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Survey Design Efficiency of DFO and NEFSC Surveys for Cod, Haddock, and Yellowtail Flounder on Georges Bank

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TABLE OF CONTENTS

* The two appendices for this document contain many colour graphs; therefore, for the electronic version of the document available on the TRAC website (http://www2.mar.dfo-mpo.gc.ca/science/TRAC/rd.html), the appendices are included as two separate files.

ABSTRACT

Both the Canadian Department of Fisheries and Oceans (DFO) and the US Northeast Fisheries Science Center (NEFSC) conduct bottom trawl surveys on Georges Bank using stratified random sampling, but use different areal stratifications. Since both the DFO and NEFSC surveys are ecosystem based, neither survey can be focused on a single species to take full advantage of variance reduction due to optimal sample allocation. However, the allocation and stratification effects can be measured for cod, haddock, and yellowtail flounder based on observed catches in the surveys over time. There is no obvious change in sampling allocation for any of the three surveys that would benefit all three species in terms of relative efficiency. Furthermore, any proposed changes for these three species would have to be considered in the larger context of the many other species that rely on the survey for abundance indices. One general result of this analysis is that the efficiency of all three surveys relative to simple random sampling is lower for yellowtail flounder compared to cod and haddock. Based on this analysis of survey design efficiency, all three surveys are considered to provide appropriate indices of population abundance for the three management units of cod, haddock, and yellowtail flounder evaluated in TRAC.

RÉSUMÉ

Pêches et Océans Canada (MPO) et le Northeast Fisheries Science Center des États-Unis effectuent des relevés au chalut de fond sur le banc Georges à l'aide d'un échantillonnage aléatoire stratifié, mais les deux utilisent différentes stratifications spatiales. Étant donné que les relevés du MPO et du Northeast Fisheries Science Center sont axés sur les écosystèmes, aucun relevé ne peut se concentrer sur une seule espèce pour tirer pleinement profit de la réduction de variance due à la répartition optimale des échantillons. Toutefois, les effets de la répartition et de la stratification peuvent se mesurer pour la morue, l'aiglefin et la limande à queue jaune selon les prises observées dans les relevés au fil du temps. Il n'y a aucun changement évident dans la répartition des échantillons des trois relevés qui profiterait aux trois espèces en termes d'efficacité relative. En outre, tout changement proposé pour ces trois espèces devrait être examiné dans le contexte plus large des nombreuses autres espèces qui dépendent du relevé pour les indices d'abondance. L'un des résultats généraux de cette analyse est que l'efficacité des trois relevés quant à l'échantillonnage aléatoire simple est plus faible pour la limande à queue jaune que pour la morue et l'aiglefin. D'après cette analyse de l'efficacité de la conception des relevés, on considère que les trois relevés fournissent des indices d'abondance de la population appropriés pour les trois zones de gestion de la morue, de l'aiglefin et de la limande à queue jaune évaluées par le Comité d'évaluation des ressources transfrontalières (CERT).

INTRODUCTION

Both the Canadian Department of Fisheries and Oceans (DFO) and the US Northeast Fisheries Science Center (NEFSC) conduct bottom trawl surveys on Georges Bank using stratified random sampling. The stratifications used by the two countries to define survey strata and stock boundaries differ (Figure 1). Cod and haddock are assessed in TRAC on eastern Georges Bank only, corresponding to the shaded portions of Figure 1. The eastern Georges Bank region contains all of 5Z1 and 5Z2 and portions of 5Z3 and 5Z4 in the DFO survey and all of 16 through 18 and portions of 19 through 22 in the NEFSC survey to develop the indices of abundance (Table 1). The boundary for eastern Georges Bank differs slightly between the two surveys in the southwest region because the DFO designation is based on the commercial reporting areas while the NEFSC designation also utilizes the survey boundaries. The total amount of area used to derive indices of abundance differs as well, with the NEFSC strata including 46% and 11% more than DFO strata for Georges Bank and eastern Georges Bank, respectively. Please note, the Georges Bank strata used in this analysis were chosen for comparative purposes and do not reflect the complete strata set used in the NEFSC Georges Bank cod and haddock assessments.

The stratified random sampling employed in both surveys serves a number of purposes. It forces the station locations to be spread over the entire area, it allows differential sampling intensity among strata, and it facilitates use of the catch data in different stock or management definitions. Since both the DFO and NEFSC surveys are ecosystem based, meaning that data is collected for a wide range of species caught, neither survey can be focused on a single species to take full advantage of variance reduction due to optimal sample allocation. However, the allocation and stratification effects can be measured for cod, haddock, and yellowtail flounder using both the total and eastern Georges Bank strata sets by following the methodology described in Gavaris and Smith (1987).

In essence, the allocation and stratification components of stratified random sampling can be compared to simple random sampling to show the gains or losses in survey design efficiency due to the use of the strata. The allocation component reflects how the total number of tows was divided among the strata while the stratification component reflects the changes in mean density within and among the strata. The hope is that the mean density of fish will be more similar within strata than among them, so the strata component should generally be positive. When the strata component is negative, it implies that the stratification scheme is not effectively reducing variance within strata. In contrast, the allocation component can be either positive or negative, which reflects whether the tows were better or worse than if they were divided among strata strictly in proportion to the amount of area in each stratum. For optimal allocation, tows would be allocated in proportion to the true variance in each stratum, assuming equal cost of sampling in all strata.

The performance of each survey in each year can be compared to an optimal allocation of tows for each species under the assumption that the estimated variance in each stratum is unbiased. The theoretical optimum allocation often leads to zero tows being allocated to some strata, which occurs when no catch of the species under consideration was observed in that stratum during that survey. To avoid having strata with zero tows, a compromise allocation (constrained optimum) scheme can be estimated which has at least two tows in each stratum and then optimizes the allocation of the remaining number of tows (see Gavaris and Smith 1987). If all species have a consistent pattern of tow allocation which differs from the one actually employed, this could be used as the basis for changing the survey tow allocations.

This paper examines the relative efficiency of the DFO and NEFSC surveys on Georges Bank and eastern Georges Bank for cod, haddock, and yellowtail, distinguishing the allocation and stratification components for each case. It also compares the observed tow allocation with a compromise allocation, defined as optimal with at least two tows per stratum for each species and region combination. The compromise allocation analysis assumes no change in the number of tows that have been made in each year, so any results that propose increasing the allocation of tows for a subset of strata would be offset by reductions in the number of tows for other strata. Both aspects address the Term of Reference

- Review details of survey design and implementation for both the DFO and NEFSC groundfish surveys including e.g. criteria for strata definition, station selection, and station allocation. Evaluate survey design efficiency for each survey for cod, haddock, and yellowtail flounder.

METHODS

The DFO and NEFSC data were compiled using the programs STRANAL and SAGA, respectively. The DFO data ranges from 1987 to 2010 while the NEFSC spring data ranges from 1968 to 2010 and the NEFSC fall data ranges from 1963 to 2010. Each dataset contains position location that allows determination of which stratum, or subset of a stratum, each tow is assigned. The basic unit of measurement used in all analyses is the catch per tow in kilograms of each species. The DFO survey data were standardized to a consistent time towed while the NEFSC data were not, both according to their respective standard operating procedures. Conversion coefficients for NEFSC surveys were applied for cod, haddock, and yellowtail flounder to account for different vessel, door, and net effects for years 1963-2008 (Table 2). Since 2009, the NEFSC survey has been conducted by the Henry B. Bigelow due to the retirement of the Albatross IV. Conversions for the Bigelow were single values converting catch weight of the Bigelow into Albatross units (Miller et al. 2010, Table 2). The use of all these conversion factors should result in a more consistent time series in comparable measures of catch per tow.

Survey design efficiency calculations were made using the same approach as Gavaris and Smith (1987), who based their work on Sukhatme and Sukhatme (1970). The relative efficiency (RE) of a survey is defined as:

$$RE = \frac{Allocate + Strata}{Simple}$$

where

$$Allocate = \sum_h \left(\frac{1}{n} - \frac{W_h}{n_h}\right) W_h s_h^2$$

$$Strata = \left(\frac{N-n}{n(N-1)}\right)\left(\sum_h W_h(\bar{y}_h - \bar{y}_s)^2 - \sum_h W_h(1-W_h)s_h^2/n_h\right)$$

$$Simple = \left(\frac{1}{n} - \frac{1}{N}\right)\sum_h W_h s_h^2 + \left(\frac{N-n}{n(N-1)}\right)\left(\sum_h W_h(\bar{y}_h - \bar{y}_s)^2 - \sum_h W_h(1-W_h)s_h^2/n_h\right)$$

n_h = sample size in stratum h
N_h = number of sampling units in stratum h
$n = \sum_h n_h$
$N = \sum_h N_h$
$W_h = N_h / N$
$\bar{y}_h$ = estimated mean abundance in stratum h
$\bar{y}_s = \sum_h W_h \bar{y}_h$ = stratified estimate of population mean
s_h^2 = estimated variance in stratum h.

These calculations were performed using the R package "NMFSsurvey," created by Stephen J. Smith (DFO), for each species, survey, and year. This R package also computes the compromise allocation scheme. Relative efficiency and compromise plots are presented for all combinations of species and region for each survey for completeness, although the combinations of main interest for TRAC are the eastern Georges Bank cod and haddock and the Georges Bank yellowtail flounder.

RESULTS AND DISCUSSION

The DFO survey relative efficiency results are fairly consistent between the eastern Georges Bank and Georges Bank regions (Figure 2a-b). In both cases, the cod and haddock time series show mostly positive allocation components, with the occasional negative allocation component, while the yellowtail time series shows mostly negative allocation components and generally lower strata components relative to cod and haddock. There are no strong signals over time in any of these six time series. This consistency between eastern Georges Bank and Georges Bank results is most likely due to the relatively small additional area included in the whole Georges Bank region for the DFO survey (Figure 1, Table 1). Of note for the DFO survey is the lack of obvious response of the relative efficiency to the large yellowtail flounder tows in 2008 and 2009, which have caused so much discussion during TRAC meetings.

The NEFSC spring survey relative efficiency results are also fairly consistent between the eastern Georges Bank and Georges Bank regions (Figure 2c-d). In all cases, the allocation component is generally negative, but the consistency and magnitude of this component varies by species. Cod and haddock show more positive allocation components than yellowtail. There is a strong time trend seen in both the eastern Georges Bank and Georges Bank allocation component for yellowtail flounder. The eastern Georges Bank and Georges Bank relative efficiencies are not as similar as the DFO ones because there is more area added to the eastern Georges Bank region to form the Georges Bank region in the NEFSC surveys than in the DFO survey (Figure 1, Table 1).

Finally, the NEFSC fall survey relative efficiency results are fairly consistent between the eastern Georges Bank and Georges Bank regions (Figure 2e-f). In both regions, the cod and haddock time series show mostly positive allocation components, while the yellowtail flounder allocation components are mostly negative. There are indications of changes over time for all three stocks in both regions. Haddock and yellowtail flounder show large negative allocation components in years 1963-1971 followed by relatively consistent positive allocation components for haddock or a variable but slowly increasing trend for yellowtail. Cod have a period of high consistent allocation components in the 1990s with more variable and more negative values before and after this period.

The comparisons of observed and compromise allocations are arranged in the same manner as the relative efficiency plots. The bars in these figures denote the mean proportion of tows which occurred in that stratum while the vertical lines denote the minimum and maximum proportion of tows over the length of the time series. Since the sum over the strata must equal one in all years, it is not possible to have only the maximum or only the minimum proportions in any year. Proportions were used instead of actual number of tows due to the varying number of tows conducted each year, which can be caused by either an intentional change in survey tow allocation or by mechanical issues at sea preventing the desired number of tows from being conducted.

The DFO survey comparisons of observed and compromise tow allocations were quite similar between the eastern Georges Bank and Georges Bank regions. The means indicate that better performance, meaning reduced variance, of the survey for cod and haddock would occur if the number of tows in 5Z1 (cod only) and 5Z4 were reduced while the number of tows in 5Z2 were increased (Figure 3a-b). In contrast, the yellowtail flounder means for both regions indicate that the number of tows in region 5Z4 should be increased while the number of tows in 5Z1 and 5Z2 should be reduced. However, as indicated by the large range in the vertical lines, there is a lot of year to year variability in the compromise allocations for all three species in both regions. This is exemplified by each stratum receiving the minimum allocation of two tows in the compromise results in at least one year, with the exception of stratum 5Z2 for cod and haddock in both regions. These results can be compared to the proportion of area in each stratum (Table 1) which is lower in stratum 5Z1 and 5Z2 and higher in stratum 5Z3 and 5Z4 than the observed allocations. There is not a consistent pattern among the species that indicates a change in sampling allocation could benefit all three species.

The NEFSC spring survey comparisons of observed and compromise tow allocations are slightly different between the eastern Georges Bank and Georges Bank regions for all three species (Figure 3c-d). This is partially due to strata 13-15 not being included in the eastern Georges Bank region, but also to the partial inclusion of strata 19-22 in the eastern Georges Bank region. For the eastern Georges Bank region, the means for cod indicate reductions in strata 17 and 19 offset by increases in strata 20 and 21, while the means for haddock indicate a decrease in stratum 17 offset by an increase in stratum 21, and the means for yellowtail indicate reductions in strata 17 and 21 offset by an increase in stratum 16. In contrast, for the Georges Bank region, the means for all three species indicate increases for strata 16 with offsets coming from reductions in strata 13 (cod), 20 and 22 (haddock) and 20 and 21 (yellowtail). Again, the large range shown by the error bars indicates a large amount of year to year variability in the compromise allocations, even for some of the small area strata such as 21 and 22. The compromise allocation cannot be computed for years when there was only a single tow observed in any of the strata. This limited the compromise results to reflect 22 years in the Georges Bank region and only 8 years (cod and haddock) or 13 years (yellowtail) in the eastern Georges Bank region, relative to a possible total of 43 years. The reason for the difference among the species is that stratum 22 is not included as part of the yellowtail flounder region. There is not a consistent pattern among the species that indicates a change in sampling allocation could benefit all three species.

The NEFSC fall survey comparisons of observed and compromise tow allocations are different between the eastern Georges Bank and the Georges Bank regions for all three species due in large part to the changes between observed and compromise allocations for stratum 13 (Figure 3e-f). For cod and haddock, the Georges Bank region mean compromise allocations for stratum 13 are well below the observed mean, which allows increases in stratum 16 and either 20 (cod) or 17 and 22 (haddock). For the eastern Georges Bank region, stratum 16 means for cod and haddock are almost identical between observed and compromise means, the increases in stratum 20 and 21 (cod) or 22 (haddock) are offset by a decrease in strata 17 and 19 (cod) or 19 (haddock). For yellowtail flounder, the stratum 13 mean compromise allocation is greater than the observed value in the Georges Bank region. This increase, combined with the increased mean in stratum 16 is offset by decreases in nearly all other strata. For the eastern Georges Bank region, there is only an increase in stratum 16, which is offset by decreases in all the other strata. As seen in the other two surveys, the large range shown by the errors bars indicates a large amount of year to year variability in the compromise allocations. Similar to the NEFSC spring survey, the compromise results are limited to 23 years in the Georges Bank region and only 13 years (cod and haddock) or 20 years (yellowtail) in the eastern Georges Bank region, relative to a possible total of 48 years. There is not a consistent pattern among the species that indicates a change in sampling allocation could benefit all three species.

In addition to the difference in stratification between the DFO and NEFSC surveys, the other main difference is the approach used for allocation of tows by the two countries. The DFO survey has a higher tow density (number of tows per 100 square nautical miles) for the two strata in Canadian waters (5Z1 and 5Z2) relative to the remaining strata (Table 3, Figure 4a-b). In contrast, the NEFSC survey allocates tows to strata generally in proportion to area with exceptions made for the small strata to try to ensure variance estimation is possible and the requirement of using integer number of tows (Table 3, Figure 4c-f). The overall target for the NEFSC surveys is 0.5 tows per 100 square nautical miles (usually stated at 1 tow per 200 nautical miles), which is achieved for the Georges Bank region in both surveys in 2010 (Table 3) and generally over time for both regions (Figure 5).

There have been a number of changes over time that could be influencing these results (see Appendix 1 for year by year survey catches by tow location and Appendix 2 for decadal survey catches by spatial grid). All three species have exhibited large changes in population abundance, with relatively high values in the 1970s and low values in the mid 1990s. The implementation of year-round closed areas in December 1994 may be causing a change in the distribution of yellowtail and haddock (see appendices for locations of the closed areas along with year by year and decade by decade plots of catch rates). Other large changes in management have occurred over time, including changes in mesh size, fishing effort, and allocation among gear types. The environment has also been changing over time, which could lead to changes in distribution of these species. No causative association can be made between any of these factors and the observed results of these analyses though.

These analyses do not directly address the utility of the three surveys for use as tuning indices in the stock assessments of eastern Georges Bank cod and haddock and Georges Bank yellowtail flounder. The consistency in stratified mean catch per tow observed among the three separate surveys for each of the management units indicates that a signal is being detected, as opposed to random noise. Each survey also has its own measure of uncertainty computed from standard sampling theory, which in all cases indicates fairly narrow uncertainty. This study focused on the survey design efficiency, not the accuracy or precision of the surveys as trends of abundance. Improvements in survey design efficiency would be expected to result in more precise estimates, but would not be expected to change the accuracy of the surveys because the stratified means would be expected to remain the same.

CONCLUSIONS

There is no obvious change in sampling allocation for any of the three surveys that would benefit all three species in terms of relative efficiency. Furthermore, any proposed changes for these three species would have to be considered in the larger context of the many other species that rely on the survey for abundance indices. One general result of this analysis is that the efficiency of all three surveys relative to simple random sampling is lower for yellowtail flounder compared to cod and haddock. The lower relative efficiency is due to the existing allocation of tows per strata, which is not completely compensated for by the gains in efficiency due to the stratification scheme. It should be noted, however, that these results focused only on the variance in annual abundance, and not on the mean annual trend in abundance. Based on this analysis of survey design efficiency, all three surveys are considered to provide appropriate indices of population abundance for the three management units of cod, haddock, and yellowtail flounder evaluated in TRAC.

ACKNOWLEDGEMENTS

Stephen J. Smith (DFO) is thanked for creating the NMFSsurvey package in R, which made rapid evaluation of the survey design efficiency for all combinations of species, surveys, and areas possible. Liz Brooks, Tim Miller, and Don Clark are also thanked for providing comments on an earlier version of this paper.

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Table 1. Area (square nautical miles) associated with partitioning the different survey strata into components used for management purposes. The USA columns are split into western Georges Bank and eastern Georges Bank to demonstrate the fraction of these strata used in the eastern Georges Bank assessments of cod and haddock. Note that NEFSC stratum 22 is not included in the Georges Bank yellowtail flounder assessment.

Strata	USA (wGB) (sq. nm.)	USA(eGB) (sq. nm.)	Canada (sq. nm.)	GB for YT (sq. nm.)	EGB for C&H (sq. nm.)
			DFO Strata		
5Z1	0	0	795	795	795
5Z2	0	0	1252	1252	1252
5Z3	791	1504	0	2295	1504
5Z4	1729	1350	0	3079	1350
Total	2520	2854	2047	7421	4901
			NEFSC Strata		
13	2374	0	0	2374	0
14	656	0	0	656	0
15	230	0	0	230	0
16	0	1427	1553	2980	2980
17	0	76	284	360	360
18	0	45	127	172	172
19	1395	1059	0	2454	1059
20	886	335	0	1221	335
21	136	78	210	424	288
22	223	106	125	0	231
Total	5900	3126	2299	10871	5425

Table 2. Conversion factors applied to the NEFSC catch per tow data. The Vessel correction is applied to tows which used the Delaware II instead of the Albatross IV. The Door conversion is applied in years prior to 1985 to reflect the change in doors. The Gear conversion is applied to tows which used the Yankee 41 or 45 nets instead of the standard Yankee 36 net. A conversion factor of NA means no conversion was applied. The final column denotes whether the observed catch per tow is multiplied or divided by the conversion factor to produce the standard tow.

Years	Source	Season	Cod	Haddock	Yellowtail	Applied
1963-2008	Vessel	All	0.67	0.79	0.85	Multiplied
	Door	All	1.62	1.51	1.28	Multiplied
	Gear	All	NA	NA	1.73	Divided
2009-2010	Bigelow	Spring	1.580	0.878	2.244	Divided
		Fall	1.580	1.489	2.402	Divided

Table 3. Number of successful tows (# Tows), number of tows per 100 square nautical miles (Density), and the number of tows that would have been allocated to each strata if allocation were proportional to stratum area (Prop). Values are for year 2010 only, for the DFO, NEFSC spring, and NEFSC fall surveys by stratum and total for both the Georges Bank (GB) and eastern Georges Bank (EGB) regions.

	GB			EGB		
DFO	# Tows	Density	Prop	# Tows	Density	Prop
5Z1	9	1.13	6.1	9	1.13	8.1
5Z2	23	1.84	9.6	23	1.84	12.8
5Z3	15	0.65	17.6	12	0.80	15.3
5Z4	10	0.32	23.6	6	0.44	13.8
Total	57	0.77	57.0	50	1.02	50.0
NEFSC Spring	# Tows	Density	Prop	# Tows	Density	Prop
1130	10	0.42	12.2	NA	NA	NA
1140	4	0.61	3.4	NA	NA	NA
1150	3	1.30	1.2	NA	NA	NA
1160	14	0.47	15.3	14	0.47	17.0
1170	3	0.83	1.8	3	0.83	2.1
1180	3	1.74	0.9	3	1.74	1.0
1190	9	0.37	12.6	4	0.38	6.1
1200	5	0.41	6.3	2	0.60	1.9
1210	4	0.94	2.2	3	1.04	1.6
1220	3	0.66	2.3	2	0.87	1.3
Total	58	0.51	58.0	31	0.57	31.0
NEFSC Fall	# Tows	Density	Prop	# Tows	Density	Prop
1130	10	0.42	12.2	NA	NA	NA
1140	4	0.61	3.4	NA	NA	NA
1150	2	0.87	1.2	NA	NA	NA
1160	13	0.44	15.3	13	0.44	17.6
1170	4	1.11	1.8	4	1.11	2.1
1180	4	2.33	0.9	4	2.33	1.0
1190	8	0.33	12.6	3	0.28	6.2
1200	5	0.41	6.3	2	0.60	2.0
1210	4	0.94	2.2	3	1.04	1.7
1220	4	0.88	2.3	3	1.30	1.4
Total	58	0.51	58.0	32	0.59	32.0

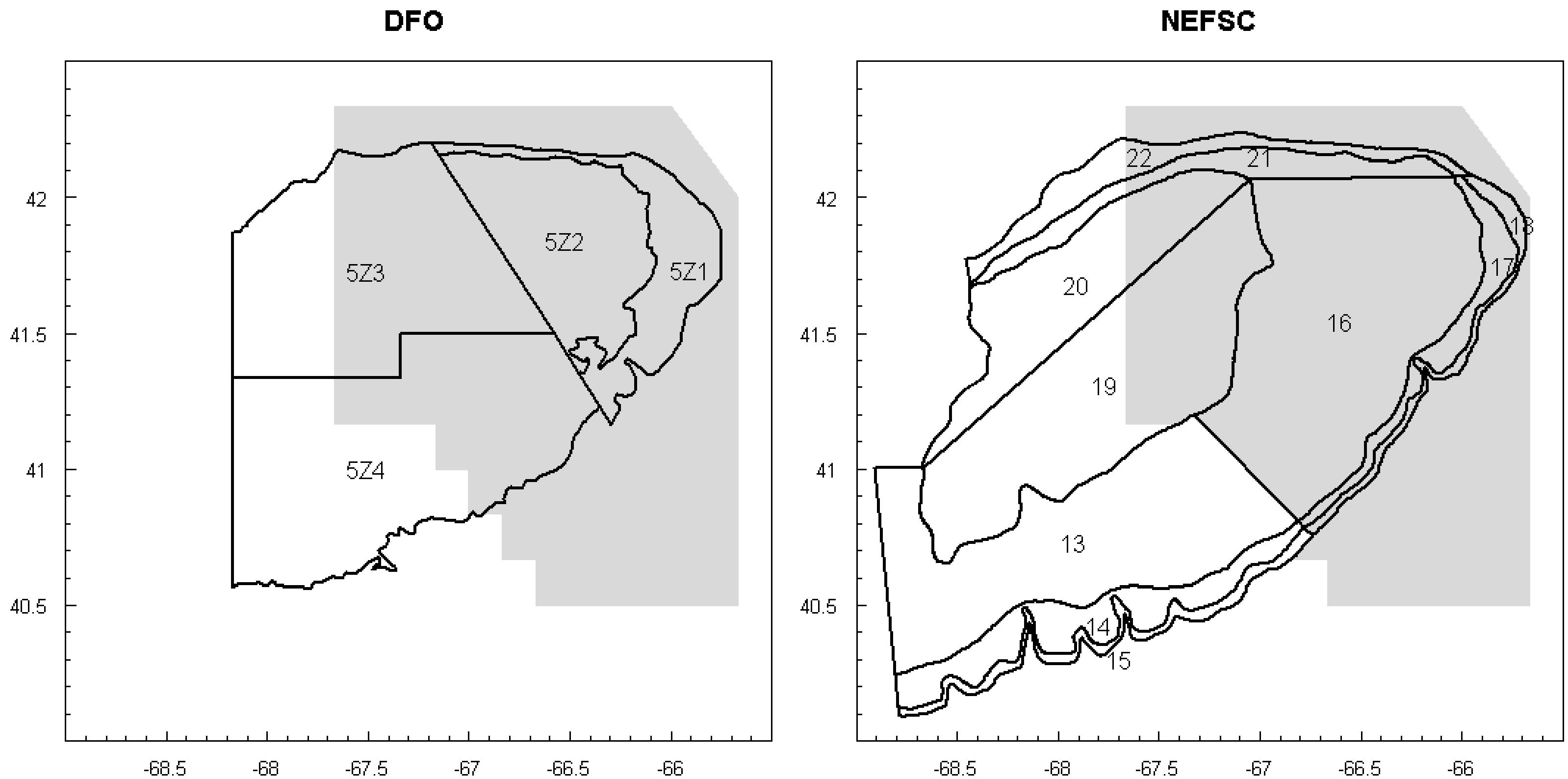


Figure 1. Georges Bank survey strata for Canada (left panel) and US (right panel). The gray area in each plot denotes the regions within the survey strata used for eastern Georges Bank assessments. Note that NEFSC stratum 22 is not used in the Georges Bank yellowtail flounder assessment.

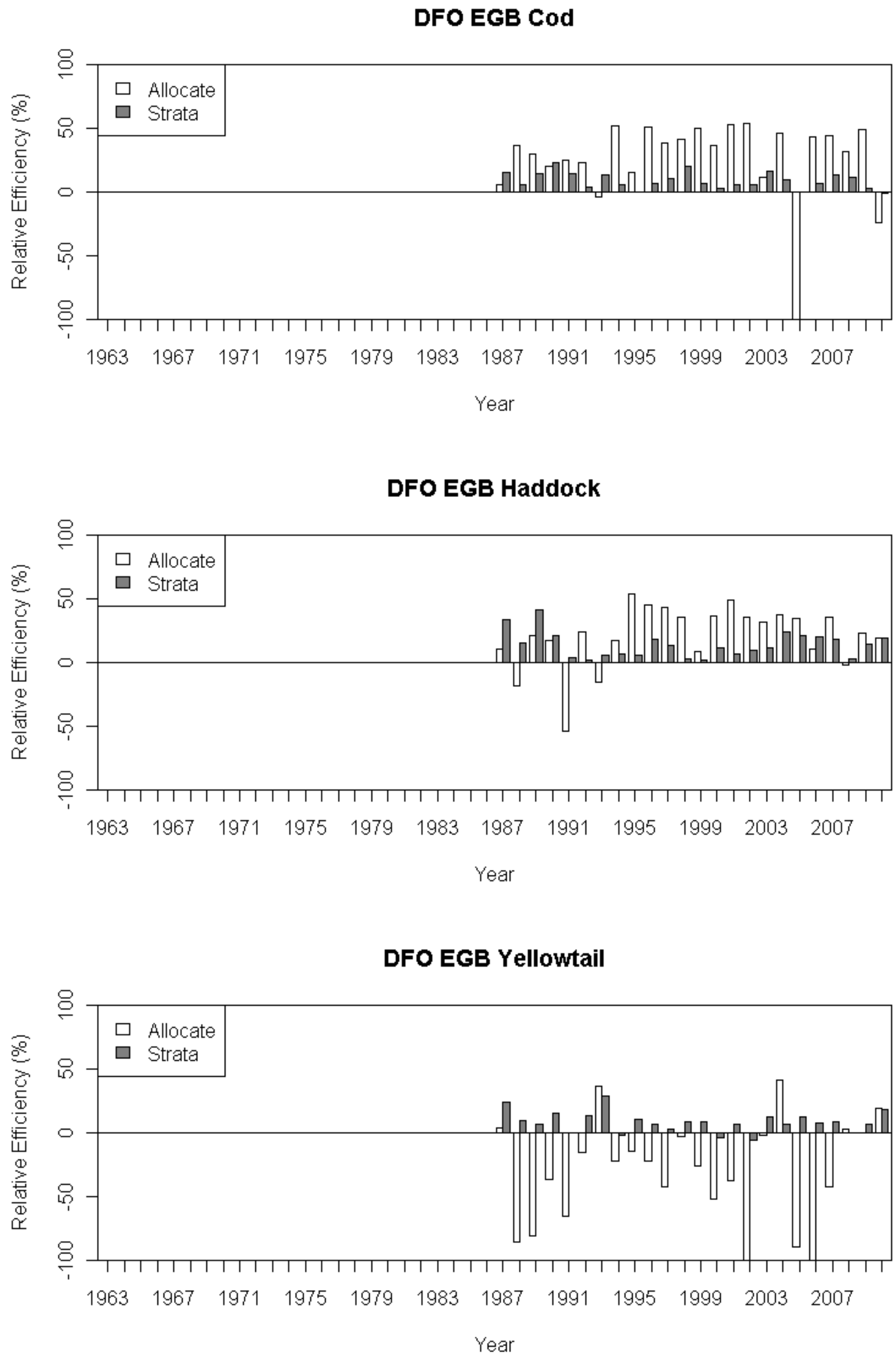


Figure 2a. Relative efficiency of the Canadian survey on eastern Georges Bank for cod, haddock, and yellowtail flounder.

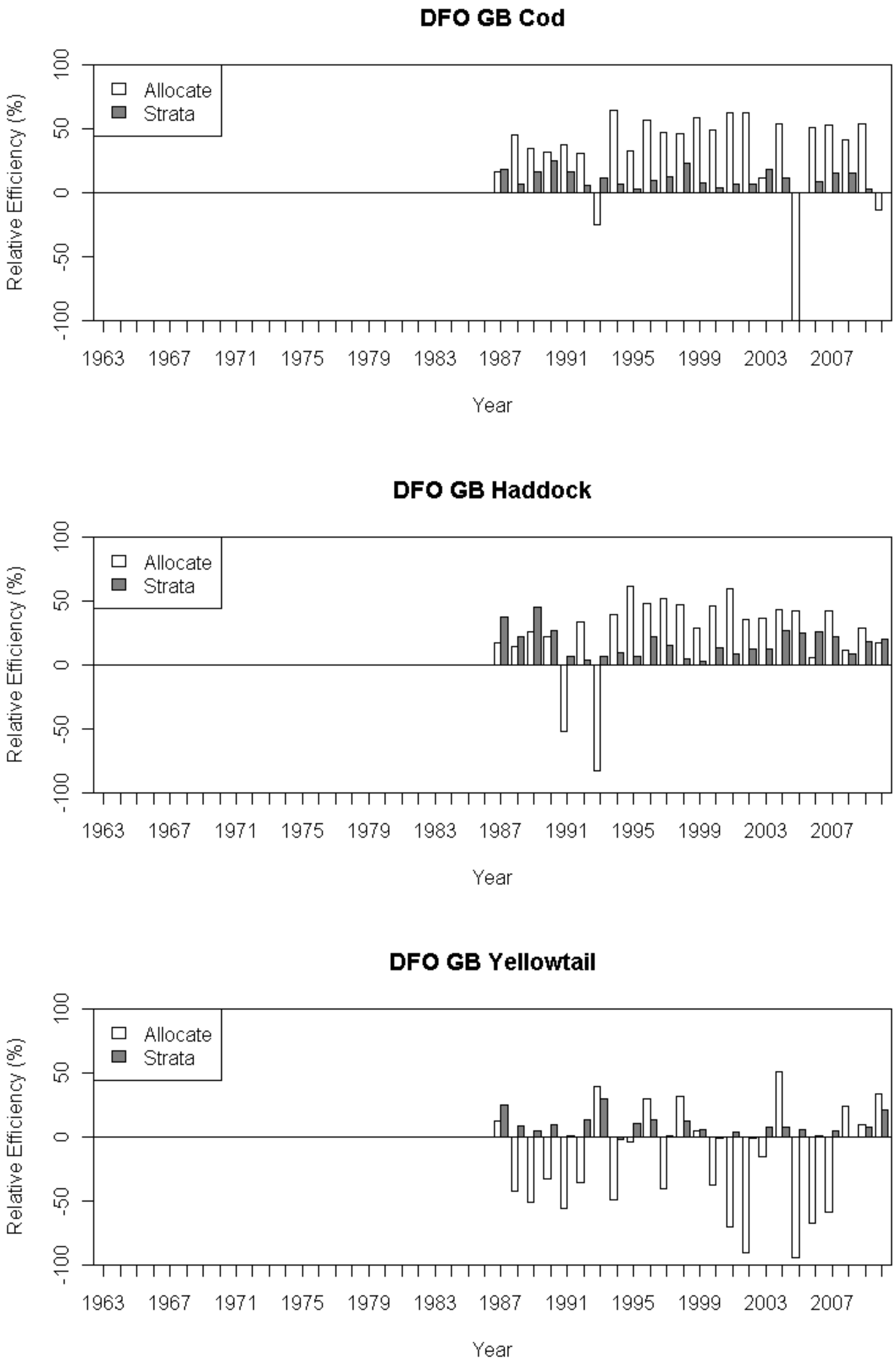


Figure 2b. Relative efficiency of the Canadian survey on Georges Bank for cod, haddock, and yellowtail flounder.

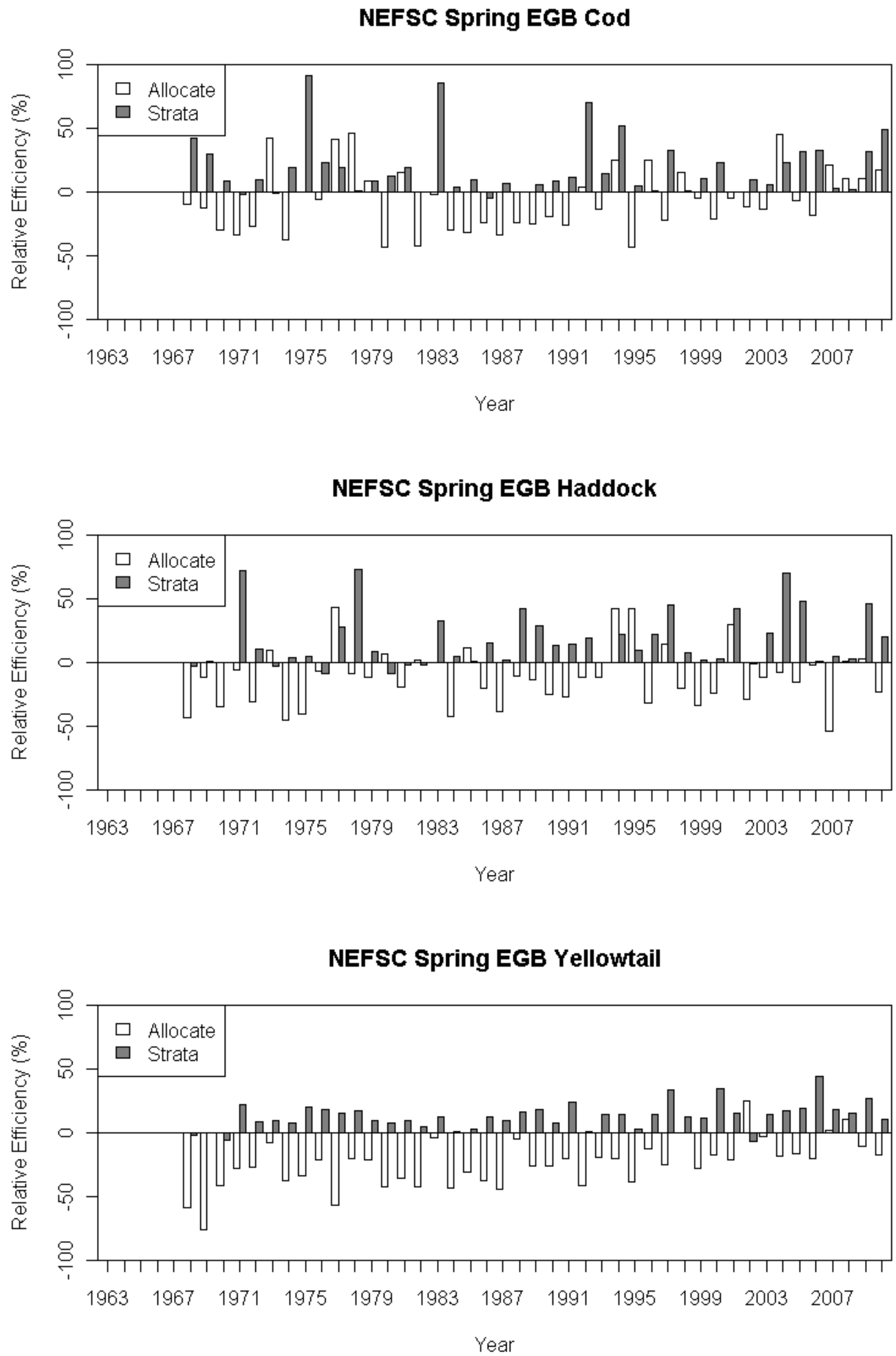


Figure 2c. Relative efficiency of the US spring survey on eastern Georges Bank for cod, haddock, and yellowtail flounder.

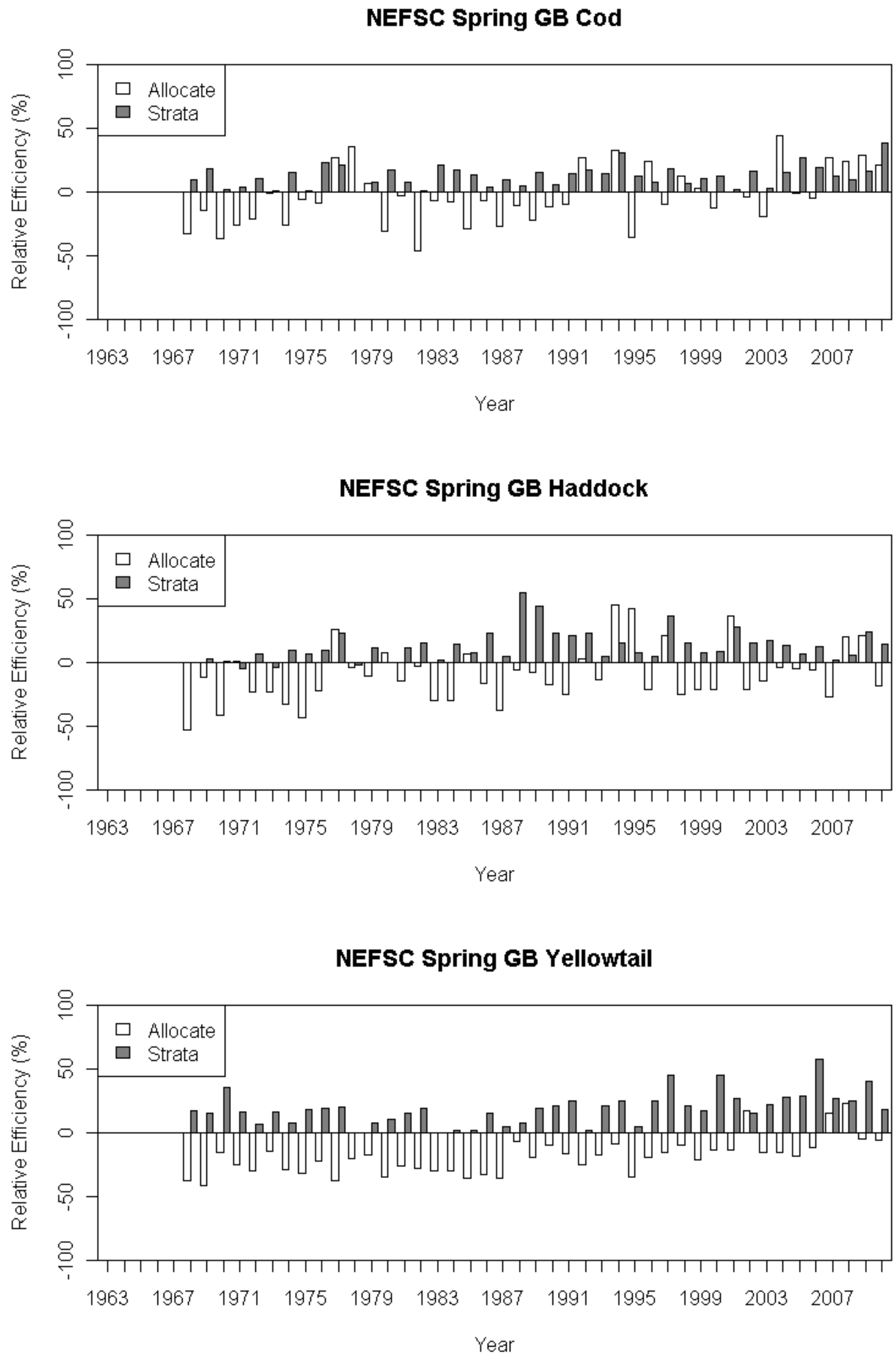


Figure 2d. Relative efficiency of the US spring survey on Georges Bank for cod, haddock, and yellowtail flounder.

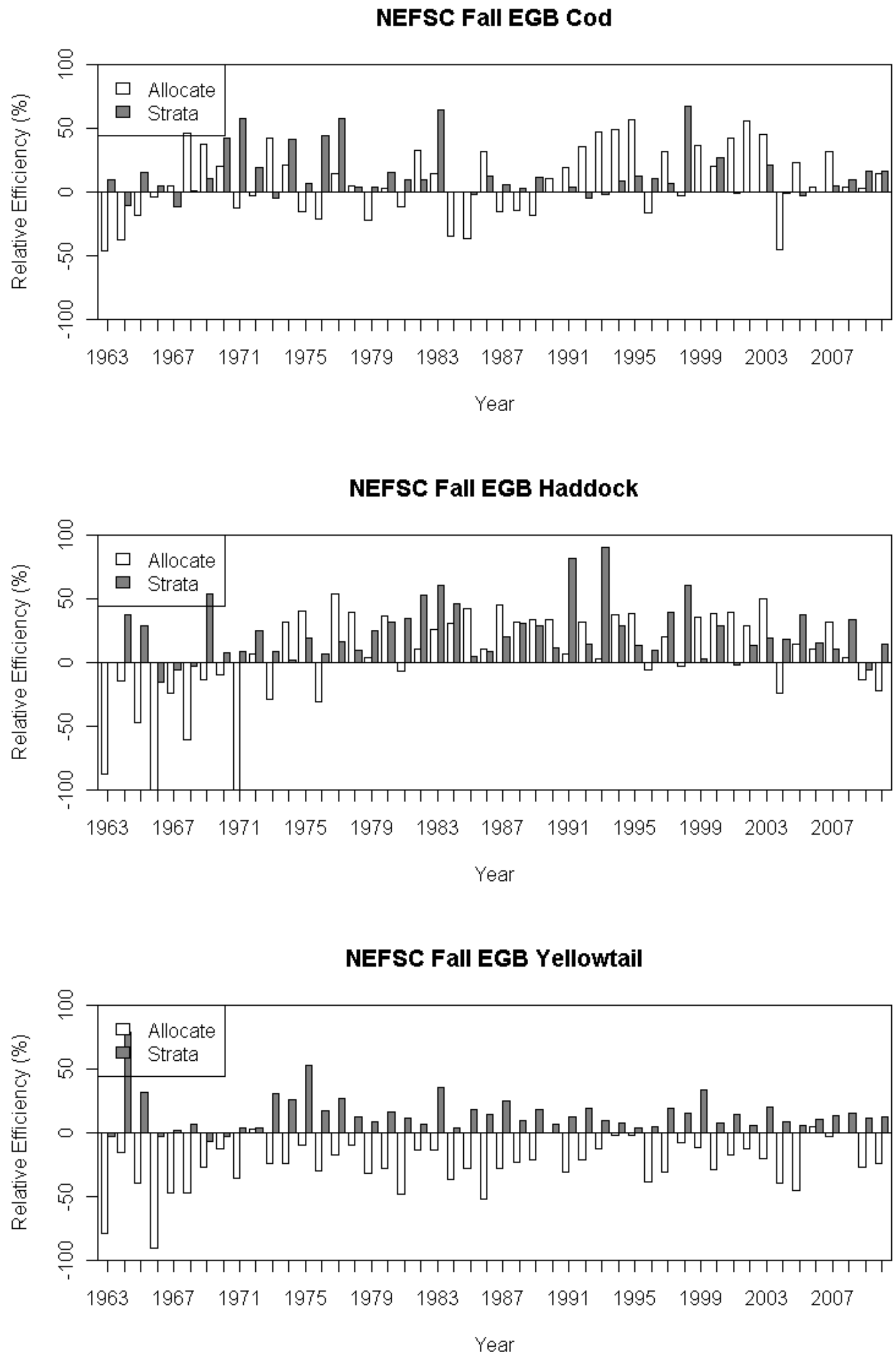


Figure 2e. Relative efficiency of the US fall survey on eastern Georges Bank for cod, haddock, and yellowtail flounder.

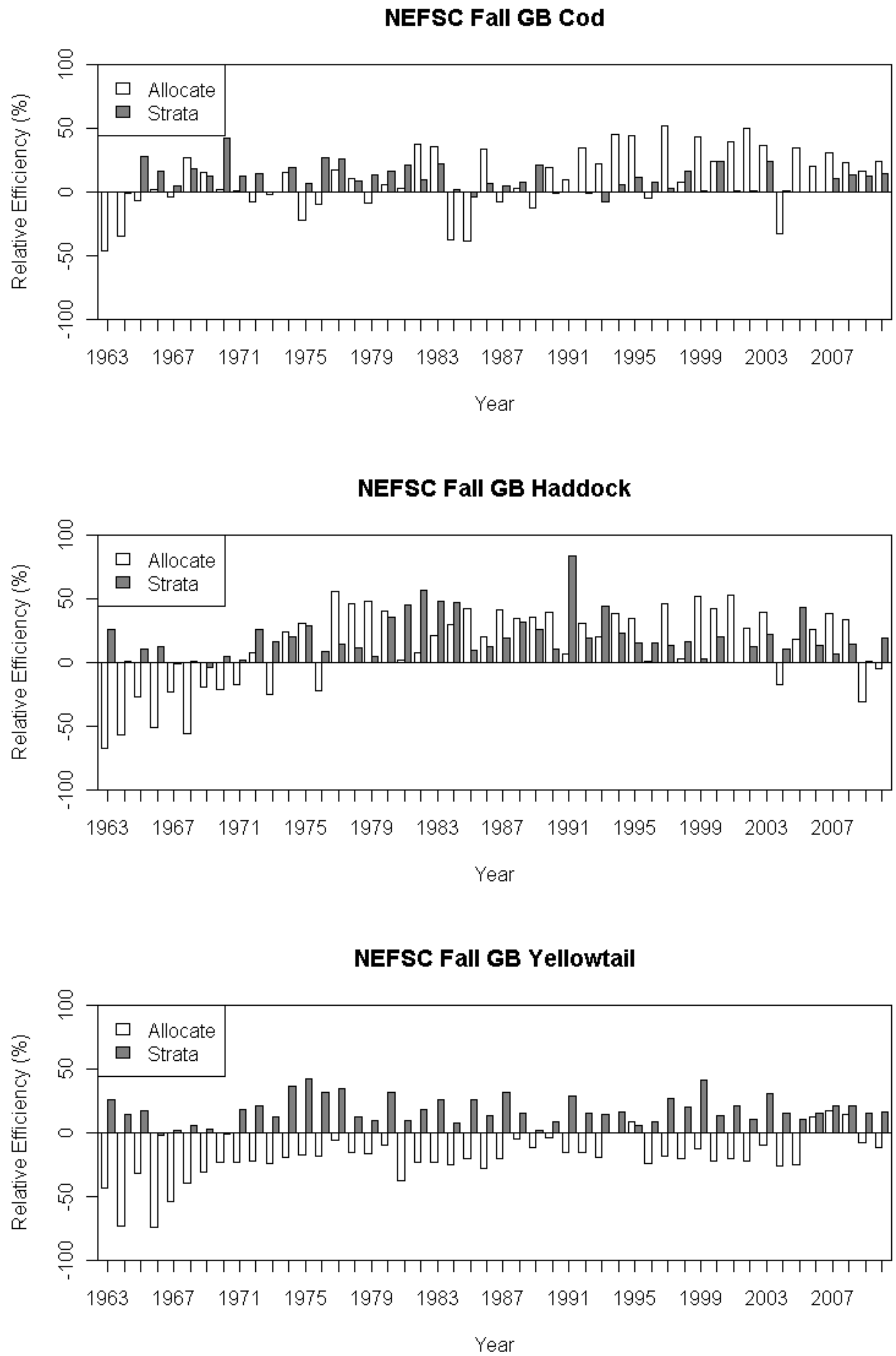
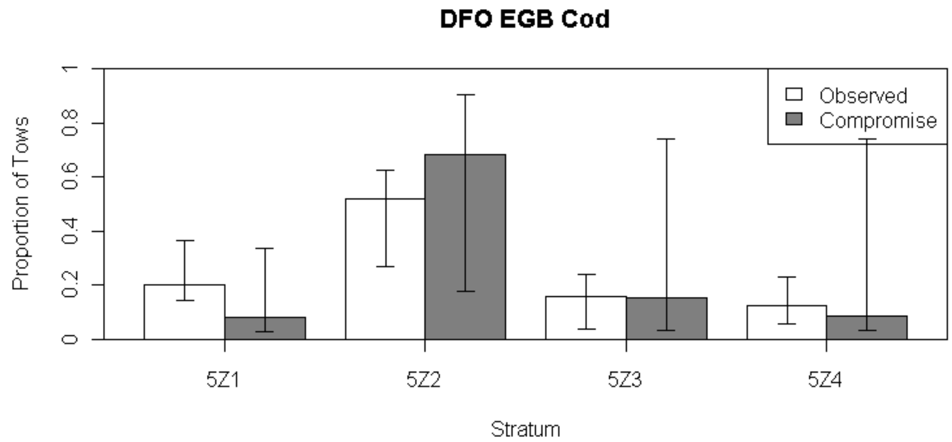
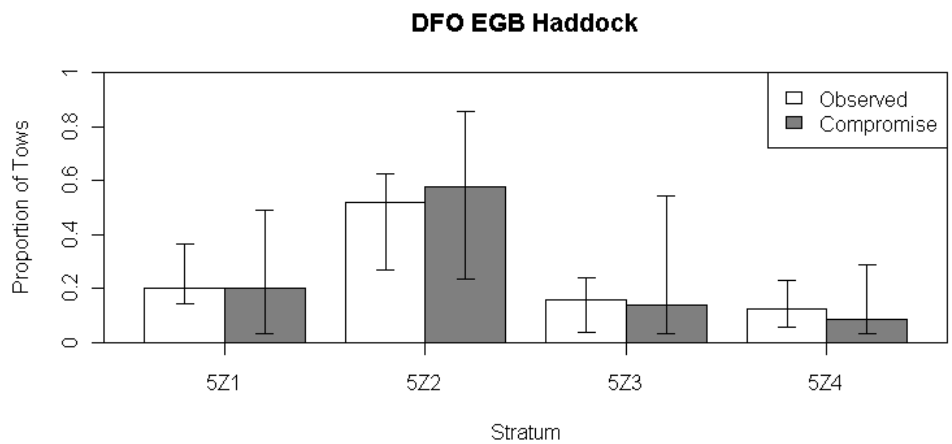


Figure 2f. Relative efficiency of the US fall survey on Georges Bank for cod, haddock, and yellowtail flounder.





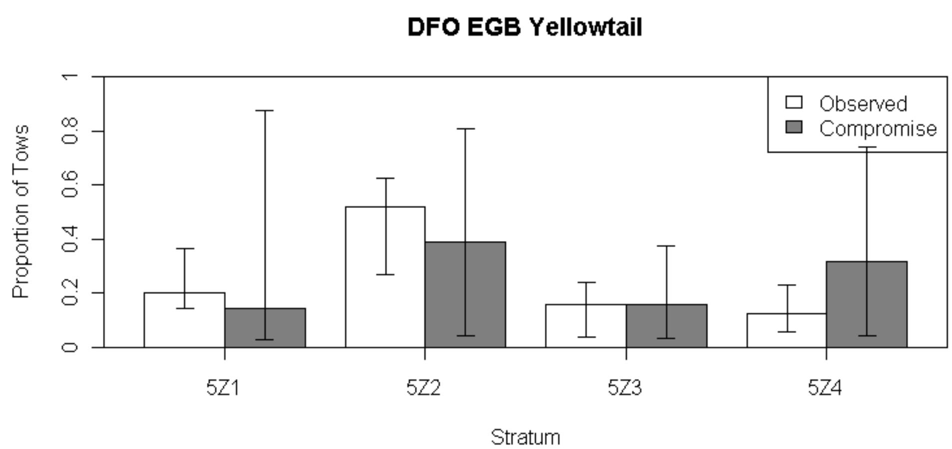


Figure 3a. Mean proportion of tows (bars) in each stratum and range of observed proportions (vertical lines) in the Canadian survey on eastern Georges Bank for cod, haddock, and yellowtail flounder.

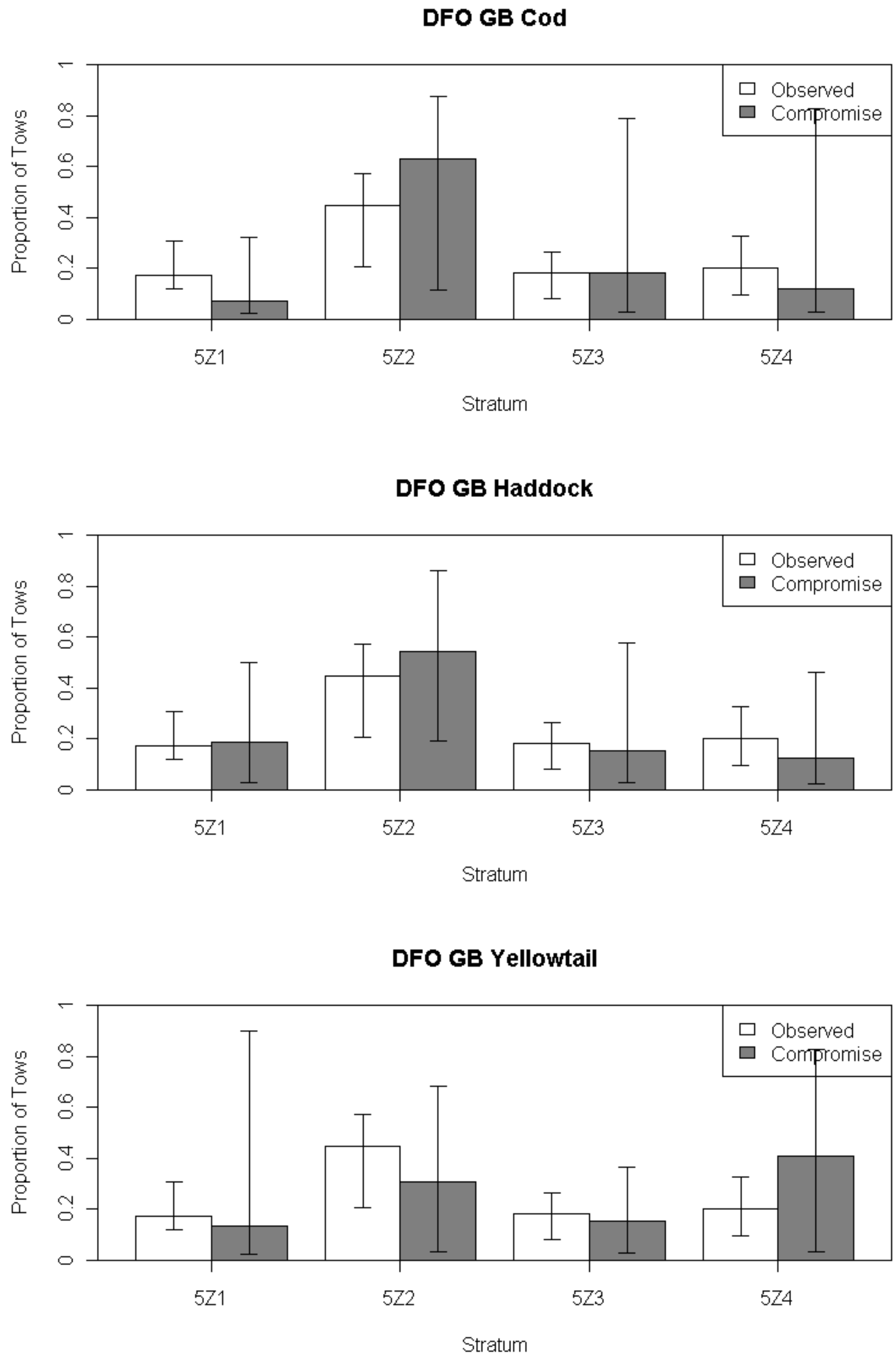
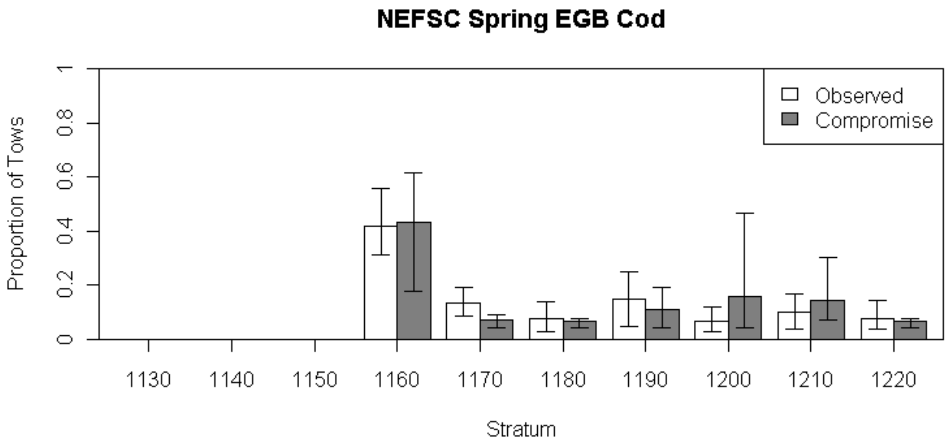
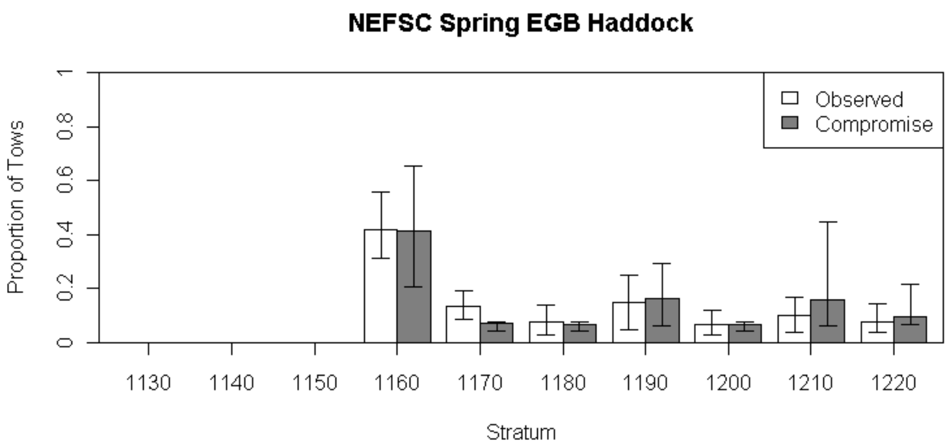


Figure 3b. Mean proportion of tows (bars) in each stratum and range of observed proportions (vertical lines) in the Canadian survey on Georges Bank for cod, haddock, and yellowtail flounder.





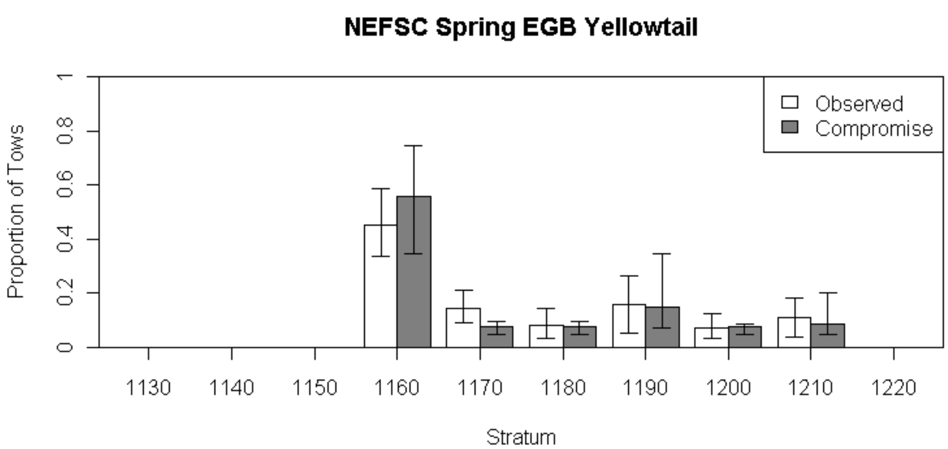


Figure 3c. Mean proportion of tows (bars) in each stratum and range of observed proportions (vertical lines) in the US spring survey on eastern Georges Bank for cod, haddock, and yellowtail flounder.

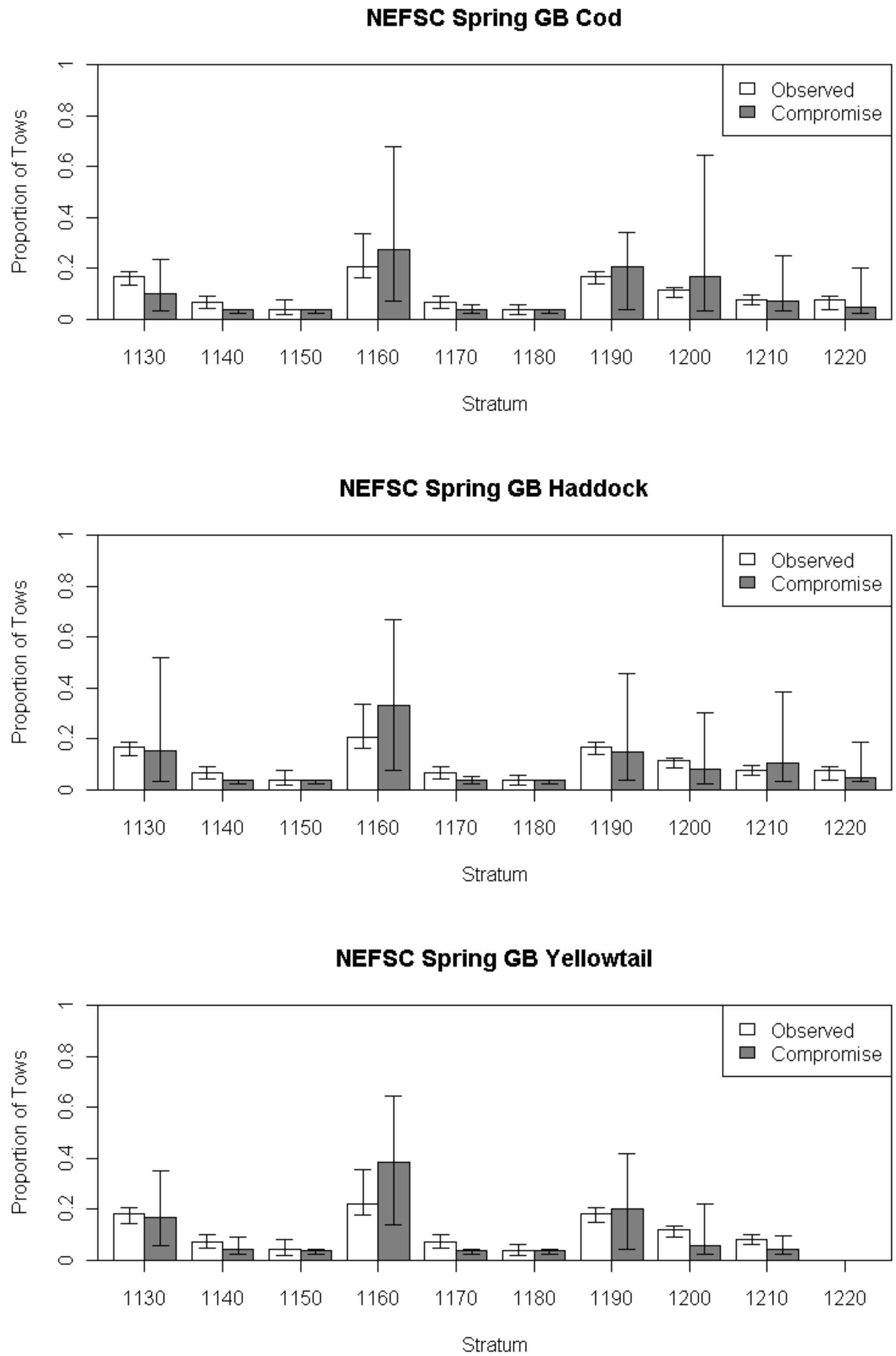


Figure 3d. Mean proportion of tows (bars) in each stratum and range of observed proportions (vertical lines) in the US spring survey on Georges Bank for cod, haddock, and yellowtail flounder.

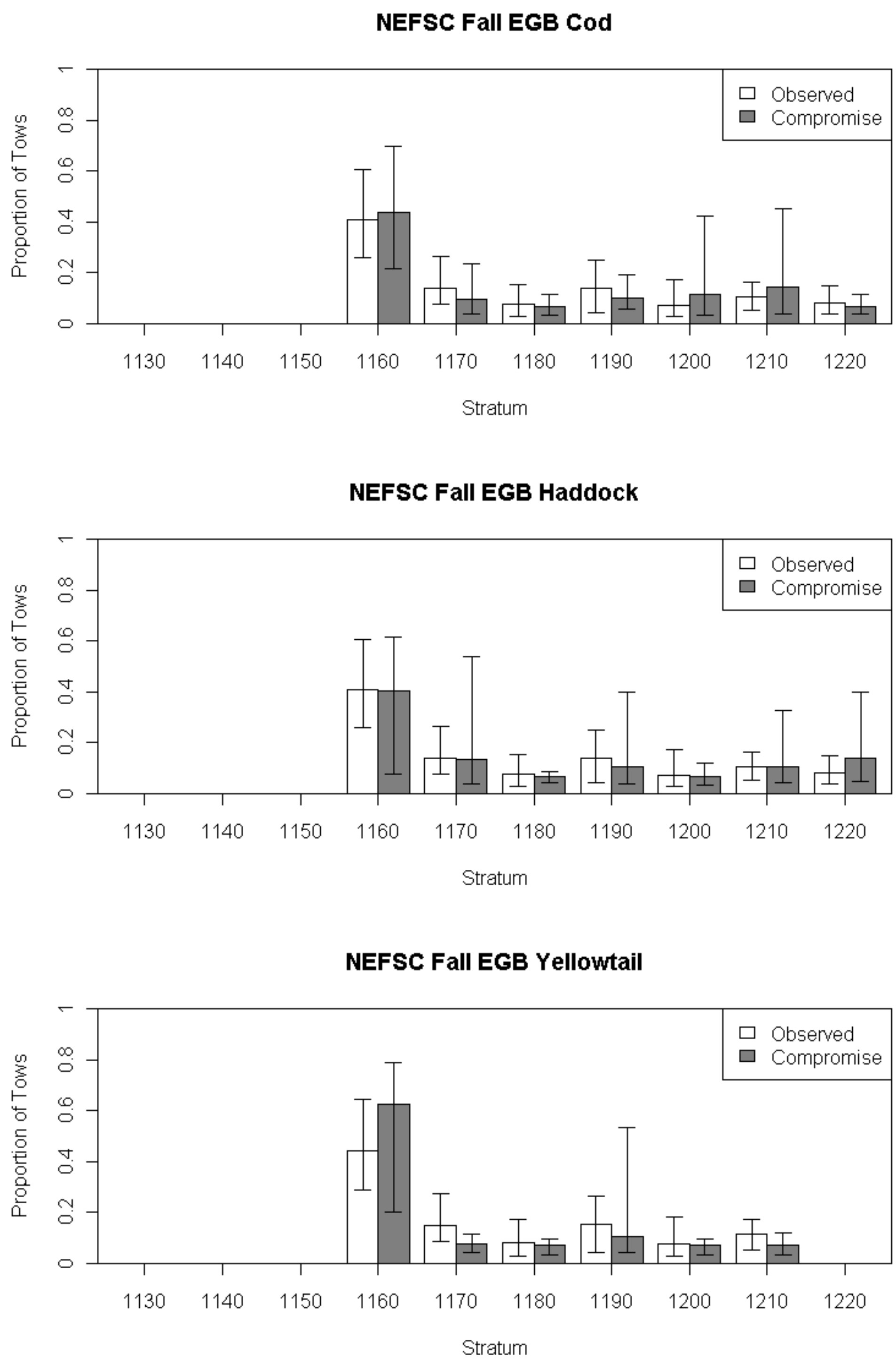


Figure 3e. Mean proportion of tows (bars) in each stratum and range of observed proportions (vertical lines) in the US fall survey on eastern Georges Bank for cod, haddock, and yellowtail flounder.

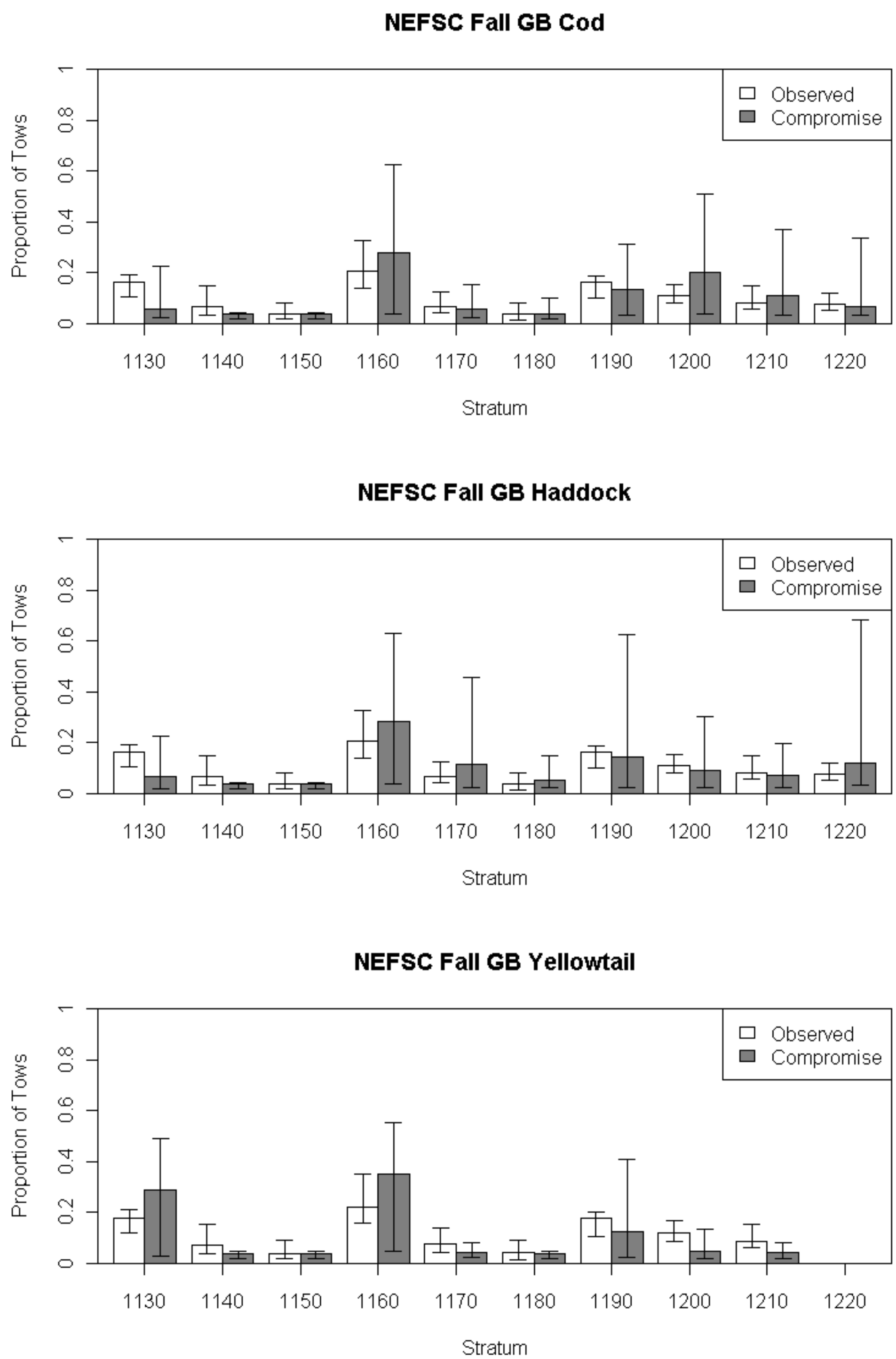


Figure 3f. Mean proportion of tows (bars) in each stratum and range of observed proportions (vertical lines) in the US fall survey on Georges Bank for cod, haddock, and yellowtail flounder.

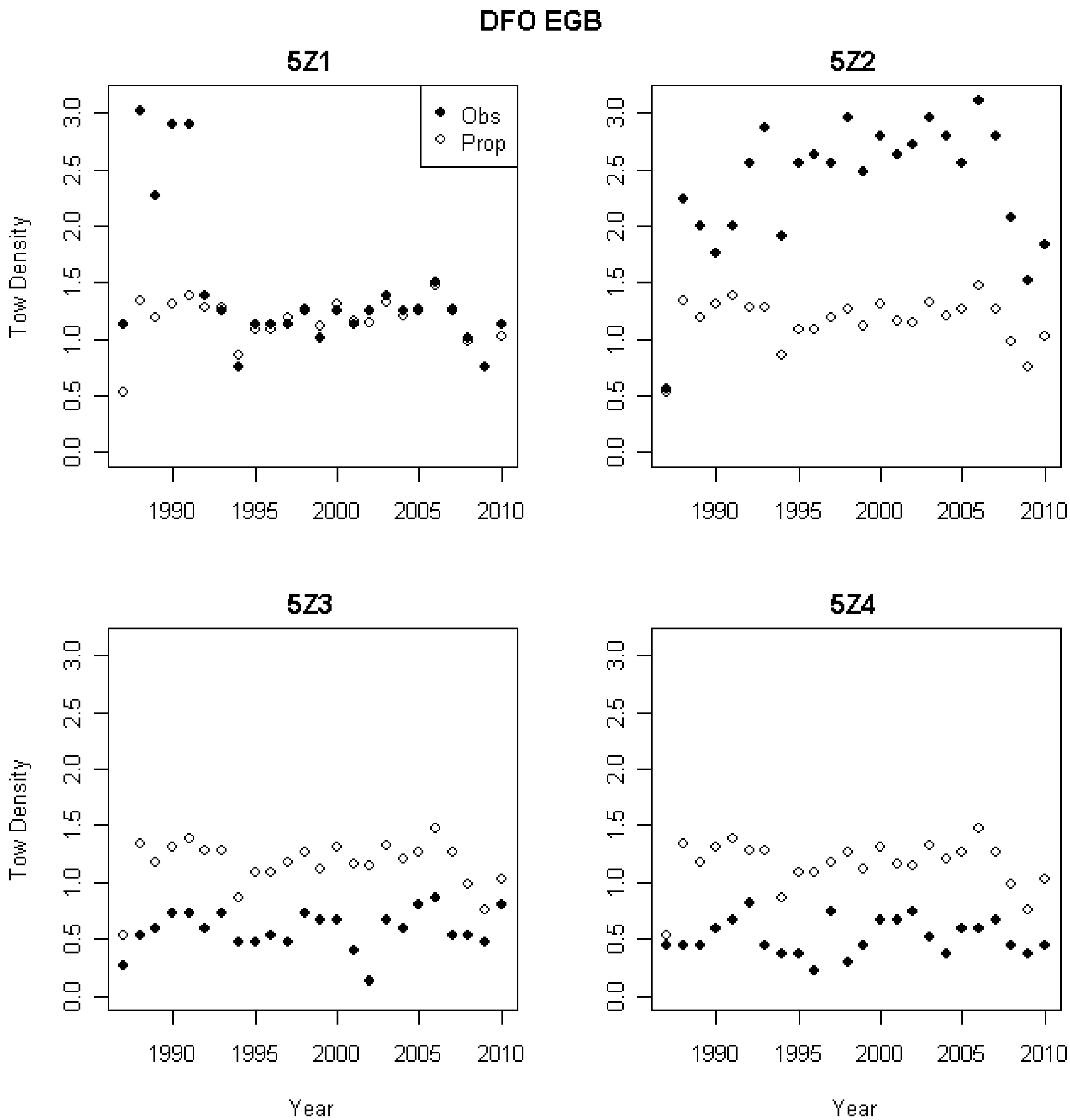


Figure 4a. Tow density (number of tows per 100 square nautical miles) for the DFO survey in the eastern Georges Bank region. The actual tow density is shown in solid circles while the tow density which would have occurred if allocation to areas was strictly proportional to area is shown in open circles.

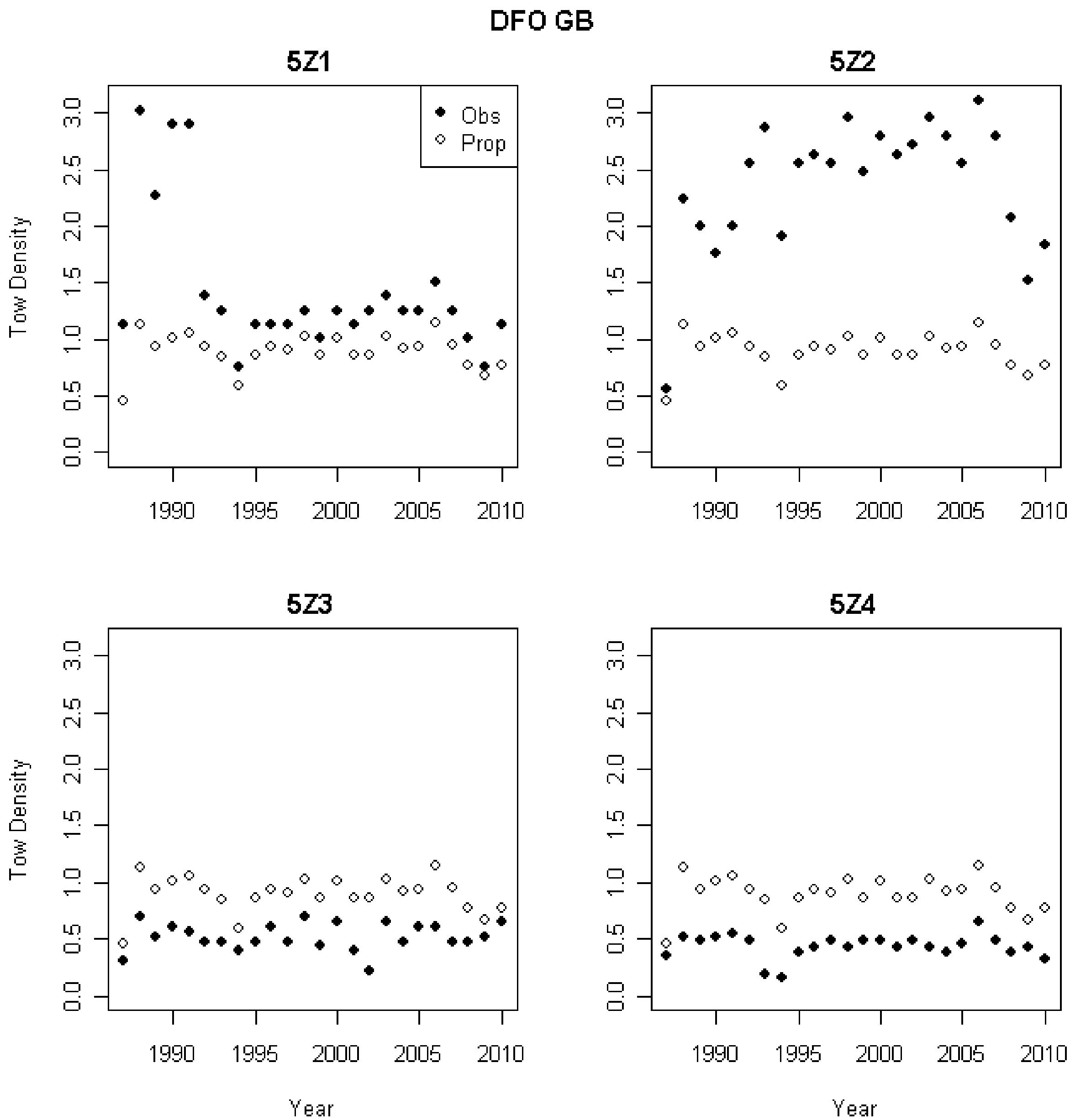


Figure 4b. Tow density (number of tows per 100 square nautical miles) for the DFO survey in the Georges Bank region. The actual tow density is shown in solid circles while the tow density which would have occurred if allocation to areas was strictly proportional to area is shown in open circles.

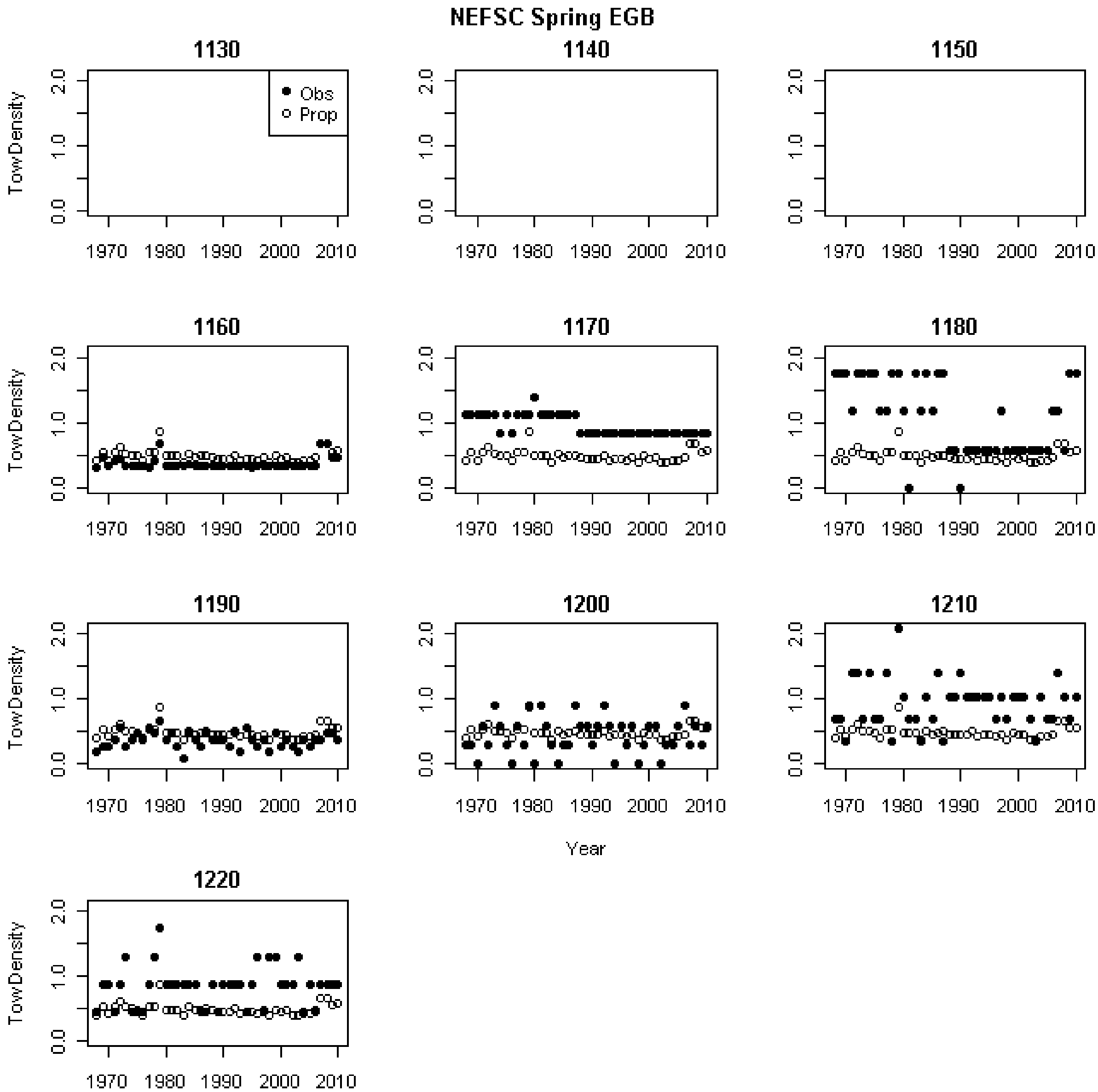


Figure 4c. Tow density (number of tows per 100 square nautical miles) for the NEFSC spring survey in the eastern Georges Bank region. The actual tow density is shown in solid circles while the tow density which would have occurred if allocation to areas was strictly proportional to area is shown in open circles.

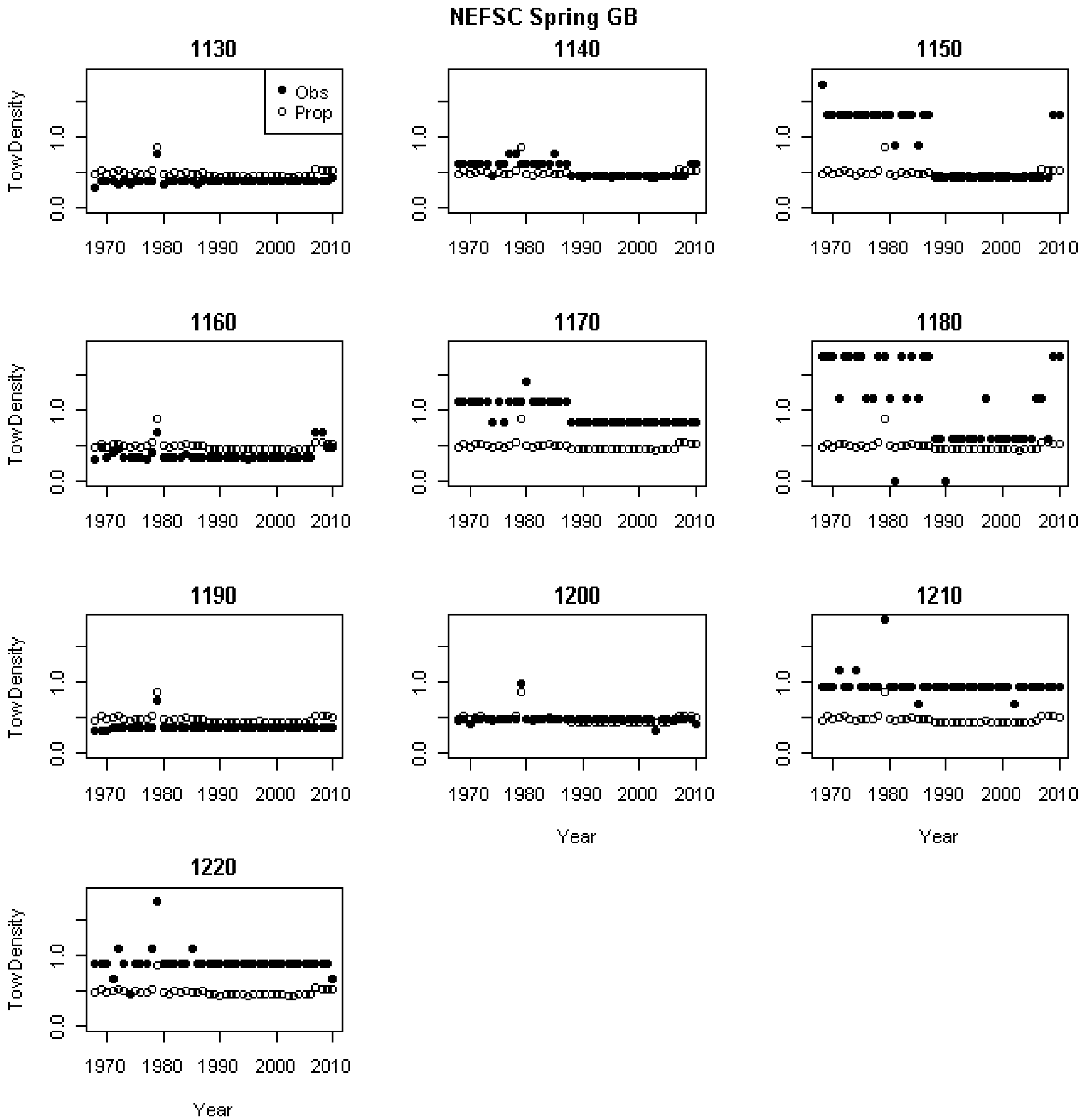


Figure 4d. Tow density (number of tows per 100 square nautical miles) for the NEFSC spring survey in the Georges Bank region. The actual tow density is shown in solid circles while the tow density which would have occurred if allocation to areas was strictly proportional to area is shown in open circles.

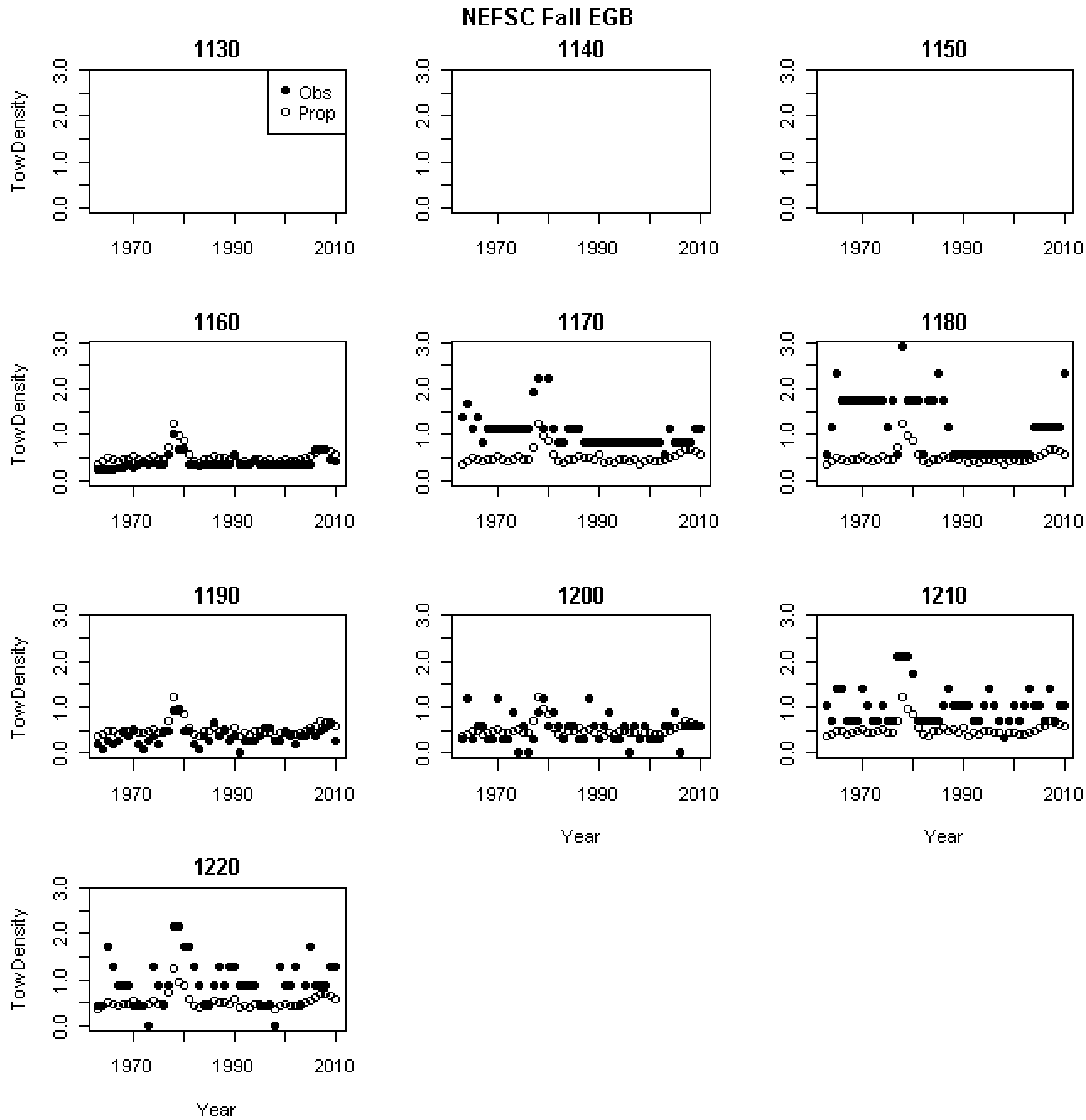


Figure 4e. Tow density (number of tows per 100 square nautical miles) for the NEFSC fall survey in the eastern Georges Bank region. The actual tow density is shown in solid circles while the tow density which would have occurred if allocation to areas was strictly proportional to area is shown in open circles.

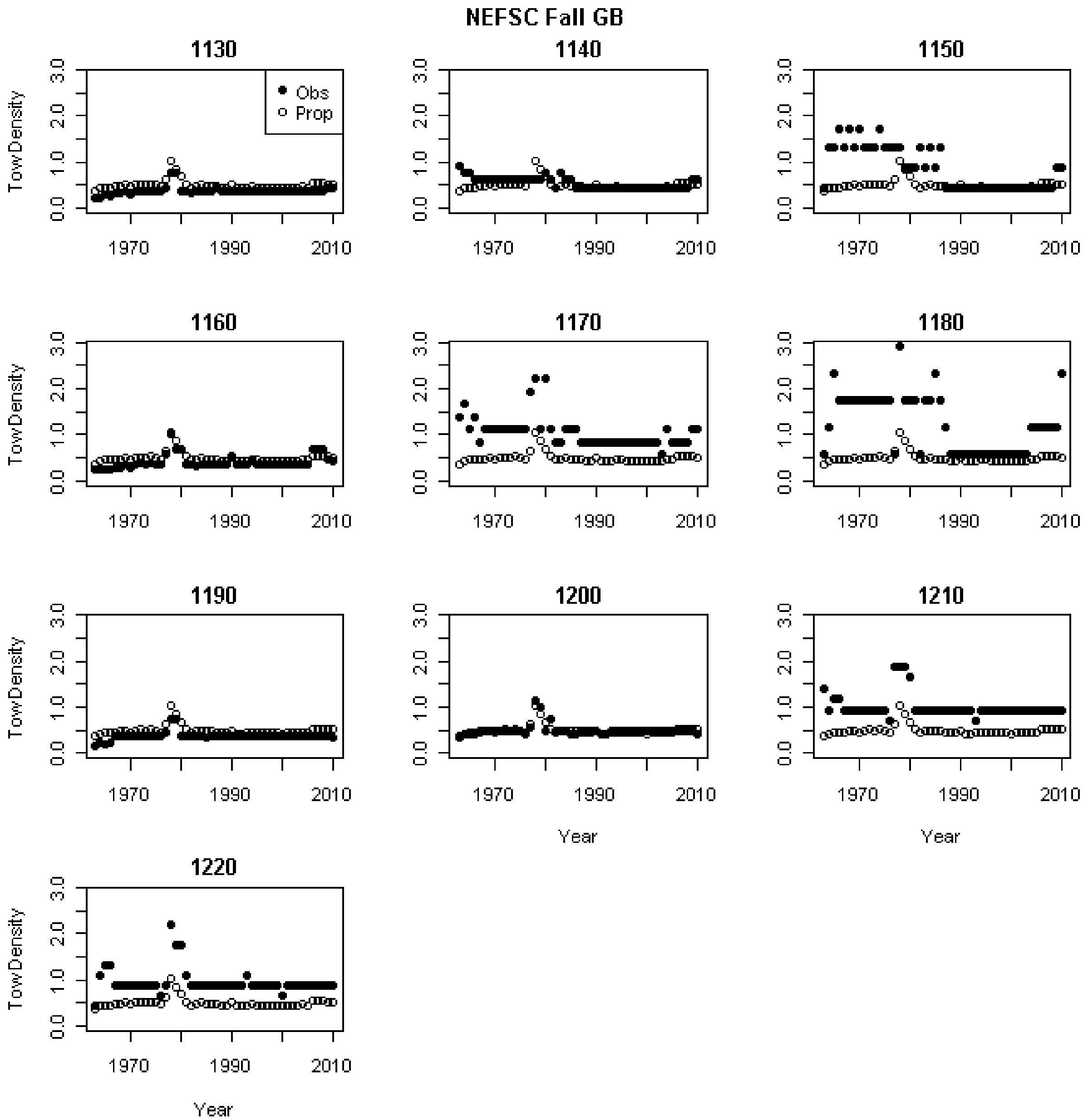


Figure 4f. Tow density (number of tows per 100 square nautical miles) for the NEFSC fall survey in the Georges Bank region. The actual tow density is shown in solid circles while the tow density which would have occurred if allocation to areas was strictly proportional to area is shown in open circles.

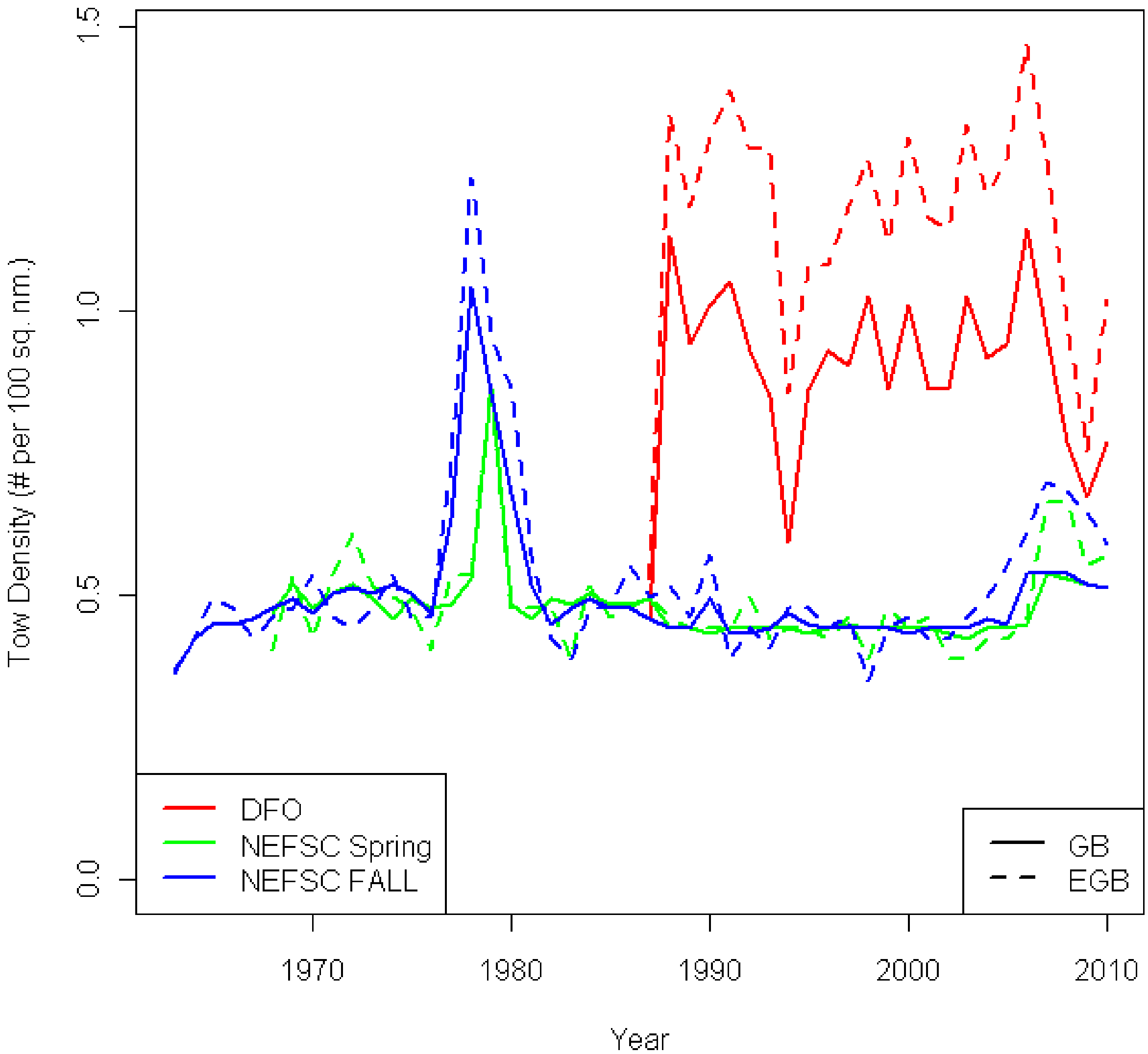


Figure 5. Tow density (number of tows per 100 square nautical miles) for each survey over time for both Georges Bank and eastern Georges Bank.