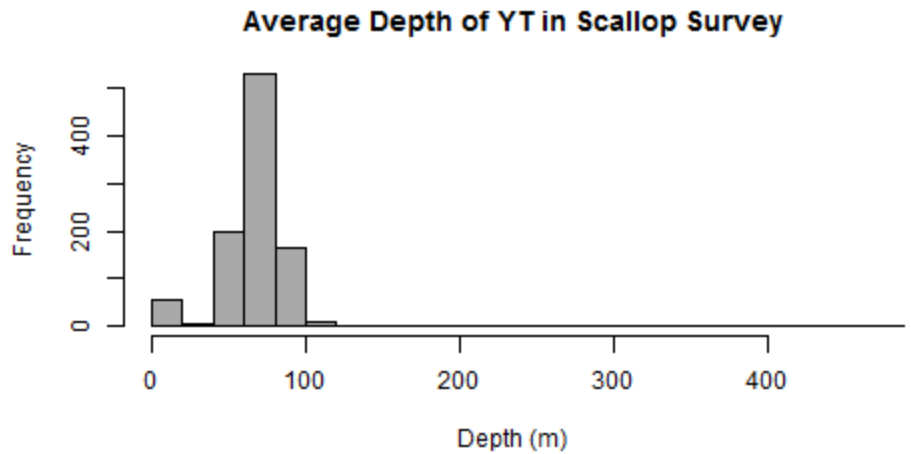
Figure 18. Average depths (m) of tows catching Georges Bank yellowtail (YT) and fourspot (FS) flounder in the NMFS sea scallop survey.