Section 3. Examination of Possible Effects of Trawl Survey Time-Series Interventions Beginning in 2000

3.1 Description of the Warp Offset Problem

The objectives of this section are to evaluate the potential effects of mismarked trawl cables on the catches of groundfish species in NEFSC R/V trawl surveys conducted since 2000. Eight surveys were affected (Spring 2000-2002, Winter 2000-2002, and Fall 2000-2001) but the magnitude of the potential changes is unknown. First principles suggest that the likely changes should be negative (i.e., lower catches in 2000-2002). Trawls are bilaterally symmetric and offset cables will induce asymmetry in the trawl's alignment. Departures from symmetry could upset the balance of dynamic forces that govern performance of the net. Catastrophic changes are relatively infrequent and readily detected in standard surveys. More subtle features such as vibrations, variability in bottom contact, reduced net width, and decreased height of the head rope are more difficult to detect. Moreover, the effects of such changes interact with contagiously-distributed fish populations whose variations in abundance and catchability may overwhelm issues of gear performance.

While pilot studies to test the effects of offset trawl cables were conducted in fall 2002, comprehensive experiments have yet to be completed. Analysis of historical data from the NEFSC time series and comparisons with other data sets, are however, instructive for gauging the magnitude of likely effects. We have pursued three basic approaches to see if effects of the trawl warp offsets are evident in the data. The first approach is descriptive. We examined the basic properties of the catch data and performed various tests to determine if changes had occurred since 1999. These analyses rely primarily on the historical data serving as a temporal control. The second approach relies on comparisons between the NEFSC time series and contemporaneous samples from other surveys. We consider comparisons between the NEFSC trawl data and similar surveys conducted by Department of Fisheries and Ocean (DFO) Canada. In addition, vessel comparison studies (R/V *Albatross IV* versus R/V *Delaware II*) conducted before and after 2000 fortuitously allow for an estimate of the relative effect of warp offsets on catches.

Finally, we used models to evaluate the consequences of hypothesized levels of bias on the relative indices for assessment of resource status. Each potential level of bias has implications for relative efficiency of capture at depth. We used simple models to predict the reduction in capture efficiency that would have led to underestimation of abundance at the hypothesized levels.

Table 3.1.1. Measured differences in trawl warp lengths at varying fishing depths.

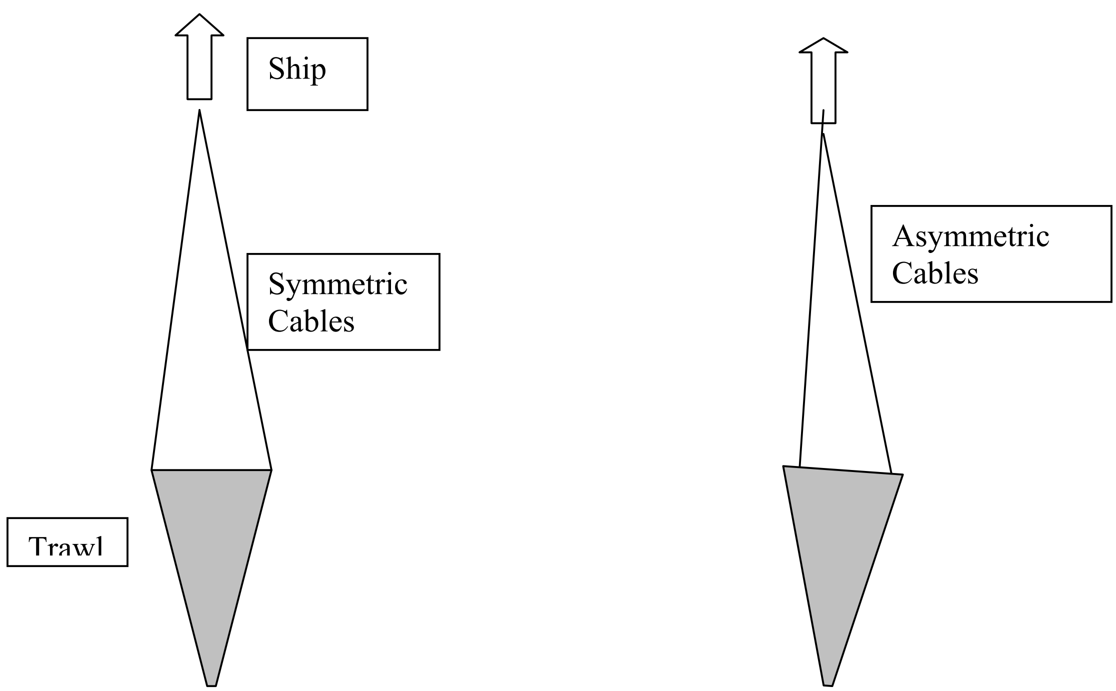
Differences in Warp length between port and starboard marks.

Warp(m)	***Depth(m)***	***Difference (inches)***	***Difference (m)***	***Difference (ft)***
0	0	0	0.00	0.0
50	17	16	0.41	1.3
100	33	1	0.03	0.1
150	50	24	0.61	2.0
200	67	39	0.99	3.3
250	83	49	1.24	4.1
300	100	67	1.70	5.6
350	117	69	1.75	5.8
400	133	81	2.06	6.8
450	150	94	2.39	7.8
500	200	107	2.72	8.9
550	220	124	3.15	10.3
600	240	131	3.33	10.9
650	260	117	2.97	9.8
700	280	150	3.81	12.5
750	300	158	4.01	13.2
800	320	164	4.17	13.7
850	340	172	4.37	14.3
900	360	188	4.78	15.7
950	380	214	5.44	17.8
1000	400	200	5.08	16.7

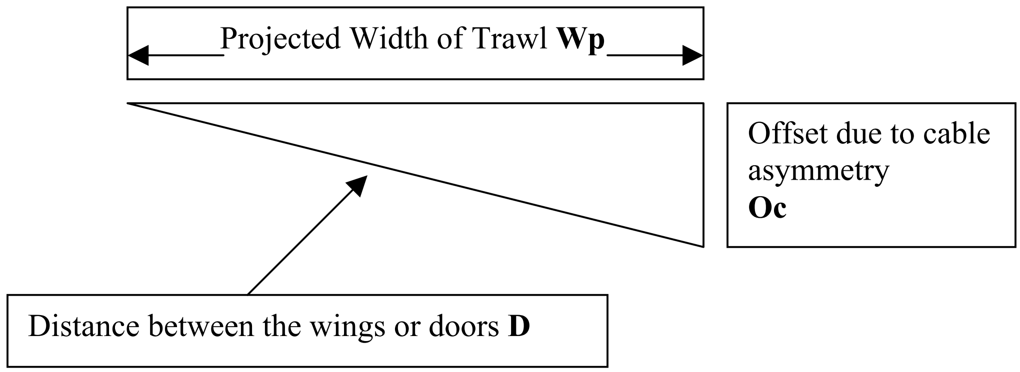
3.1.1 Trawl Geometry and Its Potential Implications for Catch Rates

The measured differences between the port and starboard cables are listed in Table 3.1.1. The ratio of the wire deployed to water depth is defined as the scope ratio. NEFSC uses a 3:1 scope for tows conducted at depths less than 150 m. At depths greater than 150 m the scope is set at 2.5:1. The difference between the cable lengths increases with the length of cable such that the differences between cables increases with fishing depth. The relationship between the warp offset and depth is linear (Fig. 3.1.1).

Basic geometric principles can be used to evaluate the potential effects of the asymmetric warp lengths on the area swept by the trawl. When the cables are of equal length, the distance between the trawl doors can be considered as the base of an isosceles triangle. A line drawn between the doors will be tangential to the direction of the ship. This distance between the wings of the net defines the measure of area swept for species which do not actively avoid the moving net. For finfish species that avoid both the net and the silt plume generated by the trawl doors, the effective area swept can be considered as the distance between the trawl doors. The minimal estimate total area swept can thus be estimated as the distance towed times the distance between the wings.



As a first approximation, the effects of asymmetric doors can be addressed with respect to the implied decrease in the distance between doors. If the Euclidean distance between the doors remains constant, then the reduction in area swept can be estimated as the base of a right-angled triangle using the Pythagorean theorem.



When the cables are symmetric then Wp=D. When the cables are asymmetric, by a distance of approximately Oc, the projected width of the trawl tangential to the axis of the ship's direction is

$$W_p = \sqrt{D^2 - Oc^2}$$

The fractional reduction in area swept per unit of towing distance can then be expressed as **$(D-W_p)/D$.** This approximation relies on the rather strong assumption that the trawl behaves like a rigid body. In reality the conformation of the trawl will depend upon the balance of forces acting on it. Detailed description of changes in net configuration and performance await the results of physical model tests, numerical model simulations, and field experiments with video observations.

The simple geometry of this example however, suggests that the consequences for changes in area swept are very small (Fig 3.1.2). At fishing depths below 300 m the difference in the area swept between the wings will less than 2%. The differences in the width swept by the doors would be about 7%. More than 90% of the NEFSC survey stations are at depths less than 200 m; at these depths, the reductions in either door width or net width would be less than 3%. Thus changes in catchability derived from considerations of simple geometry are likely to be small. Effects of the warp offset on catchability, if they exist, must manifest themselves as significant changes in net configuration or performance. Such changes could include reduced tendency to hold bottom, decreased headrope height, or excessive vibrations or pressure waves. Each of these factors should be subject to experimental confirmation through video studies and comparative fishing experiments.

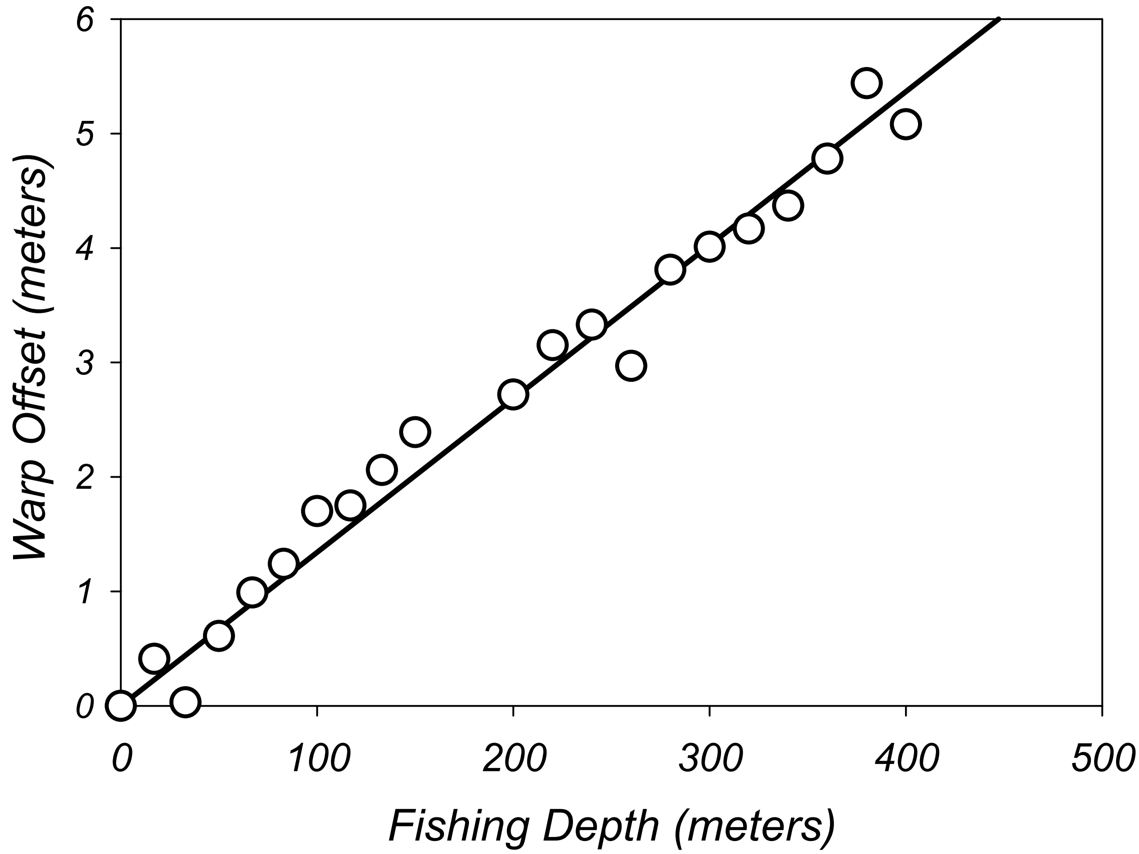
The deductive conclusions from trawl geometry provide a basis for examination of existing data. If the reductions in trawl width are greater than predicted by the static rigid-body analysis, then all species analyzed should be affected by a similar magnitude. Other modifications of trawl performance, however, are likely to have differential effects on the mix of species caught. If the warp offset causes the footrope to lose contact with the bottom, flatfish species should experience greater reductions in catches than other groundfish. Conversely, reductions in the height of the headrope should leave catch rates of flatfish unaffected but decrease catches of free-swimming species. Changes in net vibrations or increases in the net's pressure wave will tend to enhance the avoidance response of faster moving species and individuals within species. Under this hypothesis, the size composition of the catches should shift toward smaller individuals. In aggregate, these factors would be expected to increase the frequency of faulty trawl deployments, differentially reduce species-specific catch rates, and show an increasing effect with towing depth.

The following sections attempt to test these hypotheses in a variety of ways. Each section follows a general pattern of hypothesis formulation, description of the data, presentation of mathematical or statistical theory, and the results of the analyses. We attempt to inter-relate models with the observed data. In most instances, this is done in the conventional fashion of comparing statistical models with observations. In other instances, the models are used to illustrate the plausibility of hypotheses. The following table provides a guide to these hypotheses and test procedures.

Hypothesis	**Test Procedure**	**Section**
Warp offset effects should lead to an increase in frequency of gear problems during 2000-2002 compared to pre 2000 surveys. Increases between treatment and control periods should be more pronounced with increasing depth.	Examined frequency of tows with gear problems by year for the spring (1985-2002), winter (1992-2002) and fall (1985-2001) surveys for the period 1985-2002. Used generalized additive models to estimate year and depth effects.	3.2
Larger individuals should be less vulnerable to capture by an asymmetric trawl.	Compared size frequency distributions of cod, haddock, yellowtail flounder, and monkfish caught in Albatross surveys with Canadian DFO surveys, fishing power surveys on the R/V Delaware, and a special commercial survey for monkfish.	3.3
Warp offset should decrease efficiency of net leading to decreases in average abundance and higher variation in catch.	Computed variance and mean of each strata within year for fall (1963-2001), spring (1968-2002), and winter (1992-2002) surveys for 22 species-stocks. Compared 90% confidence ellipses for pre and post treatment period.	3.6
Reductions in capture efficiency at depth should shift the loci of species abundance to shallower	Computed catch (numbers/tow)-weighted and biomass (kg/tow)-weighted average depths for each year and survey type (as above) for 22 species-stocks. For selected species, compared	3.7

depths during the 2000-2002 period.	the cumulative catch distributions vs. depth by year.	
Reductions in catch rates should be more pronounced with increases in depth.	Regressed standardized pre –post treatment differences in average catch (num/tow) vs. depth (20 m intervals) and biomass (kg/tow) vs. depth (20 m intervals) for spring (1997-1999 vs. 2000-02), winter (1997-99 vs. 2000-02) and fall (1998-99 vs. 2000-01). For statistically significant changes, estimated depth dependent function to describe loss of efficiency with depth. Computed expected magnitude of underestimation for 2000-2002 indices.	3.7
Hypothesized increases in average number caught in 2000 to 2002 surveys have implication for the reductions in depth-related catch efficiency.	Estimated magnitude of depth-related decreases in efficiency for putative increases in abundance of 10%, 25% and 100% for cod, haddock, and yellowtail stocks.	3.7
Trawl surveys conducted by Canada and NEFSC scallop surveys are unaffected by warp offset. Comparisons of abundance estimates derived from these surveys with NEFSC trawl surveys should allow estimation of warp-related effects.	For annual composite abundance estimates, compared standardized log catch ratios for NEFSC trawl surveys with DFO trawl and NEFSC scallop dredge surveys for 20 species. Generalized linear model used to test for intervention effect.	3.9
Experiments to compare catch rates between the *Albatross* and *Delaware* in 1980s and 2002 provide an indirect measure of warp offset effect.	Reanalyze the vessel comparison experiments to estimate the likely magnitude of the trawl cable offset effect.	3.11
Warp offset effects may have reduced 2000-2002 indices used in assessment models. Hypothesized effect levels were 10, 25 and 100%.	Each assessment model was run with four assumed levels of warp-offset effect: 0% change, +10%, +25% and +100% for indices in 2000-02. Bootstrap estimates of biomass and full F were computed for each model run and confidence intervals were compared for terminal year estimates.	5.2

Figure 3.1.1. Difference between port and starboard warp marks vs. fishing depth



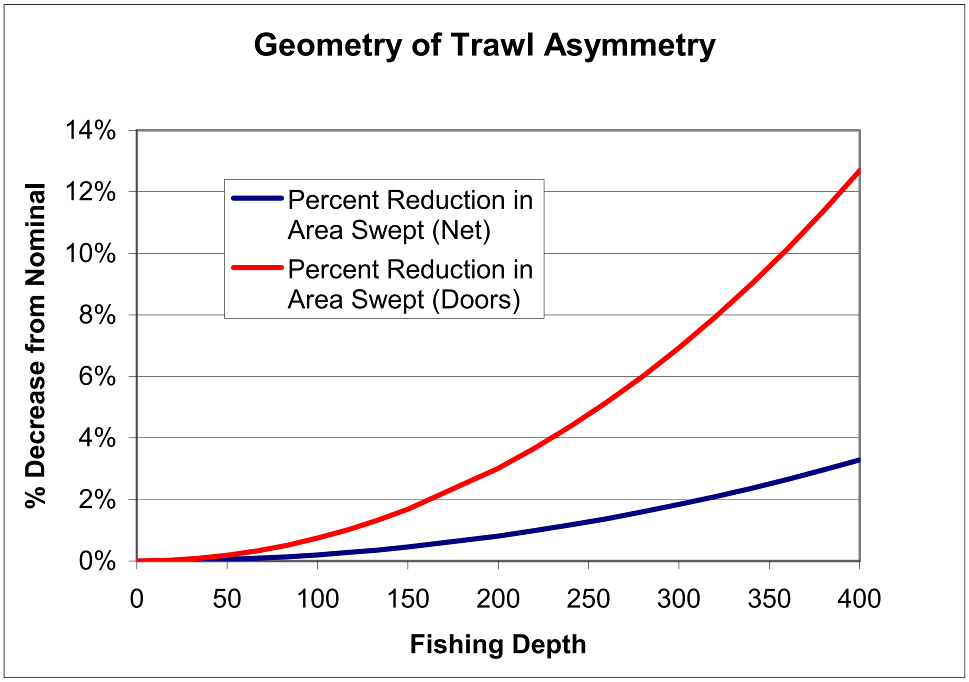


Figure 3.1.2 Predicted effect of trawl offset on reduction in area swept for fishing depths from 0 to 400 m.

3.2 Frequency of Damaged Bottom Trawl Gear in NEFSC Surveys

Summary

1) Analysis of tow records for NEFSC spring, fall and winter bottom trawl surveys by the R/V *Albatross IV* using the Yankee No. 36 bottom trawl during 1982-2002 shows that the frequency of tows with damage to survey bottom trawls varied randomly during 1983-2002, with relatively little variation during recent years.
2) Of eight surveys during 2002-2002 with mis-marked warps, two surveys had more than average levels of any gear damage while six surveys had average or less than average levels of any gear damage.
3) Simple graphical analyses and GAM model results suggest that mis-marked warps had little or no effect on the probability of gear damage.
4) Frequency of gear damage increases with depth. However, the frequency of major damage (i.e. severe enough to preclude use of the tow in stock assessment calculations) is not appreciable at depths routinely surveyed and for tows used in most stock assessments.

Introduction

Gear damage may have increased or decreased during recent surveys if mis-marked warps affected operating characteristics of the NEFSC survey bottom trawls. Gear damage data provide evidence about possible changes in net operating characteristics. However, gear damage data probably provide no information about changes in the fishing efficiency of NEFSC bottom trawls. Gear damage and fishing power are not directly linked because their relationship is unknown (a net prone to damage may catch more or less fish than a net not prone to damage), and because survey tows with major damage are routinely excluded from NEFSC stock assessment calculations.

We examined trends in survey tow records to determine if mis-marked warps changed the frequency of survey tows with gear damage. The information used was qualitative gear condition data recorded by the watch chief or chief scientist routinely following all bottom trawl survey tows. Although the data are qualitative, they were collected and recorded based on consistently applied and specific criteria that are available to all watch chiefs and chief scientists.

Tows included in the analysis were from all randomly allocated survey tows (STATYPE=1) by the NOAA Research Vessel *Albatross IV* using the Yankee No. 36 trawl during spring, fall and winter survey cruises beginning in 1983 (Table 3.2.1). Spring and fall surveys cover the same grounds and the all tows since 1983 used the same type of net. Winter surveys have consistently used a different net (with roller gear in place of a ground cable) and cover a smaller area that excludes rocky grounds (mainly on the northern half of Georges Bank) where gear damage may be more likely to occur.

Data used in this analysis were for tows at depths ≤ 620 m. The maximum depth of survey strata for tows used in stock assessments varies but is near 200 fathoms (366 m). Tows with STATYPE=1 at depths greater than 366 m were included (n=23, 0.2% of the total) because they provide useful information about gear damage at relatively extreme depths. However, tows deeper than 366 m are generally not used in stock assessment work because they are not "random" in the same way as tows randomly allocated to survey strata.

Gear damage was evaluated in in three main categories: i) "any" damage, including slight damage that does not prevent use of data from a survey tow in stock assessment work, ii) "major" damage that is severe enough to prevent use of stock assessment data from a tow, and iii) "minor" damage. The frequency of minor damage is of interest because most tows classified as minor for this analysis would also be used in stock assessments (the definitions of useful tows for stock assessment work and tows with minor damage for this assessment correspond approximately). Tows with minor damage were computed by subtraction (i.e. minor = any-major).

Survey bottom trawl tows with gear damage were identified in the NEFSC survey database using the GEARCOND variable, which is part of the data collected by the survey watch chief at the end of each tow. GEARCOND records the physical condition of the trawl on deck at the end of the tow, as judged by the watch chief or chief scientist based on specific criteria. For this analysis, tows with any gear damage were defined as tows with GEARCOND = 2 or larger. Tows with a major damage were defined as tows with GEARCOND=7 or larger.

GEARCOND=6 is used for tows that are obstructed by debris encountered during the tow. The probability of picking up debris is related to tow location and unlikely to be affected by mis-marked warps. Therefore, tows with GEARCOND=6 were excluded. Thus, the analysis dealt with the probability of gear damage in tows that were not significantly obstructed by debris.

A total of 11,402 tows were used in the analysis. In total, 1,102 tows (9.7%) had any gear damage (as defined above), 173 tows (1.5%) had major gear damage and 1102-173=929 tows (8.1%) had minor damage (Table 1 and Figures 3.2.1 to 3.2.3). Proportions for fall, spring and winter surveys were similar (see below).

	N Tows	Proportion tows with "any" gear problems (GEARCOND ≥2)	Proportion tows with "major" gear problems (GEARCOND ≥7)	Proportion tows with "minor" gear problems (GEARCOND ≥7)
FALL	4696	0.0945	0.0132	0.0813
SPRING	5402	0.0950	0.0139	0.0811
WINTER	1304	0.1112	0.0276	0.0836
All	11402	0.0966	0.0152	0.0815

There is no evidence that mis-marked warps increased the probability of gear damage based on trends in frequencies of damaged gear (Table 3.2.1 and Figure 3.2.3). Frequencies of damaged bottom trawls in surveys during 2002-2003 with mis-marked warps were generally lower than average. In particular, six out of eight surveys (75%) during 2000-2002 had lower than average levels of any gear damage. Four out of eight surveys (50%) during 2000-2002 had below average levels of major gear damage. Gear damage was more variable for the fall survey prior to 1988 and for the winter survey prior to 1996. Trends in gear damage for recent surveys with mis-marked warps were similar to trends in prior years.

Modeling

Generalized additive models (GAMs) were used to refine estimates of probability for gear damage during each cruise. Separate GAM models for major and minor gear damage were fit to tow-by-tow survey data by maximum likelihood assuming that the occurrence of gear damage followed a binomial distribution (i.e. as in logistic regression). Cruise id number, season (fall, spring or winter) and mis-marked warps were treated as categorical variables. Treating cruise id numbers as a categorical variable is, in effect, the same as including statistical interactions between all categorical variables that change from survey to survey (i.e. year, season, vessel and type of trawl) and makes season almost redundant. Average tow depth and swell height were included in models as covariates. The relationship between frequency of gear damage and covariates was modeled using loess scatter plot smoothers. The loess term for depth, for example, was a smooth line that allowed estimates of depth effects on gear damage to change continuously with depth.

Swell height was missing in 762 out of 11,402 tows (6.7% of the total) but was not significant in preliminary model runs using the subset of tow records that included swell height data. Therefore, swell height was omitted from further GAM modeling.

Final GAM models were identified using F-tests to measure goodness of fit. A stepwise procedure identified the best final model by eliminating variables with insignificant effect on model fit. However, mis-marked warp effects were always included in final models because they are of special interest. The best model for any damage included warps, cruise, and depth effects. The best model for major damage included only warp and depth effects.

Based on GAM model results, there was no evidence of increased probability of any or major gear damage in cruises with mis-marked warps. Warp effect estimates were very small and statistically insignificant in final models (Figure 3.2.4). Depth had a much stronger effect on the probability of gear damage than any other variable. The probability of any or major damage increases steadily with depth and loess terms for depth were highly significant ($p < 0.0000001$) in both models.

To describe the effects of depth in simple terms, predicted percent tows with any damage and with major damage were calculated from GAM models fit to data for years with and without potential warp effects. The probability of gear damage during cruises with mis-marked warps fell within the range for cruises without the potential problem (Figure 3.2.5). The probability of major gear damage during cruises with and without mis-marked warps was similar at depths < 360 m (Figure 3.2.5). Results for major damage at depths greater than 360 m were erratic for mis-marked warps due to scarcity of tows in deep water during 2000-2002.

The probability of any gear damage averages about 10% at depths less than 220 m and increases to about 25% at 360 m. The probability of major gear damage increases with depth and is less than 6% at all depths less than 360 m. For data collected at depths < 360 m and routinely used in stock assessments, almost all gear damage was minor.

Table 3.2.1. Gear damage and summary information for bottom trawl survey cruises by the *R/V Albatross IV* during 1983-2002. The proportion tows with “any” gear damage is the proportion tows with GEARCOND ≥2. The proportion tows with “major” gear damage is the proportion tows with GEARCOND≥7. Proportion tows with “minor” gear problems was computed by subtraction (any-major). Obstructed tows (GEARCOND=6) were excluded Eight surveys during 2000-2002 had mis-marked warps.

Cruise	Year	Season	N Tows	Proportion tows with “any” gear problems (GEARCOND ≥2)	Proportion tows with “major” gear problems (GEARCOND ≥7)	Proportion tows with “minor” gear problems (GEARCOND ≥7)
198306	1983	Fall	410	0.059	0.010	0.049
198405	1984	Fall	347	0.115	0.009	0.107
198508	1985	Fall	148	0.122	0.027	0.095
198606	1986	Fall	251	0.187	0.012	0.175
198705	1987	Fall	319	0.053	0.016	0.038
198803	1988	Fall	305	0.079	0.013	0.066
199206	1992	Fall	332	0.123	0.018	0.105
199406	1994	Fall	332	0.120	0.018	0.102
199507	1995	Fall	329	0.067	0.006	0.061
199604	1996	Fall	315	0.137	0.022	0.114
199706	1997	Fall	318	0.072	0.006	0.066
199804	1998	Fall	322	0.084	0.012	0.071
199908	1999	Fall	326	0.077	0.015	0.061
200005	2000	Fall	317	0.060	0.003	0.057
200109	2001	Fall	325	0.105	0.018	0.086
198303	1983	Spring	410	0.132	0.015	0.117
198402	1984	Spring	400	0.098	0.013	0.085
198502	1985	Spring	371	0.078	0.016	0.062
198603	1986	Spring	362	0.088	0.006	0.083
198702	1987	Spring	281	0.121	0.007	0.114
198801	1988	Spring	315	0.067	0.010	0.057
199202	1992	Spring	316	0.095	0.013	0.082
199302	1993	Spring	319	0.103	0.013	0.091
199503	1995	Spring	325	0.055	0.012	0.043
199602	1996	Spring	344	0.142	0.026	0.116
199702	1997	Spring	326	0.077	0.012	0.064
199802	1998	Spring	360	0.097	0.017	0.081
199902	1999	Spring	317	0.066	0.016	0.050
200002	2000	Spring	325	0.095	0.015	0.080
200102	2001	Spring	315	0.095	0.016	0.079
200202	2002	Spring	316	0.101	0.016	0.085
199201	1992	Winter	62	0.048	0.032	0.016
199301	1993	Winter	116	0.043	0.000	0.043
199502	1995	Winter	151	0.179	0.040	0.139
199601	1996	Winter	134	0.112	0.037	0.075
199701	1997	Winter	124	0.121	0.032	0.089
199801	1998	Winter	133	0.128	0.023	0.105
199901	1999	Winter	139	0.122	0.036	0.086
200001	2000	Winter	124	0.105	0.032	0.073
200101	2001	Winter	167	0.114	0.018	0.096
200201	2002	Winter	154	0.091	0.026	0.065

Figure 3.2.1. Location of tows by the *R/V Albatross IV* with "any" damage in NEFSC fall, spring and winter surveys during 1983-2002.

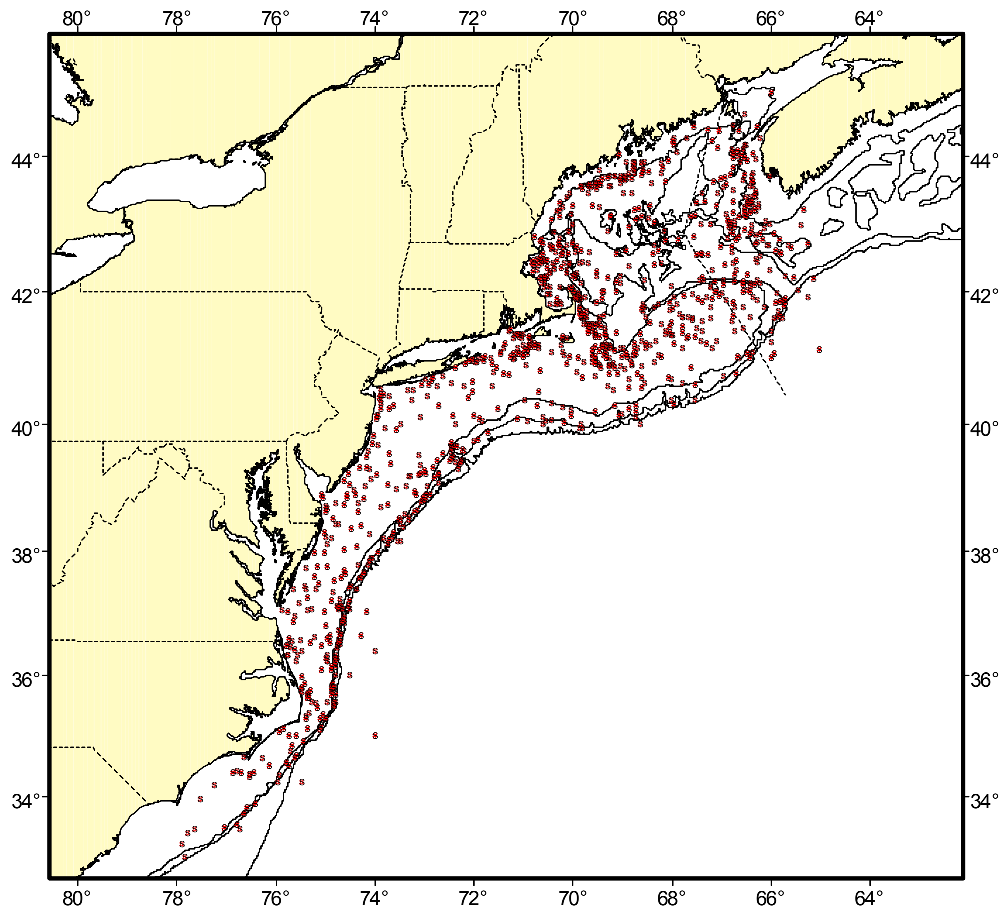


Figure 3.2.2. Location of tows by the *R/V Albatross IV* with “major” damage in NEFSC fall, spring and winter surveys during 1983-2002.

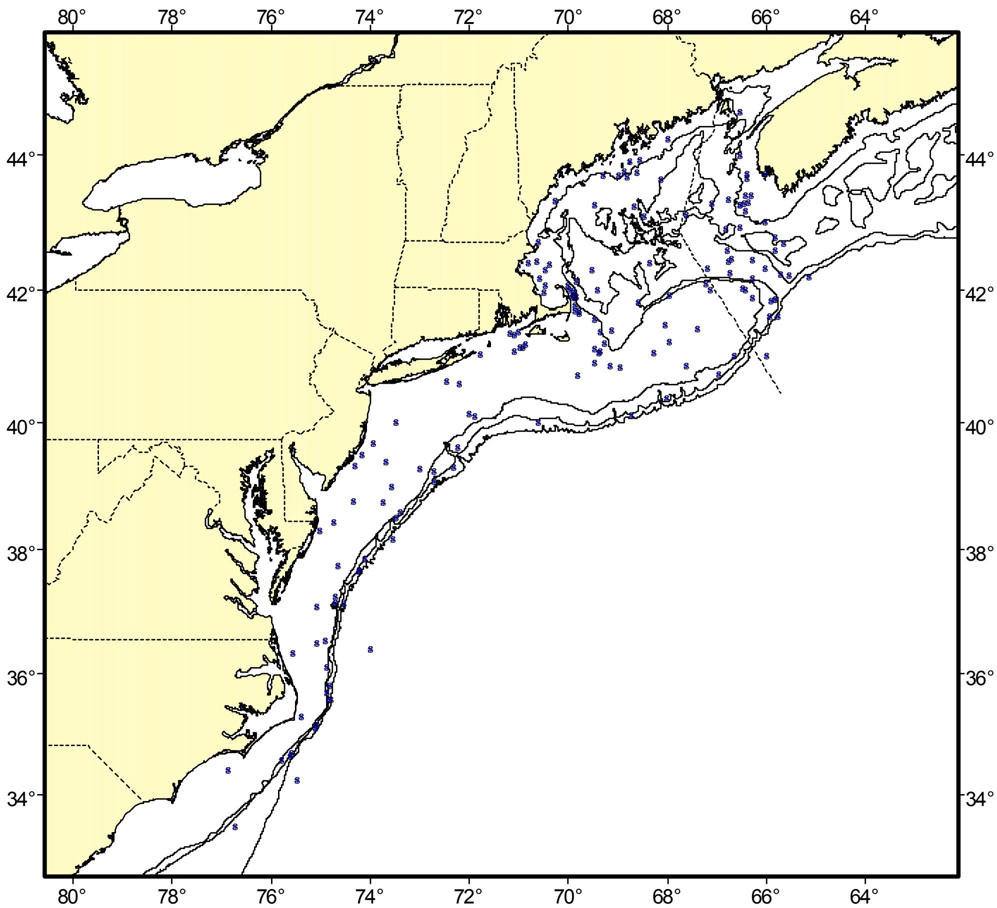
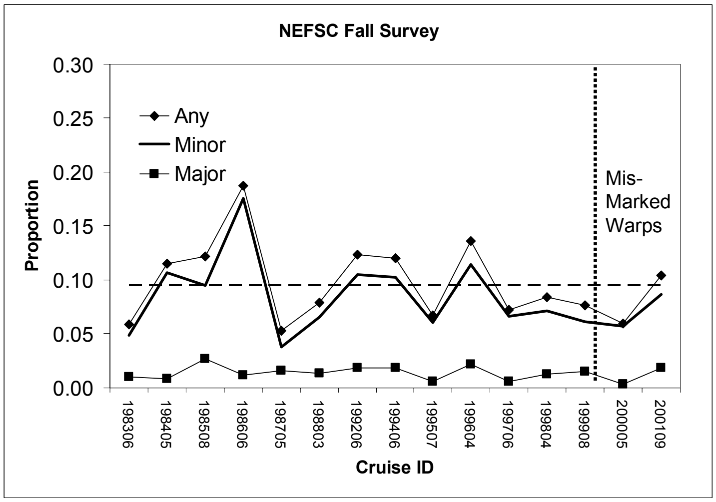
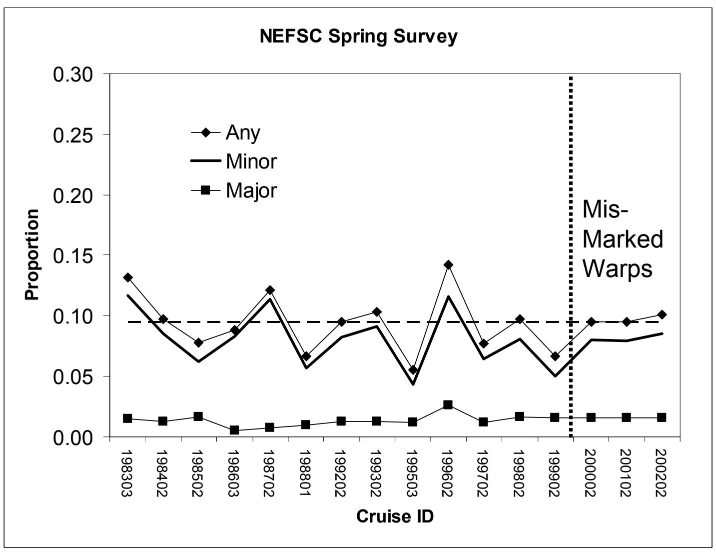


Figure 3.2.3. Proportion of tows with any, minor and major damage in NEFSC fall, spring and winter surveys during 1983-2002. The vertical line in each plot separates tows with and without mis-marked warps. The horizontal line in each plot shows the average proportion of tows in each survey with any gear damage.





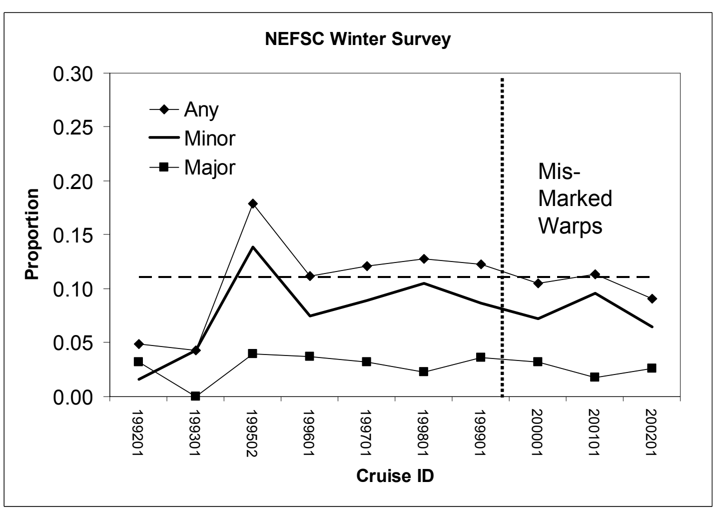


Figure 3.2.4. Estimated warp effects in the final GAM model for the frequency of any damage during NEFSC survey tows. The dotted lines are 95% confidence intervals for the parameter estimates. Results from models for major damage were similar.

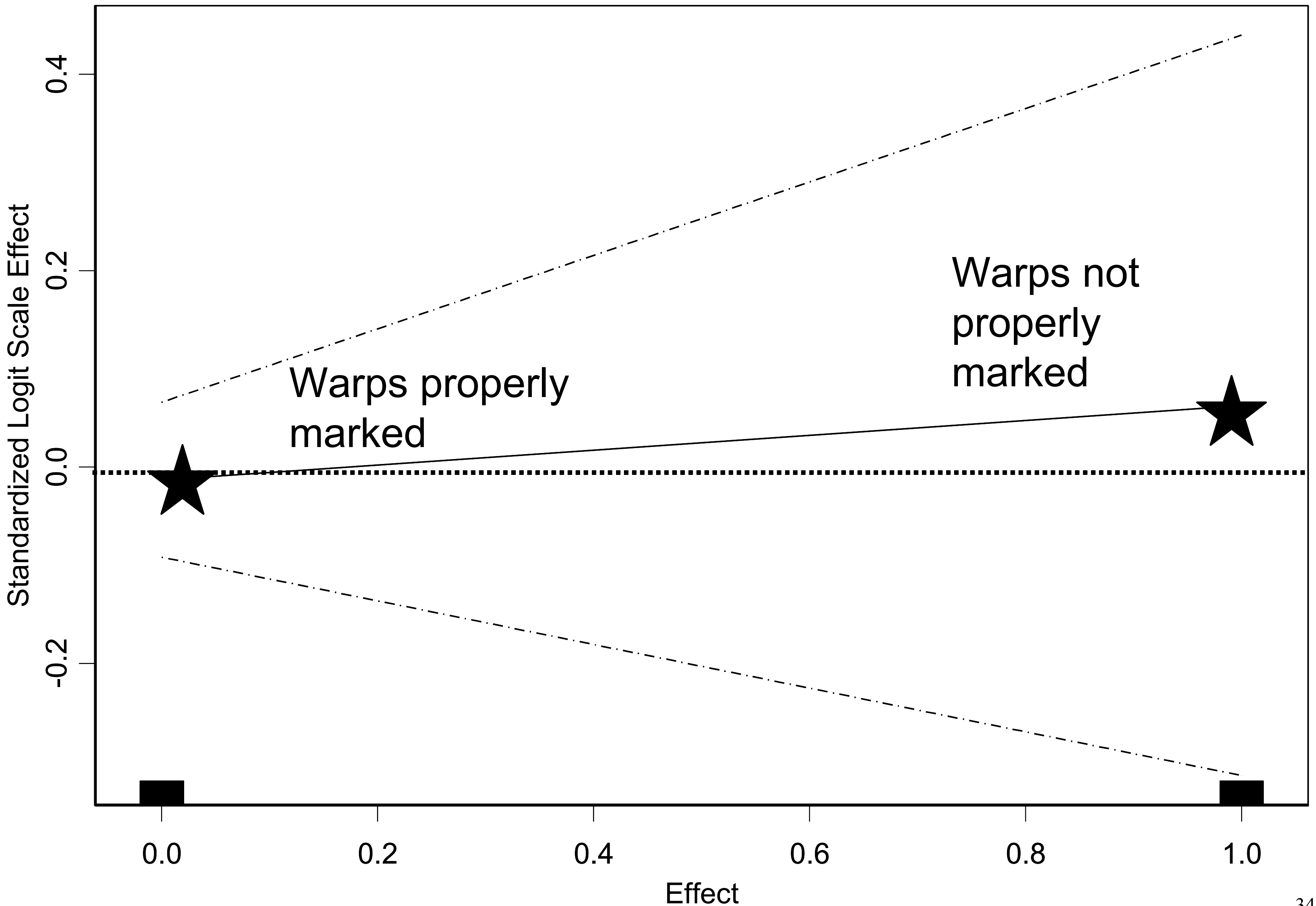
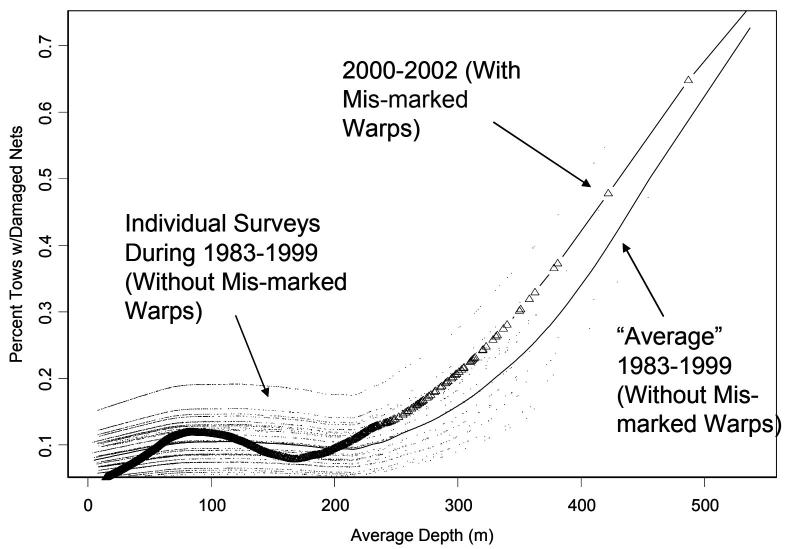
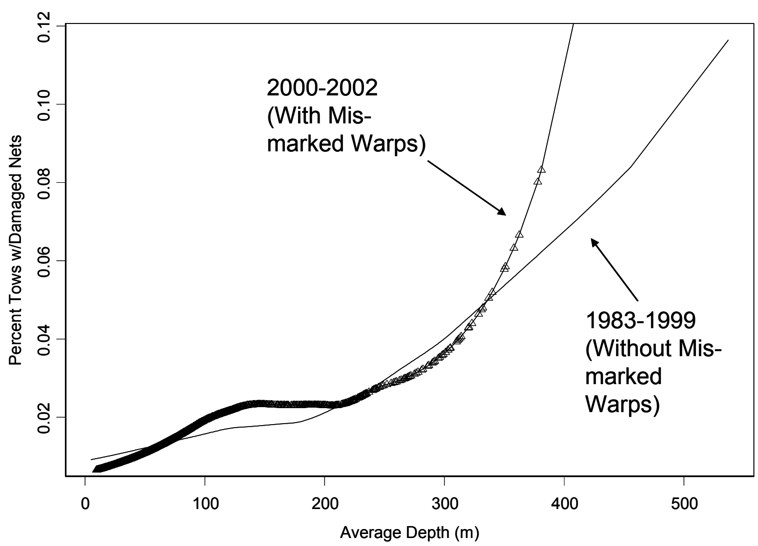


Figure 3.2.5. Predicted frequency of tows with any (top) and major (bottom) gear damage as a function of tow depth, based on separate GAM models for surveys during 2000-2002 with mis-marked warps and surveys during 1983-2001 without mis-marked warps. The GAM model for any damage with warp effects includes depth only. The best GAM model for any damage included cruise effects and predictions for each cruise are plotted ".". In addition, "average" results for any damage from a simplified model with cruise effects omitted are also shown.





3.3 Evaluation of Fish Size in Relation to Offsets

Summary and Conclusions

There is no evidence that mis-marked warps affected length composition of cod, haddock or yellowtail flounder taken by the *R/V Albatross IV*. Mis-marked warps did not appear to reduce or increase, on a proportional basis, the catch of large or small fish.

Introduction

In this analysis, survey length composition data from NEFSC survey bottom trawls with mis-marked warps were compared to length composition data from other bottom trawl surveys and from commercial bottom trawls. The purpose of the analysis was to test the hypothesis that mis-marked warps affected the catch of small or large fish in NEFSC survey bottom trawls during 2000-2002. The analysis focused on three key species (cod, haddock and yellowtail flounder) and there were three groups of comparisons (see below).

The first group of analyses (Figures 3.3.1 to 3.3.3) used data from NEFSC and DFO (Department of Fisheries and Oceans Canada) spring surveys over the Canadian portion of Georges Bank during 1997-1999 ("pre-warps") and 2000-2002 ("post warps"). Both spring bottom trawl surveys cover the same area on Georges Bank at about the same time of year. The Canadian portion of Georges Bank (DFO bottom trawl strata 5Za-5Zb; NEFSC offshore survey strata 16-18 and 21-22) was selected for analysis because fish abundance is relatively high on the Canadian side and intensity of DFO sampling is reduced in US portions of Georges Bank. Data were for depths less than 100 fathoms (183 m) because the DFO survey does not sample deeper water near Georges Bank.

The second group of analyses involved monkfish length composition data for the Georges Bank and Mid-Atlantic Bight areas from the 2001 NEFSC winter bottom trawl survey (with mis-marked warps) and length composition data collected by commercial vessels (6 inch mesh codends with no liner) during the 2001 cooperative monkfish survey.

The third group of analyses involved length composition data for paired tows in a fishing power experiment during the 2001 NEFSC spring bottom trawl survey. For the fishing power experiment, the *R/V Delaware II* (no mis-marked warps) towed the same type of net beside the track towed by the *R/V Albatross I* (with mis-marked warps) at the same time or approximately the same time. The purpose of the experiment was to calibrate catches by the vessels. Problems with mis-marked warps on the *R/V Albatross IV* were unknown at the time. Fishing power of the two vessels differs for some species but length composition data depend primarily on the type and configuration of the trawl. Thus, length composition data from the two vessels should differ if mis-marked warps affected the length composition of catches by the *R/V Albatross IV*.

Average length composition data for each time period were used in most comparisons. Averages were computed by expressing the length composition for each survey (or tow) as proportions and then averaging the proportions for each survey.

Results

Length composition data for cod and yellowtail flounder from the Canadian portion of Georges Bank were similar in the two spring surveys and in the pre-and post warp periods (Figures 3.3.1 to 3.3.3). The DFO survey took more large haddock and less small haddock, on a proportional basis, than the NEFSC survey during both periods. Length composition data for haddock in the NEFSC survey appear more variable than for the DFO survey, probably because the sample size (number of tows, see below) is lower in the NEFSC survey for the Canadian side of Georges Bank. Given the sample size for NEFSC surveys, the wide range of sizes, and natural variability in haddock, the differences in length composition data for haddock in the pre- and post-warp periods are best attributed to random variability in the data.

Survey	**Number Pre-Warp Tows (1997-1999)**	**Number Post warp Tows (2000-2002)**
NEFSC Spring	67	65
DFO	127	131

Length composition data from the 2001 NEFSC bottom trawl survey and commercial vessels in the Cooperative Monkfish Survey show that NEFSC survey bottom trawls took proportionally more small monkfish due to the small mesh liner in survey bottom trawls (< 25 cm, Figure 3.3.4). However, length composition data for larger monkfish (> 25 cm) were similar suggesting that mis-marked warps had little effect on size composition of monkfish in the NEFSC survey.

Length composition data from paired tows by the R/V *Albatross IV* (with mis-marked warps) and R/V Delaware II (without mis-marked warps) during the 2002 spring survey fishing power experiment were virtually identical for cod, haddock and yellowtail flounder (Figure 3.3.5).

Fig. 3.3-1. Length composition data for cod on Georges Bank in spring surveys.

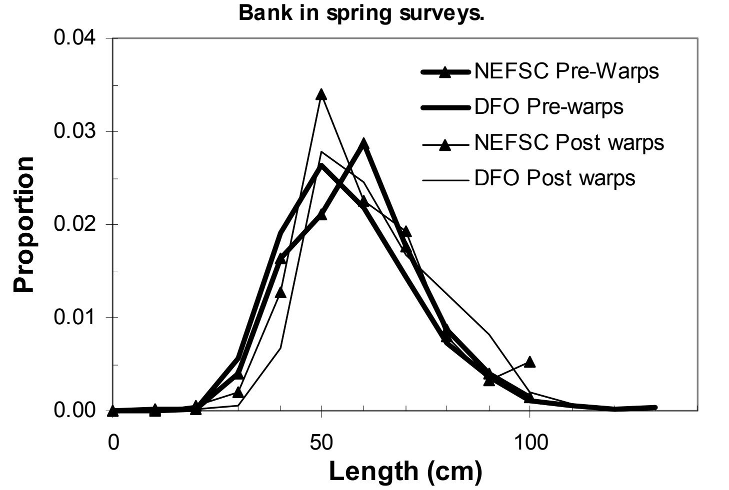


Fig. 3.3-2. Length composition data for haddock on Georges Bank in spring surveys.

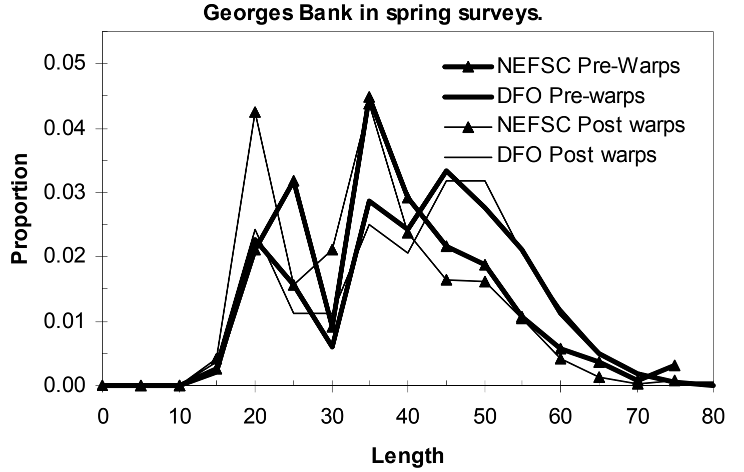


Fig. 3.3-3. Length composition data for yellowtail flounder on Georges Bank in spring surveys.

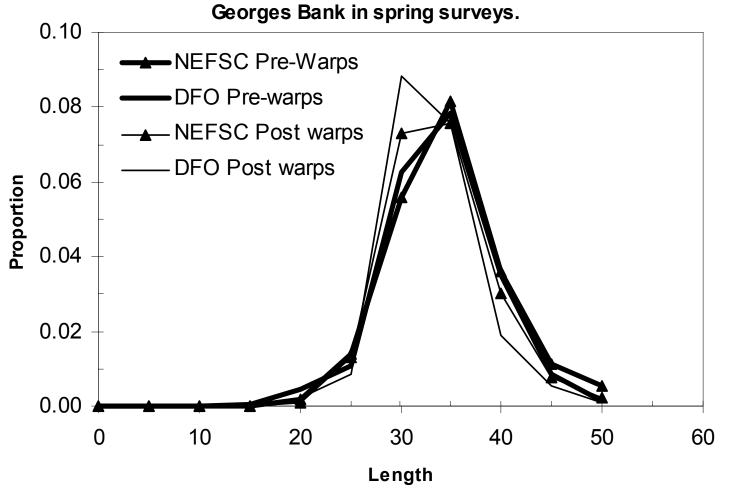


Figure 3.3-4. Length compostion data for monkfish during 2001 in the NEFSC winter survey (northern and souther areas) and commercial vessels in the Cooperative Monkfish Survey (southern area).

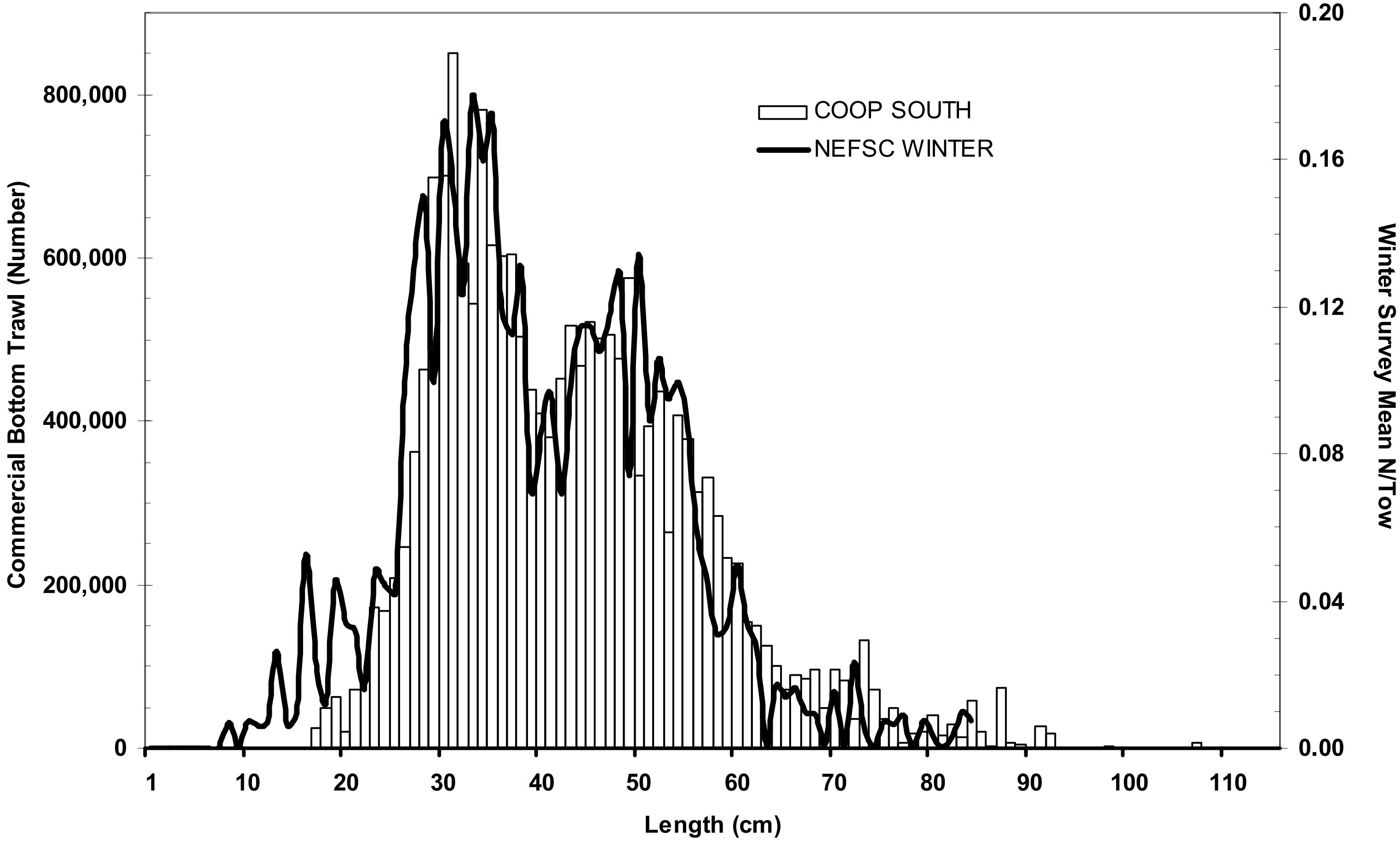
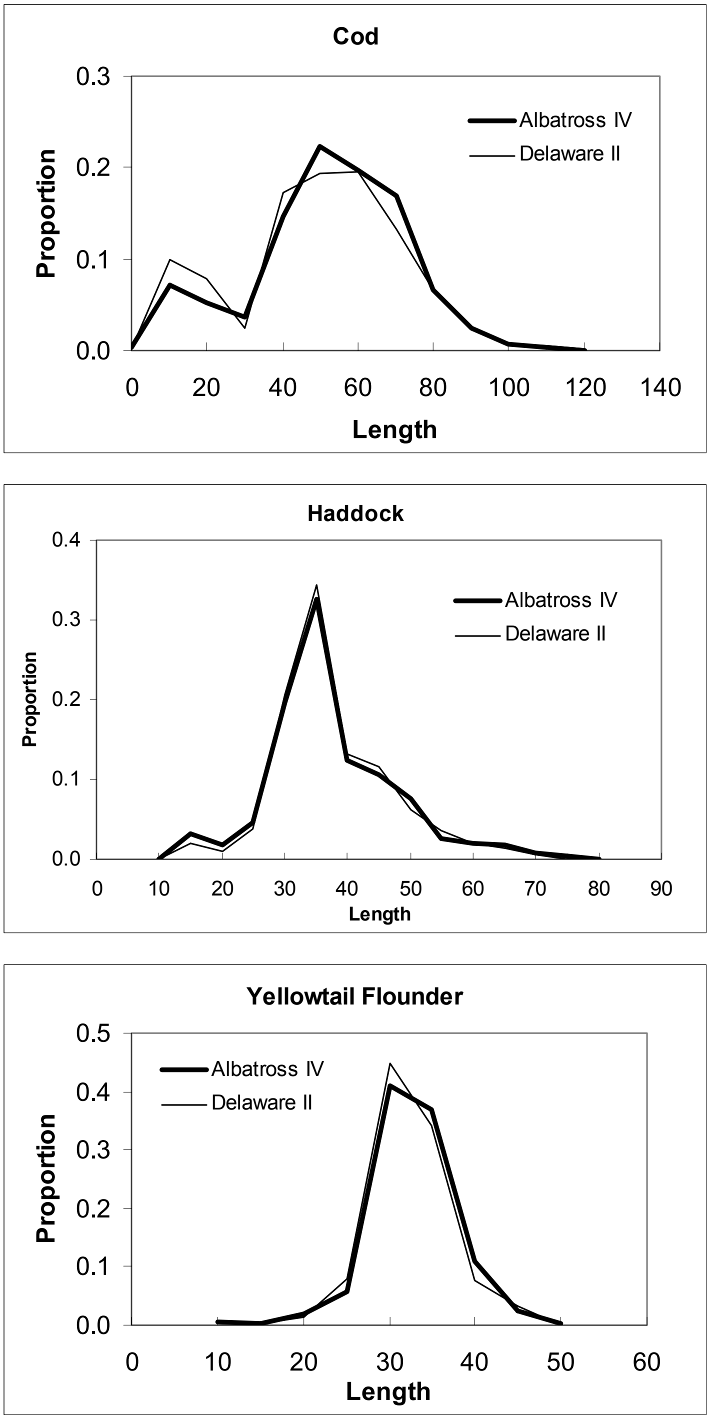


Figure 3.3.5. Length composition data for cod, haddock and yellowtail flounder in paired tows for a fishing power experiment during the spring of 2002.



3.4 Evaluation of Gear Mensuration Data from the R/V *Albatross IV* Trawl Warp Offset Experiment

The effects of trawl warp length offsets on the gear performance of the R/V *Albatross* were assessed during a controlled experiment, conducted on September 25-26, 2002, at six stations ranging in depth from 46-91 m (Figure 3.4.1). During each tow, gear performance was assessed through videotaping and logging of gear mensuration data from Simrad sensors mounted on the doors and the trawl wing ends and headrope of a Yankee 36 net. In addition, several other variables logged by the Simrad ITI system, such as speed over ground, vessel location and water depth were evaluated.

During each tow, warp length offsets of 0 ft. (equal port and starboard warp lengths), 2 ft., 4 ft., 6 ft., and 12 ft. were paid out from the starboard side of the vessel, followed by the port side of the vessel. An additional offset of 18 ft. was fished at the deepest station sampled (station 907). At each station, the trawl winches were locked and the trawl was allowed to reach the bottom and stabilize before beginning the experiment. During each tow, the trawl remained in the water throughout all offset changes, and after consistent sensor readings were observed, was allowed to fish for variable periods of time.

Changes in trawl geometry were evaluated graphically and statistically. Wing spread and headrope height readings from each station were graphed over time, between the winch lock and re-engage period, and each warp offset change was denoted. No headrope height readings were obtained at station 904. Door spread was not evaluated because the door sensors did not operate consistently. However, door spread is geometrically related to wing spread and wing spread data were evaluated.

In summary, graphs of headrope height and wingspread were similar across warp offset treatments (horizontal trend) and there was no indication of a change in this trend across stations (depths; Figure 3.4.2).

Headrope height and wingspread data, for port and starboard offsets were also evaluated statistically. At each station, the means and standard deviations of headrope height and wingspread were calculated separately, for port and starboard offsets, for each warp offset time interval (Figure 3.4.3). Headrope height and wingspread data collected at stations 904 and 905 represent single readings, so no statistical evaluation of these data was conducted. Means and standard deviations of headrope height and wingspread for the combined stations (stations 906, 907, 908 and 909) were also computed.

In summary, port and starboard wingspread means for each warp offset treatment were similar. The same was true for headrope height means. In addition, there was no significant difference detected between wingspread means for warp length offsets of 0-6 ft. at depths of 49-91 m. The same was true for headrope height means. Differences between headrope height means for even warps and warp length offsets of 12 ft. varied in significance between stations. The same was true for wingspread means. There was no significant difference detected between wingspread means, for all stations combined, for warp length offsets of 0-12 ft. at depths of 49-91 m. The same was true for headrope height means for all stations combined (Figure 3.4.4). At the deepest station (91 m), there was no significant difference between headrope height means of warp length offsets of 0-18 ft. The same was true for wingspread means for the starboard side.

These data indicate that even at warp offsets greater than depths where groundfish stocks are typically found (Figure 3.7.31), the net remains spread and open, with mensuration readings very similar to the no-offset condition. While this does not prove that warp offsets on catch rates are negligible, had net dimensions changed dramatically, survey catches would most likely have been affected.

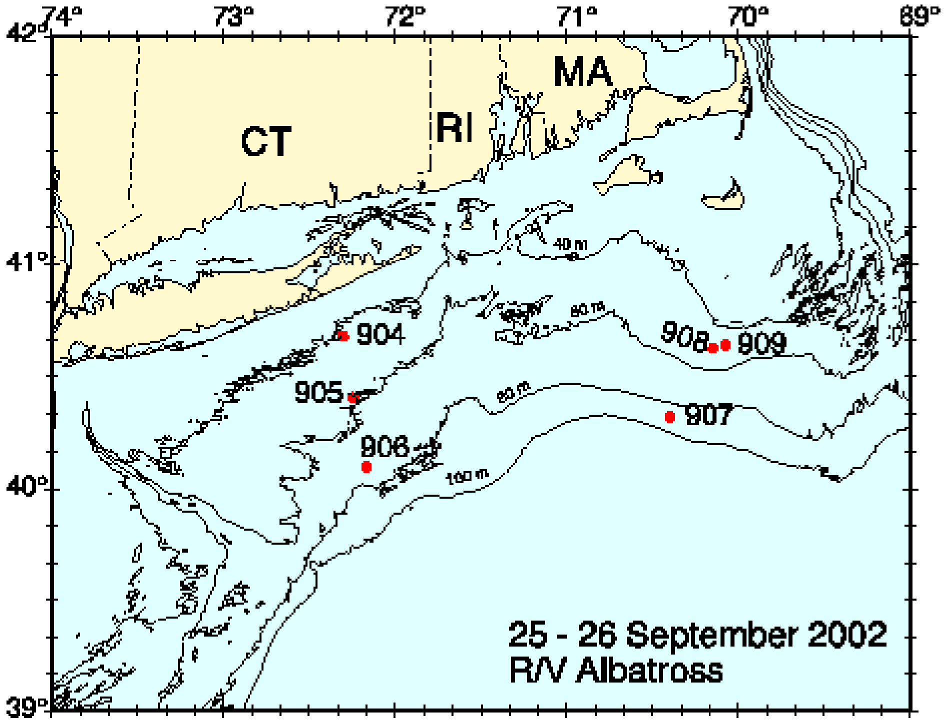


Figure 3.4.1. Locations of stations where video and trawl sensor data were collected to assess the effects of warp length offsets on the trawl performance (Yankee 36 net) of the R/V *Albatross IV* during 25-26 September, 2002.

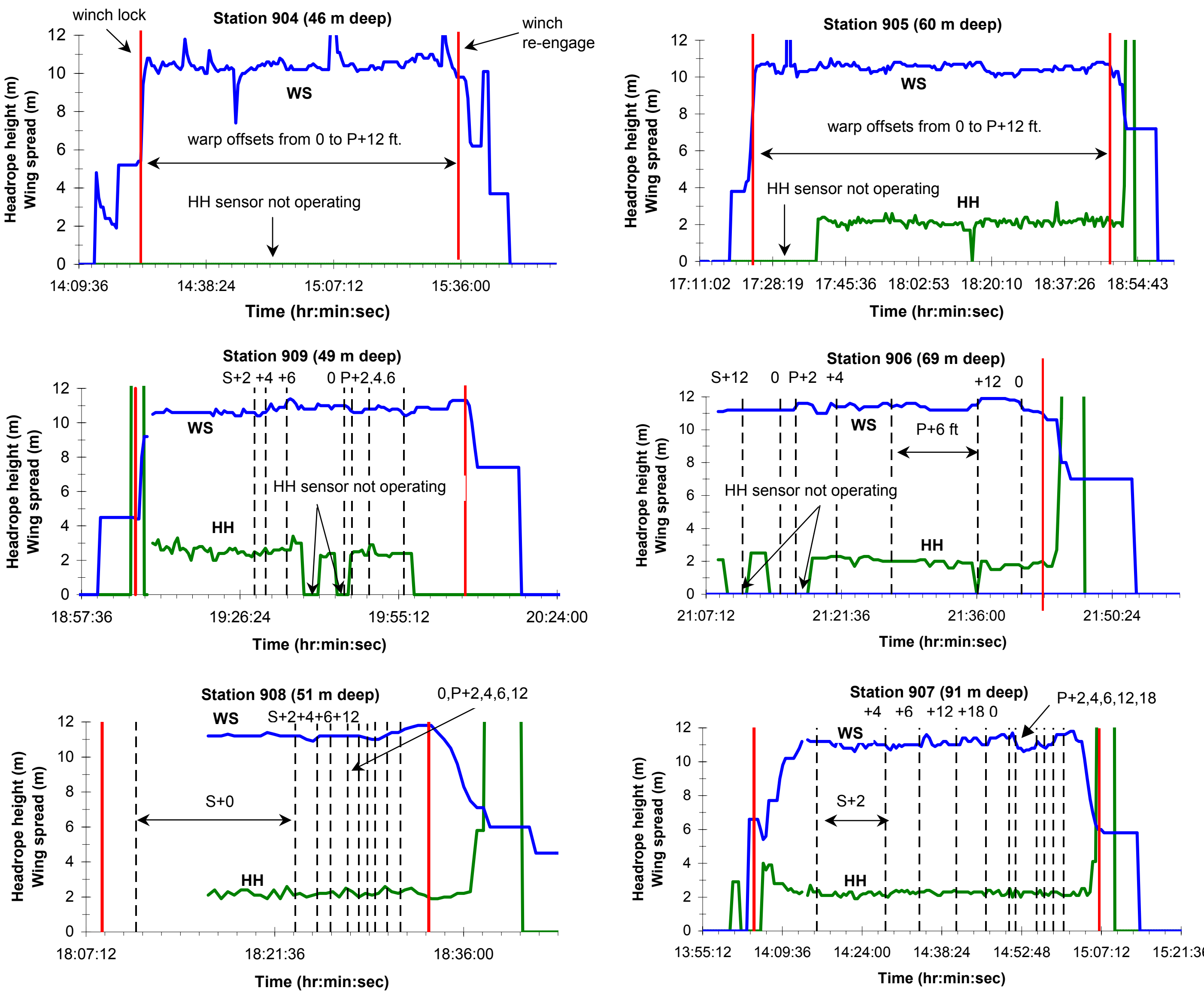
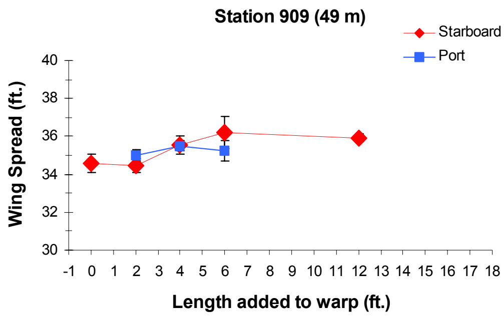
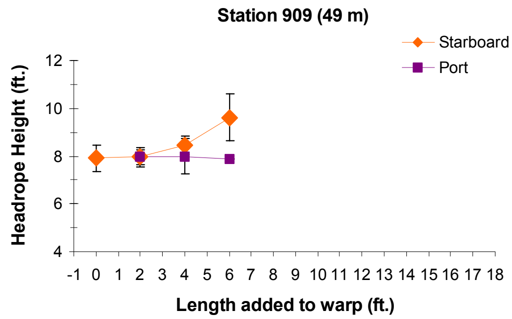
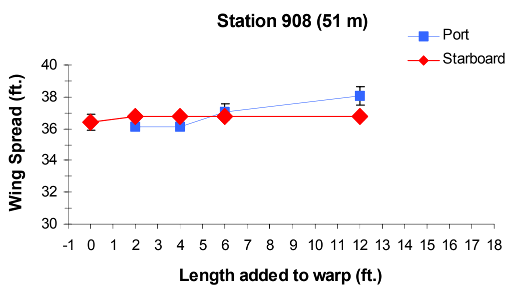
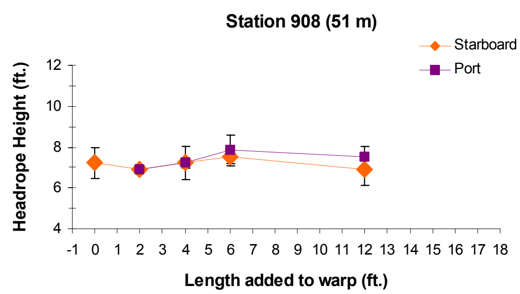


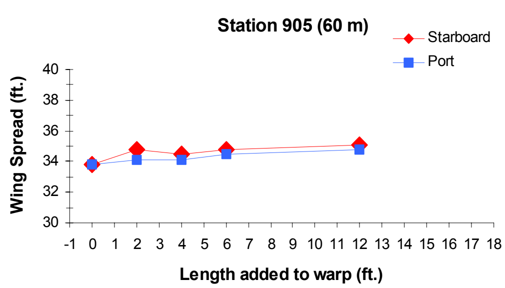
Figure 3.4.2. Yankee 36 headrope height (ft.) and wing spread (ft.) measurements recorded by the Simrad ITI system of the R/V *Albatross IV* at stations sampled during a 25-26 September, 2002 warp length offset experiment. Dashed lines represent starboard (S) and port (P) trawl warp length offsets of 0 ft., 2 ft., 4 ft., 6 ft., 12 ft. and 18 ft.

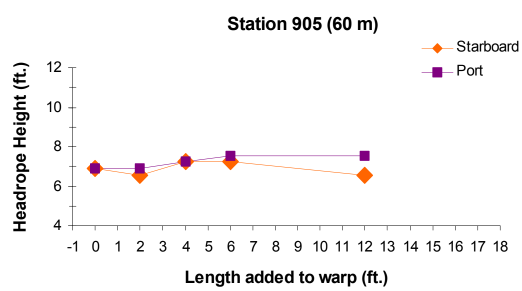

Station 909 (49 m)
Starboard
Port
Wing Spread (ft.)
30 32 34 36 38 40
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)

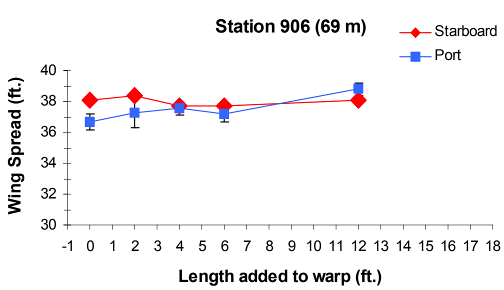

Station 909 (49 m)
Starboard
Port
Headrope Height (ft.)
4 6 8 10 12
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)

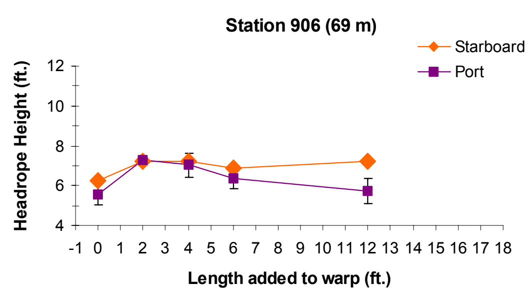

Station 908 (51 m)
Port
Starboard
Wing Spread (ft.)
30 32 34 36 38 40
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)

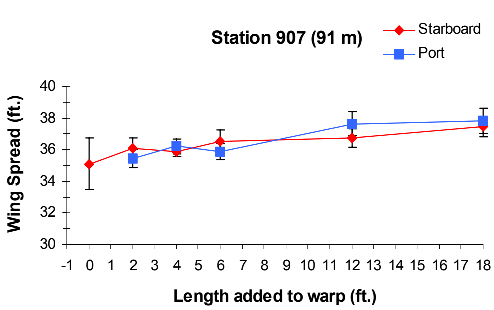

Station 908 (51 m)
Starboard
Port
Headrope Height (ft.)
4 6 8 10 12
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)

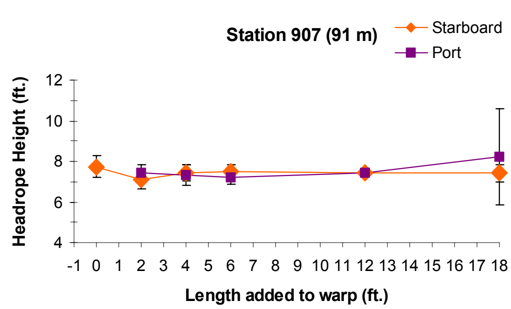

Station 905 (60 m)
Starboard
Port
Wing Spread (ft.)
30 32 34 36 38 40
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)

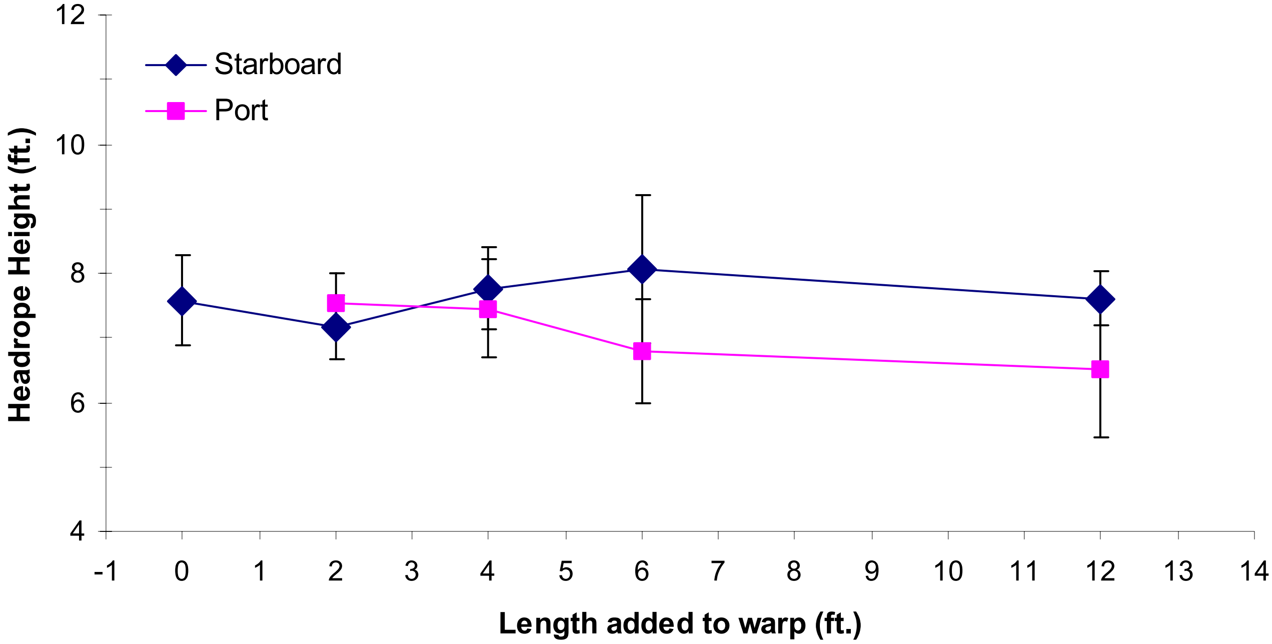

Station 905 (60 m)
Starboard
Port
Headrope Height (ft.)
4 6 8 10 12
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)


Station 906 (69 m)
Starboard
Port
Wing Spread (ft.)
30 32 34 36 38 40
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)


Station 906 (69 m)
Starboard
Port
Headrope Height (ft.)
4 6 8 10 12
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)


Station 907 (91 m)
Starboard
Port
Wing Spread (ft.)
30 32 34 36 38 40
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)


Station 907 (91 m)
Starboard
Port
Headrope Height (ft.)
4 6 8 10 12
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Length added to warp (ft.)



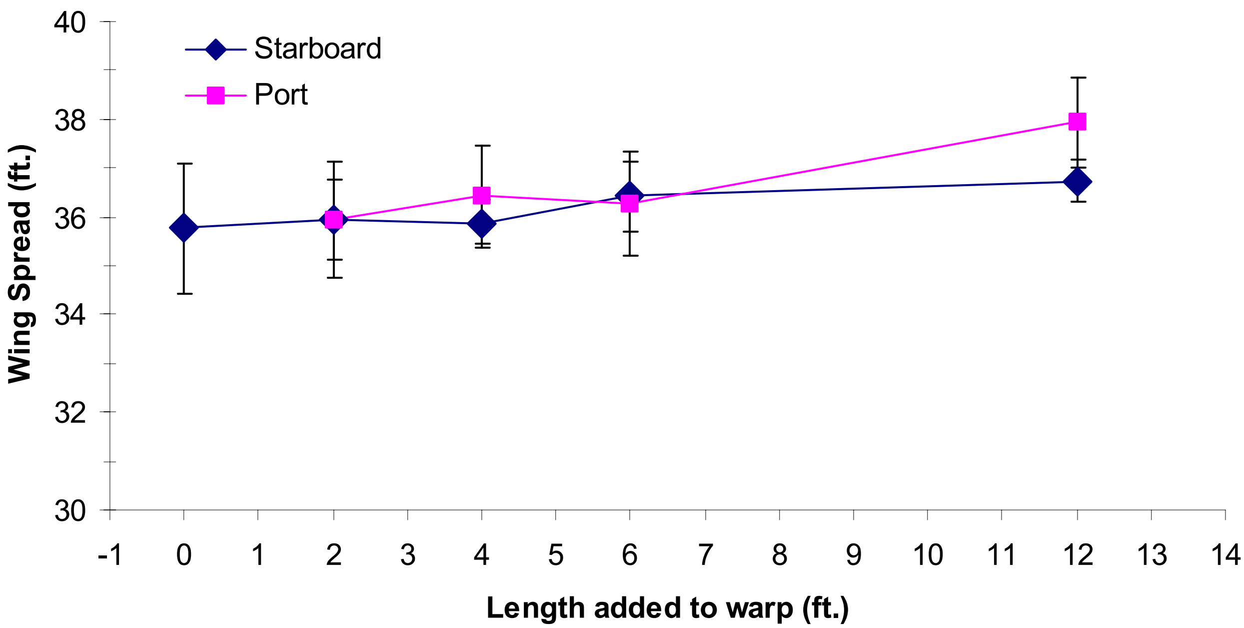


Figure 3.4.4. Means and standard deviations of headrope height (ft.) and wing spread (ft.) measurements of the Yankee 36 net of the R/V *Albatross IV,* at starboard and port trawl warp length offsets of 0 ft., 2 ft., 4 ft., 6 ft., 12 ft., for stations 906, 907,908 and 909 combined. Starboard warp offsets of 0-6 ft. do not include station 906 because these data were not obtained.

3.5 Models to Evaluate Changes in Relative Efficiency

The nature of the mismarked cables (i.e., discrepancies increasing with wire length) and the basic geometry of asymmetry suggest that the catchability bias should increase monotonically with depth. A variety of simple models were examined to explain potential effects of reduced catchability. A basic derivation of the alternative models is presented below.

Regression analysis of warp difference vs. fishing depth (Fig. 3.1.1) suggests a highly significant regression (R^2=0.98) in which the warp difference $\boldsymbol{dW}$ is proportional to depth $\boldsymbol{D}$.

$$dW = 0.0134\, D \qquad (1)$$

Since the NEFSC trawl surveys began in 1963, 99.9% of the tows have been conducted at depths of less than 390 m. This suggests that the maximum value of dW should be about 5.55 m. If the reduction in relative efficiency dE is proportional to the ratio of the $\boldsymbol{dW}$ to $\boldsymbol{dW_{max}}$ then one can write

$$dE = \left(\frac{dW}{dW_{\max}} \right) H_{effect} \qquad (2)$$

where $\boldsymbol{H_{effect}}$ is an assumed level of reduction in efficiency at the maximum depth. For example, if 99% of the fish would have been captured at shallower depths were not captured at depth $\boldsymbol{D_{max}}$ then $\boldsymbol{H_{effect}}$ = 0.99. The revised estimate of catch can then be written as

$$C_{rev} = \frac{C_{obs}}{1 - dE} = \frac{C_{obs}}{1 - \left(\frac{0.0134\, D}{W_{\max}} \right) H_{effect}} \qquad (3)$$

Equation 3 can be used to explore the consequences of varying levels of reductions in catch efficiency. For example, the ability to the model to explain a 2X increase in abundance (e.g., if the survey estimates in 2002 were actually 100% higher than estimated) can be tested by summing overall depths and catches in a survey.

$$\sum_j C_{j\,rev} = 2\sum_j C_{j,obs} = \sum_j \left(\frac{C_{j,obs}}{1-\left(\frac{0.0134D_j}{W_{\max}}\right)H_{effect}} \right) \quad (4)$$

Initial tests with this model however, suggested that it was inadequate to explain increases in catch as high as 50%. This occurs because H_{effect} must be less than 1.0. This simple model deduction suggested that the warp offset effect, if it exists, must be nonlinear. Another simple model that allows for more complicated behavior is to define ***dE(D)*** as

$$dE = \left(\frac{dW}{dW_{\max}}\right)^{\theta} = \left(\frac{0.0134D}{dW_{\max}}\right)^{\theta} \quad (5)$$

where θ can vary from 0 to infinity. When θ exceeds 1 dE will become smaller. As dE approaches zero, dE will approach 1. Substituting Eq. 5 into Eq. 3 leads to Model 2, which is defined as:

$$C_{rev} = \frac{C_{obs}}{1-dE} = \frac{C_{obs}}{1-\left(\frac{0.0134\,D}{W_{\max}}\right)^{\theta}} \quad (6)$$

Model 2 (Eq. 6) allows for changes in relative efficiency that are linear when θ is 1, convex when θ <1 concave when θ >1. Note that the expression dW/dW_{max} will always be less than one. Model 2 assumes that the reduction in efficiency will approach 1 as depth approaches Dmax when θ is less than one. Under these conditions, the rescaled catch will be much higher than the observed, and the hypothesized effect of a small warp offset is large even at the most shallow depths. In contrast, the reduction in efficiency will stay near zero at nearly all depths when θ >>1, and relatively little difference in catch rates should be evident. The basic premise of the model is that the effect of the warp offset on gear performance should be a monotonically increasing function of warp offset (Fig. 3.5.1). Since the magnitude of warp offset increases with fishing depth, reductions in catch should be more evident at deeper stations.

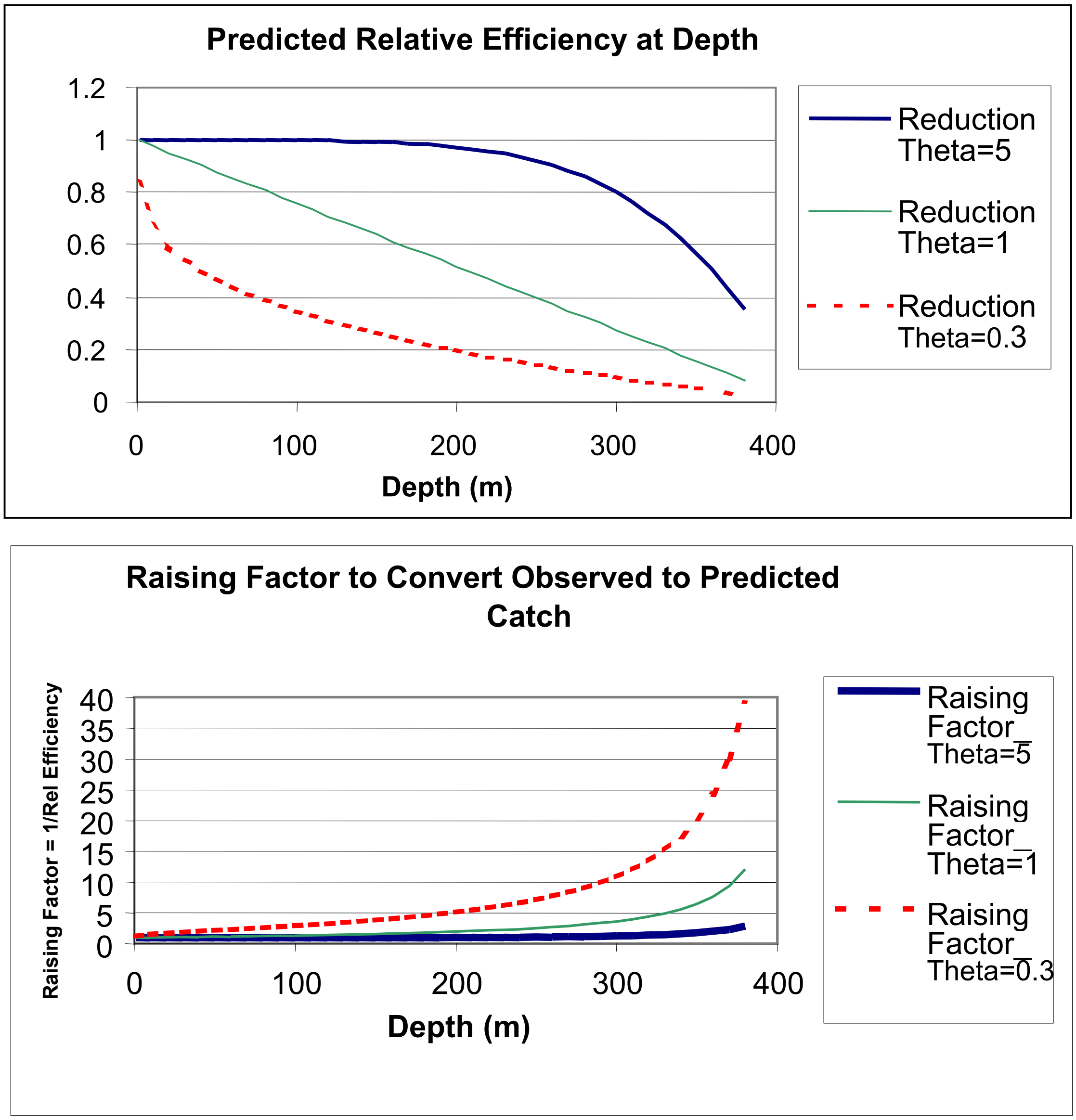


Fig. 3.5.1. Example behavior of Model 2 (Eq. 6) for varying levels of θ. Top panel shows predicted decline in relative efficiency. Bottom panel illustrates raising factor that would be applied to convert observed catch to predicted catch without the warp offset effect.

3.6. Variance vs. Mean Relationships

We hypothesized that potential reductions in gear efficiency owing to asymmetric trawl warps may lead to decreases in average catch rates and increases in variance of estimates. To test this hypothesis, we examined survey data from the NEFSC database for the fall, spring, and winter surveys for the period 1963 to 2002. A database of 28,734 tows for 22 species-stocks was used. Total catch in numbers and total weight per tow were the primary response variables; no age or length information was used. Survey catches were subsequently processed to compute statum means and variances (Section 3.6) as well as catch-weighted average depths (Section 3.7). Where appropriate, defined management-based stocks were treated separately. The species (stocks) were—cod(GB,GOM), haddock(GB, GOM), yellowtail flounder(GB, SNE, CC), American plaice, witch flounder, redfish, pollock, halibut, white hake, winter flounder (GB, SNE), windowpane flounder (Northern, Southern), ocean pout, summer flounder, spiny dogfish, fourspot flounder, and longhorn sculpin. Several non-groundfish species were added to evaluate changes in stocks that are ubiquitous (spiny dogfish), lightly fished (fourspot flounder) or unfished (longhorn sculpin).

Coefficients of variation (CV) for catch in numbers and total weight for each stratum were computed as the ratio of the standard error of the mean divided by the stratum mean. It can be shown that this form of the CV has an upper bound of 1.0 for nonnegative random variables. The upper bound of 1.0 arises when all but one of the observations in a set is zero. The distribution of stratum specific CVs was characterized by a box plot which illustrate the median CV as a horizontal center line, and the interquartile range as lower and upper bounds of a box. Time series of the CVs were plotted for each species, stock and survey in Fig. 3.6.1-3.6.20. Halibut catches were considered too infrequent to permit meaningful estimates of stratum specific variances.

If the underlying pattern of catches in the trawls were adversely affected by the trawl offset one would expect to see an increase in the relative variation of catches in the affected survey years (2000-2002). Visual inspection of the 60 time-series plots revealed no apparent change in the magnitude of the CV during the affected period. The interquartile range of CVs since 2000 agreed well (i.e., overlapped) with the trendless pattern of CVs for each species and survey prior to 2000. The absence of change in either the median CV or the interquartile range of the CVs reaffirms the general principle that variation in catches increases with the mean, that this property holds across all of the species examined, and that the potential effects of the trawl warp offset, if any, are small relative to the usual variation in catches. These properties appear to apply to exploited as well as unexploited stocks.

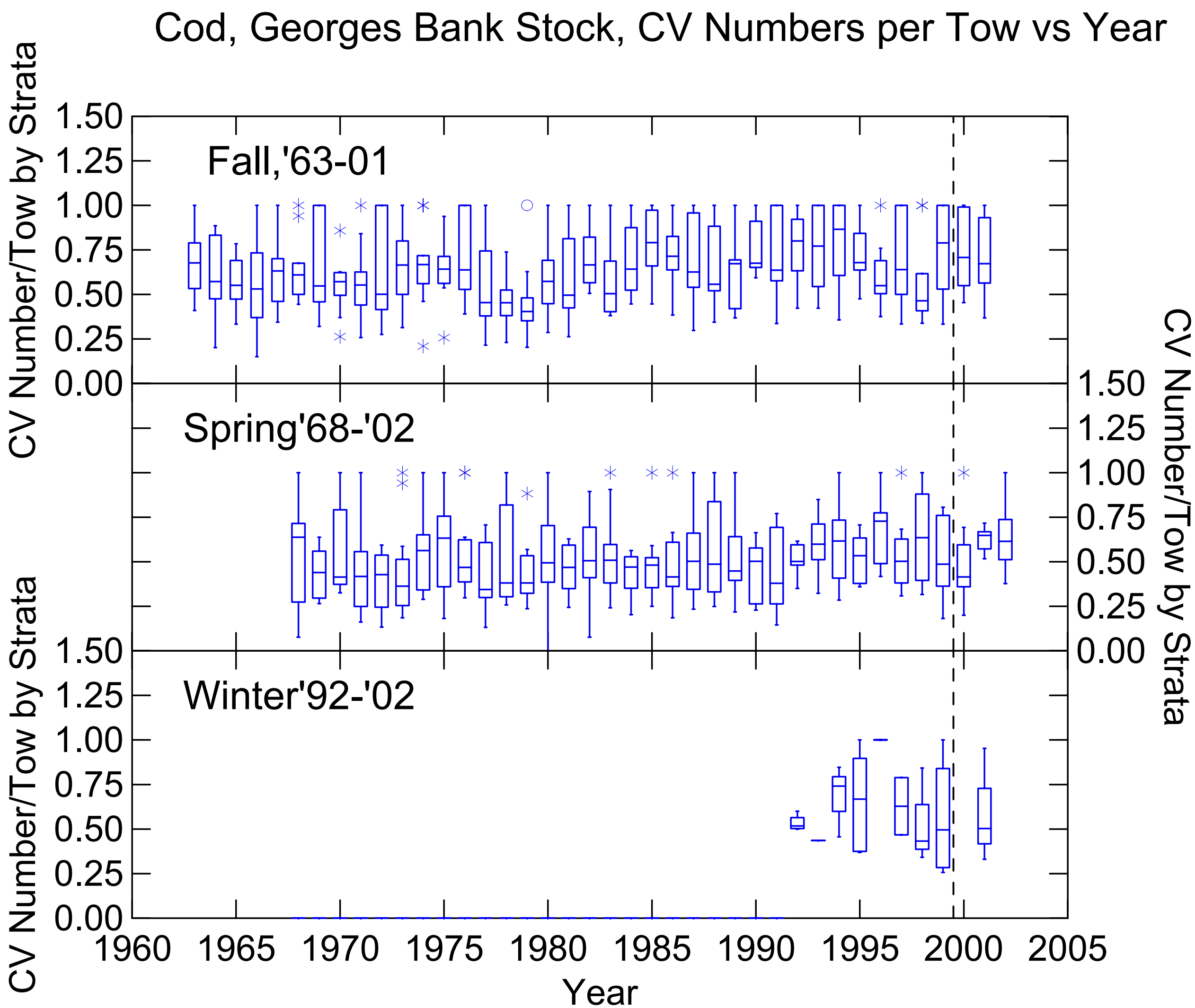


Fig. 3.6.1. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of cod for fall, spring , and winter NEFSC trawl surveys.

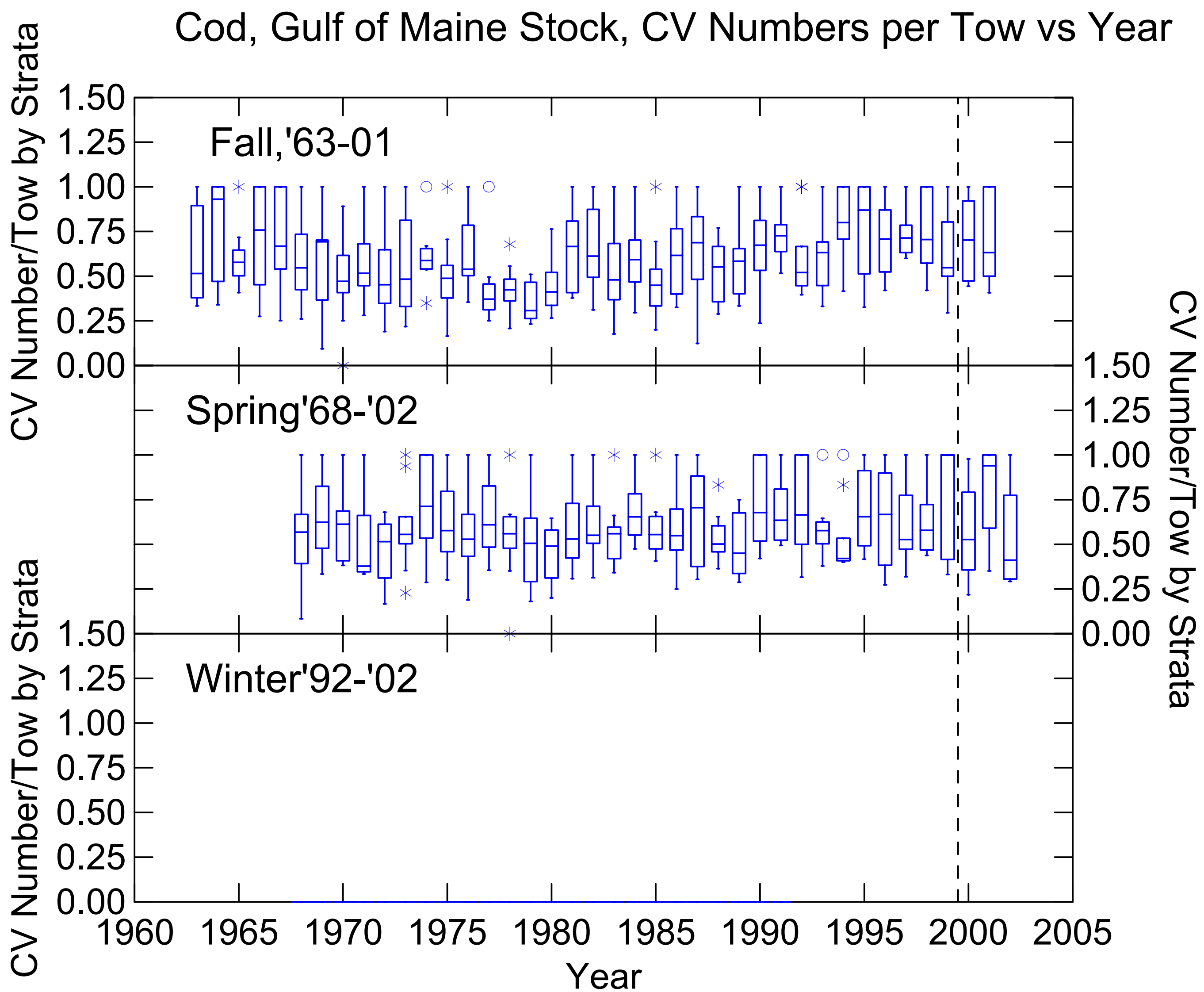


Fig. 3.6.2. Box plots of stratum-specific coefficients of catch (numbers/tow) for Gulf of Maine stock of cod for fall, spring , and winter NEFSC trawl surveys.

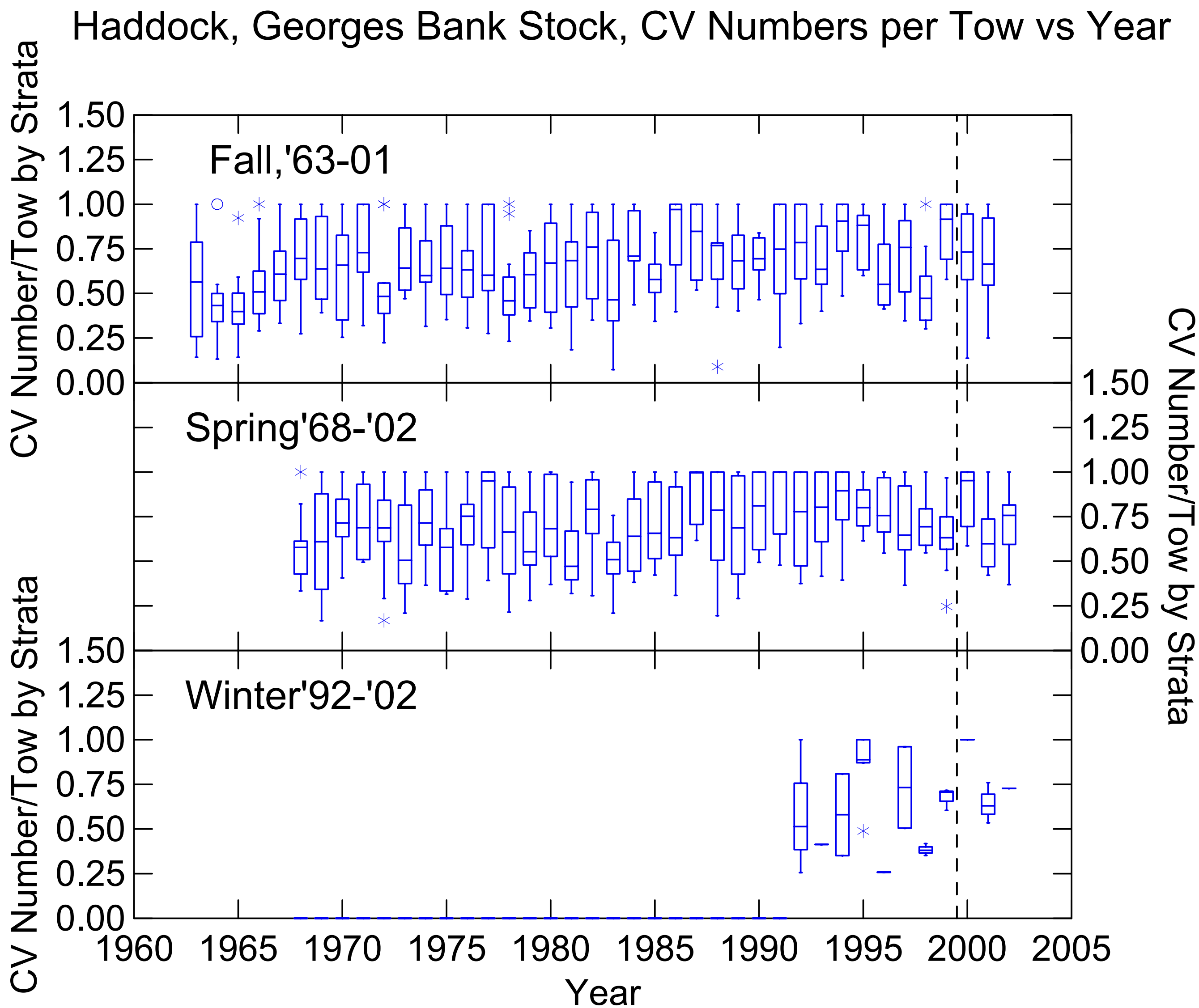


Fig. 3.6.3. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of haddock for fall, spring , and winter NEFSC trawl surveys.

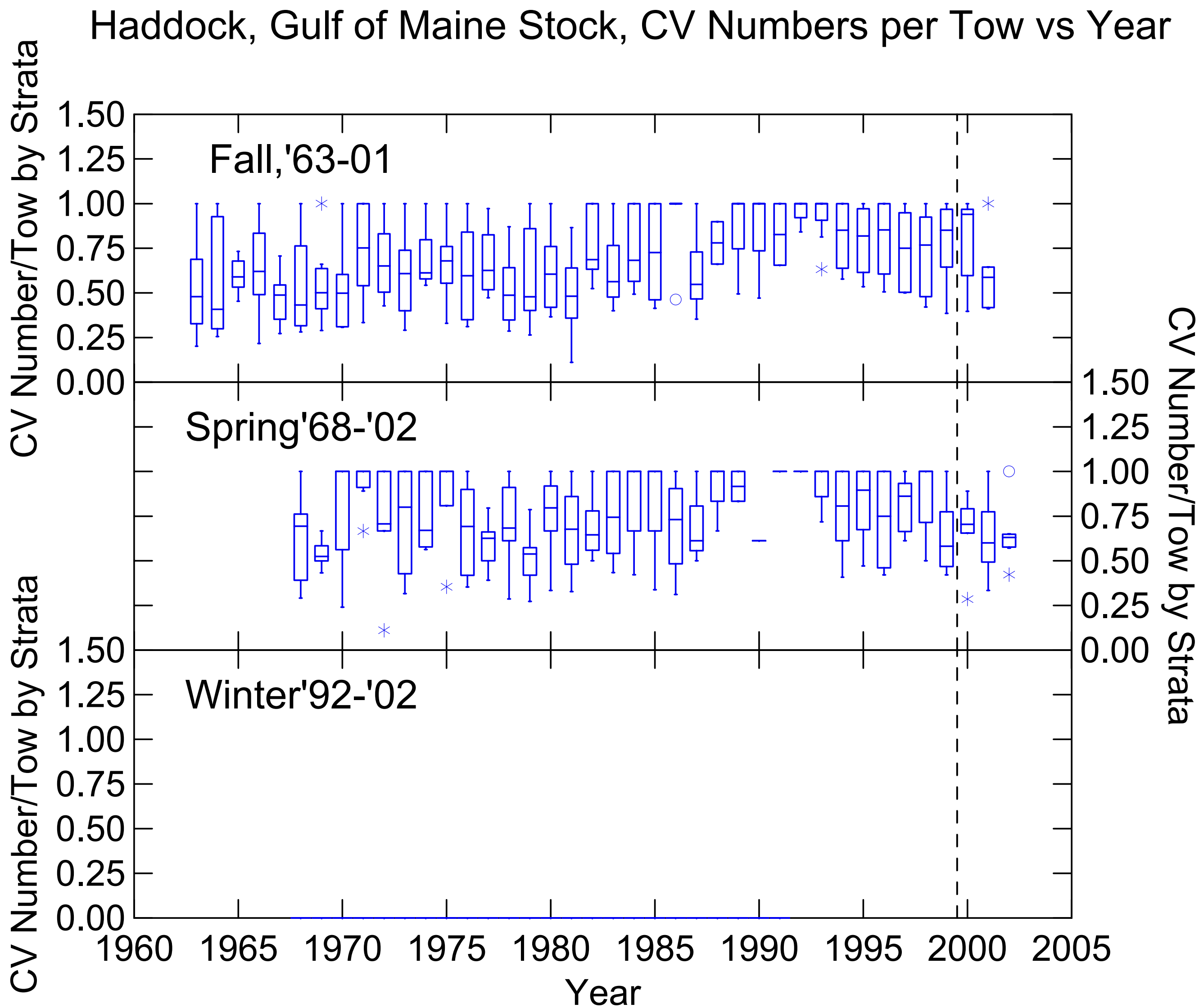


Fig. 3.6.4. Box plots of stratum-specific coefficients of catch (numbers/tow) for Gulf of Maine stock of haddock for fall, spring , and winter NEFSC trawl surveys.

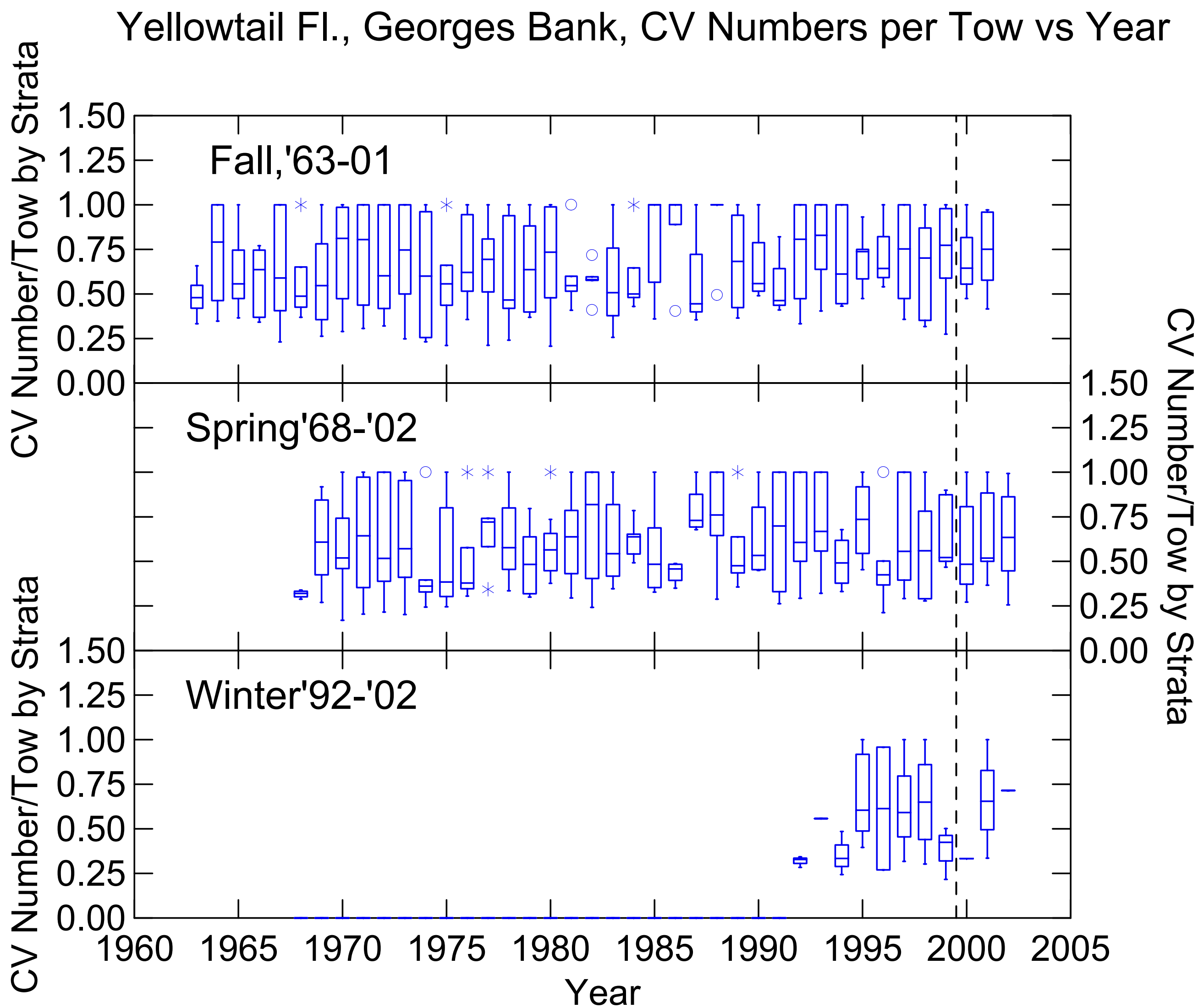


Fig. 3.6.5. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of yellowtail flounder for fall, spring , and winter NEFSC trawl surveys.

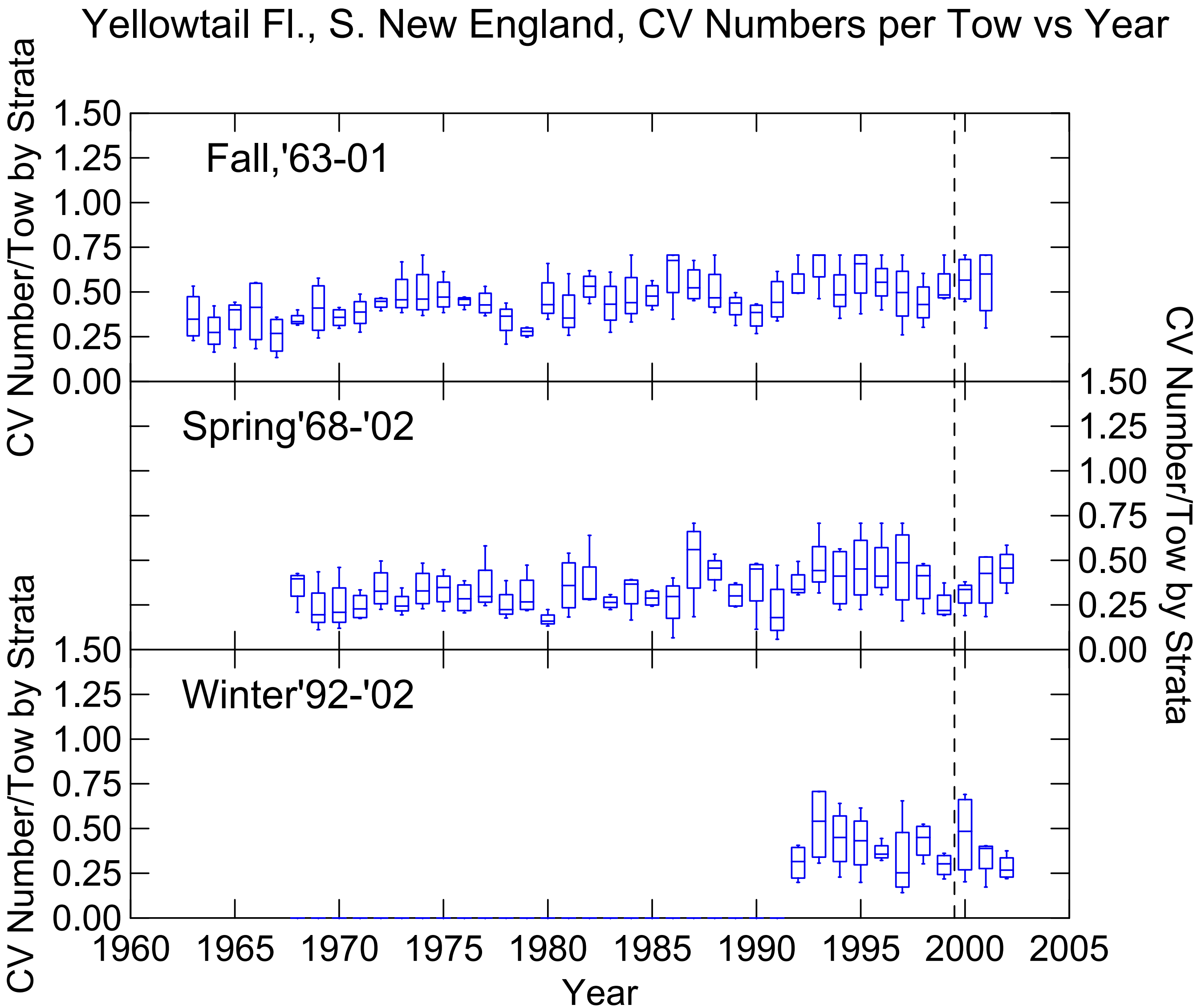


Fig. 3.6.6. Box plots of stratum-specific coefficients of catch (numbers/tow) for Southern New England stock of yellowtail flounder for fall, spring , and winter NEFSC trawl surveys.

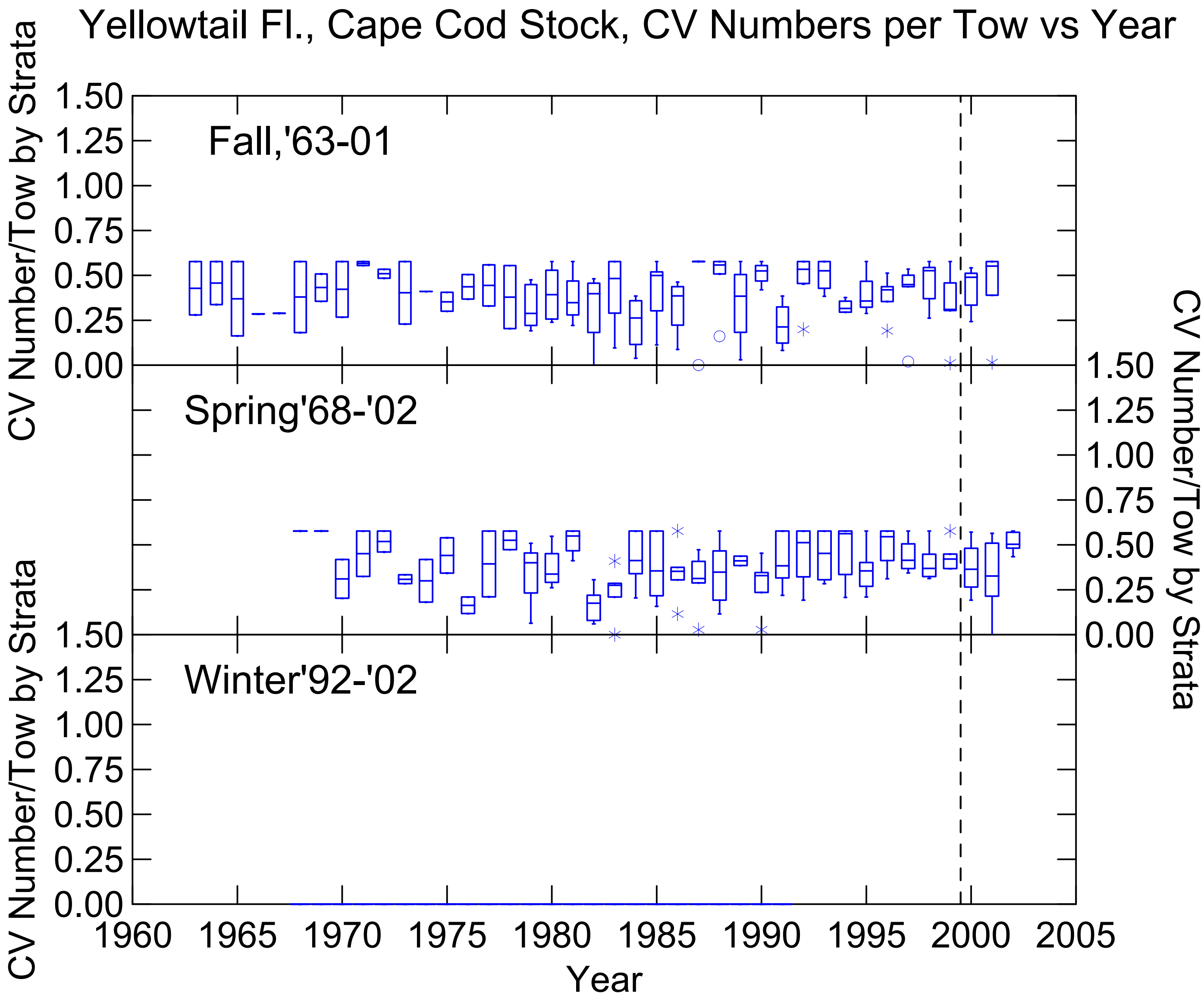


Fig. 3.6.7. Box plots of stratum-specific coefficients of catch (numbers/tow) for Cape Cod stock of yellowtail flounder for fall, spring , and winter NEFSC trawl surveys.

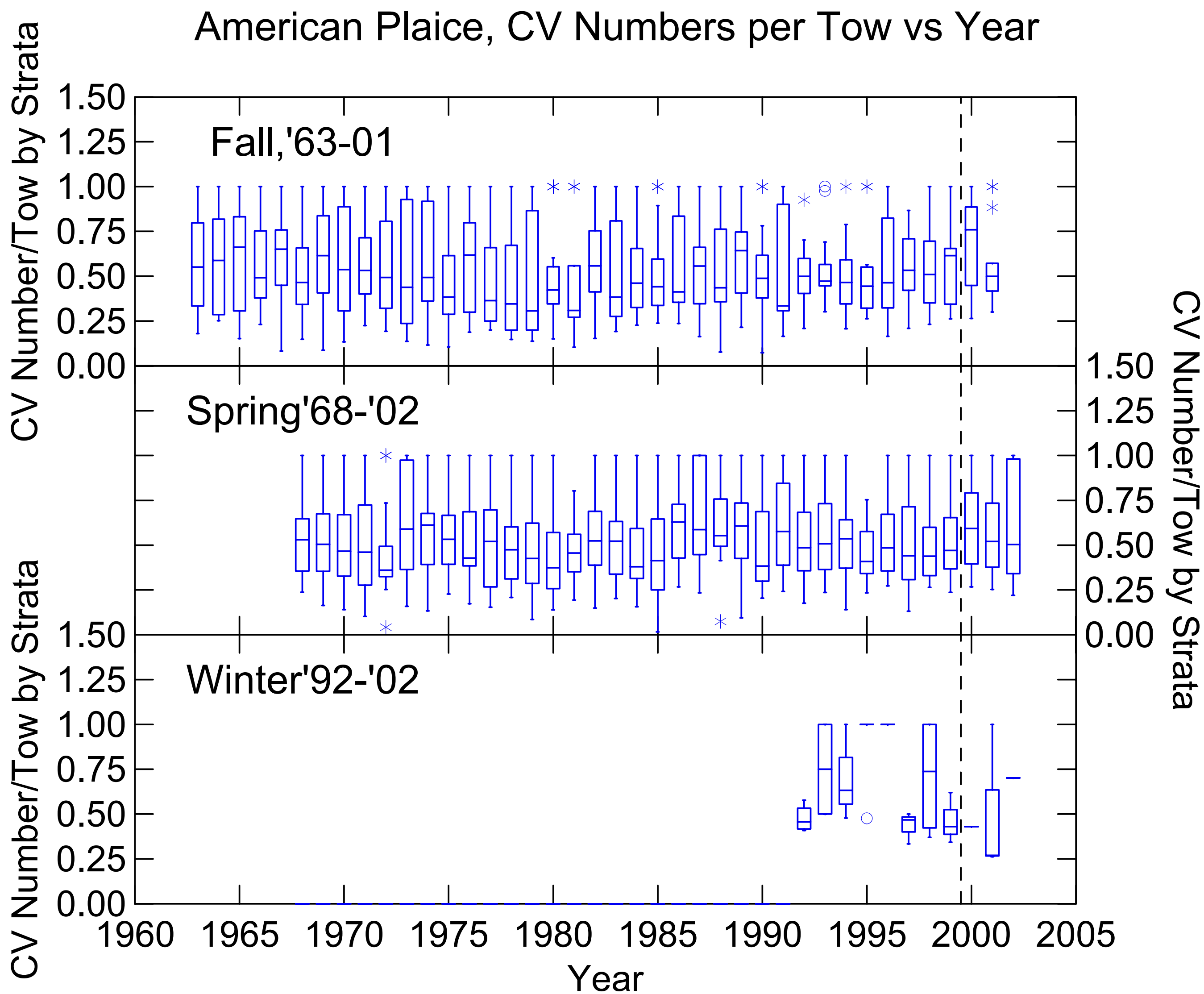


Fig. 3.6.8. Box plots of stratum-specific coefficients of catch (numbers/tow) for American plaice for fall, spring , and winter NEFSC trawl surveys.

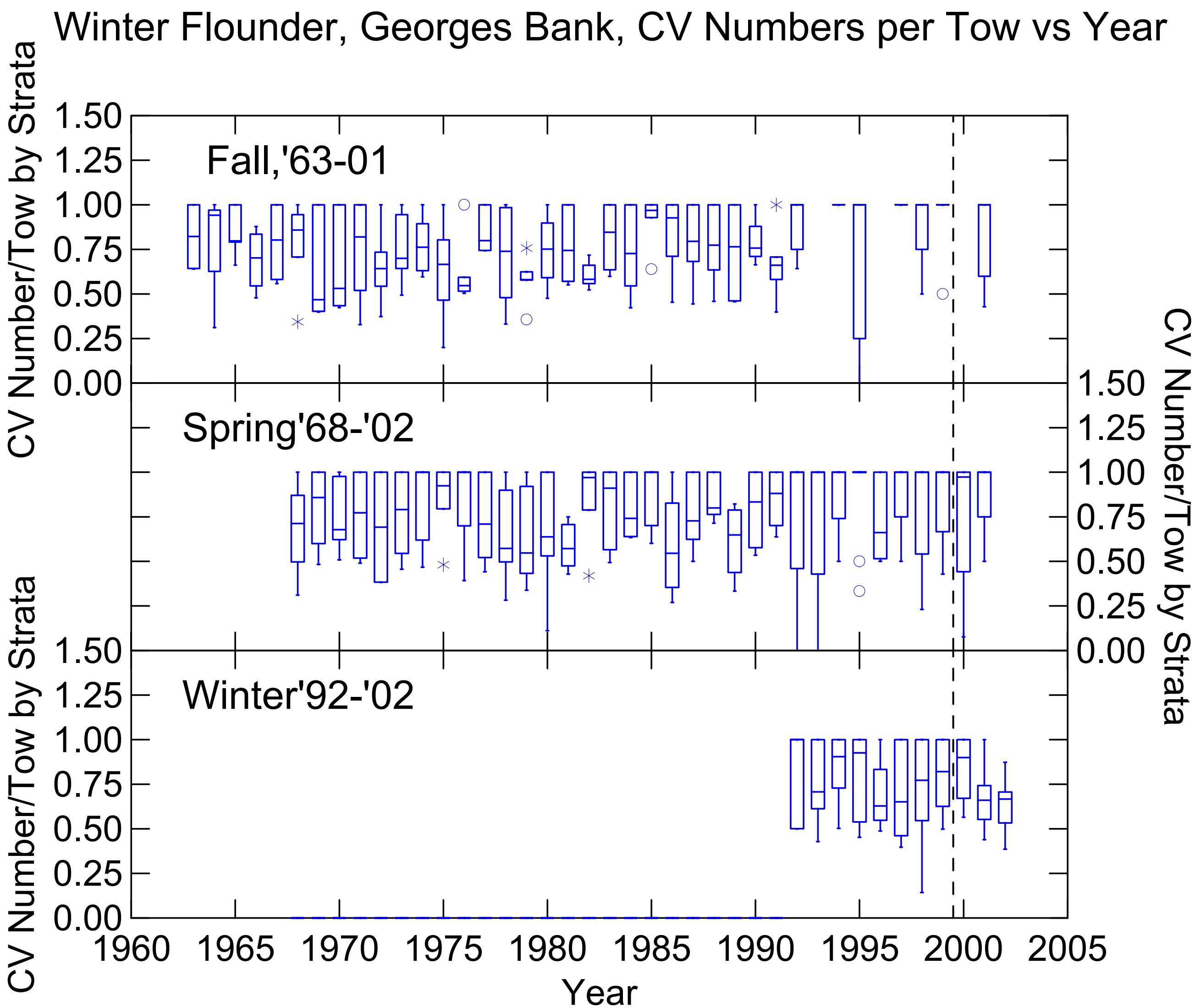


Fig. 3.6.9. Box plots of stratum-specific coefficients of catch (numbers/tow) for Georges Bank stock of winter flounder for fall, spring , and winter NEFSC trawl surveys.

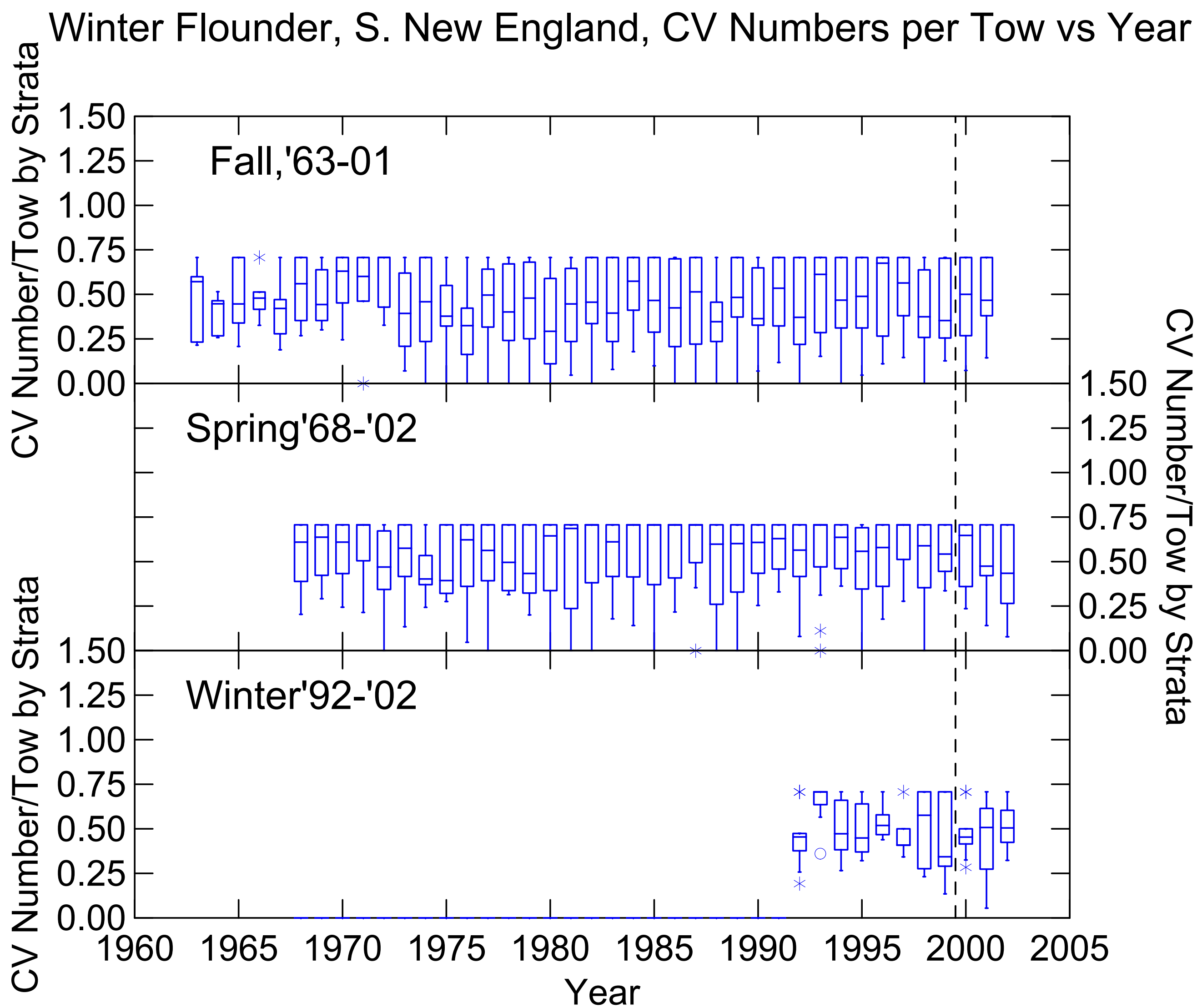


Fig. 3.6.10. Box plots of stratum-specific coefficients of catch (numbers/tow) for Southern New England stock of winter flounder for fall, spring , and winter NEFSC trawl surveys.

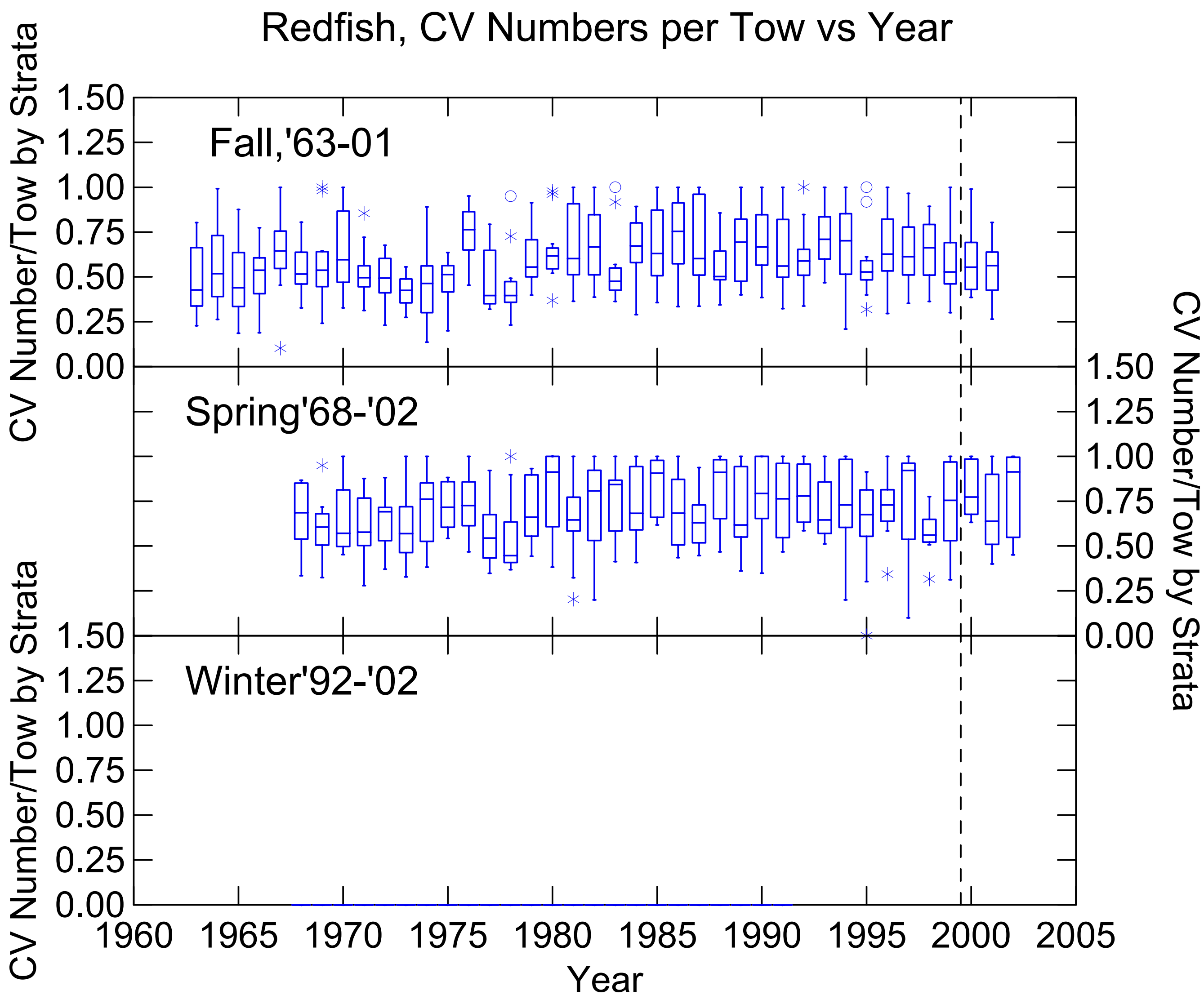


Fig. 3.6.11. Box plots of stratum-specific coefficients of catch (numbers/tow) for Acadian redfish for fall, spring , and winter NEFSC trawl surveys.

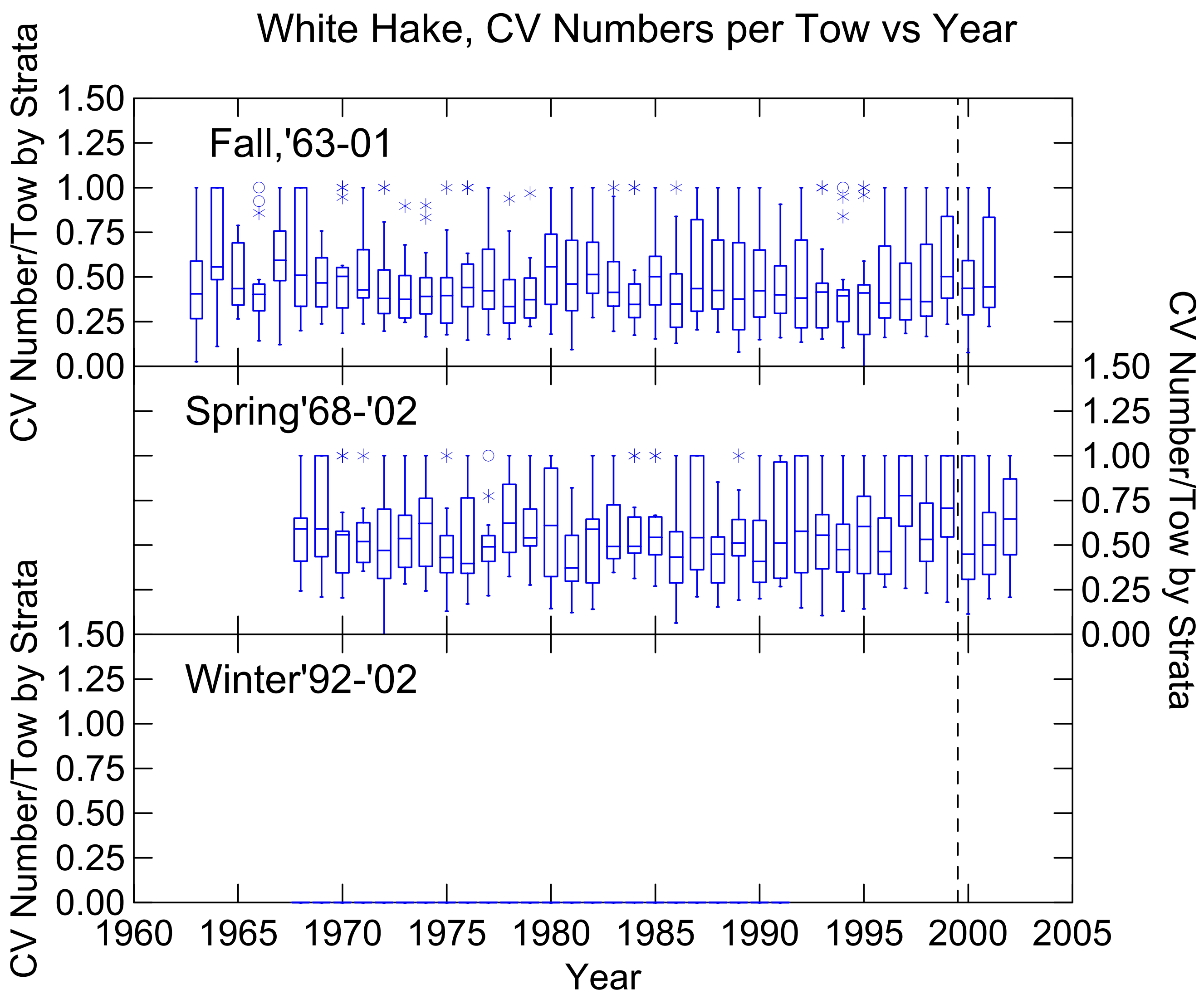


Fig. 3.6.12. Box plots of stratum-specific coefficients of catch (numbers/tow) for white hake for fall, spring , and winter NEFSC trawl surveys.

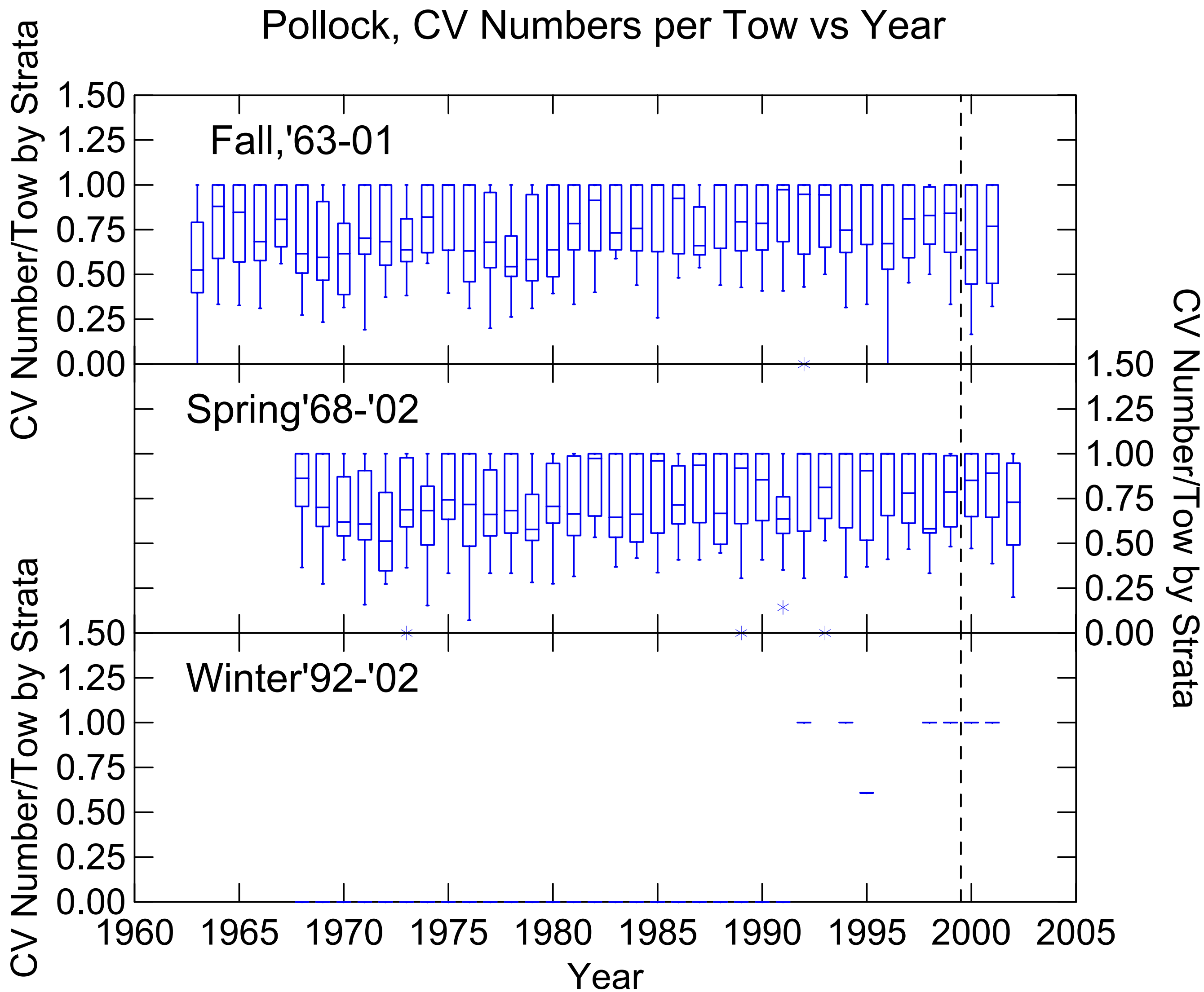


Fig. 3.6.13. Box plots of stratum-specific coefficients of catch (numbers/tow) for pollock for fall, spring , and winter NEFSC trawl surveys.

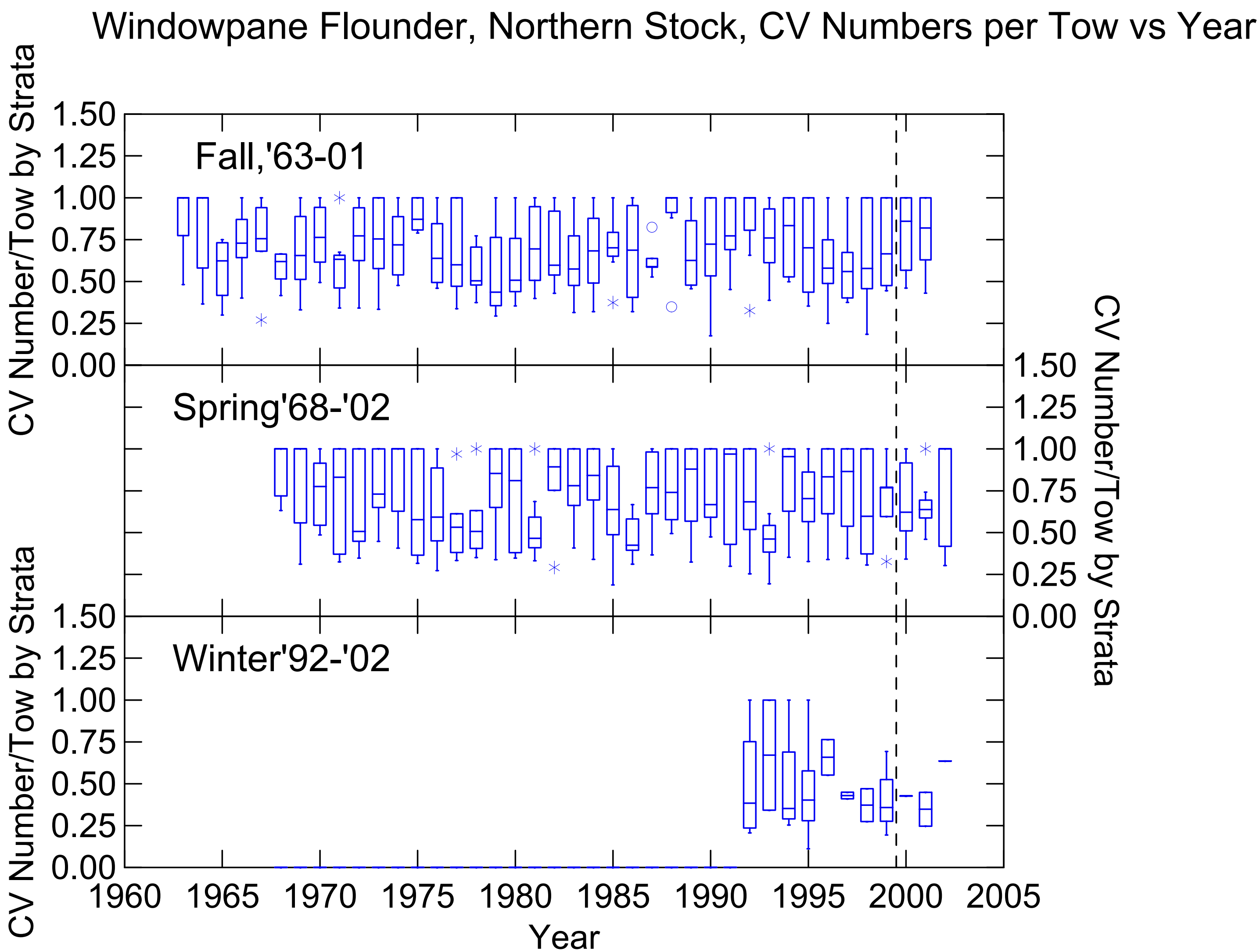


Fig. 3.6.14. Box plots of stratum-specific coefficients of catch (numbers/tow) for northern stock of windowpane flounder for fall, spring , and winter NEFSC trawl surveys.

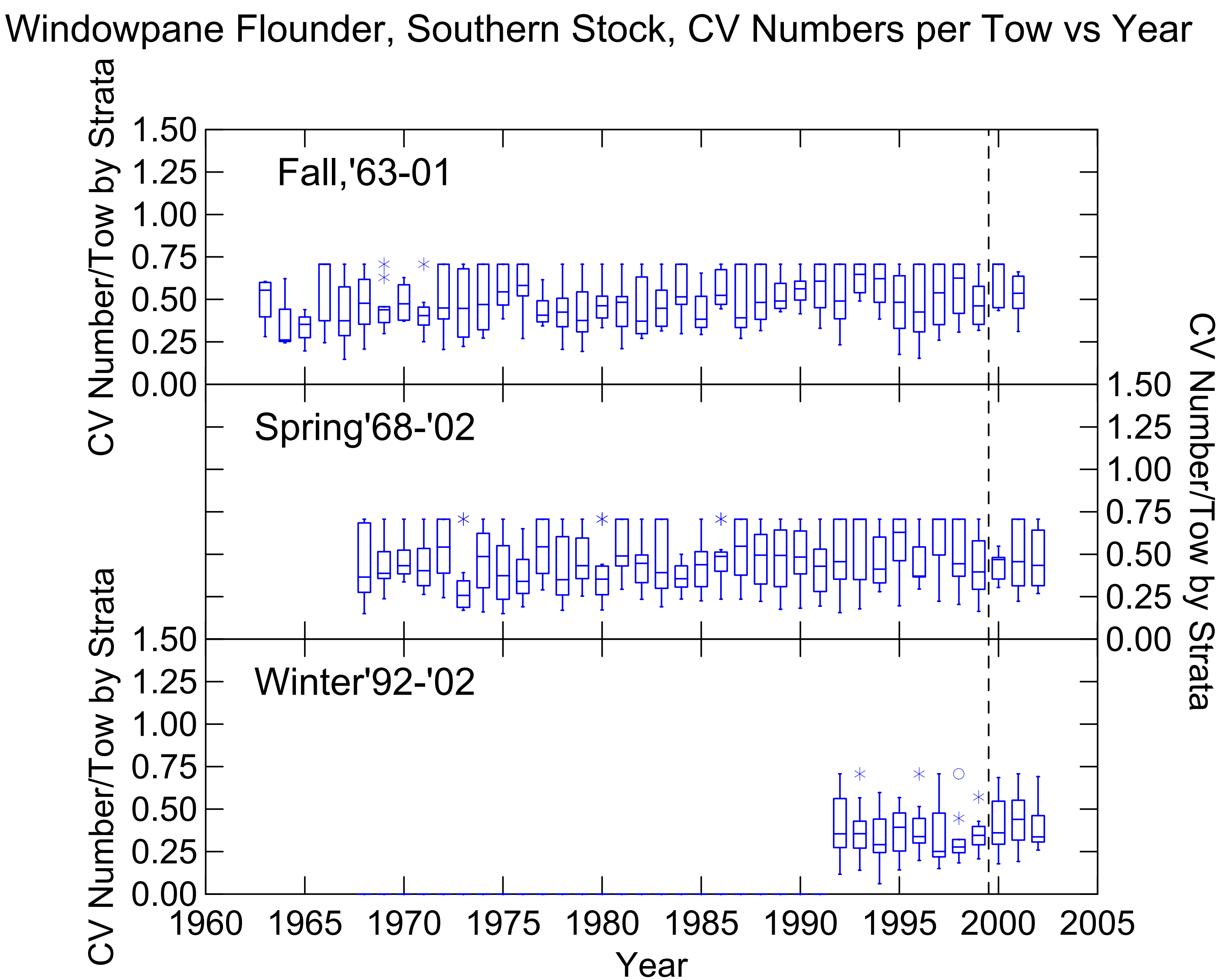


Fig. 3.6.15. Box plots of stratum-specific coefficients of catch (numbers/tow) for southern stock of windowpane flounder for fall, spring , and winter NEFSC trawl surveys.

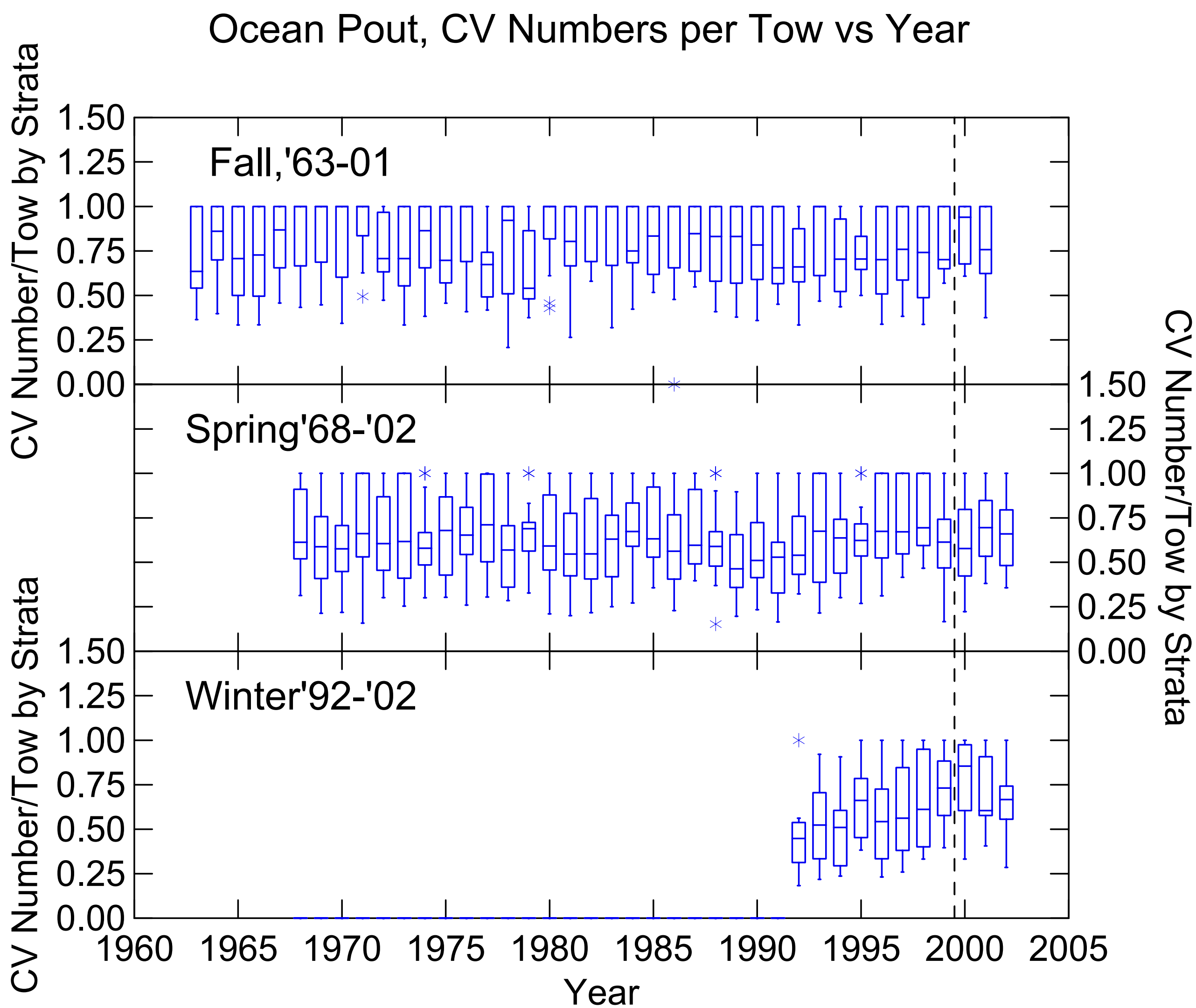


Fig. 3.6.16. Box plots of stratum-specific coefficients of catch (numbers/tow) for ocean pout for fall, spring , and winter NEFSC trawl surveys.

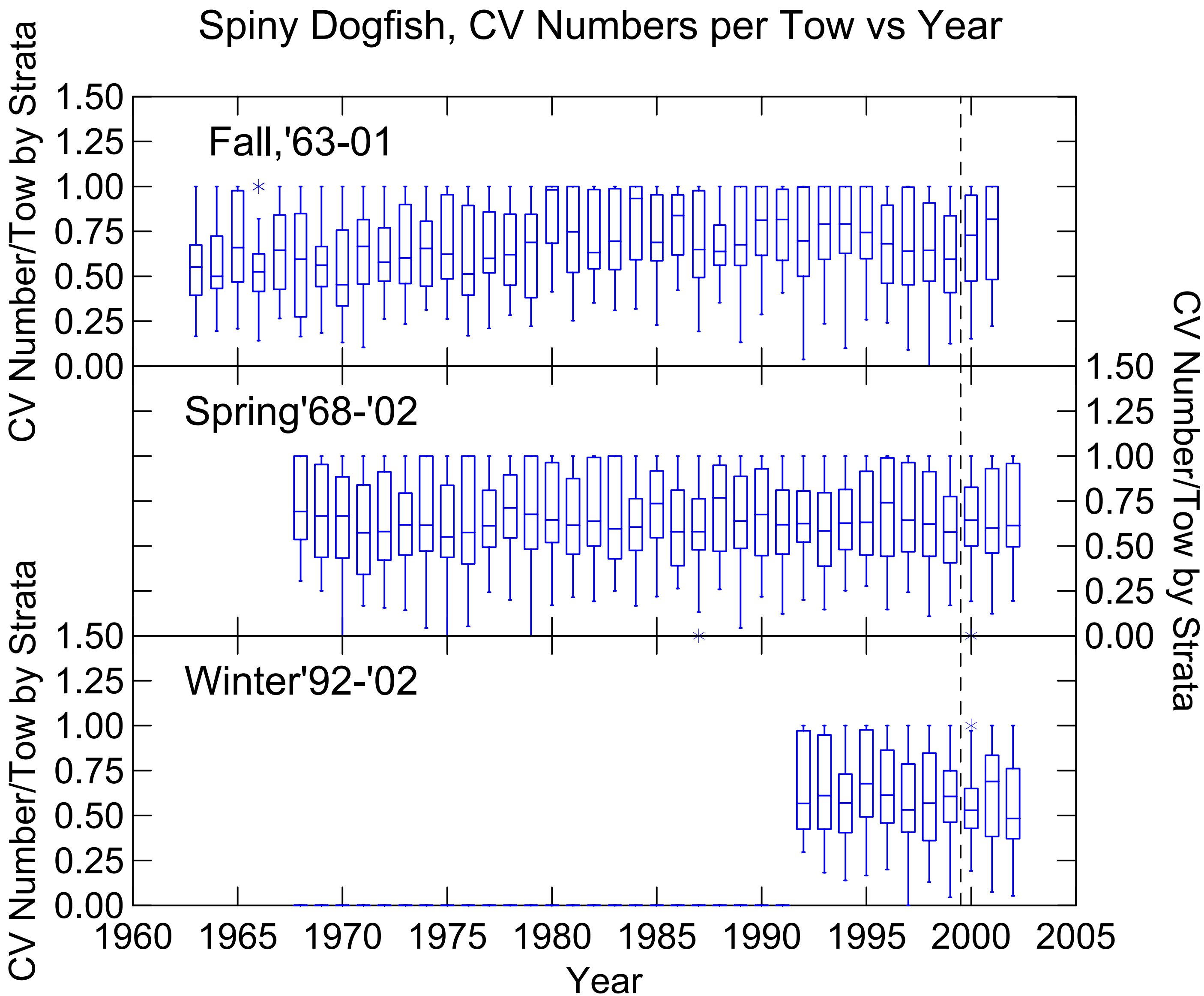


Fig. 3.6.17. Box plots of stratum-specific coefficients of catch (numbers/tow) for spiny dogfish for fall, spring , and winter NEFSC trawl surveys.

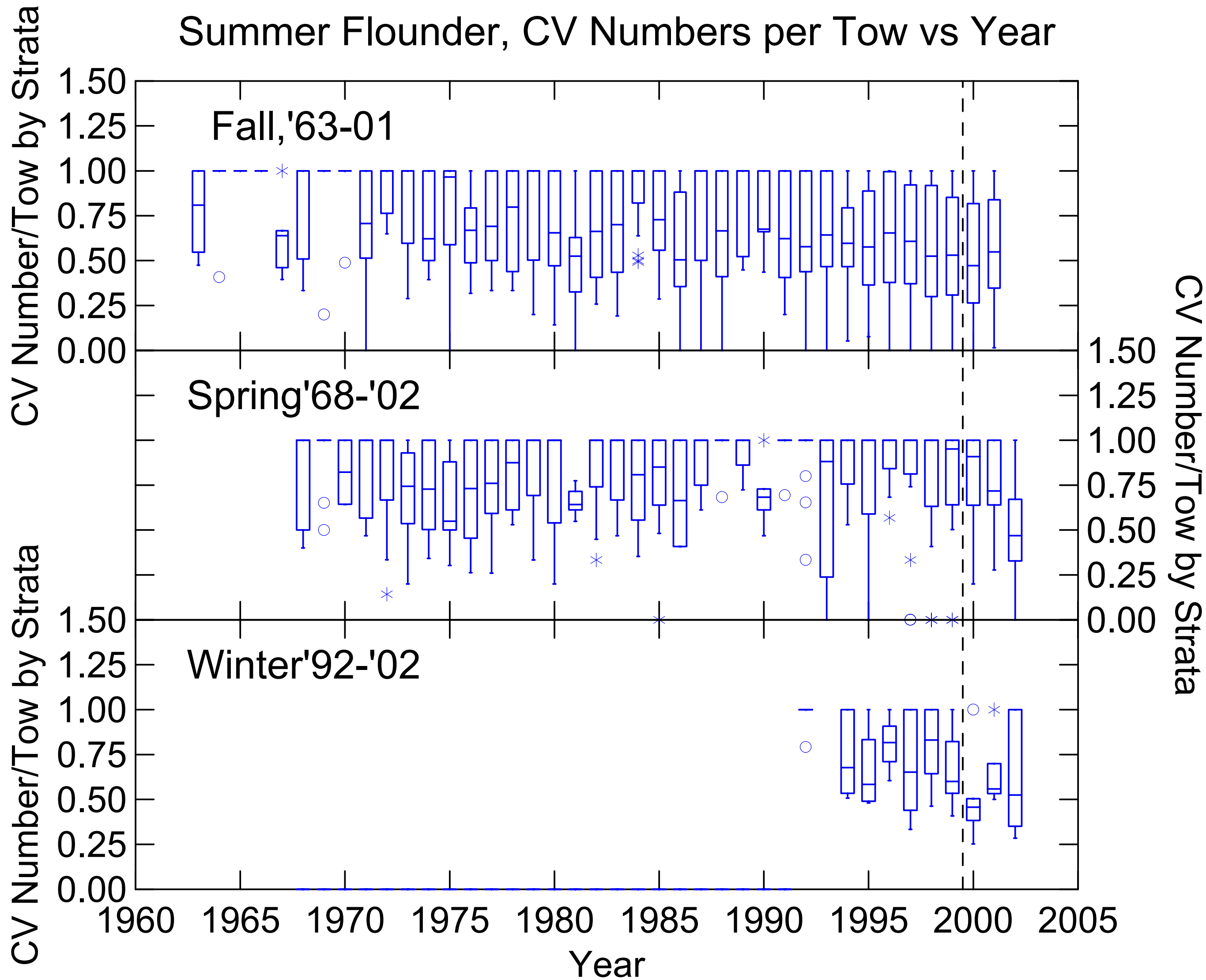


Fig. 3.6.18. Box plots of stratum-specific coefficients of catch (numbers/tow) for summer flounder for fall, spring , and winter NEFSC trawl surveys.

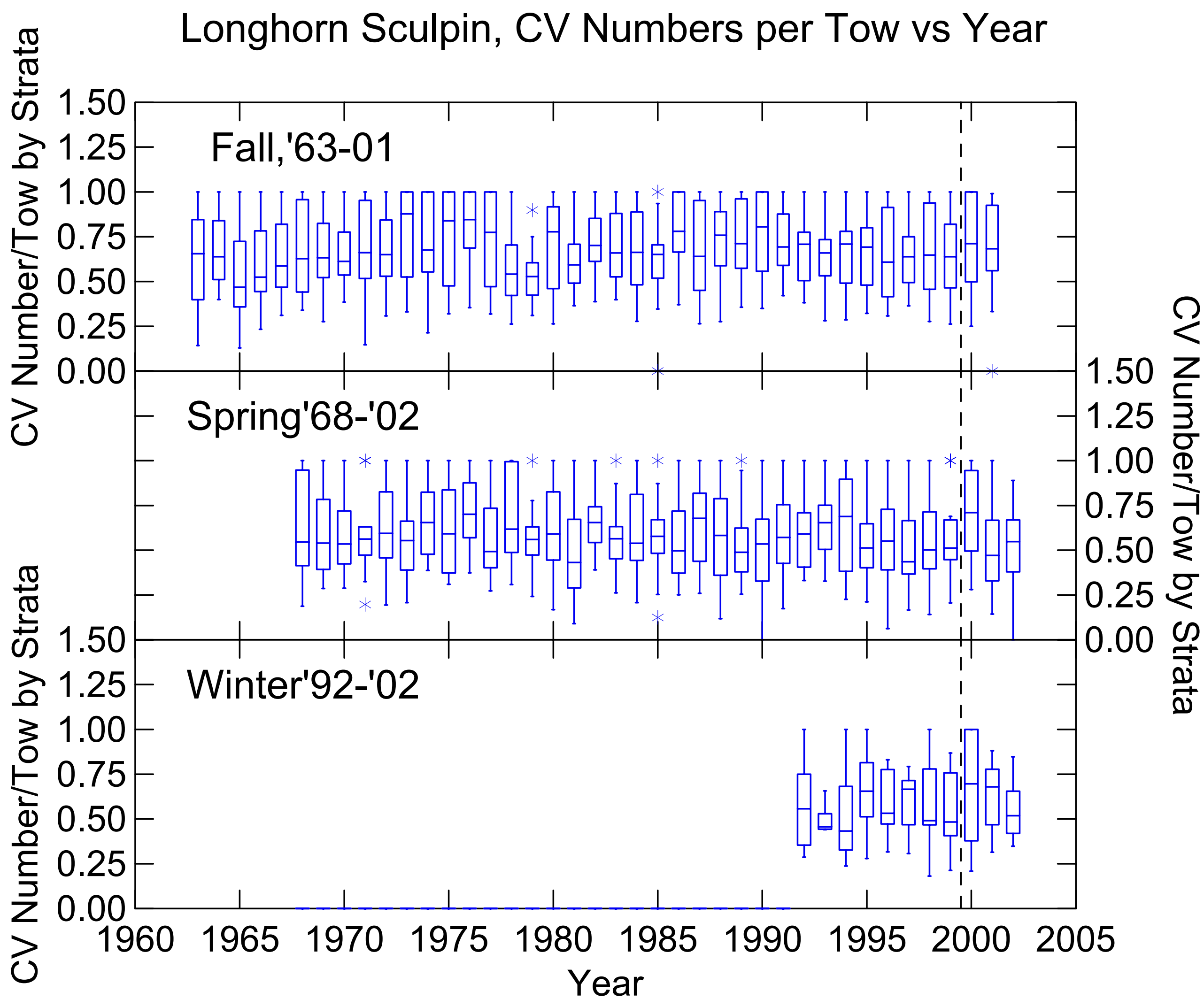


Fig. 3.6.19. Box plots of stratum-specific coefficients of catch (numbers/tow) for longhorn sculpins for fall, spring , and winter NEFSC trawl surveys.

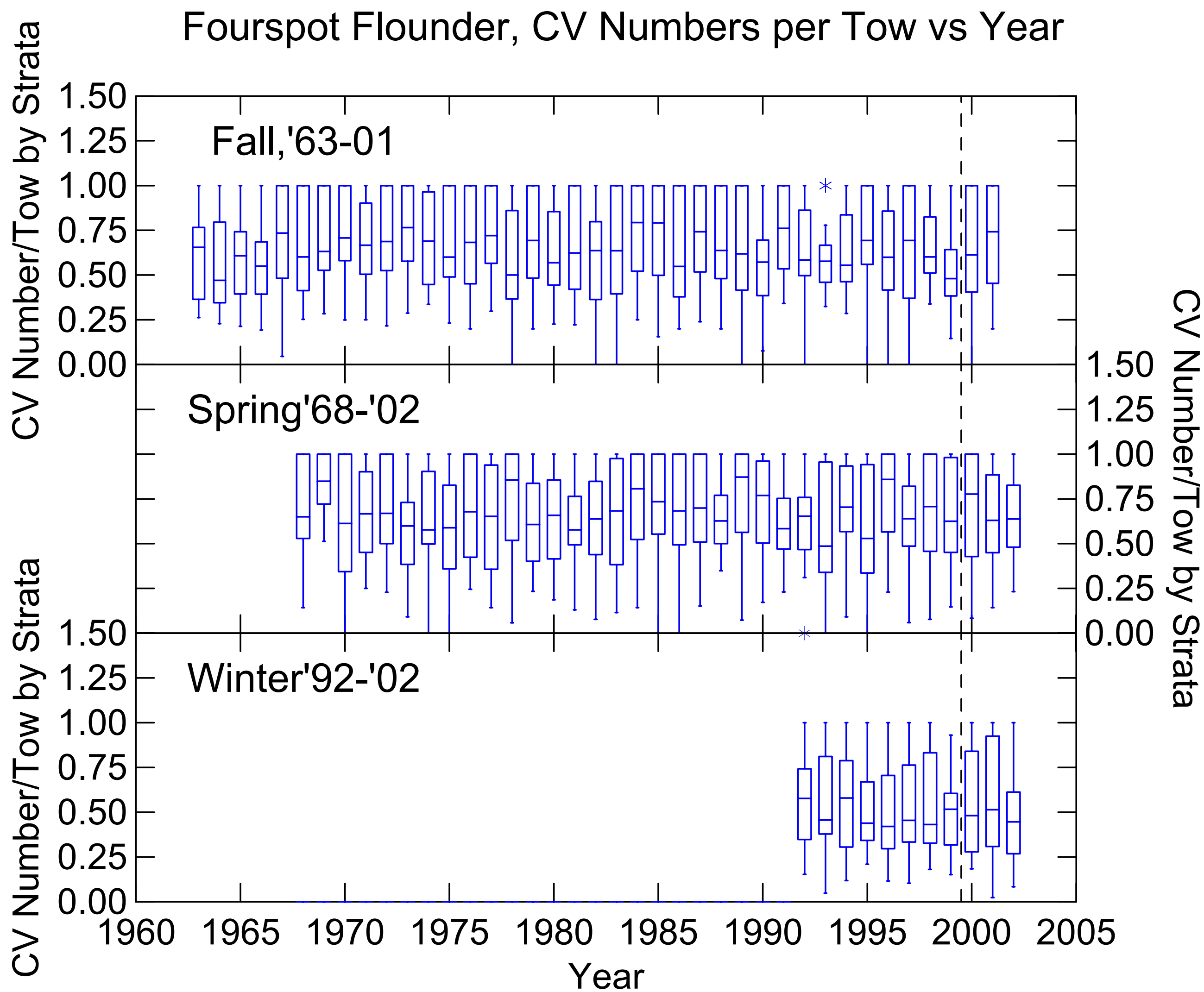


Fig. 3.6.20. Box plots of stratum-specific coefficients of catch (numbers/tow) for fourspot flounders for fall, spring , and winter NEFSC trawl surveys.

3.7. Changes in Observed Depth Distribution

The geometric arguments in Section 3.1 suggest that the efficiency of the trawl should decrease with increasing depth. Under this hypothesis, one would expect a greater fraction of the population to be caught at shallower depths. The loci of population abundance, as measured by a catch-weighted average depth, should be lower in the affected years (2000-2002) than in the base period. The long-term time series of trawl survey data allows the characterization of the seasonal and annual shifts in abundance for each species. Many species have distinct seasonal changes in average depth, coinciding with temperature changes, spawning events, feeding migrations and so forth. The timing of these events is likely to change with environmental conditions and to a lesser extent, with variations in the timing of the NEFSC surveys. The historical pattern of catches can thus serve as a sampling distribution of the catch-weighted average depth. If the warp offset factor caused a severe decline in capture rates at depth, one would expect the mean depth at capture to lie outside the range of historical values.

3.7.1. Catch-Weighted Average Depth

The time series of depth distribution patterns was examined in several different ways. At the aggregate level, the mean and variance of catch-weighted average depths were computed for each species, stock, survey, and year. Both numbers per tow and weight (kg) per tow were used to weight the depth at capture. The stratum area information associated with the survey tows was not incorporated into the estimates. The following estimators were used:

$$\overline{D}_{C,t} = \frac{\sum_{k=1}^{n_t} D_{k,t} C_{k,t}}{\sum_{k=1}^{n_t} C_{k,t}} \qquad (7)$$

where $D_{k,t}$ is the depth of tow k, n_t is the total number of tows in year t, and $C_{k,t}$ is the catch in either numbers or weight in tow k and year t. The variance of the catch-weighted depth was estimated as

$$V(\overline{D}_{C,t}) = \frac{\sum_{k=1}^{n_t} D_{k,t}^2 C_{k,t} - \left(\sum_{k=1}^{n_t} D_{k,t} C_{k,t} \right)^2}{\sum_{k=1}^{n_t} C_{k,t} \left(\sum_{k=1}^{n_t} C_{k,t} - 1 \right)} \qquad (8)$$

The standard error of the $D_{C,t}$ was estimated as

$$SE(\overline{D}_{C,t}) = \frac{\sqrt{V(\overline{D}_{c,t})}}{n_t} \qquad (9)$$

The time series of these values are plotted in Fig. 3.7.1 to 3.7.22 for each species. Lowess smooths were used to identify any apparent trends in average depth. These plots show that in nearly every instance, the average depths in 2000-2002 were within the range of historical variation.

The distribution of average depths before and after 2000 were compared using both parametric and nonparametric statistical tests (Table 3.7.1). Parametric t-tests were used to test whether the mean of the average or mean of the standard deviation of catch-weighted depths during the 2000-2002 period were significantly different from the earlier values. T-tests were computed in two way—with a pooled estimate of a common variance, and with separate variances for each group. Of the 88 tests conducted with each method, 10 (11%) were significant at the 5% level. If the Bonferroni adjustment factor for multiple tests is applied, the Type 1 error rate becomes 0.05/(2*88). At this level of statistical significance, only one of the tests was significant.

The t-test was applied to a pooled set of observations of annual means for all survey types combined. To look at finer scale patterns with respect to each survey (i.e. fall,winter, spring) we used a Kruskall-Wallis test. Under this partitioning of the data, a reliable estimate of the variance for the treatment group was not possible (2-3 observations). Of the 232 tests conducted, 15 (6.5%) were significant at the 5% level. The Bonferroni criterion is quite stringent (0.05/(2*232)) and none of the tests suggested that the catch-weighted average depth during the post treatment period was significantly different from the pre-treatment means.

In summary, there is no compelling evidence of statistically significant changes in the average depth distribution of the 22 stocks examined. Significant tests, when they arose, were usually associated with a difference in the mean of the standard errors of the catch weighted average depth. The low number of statistically significant tests, and the absence of any apparent pattern in the tests suggest that the effects of warp offset factors, if any, are minor.

Analysis of the cumulative frequency distribution of catches with respect to depth may be found in Appendix 2.

3.7.2 Comparisons of Catch Rates at Depth: 1997-1999 vs. 2000-2002

The analyses of gear problem rate, mean-variance relationships and catch weighted average depth all fail to provide evidence of a significant effect of the mismarked cables on trawl performance. No consistent pattern emerges with respect to species groupings (e.g., round groundfish vs. flatfish) or geographical region, especially in the Gulf of Maine. Given its greater average depth one would expect a greater frequency of gear problems since 1999, a tendency to catch less fish in deeper strata, or more variation among tows. None of these features is readily discernible.

In an attempt to conduct more direct tests of potential depth effects on gear performance, it was hypothesized that average catch rates would decline with depth. Moreover, differences in catch rates between a baseline period and the 2000-2002 period should increase with depth. We tested this hypothesis by comparing average catch rates between the pre and post-treatment periods. Average catch rates in both number and weight per tow, were computed for each species, stock and season over 20 m depth intervals. Twenty m depth intervals were used to ensure that sufficient numbers of observations were available to obtain a reliable estimate of the mean. For the spring and winter surveys, we compared catch rates at depth in 2000-2002 with similar quantities for 1997-1999. For the fall survey, we compared 1998-1999 with 2000-2001. This approach ensured that the numbers of observations contributing to each mean would be roughly equal. The general equation for computing these quantities can be expressed as:

$$\overline{C}_{D_k,\tau} = \sum_{D_j \in D_k} \frac{C_{j,\tau}}{n\{D_j \in D_k\}} \quad \forall_j \qquad (10)$$

Where $C_{j,\tau}$= tow j within period τ whose average depth D_j is with the interval of depths defined by D_k. The expression n{.} denotes a counting operator that counts the number of tows within the set. Differences between the "control" and "treatment" periods this experiment were computed on the arithmetic scale, and standardized by the estimated standard deviation of the differences for a given comparison. The standardized difference can be written as

$$Z_k = \frac{\overline{C}_{D_k,\tau=1} - \overline{C}_{D_k,\tau=2}}{\hat{\sigma}} \qquad (11)$$

where τ=1 is the control period and τ=2 denotes the years in the treatment period. A simple regression model of the form

$$Z_k = \alpha + \beta D_k \qquad (12)$$

was used to test for effects of depth. When β ~0, α should equal ~zero. If β >0 it implies that the average catch rate in the control period exceeded that in the treatment period and would imply some influence of the warp offset on the catch rates. Conversely, β <0 implies that catches in the treatment period exceeded those in the control period.

Equation 12 provides a useful test for trend in catch rates with depth but it is not sufficient to isolate the influence decreasing efficiency with depth. This arises because Eq. 12 is linear and allows for changes in efficiency at shallow depths as well. These post hoc analyses cannot distinguish between true changes in abundance (which would lead to +/- variations) and effects induced by the trawl warp. However, the use of 3 surveys should help to distinguish changes that are real (e.g., all three indices increase with depth) versus artifacts of random variation. Two separate analyses of the standardized difference were conducted. First, plots of Z_k versus depth were constructed for all combinations of 21 species-stock combinations and 3 surveys (Fall, Spring, Winter). For each combination, two response variables (average numbers/tow, average weight/tow) were examined. A linear regression was computed for each combination and response variable to test for statistically significant values of α and β.

Results of the statistical tests are summarized in Table 3.7.1. Of the 112 individual tests conducted, 8 had probability levels less than 0.05. Of these, six had positive and two had negative slopes. The slope was positive for Gulf of Maine cod numbers per tow for both the spring and fall surveys. Similarly, longhorn sculpins had positive slopes for the spring survey regressions. The total number of significant tests is about that expected due to chance alone, but the association of significant tests for Gulf of Maine cod in both the spring and fall surveys merits some attention. The positive trend in the slope of the standardized difference with respect to depth is induced by a few large tows in shallow depth strata during the 2000-2002 interval rather than any general trend toward decreasing average catch rates in deeper strata.

None of the other Gulf of Maine species, notably haddock, pollock, and white hake demonstrated any trend with depth. Moreover, deeper water species, such as redfish and witch flounder did not demonstrate any significant trends of differences with depth. Had the reduced capture rate at depth been a general function of decreasing efficiency, one would have expected some of these comparisons to be significant.

A set of omnibus tests (Table 3.7. 3) in which all species were pooled, suggested no significant slopes for the differences of average numbers or weights per tow or for standardized log ratios of numbers or weights. For the fall survey, the standardized log ratio of numbers and weight in the fall survey was significantly correlated with depth—the slope however, was negative, suggesting higher overall catch rates in the post treatment period.

The second analysis considered the effects of depth on catch differences as a statistical control process. The standardization approach (Eq. 12) ensures that most differences will be between $\pm$ 3.5 standard deviations units. Moreover, 80% of the values should lie between $\pm$1.28 SD, and 95% between $\pm$1.96 SD units. Standardization of the differences also allows for pooling across species to permit testing of more general hypotheses. In particular, we examined general tests for gadoid species, flatfish species, species with median depths less than 100 m and those greater than 100 m. If general reductions in catch rates were evident with increasing depth, one would expect a general increase in positive residuals in deeper strata.

Figure 3.7.23 to 3.7.27 suggested no patterns associated with decreased relative efficiency with depth. On the contrary, the plots suggested less than expected variation in the standardized differences as depth increased. This pattern held for gadoid species, flatfish species, shallow versus deep-water species, as well as for all species combined.

A comparison of the observed and expected number of standardized differences suggested that the distribution was leptokurtotic (more peaked) compared to the expected normal distribution with mean zero and unary variance (Table 3.7.4).

In summary, the comparative tests of differences in catch rates versus depth interval did not suggest any significant trend in catch differences with depth. Increases in overall abundance during the 2000-2002 period would potentially cancel out the effects of depth related changes, but one has to postulate an awkward assumption that the increases at depth would have been greater in the deeper waters for 21 species-stocks x 3 surveys. Moreover, the likelihood that such increases would be exactly sufficient to offset the depth related decreases in efficiency, for all of these tests, seems implausible.

3.7.3 Implications of VPA Sensitivity Analyses for Relative Efficiency

Stock assessment models for the GARM investigated the implications of arbitrary increases in the 2000 to 2002 survey indices by factors of 10, 25 and 100%. These potential increases cannot be divorced from their implications for depth relative to efficiency. For example, one cannot simply postulate that the net was 25% less efficient at all fishing depths unless one also postulates that any amount of asymmetry in cable lengths leads to equal degrees of reduced efficiency. This not only denies the fact that increases in asymmetry can reduce efficiency but also asserts that unrealized differences in cable length (i.e., cable still on the winch) influence catch rates at shallower depths.

The 10, 25 and 100% raising factors also do not address the differences in depth distributions among species. By applying the same factors to both deep-water species (eg. Redfish) and shallow-water species (e.g., yellowtail flounder), one implies that the reduction in capture efficiency varies significantly among species.

These implications of these assertions were investigated by substituting Eq. 6 into Eq. 4. to obtain:

$$\sum_j C_{j\,rev} = (1+\delta)\sum_j C_{j,obs} = \sum_j \left(\frac{C_{j,obs}}{1-\left(\frac{0.0134D_j}{W_{\max}}\right)^{\theta}} \right) \qquad (13)$$

Eq. 13 can now be used to find the value of θ necessary to obtain an increase of magnitude δ when integrating over the entire depth range of a species. To illustrate this property, Eq. 13 was solved for hypothetical increases of 10%, 25% and 100% for cod, haddock, and yellowtail flounder for the 2000-2002 spring surveys, and 2000-2001 fall surveys. Model results, summarized in Fig. 3.7.28 to 3.7.30, suggest that efficiency reductions of about 50% would occur at depths of 100 m for cod and haddock if a 100% increase in the survey indices were true. For yellowtail flounder, an increase of 100% in the indices implies a rapid drop in trawl efficiency with decreases of 50% at 50 m. An important aspect of each of the analyses is that the reduction in efficiency is a concave function (i.e., $\theta > 1$). This model suggest that sharp declines in efficiency are necessary even when the asymmetry of the trawl is relatively minor.

Eq. 13 predicts the necessary decline in relative efficiency if the δ value is true. Using the data sets described in Section 3.7.2 (Eq. 10) , one can also estimate the magnitude of the expected decline supported by comparison of data in pre and post-warp offset periods. In other words, it is possible to evaluate the potential magnitude of the relative efficiency reduction if the pre- and post –periods are not unduly compromised by large changes in abundance. Results in Fig. 3.7.28-30, labeled as “Actual Data” suggest no reductions for yellowtail flounder or cod at depths less than 300 m. For haddock, (Fig. 3.7.29) the model suggests a reduction of up to 10% at 200m in the fall survey. It is important to note however, that even this magnitude of effect is insufficient to achieve even a 10% increase in the average abundance estimate. These results have important implications for the ascertaining the feasibility of certain raising factors. **On the basis of these analyses, there is no support for even the 10% level of hypothesized increase in survey abundances for cod, haddock or yellowtail flounder.**

3.7.4 Comparisons of Catch-Weighted Depth at Capture

Differences in catch-weighted depth at capture are summarized in Figures 3.7.31 and 3.7.32. Data are organized by species average depths at capture, and are divided for each into pre- and post-warp offset periods. The entire (1963-1999) pre-warp period is included in Figure 3.7.31, and, because of potential time trends of depth at capture, only the period 1997-1999 is included as the pre warp period in Figure 3.7.32. These analyses clearly demonstrate that the average depths of capture are not significantly different pre- and post-warp offset, and that there are no progressive differences between depths at capture among the periods as a function of species depth ranges. Virtually all of the catches of groundfish species included in the GARM updates are made in depths where the offsets were about 9 feet or less.

Table 3.7.1. Summary of statistical tests to evaluate the likelihood that the catch-weighted average depth and variance of catch-weighted depth had changed in reponse to warp offset factors in 2000 to 2002
Catch weighted average depths are based on either numbers/tow [N] or weight (kg)/tow [W].
Numbers of samples for the tests depends on the number of years and seasons considered.
The number of pre- and post-intervention cases for spring only comparisons is 32 vs 3, for fall only, 37 vs 2 and for winter only, 8 vs 3.
When all seasons are combined the number of cases for the pre- and post intervention period is 77 vs 8.

					Significance levels for t-test comparisons using alternative variance estimators		Significance levels for Nonparametric
species	**stock**	**season**	**Response Variable**	**Weighting Factor: N=num/tow, W=kg/tow**	***p*: sep var t-test**	***p*: pooled var t-test**	***p*: Kruskal Wallis test**
Haddock	Georges Bank	all	SD	W	0.289862	0.433023	
Haddock	Georges Bank	all	SD	W	0.14826	0.163566	
Haddock	Georges Bank	all	SD	W	0.052296	0.266823	
Haddock	Georges Bank	all	SD	W	0.105207	0.139573	
Haddock	Georges Bank	fall	SD	W			0.798966
Haddock	Georges Bank	fall	SD	W			0.524311
Haddock	Georges Bank	fall	SD	W			0.339541
Haddock	Georges Bank	fall	SD	W			0.279068
Haddock	Georges Bank	spring	SD	W			0.859684
Haddock	Georges Bank	spring	SD	W			0.859684
Haddock	Georges Bank	spring	SD	W			0.723674
Haddock	Georges Bank	spring	SD	W			0.679988
Haddock	Georges Bank	winter	SD	W			0.794003
Haddock	Georges Bank	winter	SD	W			0.29627
Haddock	Georges Bank	winter	SD	W			0.601508
Haddock	Georges Bank	winter	SD	W			0.794003
Cod	Georges Bank	all	SD	W	0.904804	0.90178	
Cod	Georges Bank	all	SD	W	0.640815	0.684401	
Cod	Georges Bank	all	SD	W	0.906653	0.908996	
Cod	Georges Bank	all	SD	W	0.64553	0.706991	
Cod	Georges Bank	fall	SD	W			0.610492
Cod	Georges Bank	fall	SD	W			0.949232
Cod	Georges Bank	fall	SD	W			0.444833
Cod	Georges Bank	fall	SD	W			0.949232
Cod	Georges Bank	spring	SD	W			0.953011
Cod	Georges Bank	spring	SD	W			0.637352
Cod	Georges Bank	spring	SD	W			0.637352
Cod	Georges Bank	spring	SD	W			0.288844
Cod	Georges Bank	winter	SD	W			0.245278
Cod	Georges Bank	winter	SD	W			0.121335
Cod	Georges Bank	winter	SD	W			0.698535
Cod	Georges Bank	winter	SD	W			0.438578
Yellowtail	Georges Bank	all	SD	W	0.996997	0.995838	
Yellowtail	Georges Bank	all	SD	W	0.000071	0.02002	
Yellowtail	Georges Bank	all	SD	W	0.784343	0.709294	
Yellowtail	Georges Bank	all	SD	W	0.00437	0.019447	
Yellowtail	Georges Bank	fall	SD	W			0.048403
Yellowtail	Georges Bank	fall	SD	W			0.226372
Yellowtail	Georges Bank	fall	SD	W			0.085591
Yellowtail	Georges Bank	fall	SD	W			0.074619
Yellowtail	Georges Bank	spring	SD	W			0.813664
Yellowtail	Georges Bank	spring	SD	W			0.025145
Yellowtail	Georges Bank	spring	SD	W			0.595883
Yellowtail	Georges Bank	spring	SD	W			0.015694
Yellowtail	Georges Bank	winter	SD	W			0.414216
Yellowtail	Georges Bank	winter	SD	W			0.153042
Yellowtail	Georges Bank	winter	SD	W			0.540291
Yellowtail	Georges Bank	winter	SD	W			0.414216

Table 3.7.1 (continued).

American Plaice	Georges Bank	all	SD	W	0.437437	0.325598	
American Plaice	Georges Bank	all	SD	W	0.062179	0.000586	
American Plaice	Georges Bank	all	SD	W	0.322863	0.194199	
American Plaice	Georges Bank	all	SD	W	0.06563	0.000953	
American Plaice	Georges Bank	fall	SD	W			0.566616
American Plaice	Georges Bank	fall	SD	W			0.70244
American Plaice	Georges Bank	fall	SD	W			0.70244
American Plaice	Georges Bank	fall	SD	W			0.898669
American Plaice	Georges Bank	spring	SD	W			0.443657
American Plaice	Georges Bank	spring	SD	W			0.0771
American Plaice	Georges Bank	spring	SD	W			0.238593
American Plaice	Georges Bank	spring	SD	W			0.013328
American Plaice	Georges Bank	winter	SD	W			0.305059
American Plaice	Georges Bank	winter	SD	W			0.030368
American Plaice	Georges Bank	winter	SD	W			0.21
American Plaice	Georges Bank	winter	SD	W			0.052705
Witch Flounder	Georges Bank	all	SD	W	0.124172	0.200626	
Witch Flounder	Georges Bank	all	SD	W	0.543153	0.617123	
Witch Flounder	Georges Bank	all	SD	W	0.351447	0.269114	
Witch Flounder	Georges Bank	all	SD	W	0.923525	0.930964	
Witch Flounder	Georges Bank	fall	SD	W			0.444833
Witch Flounder	Georges Bank	fall	SD	W			0.524311
Witch Flounder	Georges Bank	fall	SD	W			0.655814
Witch Flounder	Georges Bank	fall	SD	W			0.566616
Witch Flounder	Georges Bank	spring	SD	W			0.443657
Witch Flounder	Georges Bank	spring	SD	W			0.859684
Witch Flounder	Georges Bank	spring	SD	W			0.215925
Witch Flounder	Georges Bank	spring	SD	W			0.4795
Acadian Redfish	Georges Bank	all	SD	W	0.573568	0.76492	
Acadian Redfish	Georges Bank	all	SD	W	0.010728	0.001963	
Acadian Redfish	Georges Bank	all	SD	W	0.174974	0.584986	
Acadian Redfish	Georges Bank	all	SD	W	0.034491	0.023123	
Acadian Redfish	Georges Bank	fall	SD	W			0.798966
Acadian Redfish	Georges Bank	fall	SD	W			0.111433
Acadian Redfish	Georges Bank	fall	SD	W			0.655814
Acadian Redfish	Georges Bank	fall	SD	W			0.444833
Acadian Redfish	Georges Bank	spring	SD	W			0.516868
Acadian Redfish	Georges Bank	spring	SD	W			0.006717
Acadian Redfish	Georges Bank	spring	SD	W			0.443657
Acadian Redfish	Georges Bank	spring	SD	W			0.015694
White Hake	Georges Bank	all	SD	W	0.172133	0.093167	
White Hake	Georges Bank	all	SD	W	0.658388	0.724624	
White Hake	Georges Bank	all	SD	W	0.333881	0.263352	
White Hake	Georges Bank	all	SD	W	0.001484	0.155635	
White Hake	Georges Bank	fall	SD	W			0.126484
White Hake	Georges Bank	fall	SD	W			0.111433
White Hake	Georges Bank	fall	SD	W			0.444833
White Hake	Georges Bank	fall	SD	W			0.202866
White Hake	Georges Bank	spring	SD	W			0.238593
White Hake	Georges Bank	spring	SD	W			0.637352
White Hake	Georges Bank	spring	SD	W			0.316472
White Hake	Georges Bank	spring	SD	W			0.288844
Pollock	Georges Bank	all	SD	W	0.956284	0.94036	
Pollock	Georges Bank	all	SD	W	0.235266	0.183857	
Pollock	Georges Bank	all	SD	W	0.232096	0.085014	
Pollock	Georges Bank	all	SD	W	0.897456	0.906902	
Pollock	Georges Bank	fall	SD	W			0.848514
Pollock	Georges Bank	fall	SD	W			0.566616
Pollock	Georges Bank	fall	SD	W			0.339541
Pollock	Georges Bank	fall	SD	W			0.750214
Pollock	Georges Bank	spring	SD	W			0.768278
Pollock	Georges Bank	spring	SD	W			0.029239
Pollock	Georges Bank	spring	SD	W			0.03917
Pollock	Georges Bank	spring	SD	W			0.723674

Table 3.7.1 (continued).

Ocean Pout	Georges Bank	all	SD	W	0.67499	0.58049	
Ocean Pout	Georges Bank	all	SD	W	0.987109	0.987866	
Ocean Pout	Georges Bank	all	SD	W	0.80934	0.758454	
Ocean Pout	Georges Bank	all	SD	W	0.838922	0.872914	
Ocean Pout	Georges Bank	fall	SD	W			0.048403
Ocean Pout	Georges Bank	fall	SD	W			0.161282
Ocean Pout	Georges Bank	fall	SD	W			0.041601
Ocean Pout	Georges Bank	fall	SD	W			0.407824
Ocean Pout	Georges Bank	spring	SD	W			0.140714
Ocean Pout	Georges Bank	spring	SD	W			0.111612
Ocean Pout	Georges Bank	spring	SD	W			0.175326
Ocean Pout	Georges Bank	spring	SD	W			0.08748
Ocean Pout	Georges Bank	winter	SD	W			0.683091
Ocean Pout	Georges Bank	winter	SD	W			0.540291
Ocean Pout	Georges Bank	winter	SD	W			0.307434
Ocean Pout	Georges Bank	winter	SD	W			0.683091
Windowpane	Northern	all	SD	W	0.673309	0.634325	
Windowpane	Northern	all	SD	W	0.114477	0.219954	
Windowpane	Northern	all	SD	W	0.537566	0.437876	
Windowpane	Northern	all	SD	W	0.08611	0.195187	
Windowpane	Northern	fall	SD	W			0.339541
Windowpane	Northern	fall	SD	W			0.339541
Windowpane	Northern	fall	SD	W			0.655814
Windowpane	Northern	fall	SD	W			0.202866
Windowpane	Northern	spring	SD	W			0.194851
Windowpane	Northern	spring	SD	W			0.316472
Windowpane	Northern	spring	SD	W			0.26289
Windowpane	Northern	spring	SD	W			0.859684
Windowpane	Northern	winter	SD	W			0.838256
Windowpane	Northern	winter	SD	W			0.414216
Windowpane	Northern	winter	SD	W			0.683091
Windowpane	Northern	winter	SD	W			0.220671
Halibut	Georges Bank	all	SD	W	0.777323	0.648636	
Halibut	Georges Bank	all	SD	W	0.296723	0.356407	
Halibut	Georges Bank	all	SD	W	0.734529	0.67077	
Halibut	Georges Bank	all	SD	W	0.116645	0.081905	
Halibut	Georges Bank	fall	SD	W			0.898664
Halibut	Georges Bank	fall	SD	W			0.898669
Halibut	Georges Bank	fall	SD	W			1
Halibut	Georges Bank	fall	SD	W			0.949232
Halibut	Georges Bank	spring	SD	W			0.634226
Halibut	Georges Bank	spring	SD	W			0.078983
Halibut	Georges Bank	spring	SD	W			0.906186
Halibut	Georges Bank	spring	SD	W			0.021556
Dogfish	Georges Bank	all	SD	W	0.657296	0.766204	
Dogfish	Georges Bank	all	SD	W	0.268458	0.221025	
Dogfish	Georges Bank	all	SD	W	0.725488	0.800442	
Dogfish	Georges Bank	all	SD	W	0.311377	0.247918	
Dogfish	Georges Bank	fall	SD	W			0.308325
Dogfish	Georges Bank	fall	SD	W			0.161282
Dogfish	Georges Bank	fall	SD	W			0.226372
Dogfish	Georges Bank	fall	SD	W			0.226372
Dogfish	Georges Bank	spring	SD	W			0.175326
Dogfish	Georges Bank	spring	SD	W			0.345779
Dogfish	Georges Bank	spring	SD	W			0.516868
Dogfish	Georges Bank	spring	SD	W			0.376759
Dogfish	Georges Bank	winter	SD	W			0.414216
Dogfish	Georges Bank	winter	SD	W			0.307434
Dogfish	Georges Bank	winter	SD	W			0.307434
Dogfish	Georges Bank	winter	SD	W			0.414216

Table 3.7.1 (continued).

Fourspot Flounder	Georges Bank	all	SD	W	0.468537	0.520394	
Fourspot Flounder	Georges Bank	all	SD	W	0.782591	0.818612	
Fourspot Flounder	Georges Bank	all	SD	W	0.674166	0.73479	
Fourspot Flounder	Georges Bank	all	SD	W	0.636316	0.732836	
Fourspot Flounder	Georges Bank	fall	SD	W			0.610492
Fourspot Flounder	Georges Bank	fall	SD	W			0.111433
Fourspot Flounder	Georges Bank	fall	SD	W			0.750214
Fourspot Flounder	Georges Bank	fall	SD	W			0.70244
Fourspot Flounder	Georges Bank	spring	SD	W			0.03917
Fourspot Flounder	Georges Bank	spring	SD	W			0.09896
Fourspot Flounder	Georges Bank	spring	SD	W			0.033895
Fourspot Flounder	Georges Bank	spring	SD	W			0.09896
Fourspot Flounder	Georges Bank	winter	SD	W			0.066193
Fourspot Flounder	Georges Bank	winter	SD	W			0.066193
Fourspot Flounder	Georges Bank	winter	SD	W			0.066193
Fourspot Flounder	Georges Bank	winter	SD	W			0.066193
Longhorn Sculpin	Georges Bank	all	SD	W	0.180463	0.110084	
Longhorn Sculpin	Georges Bank	all	SD	W	0.353837	0.205575	
Longhorn Sculpin	Georges Bank	all	SD	W	0.140948	0.107944	
Longhorn Sculpin	Georges Bank	all	SD	W	0.209937	0.107135	
Longhorn Sculpin	Georges Bank	fall	SD	W			0.407824
Longhorn Sculpin	Georges Bank	fall	SD	W			0.655814
Longhorn Sculpin	Georges Bank	fall	SD	W			0.483686
Longhorn Sculpin	Georges Bank	fall	SD	W			0.610492
Longhorn Sculpin	Georges Bank	spring	SD	W			0.316472
Longhorn Sculpin	Georges Bank	spring	SD	W			0.4795
Longhorn Sculpin	Georges Bank	spring	SD	W			0.288844
Longhorn Sculpin	Georges Bank	spring	SD	W			0.316472
Longhorn Sculpin	Georges Bank	winter	SD	W			0.220671
Longhorn Sculpin	Georges Bank	winter	SD	W			0.414216
Longhorn Sculpin	Georges Bank	winter	SD	W			0.307434
Longhorn Sculpin	Georges Bank	winter	SD	W			0.414216
Winter Flounder	Georges Bank	all	SD	W	0.483801	0.440467	
Winter Flounder	Georges Bank	all	SD	W	0.363302	0.4133	
Winter Flounder	Georges Bank	all	SD	W	0.468608	0.411567	
Winter Flounder	Georges Bank	all	SD	W	0.302825	0.352209	
Winter Flounder	Georges Bank	fall	SD	W			0.135682
Winter Flounder	Georges Bank	fall	SD	W			0.193759
Winter Flounder	Georges Bank	fall	SD	W			0.135682
Winter Flounder	Georges Bank	fall	SD	W			0.193759
Winter Flounder	Georges Bank	spring	SD	W			0.143235
Winter Flounder	Georges Bank	spring	SD	W			0.305507
Winter Flounder	Georges Bank	spring	SD	W			0.124283
Winter Flounder	Georges Bank	spring	SD	W			0.213399
Winter Flounder	Georges Bank	winter	SD	W			0.10247
Winter Flounder	Georges Bank	winter	SD	W			0.414216
Winter Flounder	Georges Bank	winter	SD	W			0.10247
Winter Flounder	Georges Bank	winter	SD	W			0.414216
Summer Flounder	Georges Bank	all	SD	W	0.605129	0.699592	
Summer Flounder	Georges Bank	all	SD	W	0.820766	0.879866	
Summer Flounder	Georges Bank	all	SD	W	0.699944	0.751436	
Summer Flounder	Georges Bank	all	SD	W	0.473265	0.653004	
Summer Flounder	Georges Bank	fall	SD	W			0.150382
Summer Flounder	Georges Bank	fall	SD	W			0.3268
Summer Flounder	Georges Bank	fall	SD	W			0.191063
Summer Flounder	Georges Bank	fall	SD	W			0.214211
Summer Flounder	Georges Bank	spring	SD	W			0.906186
Summer Flounder	Georges Bank	spring	SD	W			0.4795
Summer Flounder	Georges Bank	spring	SD	W			0.813664
Summer Flounder	Georges Bank	spring	SD	W			0.443657
Summer Flounder	Georges Bank	winter	SD	W			0.21
Summer Flounder	Georges Bank	winter	SD	W			0.73244
Summer Flounder	Georges Bank	winter	SD	W			0.21
Summer Flounder	Georges Bank	winter	SD	W			0.305059

Table 3.7.1 (continued).

Haddock	Gulf of Maine	all	SD	W	0.870036	0.905378	
Haddock	Gulf of Maine	all	SD	W	0.031405	0.058599	
Haddock	Gulf of Maine	all	SD	W	0.132005	0.270298	
Haddock	Gulf of Maine	all	SD	W	0.106911	0.178393	
Haddock	Gulf of Maine	fall	SD	W			1
Haddock	Gulf of Maine	fall	SD	W			0.097832
Haddock	Gulf of Maine	fall	SD	W			0.143073
Haddock	Gulf of Maine	fall	SD	W			0.202866
Haddock	Gulf of Maine	spring	SD	W			0.859684
Haddock	Gulf of Maine	spring	SD	W			0.157299
Haddock	Gulf of Maine	spring	SD	W			0.927432
Haddock	Gulf of Maine	spring	SD	W			0.236415
Cod	Gulf of Maine	all	SD	W	0.530754	0.584534	
Cod	Gulf of Maine	all	SD	W	0.393274	0.450724	
Cod	Gulf of Maine	all	SD	W	0.183749	0.398397	
Cod	Gulf of Maine	all	SD	W	0.047991	0.094618	
Cod	Gulf of Maine	fall	SD	W			1
Cod	Gulf of Maine	fall	SD	W			0.111433
Cod	Gulf of Maine	fall	SD	W			0.524311
Cod	Gulf of Maine	fall	SD	W			0.161282
Cod	Gulf of Maine	spring	SD	W			0.316472
Cod	Gulf of Maine	spring	SD	W			0.953011
Cod	Gulf of Maine	spring	SD	W			0.345779
Cod	Gulf of Maine	spring	SD	W			0.288844
Yellowtail	S. New England	all	SD	W	0.702098	0.801407	
Yellowtail	S. New England	all	SD	W	0.046119	0.031408	
Yellowtail	S. New England	all	SD	W	0.949283	0.957267	
Yellowtail	S. New England	all	SD	W	0.04699	0.045465	
Yellowtail	S. New England	fall	SD	W			0.566616
Yellowtail	S. New England	fall	SD	W			0.226372
Yellowtail	S. New England	fall	SD	W			0.251759
Yellowtail	S. New England	fall	SD	W			0.251759
Yellowtail	S. New England	spring	SD	W			0.859684
Yellowtail	S. New England	spring	SD	W			0.345779
Yellowtail	S. New England	spring	SD	W			0.768278
Yellowtail	S. New England	spring	SD	W			0.26289
Yellowtail	S. New England	winter	SD	W			0.683091
Yellowtail	S. New England	winter	SD	W			0.10247
Yellowtail	S. New England	winter	SD	W			1
Yellowtail	S. New England	winter	SD	W			0.041227
Windowpane	Southern	all	SD	W	0.673705	0.664883	
Windowpane	Southern	all	SD	W	0.769474	0.791003	
Windowpane	Southern	all	SD	W	0.715402	0.71455	
Windowpane	Southern	all	SD	W	0.59928	0.632188	
Windowpane	Southern	fall	SD	W			0.226372
Windowpane	Southern	fall	SD	W			0.566616
Windowpane	Southern	fall	SD	W			0.279068
Windowpane	Southern	fall	SD	W			0.898669
Windowpane	Southern	spring	SD	W			0.953011
Windowpane	Southern	spring	SD	W			0.4795
Windowpane	Southern	spring	SD	W			0.813664
Windowpane	Southern	spring	SD	W			0.637352
Windowpane	Southern	winter	SD	W			0.838256
Windowpane	Southern	winter	SD	W			0.540291
Windowpane	Southern	winter	SD	W			0.838256
Windowpane	Southern	winter	SD	W			0.414216

Table 3.7.1 (continued).

Winter Flounder	S. New England	all	SD	W	0.032823	0.003262	
Winter Flounder	S. New England	all	SD	W	0.125266	0.135732	
Winter Flounder	S. New England	all	SD	W	0.054484	0.009231	
Winter Flounder	S. New England	all	SD	W	0.138046	0.123636	
Winter Flounder	S. New England	fall	SD	W			0.143073
Winter Flounder	S. New England	fall	SD	W			0.339541
Winter Flounder	S. New England	fall	SD	W			0.161282
Winter Flounder	S. New England	fall	SD	W			0.483686
Winter Flounder	S. New England	spring	SD	W			0.26289
Winter Flounder	S. New England	spring	SD	W			0.768278
Winter Flounder	S. New England	spring	SD	W			0.345779
Winter Flounder	S. New England	spring	SD	W			0.516868
Winter Flounder	S. New England	winter	SD	W			0.220671
Winter Flounder	S. New England	winter	SD	W			0.307434
Winter Flounder	S. New England	winter	SD	W			0.10247
Winter Flounder	S. New England	winter	SD	W			0.307434
Yellowtail	Cape Cod	all	SD	W	0.348209	0.247442	
Yellowtail	Cape Cod	all	SD	W	0.499274	0.654831	
Yellowtail	Cape Cod	all	SD	W	0.347324	0.253839	
Yellowtail	Cape Cod	all	SD	W	0.368072	0.562796	
Yellowtail	Cape Cod	fall	SD	W			0.898669
Yellowtail	Cape Cod	fall	SD	W			0.949232
Yellowtail	Cape Cod	fall	SD	W			0.949232
Yellowtail	Cape Cod	fall	SD	W			1
Yellowtail	Cape Cod	spring	SD	W			0.194819
Yellowtail	Cape Cod	spring	SD	W			0.443657
Yellowtail	Cape Cod	spring	SD	W			0.236415
Yellowtail	Cape Cod	spring	SD	W			0.378639
				Total Tests	88	88	232
	Num P levels less than 0.05				0	0	0
	Fraction pf tests with less than 0.05				0.000	0.000	0.000
	Bonferroni P level for multiple tests, each with 5% Type I errors				0.000284091	0.000284091	0.000107759
	Number of tests that with probability levels less than Bonferroni limit				0	0	0

Table 3.7.2. Summary of statistical test of regression model for standardized difference of pre-post treatment catch rates versus depth for numbers per tow, and biomass (kg) per tow.
Model type refers to response variable: num/tow= Nd_stan, weight per tow=Wd_stan.

model type	Species	Stock	Season	Effect: Constant	Effect: DepthMid	Adj R^2	p-value
Nd_stan	Acadian Redfish	all	fall	0.473255	-0.002754	0	0.573
Wd_stan	Acadian Redfish	1	fall	0.699839	-0.004073	0	0.399
Nd_stan	Acadian Redfish	all	spring	0.203443	-0.001017	0	0.772
Wd_stan	Acadian Redfish	all	spring	0.005724	-0.000029	0	0.994
Nd_stan	American Plaice	all	fall	0.707636	-0.00467	0.063654	0.205
Wd_stan	American Plaice	all	fall	0.709069	-0.004679	0.06428	0.204
Nd_stan	American Plaice	all	spring	-0.379685	0.002109	0	0.456
Wd_stan	American Plaice	all	spring	-0.336627	0.00187	0	0.509
Nd_stan	American Plaice	all	winter	2.350554	-0.019588	0.421454	0.097
Wd_stan	American Plaice	all	winter	2.748405	-0.022903	0.667988	0.029
Nd_stan	cod	GB	fall	-0.113871	0.000949	0	0.875
Wd_stan	Cod	GB	fall	-0.400822	0.00334	0	0.575
Nd_stan	cod	GB	spring	0.00633	-0.000053	0	0.993
Wd_stan	Cod	GB	spring	-0.055814	0.000465	0	0.938
Nd_stan	cod	GB	winter	0.270265	-0.002252	0	0.874
Wd_stan	Cod	GB	winter	-0.739223	0.00616	0	0.660
Nd_stan	cod	GM	fall	-1.586011	0.009231	0.346768	0.033
Wd_stan	Cod	GM	fall	-1.368388	0.007964	0.229734	0.077
Nd_stan	cod	GM	spring	-1.774249	0.008871	0.513467	0.002
Wd_stan	Cod	GM	spring	-0.646247	0.003231	0	0.350
Nd_stan	Dogfish	all	fall	-0.236035	0.001475	0	0.674
Wd_stan	Dogfish	all	fall	-0.018783	0.000117	0	0.973
Nd_stan	Dogfish	all	spring	0.333086	-0.00185	0	0.514
Wd_stan	Dogfish	all	spring	0.348654	-0.001937	0	0.494
Nd_stan	Dogfish	all	winter	0.511442	-0.003086	0.005047	0.322
Wd_stan	Dogfish	all	winter	0.773519	-0.004668	0.118831	0.123
Nd_stan	Fluke	all	fall	-0.22145	0.001845	0	0.680
Wd_stan	Fluke	all	fall	-0.290864	0.002424	0	0.587
Nd_stan	Fluke	all	spring	-0.880215	0.007335	0.207759	0.077
Wd_stan	Fluke	all	spring	-0.960853	0.008007	0.266731	0.049
Nd_stan	Fluke	all	winter	-0.783761	0.009797	0	0.475
Wd_stan	Fluke	all	winter	-0.10594	0.001324	0	0.926
Nd_stan	Fourspot Flounder	all	fall	-0.595604	0.004803	0	0.367
Wd_stan	Fourspot Flounder	all	fall	-0.517414	0.004173	0	0.436
Nd_stan	Fourspot Flounder	all	spring	-0.807506	0.005383	0.10089	0.154
Wd_stan	Fourspot Flounder	all	spring	-0.878435	0.005856	0.136065	0.117
Nd_stan	Fourspot Flounder	all	winter	-0.26492	0.001599	0	0.614
Wd_stan	Fourspot Flounder	all	winter	-0.355459	0.002145	0	0.496
Nd_stan	haddock	GB	fall	-0.084348	0.000588	0	0.887
Wd_stan	Haddock	GB	fall	-0.19594	0.001367	0	0.741
Nd_stan	haddock	GB	spring	-0.41692	0.002396	0	0.413
Wd_stan	Haddock	GB	spring	-0.070542	0.000405	0	0.891
Nd_stan	haddock	GB	winter	-1.413863	0.011782	0	0.382
Wd_stan	Haddock	GB	winter	-1.154848	0.009624	0	0.483
Nd_stan	haddock	GOM	fall	-0.197185	0.001232	0	0.838
Wd_stan	Haddock	GOM	fall	-0.537264	0.003358	0	0.573
Nd_stan	haddock	GOM	spring	-0.115982	0.000725	0	0.904
Wd_stan	Haddock	GOM	spring	-0.513181	0.003207	0	0.591
Nd_stan	Longhorn Sculpin	all	fall	0.568906	-0.004741	0	0.421
Wd_stan	Longhorn Sculpin	all	fall	0.687844	-0.005732	0.010532	0.326
Nd_stan	Longhorn Sculpin	all	spring	-1.668872	0.013907	0.672825	0.002
Wd_stan	Longhorn Sculpin	all	spring	-1.580484	0.013171	0.590553	0.006
Nd_stan	Longhorn Sculpin	all	winter	-1.382063	0.017276	0.272292	0.165
Wd_stan	Longhorn Sculpin	all	winter	-1.354093	0.016926	0.251366	0.177
Nd_stan	Ocean Pout	all	fall	0.629009	-0.004839	0.003345	0.336
Wd_stan	Ocean Pout	all	fall	0.587859	-0.004522	0	0.370
Nd_stan	Ocean Pout	all	spring	-0.288995	0.002223	0	0.665
Wd_stan	Ocean Pout	all	spring	-0.217109	0.00167	0	0.746
Nd_stan	Ocean Pout	all	winter	0.080832	-0.000652	0	0.905
Wd_stan	Ocean Pout	all	winter	0.3447	-0.00278	0	0.608

Table 3.7.2 (continued).

Nd_stan	Pollock	all	fall	0.665613	-0.004392	0.045841	0.235
Wd_stan	Pollock	all	fall	0.49967	-0.003297	0	0.380
Nd_stan	Pollock	all	spring	0.165327	-0.000918	0	0.747
Wd_stan	Pollock	all	spring	0.704614	-0.003915	0.077428	0.155
Nd_stan	White Hake	all	fall	0.74412	-0.00491	0.080002	0.181
Wd_stan	White Hake	all	fall	0.973632	-0.006425	0.201691	0.070
Nd_stan	White Hake	all	spring	1.250393	-0.006947	0.39734	0.005
Wd_stan	White Hake	all	spring	1.299752	-0.007221	0.43508	0.003
Nd_stan	Windowpane	North	fall	0.811478	-0.005796	0.092174	0.176
Wd_stan	Windowpane	North	fall	0.972239	-0.006945	0.175858	0.097
Nd_stan	Windowpane	North	spring	-1.1458	0.007161	0.305566	0.024
Wd_stan	Windowpane	North	spring	-1.178886	0.007368	0.32835	0.019
Nd_stan	Windowpane	North	winter	-2.544398	0.021203	0.536766	0.060
Wd_stan	Windowpane	North	winter	-2.444078	0.020367	0.475948	0.078
Nd_stan	Windowpane	South	fall	-0.472428	0.004395	0	0.502
Wd_stan	Windowpane	South	fall	-0.652119	0.006066	0.007209	0.345
Nd_stan	Windowpane	South	spring	-0.411368	0.002904	0	0.496
Wd_stan	Windowpane	South	spring	-0.134864	0.000952	0	0.825
Nd_stan	Windowpane	South	winter	-0.340323	0.002054	0	0.515
Wd_stan	Windowpane	South	winter	-0.509875	0.003077	0.004506	0.324
Nd_stan	Winter Flounder	GB	fall	1.414214	-0.070711	n/a	n/a
Wd_stan	Winter Flounder	GB	fall	1.414214	-0.070711	n/a	n/a
Nd_stan	Winter Flounder	GB	spring	-1.358549	0.045285	0.640582	0.279
Wd_stan	Winter Flounder	GB	spring	-1.424703	0.04749	0.804248	0.203
Nd_stan	Winter Flounder	GB	winter	0.829594	-0.007392	0.072265	0.243
Wd_stan	Winter Flounder	GB	winter	0.874185	-0.00779	0.096012	0.216
Nd_stan	Winter Flounder	SNE	fall	-0.387029	0.002908	0	0.423
Wd_stan	Winter Flounder	SNE	fall	-0.375643	0.002823	0	0.438
Nd_stan	Winter Flounder	SNE	spring	0.386662	-0.002379	0	0.378
Wd_stan	Winter Flounder	SNE	spring	0.487718	-0.003001	0.023735	0.262
Nd_stan	Winter Flounder	SNE	winter	-0.533972	0.006675	0	0.456
Wd_stan	Winter Flounder	SNE	winter	-1.248604	0.015608	0.241034	0.060
Nd_stan	Witch Flouder	all	fall	0.197154	-0.001301	0	0.733
Wd_stan	Witch Flouder	all	fall	-0.084724	0.000559	0	0.884
Nd_stan	Witch Flouder	all	spring	0.229952	-0.001278	0	0.654
Wd_stan	Witch Flouder	all	spring	0.663112	-0.003684	0.060409	0.183
Nd_stan	Yellowtail	GB	fall	-0.525323	0.005837	0	0.585
Wd_stan	Yellowtail	GB	fall	-0.524222	0.005825	0	0.586
Nd_stan	Yellowtail	GB	spring	-0.266372	0.00333	0	0.814
Wd_stan	Yellowtail	GB	spring	-0.280611	0.003508	0	0.804
Nd_stan	Yellowtail	GB	winter	-2.389447	0.019912	0.443857	0.089
Wd_stan	Yellowtail	GB	winter	-2.266207	0.018885	0.37413	0.116
Nd_stan	Yellowtail	SNE	fall	-0.622878	0.010381	0	0.732
Wd_stan	Yellowtail	SNE	fall	-2.005485	0.033425	0.617214	0.137
Nd_stan	Yellowtail	SNE	spring	-0.787223	0.011246	0	0.557
Wd_stan	Yellowtail	SNE	spring	-1.35803	0.0194	0.168502	0.271
Nd_stan	Yellowtail	SNE	winter	0.387471	-0.005535	0	0.778
Wd_stan	Yellowtail	SNE	winter	-0.132346	0.001891	0	0.924
Nd_stan	Yellowtail	CC	fall	0.694145	-0.013883	0	0.460
Wd_stan	Yellowtail	CC	fall	0.67586	-0.013517	0	0.473
Nd_stan	Yellowtail	CC	spring	0.313874	-0.005231	0	0.710
Wd_stan	Yellowtail	CC	spring	0.228901	-0.003815	0	0.787

Table 3.7.3. Summary of statistical tests of regression model for standardized difference of pre-post treatment catch rates versus deoth for numbers per tow, and biomass (kg) per tow. Model type refers to response variable: num/tow= Nd_stan, weight per tow=Wd_stan. For these analyses, all species are pooled; the depth effect coefficient represents the change in the standardized difference. Positive values imply that the pre-treatment catch rates exceeded the post-treatment catch rates.

Model Type	Difference	Season	Constant	Depthmid	Adj. R^2	p-value
Wd stan	Weight	spring	-0.018886	0.000121	0	0.8621
Nd_stan	Number	spring	-0.142906	0.000914	0.002964	0.1879
lnWd_stan	ln W	spring	0.023038	-0.000147	0	0.8322
lnNd_stan	ln N	spring	0.081126	-0.000519	0	0.4553
Wd stan	Weight	fall	0.066983	-0.000492	0	0.5780
Nd_stan	Number	fall	0.075799	-0.000556	0	0.5289
lnWd_stan	ln W	fall	0.358677	-0.002632	0.037413	0.0026
lnNd_stan	ln N	fall	0.416881	-0.003059	0.052196	0.0004
Wd stan	Weight	winter	-0.065415	0.000521	0	0.6700
Nd_stan	Number	winter	-0.064781	0.000515	0	0.6730
lnWd_stan	ln W	winter	-0.085622	0.000681	0	0.5769
lnNd_stan	ln N	winter	0.002906	-0.000023	0	0.9849

Table 3.7.4. Summary of frequencies of standardized residuals of average catch (number/tow) vs Depth for all species combined.
Expected frequencies are based on assumption that standardized residuals are normally distributed.

80%CI				80% CI				
90% CI			90% CI					
95% CI		95% CI						
min Stan Dif	<-1.96	-1.96	-1.645	-1.282	0	1.282	1.645	
max Stan Dif		-1.645	-1.282	0	1.282	1.645	1.96	>1.96

Depth Interval (m)	<0.025	(0.025-0.05)	(0.05-0.10)	(0.10-0.50)	(0.50-0.90)	(0.90-0.95)	(0.95-0.975)	>0.975	Total
10	0	0	0	5	3	0	0	0	8
30	3	1	0	17	23	0	0	2	46
50	3	0	1	16	18	4	2	1	45
70	4	4	4	16	21	2	2	2	55
90	4	1	2	24	20	1	2	1	55
110	4	0	1	21	23	2	2	0	53
130	0	1	2	17	24	3	2	1	50
150	4	0	2	11	22	1	1	4	45
170	2	0	0	15	24	1	0	1	43
190	1	2	0	17	15	0	0	0	35
210	2	0	0	12	20	1	1	2	38
230	0	0	0	15	17	2	0	0	34
250	0	0	0	5	15	1	0	0	21
270	1	0	0	6	8	0	0	0	15
290	0	0	1	7	13	0	0	0	21
310	0	0	0	4	5	0	0	0	9
330	1	0	1	4	6	0	0	0	12
Total	29	9	14	212	277	18	12	14	585
Percent	0.050	0.015	0.024	0.362	0.474	0.031	0.021	0.024	
Expected%	0.025	0.025	0.05	0.34135	0.34135	0.05	0.025	0.025	
Expected #	14.6	14.6	29.3	199.7	199.7	29.3	14.6	14.6	

Cod, Georges Bank Stock

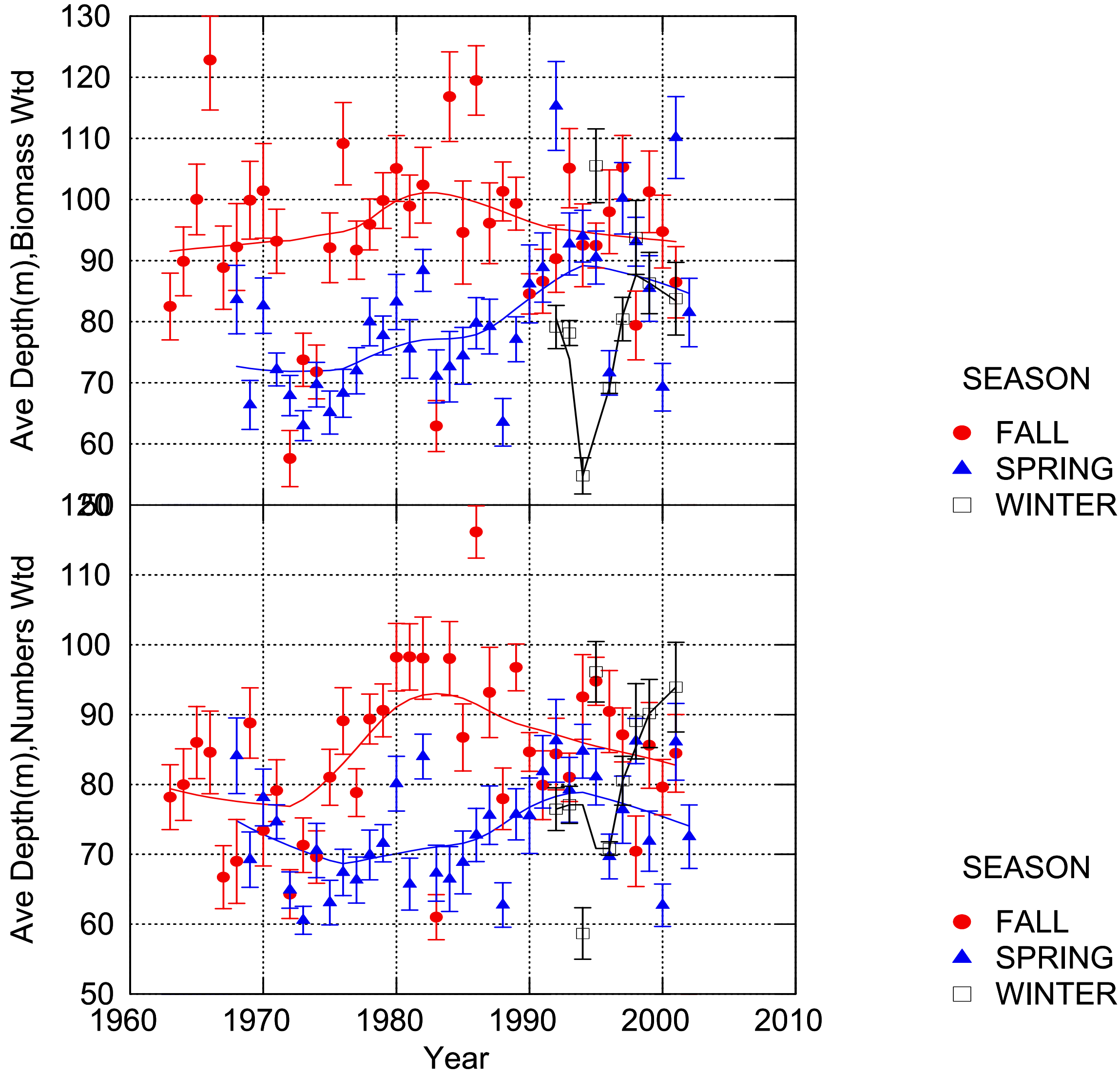


Fig. 3.7.1. Temporal trends in catch weighted average depth for Georges Bank Cod stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

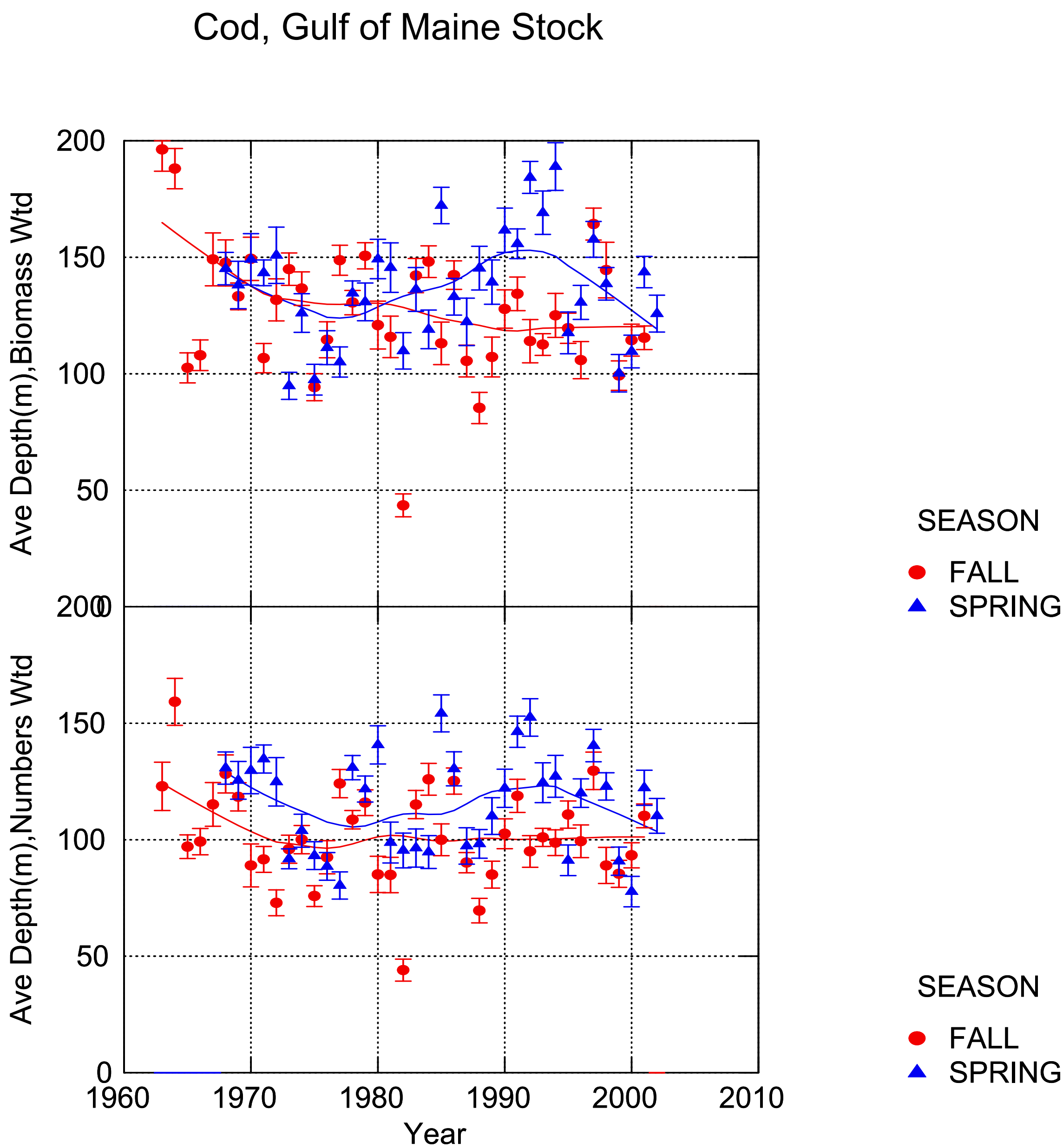


Fig. 3.7. 2. Temporal trends in catch weighted average depth for Gulf of Maine Cod stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Haddock, Georges Bank Stock

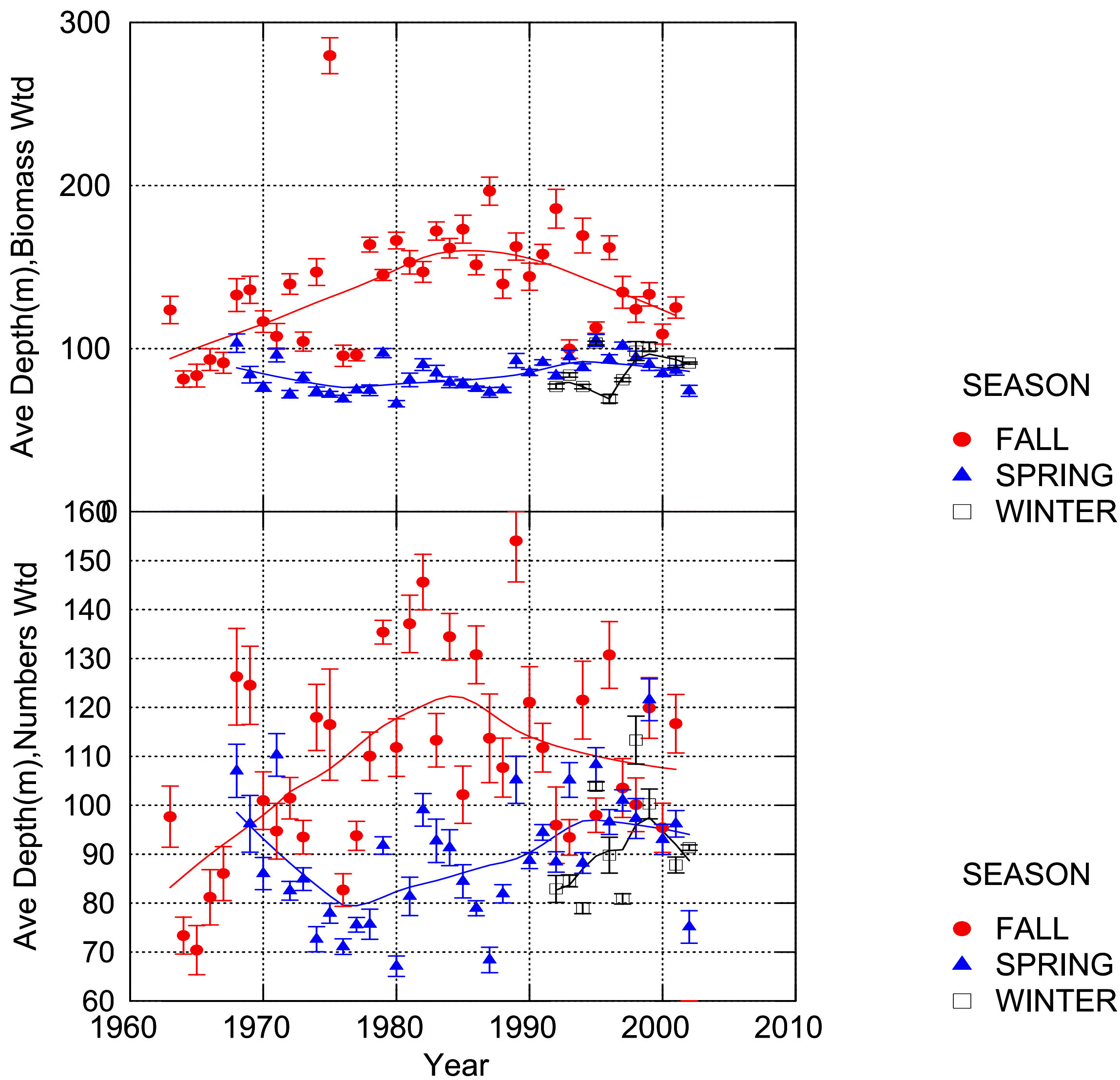


Fig. 3.7.3. Temporal trends in catch weighted average depth for Georges Bank Haddock stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

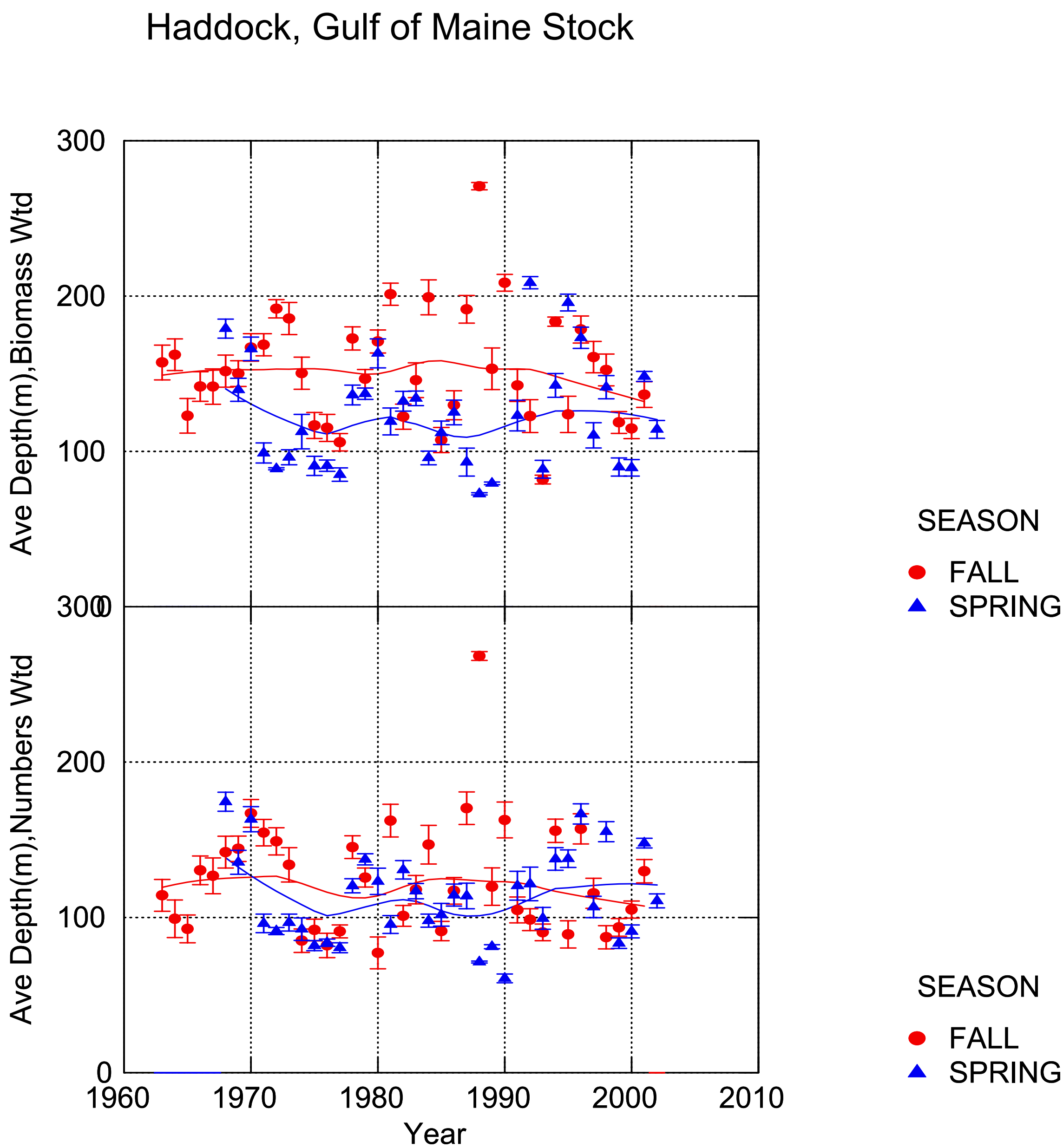


Fig. 3.7.4. Temporal trends in catch weighted average depth for Gulf of Maine Haddock stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

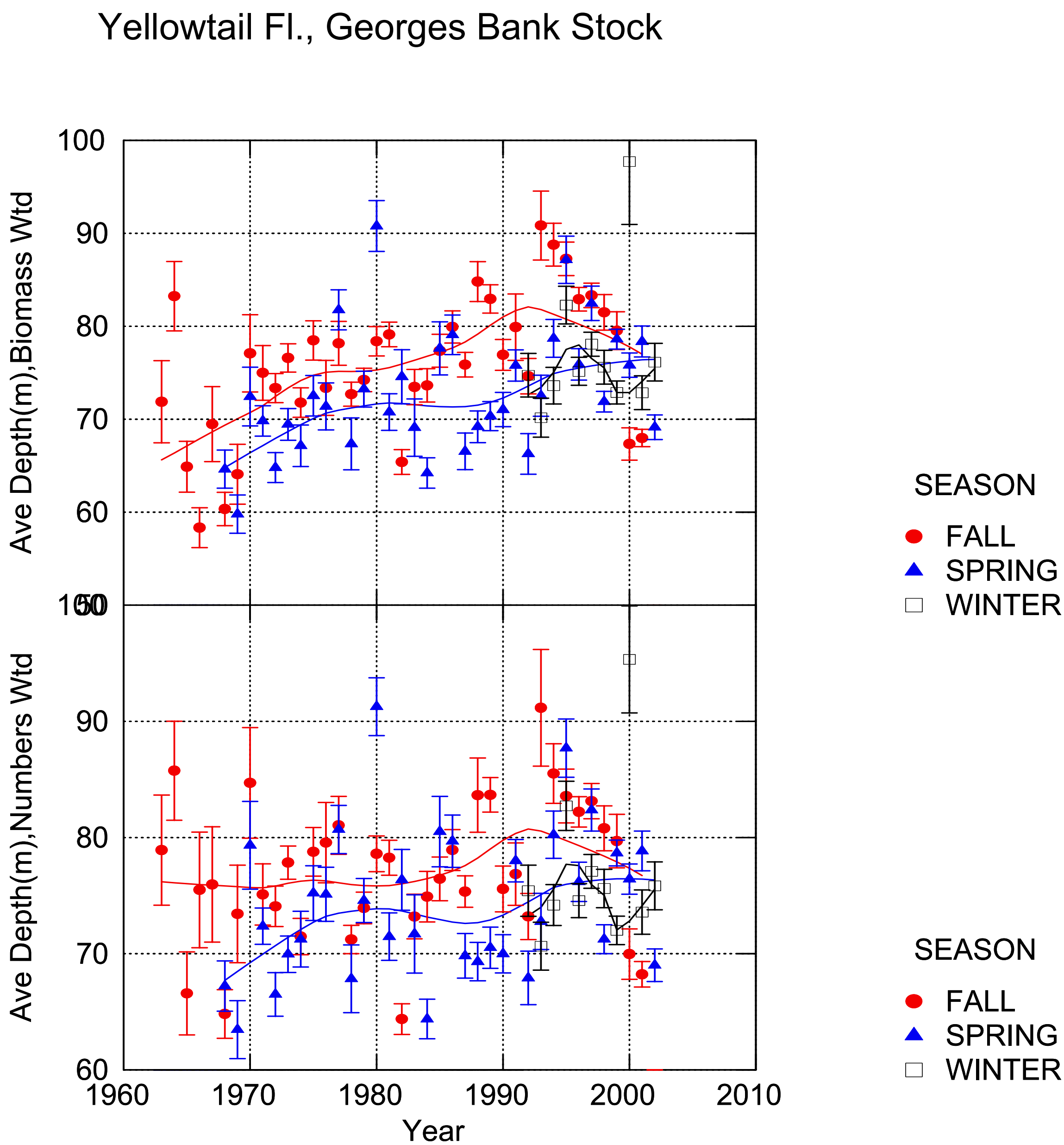


Fig. 3.7.5. Temporal trends in catch weighted average depth for Georges Bank Yellowtail stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

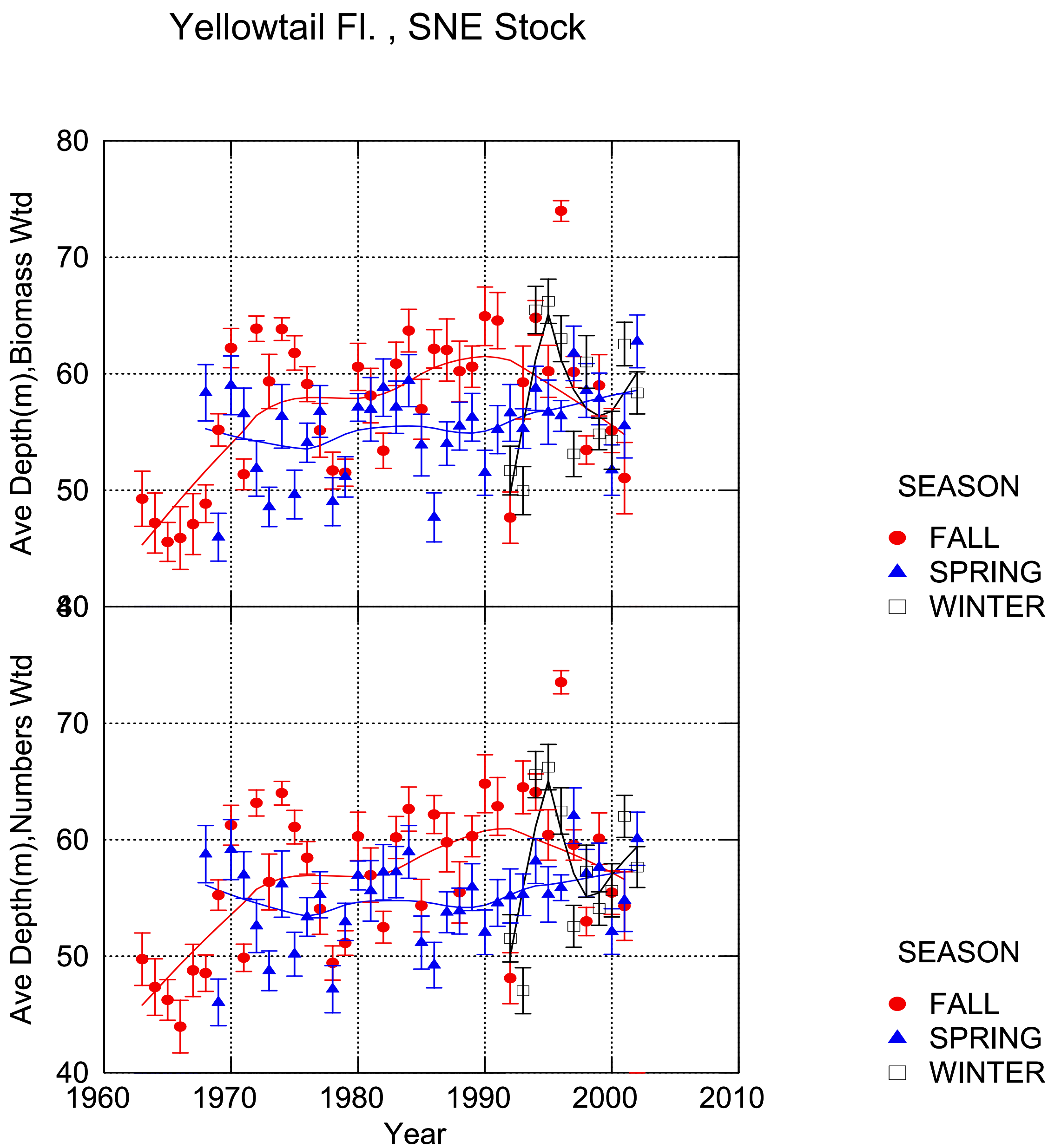


Fig. 3.7.6. Temporal trends in catch weighted average depth for Southern New England Yellowtail stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Yellowtail Fl., Cape Cod Stock

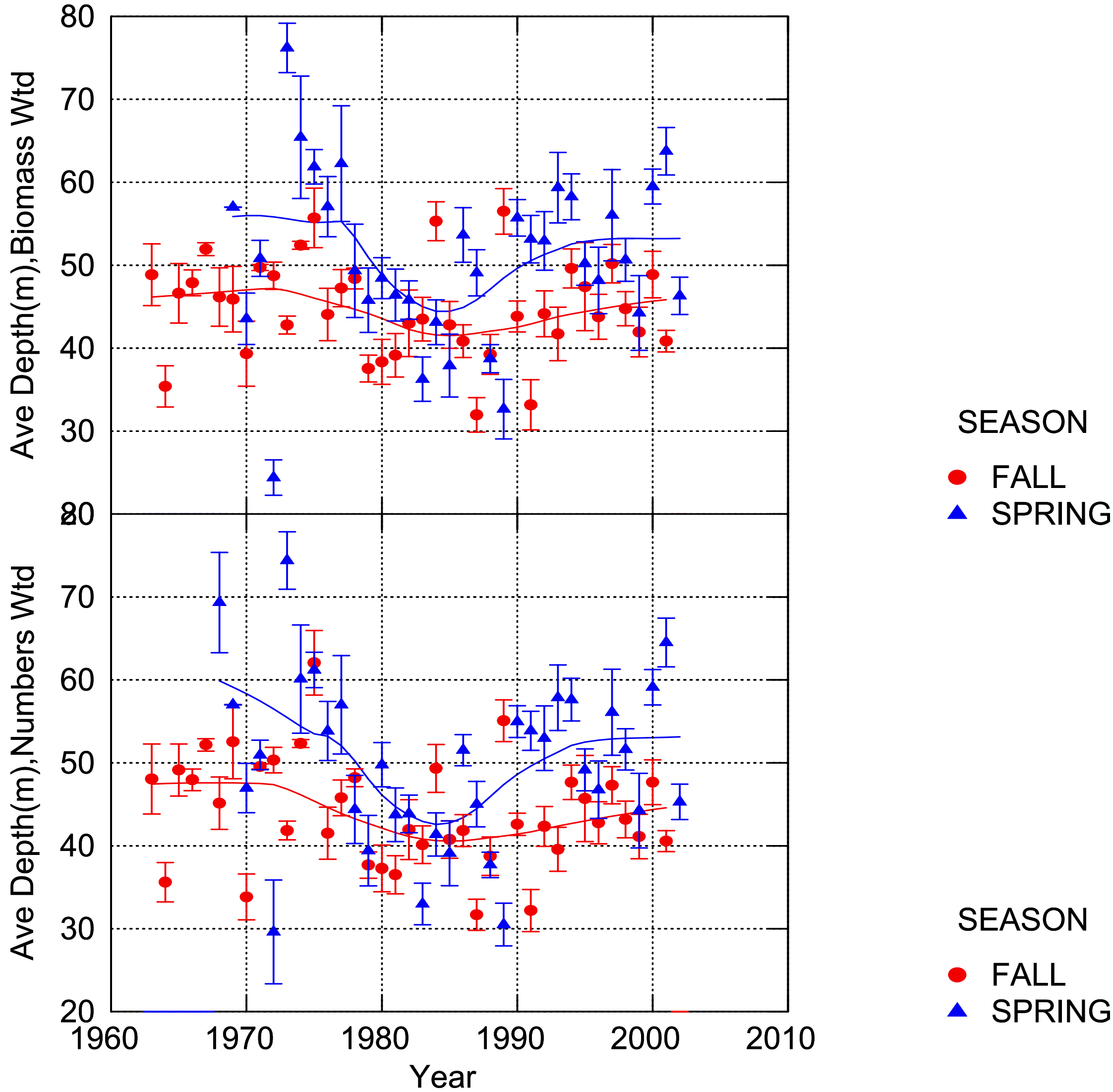


Fig. 3.7.7. Temporal trends in catch weighted average depth for Cape Cod Yellowtail Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

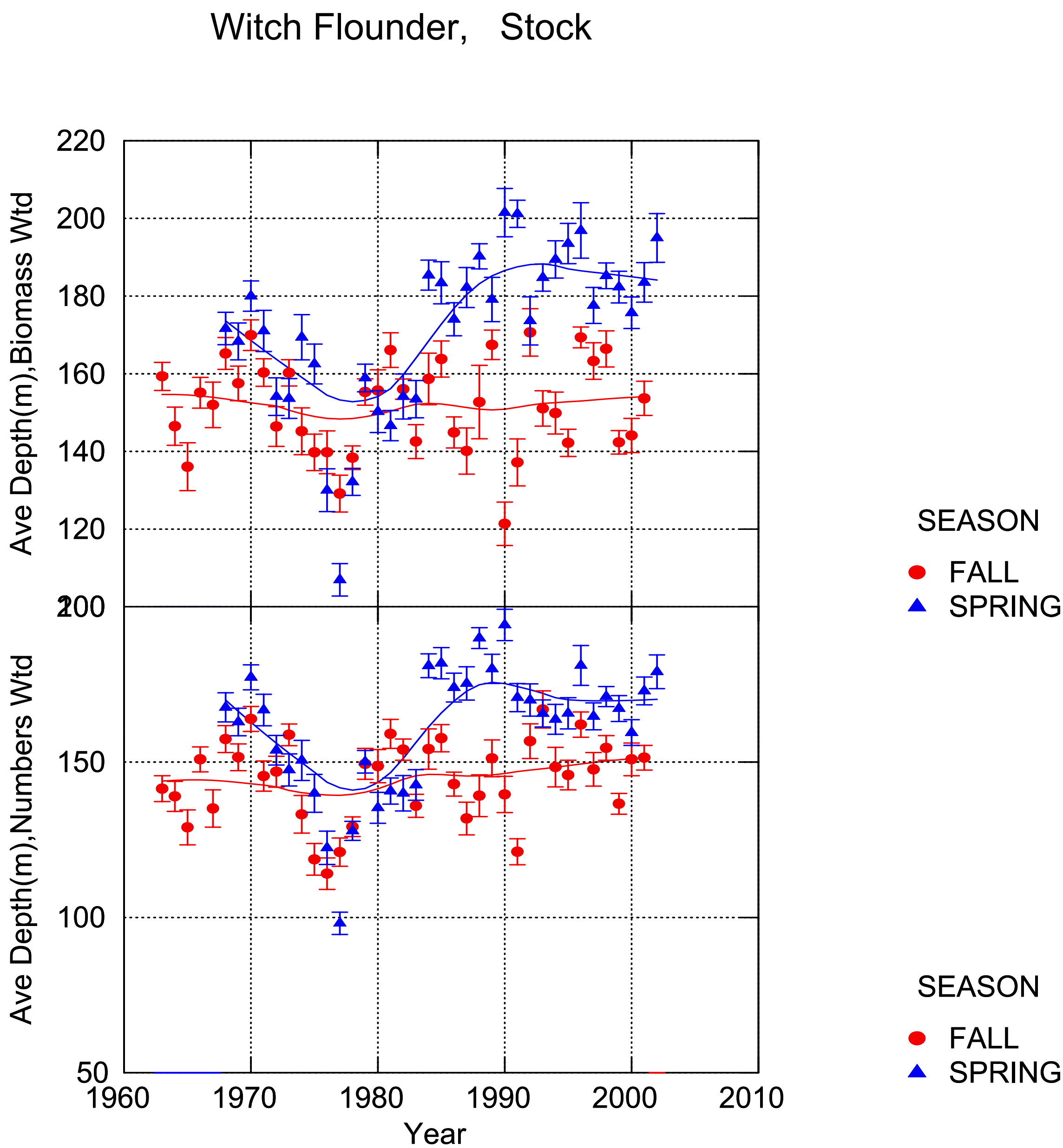


Fig. 3.7.8. Temporal trends in catch weighted average depth for Witch Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

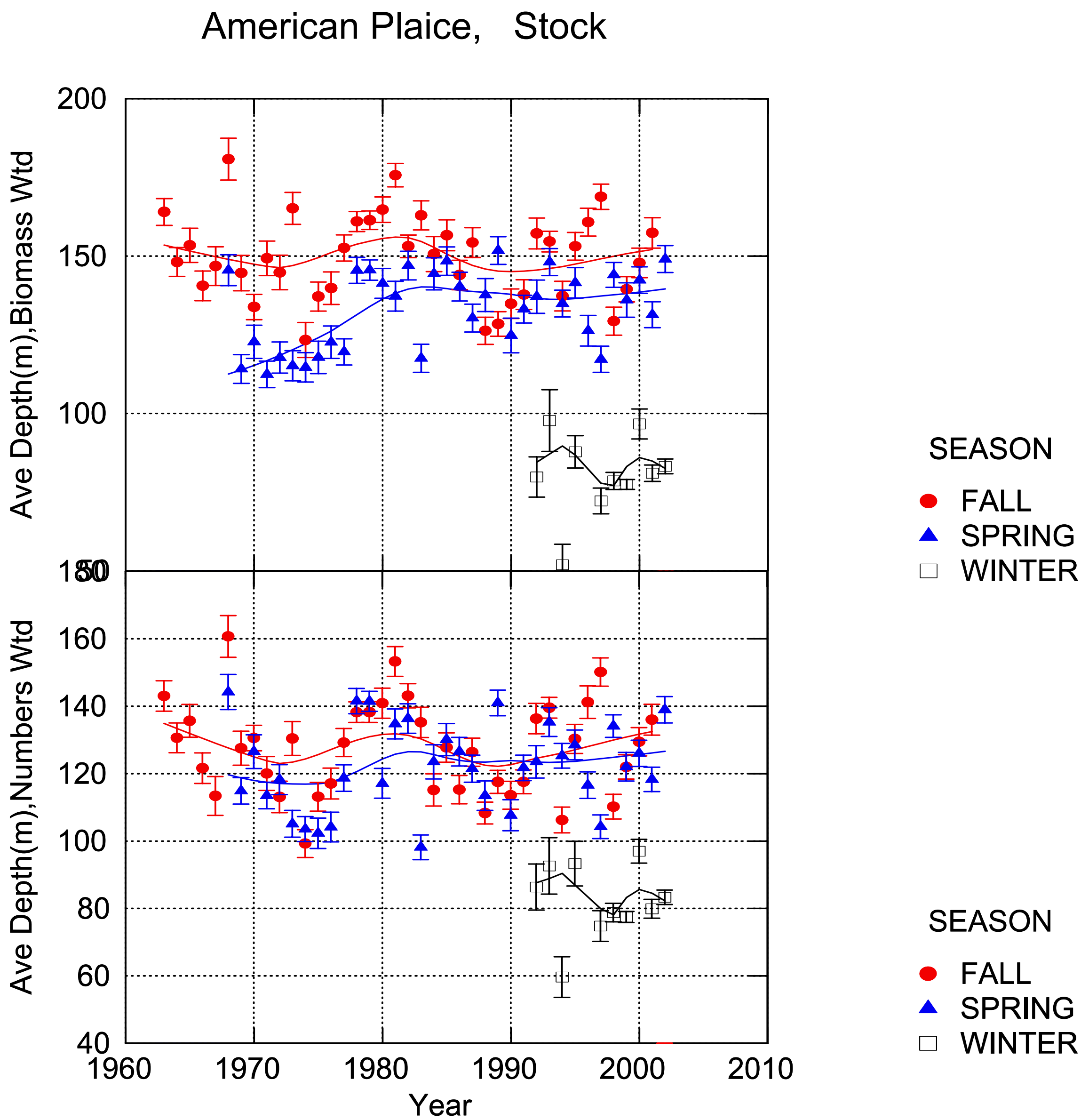


Fig. 3.7.9. Temporal trends in catch weighted average depth for American Plaice stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

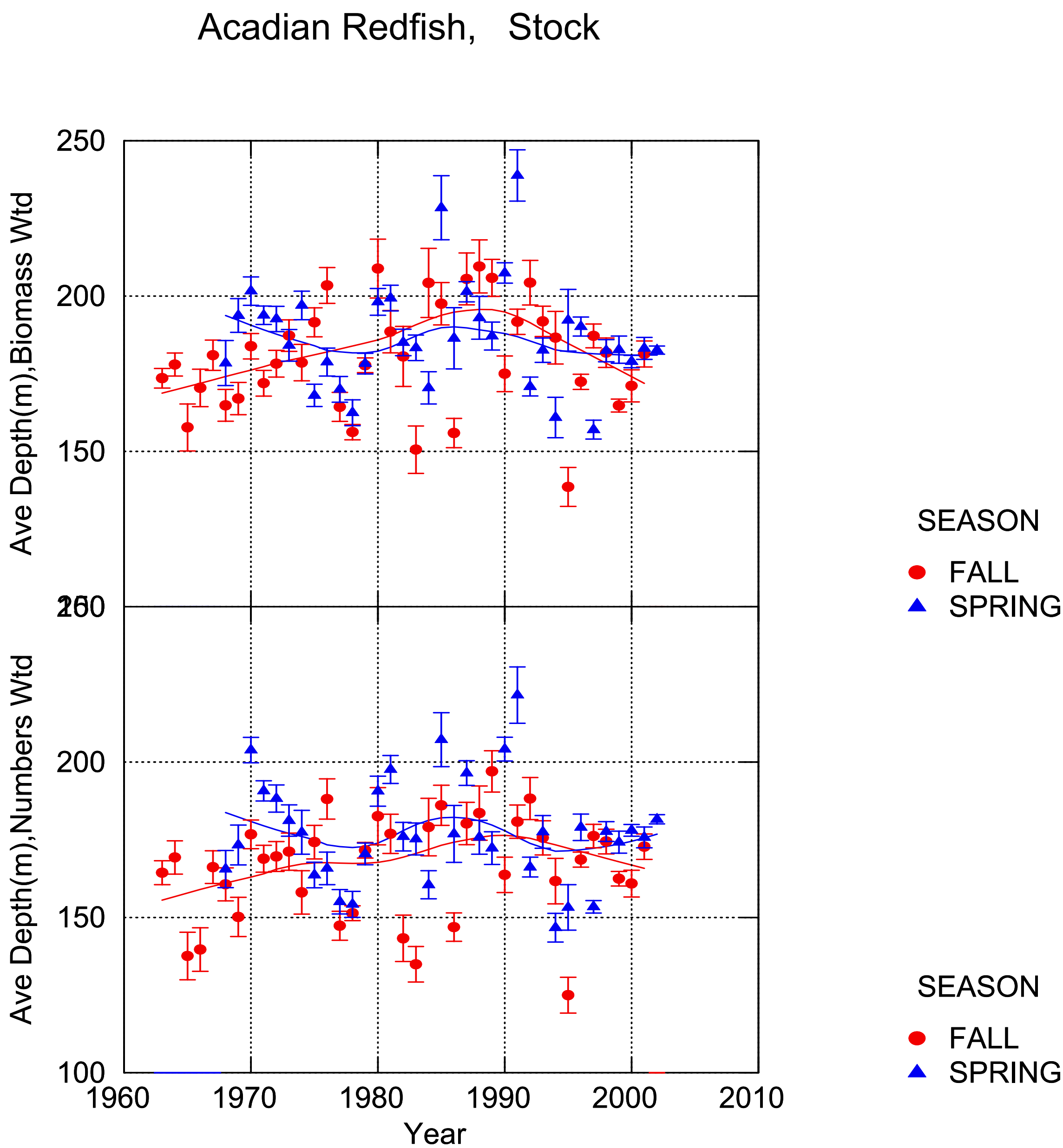


Fig. 3.7.10. Temporal trends in catch weighted average depth for Acadian Redfish stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

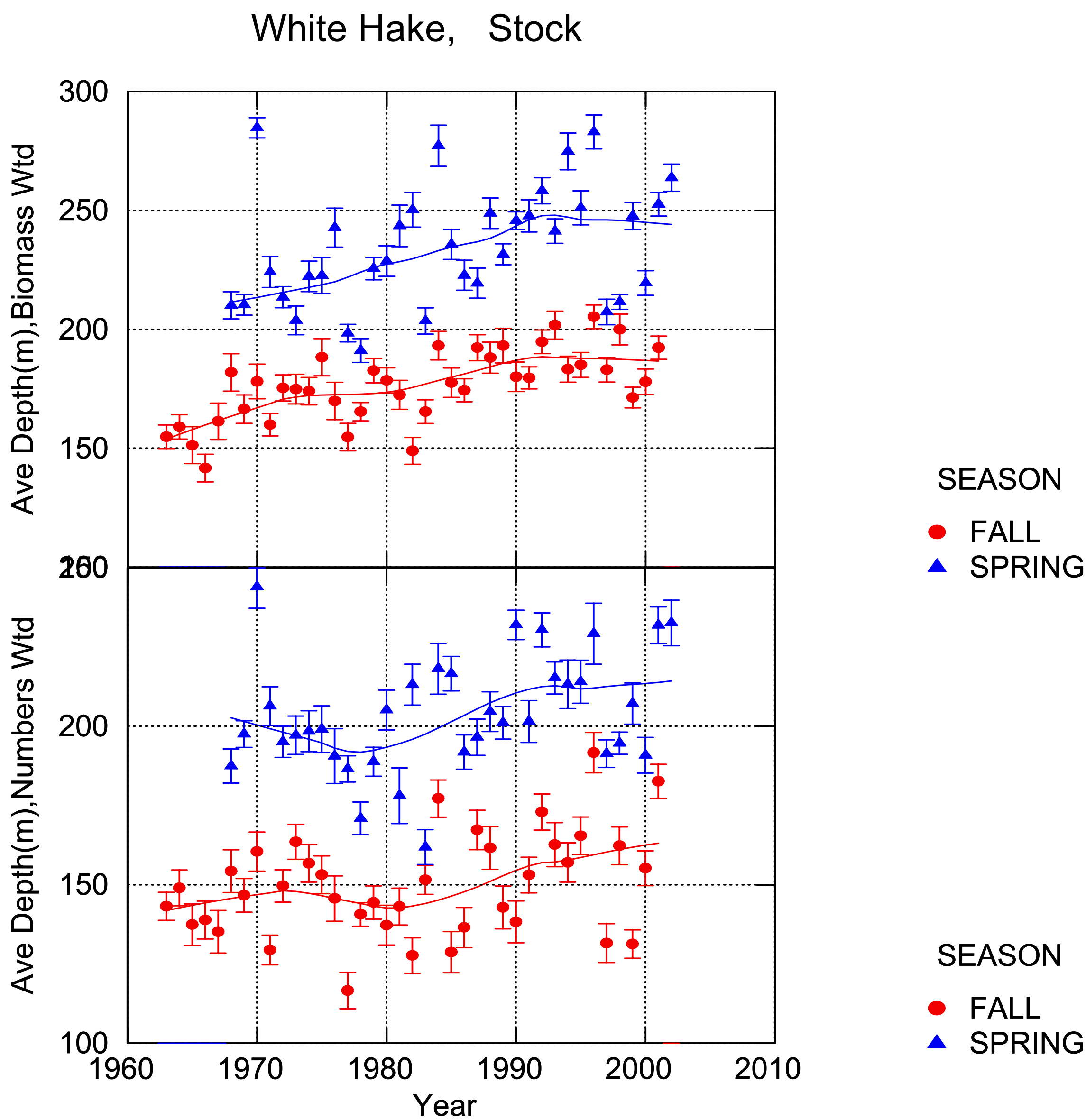


Fig. 3.7.11. Temporal trends in catch weighted average depth for White Hake stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

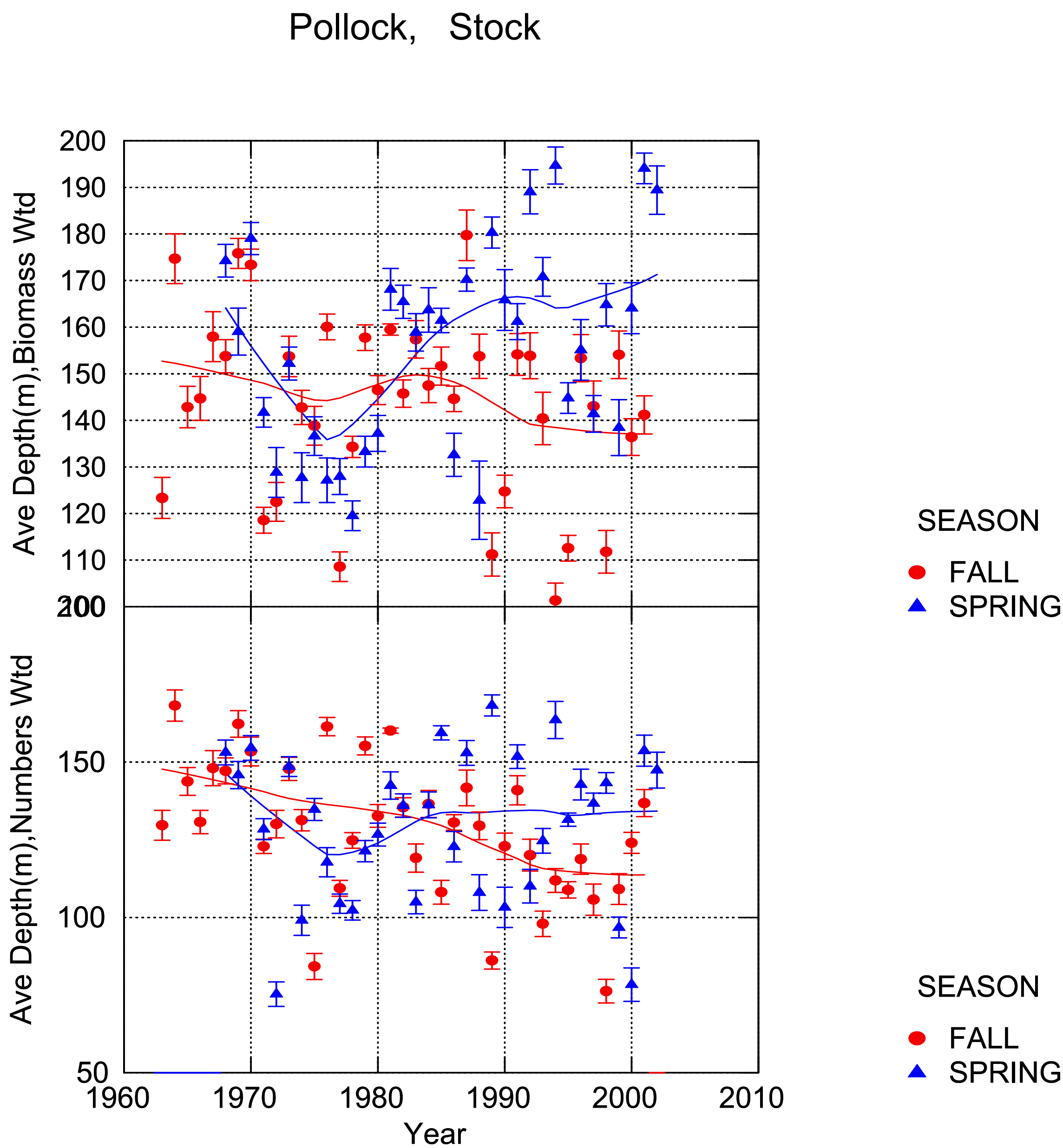


Fig. 3.7.12. Temporal trends in catch weighted average depth for Pollock stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

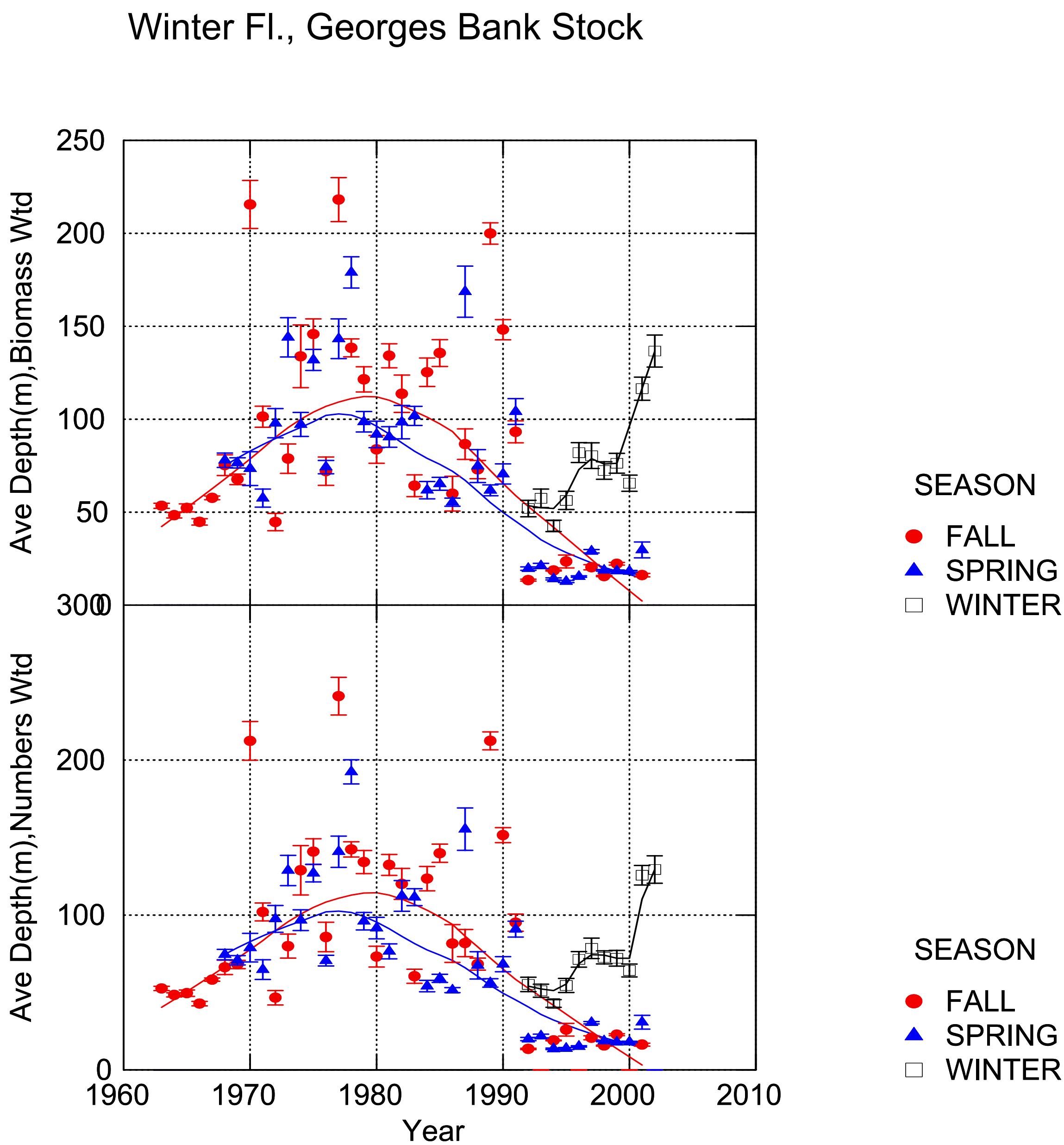


Fig. 3.7.13. Temporal trends in catch weighted average depth for Georges Bank Winter Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Winter Flounder, SNE Stock

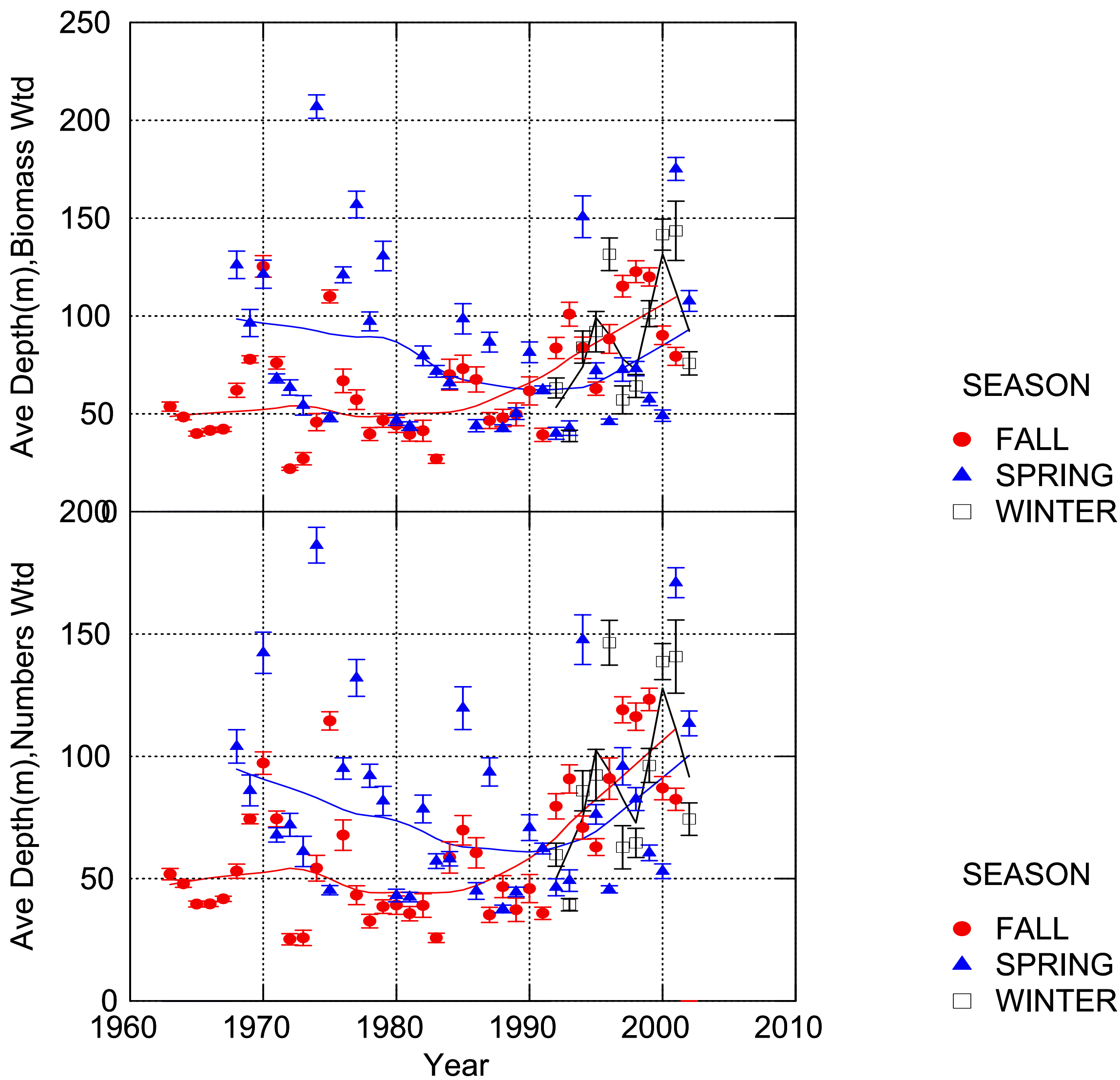


Fig. 3.7.14. Temporal trends in catch weighted average depth for Southern New England Winter Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

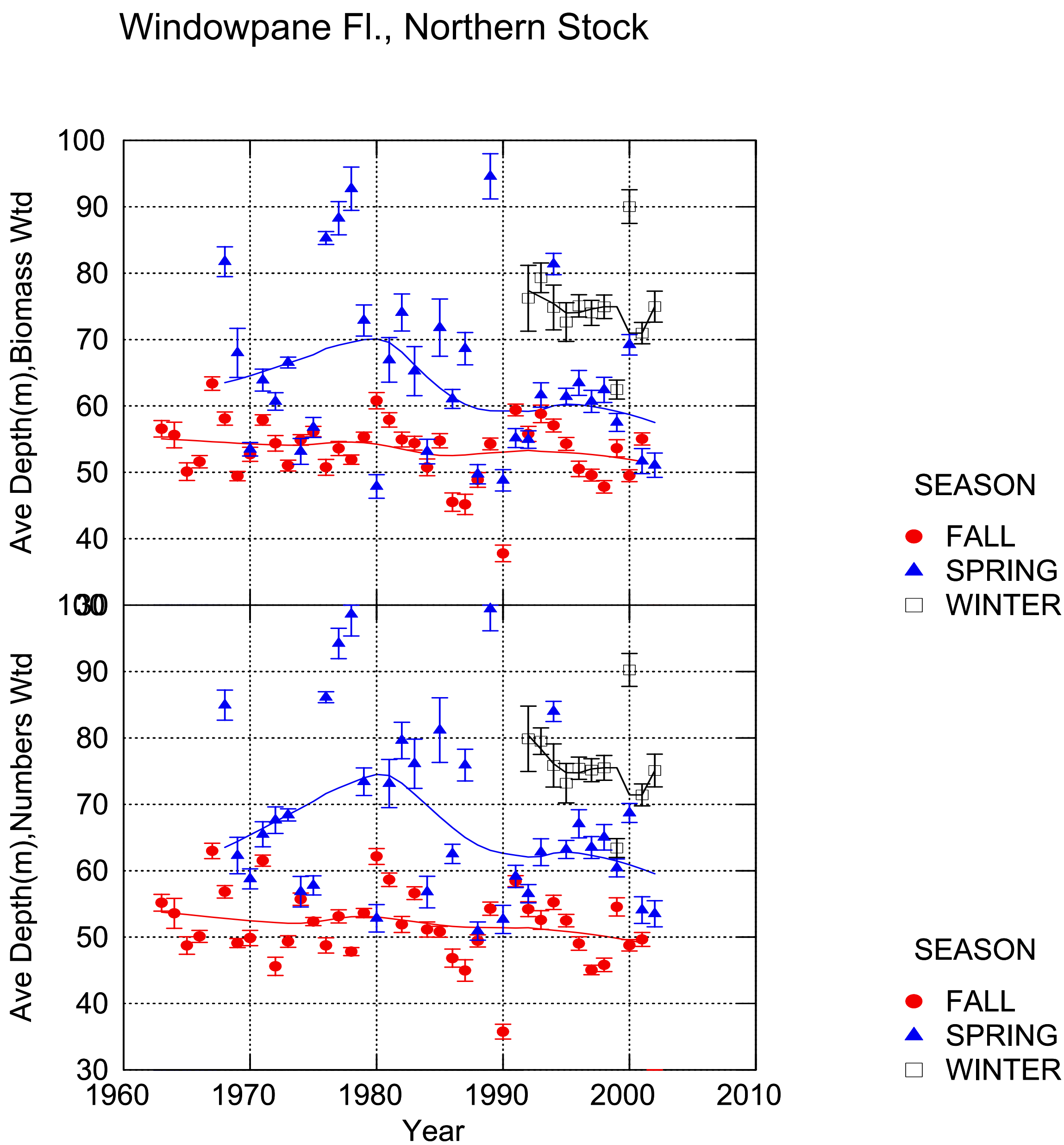


Fig. 3.7.15. Temporal trends in catch weighted average depth for Northern Windowpane Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Windowpane Fl., Southern Stock

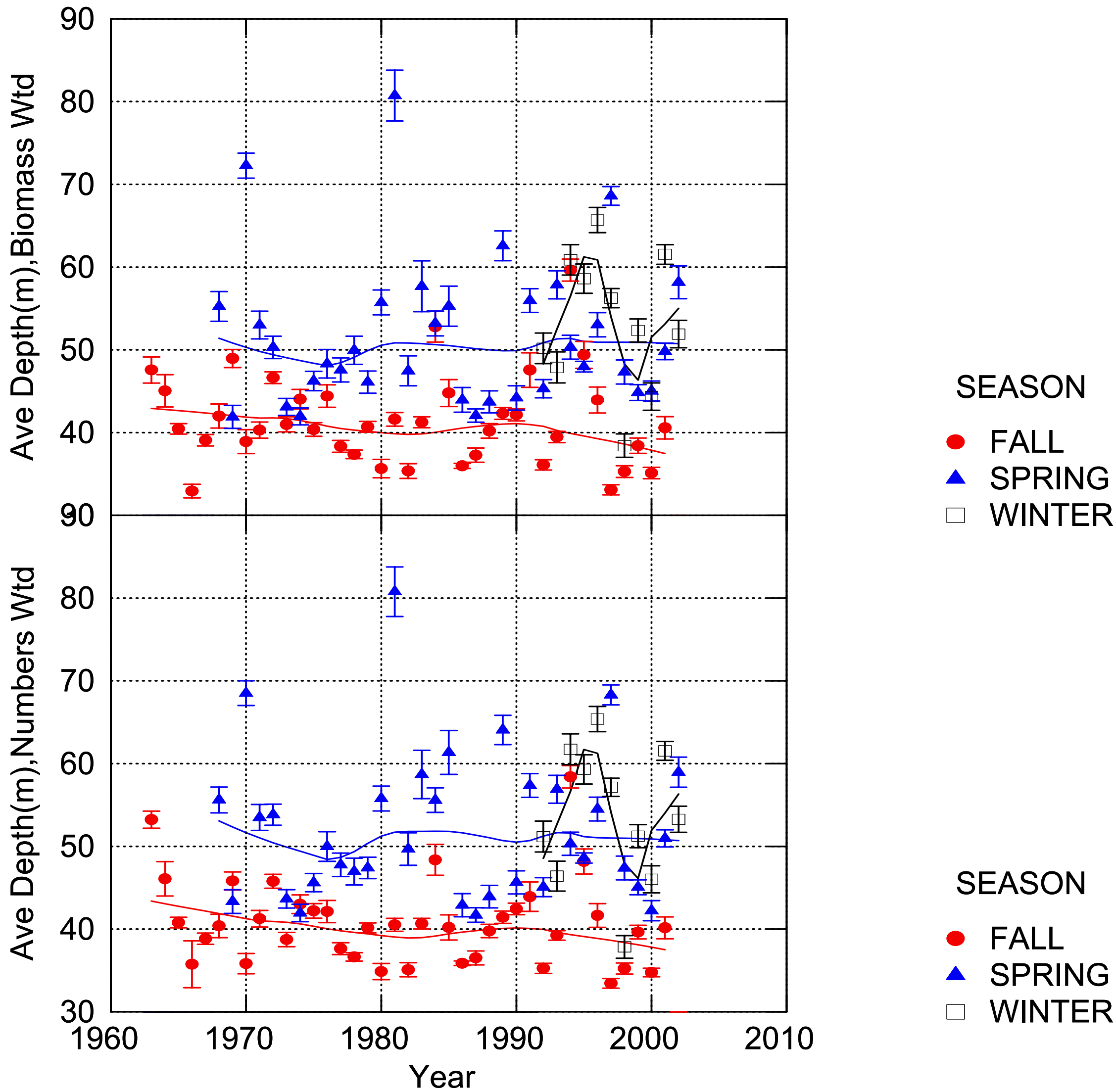


Fig. 3.7.16. Temporal trends in catch weighted average depth for Windowpane Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

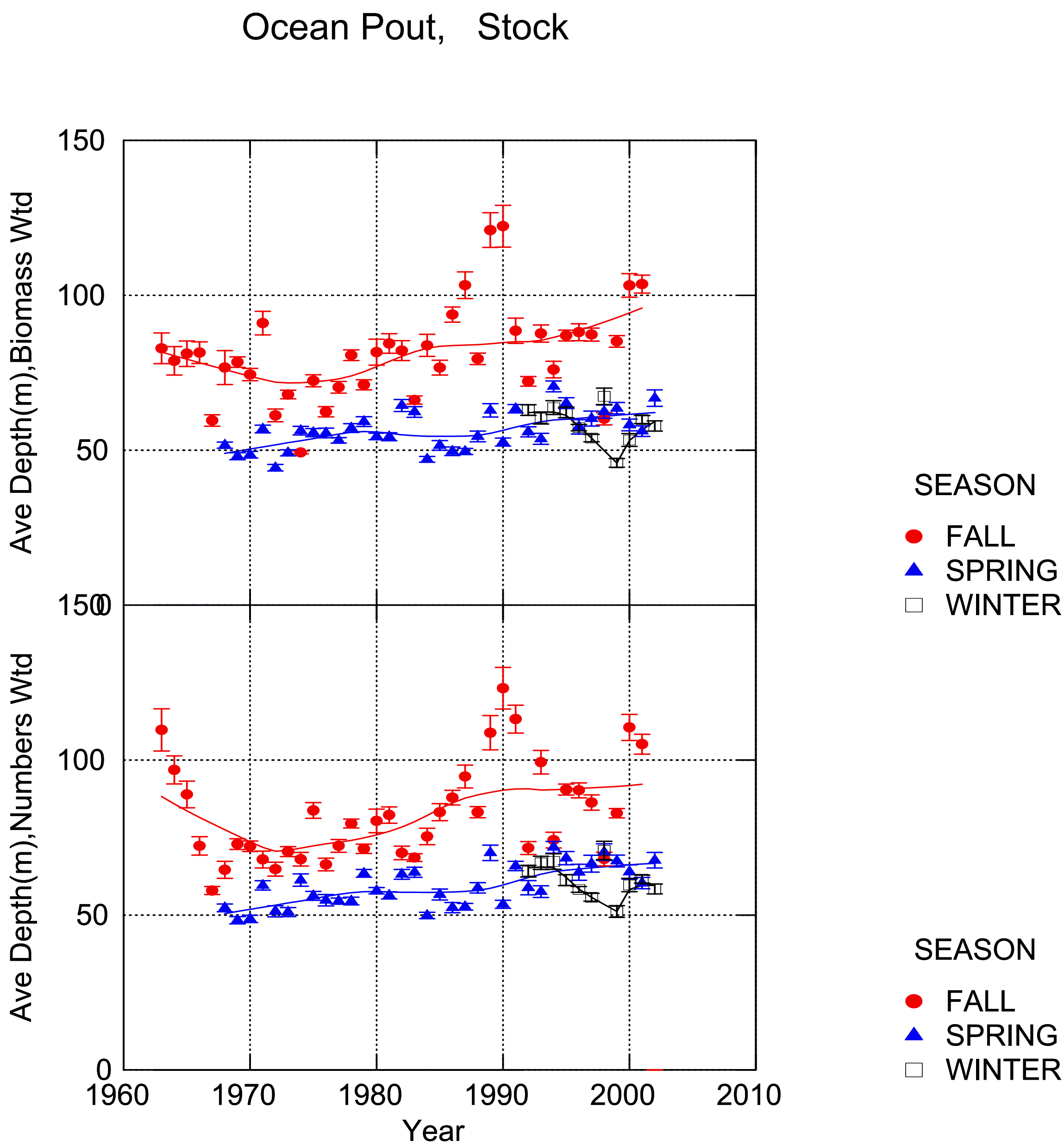


Fig. 3.7.17. Temporal trends in catch weighted average depth for Ocean Pout stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Spiny Dogfish, Stock

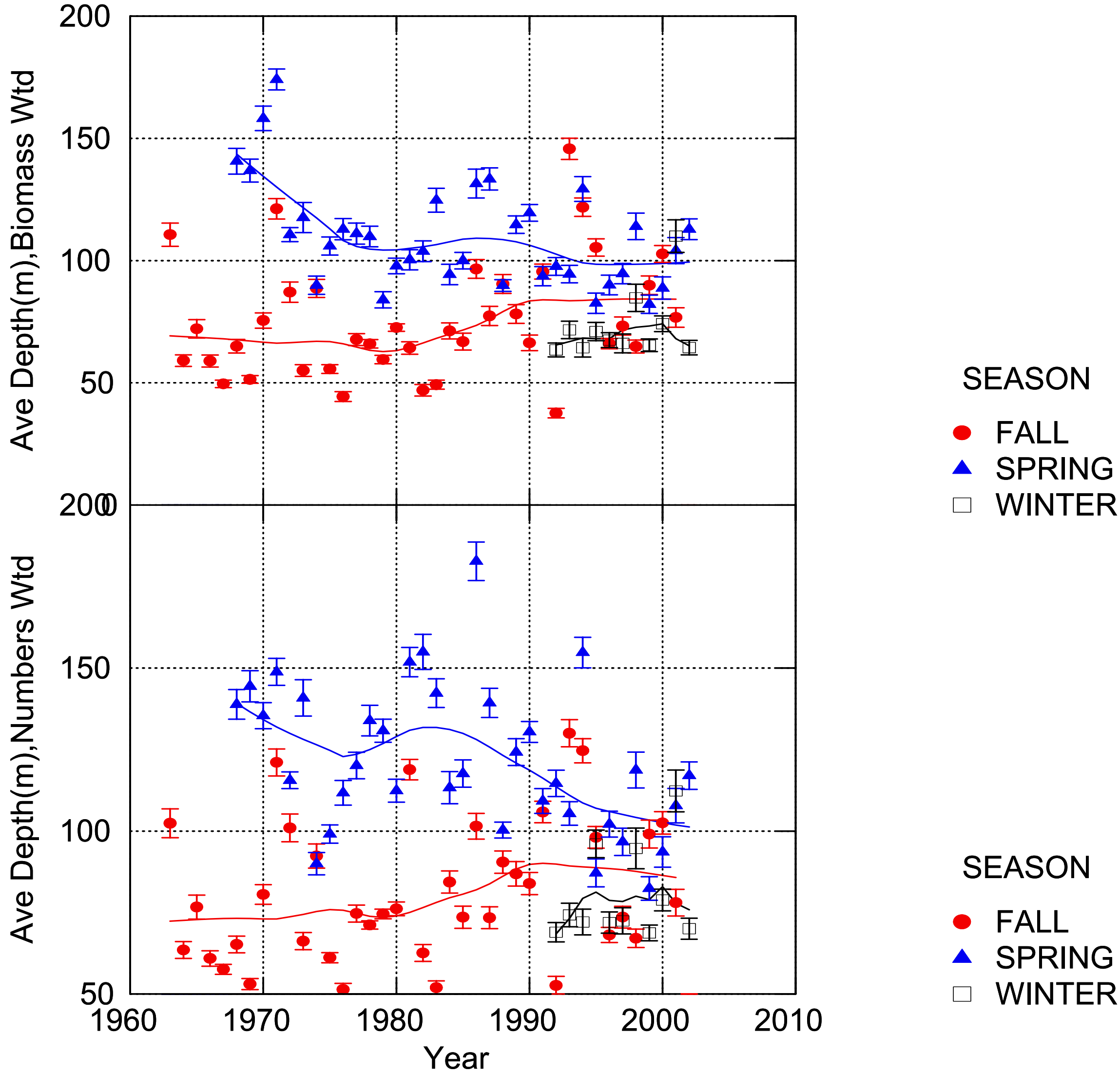


Fig. 3.7.18. Temporal trends in catch weighted average depth for Spiny Dogfish stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Summer Flounder,   Stock

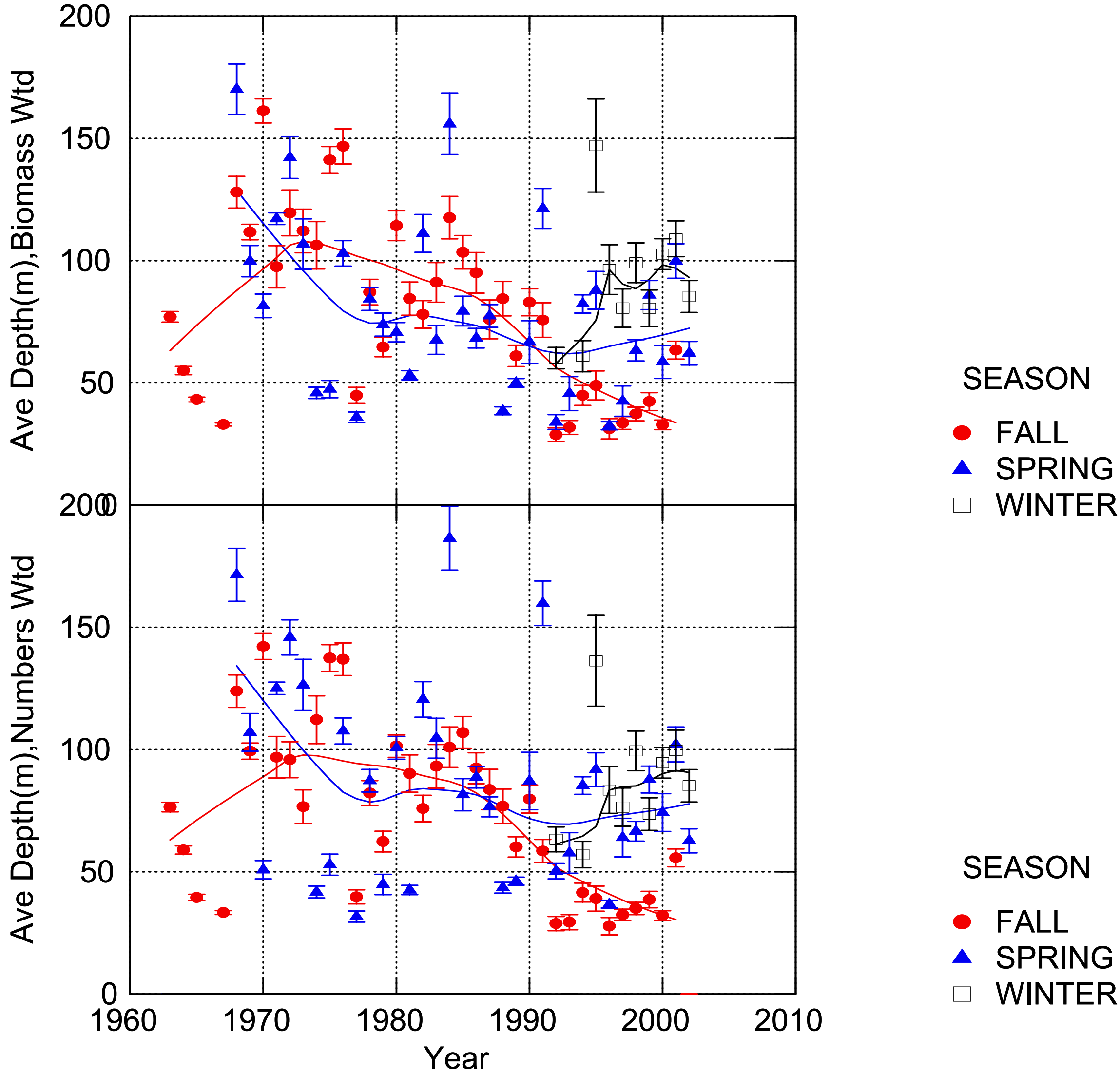


Fig. 3.7.19. Temporal trends in catch weighted average depth for Summer Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

Fourspot Fl., Stock

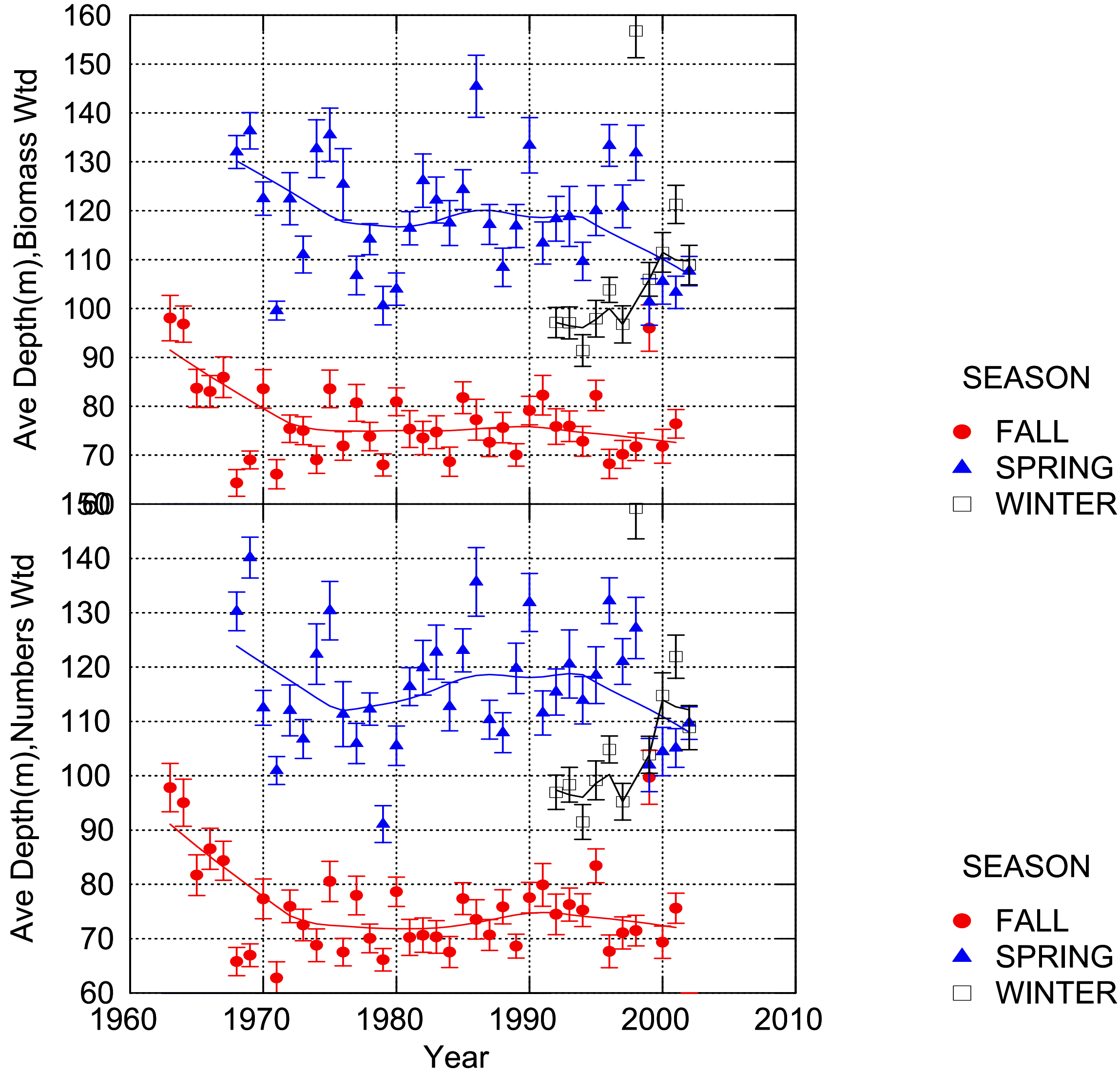


Fig. 3.7.20. Temporal trends in catch weighted average depth for Fourspot Flounder stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

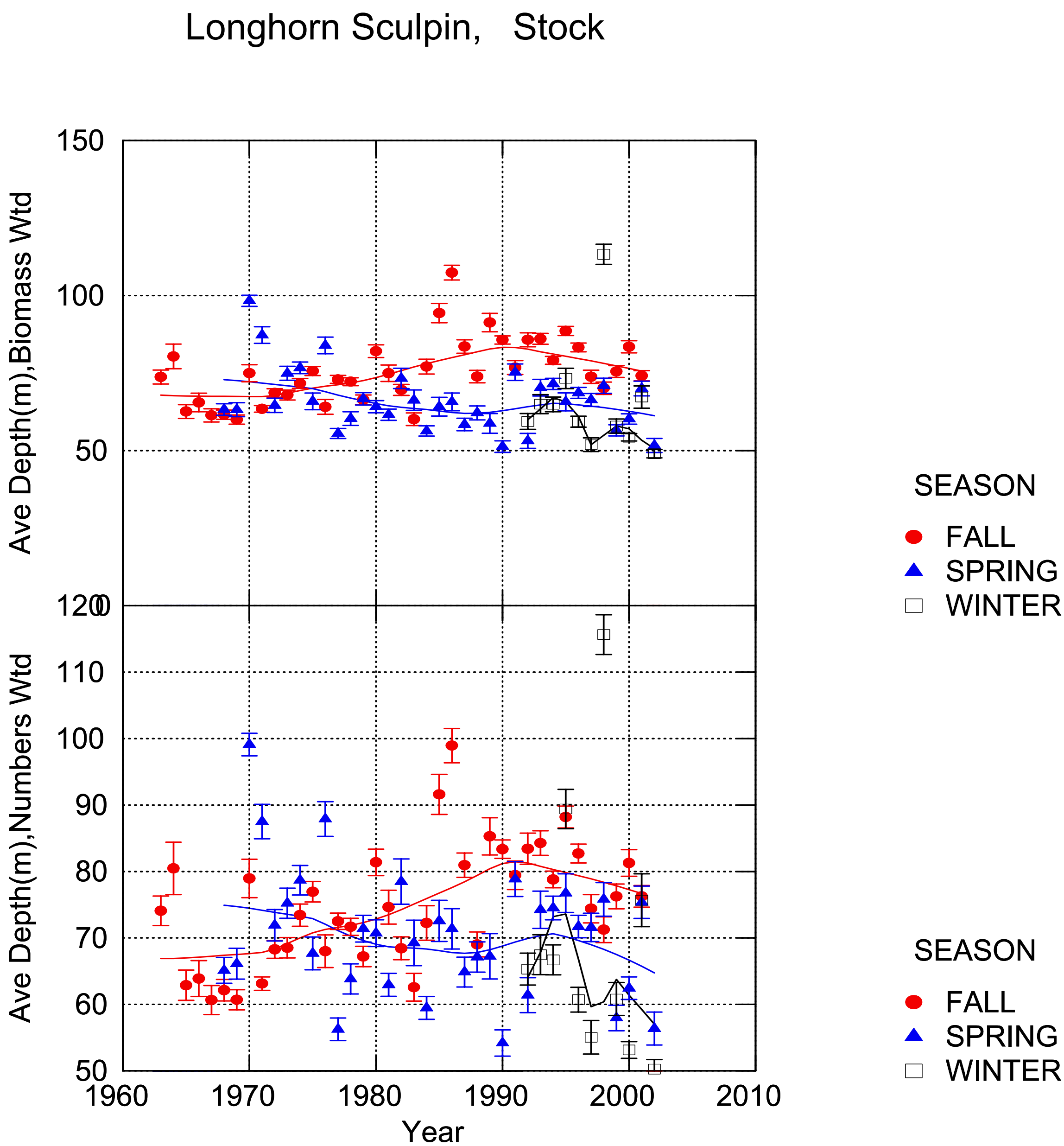


Fig. 3.7. 21. Temporal trends in catch weighted average depth for Longhorn Sculpin stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.

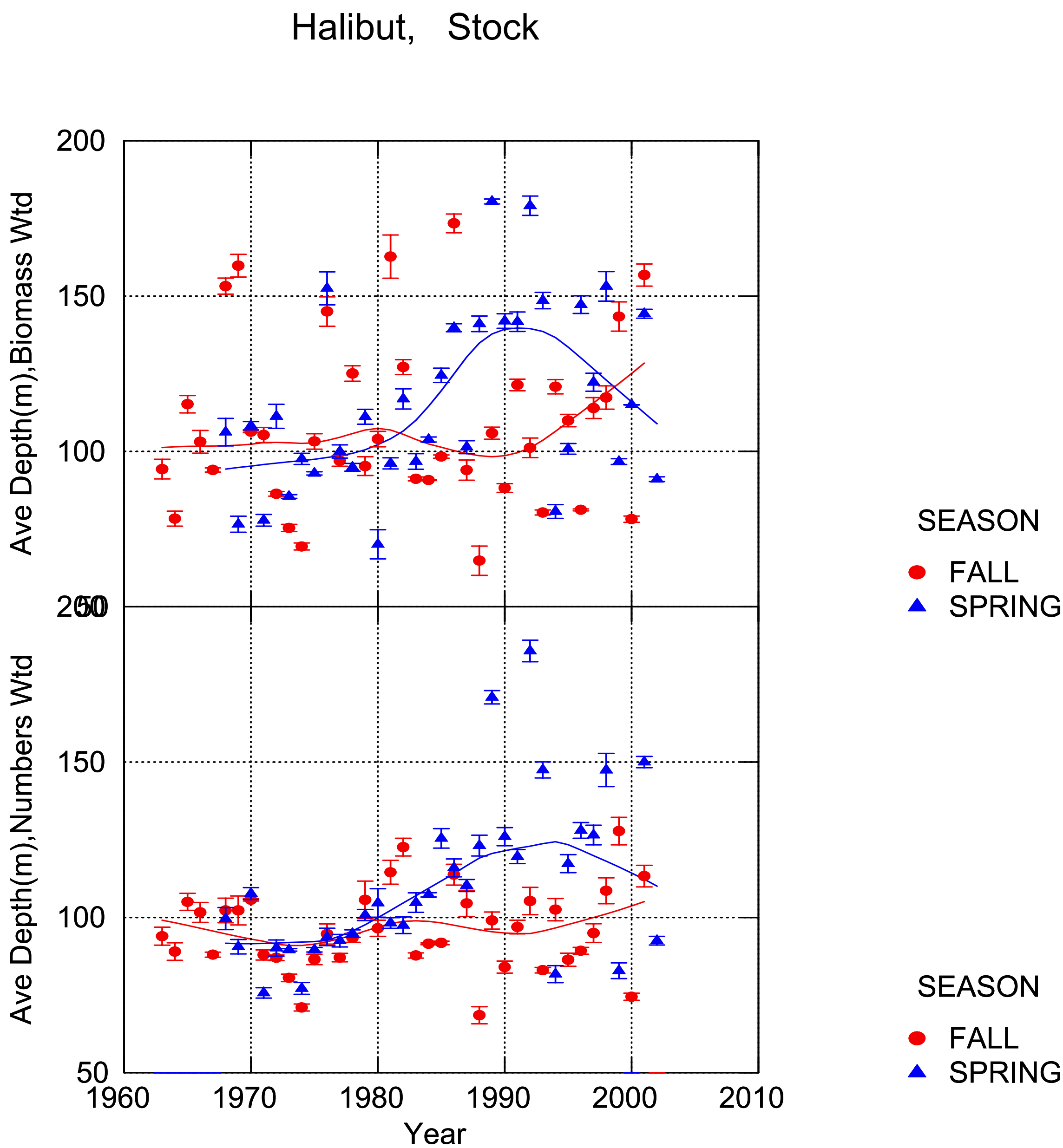
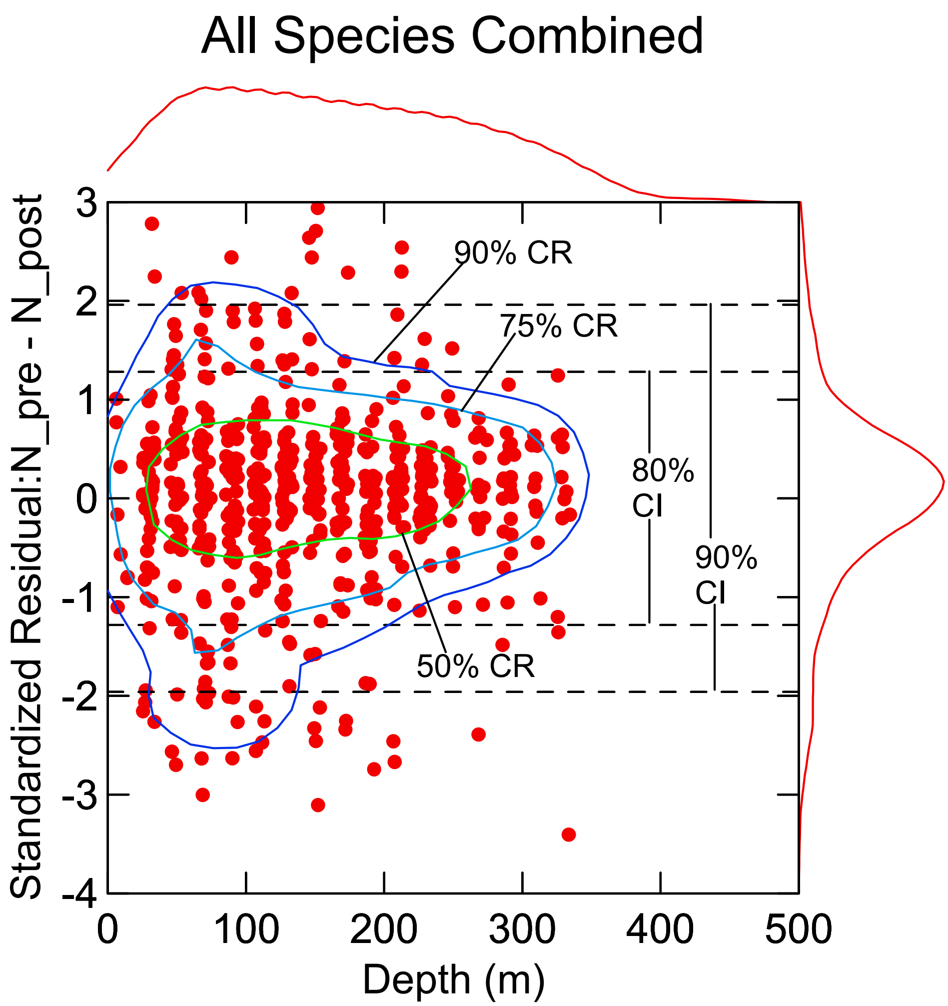


Fig. 3.7.22. Temporal trends in catch weighted average depth for Halibut stock for fall, winter and spring surveys. Top panel- biomass (kg/tow) weighted average depth; bottom panel- numbers (#/tow) weighted average depth. Error bars represent ± 1 SD. Lines are Lowess smooths with tension=0.5.



Fi.g. 3.7.23. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for all species combined. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

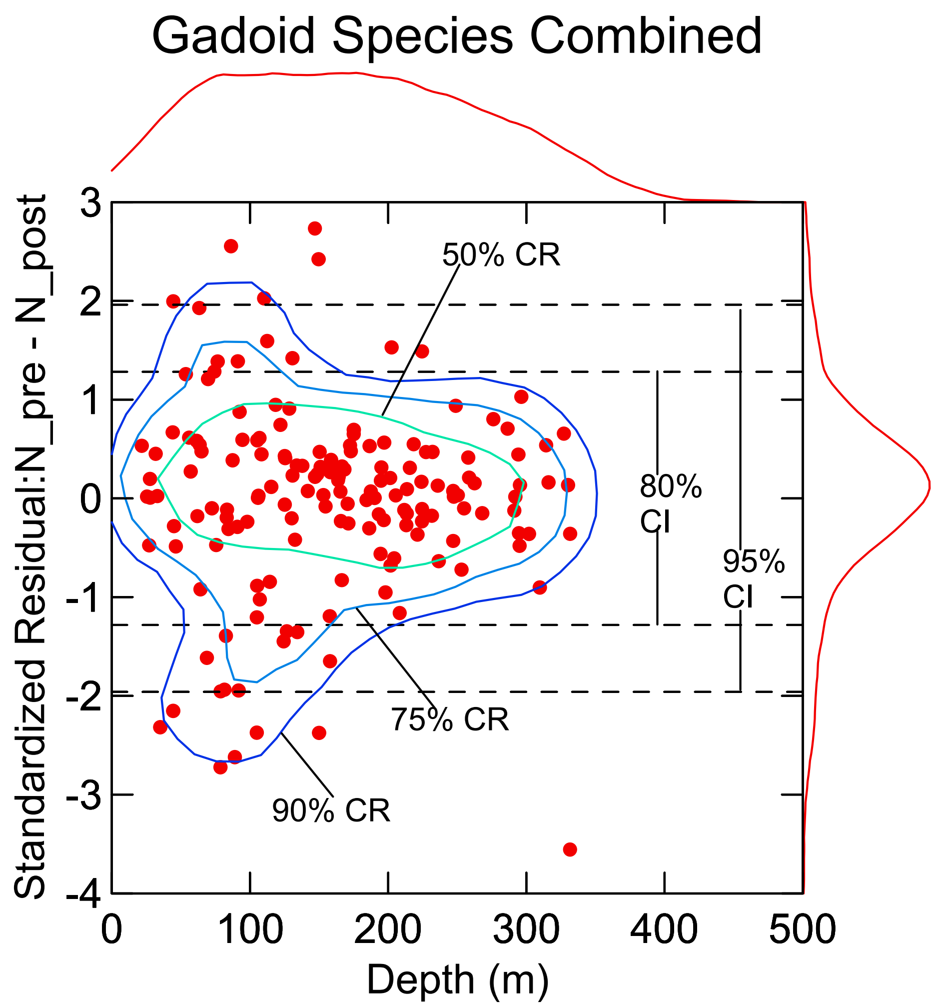


Fig. 3.7.24. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for gadoid species (GB cod, GOM cod, GB haddock, GOM haddock, white hake, and pollock. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

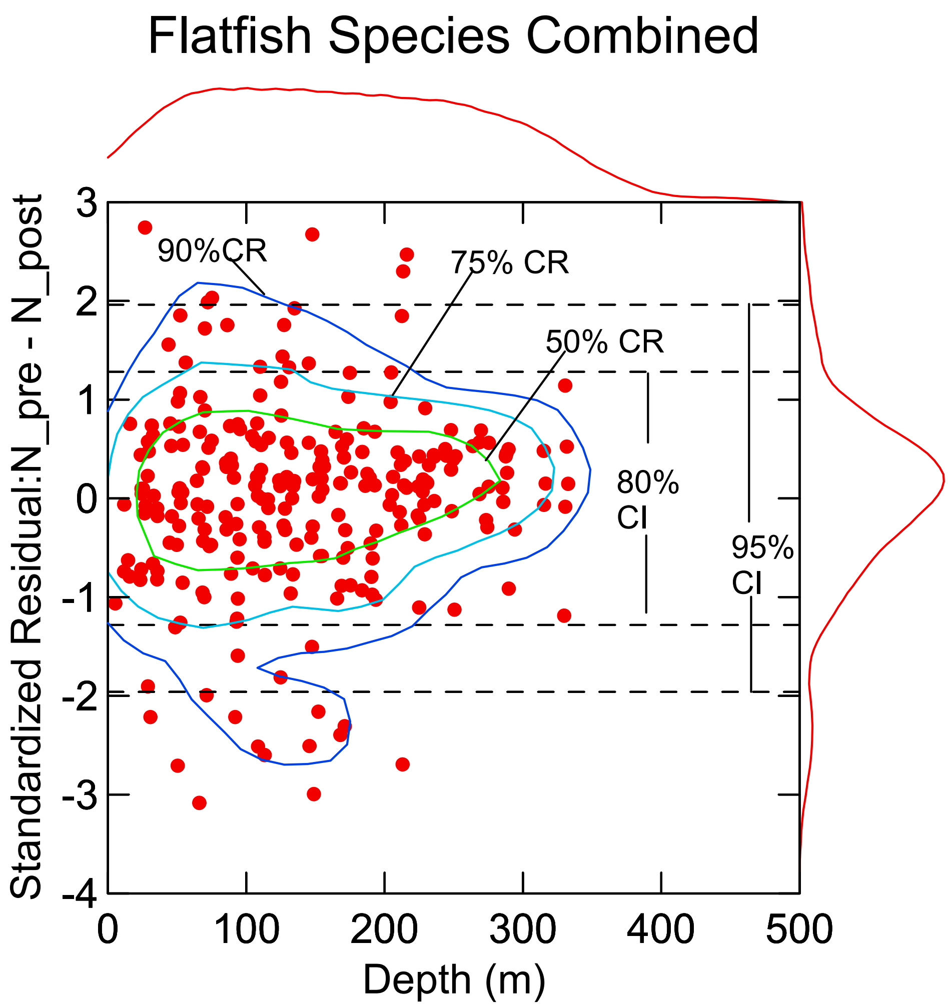


Fig. 3.7.25. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for flatfish species (GB yellowtail, SNE yellowtail, Cape Cod yellowtail, American plaice, witch flounder, windowpane (Northern and Southern), GB winter flounder SNE winter flounder, summer flounder, and fourspot flounder. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

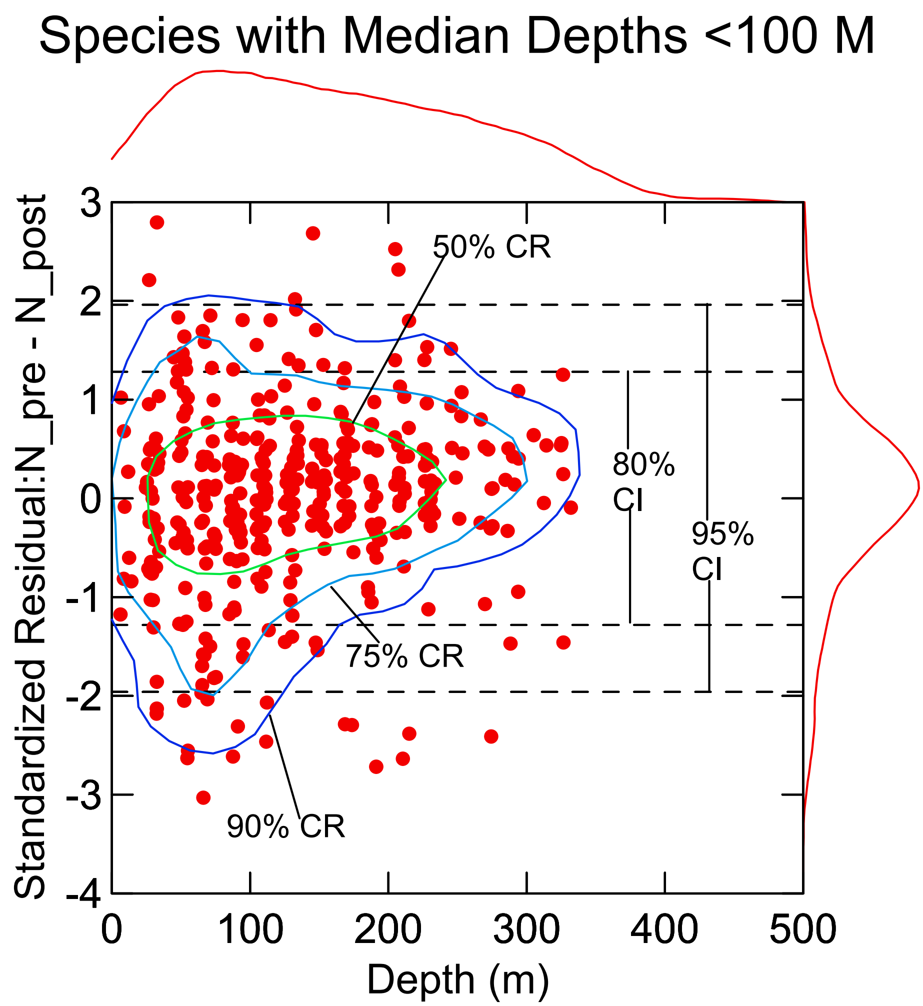


Fig. 3.7.26. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for flatfish species (GB yellowtail, SNE yellowtail, Cape Cod yellowtail, windowpane flounder (Northern and Southern), GB winter flounder, GB cod, GOM cod, SNE winter flounder, summer flounder, fourspot flounder, ocean pout, longhorn sculpin, spiny dogfish. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.

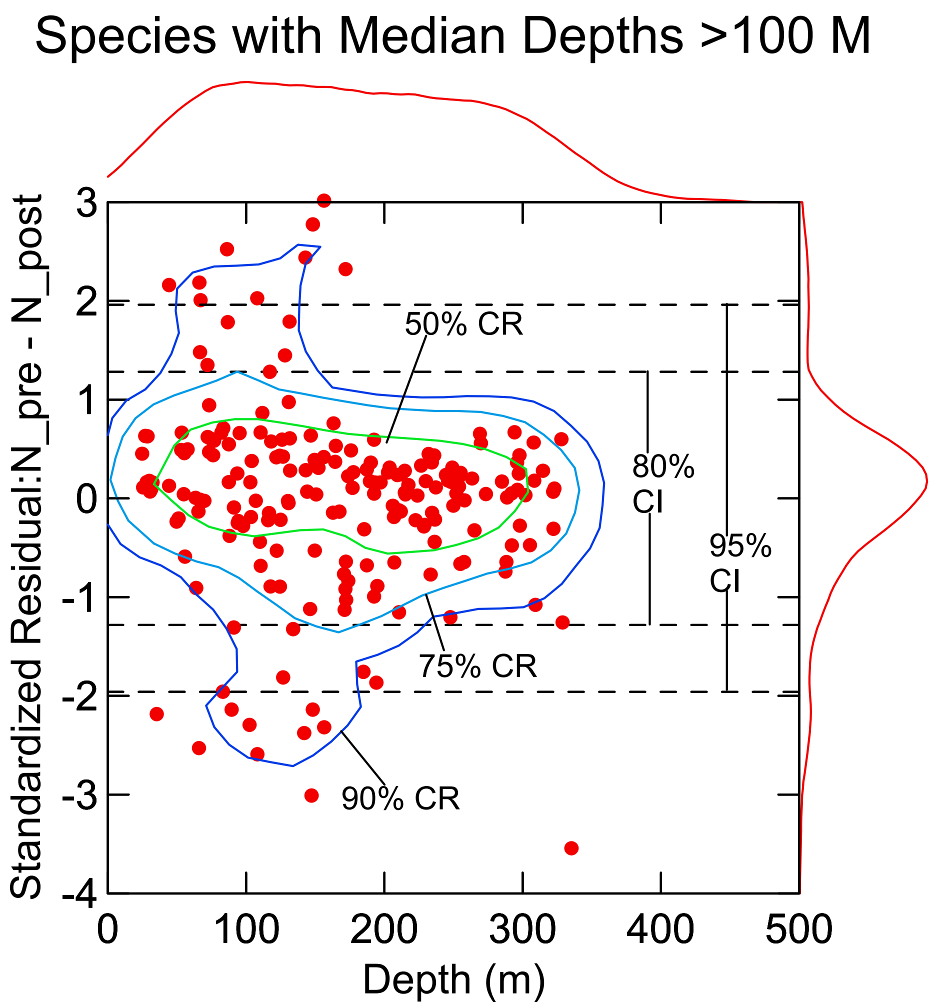
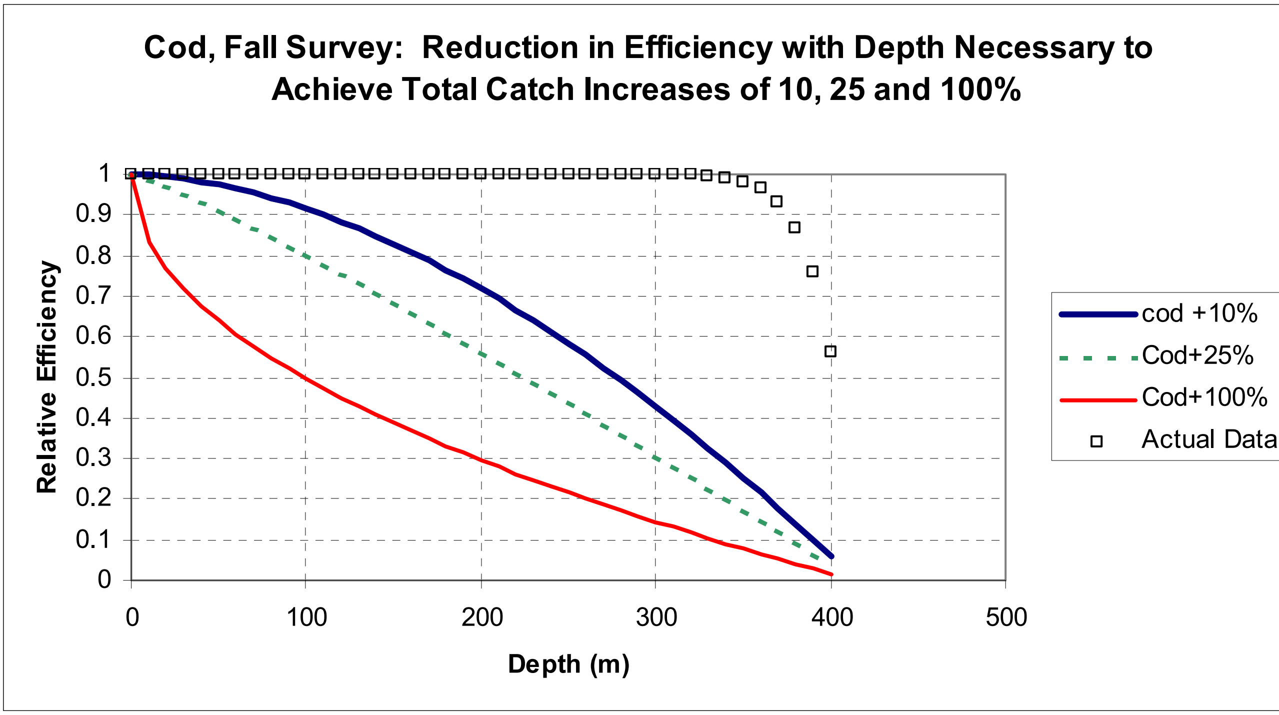


Fig. 3.7.27. Distribution of standardized difference in catch rates(numbers/tow) vs depth interval for flatfish species (GB haddock, GOM haddock, white hake, pollock, American plaice, witch flounder, and Acadian redfish. Each point represents a separate species, stock and survey combination for difference in number per tow in the 2year period (1998-99) vs 2000-2001 for the fall survey, and 3 yr period (1997-99) vs 2000-02 for the spring and winter surveys. Approximate confidence intervals for the standardized differences are denoted by dashed lines. The 50, 75 and 95% confidence regions are approximated by an Epanechnikov kernel. Marginal kernel distribution of the distribution of differences are described by the right-hand border. The top border is the kernel of differences by depth category.



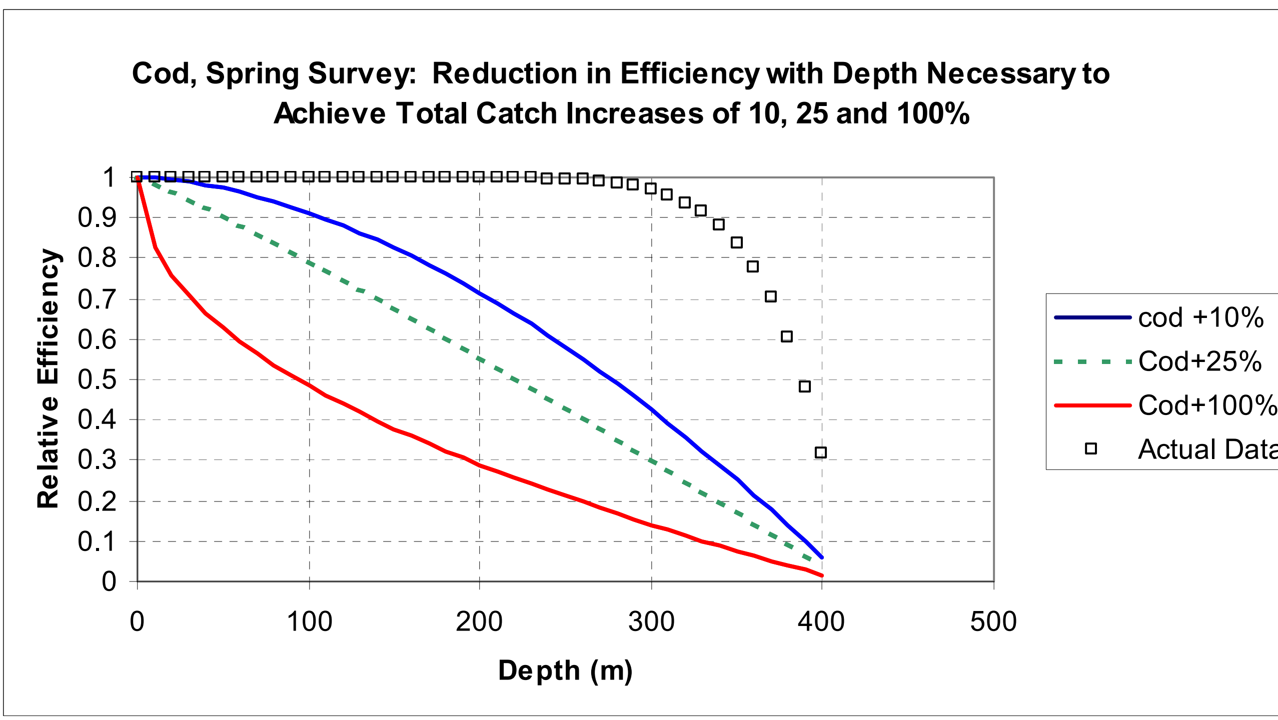
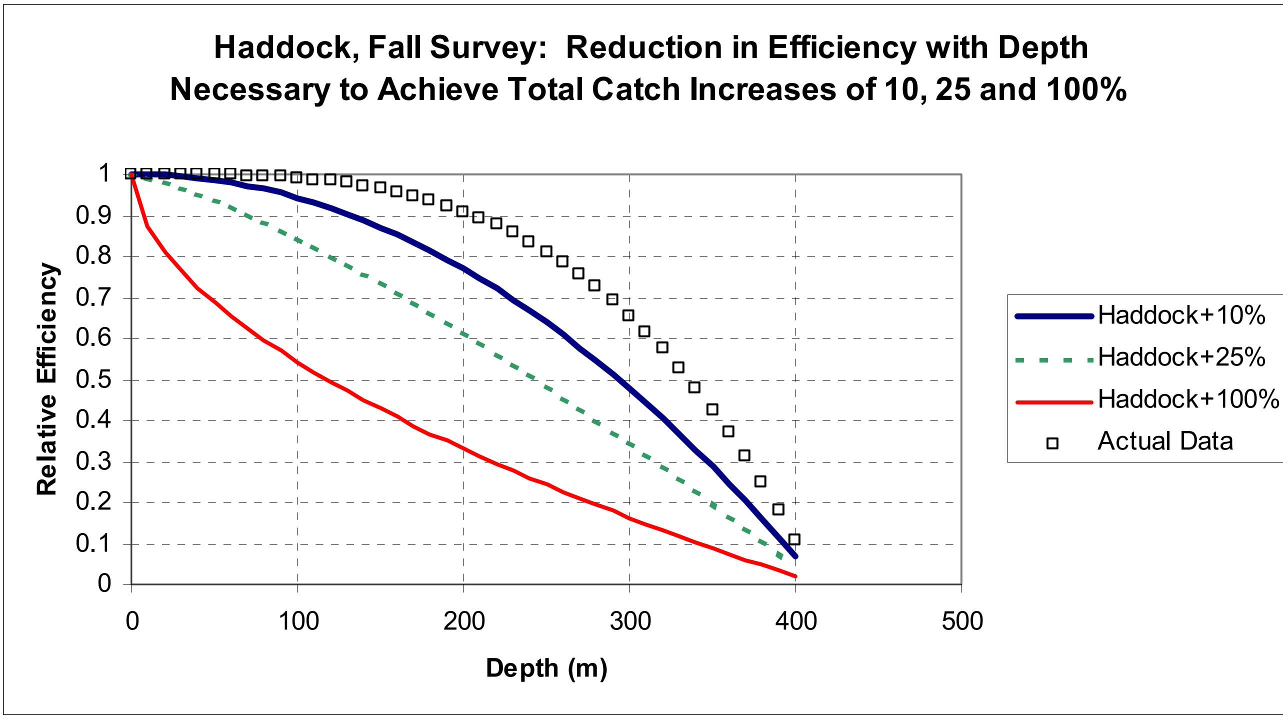


Fig. 3.7.28. Predicted reductions in relative efficiency of capture for cod in fall and spring surveys given hypothesized increases in overall abundance of 10, 25, and 100%. Relative efficiency predictions are based on fit of Eq. 13 to observed survey catches at depth for the 2000-2002 spring survey data and 2000-01 fall survey data. "Actual data" plots refer to nonlinear least squares estimates based on comparisons of between pre and post-trawl warp asymmetry periods.



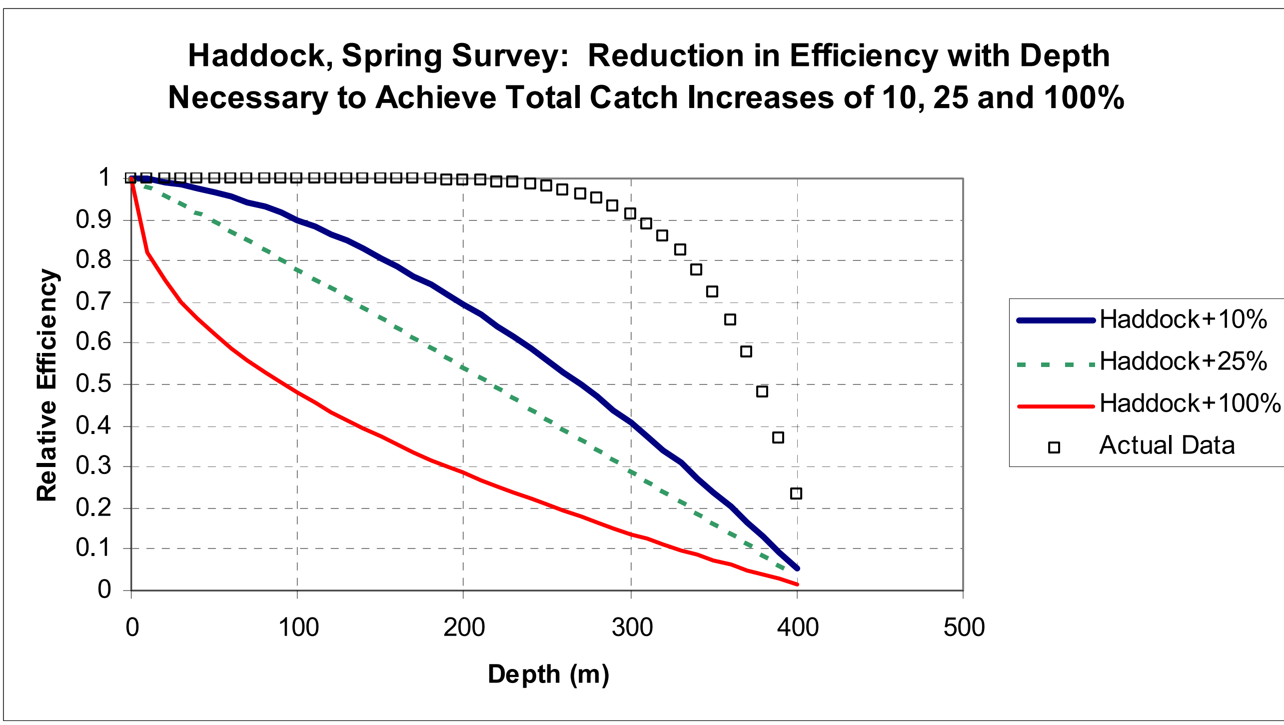
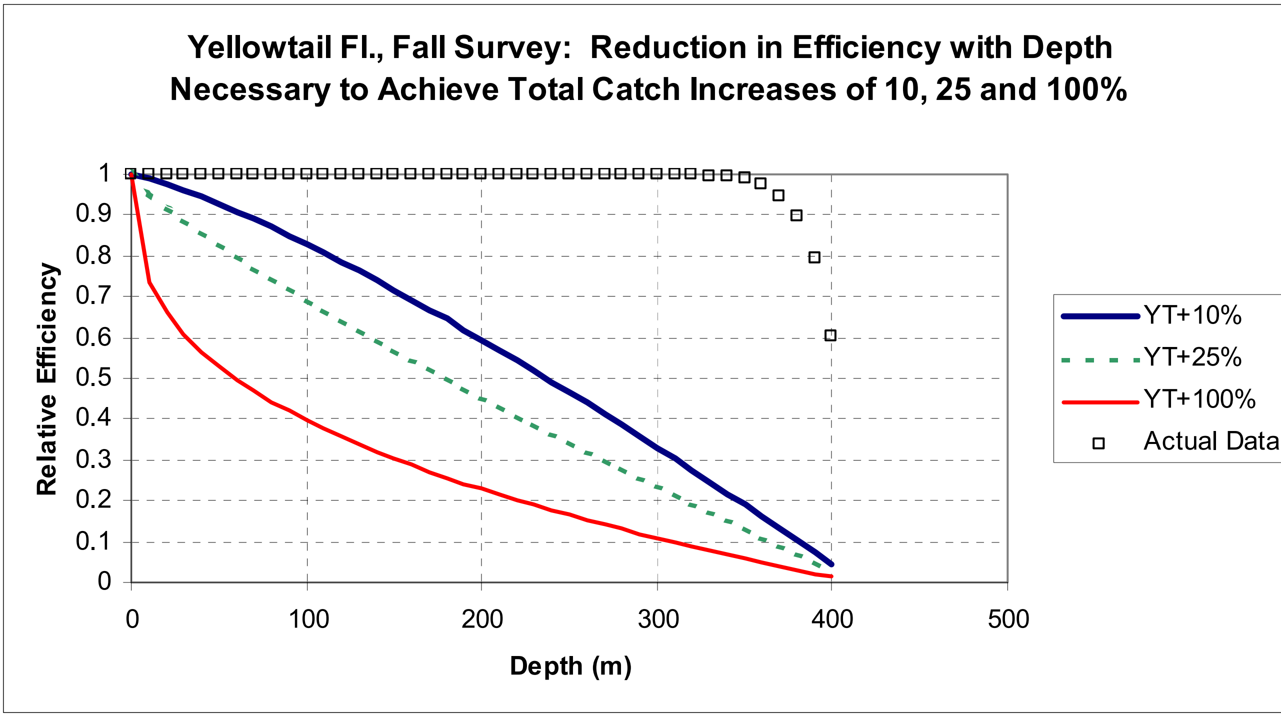


Fig. 3.7.29. Predicted reductions in relative efficiency of capture for haddock in fall and spring surveys given hypothesized increases in overall abundance of 10, 25, and 100%. Relative efficiency predictions are based on fit of Eq. 13 to observed survey catches at depth for the 2000-2002 spring survey data and 2000-01 fall survey data. “Actual data” plots refer to nonlinear least squares estimates based on comparisons of between pre and post-trawl warp asymmetry periods.



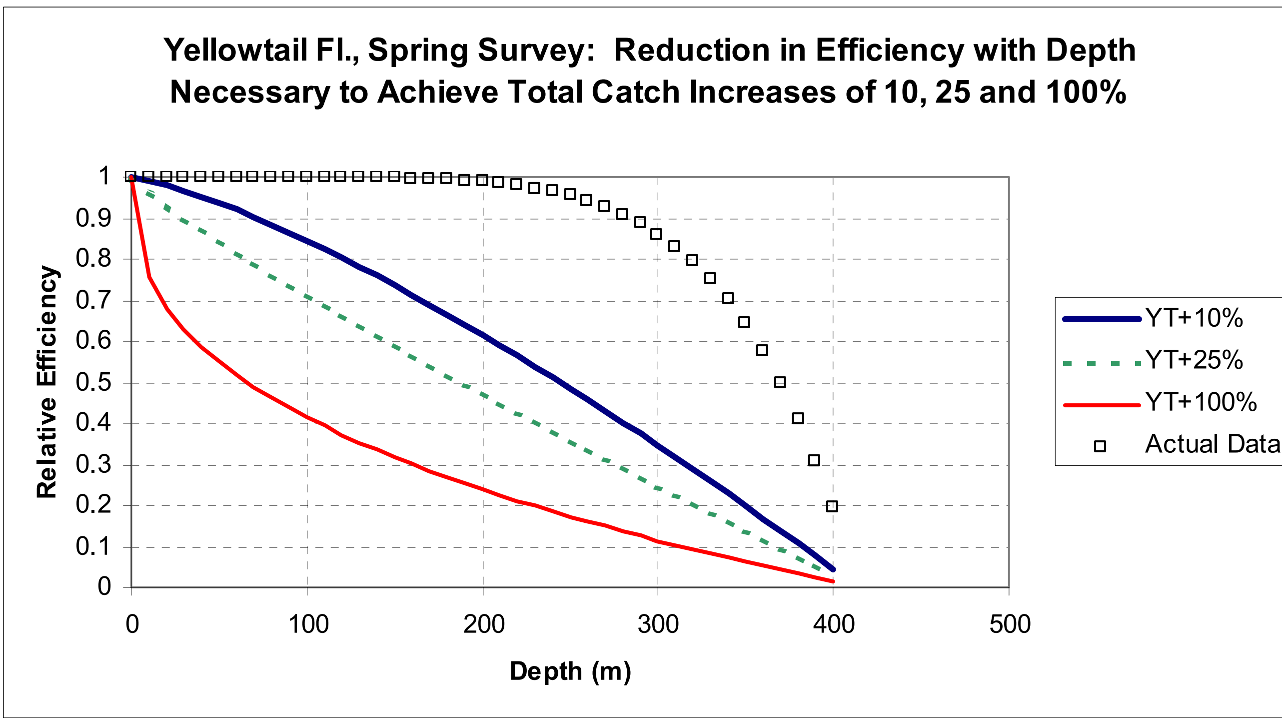


Fig. 3.7.30. Predicted reductions in relative efficiency of capture for yellowtail flounder in fall and spring surveys given hypothesized increases in overall abundance of 10, 25, and 100%. Relative efficiency predictions are based on fit of Eq. 13 to observed survey catches at depth for the 2000-2002 spring survey data and 2000-01 fall survey data. “Actual data” plots refer to nonlinear least squares estimates based on comparisons of between pre and post-trawl warp asymmetry periods.

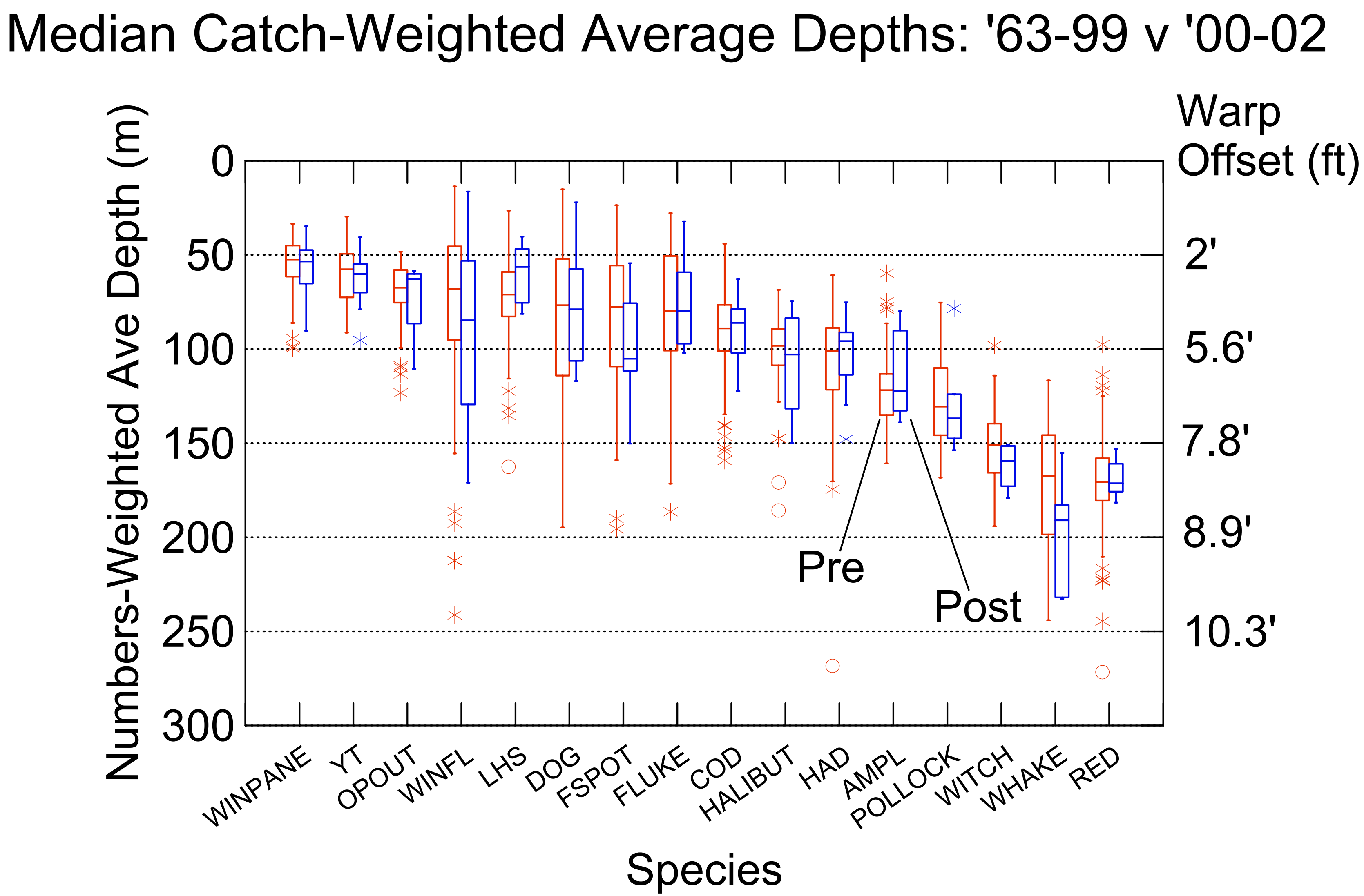


Figure 3.7.31. Catch weighted average depths at capture for 16 species of groundfish taken in NEFSC bottom trawl surveys. Data are presented for pre- and post trawl warp offset periods. The pre-warp period includes all data from 1963 onward until 1999.

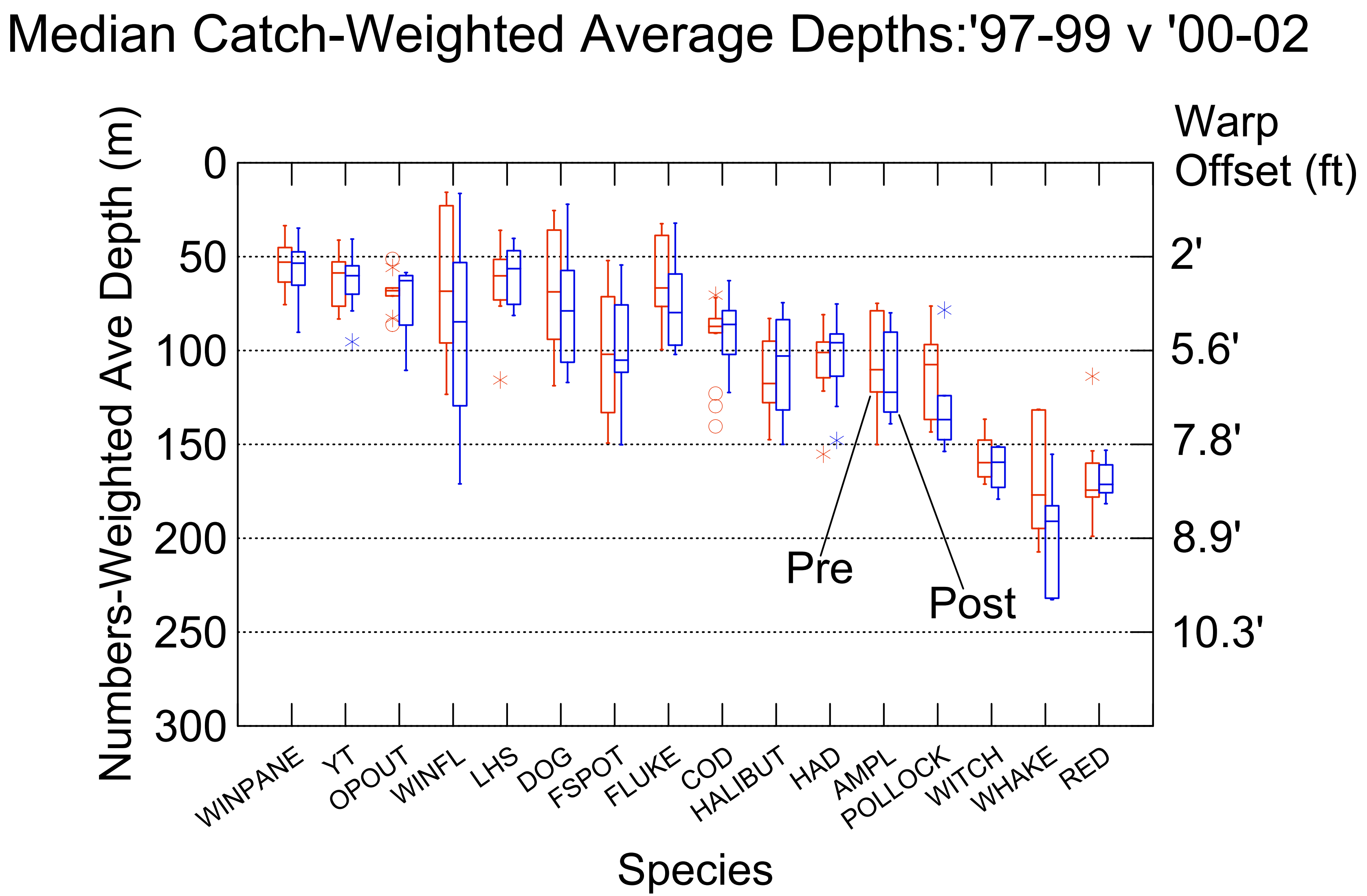


Figure 3.7.32. Catch weighted average depths at capture for 16 species of groundfish taken in NEFSC bottom trawl surveys. Data are presented for pre- and post trawl warp offset periods. The pre-warp period includes all data from 1997-1999.

3.8 Changes in Abundance Indices Pre- and Post Warp Intervention

Various abundance indices using the *Albatross IV* survey vessel are available for all 20 of the stocks assessed in section 2 of this document. Surveys potentially influenced by the warp offsets include the winter, spring and autumn bottom trawl time series. Overall there are 39 trawl survey series that are used in the assessments of the 20 stocks (Table 3.8). This analysis considers patterns in the directional change (positive, negative or the same) for each stock and survey series in pairs of adjacent years (e.g., 1998 to 1999, 1999 to 2000, etc.) to determine whether there are patterns in proportions of stocks increasing, decreasing or remaining the same associated with the warp offset intervention. The absolute abundance change from one year to the next is confounded by the underlying abundance changes in the stocks under consideration. The directional analysis, however, is likely more robust to the confounding influences of stock size changes in looking for potential interventions in the data series.

The directional changes for each stock and survey series (+, - or no change) are compiled in Table 3.8. Overall there were 25 series showing positive changes in stock abundance indices from 1998 to 1999, and 14 stocks showing stock declines. The potential intervention due to trawl warp offsets would have been manifested in the directional changes between 1999 and 2000. In that pair of years, the proportion of stocks showing positive changes was nearly identical to that in the previous year (23 of 39 stocks), with 15 showing a decline and one unchanged (Figure 3.8). For the years 2000-2001 and 2001-2002 the intervention would have been included in both years, so there would be no expected decline in the proportion of increasing/declining stocks due to the potential effects of the warp offsets. Interestingly, in 2000/2001, the proportion of declining versus increasing stocks reversed from the previous years, suggesting a year effect in these data. In 2001-2002 (winter and spring indices only), increasing stocks again dominated the total (12/17).

The overall patterns of increasing/declining stocks in the "intervention" year was thus very similar to the year previous, suggesting no systematic pattern of reduced catch efficiency that would be great enough to be discerned in such analyses. Based on the degree of warp offset by fishing depth, if such an intervention were to influence abundance indices, the effect would likely be most pronounced for the deepest dwelling species (i.e., where the warp offset was greatest). The deepest-dwelling of the groundfish stocks considered (based on catch-weighted median depths at capture, section 3.7) are American plaice, pollock, witch flounder, white hake, and redfish. There are nine survey series used in the assessments of these five stocks (Table 3.8). Data from the intervention year (i.e., 1999-2000) indicate that in 8 of these 9 series, the direction of change in abundance indices was actually positive (pollock in the autumn survey was the only negative change for the five stocks). Thus, analysis does not suggest a strong year effect coincident with a trawl warp offset intervention.

Table 3.8. Directional change in abundance (numbers per tow) of various species/stocks for pairs of years. For each stock all tuning indices used in the assessment that were influenced by the warp offsets in 2000-2002 are included. Positive (+) changes between years indicates the index increased. The warp change on Albatross occurred between 1999 and 2000.

Stock/Species	**Surveys Series**	**1998-1999**	**1999-2000**	**2000-2001**	**2001-2002**
GB Cod	Spring	-	+	-	+
	Fall	-	+	-	
GB Haddock	Spring	+	-	+	+
	Fall	+	-	+	
GB Yellowtail	Spring	+	-	-	+
	Fall	+	-	+	
SNE Yellowtail	Spring	+	-	-	+
	Fall	-	+	-	
	Winter	+	-	+	-
CC Yellowtail	Spring	+	+	-	+
	Fall	+	-	-	
GM Cod	Spring	+	+	-	+
	Fall	+	+	-	
Witch	Spring	-	+	+	+
	Fall	+	+	+	
Plaice	Spring	-	+	+	-
	Fall	+	+	-	
GB Winter Flounder	Spring	+	+	-	+
	Fall	-	+	+	
SNE Winter Flounder	Spring	+	-	-	+
	Fall	-	+	-	
	Winter	+	-	-	-
White hake	Spring	+	+	-	+
	Fall	+	+	-	
Pollock	Spring	-	+	+	
	Fall	+	-	+	
Redfish	Fall	-	+	-	
Ocean Pout	Spring	+	-	+	-
N Windowpane	Fall	-	o	+	
S Windowpane	Fall	-	+	+	
MAB Yellowtail	Spring	+	-	-	
	Fall	-	+	-	
	Winter	-	+	-	
GM Haddock	Spring	+	-	-	+
	Fall	+	+	-	
Atlantic Halibut	Spring	+	-	+	-
	Fall	-	-	-	
GM Winter Flounder	Spring	+	+	-	+
	Fall	+	+	-	
	Sum Increases (+)	25	23	14	12
	Sum Decreases (-)	14	15	25	5
	Sum No Change (o)	0	1	0	0

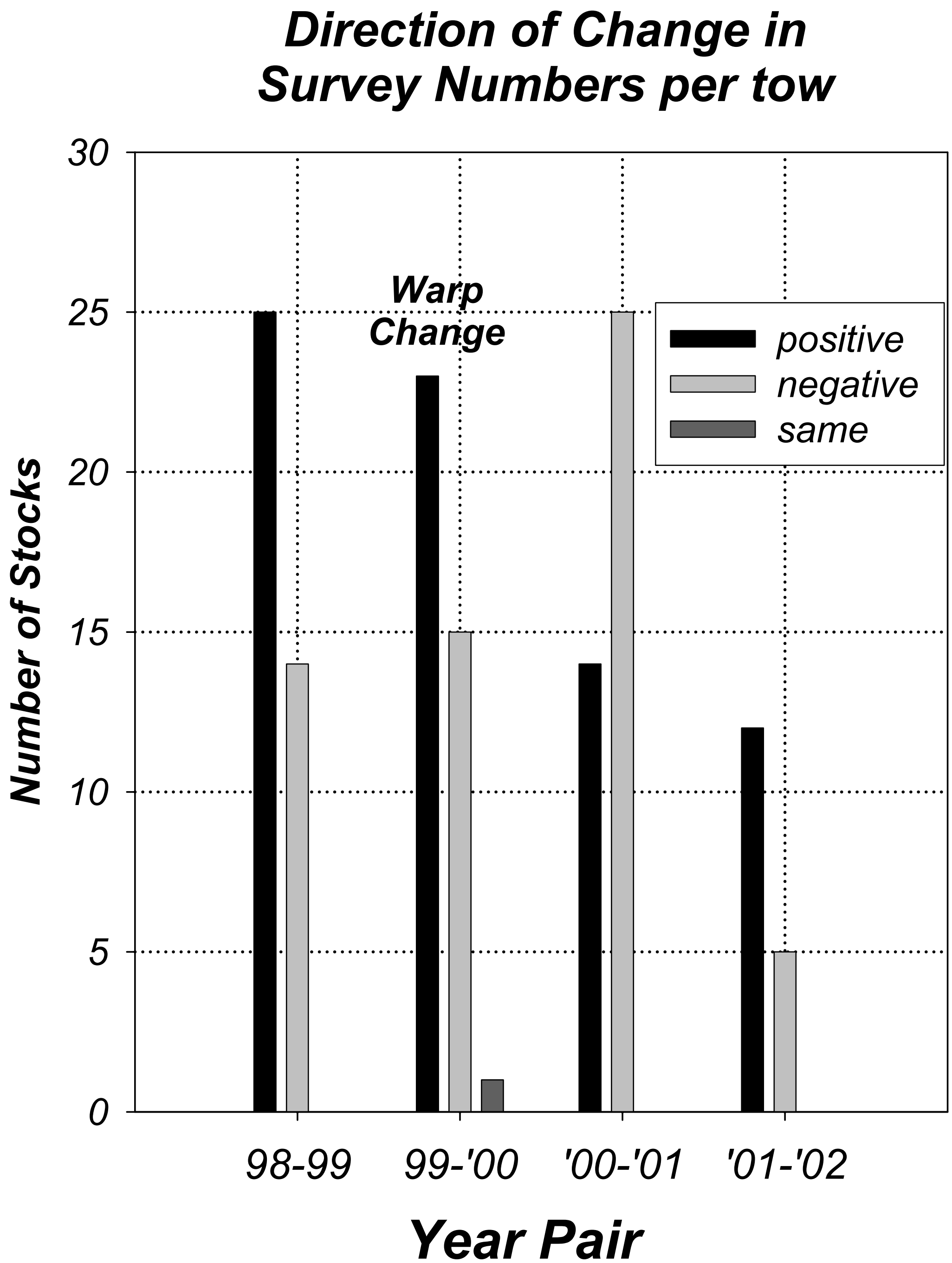


Figure 3.8. Directional change in abundance (numbers per tow) of various species/stocks for pairs of years. For each stock all tuning indices used in the assessment that were influenced by the warp offsets in 2000-2002 are included. Positive changes between years indicates the index increased. The warp change on *Albatross* occurred between 1999 and 2000.

3.9 Trends in Relative Fishing Power for NEFSC Bottom Trawl Surveys during 2000-2002

Summary and Conclusions

1) Trends in relative fishing power of bottom trawls used in NEFSC surveys were characterized using an index calculated from NEFSC bottom trawl, DFO bottom trawl and NEFSC sea scallop survey data. Index trends were examined to determine if relative fishing power of NEFSC bottom trawls declined during 2000-2002 while mis-marked warps were used.
2) Twenty species were included in the analysis: American plaice, Atlantic mackerel, cod, spiny dogfish, fourspot flounder, goosefish, haddock, herring, little skate, ocean pout, Pollock, red hake, redfish, sea scallop, silver hake, white hake, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder.
3) Catch rates for NEFSC bottom trawl and other surveys had similar trends.
4) There were a total of 323 index values in 22 comparisons. Of these, 63 (20%) were for years when NEFSC bottom trawls had mis-marked warps.
5) Results suggest that relative fishing power varies to some extent over time in all species and surveys. For all species as a group, relative fishing power in NEFSC bottom trawl surveys was somewhat above average during 2000-2002 while warps were mis-marked.
6) Based on these data, there is no evidence that mis-marked warps systematically reduced the fishing power of NEFSC bottom trawls during 2000-2002 for all species.

Introduction

Indices of relative fishing power were computed using survey data (number caught per standard tow) from NEFSC bottom trawl, DFO (Department of Fisheries and Oceans Canada)[1] bottom trawl, and NEFSC sea scallop surveys. Indices of relative fishing power for each species were examined qualitatively and statistically to determine if relative fishing power of NEFSC bottom trawls declined during 2000-2002 with mis-marked warps. Most of the comparisons involved NEFSC and DFO spring bottom trawl surveys but NEFSC winter bottom trawl, fall bottom trawl and scallop surveys were used as well. Species examined include American plaice, Atlantic mackerel, cod, spiny dogfish, fourspot flounder, goosefish, haddock, herring, little skate, ocean pout, pollock, red hake, redfish, sea scallop, silver hake, white hake, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder. The data used in comparisons were similar in terms of area surveyed and survey timing.

As many species-survey comparisons as possible were included in the analysis and the statistical approaches used to analyze index trends accommodated all comparisons simultaneously because it would be difficult to detect a small or moderate size change in fishing power for any single species.

[1] Dr. J. Hunt, Fisheries and Oceans Canada, Marine Fish Division, Gulf of Maine Section, 531 Brandy Cove Rd., St. Andrews, New Brunswick, E5B 2L9, CANADA

Materials and Methods

NEFSC bottom trawl survey data were either spring, fall or winter survey catch rates (mean number per standard tow) in "successful" tows (database SHG values ≤ 136) in NEFSC offshore survey strata. Bottom trawl survey and scallop survey data were tabulated by combining strata that made the area covered by both surveys as similar as possible. In particular, DFO spring survey data used in comparisons for Georges Bank (GBK) were for DFO bottom trawl strata 5Za-5Zh. NEFSC bottom trawl survey data used in comparisons with DFO or scallop survey data for GBK were from NEFSC offshore bottom trawl survey strata 9-11, 13-14, 16-17 and 19-25. NEFSC offshore strata for GBK exclude the deepest NEFSC strata that are not sampled in the DFO survey. NEFSC bottom trawl survey data used in comparisons with scallop survey data for the Mid-Atlantic Bight (MAB) area were from NEFSC offshore bottom trawl survey strata 1, 2, 65-66, 69-70, and 73-74 and were chosen to maximize overlap with the MAB area assumed in sea scallop assessments. Scallop survey data used in comparisons were for NEFSC shellfish strata 46-47, 49-55, 58-63, 65-66, 71-72 and 74 (the GBK stock area used in sea scallop stock assessments) or 6-7, 10-11, 14-15, 18-19, 22-31 and 33-35 (the MAB stock area used in sea scallop assessments).

During the years included in this analysis (beginning in either 1979, 1982 or 1987, depending on the species and surveys), NEFSC spring and fall surveys used two vessels (*R/V Albatross IV* and *R/V Delaware II*), two types of bottom trawls (Yankee No. 41 in the spring survey during 1979-1981; Yankee No. 36 otherwise and in all years for the fall survey), and two types of trawl doors (BMV doors prior to 1985, polyvalent doors afterwards). The NEFSC winter survey began in 1992 and used both vessels with the standard 60-80 bottom trawl. Based on standard NEFSC procedures, vessel, trawl and door correction factors were applied where available to make catch rates on all surveys comparable to the Yankee No. 41 trawl with polyvalent doors fished by the *R/V Albatross IV*. Correction factors are probably imprecise but, fortunately, the majority of comparisons involved the NEFSC and DFO bottom trawl surveys beginning in 1987. Different vessels were used in the spring survey after 1986 in some years. However, only one type of bottom trawl and one type of trawl door was used after that date.

DFO spring bottom trawl data were compared to NEFSC spring bottom trawl survey data for GBK (see below). DFO data were survey catch rates (mean number per standard tow, adjusted for distance towed based on standard DFO procedures) for "good, random survey tows" in DFO ground fish strata 5Za-5Zh (at depths < 100 fathoms) during 1987-1992 and 1995-2002. There was no DFO survey over Georges Bank during 1993 and coverage was incomplete during 1994. Therefore, catch rates during 1993-1994 were excluded from comparisons. DFO survey data for Georges Bank used in this analysis were collected by a single vessel (*R/V Alfred Needler*) and one type of bottom trawl gear (Western 2A bottom trawl). Sea scallop was excluded from comparisons for GBK because trawls are relatively inefficient for sea scallop on rough grounds found across much of GBK.

Georges Bank Species	Years Comparing NEFSC and DFO Spring Surveys
American plaice	14
Atlantic mackerel	12
Cod	14
Spiny dogfish	14
Fourspot	14
Haddock	14
Herring	14
Little skate	14
Ocean pout	14
Pollock	14
Red hake	13
Redfish	14
Silver hake	14
White hake	14
Windowpane flounder	14
Winter flounder	14
Witch flounder	14
Yellowtail flounder	14
Total	249

Catch rates for fish and sea scallops in annual NEFSC sea scallop surveys were compared to NEFSC survey bottom trawl catch rates (see below). The scallop survey during 2000-2002 was not affected by mis-marked warps on the *R/V Albatross IV* because the survey scallop dredge is towed by a single wire. Comparisons with scallop survey catches are potentially important because the scallop survey takes species on the bottom that might be missed by the bottom trawl if mis-marked warps reduced trawl bottom contact during 2000-2002. The scallop survey is conducted annually in the summer using a standard 8’ New Bedford style scallop dredge with 2” rings and a 1.75” plastic liner. However, in accord with standard procedures for scallop assessments, empty strata in some years were filled by borrowing catches from the same strata in the preceding and following year.

Scallop survey catch data used in this analysis were limited to sea scallops, goosefish and yellowtail flounder per standard tow because scallop survey catches have not been fully computerized for most fish species. Scallop survey data (mean number per standard tow) for the GBK and MAB regions were compared to the average of spring and fall NEFSC survey data during the same year because the scallop survey is carried out in the summer after the spring survey and before the fall survey. Comparisons involving average spring and fall survey data excluded 2002 because only the spring survey had mis-marked warps during 2002. In addition, catch rates for goosefish in MAB from the scallop survey were compared to NEFSC winter bottom trawl catch rate, because the winter survey takes substantial numbers of goosefish.

Goosefish were the only case of a comparison involving NEFSC winter survey and scallop survey data.

Catch rates used in species-comparisons were for all sizes with several exceptions. Data for GBK yellowtail < 20 cm TL in the scallop survey were excluded because survey bottom trawls are not efficient for yellowtail < 20 cm TL. Goosefish data for MAB from the scallop survey were for individuals 20-59 cm TL because survey bottom trawls are not efficient for goosefish smaller than 20 cm and scallop dredges are not efficient for goosefish larger than 60 cm. Comparisons of scallop catch rates were for scallops with shell heights of 9-13.9 cm because bottom trawls and scallop dredges both catch considerable numbers of scallops in this size range and because scallop dredges and commercial bottom trawls sample large (9-13.9 cm) and small (< 9 cm) scallops with different efficiency. Goosefish and yellowtail flounder comparisons began in 1982 because the scallop survey did not cover all of the Georges Bank strata in earlier years and because goosefish catches had not been recorded earlier.

MAB yellowtail and GBK goosefish were not used for comparisons because catch rates in NEFSC scallop, spring and fall surveys were too low and variable. The winter NEFSC winter survey takes substantial numbers of goosefish but does not cover the entire GBK region.

Mid-Atlantic Bight Species	Years Comparing GBK Scallop and Average NEFSC Spring & Fall	Years Comparing MAB Scallop and Average NEFSC Spring & Fall	Years Comparing MAB Scallop and NEFSC Winter	Total
Goosefish	--	20	11	31
Sea scallop	--	23	--	23
Yellowtail flounder	20	--	--	20
Total	20	43	11	74

Catch rates for NEFSC bottom trawl and other surveys followed similar trends in most cases (Figure 3.9-1). Correspondence in trends for scallops in the scallop, spring and fall surveys was surprisingly strong.

Standardized log catch rate ratios

The ratio of mean catch rates in two surveys during the same year is a measure of the relative fishing power of the two surveys. For each species in the analysis, we computed annual values of log survey catch ratios:

$$X_y = \ln\left(\frac{I_y}{K_y}\right)$$

where I_y is the catch rate (number per standard tow) during year y for the NEFSC bottom trawl survey, and K_y is the catch rate for the same species in the DFO or scallop survey. Log catch ratios have better statistical properties (i.e. symmetrical statistical distributions and constant variance) than the original values.

For ease in analysis and plotting, standardized log survey catch ratios for each species were standardized (Tables 3.9.1 and Figure 3.9.2):

$$\chi_y = \frac{\left(X_y - \bar{X}\right)}{\sigma}$$

where χ_y is the standardized log survey catch rate SLSCR index of relative fishing power, $\bar{X}$ is the average of X_y values prior to 2000 and σ is the standard deviation of X_y values prior to 2000. Means and standard deviations used in standardization calculations were for years prior to 2000 so that the mean SLSCR for years prior to 2000 would average zero and the standard deviation for years prior to 2000 would be one. This convention facilitated analyses but had no effect on results.

NEFSC spring, fall or winter catch rates were always in the numerator of ratios used to compute SLSCR index values. This is important because increases in ratios indicate possible increases in relative fishing power for bottom trawls used in NEFSC spring fall or winter surveys, and vice-versa. If mis-marked warps reduced the fishing power of bottom trawls used in the NEFSC spring survey relative to the DFO spring survey, for example, then SLSCR values for 2000-2002 in the comparison should tend to be small or negative. In addition, an abrupt change in index values may be evident in the index values for 1999-2000.

There were 22 species comparisons in the final data set with a total of 323 SLSCR index values. Of the total, 63 (20%) were for surveys with mis-marked warps during 2000-2002.

Interpretation of SLSCR index values

In theory, both the direction and magnitude of SLSCR index values have meaning. An index value of zero means no apparent change in relative fishing power, positive indices indicate above average relative fishing power, negative values indicate below average relative fishing power, and larger changes in index values suggest larger changes in relative fishing power. However, theory aside, there are a number of important issues to keep in mind while interpreting SLSCR index values (see below). In view of these issues, it is prudent to focus on results for groups of species and groups of years. In comparing index values for a single or few species over a short period of time, it is prudent to focus on the sign (positive or negative) of SLSCR values.

Changes in relative fishing power of both surveys in a comparison are confounded in SLSCR values. For example, increases in SLSCR could be due to values and increased relative fishing power in NEFSC bottom trawl surveys could be due to changes in either the numerator (NEFSC bottom trawl catch rates) or the denominator (DFO or scallop survey catch rates). This is an important because, in theory, variation in SLSCR values in a particular comparison could be due entirely to variability in fishing power of either the NEFSC bottom trawl (in the numerator) or the survey (DFO or scallop) used for comparison in the denominator.

Environmental factors likely influence both surveys in a comparison so that there is a covariance between catch rates and fishing power for both surveys. Further, trends in abundance will affect catch rates in both surveys so that catch rates are correlated. SLSCR was calculated using ratios, however, so that environmental "year effects" and "abundance" effects should cancel out.

SLSCR index values measure relative fishing power ***but can not be interpreted as percentage or proportional changes***. For example, if the SLSCR for a species was 0.0 for 1997, 0.1 for 1998, and -0.5 in 1999, one could conclude that relative fishing power was near average in 1997, apparently increased slightly in 1998 and apparently declined substantially in 1999. However, it would be incorrect to conclude that relative fishing power increased by 10% of the average value in 1998 and then declined by 60% of the average value during 1999.

The variance of SLSCR index values has not been measured and both the direction and magnitude of changes in the index may be largely random. Variance and statistical properties were not calculated in this analysis due to lack of time. Variance is likely considerable and the possibility of bias or autocorrelation in index values has not been fully explored. Survey catch rate data are intrinsically variable and there may be covariances between catches in two different surveys during the same year that do not cancel. Covariances may exist between SLSCR values for one species in adjacent years (autocorrelation) and among species in the same year. These types of correlations almost certainly increase uncertainty in SLSCR index values by reducing information about relative fishing power in the survey data. Therefore, patterns in these indices were evaluated for overall trends rather than for individual species/stocks in specific surveys.

Results

SLSCR index values indicate that relative fishing power for all species taken together was slightly above average (0.06) during 1999 and increased a small amount to 0.09 in 2000, the first year with mis-marked warps (Table 3.9.1). The average SLSCR value for all species taken together during 2000-2002 was 0.14, indicating that average fishing power for NEFSC bottom trawls was above average during 2000-2002 while warps were mis-marked. There was no obvious relationship between mean depth for each species and SLSCR values during 2000-2001 (Table 3.9.1). Depth is of interest because of hypotheses that effects of mis-marked warps increased with depth.

The sign of SLSCR values (i.e. positive for increased fishing power, negative for decreased fishing power; Table 3.9.2) also indicate about average overall fishing power for NEFSC bottom trawls with mis-marked warps during 2000-2002. SLSCR values were positive in 11 out of 22 (50%) comparisons for 1999 and 12 out of 22 (55%) comparisons for 2000. Considering all comparisons during 2000-2002, SLSCR values were positive in 34 out of 63 (54%) of cases, compared to 33 out of 66 (50%) during 1997-1999. Thus, the number of species for which fishing power of NEFSC survey bottom trawls was above average was about 50% before and after the introduction of mis-marked warps. There was no obvious relationship between species mean depth and the sign of SLSCR values during 2000-2001 (Table 3.9.2). There are a number of other such comparisons (e.g. between NMFS fall surveys and Canadian surveys) that could be pursued. However, results presented in section 3.8 indicate similar conclusions regarding the lack of a detectable intervention due to the warp offset issue.

Table 3.9.1. Standardized SLSCR indices of relative fishing power for NEFSC bottom trawls during 1991-2002. Positive values mean that the NEFSC bottom trawl survey had above average relative fishing power, and vice versa. Index values do not measure percentage or proportional changes in relative fishing power. For example, a value 0f 0.1 does not imply a 10% increase. Species are sorted roughly in order of average depth in spring NEFSC survey catches during 1968-2002 (shallow depths at the top). Few indices are available for 1993-1994 because DFO surveys were not carried out or were incomplete on Georges Bank.

Species	Surveys	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	1997-1999	2000-2002
Little Skate	Spring-DFO	0.93	2.16			-0.71	0.56	-1.31	-0.26	0.02	-0.59	0.31	0.92	-0.51	0.21
Windowpane	Spring-DFO	1.23	-0.23			-0.86	-0.96	-0.44	-1.09	-0.67	0.62	0.57	-0.17	-0.73	0.34
Winter Flounder	Spring-DFO	0.90	-0.28			-0.29	-0.26	-0.71	-0.18	2.41	1.69	0.29	1.30	0.51	1.09
Yellowtail	Spring-DFO	0.62	-0.66			0.67	-0.24	-0.89	0.66	-0.22	-0.47	-1.58	0.16	-0.15	-0.63
Yellowtail	Spr&Fall-Scallop	-1.04	0.37	-1.76	-0.55	-0.94	-1.23	-0.73	-0.64	0.29	-0.16	1.25		-0.36	0.55
Ocean Pout	Spring-DFO	0.63	-1.60			0.71	0.16	0.73	0.15	0.84	1.93	1.87	3.92	0.57	2.57
Mackerel	Spring-DFO	-1.60	-0.33			-0.14	0.24	0.84	-1.42	0.49	0.92	-0.69	-0.47	-0.03	-0.08
Herring	Spring-DFO	-0.84	0.66			0.03	0.08	-0.54	1.47	-0.86	-0.88	-0.89	0.94	0.02	-0.28
Scallop	Spr&Fall-Scallop	0.17	0.70	-0.08	0.75	-0.02	-1.32	0.31	0.96	0.63	0.70	-0.37		0.63	0.17
Cod	Spring-DFO	0.07	-1.26			0.73	-1.73	-0.31	2.05	-0.37	-0.96	-0.30	-0.88	0.46	-0.71
Haddock	Spring-DFO	-0.32	-1.97			0.13	1.34	1.27	-0.69	-0.68	-1.83	-0.54	-0.10	-0.03	-0.82
Red Hake	Spring-DFO	1.17				0.70	-2.01	-0.01	1.45	-0.03	0.53	-0.18	0.84	0.47	0.40
Fourspot	Spring-DFO	-0.35	-0.83			0.41	1.86	-0.32	0.29	-1.96	1.32	-0.81	0.45	-0.67	0.32
Dogfish	Spring-DFO	0.04	-1.59			-1.09	0.06	0.62	1.69	1.41	0.05	0.14	0.91	1.24	0.37
Goosefish	Spr&Fall-Scallop	0.88	-0.91	-0.33	-0.06	-0.47	-0.94	-0.50	-0.26	-0.15	0.69	-0.25		-0.31	0.22
Goosefish	Winter-Scallop		-0.31	0.88	-0.96	0.05	1.83	-0.50	0.26	-1.25	0.16	1.27	1.75	-0.49	1.06
Plaice	Spring-DFO	0.14	-2.25			0.56	0.63	-0.73	0.74	-0.79	0.49	0.14	-0.11	-0.26	0.17
Pollock	Spring-DFO	0.44	-1.58			1.86	-0.21	0.26	0.82	0.45	-0.39	0.16	-3.05	0.51	-1.09
Silver hake	Spring-DFO	-0.33	-1.32			-0.66	-1.19	-0.13	1.31	0.10	-1.44	-0.24	1.31	0.43	-0.12
Witch Flounder	Spring-DFO	0.29	-0.66			-0.29	0.22	-2.16	1.88	-0.35	-1.14	-0.79	0.01	-0.21	-0.64
Redfish	Spring-DFO	-1.54	1.76			-0.37	0.18	0.50	0.68	0.51	1.50	1.28	-0.29	0.57	0.83
White hake	Spring-DFO	-0.21	-1.13			-0.63	-0.10	-0.85	0.87	1.41	-0.66	-1.59	0.06	0.48	-0.73
Count All		21	21	4	4	22	22	22	22	22	22	22	19	66	63
Average All		0.06	-0.54			-0.03	-0.14	-0.25	0.49	0.06	0.09	-0.04	0.39	0.10	0.14

Table 3.9.2. The sign ("+" for above and "–" for below average) of SLSCR relative fishing power indices during 1991-2002. Species are sorted roughly in order of average depth in spring NEFSC survey catches during 1968-2002 (shallow depths at the top). Few indices are available for 1993-1994 because DFO surveys were not carried out or were incomplete on Georges Bank.

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	1997-1999	2000-2002
Little Skate	+	+			-	+	-	-	+	-	+	+	0.33	67%
Windowpane	+	-			-	-	-	-	-	+	+	-	0.00	67%
Winter Flounder	+	-			-	-	-	-	+	+	+	+	0.33	100%
Yellowtail	+	-			+	-	-	+	-	-	-	+	0.33	33%
Yellowtail	-	+	-	-	-	-	-	-	+	-	+		0.33	50%
Ocean Pout	+	-			+	+	+	+	+	+	+	+	1.00	100%
Mackerel	-	-			-	+	+	-	+	+	-	-	0.67	33%
Herring	-	+			+	+	-	+	-	-	-	+	0.33	33%
Scallop	+	+	-	+	-	-	+	+	+	+	-		1.00	50%
Cod	+	-			+	-	-	+	-	-	-	-	0.33	0%
Haddock	-	-			+	+	+	-	-	-	-	-	0.33	0%
Red Hake	+				+	-	-	+	-	+	-	+	0.33	67%
Fourspot	-	-			+	+	-	+	-	+	-	+	0.33	67%
Dogfish	+	-			-	+	+	+	+	+	+	+	1.00	100%
Goosefish	+	-	-	-	-	-	-	-	-	+	-		0.00	50%
Goosefish		-	+	-	+	+	-	+	-	+	+	+	0.33	100%
Plaice	+	-			+	+	-	+	-	+	+	-	0.33	67%
Pollock	+	-			+	-	+	+	+	-	+	-	1.00	33%
Silver hake	-	-			-	-	-	+	+	-	-	+	0.67	33%
Witch Flounder	+	-			-	+	-	+	-	-	-	+	0.33	33%
Redfish	-	+			-	+	+	+	+	+	+	-	1.00	67%
White hake	-	-			-	-	-	+	+	-	-	+	0.67	33%
Count All	21	21	4	4	22	22	22	22	22	22	22	19	66	63
Count (+) All	13	5	1	1	10	11	7	15	11	12	10	12	33	34
Percent (+) All	62%	24%			45%	50%	32%	68%	50%	55%	45%	63%	50%	54%

Figure 3.9.1. Time series of survey catch rates for all species comparisons in this analysis. Original catch rates were rescaled for ease in plotting to a mean value of zero and a standard deviation of one.

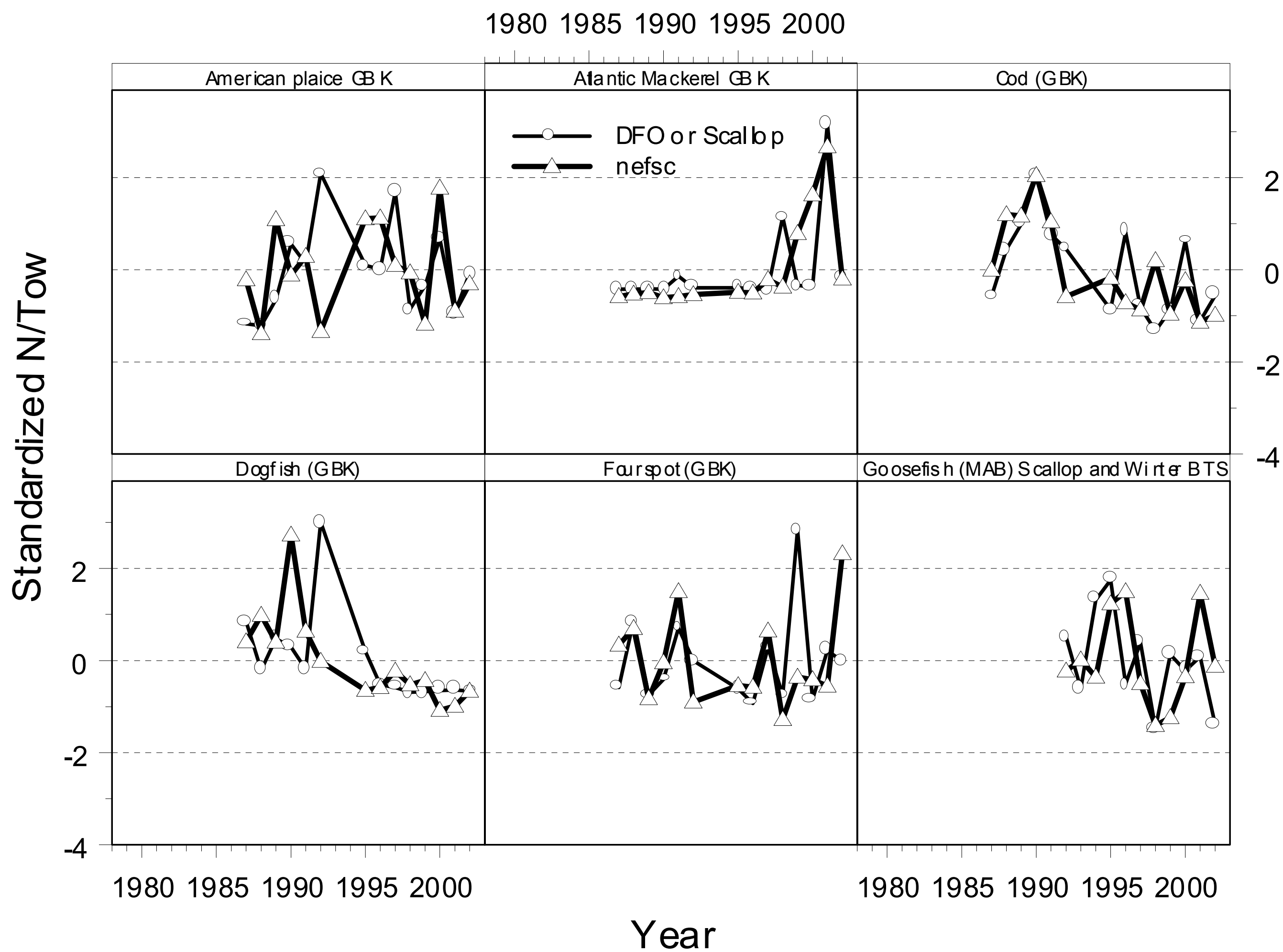


Figure 3.9.1. (cont.)

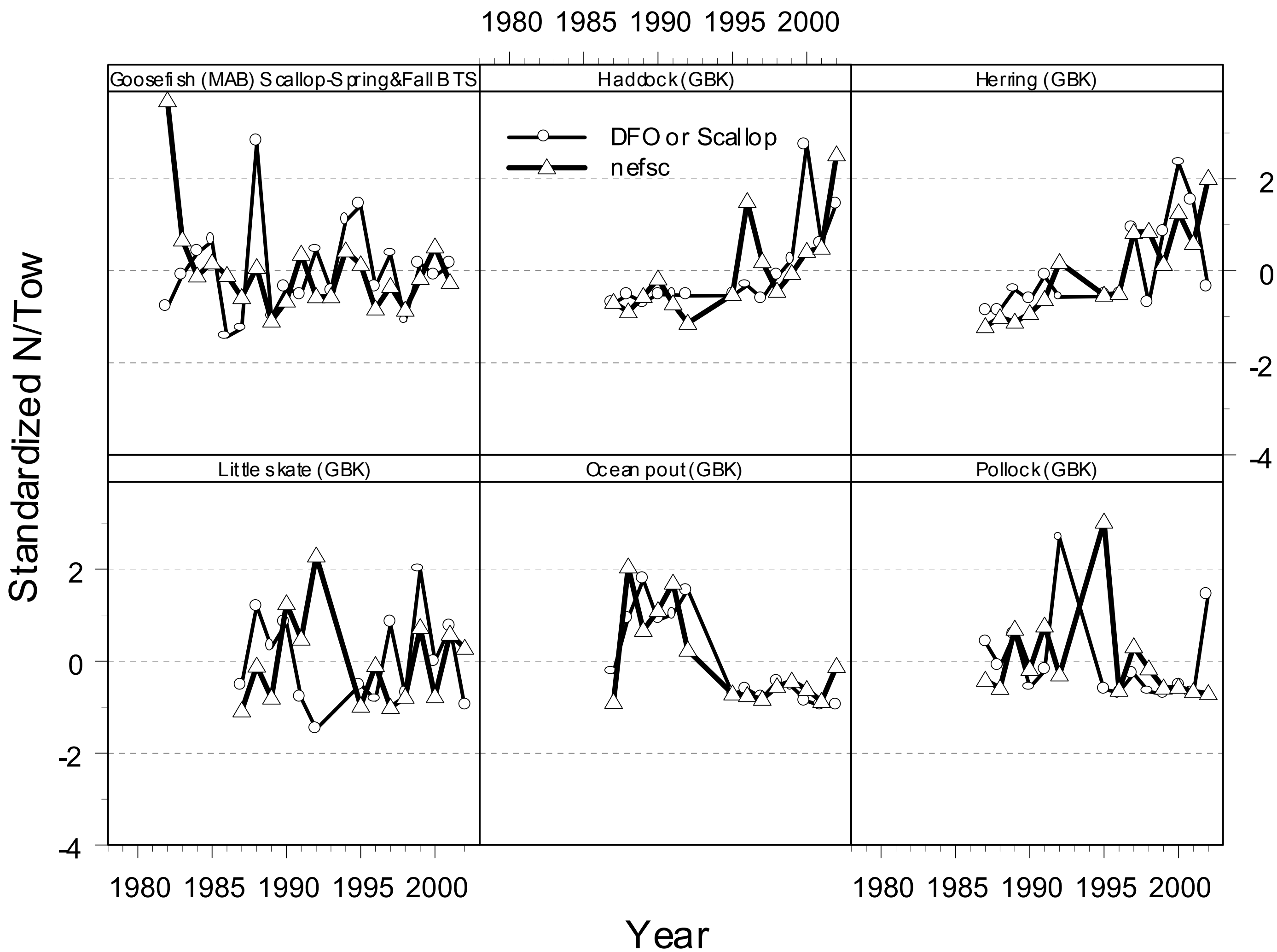


Figure 3.9-1. (cont.)

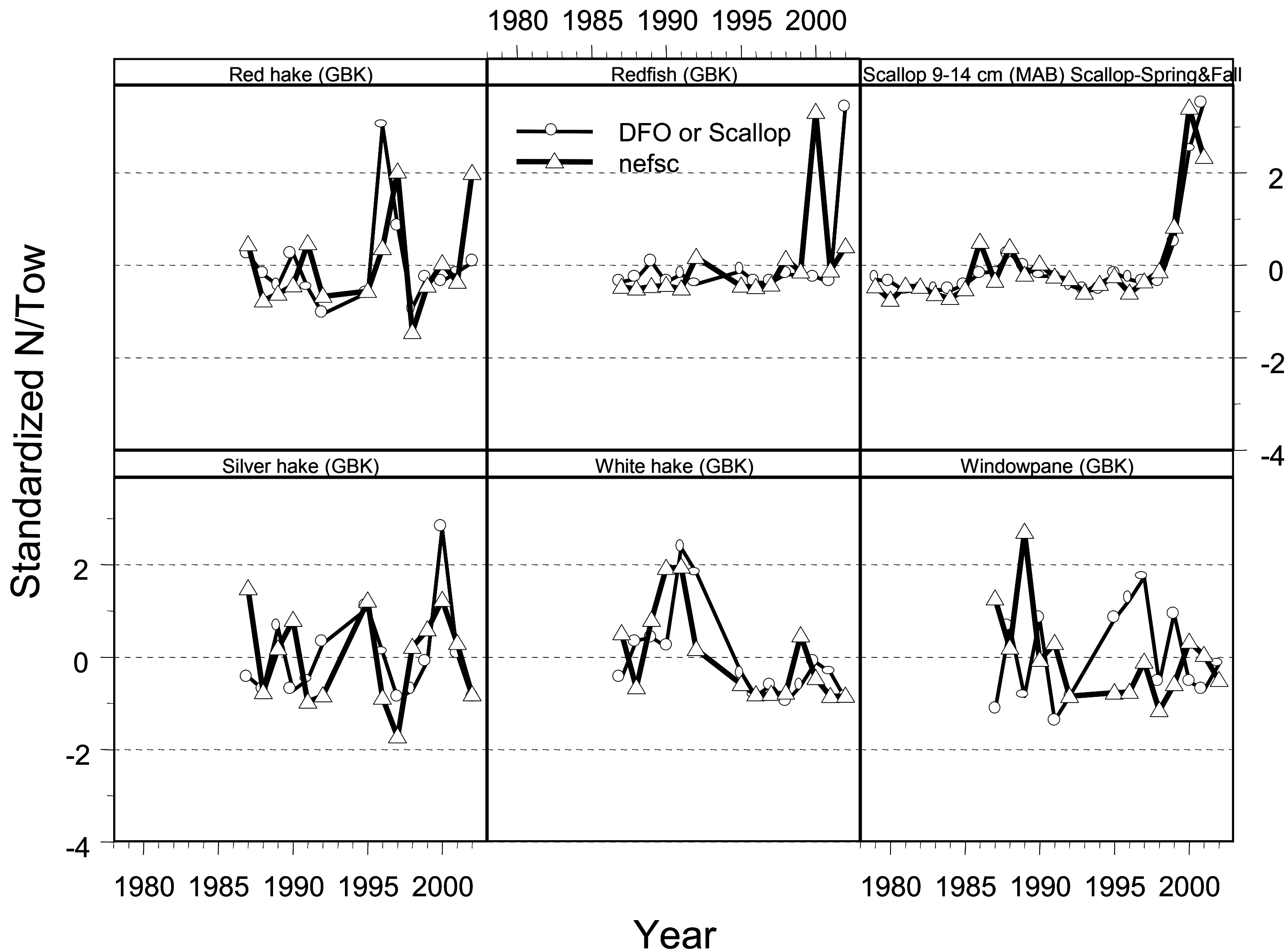


Figure 3.9.1. (cont.)

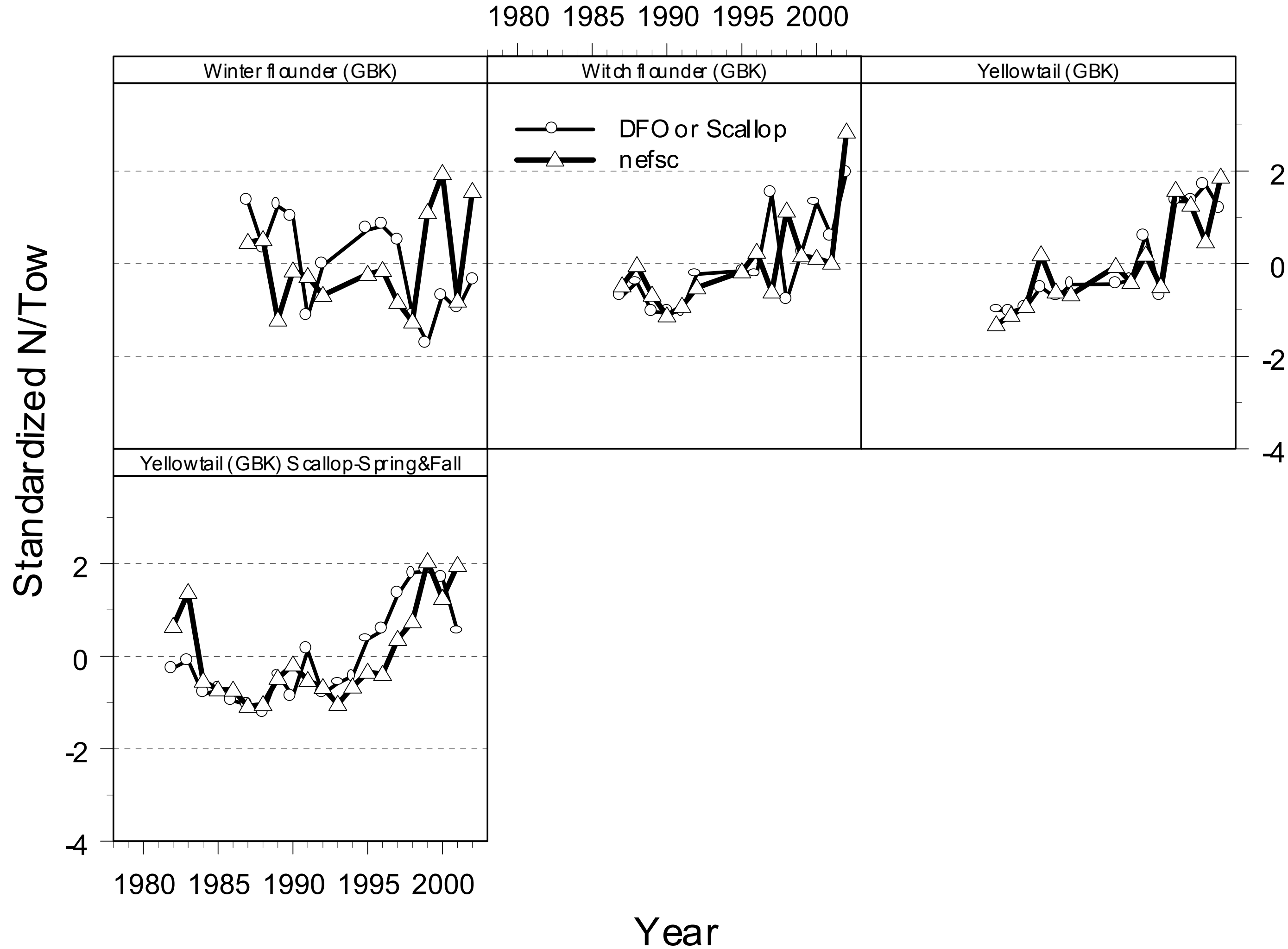


Figure 3.9.2. Time series of SLSCR indices of relative fishing power for all species comparisons in this analysis.

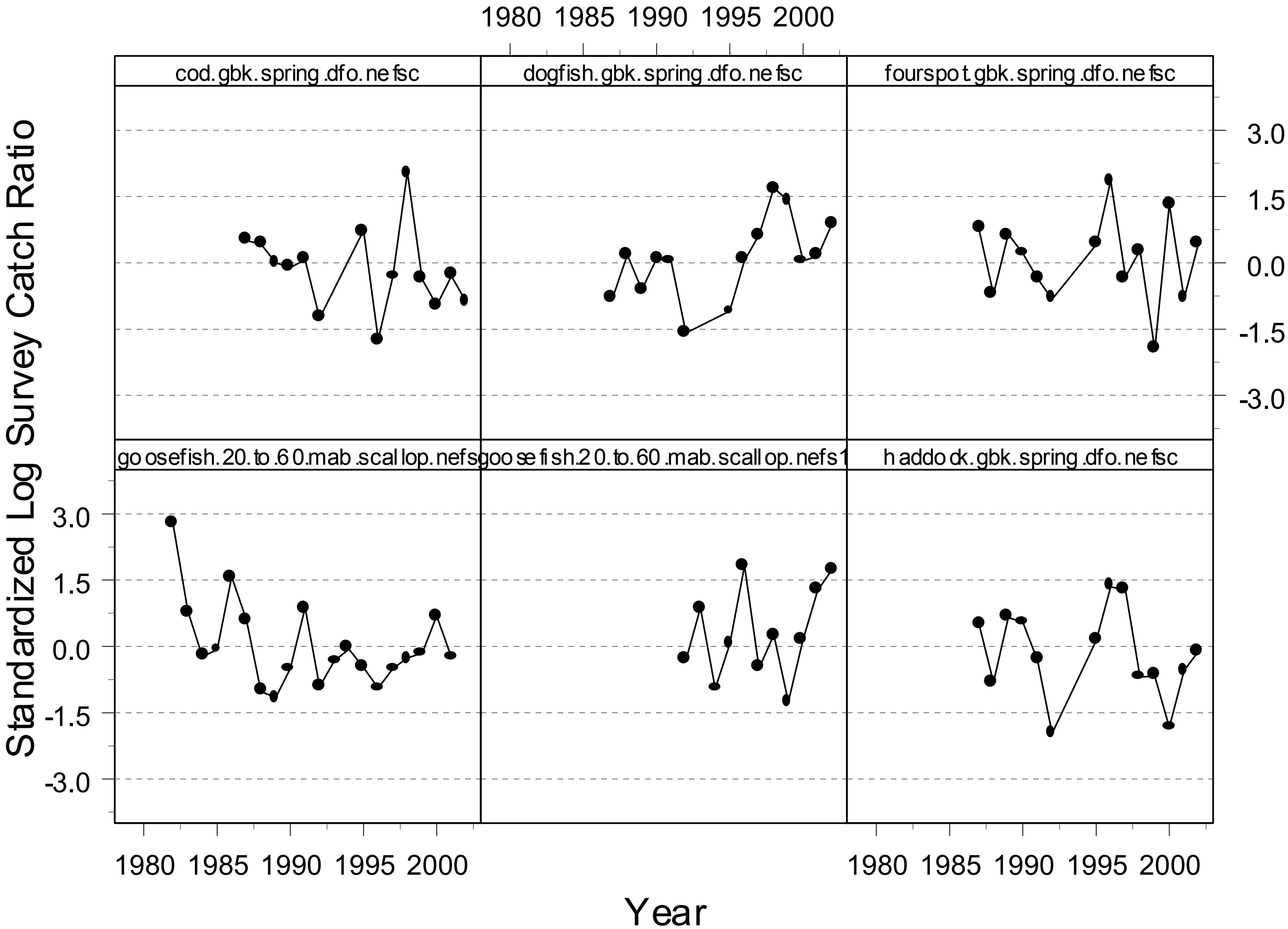


Figure 3.9.2. (cont.)

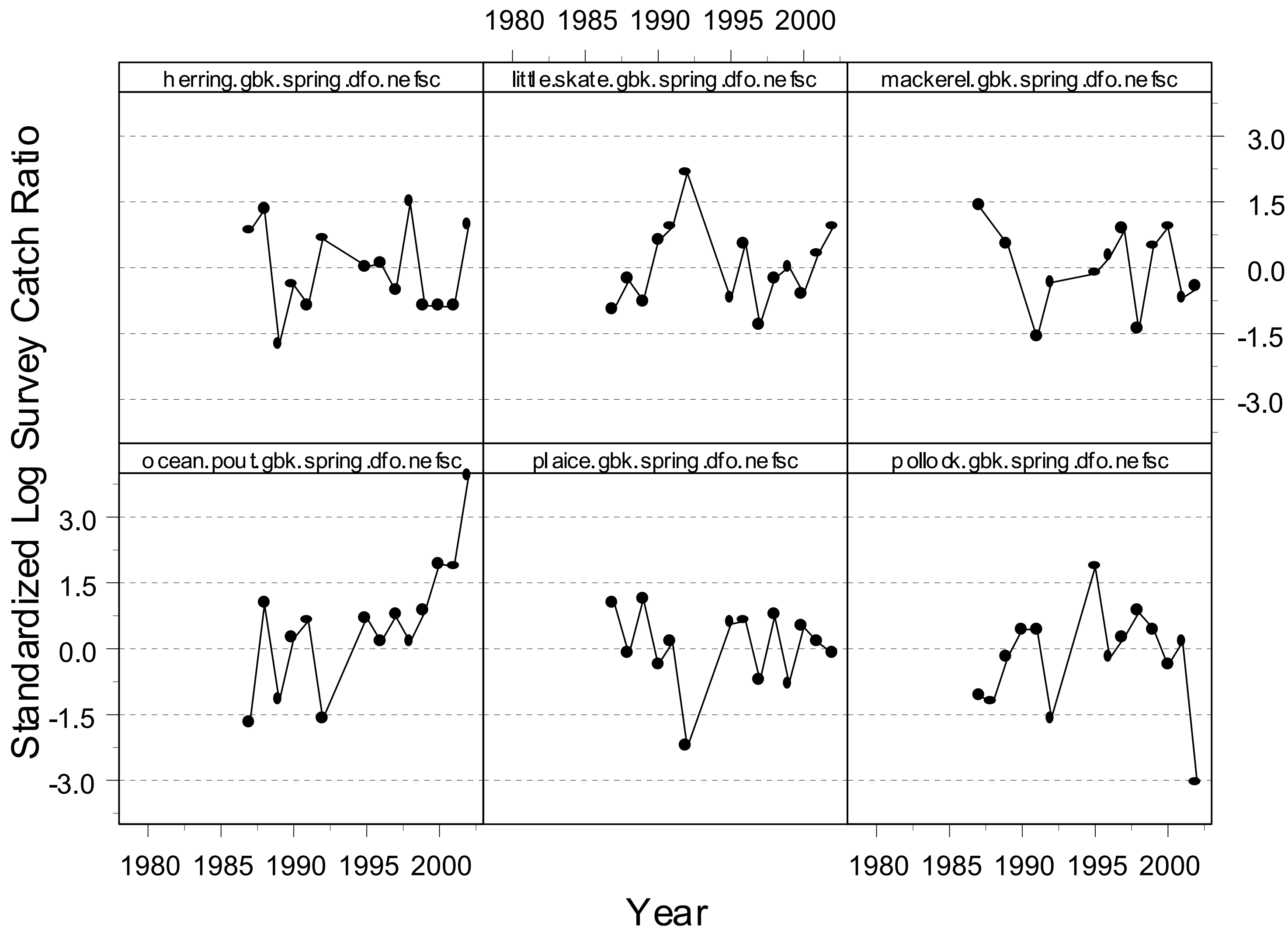


Figure 3.9.2. (cont.)

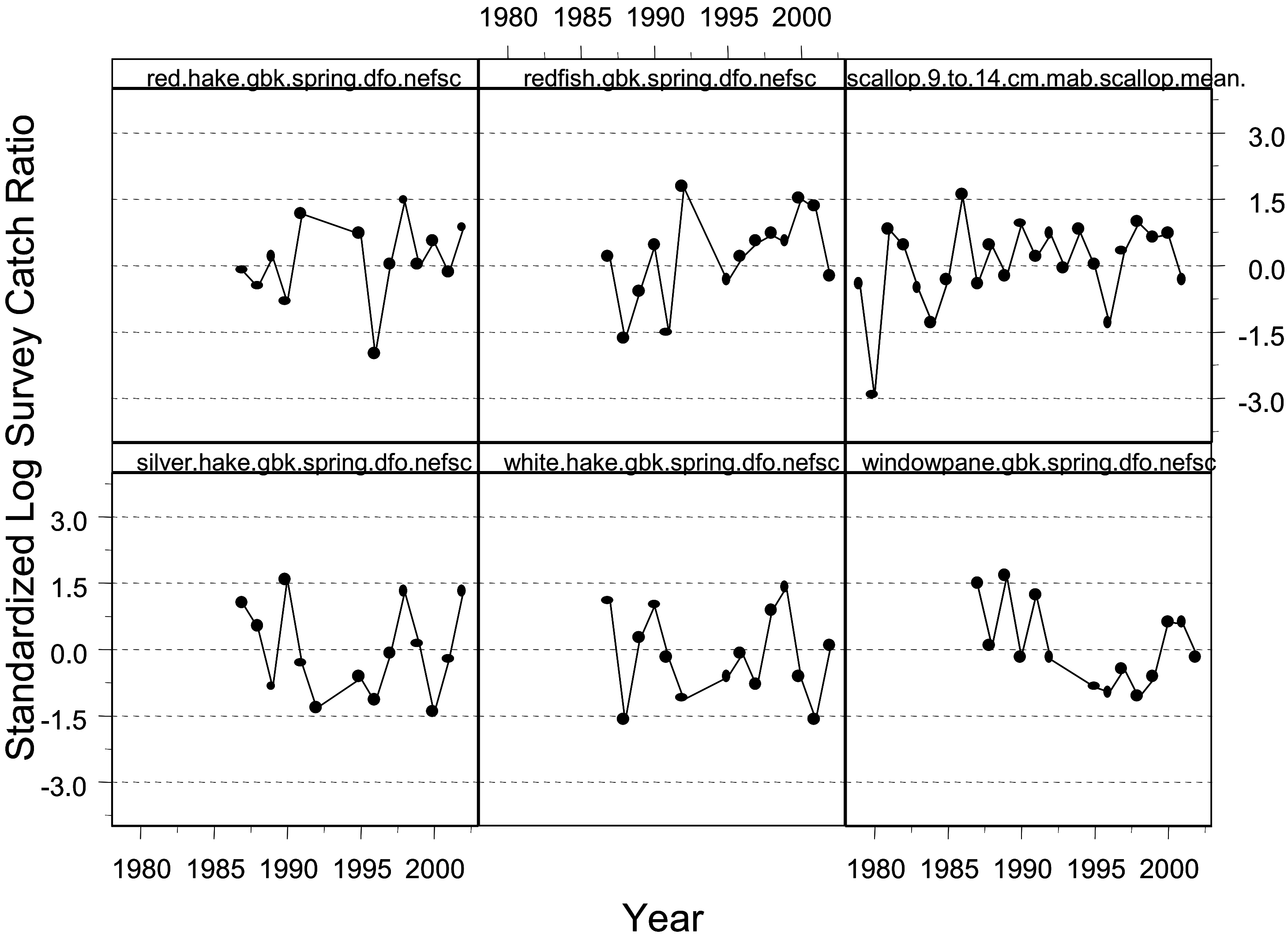
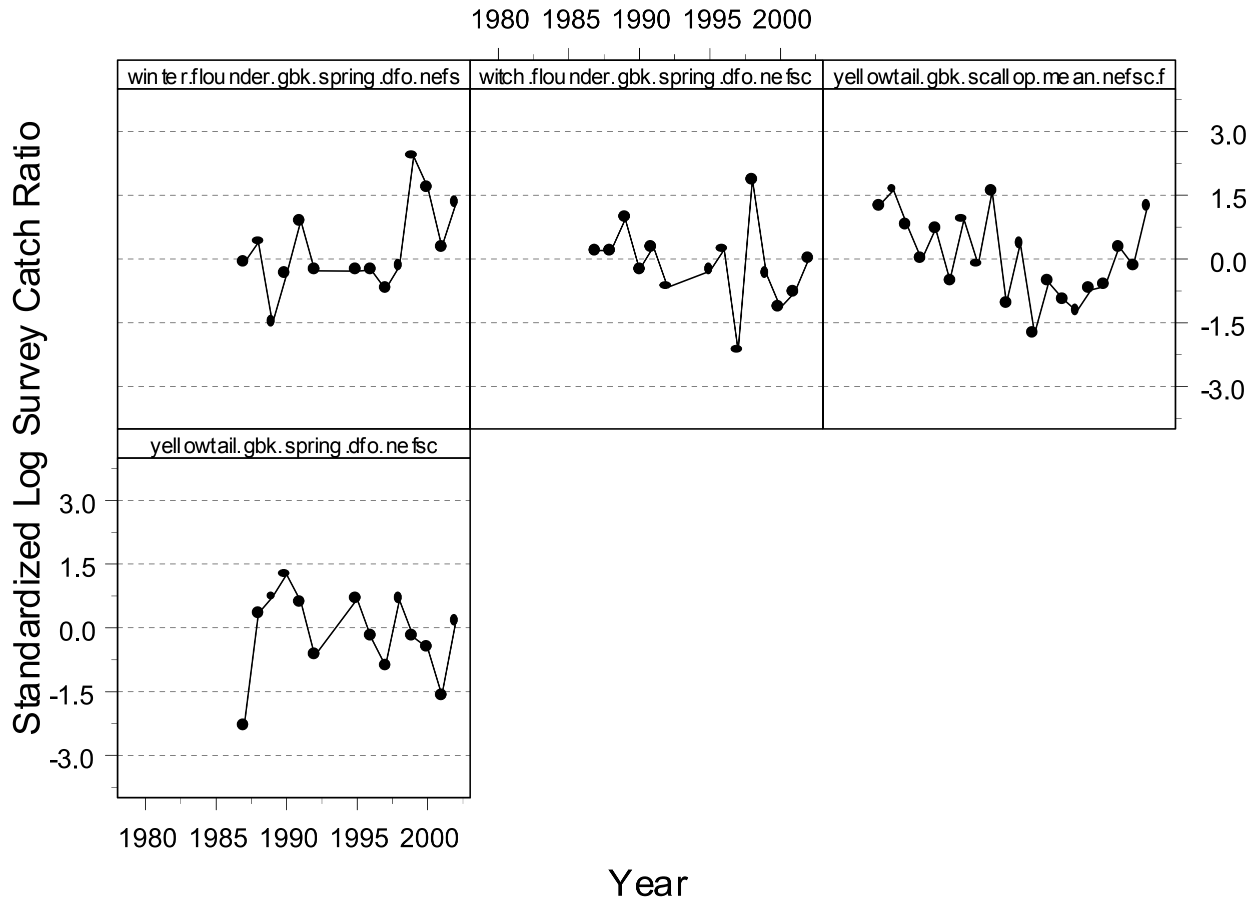


Figure 3.9-2. (cont.)



3.10 VPA Performance

The virtual population analysis results under the sensitivity runs (increasing the warp-impacted surveys by arbitrary levels of 10%, 25% and 100%) were examined for signs of improved fit relative to the base run. If in fact the warp-impacted surveys were catching fewer fish than expected, an improved fit and decrease of residuals would be expected under the sensitivity runs. However, of eight stocks examined, five decreased in fit, one remain unchanged, and two improved (Table 3.10.1). On average, the fit remain unchanged for the 10% run, decreased by 1% for the 25% run, and decreased by 4% for the 100% run. The overall fits of the virtual population analyses do not indicate a loss of fish in the warp impacted surveys.

The VPA performance was further examined by comparing the survey and year specific residuals from the sensitivity runs with the base case for each stock. These changes in residual were plotted so that positive values denote an improvement in fit while negative values denote a decrease in fit. Note that due to the backward convergence of VPA these changes will decrease for earlier years. If in fact the warp impacted surveys catch fewer fish than expected, trends in the residuals should be seen, viz., more positive changes than negative ones, especially for the impacted surveys. However, examination of these changes in residuals resulted in either random patterns or sets of decreased fits that were not balanced by associated increased fits. As the warp impacted surveys were increased, the magnitude of change in the residuals increased, as expected, but did not produce more positive changes than negative ones for either all indices or the warp-impacted survey indices taken alone. The changes in residuals from the sensitivity VPA runs do not indicate a loss of fish in the impacted surveys.

Retrospective patterns are common in VPA results and were seen for many of these stocks. If the warp impacted surveys were catching fewer fish than expected, a decrease in retrospective pattern would be expected under the sensitivity runs. However, the sensitivity runs had similar retrospective patterns to the base case for those stocks examined. The changes in retrospective patterns do not indicate a loss of fish in the impacted surveys.

Table 3.10.1 Mean square residual and change in mean square residual relative to the base run (positive values denote an improved fit) from eight stocks assessed with VPA. The three sensitivity analyses correspond to increasing the warp impacted surveys by 10%, 25% and 100%.

	Mean Square Residual			
	base	x1.10	x1.25	x2.00
GBCod	0.58880	0.58822	0.58839	0.59875
GBHaddock	0.69544	0.69435	0.69402	0.70135
GBYTF	0.71389	0.71046	0.70664	0.70068
SNEYTF	1.07064	1.07141	1.07089	1.07124
CCYTF	0.82761	0.83632	0.84960	0.90921
GOMCod	0.44121	0.44242	0.44498	0.46370
Witch	0.76730	0.76576	0.76248	0.75622
Plaice	0.38929	0.39456	0.40283	0.44496

	Relative Change in Mean Square Residual		
	x1.10	x1.25	x2.00
GBCod	0%	0%	-2%
GBHaddock	0%	0%	-1%
GBYTF	0%	1%	2%
SNEYTF	0%	0%	0%
CCYTF	-1%	-3%	-10%
GOMCod	0%	-1%	-5%
Witch	0%	1%	1%
Plaice	-1%	-3%	-14%
average	0%	-1%	-4%

3.11 Results from Comparative Fishing Power Studies Between *Albatross IV* and *Delaware II*

Fishing power studies (calibration experiments) are necessary if significant changes are made to elements of the trawl survey system over the time series. Such studies have been conducted in the past for the NEFSC bottom trawl surveys when elements such as survey ships and trawl doors have been changed (Sissenwine and Bowman, 1978; Byrne and Forrester, 1991; Forrester unpublished ms). These studies rely on side-by-side or repeat towing, with tows taken by one vessel serving as control, and the element of change (e.g., doors or ships) as the primary factor under investigation. Other variables such as the order of tows in repeat towing or the orientation of side-by-side towing (port vs. starboard) are usually randomized.

A one-time change in the trawl gear that affected the catching efficiency and, hence, the survey series was made in the 1980s as the doors were upgraded from a BMV wood and metal door to an all-metal oval polyvalent door (Byrne and Forrester 1991). To appropriately adjust the time series, conversion factors were estimated from replicated towing experiments to maintain the integrity of the time series, as the new doors generally improved the catch efficiency of the survey tows. Similarly, while the *Albatross IV* has been the primary survey vessel used in the bottom trawl time series, because of various scheduled and unscheduled maintenance and repair issues, the *Delaware II* has periodically been substituted as the survey ship. Therefore, a series of side-by-side comparison tows have been made since the early 1980s to estimate the relative efficiency of the two ships, by species, for use in calibration (Byrne and Forrester 1991). Following calibration, data from the two vessels are comparable. Since the *Albatross* will enter the shipyard for extensive repairs in late 2002, it was anticipated that the *Delaware II* would be used as the bottom trawl survey ship for the winter 2003 and spring 2003 surveys. Therefore, additional side-by-side tows were conducted in conjunction with the spring 2002 bottom trawl survey.

Unbeknownst to the NEFSC at the time, the spring 2002 side-by-side towing between *Albatross* and *Delaware* essentially compared one vessel with systematic and progressive trawl warps offset (*Albatross*) against a ship with small but non-biased warp measurement differences (*Delaware* warp offsets averaged 18", varying randomly between port and starboard sides). Since there are differences in fishing power by ship (Byrne and Forrester 1991), the side-by-side towing results in 2002 cannot be compared directly to measure effects of the warp offset on *Albatross*. However, the results of the hundreds of side-by-side tows made between 1982 and 1988 can be compared to 2002 results to see if the ratio of *Albatross* to *Delaware* catches (by species) have changed (catch rates cannot be compared directly between the two time periods since underlying abundances have changed). Thus, the *Delaware* effectively serves as control, because its operating procedure was constant before and after the warp offset on *Albatross*.

If the warp offsets on *Albatross* had a significant impact on trawl catch efficiency then this would be manifested as a difference in the ratio of *Albatross* to *Delaware* catches between time periods. Information on the mean ratio of catches (A/D) and their 95% confidence intervals are presented for the two time periods in Table 3.11 and Figure 3.11.1, for 10 species where there were sufficient pairs of data to provide meaningful and reliable information for analysis. Sample sizes were 484 pairs of tows in the 1980s and 132 pairs in 2002. Over the 10 stocks considered, the mean ratio of *Albatross* to *Delaware* catch in the 1980s was 0.88, and in 2002 was 0.91. For the 10 species investigated, five had higher mean ratios in 2002 versus the 1980s, and 5 the opposite trend. Of the 10 species investigated, there were no statistically significant changes in the ratio of *Albatross* to *Delaware* catches in nine; the one significant difference was for yellowtail flounder, which indicated an apparent increase in fishing power of the *Albatross* relative to the *Delaware* in 2002. Because the experimental units are the trawl hauls, the results for the 10 species are not independent, and thus the most robust measure of change is based on the composite of species. The apparent increase in catching efficiency for yellowtail flounder could be spurious (one false positive out of ten is not unlikely; on average this occurs in one out of 20 times in tests at the 5% significance level).

In order to discern the ability of this test to detect differences in relative fishing power between ships and time periods, the 2002 data were subjected to a power analysis. Information presented is the percent difference in the ratio of *Albatross* to *Delaware* catches, by species, that can be detected at the 5% significance level in a two-sided test. For all species the average difference in catch ratios that could be detected was 21.4%, varying from 12.2% (haddock) to 34.6% (winter flounder; Table 3.11; Figure 3.11.2).

Estimates of fishing power coefficients (ratio of *Albatross* to *Delaware* catches) were thus similar between vessels in experiments before and after the warp change on *Albatross IV*. There was only one statistically significant change in this ratio after the warp change in the 10 species examined (and this result could be spurious). These paired comparison tests (although not intended for the purpose when they were conducted) provide robust data to test the warp effects (and include any other systematic changes in the fishing system since 1988 such as the new method for lashing the net to the traveler wire). Based on information from 2002, the catch ratio test can detect differences of between 12% and 35%, with 95% probability, depending on species. Therefore, large (greater than 40%-50%) reductions in catchability of the *Albatross* survey during the period of the warp offset are highly unlikely as they should have been detected.

References

Byrne, C.J., and J.R.S. Forrester. 1991. Relative fishing power of NOAA R/Vs Albatross IV and Delaware II. National Marine Fisheries Service, Stock Assessment Workshop Working Paper SAW/12/P1. 8 pp (mimeo).

Forrester, J.R.S. (m.s.). A trawl survey conversion coefficient suitable for lognormal data. National Marine Fisheries Service, Woods Hole laboratory 17 pp (mimeo)

Sissenwine, M.P. and E.W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. ICNAF Research Bulletin 13: 81-87.

Table 3.11. Estimated relative fishing power coefficients (ratio of *Albatross* to *Delaware*) for side-by-side trawling studies done between 1982 and 1988 and in spring 2002. Data are given for 10 species for which sufficient numbers of catch pairs (Albatross and Delaware) are available to support the analysis. The percent of difference in fishing power that is detectable at the 0.05 level of significance (two-tailed test), based on 2002 data is also presented. Means over species and experiments are given.

Species	1982-1988 Ratio	1982-1988 SE	1982-1988 L-95% CI	1982-1988 U-95% CI	2002 Ratio	2002 SE	2002 L-95% CI	2002 U-95% CI	2002 % Detectable Difference
Yellowtail Flounder	0.7390	0.0512	0.6386	0.8394	1.1087	0.1118	0.8896	1.3278	19.8
Winter Skate	0.8450	0.1036	0.6419	1.0481	0.7750	0.0874	0.6037	0.9463	22.1
Winter Flounder	0.9745	0.0892	0.7997	1.1493	0.8781	0.1548	0.5747	1.1815	34.6
Four Spot Flounder	0.8396	0.0405	0.7602	0.9190	1.0530	0.1019	0.8533	1.2527	19.0
Cod	0.7190	0.1007	0.5216	0.9164	0.8780	0.1520	0.5801	1.1759	33.9
Haddock	1.1056	0.2069	0.7001	1.5111	0.8096	0.0506	0.7104	0.9088	12.2
Red Hake	0.8965	0.1073	0.6863	1.0167	0.8096	0.0507	0.7102	0.9090	12.3
Silver Hake	1.1040	0.2740	0.5670	1.6410	0.8620	0.0740	0.7170	1.0070	16.8
American Plaice	0.7802	0.0670	0.6489	0.9115	0.8975	0.0851	0.7307	1.0643	18.6
White Hake	0.7818	0.0949	0.5958	0.9678	1.0620	0.1320	0.8033	1.3207	24.4
Mean	0.8785	0.1135	0.6560	1.1010	0.9134	0.1000	0.7173	1.1094	21.4

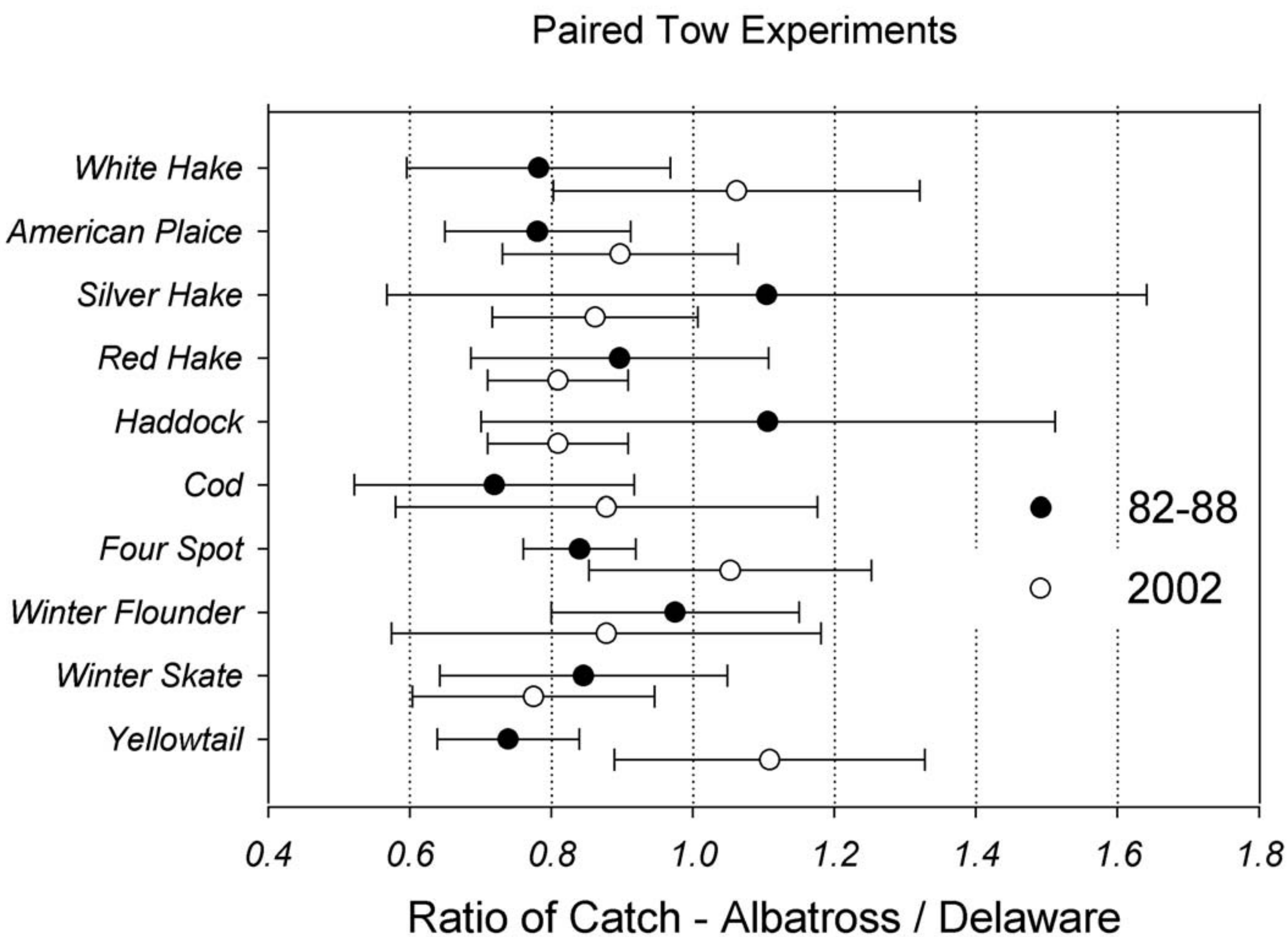


Figure 3.11.1. Results of fishing power calibration studies for NOAA R/Vs *Albatross IV* and *Delaware II* during two time periods. Data are the mean ratio of catch by species (A/D) and the 95% confidence intervals

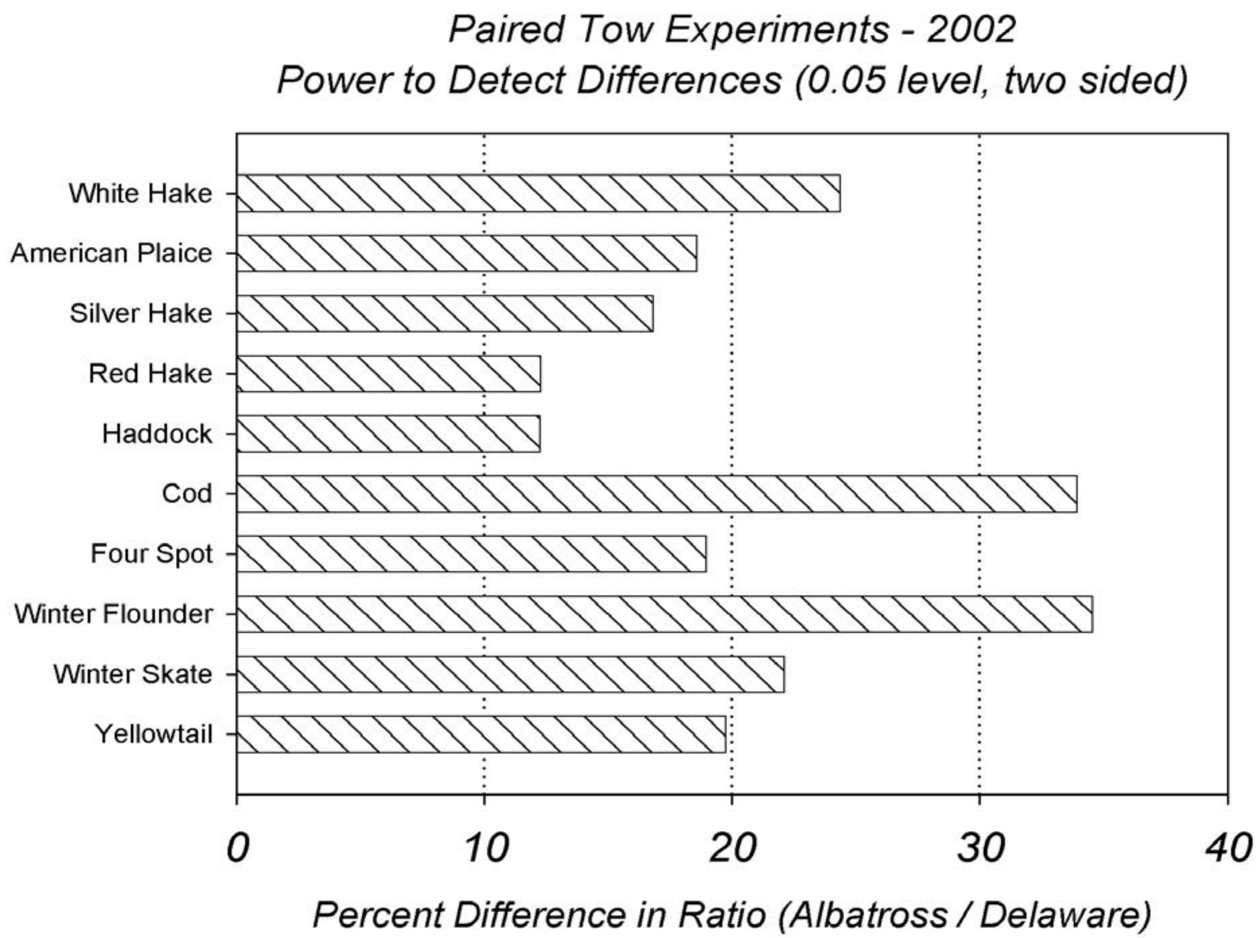


Figure 3.11.2. Calculated ratios of *Albatross* to *Delaware* surveys that can be detected at the 0.05 level of significance, using a two-tailed test. Analyses are based on 2002 side-by-side trawling experiments