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Potential environmental and spatial effects on survey data and assessments for GARM stocks[1]

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Note-the tables and figures in this report should be printed in color or viewed as a PDF file in color on a computer to facilitate interpretation.

Conclusions and Summary

The purpose of this paper was to examine hypotheses about environmental and spatial factors that may affect NEFSC bottom trawl survey catchability parameters and interpretation of survey trend data used in GARM stock assessments. Catchability parameters are key parameters in stock assessment models that convert relative survey abundance trends into measures of actual stock abundance. Six hypothesis and potential mechanisms that might change survey catchabilities and assessments for multiple species were evaluate.

Results show that temperature and depth distributions for GARM species depend on length and season in a stock-specific manner (Table B1 and Appendix Figures B1-B10). In most cases, smaller fish are found in relatively shallow waters which are warm in fall and cooler in spring. These results reflect what is already known for GARM stocks, but are worth repeating because they are important in interpreting the remainder of this analysis.

Trend analysis using fall, winter and spring NEFSC bottom trawl survey data shows that mean bottom temperature, depth, latitude and longitude for many GARM species and size groups changed over time within survey strata sets used for stock assessments, potentially changing survey catchability (Tables C1-C2). There were 127

[1] "This information is distributed solely for the purpose of pre-dissemination peer review. It has not been formally disseminated by NOAA. It does not represent any final agency determination or policy."

tests for trends in annual means for each environmental variable when length groups and stocks were combined. Using the p=0.1 level to judge statistical significance, 15%, 20%, 31% and 33% of the tests were significant for trends in mean temperature, depth, latitude and longitude (Table C2). Similarly, trends in survey mean depth- and length at age were significant more often than could be expected based on chance, but results are harder to interpret statistically because sampling was not random. Exact tests for groups of trends gave similar results (Table C3). Some stocks have spatial distributions that shifted towards closed areas after closed area management was implemented in 1994. For example, large (>30 cm) GBK yellowtail flounder appear to have shifted in distribution towards closed area II and Canadian waters since 1994 (Figure C1). In many cases, trends appear to be occurring still.

Effective area swept by NEFSC bottom trawls probably changes with depth (Figure E1) but there is little effect on trends in survey abundance, length composition or abundance at age data (Figures E2-E4).

Survey catchability coefficients for small (young) haddock, pollock, and white hake may be affected by the presence of large numbers of recruits in strata outside of the strata sets used for assessments during some years, although more investigation is required (Figure F1).

Changes in mean size at age of GBK haddock (Figure G2 and see the report by O'Brien et al.) appear to have changed fall survey catchability at age (Figure G3). Results are preliminary, however, and more work with GBK haddock and other stocks required.

The conclusions and recommendations in this report should be robust to the underlying mechanism and will hopefully help improve GARM stock assessments under a wide range of conditions. Assessment scientists and experts should evaluate recommendations on a stock by stock basis, but alternate approaches to handling or modeling survey data may benefit GARM stock assessments. In particular, use of relatively large survey strata sets (including additional offshore and particularly inshore strata where possible) would probably make survey data trends more robust to changes in environmental and spatial factors. Assessments should consider expanding survey strata sets for age structured assessment models to include additional inshore and offshore strata sampled consistently since (but not before) the first year with survey age data. Survey "holes" (years of missing data for some survey strata) could be filled using some sort of statistical model so that survey data from additional strata could be used in assessment strata sets and to facilitate interpretation of survey trends. Database management software should include procedures for post-stratifying survey data by splitting large strata that overlap stock boundaries or other regions of particular interest (e.g. closed areas). Given potential changes in survey catchability at age associated with changes in size at age, it would be useful to consider stock assessment modeling approaches that use survey length composition or models that accommodate changes in survey catchability at age in some other manner.

A. Introduction

This work enters the scope of the GARM-3 data meeting under terms of reference (TOR) #4 ("D. Fishery independent surveys") but is also related to #5 ("E. Ecosystem data"). Only summary information is available in this document. Detailed graphics and tables are available in an appendix.[2]

All environmental and spatial factors mentioned in this report have the potential to affect interpretation of survey data used in GARM assessments by changing age-specific survey catchability parameters in a wide range of species. Catchability parameters are used in stock assessment models to relate abundance at age in the stock to survey abundance at age trend data, which are used in assessment models. Hypotheses and potential mechanisms are given below.

Hypothesis 1-Depth and bottom temperature distributions differ among species, stocks, seasons and size groups. This hypothesis is known to be true, but summarizing basic biology about depth and temperature distributions for fish of different sizes in each GARM stock is important in later steps.

Hypothesis 2-Environmental and spatial (temperature, depth, latitude and longitude) distributions of GARM species have changed relative to the survey strata sets used in stock assessments, potentially affecting survey catchability. These changes may be due to closed area management, changes in size or age structure due to fishing or stock rebuilding, changes in the areas covered by a stock due to changes in abundance, climate change or other factors. The cause of changes in spatial distributions is not a key element in these analyses. The focus is on detecting changes and potential effects on interpretation of survey data in GARM assessments.

Hypothesis 3-Area swept per standard tow (a primary determinant of catchability) changes with depth of survey tows and mean depth at size has changed over time, potentially affecting survey catchability.

Hypothesis 4-The geographic distribution of GARM stocks has changed relative to survey strata sets used in stock assessments, possibly affecting survey catchabilities. Survey strata sets are groups of survey strata covering specified geographic areas that are used to tabulate survey data for use in modeling. Overlap between survey strata sets and fish stocks is a primary determinant of catchability. Strata with missing data in some years may exacerbate this potential problem. This hypothesis is closely related to hypothesis #1 but was addressed using different analytical methods.

Hypothesis 5-Variation in mean size at length changed age-specific catchability coefficients. Size at age has changed in many GARM stocks. Fish in the same stock of different lengths often have different spatial distributions relative to survey strata sets; thus length helps determine whether a fish contacts survey

[2] Jacobson L., Correia, S. and J. Blaylock. Appendix tables and figures for "Potential environmental and spatial effects on survey data and assessments for GARM stocks" (for GARM-3 2007 data meeting)

gear. In addition, size determines whether a fish that contacts survey gear is likely to be caught.

Hypothesis 6-Different methods of handling or modeling survey trend data would reduce potential effects of environmental and spatial factors. A number of short- and long term research recommendations are provided.

Fall and spring NEFSC survey data are emphasized in this analysis because NEFSC winter survey data used for just two GARM stocks (Table A1). Other bottom trawl surveys carried out by states (Maine, Massachusetts, Rhode Island, Connecticut and New Jersey) in relatively small near shore and shallow areas are also used in some GARM stock assessments. State survey data were not included in this analysis but are considered in the Discussion in view of results for NEFSC surveys.

Survey data used in this analysis (Tables A1-A3 and see inshore and offshore stratum maps Appendix Figures A1-A2) consists of survey data collected on an annual basis during fall, winter and spring surveys from survey strata sets (sets of survey strata used in stock assessments for a particular species) defined for the last GARM and described in Mayo and Terceiro (2005). Windowpane flounder strata sets are the exception because they include additional inshore strata, which the assessment analyst intends to add for use in the current cycle of GARM assessments. Unless otherwise stated, inconsistently sampled strata (zero tows during one or more years) were omitted from strata sets prior to analysis.

All survey data were from randomly selected and successful tows (database code SHG ≤ 136), per standard groundfish assessment procedures. Unless otherwise mentioned, correction factors were not used to adjust survey catches for changes in trawl doors, vessels and net type (in most cases, the correction factors would have no effect on results). Depending on the analysis, the survey data used are for years included in the assessment model or for 1979-2006 (1979 was the beginning of consistent sampling for many inshore strata).

The first section uses boxplots to show relationships between survey catches, length, depth and temperature. The second section tests for trends over time in average location, depth and temperature. The third section evaluates trends in mean depth at age and mean length at age using raw biological samples from survey catches. The fourth section estimates effects of depth on area swept in NEFSC surveys, and evaluates potential effects on trends in survey abundance indices. The fifth section deals with coverage of survey strata used in stock assessments. The sixth section relates variation in size at age to variation in survey catchability at age. The final section synthesizes results, presents and evaluates hypothesis, gives conclusions, and makes recommendations.

B. Box plots for depth, temperature by length group

This analysis used boxplots to describe the distribution of GARM stocks as a function of depth and temperatures for a range of length groups. Data were for years used in stock assessment modeling. Strata from assessment strata sets but individual strata were omitted if not consistently sampled during all years in the analysis (Appendix Tables C1-C10). Catch records used in box plots were replicated N=trunc(10n) times

(where n is the number of fish caught on the original tow) so that the boxplots were effectively abundance (survey catch) weighted.[3]

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Results

For most stocks, younger fish are distributed in shallower water and larger fish are distributed in deeper water (Table B1, Appendix Figures B1-B10). Shallow water is relatively warmer than deeper waters during fall and vice versa and this oceanographic feature is important in determining distributions with respect to bottom temperatures.

C. Trends in stock distribution

Using the same data used for boxplots, survey abundance (abundance measured as survey catch per standard tow) weighted stratified mean depth, location (latitude and longitude) and bottom temperature were calculated for each stock and a range of size groups. Averages were computed in two steps. In the first step (using latitude as an example), mean latitude was computed for each stratum and year using survey catch in each tow as weights so that the latitude of a tow with a large catch received a higher weight than the latitude of a tow with a small catch. In the second step, the means for each stratum in the same year were averaged using year- and stratum specific survey abundance as weights. Survey abundance weights were the mean survey catch per tow in the stratum and year (from step 1) multiplied by stratum area. Tows with zero catches were omitted from this analysis because they received zero weight. The weighted means used here should measure average position and environmental conditions encountered by stocks. Mean latitudes and longitudes during each year and for each size group and stock were used in regression analyses to detect trends (see below) and plotted on maps to aid in understanding trends.

Linear regression analyses with year as the independent variable and mean bottom temperature depth latitude or longitude as the dependent variable were used to test for trends in location. Nonlinear loess regression lines were also used, but only to help visualize trends in plots. Linear trends and other parameters estimated in this analysis were judged statistically significant if the p-value for the slope parameter in a linear regression was $p \leq 0.1$. In addition, an "exact" binomial test was used to test the two-sided null hypothesis of no trends in a set of regression lines.

The exact binomial test is a statistical approach based on the probability of seeing the observed or a larger number of positive or negative slopes in a set of linear regressions under the null hypothesis. Under the null hypothesis of no trends and no correlation among groups, positive and negative slopes are equally likely. For example, if eight length groups for a stock had six positive and two negative trends, then p= 0.29 and the exact test is not statistically significant. In contrast, if five length groups all had positive slopes, then p=0.0625 and the exact test is statistically significant. The binomial

[3] The boxplots show general relationships between environmental variables and size and probably depict medians, percentiles and extreme values with reasonable accuracy. However, the data were from stratified random surveys with different sampling rates (stations per km^2) among strata but stratified sampling was ignored in computing the boxplots. The adjustment to sample size N=trunc(10n) and lack of adjustment for stratified random sampling mean that the statistical aspects of the boxplots (especially confidence intervals for the median) in this analysis are not clear.

test is most useful with at least five size groups, because a significant p-value ($p \leq 0.1$) can occur only with five or more size groups. Therefore, only stocks with at least five size or age groups are used in some analyses.

Results

Ignoring exact tests for groups of trends and combining surveys, there were 127 trends estimated for depth, latitude, longitude and temperature (Table C1, Appendix Tables C1-C10). Combining stocks and surveys (Table C2), Nineteen trends in mean temperature (15%) were statistically significant at the p=0.1 level, which is higher that the expectation of 10% under the null hypothesis. Other variables also had higher percentage of significant trends than could be expected under the null hypothesis of no trends. Twenty-six trends in mean depth (20%) were significant. Thirty-nine trends in mean latitude (31%) and forty-two trends in mean longitude (33%) were significant.

In a relatively high number of cases, exact test results indicate that the direction of estimated trends for different size groups in the stock was nonrandom (Tables C1 and C3; Appendix Tables C1-C10). Visual inspection of the results shows that positive and negative slopes seemed to occur together in groups (Table C1 and Appendix Tables C1-C10). There were 21 exact tests for similarity in direction of trend for each variable, but only 15 exact tests with at least five size groups necessary for p-values ≤ 0.1 (Table C3). Of these, 4 exact tests (27%) were statistically significant for trends in mean temperature, latitude and longitude while five tests (33%) were statistically significant for trends in mean depth.

Trends in the spring and fall surveys suggest changes in variance over time for some variables and stocks. In some cases, trends seemed obviously nonlinear and were poorly explained by the linear regression lines.

D. Trends in mean "survey" depth at age and length at age

We calculated the simple average depth for each age in biological sample data to determine if there were trends in mean "survey" depth at age over time. Biological sample records with age information were linked to their corresponding station records (which contain depth data) so that average depth could be computed for each stock, stock area and age. Similarly, mean size at age was computed directly from biological sample data records with both age and length data to examine potential trends in mean survey size at age. Trends were tested by linear regression with numbers of samples (age measurements used to compute the annual mean) as weights.

It is important to realize that the simple approach used to compute mean survey depth and length at age in this analysis is ad-hoc and has uncertain statistical properties as an estimator of population means, because sampling for age is length stratified, instead of random (survey sampling protocols usually ask a fixed number of age samples per length group per stratum). Trends in population mean size at age based on age-length keys are dealt with in a separate analysis and more reliable information about underlying populations (O'Brien, in prep.).

Results-survey depth at age

Trends in mean survey depth at age were generally consistent among ages in the same stock and in the same survey, but patterns were complex (Tables C1-C3). In some cases, nearly all age groups had trends in the same directions. In others, groups of adjacent age groups had the same trend. For example, survey depth at age trends were consistently negative (towards shallow water) in the fall survey and consistently positive (toward deeper water) in the spring survey for GBK cod (Tables C1-C2 and Appendix Table C1). In contrast, survey depth at age trends for GOM cod were almost all negative in both surveys (Tables C1-C2 and Appendix Table C2). American plaice (fall and spring, Appendix Table C3), SNEMA winter flounder (spring, Appendix Table C6), SNEMA yellowtail flounder (fall and spring, Appendix Table C9) and GBK yellowtail flounder (fall and spring, Appendix Table C10) had contiguous groups of age groups with positive and negative trends in survey depth at age.

Survey trends were computed for 228 age groups in the fall and spring surveys for all stocks (there were no age data for SNEMA winter flounder in the winter survey). Eighty individual trends (35%) in mean survey depth at were statistically significant at the p=0.1 level (Tables C1-C2).

There were 21 exact tests (all stocks and surveys had at least 5 ages) for trends in survey depth at age. Of these, ten exact tests (48%) were statistically significant (Table C3).

Results-survey length at age

Survey lengths at age trends (Tables C1-C10) were usually negative and consistent within stocks. The exceptions include CCGOM and SNEMA yellowtail flounder stocks with consistently positive trends. SNEMA winter flounder and GBK yellowtail had mixed trends that were consistent for contiguous length groups in the same survey. See the paper by O'Brien et al. for more information about population length at age.

E. Station depth and area swept

Effective area swept by a bottom trawl is the product of the effective width of the trawl and tow distance. Effective trawl width is difficult to determine and probably varies between fish species (Henry Milliken, Northeast Fisheries Science Center, Woods Hole, MA, pers. comm.). However, trawl wing spread can be used an upper bound estimate of effective tow width for species that are probably not herded by the trawl doors (e.g. flounders) and door spread can be used as an upper bound estimate for species that are likely to be herded by the trawl doors (e.g. roundfish). Tow distance may depend on depth.

Wing and door spread

Acoustic sensors were used to collect wing and door spread data during the fall 2005 and spring 2006 NEFSC bottom trawl surveys. The data for each tow were screened to remove outliers before mean wing and door widths were computed for each tow (Phil Politis, Northeast Fisheries Science Center, Woods Hole, MA, pers. comm.).

The statistical model used in this analysis (in the S-plus and R programming languages) was `gam(W ~ lo(D)+paste(S)),` where W is door or wingspread in

meters, *D* is depth in meters, and *S* is a categorical variable for the 2005 and 2006 surveys. The function *lo()* was a local linear loess regression term with span 0.75. The *paste()* controls the way categorical variable names are formatted in plots. A step-wise model selection procedure and the AIC statistic, followed by *F*-tests, were used to find the "best" model.

There was some variability between the two surveys (Appendix Figure E1), but both wing and door spread increased with depth down to about 175 m, and then decreased with depth down to about 250 m. Door and wing measurements varied without trend beyond 250 m.

Depth and survey were both statistically significant although the difference between surveys was slight in practical terms for both wing and door spread (Appendix Figure E2). Residual plots indicated acceptable model fit. Predicted values from the best model were averaged by 25 m depth bin and used in further analysis. To normalize results for use in later calculations, adjustment factors for wing and door spread were computed by dividing predicted values by predicted wing and door spread in the shallowest depth bin (Table E1).

Tow distance

Bottom contact sensors (inclinometers) were used to collect time on bottom data during the 2002 vessel calibration cruised carried out by the *R/V Albatross IV* and *R/V Delaware II*. The experiment involved nonrandom paired tows with both vessels operating at about the same place, under about the same conditions and at about the same time of day. Both vessels used the same standard bottom trawl survey tow protocol (30 minutes at 3.8 kts). Sensor data were carefully screened to remove outliers. Time on and off bottom was determined by visual inspection of the sensor data, and total time on bottom was calculated for each tow (Henry Milliken, Northeast Fisheries Science Center, Woods Hole, MA, pers. comm.).

The statistical model used to analyze the data was the same as the model for wing and door spread except that time on bottom was the dependent variable. Potential differences between vessels were tested statistically, but paired tow aspects of the gear calibration experiment were ignored so that all useful tows could be used. For example, if a tow by the *R/V Albatross IV* was successful at a station but the corresponding tow by the *R/V Delaware II* was not due to gear damage, then data from the successful tow was used in modeling and data from the unsuccessful tow was not.

There was some variability between the two surveys (Appendix Figure E3), but time on bottom for both vessels increased with depth down to about 150 m and decreased with depth down to about 200 m. Time on bottom continued to decrease after 200 m for the *R/V Albatross IV*. There was too little data available to estimate time on bottom at depths > 200 m for the *R/V Delaware II*.

Depth and vessel effects were both statistically significant although the difference between vessels was slight in practical terms (Appendix Figure E3). Residual plots indicated acceptable model fit. Predicted time on bottom was greater than the nominal 30 minute tow time at all depths. Predicted values from model were averaged by 25 m depth bin and used in further analysis. To normalize results for use in later calculations, adjustment factors for time on bottom and effective tow distance were computed by

dividing predicted values by predicted time on bottom in the shallowest depth bin (Table E1).

Area swept

Assuming that vessel speed was the same for all tows, an adjustment factor for area swept was computed as the product of the adjustment factors for predicted time on bottom and predicted wing or door spread for each 25 m depth bin. The normalized factors should adjust area swept (or net spread and time on bottom) at depth to the correct level *relative* to other depths. The factors will not, however, adjust area swept at depth to the correct absolute value. To adjust to the correct absolute value, multiply the normalized adjustments (or net spread and time on bottom) by the predicted actual value in the shallowest depth interval.

The normalized adjustment factors for area swept based on depth were similar in shape to normalized adjustment factors for door spread, wing spread and time on bottom

Effects on mean survey catch per tow

Survey data (total number caught and numbers caught in each length group) for witch flounder (spring survey) and GOM winter flounder (fall survey) were adjusted based on depth to reflect potential differences in area swept. Stratified mean numbers per tow, stratified mean length compositions and survey abundance at age were calculated in the normal fashion and compared for both species to determine if adjustments for station depth affected trends in survey data used in stock assessments.

Stratified mean numbers per tow and survey abundance indices were always higher with adjusted survey data but trends based computed using adjusted and unadjusted data were very similar (Figure E2). Ratios of numbers at age with and without swept area adjustments based on door spread and bottom time (Figures E3-E4) did not show consistent trends over time indicating that adjusted and unadjusted data had similar trends over time. Deviations in trend of the adjusted index from the unadjusted age indices were on the order of 2-5%. Length composition data (particularly after normalizing to sum to one) with and without depth adjustments were very similar.

F. Strata set coverage based on survey abundance and biomass

Survey data used in this analysis were for all strata sampled during spring and fall surveys during 1979-2006. The first year was 1979 because inshore strata were first sampled on a consistent basis in 1979 (Table A3). Measures of survey abundance and biomass were computed for each species, stratum and year, for example survey abundance was $N_{s,y} = \left(n_{s,y} / T_{s,y}\right) A_s$ where $n_{s,y}$ is the total catch in number for a particular species in stratum s during year y, $T_{s,y}$ is the number of tows including those with zero catch, and A_s is the stratum area. Abundance and biomass estimates for the same strata during 1979-2006 were averaged to compute average values $\overline{N}_s = \left(\sum_{y=1979}^{2006} N_{s,y} \right) \Big/ 28$.

Average proportions of stock biomass in each stratum during 1979 to 2006 were computed as $\overline{p}_s = \overline{N}_s \Big/ \sum_{j=1}^{M} \overline{N}_j$ where M was the number of inshore plus offshore strata.

Strata were assigned to a stock or "other" area and proportions of total survey abundance and biomass assigned or not assigned to stock areas were computed by summing proportions.

Strata sets for some stocks include strata in adjacent Canadian waters (Appendix Figure A2). Catches in strata in Canadian waters were assigned to an artificial stratum named "4X" if they were not already assigned to a stratum set used for assessing US stocks. Thus, survey catches in Canadian waters were assumed never to originate from the "other" areas. This approach likely biases results of this analysis towards low estimates of stock biomass not included in assessment strata sets, but other approaches based on particular details about individuals stocks were too complex.

In addition to examining average survey abundance and biomass, annual proportions in each stratum were calculated and plotted for each stock and survey to examine trends. Annual proportions were calculated $p_{s,y} = N_{s,y} \Big/ \sum_{j=1}^{M} N_{j,y}$

Results

Depending on the species, survey, season and type of stock measurement (abundance or biomass), portions of total survey catch "outside" the assessment strata set (not assigned to a stock area) ranged from 0% to 48% (Table F1). Median percentages outside assessment strata sets ranged 5%-10%, depending on season and type of stock assessment (Table F1). Atlantic cod, haddock, ocean pout, and white hake had relatively high proportions (≥ 15% on average). Winter flounder and yellowtail flounder had intermediate proportions that averaged ≥ 10%.

Results (Table F1) support the proposal to augment the strata sets for windowpane flounder in Mayo and Terceiro (2005) by addition of inshore survey strata. With the original strata sets, 23%-28% of survey abundance and biomass for windowpane flounder was not assigned to a strata set and would not be used in the assessment (estimates not shown). With the augmented strata set, 0% of abundance and biomass was not assigned to an assessment strata set (Table F1).

The highest proportion of abundance outside (48%) was for haddock during the fall survey because of a very high average catches of small fish in outside strata during 1986, 2003 and 2005 (Table F1, Figure C1 and see Discussion).

Trends in percent survey abundance and biomass "inside" assessment survey strata (1 - percent outside) are easier to see than trends in percent outside and provide the same information (Figure F1). Trends in survey abundance were generally more variable than trends in survey biomass because abundance of young fish and variation in recruitment strength contributes more variance to abundance trends than to biomass trends (see Discussion).

Percent of stock abundance within assessment strata sets (Figure F1) was highly variable (max – min ≥ 25%) for American plaice (spring), cod (spring), ocean pout (spring and fall), pollock (spring), white hake (spring and fall), and yellowtail flounder (spring and fall).

There were relatively clear trends in percent of stock within assessment strata sets (Figure F1) for cod (fall abundance), white hake (fall and spring abundance), and yellowtail flounder (spring abundance and biomass).

G. Linking trends in size at age to trends in survey selectivity

Trends in mean length at age for some GARM stocks (Section D, O'Brien et al.) may induce trends in age-specific survey catchability parameters, which are usually assumed to be constant over time. Length influences the probability that a fish will be in the survey strata set, the probability that the fish will encounter a survey bottom trawl (given that both are in the strata set), and the probability that the fish will be retained by the survey bottom trawl if it encounters one.

Age-specific survey catchability coefficient estimates for GBK haddock ages 1-6 years in the fall bottom trawl survey were taken from the VPA assessment model run used in Mayo and Terceiro (2005), and re-scaled to a maximum value of one (Figure G1). Survey selectivity was calculated by normalizing the catchability at age estimates for the so that the maximum value was one. The VPA catchability and survey selectivity estimates indicate a commonly seen pattern with selectivity increasing with age and then flattening out or decreasing (Figure G1). In this context, survey selectivity at age consists of parameters that can be used to transform survey age composition to population length composition.

Based on stratified random mean survey data calculations, size at age in haddock in the fall survey is variable over time and was relatively low in recent years (Figure G2). An "average" von Bertalanffy growth curve L_A=70.9 [1-e$^{0.313(A-0.218)}$], where L_A is predicted length at age A, was fit to all of the mean size at age data from the fall survey during 1963-2006. The growth curve was inverted and used to convert the VPA survey selectivity at ages 1-8, into equivalent survey selectivity at length (Figure G1).

The apparently dome shaped pattern in selectivity at length was approximated by a cubic linear regression S_A = -4.927266286 + 0.347706923 A - 0.00665966 A^2 + 4.09969E-05 A^3, where S_A is survey selectivity at age A (Figure G1). Annual selectivity at age values were calculated for the fall survey during 1963-2006 using the regression model and observed mean lengths at age in the survey (Figure G3). Finally, predicted selectivity at age values were plotted against survey year using a loess regression line to show trends and remove some of the noise in the data. Trends in the estimated selectivity at age reflect parallel trends in survey catchability at age.

Results

Trends in predicted catchability at age over time were most variable for age one haddock (catchabilities ranged from about 0.55 to 0.75), which had lengths and ages on the ascending limbs of the selectivity curve (Figure G3). Catchabilities at ages 4-6 were almost as variable over time, ranging from a little more than 0.8 to about 0.95 (Figure G3).

Discussion

Environmental and spatial factors may hinder interpretation of survey trend data in stock assessment models for GARM species by altering catchability coefficients q in the relationship $I_t q = N_t$, where I_t is survey trend data for year t, N_t is estimated abundance from a stock assessment model, and catchability q is usually assumed constant in

modeling over relatively long periods of time. Random variation in catchability parameters probably occurs, but random variability is not the main topic in this paper. Long term changes in catchability parameters are of greater interest.

Differences among stocks of the same species detected in this paper do not necessarily imply differences in innate biological characteristics. Results were affected by the survey strata sets used to aggregate survey data for each stock, in addition to biological characteristics. Survey strata sets may not include the full range of latitude, longitude, temperatures and depth for a particular stock, particularly when inconsistently sampled strata were dropped from the assessment surveys sets.

Hypothesis 1-Depth and bottom temperature distributions differ among species, stocks, seasons and size groups.

Boxplot results (Table B1 and Appendix Figures B1-B10) indicate that the distributions of GARM species are sensitive to depth and bottom temperatures and that the response of individuals in a stock depends on body size. Environmental effects are complex with differences between species, stocks, seasons and length groups. Environmental factors on spatial distribution of GARM stocks and variability among size groups is a key assumption in hypotheses discussed below.

Most GARM species showed generally similar ontogenetic relationships between depth, temperature, size during each season (Table B1 and Appendix Figures B1-B10). In particular, small fish tend to be found in shallow water, which is warm in the fall and cool in the winter and spring. Larger fish tend to be found in deeper water (cool in the fall and warm in the winter-spring). GBK haddock are an interesting exception with large fish in cool shallow water during spring when large mature individuals apparently occupy shallow coastal areas for spawning (Figure B1).

Seasonal migrations are clearly evident for larger size groups of GBK cod, GBK haddock, GOM and SNEMA winter flounder, and CCGOM and SNEMA yellowtail flounder (Table B1 and Appendix Figures B1-B10). As mentioned above, depth distributions tend to be relatively deep during winter-spring and relatively shallow during fall.

Hypothesis 2-Spatial distributions have changed relative to survey strata sets used in stock assessments

Trend analyses indicate substantial changes in spatial distributions (Table C1, Appendix Tables C1-C10). Forty-two trends (31%) were statistically significant at p=0.1 for trends over time in mean depth. Forty-four trends (34%) were significant for mean latitude. Fifty-four trends (40%) were significant for mean longitude. Scarcity of trends in temperature was probably due to fish changing location (depth, latitude and longitude) to find desired temperature levels. These results are important because several hypotheses described below assume that stock distributions have changed.

Results suggest changes in variance over time in depth or location for some stocks. Some trends over time were obviously nonlinear and poorly explained by the linear regression lines. In many cases, trends seemed to be continuing with no sign of abating during recent years.

Statistical analysis and visual inspection of plots shows that positive and negative slopes seemed to occur together for adjacent size groups in the same stock (Table C1 and Appendix Tables C1-C10). Four out of 13 (31%) exact tests with at least 5 size groups were statistically significant at p=0.1 for mean temperature, mean depth and mean longitude. Two exact tests (15%) were significant for mean latitude.

A number of stocks (e.g. GBK yellowtail flounder, Figure C1) have spatial distributions that shifted towards closed areas after closed area management was implemented in 1994. Fishing is prohibited in closed areas and substantial abundance and biomass levels may accumulate there. In addition, the displacement of fishing effort from areas inside to outside closed area boundaries may further reduce the proportion of total stock outside of the closed areas. Other potential explanations involve climate change (particularly in warm near shore areas south of Cape Cod), ecological factors affecting growth, changes in size structure associated with overfished and rebuilding stocks, density dependence in stocks at low and high abundance, and changes in stock area associated with changes in abundance (stocks may be distributed over wider geographic areas when they are more abundant).

Hypothesis 3-Changes in area swept at depth and depth distributions of GARM species changed survey catchability coefficients.

Area swept by NEFSC bottom trawls apparently changes with depth (Table E1 and Figure E1). Adjustment factors based on door spread were larger than adjustment factors based on wing spread. Assuming that wing spread measures effective tow width, area swept increases by about 9% as depth increases to about 137 m, and then decreases to about 0% at 350 m. Assuming that door spread measures effective tow width, area swept increases by about 17% as depth increases to about 137 m, and then decreases to about 4% by about 363 m.

Depth distributions have apparently changed for length and age groups in some stocks (Table C1, Appendix Tables C1-C10). Changes in depth distributions and mean depth at age in GARM stocks together with changes in area swept at depth make depth related changes in survey catchability seem possible. However, survey abundance indices (total number caught and numbers caught in each length group) for witch flounder (spring survey) and GOM winter flounder (fall survey) with adjustments for the depth of each tow were similar in trend to unadjusted survey abundance indices (Figure E5). Survey length compositions (not shown) and trends in survey abundance at age were also similar (Figure E6) with and without adjustments for tow depth. Deviations from trends were generally small (2-5%) and mostly without a temporal trend. It seems reasonable to reject the hypothesis that changes in depth distributions changed survey data enough to cause problems in stock assessment models. There were small changes in the magnitude of survey trends and data after adjustments for depth but only trends are important in stock assessments for GARM species.

Hypothesis 4-Changes in spatial distributions for GARM stocks relative to survey strata sets used in stock assessments caused changes in survey catchability.

Relatively small changes in proportion of stock abundance in a strata set can have surprisingly large effects on survey catchability. In the VPA models typically used for GARM species, $I=Nq$ where I is survey abundance, N is stock abundance, and q is the catchability coefficient. If the proportion of total abundance in a stock strata set changes from 70% to 60%, then the catchability coefficient q will be reduced by 0.1/0.7= 14%. If the loss from the first stock resulted in an increase in proportion of total abundance in a second stock from 30% to 40%, then the catchability coefficient for the second stock would increase by 0.1/0.3= 33%.

Results suggest that the spatial distribution of small recruits shifts outside of survey strata sets in some years. In particular, survey catchability coefficients for young haddock, pollock, and white hake may be affected by the presence of large numbers of recruits in strata outside of the strata sets used for assessments. The highest proportion of survey abundance outside of stock assessment strata sets (48%) was for haddock during the fall survey because of a very high average catches outside the strata set during 1986, 2003 and 2005 (Figure F1). The average weights of individuals in these large outside catches were apparently very low because proportions of survey biomass were not unusual in the fall survey during the same years. Similar patterns with a large deviation in percent abundance and a small deviation in percent biomass during the same year (implying large catches of small fish from outside strata) occurred in haddock during the spring survey, pollock in the spring survey and white hake in the fall survey (Figure F1).

Trends in percent survey abundance within stock strata sets used in stock assessments (Figure F1) were more variable than trends in survey biomass because abundance of young fish and variation in recruitment strength contributes more variance to abundance trends than to biomass trends. This factor may make biomass dynamic models that use survey biomass trends instead of age structure, more robust than typical numerical models. Contributions of young fish to biomass trends are minimized because their average body weight is low. Variability in abundance trends is particularly important in the age structured stock assessment models for GARM species because they use survey abundance (at age) data.

Hypothesis 5- Variation in mean size at length changed age-specific catchability coefficients.

Results for GBK haddock and the fall survey (Figure G3) suggest that selectivity at age may vary substantially for age groups with selectivity values on ascending or descending sections of selectivity curves, particularly when changes in length at age are pronounced. Changes would probably be pronounced for stocks with dome shaped selectivity patterns that have an ascending limb over young fish of small sizes, a descending limb over older fish of larger sizes, and the highest selectivity at intermediates sizes and ages.

Additional work is required to investigate potential changes in selectivity for other GARM species and surveys, but the hypothesis has the potential to apply to all

GARM species with trends in size at age. Additional work should be carried out in the near term to investigate possible relationships between "shrinking fish" and changes in survey selectivity. If catchability patterns appear to be sensitive to mean size at age, then other stock assessment modeling approaches may be useful (see below).

Hypothesis 6-Different methods of handling or modeling survey trend data might reduce potential effects of environmental and spatial factors.

This section points out potential short- and longer term research opportunities in GARM assessments that occurred to the authors of this paper. These comments are offered for consideration by GARM assessment scientists only. It was not possible to make definitive recommendations for particular stocks because important assessment decisions about assessment approaches should be made on a stock by stock basis by the assessment scientists themselves. The authors of this paper were not familiar with important details for the individual stocks and unique details and circumstances for individual stocks were not considered.

Increasing area covered by survey strata sets

Many results of this analysis suggest that relatively large survey strata sets would be more robust to spatial and environmental effects than smaller survey strata sets. In making decisions about survey strata sets for assessment work and evaluating merits and disadvantages potential strata combinations, it may be useful to consider larger strata sets to make estimates of survey catchability from stock assessment models more robust to changes in distributional changes induced by to environmental and spatial factors.

Potential problems and effects on catchability increase with smaller strata sets because the proportion of the stock within the strata set is more likely to change due, for example, to movement of fish or implementation of closed area management. Loss of survey coverage over prime habitat (particularly for juvenile fish in inshore areas) is more likely as strata sets become smaller and as inshore strata are ignored. Changes in distribution that occur naturally when abundance changes and stock distributions expand have more effect on the proportion of the stock within small strata sets. Spatial and environmental factors are likely to affect the distribution of length and age groups in the same stock differently, complicating the situation when strata sets are small relative to the stock. Most of the items discussed below are related to increasing the size of areas covered by survey strata sets.

It is likely that surveys which cover small areas such as state surveys in near shore areas will be particularly sensitive to environmental and spatial changes that may affect catchability, particularly if environmental changes (e.g. warming water temperatures) are pronounced in near shore areas or use of near shore juvenile habitat expands with strong year classes. Trends in surveys that cover small areas may become too difficult to interpret in typical assessment models.

Filling holes in survey data

Consideration should be given to imputing survey data for offshore (Table A2) and, particularly, inshore (Table A3) strata that are intermittently skipped during surveys.

If the holes were filled, then additional strata could be more easily included in stock assessment strata sets. In addition, strata with missing years of survey data could me more readily interpreted. Coverage of inshore strata areas used by many stocks as juvenile could, in particular, be improved.

Very simple modeling procedures (e.g. interpolation) may suffice for imputing missing survey data, although new tools that permit GLM modeling with data from negative binomial or over-dispersed Poisson distributions) have proven useful for other species (e.g. Atlantic sea scallops, NEFSC 2007). Problems in estimating length and age compositions are significant but surmountable. In any case, technical problems with imputing survey data for missing data may be less important than potential effects of omitting strata completely or including strata with missing data in some years.

Use and exclusion of strata with missing data

Some GARM assessments (Tables C1, C3, C5, C6 and C8) use strata sets that include missing data. Missing strata will change catchability coefficients for years with when data are missing although the magnitude of the effect is unknown and probably depends on the stock and stratum. Other GARM assessments (Tables C2, C4, C7 and C9-C10) appear to omit strata with missing data, although historical reasons for strata set choices were not reviewed in this analysis). Strata in a stock area but excluded completely from the assessment strata set will cause changes in catchability to the extent that the fraction of total abundance in the excluded strata changes over time. Both problems tend to become moot if holes in survey data are filled using an appropriate statistical model and strata set coverage is increased to the extent possible.

Post-stratification of survey data by splitting strata

Some assessments reportedly exclude relatively large strata that fall between two stocks of the same species because survey data from the same stratum cannot be split (post-stratified) using current NEFSC survey analysis software for groundfish.[4] In contrast, database software for the NEFSC scallop survey and Canadian groundfish data routinely post-stratify scallop survey data by combining and splitting the original strata. The importance of large survey strata and the increasing importance of management areas that cross survey stratum boundaries (e.g. closed areas) indicate a need for modifying software to post-stratify survey data by splitting strata. In the interim, it may be a good idea to assign strata overlapping stock boundaries to strata sets for both stocks.

Survey coverage for long and short survey time series

Although the basis for strata set choices was not reviewed, some assessments appear to use offshore strata in order to present a long term time series of survey data for consistently sampled strata that dates back to years before the first year in the age structured stock assessment model. In some cases, the intention may be to use a single set of long term survey data in an age-structured assessment model and in a biomass dynamic model, which does not utilize age structured survey data. This approach tends to reduce the size of strata sets used for stock assessments with age structured models because inshore strata were first sampled consistently in 1979 long after the fall and

[4] Recently developed software allows re-stratification by combining, but not splitting strata.

spring bottom trawl surveys were started, and because the number of strata with missing data tends to increase over time.

There are advantages to presenting long term time series but potential effects of relatively small survey strata sets on assessment model results and increased sensitivity to environmental factors are potentially severe. Also, best estimates from age structured stock assessment models used by managers should probably be based on the best available information for years in the model. Long term time series based on smaller offshore strata sets can be presented graphically and used in biomass dynamics models if necessary. However, relatively short term time series with age composition data could still be based on larger strata sets for use in age structured models that are used to provide management (Steve Cadrin, School of Marine Science and Technology, New Bedford, MA, pers. comm.).

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Table A1. Stocks and survey strata sets used in assessments for GARM species in Mayo and Terceiro (2005).

Species	Stock	Surveys	Assessment Strata
ATLANTIC COD	Gulf of Maine (GOM)	Fall and spring	Offshore 26-30, 36-40
	Georges Bank (GBK)	Fall and spring	Offshore 13-25
HADDOCK	Gulf of Maine (GOM)	Fall and spring	Offshore 26-28, 36-40
	Georges Bank (GBK)	Fall and spring	Offshore 13-25, 29-30
YELLOWTAIL FLOUNDER	Georges Bank (GBK)	Fall and spring	Offshore 13-21
	Southern New England and Mid-Atlantic Bight (SNEMAB)	Fall, winter and spring	Offshore 1-2,5-6, 9-10, 69, 73-74 (strata 69, 73-74 excluded from Fall survey)
	Cape Cod (CC)	Fall and spring	Offshore 25-27, 39-40, Inshore 56-66 (Fall no offshore 27)
AMERICAN PLAICE	Unit	Fall and spring	Offshore 13-30, 36-40 (+ Inshore 55-87 used for age data)
WITCH FLOUNDER	Unit	Fall and spring	Offshore 22-30, 36-40
WINTER FLOUNDER	Gulf of Maine (GOM)	Fall and spring	Offshore 26-27, 38-40, Inshore 58-61, 65-66
	Georges Bank (GBK)	Fall and spring	Offshore 13-22
	Southern New England and Mid-Atlantic (SNEMA)	Fall, winter and spring	Offshore 1-12, 25, 69-76, Inshore 1-29, 45-56
POLLOCK	Unit	Fall and spring	Offshore 13-30, 33-34,36-40
REDFISH	Unit	Fall and spring	Offshore 24, 26-30, 36-40
WHITE HAKE	Unit	Fall and spring	Offshore 21-30, 33-40
WINDOWPANE FLOUNDER	Gulf of Maine and Georges Bank (GOMGB)	Fall and spring	Offshore 13-29, 37-40 (Inshore 56-66 to be added for GARM 2008)
	Southern New England and Mid-Atlantic (SNEMA	Fall and spring	Offshore 1-12, 61-76 (Inshore 1-55 to be added for GARM 2008)
ATLANTIC HALIBUT	Gulf of Maine and Georges Bank (GOMGB)	Fall and spring	Offshore 13-30, 36-40
OCEAN POUT	Unit	Fall and spring	Offshore 1-26, 73-76

Table A2.

Numbers of successful random survey stations (SHG≤136) in the NEFSC fall survey, by stratum during 1963-2006. Offshore strata are 01010-01990. Inshore strata are numbered 03010-03940.

STRATUM	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
01010	5	4	4	4	9	9	7	9	8	7	8	6	8	8	7	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
01020	5	4	4	4	8	7	7	7	7	7	7	7	7	8	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
01030	5	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
01040	1	3	4	4	3	3	3	3	3	3	3	3	2	3	3	1	3	3	3	3	2	3	2	3	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01050	4	5	3	5	4	5	5	5	8	7	5	6	6	6	5	10	10	4	5	5	5	5	4	5	5	5	5	5	5	5	5	6	3	5	5	5	5	5	5	4	5	5	5	7
01060	7	5	5	5	9	7	8	8	11	11	8	8	9	8	7	17	16	8	8	8	8	6	8	8	8	7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	11
01070	5	4	4	5	5	4	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
01080	2	3	4	3	3	3	3	3	3	3	3	3	2	3	2	3	3	2	2	3	2	3	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
01090	4	5	5	5	6	7	5	7	8	5	5	5	5	5	5	10	15	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	7
01100	5	5	5	5	6	9	8	9	11	9	8	8	9	8	9	15	16	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	11
01110	2	4	4	4	5	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
01120		3	4	4	4	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01130	5	5	7	6	8	8	9	7	9	9	9	9	9	9	10	18	18	9	9	8	9	9	9	9	10	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
01140	6	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	3	5	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
01150	1	3	3	4	3	4	3	4	3	3	3	4	3	3	3	3	2	2	2	3	2	3	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01160	7	7	7	7	8	8	10	8	11	12	11	12	11	10	17	30	20	20	10	10	9	10	10	10	10	10	10	16	10	10	10	13	11	10	10	10	10	10	10	10	11	10	10	20
01170	5	6	4	5	3	4	4	4	4	4	4	4	4	4	7	8	4	8	4	3	3	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	4	3	3
01180	1	2	4	3	3	3	3	3	3	3	3	3	3	3	1	5	3	3	3	1	3	3	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
01190	4	6	5	6	9	9	9	9	9	9	9	9	9	9	11	18	18	9	9	9	9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
01200	4	5	5	5	6	6	6	6	6	6	6	6	6	5	7	14	12	6	9	6	6	6	5	5	6	6	6	6	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
01210	6	4	5	5	4	4	4	4	4	4	4	4	4	3	8	8	8	7	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4
01220	2	5	6	6	4	4	4	4	4	4	4	4	4	3	4	10	8	8	5	4	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	4	3	4	4	4	4	4	4
01230	3	6	6	5	6	5	5	6	5	5	5	5	5	5	10	11	14	5	4	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5	5	4
01240	11	6	6	6	5	6	6	8	7	6	7	6	7	5	12	23	23	6	6	8	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6
01250	2	4	3	3	4	4	4	2	4	4	4	4	4	4	7	4	11	4	2	4	4	3	4	3	3	4	3	4	3	3	2	4	3	3	4	4	4	3	4	4	4	4	4	4
01260	7	4	4	4	5	4	5	5	5	5	5	5	15	9	9	15	19	5	6	5	5	4	5	5	5	5	5	5	5	4	4	5	5	5	5	6	9	5	5	3	5	5	5	8
01270	2	4	4	4	4	4	4	4	4	4	4	4	4	4	9	7	8	4	4	4	4	4	4	4	4	4	4	4	4	5	4	3	4	4	4	5	8	4	4	4	4	4	4	7
01280	6	5	6	6	7	7	7	7	7	7	7	8	7	6	11	11	15	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	7
01290	15	8	7	4	8	8	8	8	8	9	8	8	8	8	8	16	23	7	8	8	9	8	5	8	8	8	8	8	8	8	8	8	9	7	8	8	7	8	8	8	8	8	8	8
01300	1	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
01310	9	5	4	6	5	6	7	8	6	7	7	7	6	7	6	6	5	6	7	7	5	6	5	7																				
01320	6	5	5	5	4	5	5	5	5	5	6	5	5	4	5	4	4	5	5	5	5	6	5	5																				
01330	4	4	4	4	3	4	3	4	4	4	3	4	4	4	3	4	4	3	4	3	4	4	2	4	4	3	4	4	4	3	4	5	4	1	4	3	4	4	4	3	4	3	3	3
01340	5	6	5	5	5	5	5	5	6	6	5	6	7	6	4	6	6	6	6	6	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	5	6	6	6	6	6
01350		4	4	4	4	2	3	3	3	4	3	5	4	1	3	5		4	4	4		4	4	4																				
01351																									2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
01360	9	8	5	6	7	9	8	9	10	9	10	10	9	8	9	9	8	8	8	9	4	8	8	8	8	7	8	8	8	8	8	8	8	8	8	11	9	7	8	8	8	8	8	8
01370	5	5	5	4	5	5	5	5	6	5	5	6	6	6	7	15	14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5
01380	7	6	7	5	4	4	5	6	5	5	6	5	5	5	8	19	18	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	7	5	5	8	9	5	5	4	5	4	5	5
01390	2	3	3	4	3	3	3	3	5	5	3	5	5	4	4	14	11	4	5	5	3	4	5	5	3	5	3	5	5	4	5	4	5	5	4	8	5	5	6	4	4	3	4	4
01400	3	2	4	3	4	3	3	3	2	3	3	3	3	2	3	11	10	3	2	3	3	3	3	3	3	3	3	2	3	2	3	3	3	3	3	6	3	3	3	3	2	1	3	3
01410			5	4	6	6	6	15	17	18	15	18	16		18																													
01420			1	2	4	3	4	6	6	6	6	6	6		6																													
01490						1		3	3	3	3	3	3		3																													
01610					5	5	3	5	3	3	4	4	5	4	5	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
01620					2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2
01630					2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2		2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2	2	2
01640					2	2	2	2	2	2	2	2	2	2	2	2	1		2	2	2	3	2	2	1	1	1	1	1	1		1	1	1	1	1	1	1		1		1		1
01650					7	10	7	9	7	7	7	8	8	10	10	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
01660					3	3	4	3	4	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
01670					3	2	2	2	3	2	2	2	2	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
01680					2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	1	2	2		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	
01690					8	9	6	8	7	6	6	5	7	10	10	6	6	7	6	6	6	5	7	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	6	6	6	6
01700					3	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4
01710					3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	1	2	2	2	3	1	2	2
01720					3	2	2	2	3	2	2	1	2	2	2	1	2	2	2	1	2	2	2	2	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1		1
01730					7	7	5	7	5	5	6	5	5	8	8	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5
01740					5	5	4	5	4	4	4	4	5	5	5	4	4	4	4	5	4	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4
01750					3	2	3	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
01760					2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01990																																							2			1		
Total offshore	183	184	192	190	272	275	265	292	303	295	286	293	304	267	339	434	429	270	255	253	242	250	245	252	223	221	220	229	223	218	220	227	226	220	225	238	240	223	226	219	222	222	220	248

Fall survey (continued)

STRATUM	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
03010										2	2		2	1	1	1	1		1	1	1	1	1	1	1	2																		
03020										2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2
03030										2	2		2	1	1	1	1	1	1				1	1				1	1	1	1		1	1	1	1	1	1	1	1		1	1	1
03040										2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	1	3	2	2	2	2	3	2	2	2	2	2	2	2	2	3	2	2	2
03050										2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03060										2	2		1		1		1	1					1	1					1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
03070										2	2	1	3	3	2	3	2	2	3	2	3	3	2	2	2	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
03080										2	2	4	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03090										2	2		2	1	1	1	1	1	1	1		1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
03100										2	4	2	2	2	2	2	1	2	2	2	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03110										3	5	3	3	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03120										5	6			1	1	1	1	1	1		1	1	1	1			1		1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
03130										4	6	2	3	2	2	2	2	2	2	3	2	2	2	2	2	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03140										5	14	4	3	2	2	2	2	1	2	2	2	2	2	2	2	2	2	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03150										3	2				1	1	1			1	1		1	1				1	1		1	1	1			1	1	1	1		1		1	1
03160										3	2	2	3	3	2	2	2	2	3	2	2	3	2	2	2	2	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2
03170										4	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
03180										2	3		2	1	1	1	1	1	1			1	1	1				1	1	1	1	1	1	1	1		1	1	1	2	1	1	1
03190										4	3	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03200										3	4	4	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03210										3	2		2	1		1	1	1	1	1	1	1	1	1				1	1	1	1	1		1						1	1		1	1	1
03220										3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03230										3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03240										3	2		2	1	1	1	1	1	1	1	1	1	1	1			2	2	2	2	1	2	2	2	2	2	2	1	2	2	2	2	2	2
03250										4	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03260										3	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03270										1	2		2	1	1	1	1	1	1			1	1				1		1	1	1	1	1	1		1	1			1	1		1	1
03280										3	3	3	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	2
03290										3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03300										4	2		2	1	1	1		1	1			1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
03310										3	4	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03320										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03330										2	1		2	1	1	1	1	1	1		1	1	1	1			1	1	1	1	1	1	1		1	1	1		1	1	1		1	1
03340										3	3	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2
03350										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03360										3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2
03370										4	4	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03380										3	3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03390										2	2		2	1	1	1	1	1	1	1	1	1	1	2			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
03400										3	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
03410										4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03420										2	2		1	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1			1	1
03430										3	2		4	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03440										2	4	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Fall survey (continued)

STRATUM	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
03450										1			2		2	2	1	2	1	2	1	2	1	2	2	1	2	2	2	2	2	2	2	2	2	3	2	2	2	1	2	2	2	2
03460															2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	1	2
03520																							4																					
03550																	4	4	3	2	4	4	3	2	4	4	4	5	5	5	5	5	5	4	5	5	5	5	3	5	4	4	5	4
03560																	1	1				1		1	1	1		1	1	1	1		1	1	1	1	1			1		1	1	1
03580																	1	1		1	1	1	1		1	1			1	1	1	1		1	1	1	1	1	1	1		1	1	1
03590																	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1	1
03600																	2	2		2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
03610																	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	3	1	2	2	2	2	2	2	2	2	2	2	4
03630																									2					1		1		1		1	1						1	
03640																			1	1			1		1				1	1		1		1		1	1	1	1	1	2		1	1
03650																	1	1	1	1	1		2	1	1	1		1	1	1	1	1		1	1	1	1	2	2					1
03660																	2	3	3		2	1	2	2	2	2		2	1	2	2	1	1	2	2	2	2	2	2	3	1	2	3	4
03890																							1																						
03900																							2																						
03990											8																										1							
Total inshore	0	0	0	0	0	0	0	0	0	125	138	79	95	73	75	77	89	89	86	87	89	87	95	87	80	75	87	91	93	93	93	93	88	91	90	94	93	93	92	92	88	86	93	97
Total	183	184	192	190	272	275	265	292	303	420	424	372	399	340	414	511	518	359	341	340	331	337	340	339	303	296	307	320	316	311	313	320	314	311	315	332	333	316	318	311	310	308	313	345

Table A3.

Numbers of successful random survey stations (SHG≤136) in the NEFSC spring survey, by stratum during 1963-2006. Offshore strata are 01010-01990. Inshore strata are numbered 03010-03940.

STRATUM	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
01010	6	7	7	8	7	16	7	6	8	7	8	7	7	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	8	7	7	7	7	7	7	6	7	7	7
01020	5	7	9	7	8	14	6	8	7	7	8	7	7	7	7	7	7	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7
01030	4	3	6	3	5	6	3	3	3	3	3	2	3	3	3	3	3	3	3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
01040	4	3	3	3	4	3	3	3	2	3	1	3	2	1	3	3	3	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01050	4	5	5	5	5	10	4	6	5	5	7	10	17	3	5	4	4	5	5	5	6	5	5	5	4	4	5	5	4	5	5	5	5	5	5	5	5	5	5
01060	6	8	9	11	9	16	8	9	9	8	10	8	28	8	8	8	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
01070	4	3	4	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2
01080	3	3	3	3	3	3	3	2	3	2	4	3	3	2	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01090	4	5	5	6	5	5	4	5	5	6	5	15	18	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
01100	6	8	10	9	8	8	8	7	10	9	8	8	20	8	8	8	7	7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
01110	4	3	4	3	4	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	2	2
01120	3	3	3	3	4	3	3	3	3	3	2	3	2	3	3	3	2	2	3	3	1	1	1	1				1	1		1	1	1	1	1	1	1	1	1
01130	7	9	9	9	8	9	8	9	9	9	9	18	8	9	9	9	9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
01140	4	4	4	4	4	4	3	4	4	5	5	4	4	4	4	4	4	5	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
01150	4	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01160	9	14	10	12	13	10	10	10	10	9	12	20	10	10	10	10	11	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10	10	10	10	10	10
01170	4	4	4	4	4	4	3	4	3	4	4	4	5	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
01180	3	3	3	2	3	3	3	3	2	2	3	3	2		3	2	3	2	3	3	1	1		1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2
01190	8	8	8	9	9	9	9	9	9	8	9	18	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
01200	6	6	5	6	6	6	6	6	6	6	6	12	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	6	6
01210	4	4	4	5	4	4	5	4	4	4	4	8	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4
01220	4	4	4	3	5	4	2	4	4	4	5	8	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
01230	6	5	5	5	5	5	5	5	6	6	6	10	5	4	5	5	5	4	5	5	4	4	5	5	4	6	4	4	4	5	5	5	5	5	5	5	5	5	5
01240	6	6	6	7	7	6	6	6	6	7	9	12	6	6	6	6	6	5	6	6	6	6	6	6	6	6	6	6	4	6	9	6	6	6	6	6	6	6	6
01250	4	4	4	4	4	4	3	4	3	3	4	7	2	4	5	3	4	2	4	4	4	2	4	3	4	3	3	3	2	3	4	4	4	4	4	3	4	3	4
01260	5	5	5	5	5	5	5	15	14	14	5	9	5	6	7	5	4	5	5	3	5	5	5	4	5	5	5	5	5	5	8	5	5	5	5	5	5	5	7
01270	4	4	4	5	4	2	4	3	3	4	5	8	4	4	4	4	4	4	4	3	4	4	4	4	4	4	5	4	4	4	6	4	4	4	4	4	4	5	5
01280	7	7	7	7	7	7	6	7	8	9	8	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	6	7	7	7	11	7	7	7	7	7	7	7	9
01290	8	8	9	8	9	7	5	6	8	8	10	8	8	8	8	8	8	7	8	8	9	8	8	8	8	8	8	8	8	8	9	8	7	8	8	8	8	8	8
01300	3	3	3	3	3	4	2	3	3	3	4	3	3	2	3	3	3	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3
01310	6	7	11	10	7	7	6	7	7	7	8	6	7	5	6	7	5	6	4	6																			
01320	5	5	5	7	5	4	4	5	5	5	5	5	5	4	3	3	5	3	5	5																			
01330	4	3	5	4	3	4	4		4	4	5	4	4	3	4	3	3	3	3	4	3		4	3		3	3	4	2	4	4		3	4	3	4	3	4	4
01340	5	4	6	7	6	5	5	6	4	6	8	6	6	5	5	6	6	6	6	5	6	6	6	6	3	6	6	6	4	6	6	6	6	6	6	6	6	6	5
01350	3	3	4	2	4	5	4		2	4	5	4	2	2	4	3	1	3	3																				
01351																				2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	3	2	2
01360	8	8	8	9	9	8	8	7	9	9	10	8	8	7	8	8	7	6	8	8	8	8	8	8	8	8	8	8	8	8	11	8	8	8	8	8	8	8	8
01370	5	5	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	8	5	5	5	5	5	5	5	5
01380	6	5	5	6	6	5	5	5	7	7	10	9	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	7	5	5	5	5	5	4	5	6
01390	2	3	3	5	5	4	5		4	5	5	9	3	4	3	5	4	3	5	2	5	5	5	3	4	3	5	5	4	5	7	5	5	4	5	4	3	3	4
01400	2	3	3	4	2	2	2	2	3	3	4	6	2	3	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3	5	2	3	3	5	3	3	2	4
01410	6	6	8	15	17	16	13		14		19																												
01420	4	4	4	6	6	6	6		6		6																												
01490				3	3	3	3		3		3																												
01610	3	3	3	4	4	3	1		5	5	4	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3
01620	2	2	2	2	2	2	1		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	2	2
01630	2	2	2	2	2	2	1		2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	1	2	1	2	2
01640	2	2	2	2	2	2	1		2	1	2	1	2	3	2	1	2	2	2	2	1	1	1	1			1	1	2	1	1	1	1	1	2	1	1	1	1
01650	8	8	6	8	8	7	3	1	9	9	7	6	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	8	7	7	7	7	7	7	6	7	7	7
01660	4	3	4	3	3	3	3	3	3	3	4	4	3	3	3	3	3	4	4	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3
01670	2	2	1	2	1	2	1	2	2	2	2	2	2	1	2	2	2	1	1	2	2	2	2	2	2	2	2	1	3	2	2	2	2	2	2	2	2	2	2
01680	2	2	2	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
01690	7	7	7	6	7	6	5	4	9	10	7	6	6	6	6	6	6	7	6	6	6	6	6	6	6	6	6	6	7	6	6	6	6	6	6	5	6	6	6
01700	4	4	5	5	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	2	2	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4
01710	3	2	3	2	2	2	2	2	3	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
01720	3	2	2	2	2	1	2	2	2	2	2	3	2	1	2	2	2	2	2	2		1	1	1	1	1	1	1	2		1	1	1	1	1	1	1	1	1
01730	6	5	6	6	6	9	5	6	7	8	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	4	5	5	5
01740	4	4	5	5	4	6	4	4	5	5	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4
01750	3	2	4	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3
01760	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	
01990																																						1	
Total offshore	263	267	288	302	300	314	251	233	300	283	320	348	305	240	255	250	248	240	251	248	225	214	221	221	211	218	222	221	227	223	250	218	223	224	225	215	222	223	231

Spring survey (continued)

STRATUM	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
03010						2	2		1	1	1		2	1	1	1	1	1	1																				
03020						2	2	1	1	2	1	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03030						2	2	1	1		1	1	2	1		2	1								1	1	1	1		1	1	1		1		1	1	1	1
03040						2	2		2	2	2	2	4	2	3	2	1	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03050						2	2		2	3	2	2	4	2	2	1	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03060						2		1	1		1			1		1			1					1	1		1	1	1	1	1	1	1	1	1	1		1	
03070						2	4	1	2	2	2	3	3	2	3	2	3	3	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	3	2	2	2	3
03080						2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03090						3	2		1		1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
03100						3	3	3	2	2	3	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
03110						3	9	4	2	2	3	2	1	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03120						5	1	1	1	1	1	1	1	1	1									1		1	1	1		1	1	1	1	1	1	1	1	1	
03130						9	4	1	2	2	1	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
03140						23	6	3	2	2	1	2	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	3	2	2	1	2	2	2	2	2	2	2
03150						3	2	1	1			1	1	1	1	1	1								1	1	1	1			1	1		1	1		1	1	1
03160						3	3	1	2	3	2	2	2	2	1	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
03170						4	4	6	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03180						3	2	2	1	1		1	1	1	1	1	1		1					1	1	1	1	1	1	1	1	1		1	1	1		1	1
03190						4	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03200						6	3	4	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03210						3			1	1		1		1	1	1	1	1	1					1	1	1	1	1	1	1	1		1		1	1	1	1	1
03220						2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03230						2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03240						2	2			1	1	1		1	1	1	1	1	1					2	1	2	2	2	1	2	2	2	2	2	2	1	2	2	2
03250						3	3		2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03260						2	2		2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03270						3	2		1	1	1	1	1		1	1	1		1					1	1		1	1		1	1		1	1	1	1	1	1	1
03280						4	2		2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	2	2	3	2	2	2	2	2	2	2
03290						4	2		2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03300						3	2		1	1		1		1	1	1	1		1					1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
03310						6	2		2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03320						3	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
03330						3	2		1	1		1	1	1	1	1	1		1					1	1	1	1	1	2	1	1	1	1		1	1	1	1	1
03340						4	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	3	2	2	2	2	2
03350						2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
03360						2	2		1	1	1	1	1	1	1	1			1					2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03370						5	2		2	2	3	2	2	2	2	2	2	4	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03380						4	2		2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03390						3	2		1	1		1	1	1	1	1	1		1					1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
03400						4	3		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	3	2	2	2	2	2	2	2	2	2	2
03410						7	4		3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03420						2	2		1	1	1	1	1	1	1	1	1		1					1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
03430						3	2		2	2	2	2	2	2	2	2	2	5	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
03440						5	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2

Spring survey (continued)

STRATUM	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
03450						2					2	4	4	2	2	2	1	1	2	2		2	2	2	2	2	2	1	2	2	2	2	2	2	1	2	2	2	2
03460							7		2		2	3	4	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	1	2	2	2	2
03550												4	4	3	4	4	4	3	5	4	5	5	5	5	1	4	5	4	4	5	5	5	5	5	5	5	5	4	5
03560																1	1	1			1		1		1	1	1	1					1		1	1		1	1
03580												1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1
03590												1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1
03600												1	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2
03610												2	2	2	2	2	2	2	2	2	2		1	2	1	2	2	2	2	2	3	2	1	2	2	2	2	2	2
03630														1		1	1							1	1	1	1		1	1		1	1		1	1	1	1	2
03640												1	1	1	2	1				1	1						1	1	1	1	2	1	1	2		1	1	1	1
03650													1	1	1	1	1	2	1	1	1			1		1	1	1	1	1	1	1		1	1		1	1	1
03660												1	3	1		2	2	2	2	2	2		2	1	2	3	1	2	1	2	2	2	1	2	2	3	2	2	2
03940						4																																	
Total inshore	0	0	0	0	0	172	115	36	75	71	71	89	100	90	89	92	90	89	91	75	75	67	75	91	86	94	93	92	108	92	98	92	89	93	92	95	92	94	96
Total	263	267	288	302	300	486	366	269	375	354	391	437	405	330	344	342	338	329	342	323	300	281	296	312	297	312	315	313	335	315	348	310	312	317	317	310	314	317	327

Table B1. Summary of depth and temperature distribution results from boxplot analyses illustrating depth and temperature distributions for large and small size groups of GARM species in the fall and spring surveys. See boxplots in Appendix Figure B1 for details.

Stock	Depth Fall	Depth spring	Temp Fall	Temp spring
American plaice	Large length groups in deeper water during fall,	Relatively homogeneous	Relatively homogeneous	Relatively homogeneous
George Bank (GBK) cod	Larger length groups in deeper water	Mostly homogeneous but largest length groups in coldest water	Mostly homogeneous but largest length groups in coldest water	Relatively homogeneous
Gulf of Maine (GOM) cod	Larger length groups in deeper water	Larger length groups in deeper water	Larger length groups in cooler water	All length groups in cooler water
Georges Bank (GBK) haddock	Larger length groups in deeper water	Larger length groups in deeper water	Larger length groups in slightly cooler water	Relatively homogeneous
Gulf of Maine (GOM) winter flounder	Relatively homogeneous	Relatively homogeneous	Relatively homogeneous	Relatively homogeneous
Southern New England and Mid-Atlantic (SNEMA) winter flounder	Larger length groups in deeper water	Larger length groups in deeper water	Larger length groups in cooler water	Larger length groups in slightly warmer water
Witch flounder	Larger length groups in deeper water	Larger length groups in deeper water	Larger length groups in cooler water	Larger length groups in cooler water
(Cape Cod and Gulf of Maine) CCGOM yellowtail flounder	Larger length groups in slightly deeper water	Largest and smallest size groups in shallow water	Relatively homogeneous	Relatively homogeneous
Georges Bank (GBK) yellowtail flounder	Larger length groups in slightly deeper water	Relatively homogeneous	Largest in warmer water	Relatively homogeneous
Southern New England and Mid-Atlantic (SNEMA) yellowtail flounder	Relatively homogeneous	Larger length groups in deeper water	Largest length groups in cooler water	Relatively homogeneous

Table C1. Summary of trend analyses for survey abundance weighted average temperature, depth and position (latitude and longitude), as well as for mean survey depth and length at age for GARM stocks using NEFSC bottom trawl survey data, years and strata sets used in stock assessments. Trends for temperature, depth and position trends were analyzed by size group (generally 10 cm). Numbers of positive and negative trends are given for each variable. *P*-values for exact tests with length or age groups and for each variable, survey and stock are highlighted if statistically significant at $p \leq 0.1$. Positive trends in depth mean towards deeper water. Positive trends in latitude mean north. Positive trends in longitude mean west.

Stock	Survey (and total number of length and age groups)	Direction of trend	Number negative and positive slopes (and number statistically significant at p≤0.1)					
			Bottom temperature	Depth	Latitude	Longitude	Depth at age	Length at age
GBK cod	Fall (10 length and 11 age groups)	Negative	8 (2)	5 (2)	2 (0)	5 (1)	11 (3)	11 (8)
		Positive	2 (0)	5 (1)	8 (1)	5 (1)	0 (0)	0, (0)
		Exact test *p*-value	0.11	1.00	0.11	1.00	0.001	0.001
	Spring (10 length and 12 age groups)	Negative	4 (0)	2 (0)	0 (0)	8 (4)	3 (1)	12 (8)
		Positive	6 (0)	8 (2)	10 (4)	2 (1)	9 (1)	0 (0)
		Exact test *p*-value	0.75	0.11	0.002	0.11	0.15	0.0005
GOM cod	Fall (11 length and 11 age groups)	Negative	5 (0)	8 (1)	8 (0)	3 (0)	9 (7)	11 (5)
		Positive	6 (0)	3 (0)	3 (0)	8 (1)	2 (0)	0 (0)
		Exact test *p*-value	1	0.23	0.23	0.23	0.07	0.001
	Spring (11 length and 10 age groups)	Negative	5 (0)	5 (0)	10 (2)	5 (0)	10 (5)	10 (2)
		Positive	6 (1)	6 (0)	1 (0)	6 (0)	0 (0)	0 (0)
		Exact test *p*-value	1.00	1.00	0.012	1.00	0.002	0.002
American Plaice	Fall (5 length and 15 age groups)	Negative	0 (0)	2 (0)	4 (4)	5 (4)	7 (3)	14 (9)
		Positive	5 (1)	3 (0)	1 (0)	0 (0)	8 (1)	1 (0)
		Exact test *p*-value	0.06	1	0.38	0.06	1	0.001
	Spring (5 length and 14 age groups)	Negative	0 (0)	3 (0)	4 (1)	5 (3)	4 (2)	14 (8)
		Positive	5 (1)	2 (0)	1 (0)	0 (0)	10 (2)	0 (0)
		Exact test *p*-value	0.06	1	0.38	0.06	0.18	0.0001
Witch flounder	Fall (5 length and 22 age groups)	Negative	1 (0)	0 (0)	4 (1)	5 (1)	6 (0)	14 (8)
		Positive	4 (0)	5 (1)	1 (0)	0 (0)	16 (5)	8 (2)
		Exact test *p*-value	0.38	0.06	0.38	0.06	0.05	0.29
	Spring (5 length and 17 age groups)	Negative	0 (0)	0 (0)	4 (1)	5 (2)	0 (0)	12 (9)
		Positive	5 (4)	5 (4)	1 (0)	0 (0)	18 (13)	6 (0)
		Exact test *p*-value	0.06	0.06	0.38	0.06	0	0.24
GOM winter flounder	Fall (4 length and 8 age groups)	Negative	1 (0)	4 (0)	4 (3)	0 (0)	8 (3)	8 (0)
		Positive	3 (0)	0 (0)	0 (0)	4 (3)	0 (0)	0 (0)
		Exact test *p*-value	0.63	0.13	0.13	0.13	0.008	0.008
	Spring (4 length and 9 age groups)	Negative	2 (0)	3 (2)	4 (2)	0 (0)	8 (4)	8 (6)
		Positive	2 (0)	1 (0)	0 (0)	4 (2)	1 (0)	1 (0)
		Exact test *p*-value	1	0.63	0.13	0.13	0.04	0.04

Table C1. (Continued)

Stock	Survey (and total number of length and age groups)	Direction of trend	Number negative and positive slopes (and number statistically significant at p≤0.1)					
			Bottom temperature	Depth	Latitude	Longitude	Depth at age	Length at age
SNEMA winter flounder	Fall (5 length and 7 age groups)	Negative	1 (0)	3 (0)	2 (0)	3 (1)	3 (0)	3 (3)
		Positive	4 (2)	2 (0)	3 (2)	2 (0)	5 (1)	5 (3)
		Exact test *p*-value	0.38	1.00	1.00	1.00	0.73	0.73
	Spring (5 length and 9 age groups)	Negative	2 (0)	0 (0)	2 (0)	4 (3)	5 (0)	6 (1)
		Positive	3 (0)	5 (2)	3 (2)	1 (0)	4 (1)	3 (1)
		Exact test *p*-value	1.00	0.06	1.00	0.38	1.00	0.51
	Winter (4 length, 0 age groups)	Negative	0 (0)	2 (0)	2 (1)	2 (0)		
		Positive	4 (0)	2 (0)	2 (0)	2 (1)	N/A	N/A
		Exact test *p*-value	0.13	1.00	1.00	1.00		
GB haddock	Fall (8 length, 15 age groups)	Negative	6 (4)	1 (0)	0 (0)	6 (3)	1 (0)	14 (11)
		Positive	2 (0)	7 (5)	8 (3)	2 (0)	14 (9)	1 (0)
		Exact test *p*-value	0.29	0.07	0.007	0.29	0.0009	0.0009
	Spring (8 length, 12 age groups)	Negative	0 (0)	0 (0)	0 (0)	5 (2)	3 (2)	14 (8)
		Positive	7 (2)	7 (2)	7 (2)	2 (0)	11 (4)	0 (0)
		Exact test *p*-value	0.02	0.02	0.02	0.45	0.06	0.0001
CCGOM yellowtail flounder	Fall (4 length, 5 age groups)	Negative	0 (0)	4 (0)	3 (0)	3 (0)	5 (0)	2 (0)
		Positive	4 (0)	0 (0)	1 (0)	1 (0)	1 (0)	4 (1)
		Exact test *p*-value	0.13	0.13	0.63	0.63	0.22	0.69
	Spring (4 length, 8 age groups)	Negative	1 (0)	1 (0)	1 (0)	0 (0)	0 (0)	4 (1)
		Positive	3 (0)	3 (2)	3 (1)	4 (4)	7 (3)	3 (0)
		Exact test *p*-value	0.63	0.63	0.63	0.13	0.02	1
SNE yellowtail flounder	Fall (4 length, 8 age groups)	Negative	1 (0)	4 (0)	1 (0)	3 (1)	4 (1)	1 (0)
		Positive	3 (1)	0 (0)	3 (2)	1 (0)	3 (1)	6 (6)
		Exact test *p*-value	0.63	0.13	0.63	0.63	1	0.13
	Spring (4 length, 9 age groups)	Negative	3 (0)	1 (0)	1 (0)	3 (2)	5 (0)	1 (0)
		Positive	1 (0)	3 (0)	3 (2)	1 (0)	2 (1)	6 (3)
		Exact test *p*-value	0.63	0.63	0.63	0.63	0.45	0.13
	Winter (4 length, 7 Age groups)	Negative	0 (0)	0 (0)	1 (0)	3 (1)	1 (0)	3 (1)
		Positive	4 (0)	4 (1)	3 (1)	1 (0)	6 (2)	4 (2)
		Exact test *p*-value	0.13	0.13	0.63	0.63	0.13	1.00
GB yellowtail flounder	Fall (4 length, 10 age groups)	Negative	3 (0)	2 (0)	0 (0)	2 (0)	5 (1)	4 (2)
		Positive	1 (0)	2 (0)	4 (1)	2 (0)	5 (1)	6 (3)
		Exact test *p*-value	0.63	1.00	0.13	1.00	1.00	0.75
	Spring (4 length, 8 age groups)	Negative	3 (1)	2 (0)	0 (0)	4 (1)	2 (0)	5 (2)
		Positive	1 (0)	2 (1)	4 (3)	0 (0)	6 (3)	3 (3)
		Exact test *p*-value	0.63	1.00	0.13	0.13	0.29	0.73

Table C2. Summary of trend tests in Table C1 with size groups, stock and surveys combined.

Variable	N trend tests	N positive trends	Percent positive	N negative trends	Percent negative	N significant trends ($p \leq 0.1$)	Percent significant ($p \leq 0.1$)
Bottom Temperature	127	81	64%	46	36%	19	15%
Depth	127	75	59%	52	41%	26	20%
Latitude	127	70	55%	57	45%	39	31%
Longitude	127	48	38%	79	62%	42	33%
Depth at age	228	128	56%	100	44%	80	35%
Length at age	228	57	25%	171	75%	116	51%
All variables	964	459	48%	505	52%	322	33%

Table C3. Summary of exact tests in Table C1 (for stocks and surveys with at least five age or length groups).

Variable	N exact tests	N significant tests ($p \leq 0.1$)	Percent significant ($p \leq 0.1$)
Bottom Temperature	15	4	27%
Depth	15	5	33%
Latitude	15	4	27%
Longitude	15	4	27%
Depth at age	21	10	48%
Length at age	21	10	48%
All variables	102	37	36%

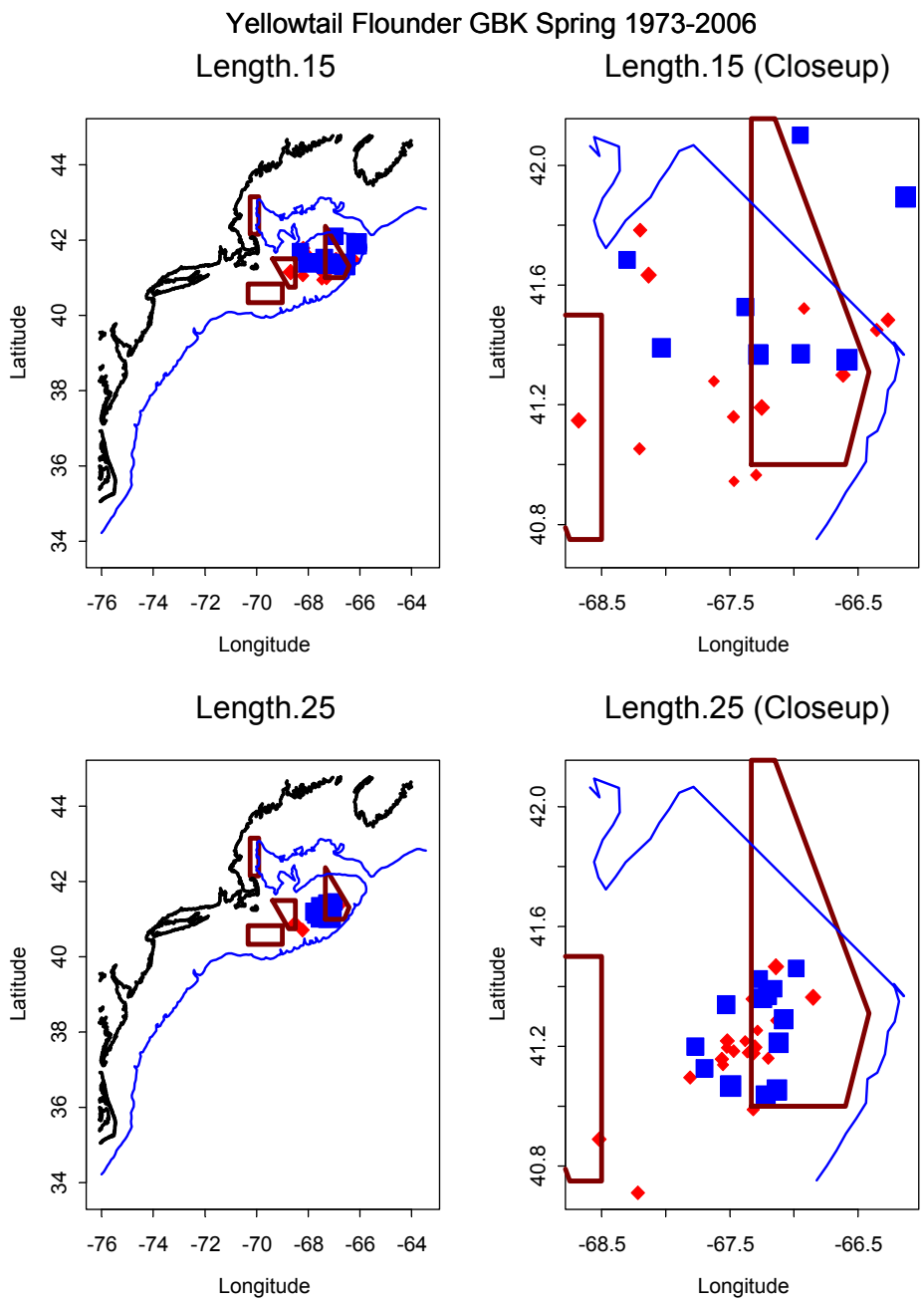
Table E1. Normalized relative adjustment factors to correct wing spread, door spread, time on bottom, and area swept in NEFSC bottom trawl surveys for depth. Twenty-five m depth intervals are identified by their mid-points so that, for example, the 25-49.9 m depth interval is labeled 37.5 m. Tows for wing and door spread in the first (0-24.9 m) depth interval were all at slightly less than 25 m. No bottom contact time measurements were taken in the first depth interval so bottom time in the first depth interval is assumed to be the same as in the second depth interval.

Depth interval (m)	Adjustments for effective trawl width proxies		Adjustment for bottom time	Adjustment factors for area swept	
	Doors	Wings		Wings x Bottom	Doors x Bottom
12.5	1.000	1.000	1.000	1.000	1.000
37.5	1.026	1.011	1.000	1.011	1.026
62.5	1.063	1.027	1.012	1.039	1.075
87.5	1.093	1.041	1.021	1.063	1.116
112.5	1.119	1.053	1.028	1.083	1.150
137.5	1.132	1.057	1.035	1.094	1.172
162.5	1.116	1.046	1.035	1.083	1.155
187.5	1.089	1.026	1.030	1.056	1.121
212.5	1.063	1.006	1.026	1.032	1.091
237.5	1.050	0.998	1.021	1.019	1.072
262.5	1.037	0.990	1.021	1.011	1.059
287.5	1.028	0.984	1.021	1.005	1.050
312.5	1.027	0.982	1.021	1.003	1.048
337.5	1.026	0.989	1.021	1.010	1.048
362.5	1.020	0.977	1.021	0.998	1.041

Table F1. Portions of fall and spring survey abundance and biomass for GARM stocks during 1979-2006 not assigned to a strata set for use in stock assessments. Results shown are for windowpane flounder using the strata set in the last GARM (Mayo and Terceiro 2005) plus additional inshore strata proposed for use in the current round of GARM stock assessments. Catches in Canadian waters were generally excluded from calculations for most species.

	Survey abundance		Survey biomass	
Species	Fall	Spring	Fall	Spring
ACADIAN REDFISH	0.01	0.01	0.01	0.01
AMERICAN PLAICE	0.06	0.09	0.02	0.05
ATLANTIC COD	0.19	0.27	0.11	0.16
ATLANTIC HALIBUT	0.05	0.04	0.03	0.04
HADDOCK	0.48	0.04	0.04	0.03
OCEAN POUT	0.23	0.24	0.26	0.23
POLLOCK	0.05	0.14	0.02	0.08
WHITE HAKE	0.26	0.18	0.06	0.11
WINDOWPANE FLOUNDER (with proposed inshore strata)	0.00	0.00	0.00	0.00
WINTER FLOUNDER	0.09	0.07	0.12	0.06
WITCH FLOUNDER	0.11	0.16	0.07	0.15
YELLOWTAIL FLOUNDER	0.17	0.11	0.13	0.11
Min	0.00	0.00	0.00	0.00
Median	0.10	0.10	0.05	0.07
Average	0.14	0.11	0.07	0.09
Max	0.48	0.27	0.26	0.23

Figure C1. Changes in the spatial distribution of GBK yellowtail flounder of different size groups based on spring survey data, relative to closed area II. Movements towards closed area II and Canadian waters are pronounced for GBK yellowtail flounder > 30 cm (next page). Closed areas are outlined by a thick brown line. Closed area II is the large closed area on Georges Bank. Small red symbols are positions during 1973-1993 (prior to implementation of closed area II in 1994). Larger blue symbols are positions during 1994-2006. Symbol size increases over time. Panels on the right are close-up views of panels on the left.



Red diamonds if year<1994; blue triangles if year>=1994 (larger size each year)

Figure C1. (Continued)

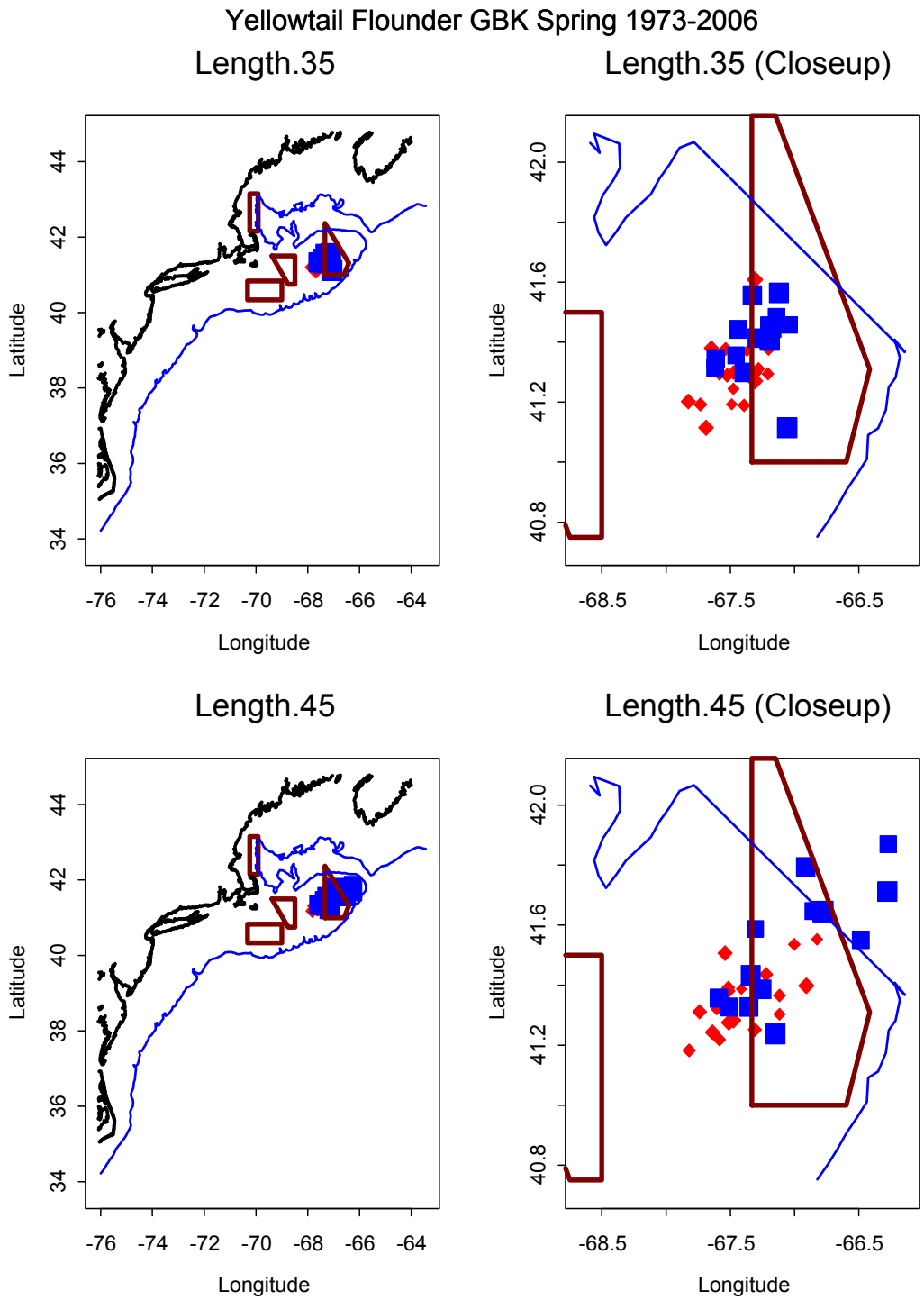


Figure E1. Adjustment factors to adjust area swept in NEFSC trawl surveys: *Top*: Adjustment factors for wingspread only (blue), bottom contact time only (red), and area swept (black, wing spread x bottom contact time). *Bottom*: Adjustment factors based on door spread only (blue), bottom contact time only (red), and area swept (black, door spread x bottom contact time). Adjustment factor estimates for doors are upper bound estimates; changes in area swept with depth for species herded by doors are likely smaller than described in the figure.

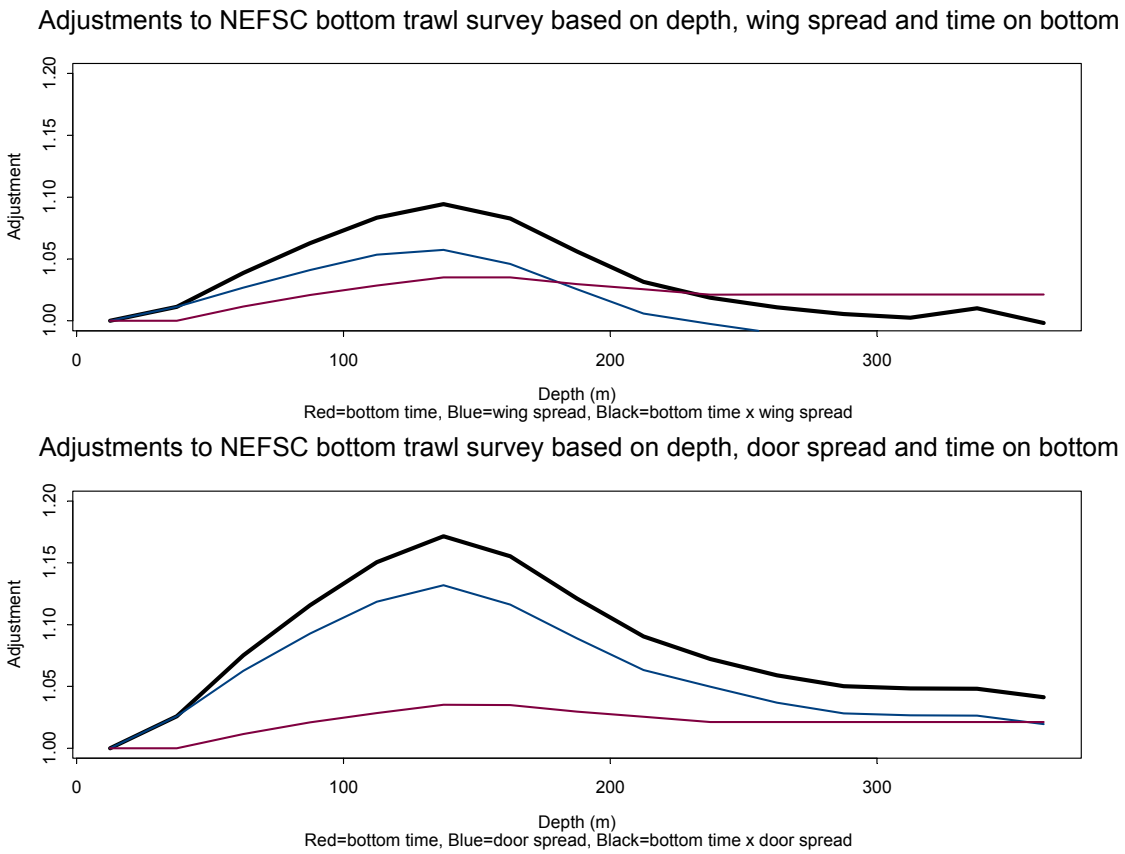
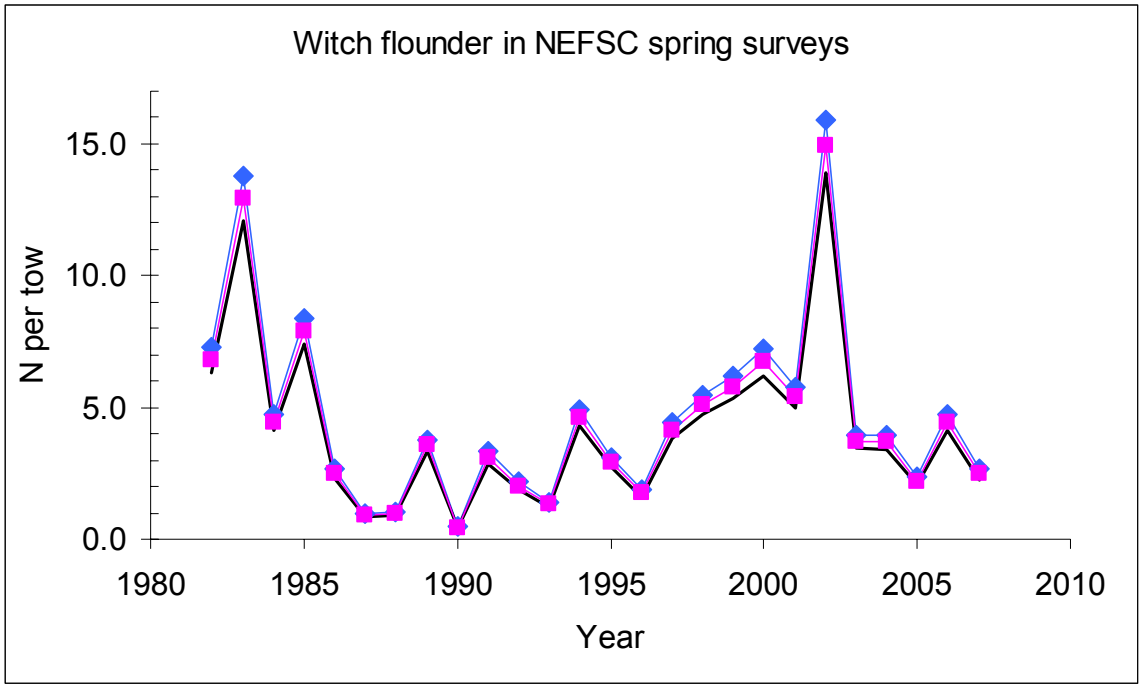


Figure E2. Survey mean numbers per tow (all sizes) for witch flounder (spring survey) and GOM winter flounder (fall survey) with and without adjustments for depth and area swept.



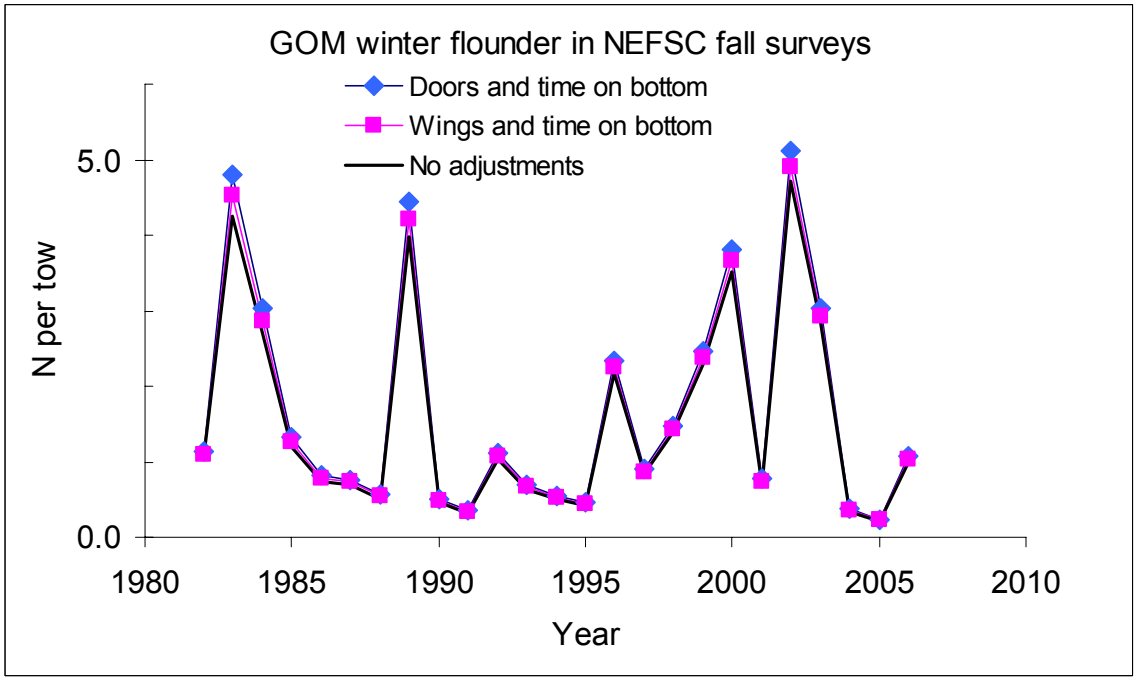


Figure E3. Trends in $\log_e$ ratios of door adjusted and unadjusted mean number per tow at age indices for GOM winter flounder in NEFSC fall surveys. Red lines are locally quadratic loess fits with span=0.6 meant to show trends.

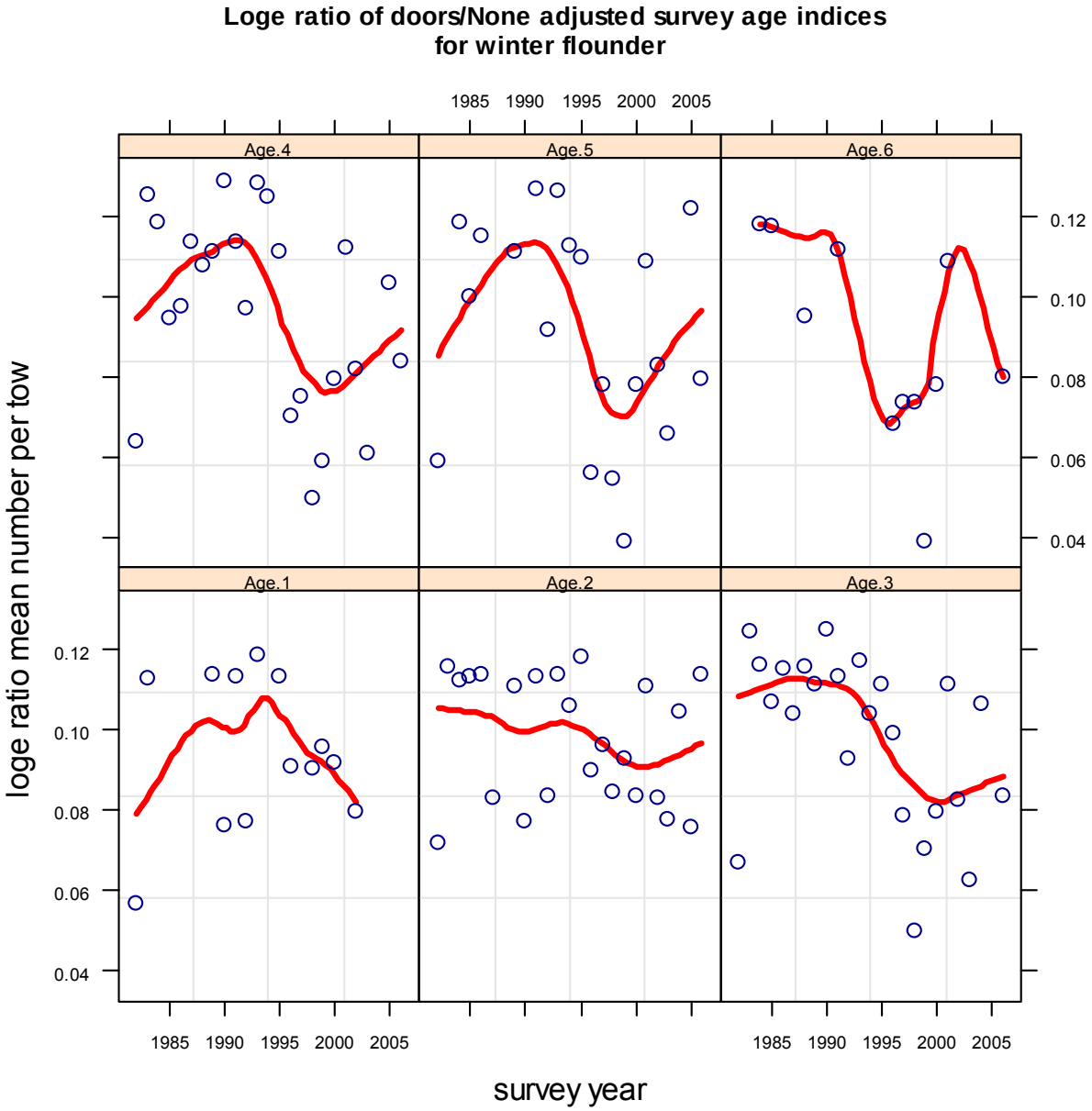

Loge ratio of doors/None adjusted survey age indices
for winter flounder
Age.4
Age.5
Age.6
Age.1
Age.2
Age.3
loge ratio mean number per tow
survey year
1985
1990
1995
2000
2005
0.04
0.06
0.08
0.10
0.12

Figure E4. Trends in $\log_e$ ratios of door adjusted and unadjusted mean number per tow at age indices for witch flounder in NEFSC spring surveys. Red lines are locally quadratic loess fits with span=0.6 meant to show trends.

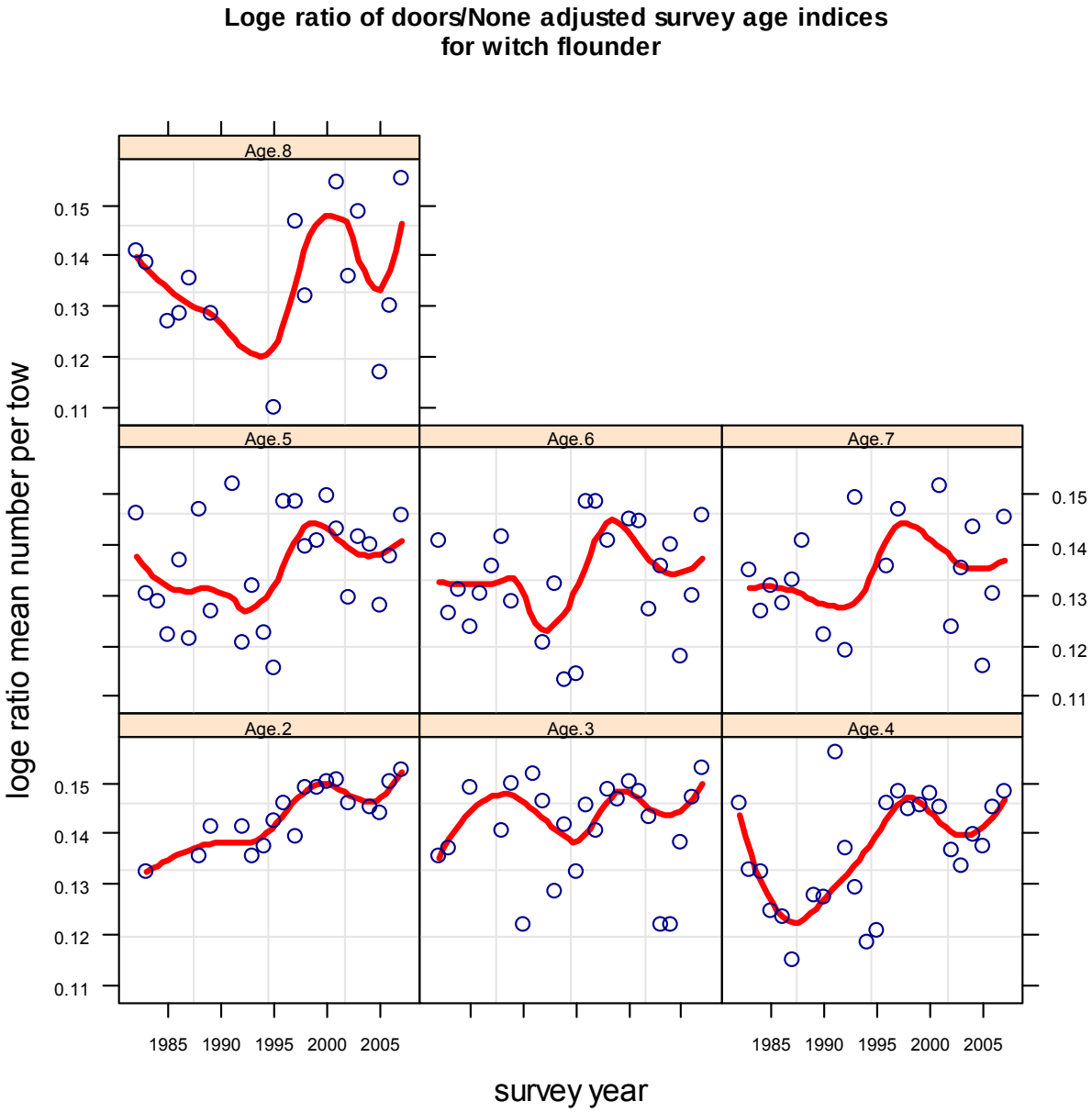


Figure F1. Trends in proportions of fall and spring survey abundance and biomass during 1979-2006 that were not assigned to strata set or stock area.

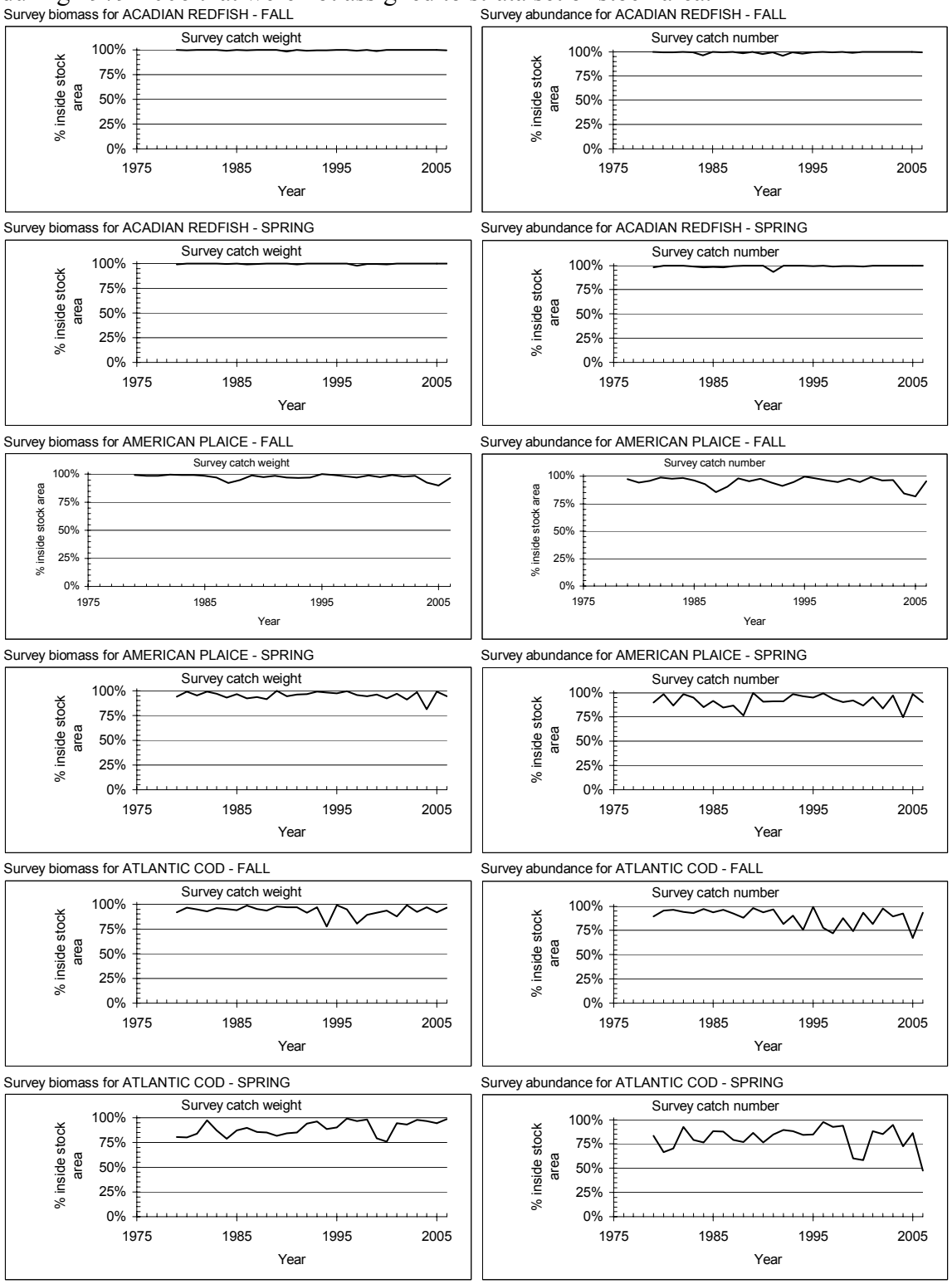
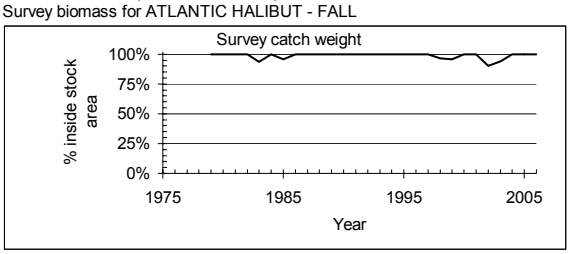
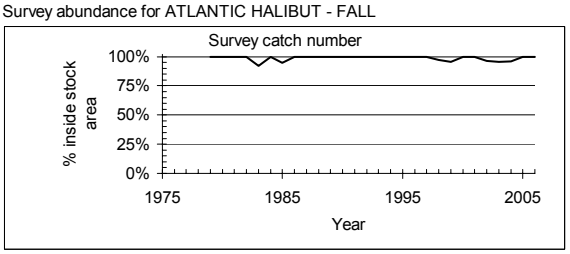


Table F1. (Continued)

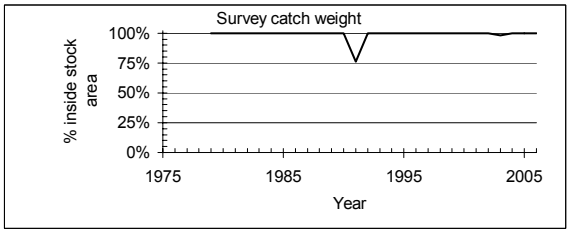
Survey biomass for ATLANTIC HALIBUT - FALL



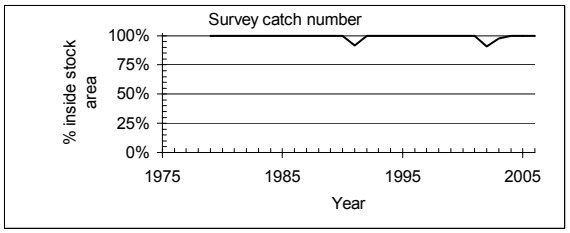
Survey abundance for ATLANTIC HALIBUT - FALL



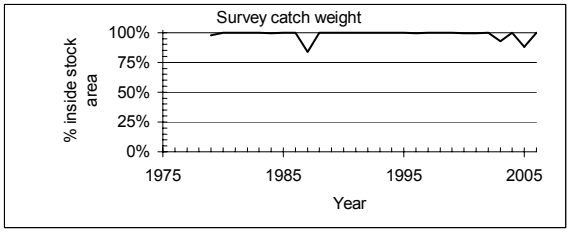
Survey biomass for ATLANTIC HALIBUT - SPRING



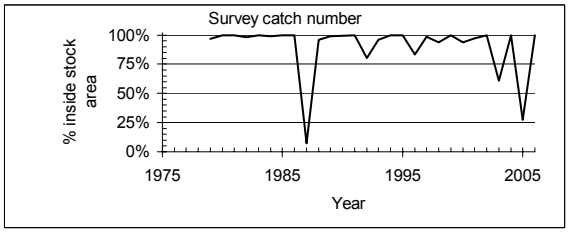
Survey abundance for ATLANTIC HALIBUT - SPRING



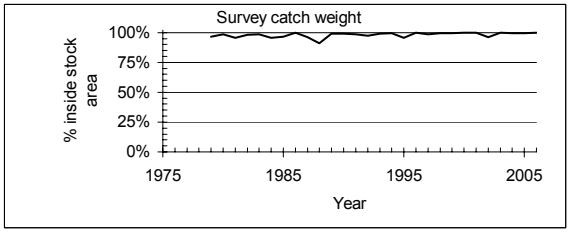
Survey biomass for HADDOCK - FALL



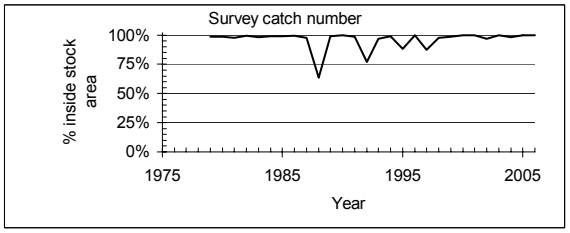
Survey abundance for HADDOCK - FALL



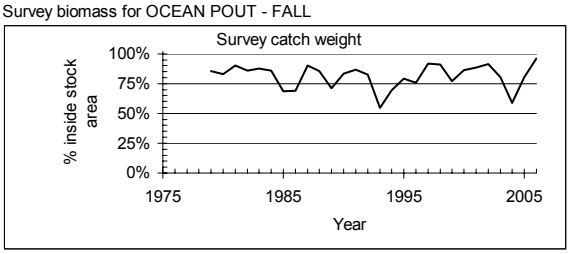
Survey biomass for HADDOCK - SPRING



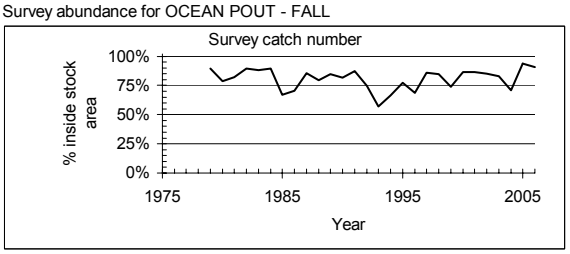
Survey abundance for HADDOCK - SPRING



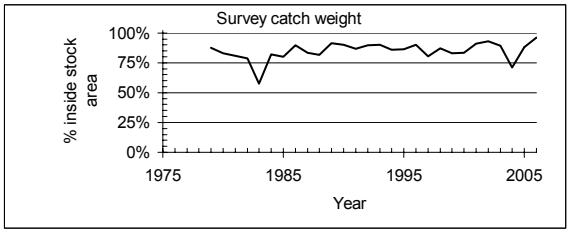
Survey biomass for OCEAN POUT - FALL



Survey abundance for OCEAN POUT - FALL



Survey biomass for OCEAN POUT - SPRING



Survey abundance for OCEAN POUT - SPRING

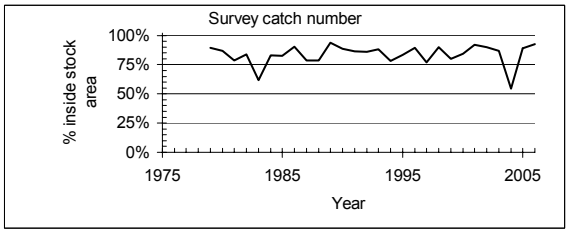
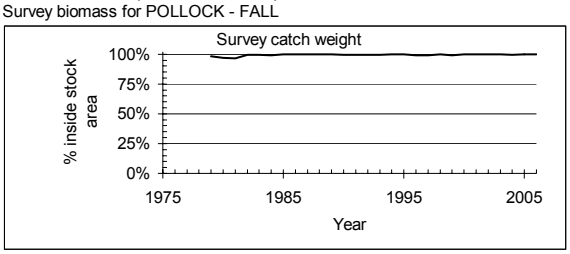
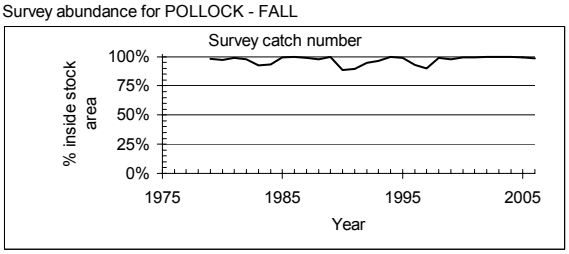


Table F1. (Continued)

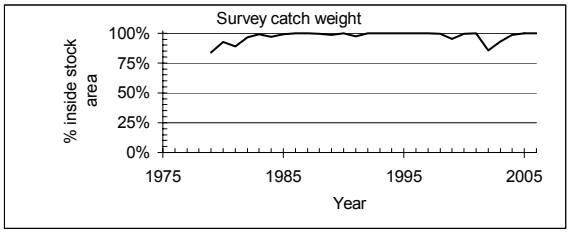
Survey biomass for POLLOCK - FALL



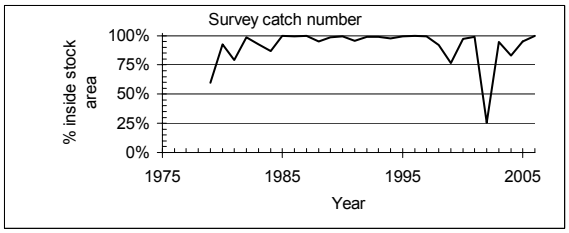
Survey abundance for POLLOCK - FALL



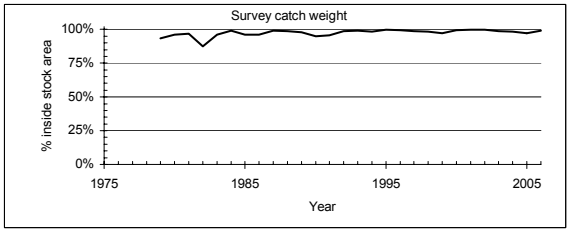
Survey biomass for POLLOCK - SPRING



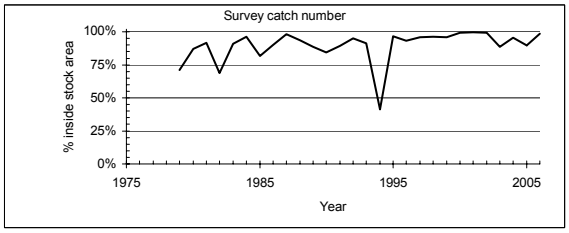
Survey abundance for POLLOCK - SPRING



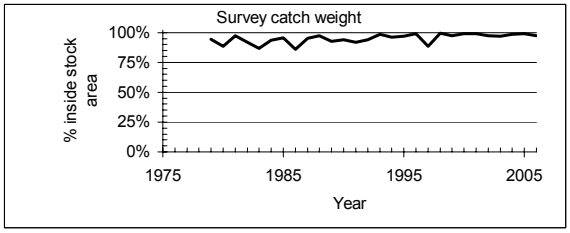
Survey biomass for WHITE HAKE - FALL



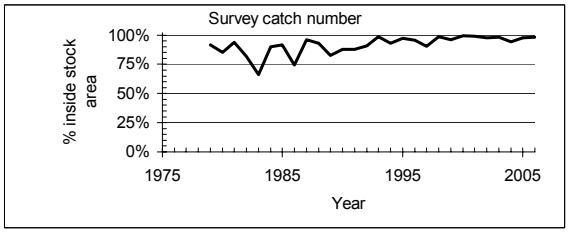
Survey abundance for WHITE HAKE - FALL



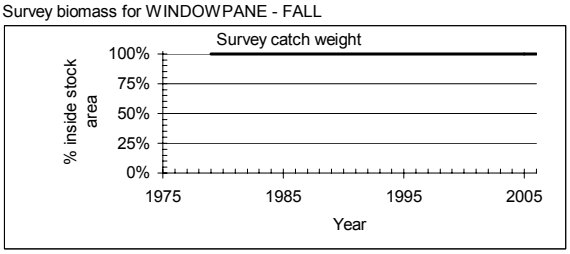
Survey biomass for WHITE HAKE - SPRING



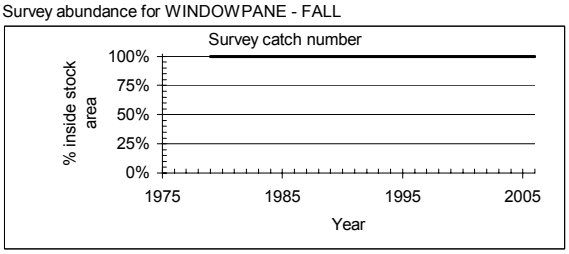
Survey abundance for WHITE HAKE - SPRING



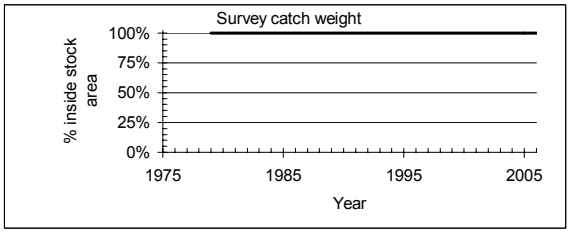
Survey biomass for WINDOWPANE - FALL



Survey abundance for WINDOWPANE - FALL



Survey biomass for WINDOWPANE - SPRING



Survey abundance for WINDOWPANE - SPRING

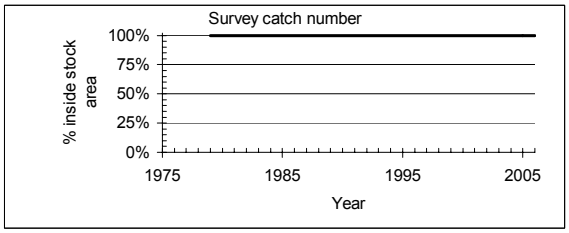
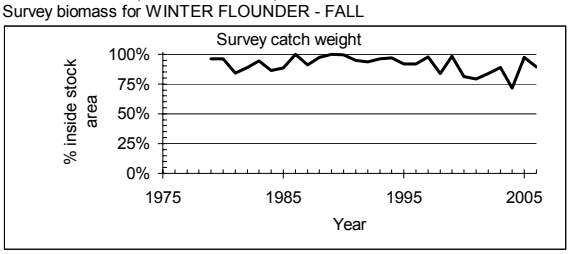
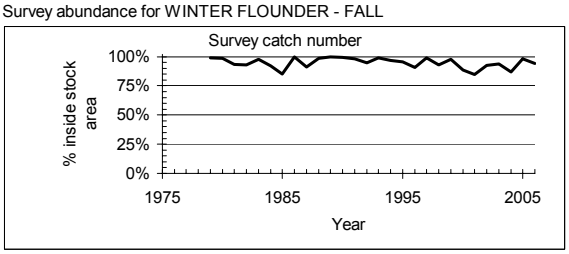


Table F1. (Continued)

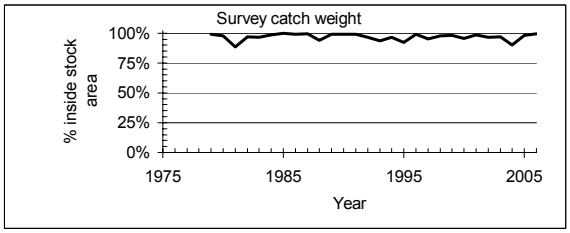
Survey biomass for WINTER FLOUNDER - FALL



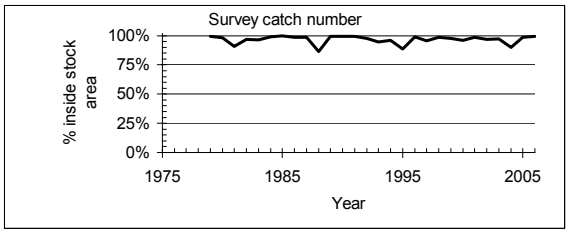
Survey abundance for WINTER FLOUNDER - FALL



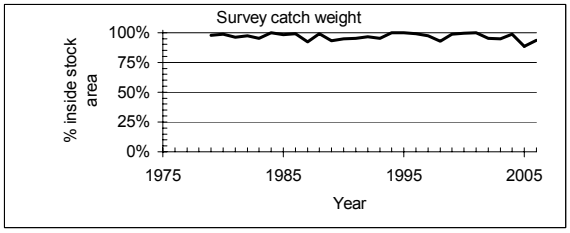
Survey biomass for WINTER FLOUNDER - SPRING



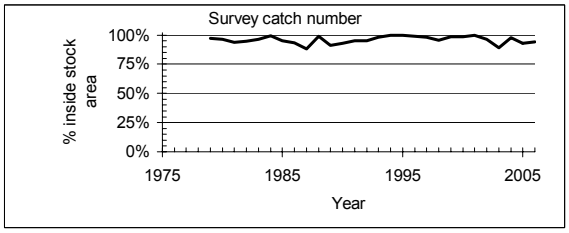
Survey abundance for WINTER FLOUNDER - SPRING



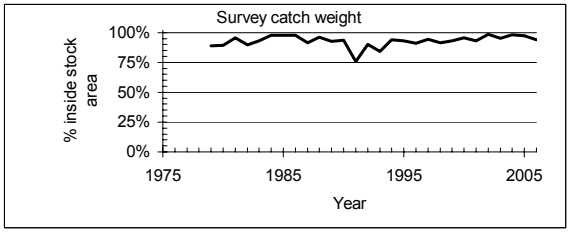
Survey biomass for WITCH FLOUNDER - FALL



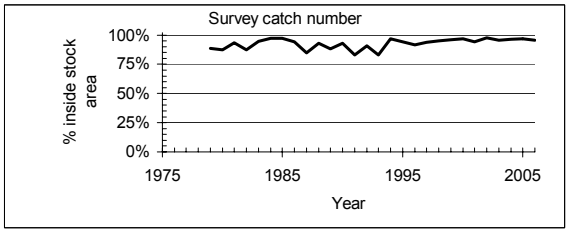
Survey abundance for WITCH FLOUNDER - FALL



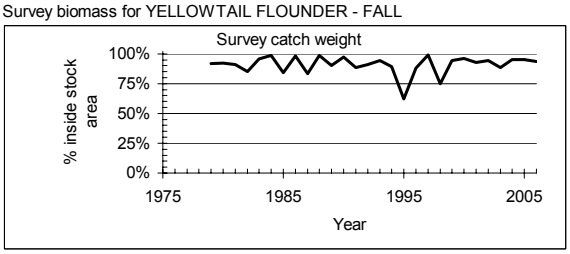
Survey biomass for WITCH FLOUNDER - SPRING



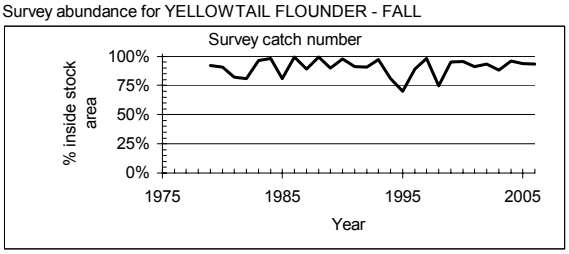
Survey abundance for WITCH FLOUNDER - SPRING



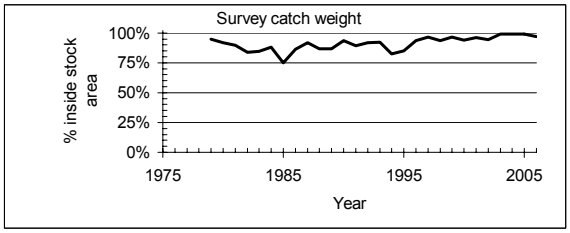
Survey biomass for YELLOWTAIL FLOUNDER - FALL



Survey abundance for YELLOWTAIL FLOUNDER - FALL



Survey biomass for YELLOWTAIL FLOUNDER - SPRING



Survey abundance for YELLOWTAIL FLOUNDER - SPRING

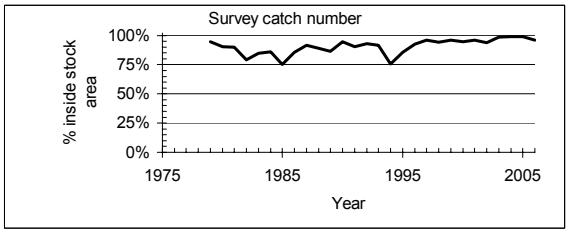


Figure G1. *Top*: Selectivity at age for GBK haddock in the fall survey from a VPA model used in the last GARM (Mayo and Terceiro 2005). *Middle*: Average size at age for GBK haddock based on a von Bertalanffy growth curve fit to fall survey data for 1963-2006. *Bottom*: Selectivity at length for GBK haddock in the fall survey calculated from selectivity at age and the von Bertalanffy growth curve.

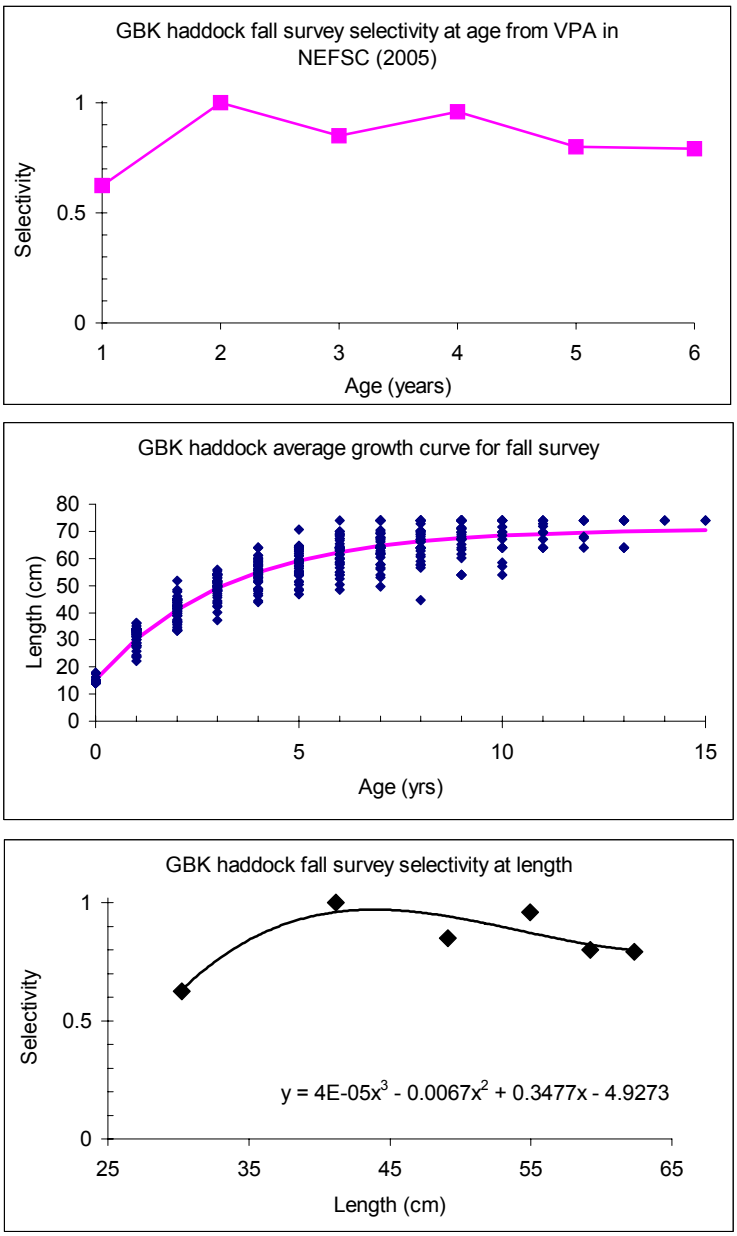


Figure G2. Trends in fall survey length at age for GBK haddock.

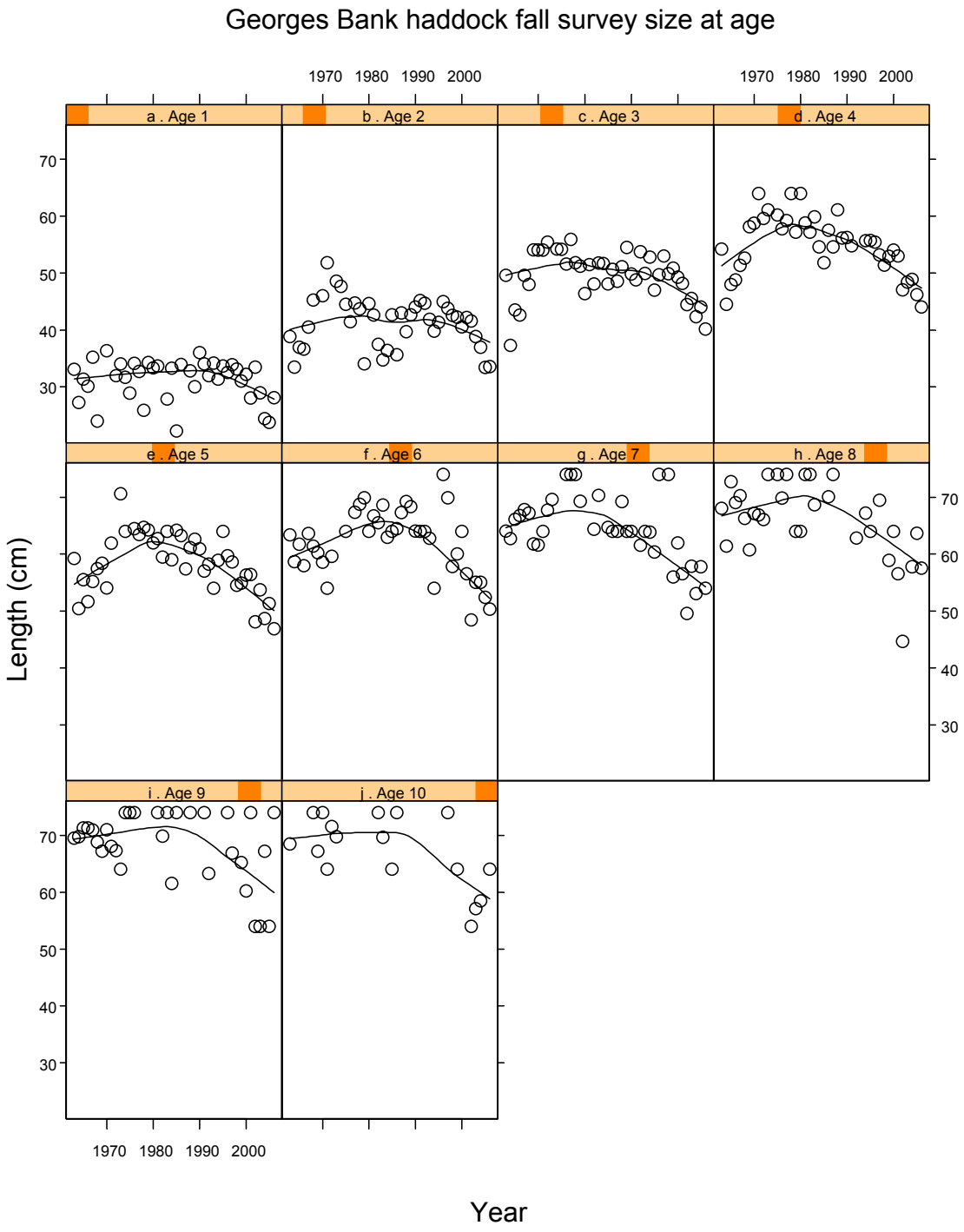
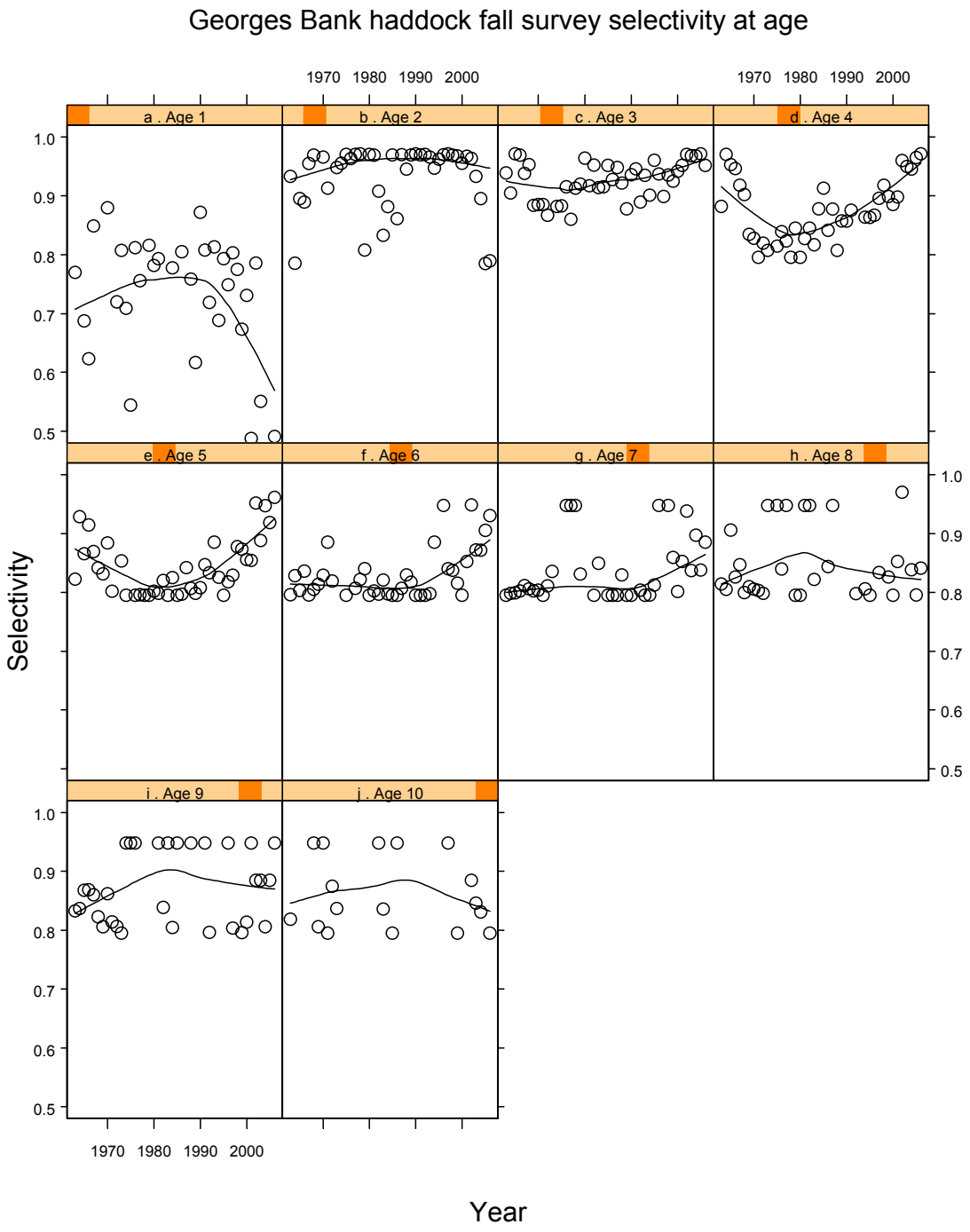



Figure G3. Trends in fall survey catchability at length for GBK haddock