Fisheries and Oceans Canada | Pêches et Océans Canada

NOAA FISHERIES
NATIONAL MARINE FISHERIES SERVICE

CERT	***TRAC***
Comité d'évaluation des ressources transfrontalières	**Transboundary Resources Assessment Committee**
Document de travail 2014/08	**Working Paper 2014/08**
Ne pas citer sans autorisation des auteurs	Not to be cited without permission of the authors

Estimation of Georges Bank Yellowtail Flounder Total Mortality by Sex from NEFSC Bottom Trawl Surveys

Christopher M. Legault

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

Ce document est disponible sur l'Internet à : This document is available on the Internet at :
http://www.mar.dfo-mpo.gc.ca/science/TRAC/trac.html

Canada

ABSTRACT

The Northeast Fisheries Science Center has conducted bottom trawl surveys on Georges Bank since 1963 in the fall and since 1968 in the spring. Catches of yellowtail flounder were assigned to age and sex bins based on standard sampling protocols. Estimation of total mortality rates by sex was conducted using both cohort and static (blocks of years combined) catch curves. Three general results emerged: 1) total mortality rates have remained high throughout the assessment period for both sexes, 2) male total mortality rates are higher than female total mortality rates, and 3) the difference in total mortality rates between the sexes is increasing in recent years, with female rates remaining the same while male rates increase. Only one of the three results has a simple explanation, the total mortality rate is higher for males than females because the natural mortality rate is higher for males than females. There may be other factors contributing to this difference by sex. There are no simple explanations for the other two results, with a number of possible explanations discussed but not supported.

Introduction

Bottom trawl surveys have been conducted on Georges Bank since 1963 in the fall and since 1968 in the spring by the Northeast Fisheries Science Center (NEFSC). These surveys have a stratified random design with nine strata used for Georges Bank yellowtail flounder (Fig. 1). Sampling of yellowtail for lengths is done randomly if catches are large, while all yellowtail are measured for length when catches are small. Of the fish measured for length at a given station, age and sex information is collected generally on a one fish per one cm length bin protocol. Recently all large fish (>40 cm) have been aged and the proportion of small fish aged has decreased. The stratified mean catch per tow at length in each season and year were combined with corresponding sex-separated age-length keys to estimate the catch per tow of yellowtail flounder by age and sex. These data were used to estimate total mortality rates (Z) by sex using different types of catch curves. Total mortality rates by season and sex were compared over the time period of the surveys.

Methods

Stratified mean catch per tow in numbers for yellowtail flounder on Georges Bank were computed for NEFSC bottom trawl surveys in the fall for years 1963-2013 and in the spring for years 1968-2013. The standard survey vessel, Albatross, and gear were replaced in 2009 by the Bigelow with new gear. Length-based calibration coefficients were applied to all catches by the Bigelow to convert them to Albatross equivalents (Brooks et al., 2010). Age-length keys with sex classified as unknown, male, or female were used each year and season to construct catch per tow at age by sex. The unknown sex observations were typically small yellowtail and so were not included in the male or female catches. Lengths with no age observations had age and sex information filled by eye based on observations in surrounding lengths. This typically happened only for lengths with few total fish caught and is not expected to cause large uncertainty in the results, but does add some amount of uncertainty because others could fill the age-length keys differently. The fall 1974 and 1976 surveys had no females observed, while the fall 1975 survey had only females at age 1 observed. This is almost certainly due to a loss of data due to changes in the databases and hardware over time, as opposed to a true lack of female fish caught in the surveys in those years. These three years were treated as missing for both males and females. Occasionally, there were no fish of a given age and sex observed in the survey. These zero observations were treated as missing in the catch curve analyses, which use the logarithm of the catch, instead of replacing the zero with some arbitrary small value.

Analyses began with simply plotting the catch per tow by age for each sex to look for consistency between the sexes. Cohort age matrices by sex were plotted to look for consistency of cohorts. In these plots, the natural logarithm of catch per tow at age x in year t is plotted against age x+y in year t+y for all age combinations. Strong linear relationships indicate strong cohort tracking in these plots.

Total mortality rates (Z) by sex were estimated using two types of catch curves. The first type of catch curve tracked cohorts through time. The negative of the slope of the relationship between the natural logarithm of catch per tow versus age is the estimate of Z. In these plots, ages which are not fully selected by the gear will cause an initial increasing trend in catch per tow versus age and should not be included. A number of different approaches were examined for the starting age to use in the regression. Peak age found the age with the highest catch per tow for each cohort. Alternatively, the first age in the regression was fixed at ages 2, 3, or 4. Using age 2 as the first age in the regression results in estimates of Z which are almost certainly biased low due to partial selectivity of age 2, but has the largest number of the fixed first ages in the regressions. Using age 4 as the first age in the regression avoids issues of partial selectivity, but results in low sample sizes for many years, especially for males. The peak age approach is the preferred approach among those examined based on Smith et al. (2002).

The second type of catch curve analysis calculated static catch curves summing the catches for blocks of 5, 10, and 15 years. These static catch curves increased the sample size which should reduce the uncertainty in the total mortality estimates relative to the cohort catch curves. However, different recruitment strengths and changes in mortality over time should increase the uncertainty in the total mortality estimates from the static catch curves relative to the cohort catch curves. Larger blocks of years will be less able to detect fine scale changes in total mortality but should be more robust to sampling variability, especially when catches are low.

Results and Discussion

The trend in catch per tow by sex over time was generally similar between the sexes in both the spring and fall bottom trawl surveys (Figs. 2-3). Ages 1 and 2 have higher catch per tow for males than females in the spring, especially in recent years, while these ages have approximately the same catch per tow by sex in the fall. One interpretation of these changes within the year is that Z is higher for males than females. Ages 3 and 4 have similar catch per tow by sex in the early years (through the mid 1990s) but have noticeably higher catch per tow for females than males since then in both seasons. As has been noted previously in the stock assessment for Georges Bank yellowtail flounder, something appears to have changed in the mid 1990s resulting in a retrospective pattern in the stock assessment (Gavaris et al., 2005). One change which did occur at this time was the year-round closure of two areas to bottom trawl fishing gear (Closed Areas I and II). Perhaps females were better able to utilize these closed areas than males? Ages 5 and 6 have more females than males in nearly every year in both season, but there are not many of either sex. Some of the large cohorts at age 5 track into age 6 the following year, but not always, and strong cohorts at these ages do not necessarily appear in both seasons.

Cohort age matrices for each sex by season indicate generally good cohort tracking with relatively high (>0.5) correlations between successive ages (Figs. 4-7). The relationships among ages more than one year apart quickly degrade due to changes in selectivity among ages, changes in mortality over time, and observation error. Also apparent in these figures is the loss of males earlier than females in both seasons, there are no age 8 and older males appearing in these plots and few ages 6 and older males relative to females. Examining the maximum age by sex (ignoring 1974-1976), the oldest male observed was age 8 in spring 1973 (age 7 in multiple years during the fall) and the oldest female observed was age 11 in spring 1974 (age 9 in multiple years during the fall).

Cohort catch curves resulted in high and constant or increasing total mortality rates over time for both sexes regardless of the rule used for the first age in the regression (Figs. 8-15). Large confidence intervals in some years can make the trends in total mortality over time difficult to see and compare between the sexes. Recognizing that there are large confidence intervals associated with the point estimates, just the point estimates for total mortality by sex were directly compared and generally showed a higher Z for males than females (Figs. 16-19). A nonstationarity in the difference in total mortality between the sexes is seen with recent years having a larger difference between the sexes relative to earlier years (Figs. 20-23). The median differences between the sexes were generally biologically meaningful, for example 0.16 to 0.29 for the find peak rule (Table 1).

Static catch curves, which summed catches over blocks of years, produced catch curves which more closely followed the assumption of exponential decline with increasing age (linear on a log scale; e.g. Figs. 24-25). The confidence intervals decreased in size as the number of years in the blocks increased (Figs. 26-31). Generally, the total mortality estimates were more similar between seasons than between sexes and Z for males was higher than for females, with the difference increasing over time. However, the patterns did vary depending on the number of years in the blocks. For the five year blocks using the peak age regression rule, Z was fairly well estimated until the mid 1990s when the size of the confidence intervals increased noticeably. The Z for all four combinations of season and sex increased noticeably in the final 5 year block (years 2008-2012). The confidence intervals for total mortality using 10 year blocks were more consistent and again showed season was more similar than sex with males having higher Z than females and the difference growing over time. The female Z remained relatively constant over time while the male Z increased over time to a maximum of approximately one between the sexes in the final block (years 2003-2012). This same pattern was seen in the 15 year blocks.

All analyses support three general conclusions: 1) Z has remained high throughout the assessment period, 2) male Z is higher than female Z, and 3) the difference in Z between the sexes is increasing in recent years. The first conclusion that Z has remained high throughout the assessment period is difficult to understand given the large reductions in catch associated with management regulations in recent years. This could be possible if the population has declined at the same rate as the catches, but the recent low catches seem to imply a much lower abundance than surveys suggest given the current use of M=0.2 in the stock assessment. Using a higher constant M in the stock assessment would produce larger population estimates, but would not address the retrospective pattern observed in the assessment (Legault et al., 2012). The total mortality rate could remain high over time if the decrease in F as catch declined was offset by an equal increase in M. This seems highly convenient and could imply a major deviation from the standard fishery stock assessment assumption that fishing and natural mortality rates are additive. There could be missing catch in recent years due to under-reporting of landings, underestimation of discards, or an increase in fishing induced mortality due to more fish being squeezed through meshes when the mesh regulations increased. We currently cannot detect large amounts of missing catch in our databases (Palmer, WP38; Palmer and Wigley, WP39; Palmer WP40), the implied discard ratios on unobserved trips would have to be much higher than the observed rates (Rago et al., WP18), and the total amount of large mesh otter trawl fishing effort has been declining on Georges Bank (Rago et al., WP18). So missing catch does not appear to be a likely explanation for the high and constant Z. Along these lines but at the early part of the time series, the catch could have been overestimated in the early years. This can lead to the type of retrospective pattern observed in the stock assessment (Legault, 2009). There is some evidence to support overreporting of catch early in the assessment period. For example, Brown et al. (1980) suggested that some of the reported catch in the late 1970s from Georges Bank and Cape Cod stocks actually came from Southern New England. However, the magnitude of overreporting needed to eliminate the retrospective pattern is likely much larger than the 1,500 – 4,000 mt suggested in Brown et al. (1980). Another possible explanation for the high constant Z is that there is ageing error and the fish are actually much older than currently thought. This explanation has been refuted using tagged fish, collecting scales at both release and recapture to verify the annual formation of growth rings, both in the past (Lux and Nichy, 1969) and recently (Alade, WP02). Finally, the survey selectivity could be domed, meaning there are actually many old yellowtail on Georges Bank but the NEFSC surveys cannot catch them. The flatfish survey of August 2013 argues against this possibility because the same size and age distributions were caught with a net designed to catch yellowtail (the flatfish survey) as the net used in the NEFSC bottom trawl surveys (Martin and Legault WP23). There is no obvious explanation for the total mortality remaining high, or even increasing in recent years, when management measures have been quite restrictive and resulted in low catches recently compared to earlier periods.

The second general conclusion from the analyses in this working paper is that the total mortality rate of male yellowtail flounders is higher than females. The simplest, most parsimonious explanation of this observation is that M is higher in males than in females. For example, this assumption is made in the arrowtooth flounder stock assessment (Turnock and Wilderbuer, 2011). For Georges Bank yellowtail flounder, the biological explanation is that as males mature they become more active and thus more readily available to predators. Differences in growth and maximum observed age by sex for yellowtail flounder have been noted since Royce et al. (1959) and could reflect a difference in natural mortality rate between the sexes. Other, less-likely, explanations for Z being higher in males than females are that F is higher in males than females, older males are less available to survey gear than older females, protandric hermaphrodism (males become females), incorrect sex determination of large yellowtail flounder, and old males being undersampled due to many more younger females occurring at the same size. There is no direct evidence to support any of these alternative hypotheses.

The third general conclusion from the analyses in this working paper is that the total mortality rate difference between males and females is increasing in recent years. The change appears generally to be due to an increase in male Z while female Z has remained about the same, although the cohort catch curves and 5 year block static catch curves indicate that female Z could be increasing in the most recent years. One possible explanation for this difference would be the outbreak of a disease that impacts males more than females. Huntsberger and Smolowitz (WP31) report on a disease affecting Georges Bank yellowtail flounder, but it appears in both sexes and there is not a time series of information to determine if this is a new outbreak or something that has been present during the entire time series. Another possible explanation is that the two sexes responded differently to the implementation of the Closed Areas in the mid 1990s, with the female total mortality rate remaining the same and the male total mortality rate increasing. Under this hypothesis, males in the areas open to fishing would be subjected to higher F than females, but declining catches argues against this possibility. Another potential explanation is that the differences in Z by sex are due to gear selectivity and that whatever causes this difference is increasing in importance over time. For example, if males are less available to bottom trawl gear than females, and temperature increases cause yellowtail to be more active, then temperature increases could result in an increasing difference in Z between the sexes. The temperature record on Georges Bank does not show a strong increase corresponding to the change in Z differences, and there is no evidence that changes in environmental conditions would differentially impact the sexes. There is no obvious explanation for the difference in Z between sexes to increase in recent years.

Conclusions

Both the cohort and static catch curves indicate three general results: 1) Z has remained high throughout the assessment period, 2) male Z is higher than female Z, and 3) the difference in Z between the sexes is increasing in recent years. Only one of the three results has a simple explanation, the male Z is higher than female Z because male M is higher than female M. There may be other factors contributing to male Z being higher than female Z. There are no simple explanations for the other two results.

Literature Cited

Brooks, E.N., T.J. Miller, C.M. Legault, L. O'Brien, K.J. Clark, S. Gavaris, and L. Van Eeckhaute. 2010. Determining length-based calibration factors for cod, haddock, and yellowtail flounder. Transboundary Resources Assessment Committee Reference Document 2010/08. 23 p.

Brown, B.E., M.P. Sissenwine, and M.M. McBride. 1980. Implications of yellowtail flounder stock assessment information for management strategies. Woods Hole Laboratory Reference No. 80-21. 12 p.

Gavaris, S., R. O'Boyle, and W. Overholtz. 2005. Proceedings of the Transboundary Resources Assessment Committee (TRAC) benchmark review of stock assessment models for the Georges Bank yellowtail flounder stock. Transboundary Resources Assessment Committee Proceedings 2005/01. 36 p.

Legault, C.M. (chair) 2009. Report of the retrospective working group. Northeast Fisheries Science Center Reference Document 09-01. 30 p.

Legault, C.M., L. Alade, H.H. Stone, and W.E. Gross. 2012. Stock Assessment of Georges Bank Yellowtail Flounder for 2012. Transboundary Resources Assessment Committee Reference Document 2012/02. 133 p.

Lux, F.E. and F.E. Nichy. 1969. Growth of yellowtail flounder, *Limanda ferruginea* (Storer), on three New England fishing grounds. ICNAF Research Bulletin 6: 5-25.

Royce, W.F., R.J. Buller, and E.D. Premetz. 1959. Decline of the yellowtail flounder (*Limanda ferruginea*) off New England. U.S. Department of the Interior, Fish and Wildlife Service, Fi.shery Bulletin 146, vol. 59, pp. 169-267.

Smith, M.W., A.Y. Then, C. Wor, G. Ralph, K.H. Pollock, and J.M. Hoenig. 2012. Recommendations for catch-curve analysis. North American Journal of Fisheries Management 32: 956-967.

Turnock, B.J. and T.K. Wilderbuer. 2011. Assessment of the arrowtooth flounder stock in the Gulf of Alaska. NPFMC Gulf of Alaska SAFE report. Pages 691-752.

Tables

Table 1. Median difference in total mortality estimates between sexes (males – females) from cohort catch curves in the two seasons of the NEFSC bottom trawl survey and four rules for finding the starting point of the regression.

Regression	Spring	Fall
Find Peak	0.29	0.16
First age 2	0.19	0.10
First age 3	0.38	0.35
First age 4	0.45	0.02

Figures

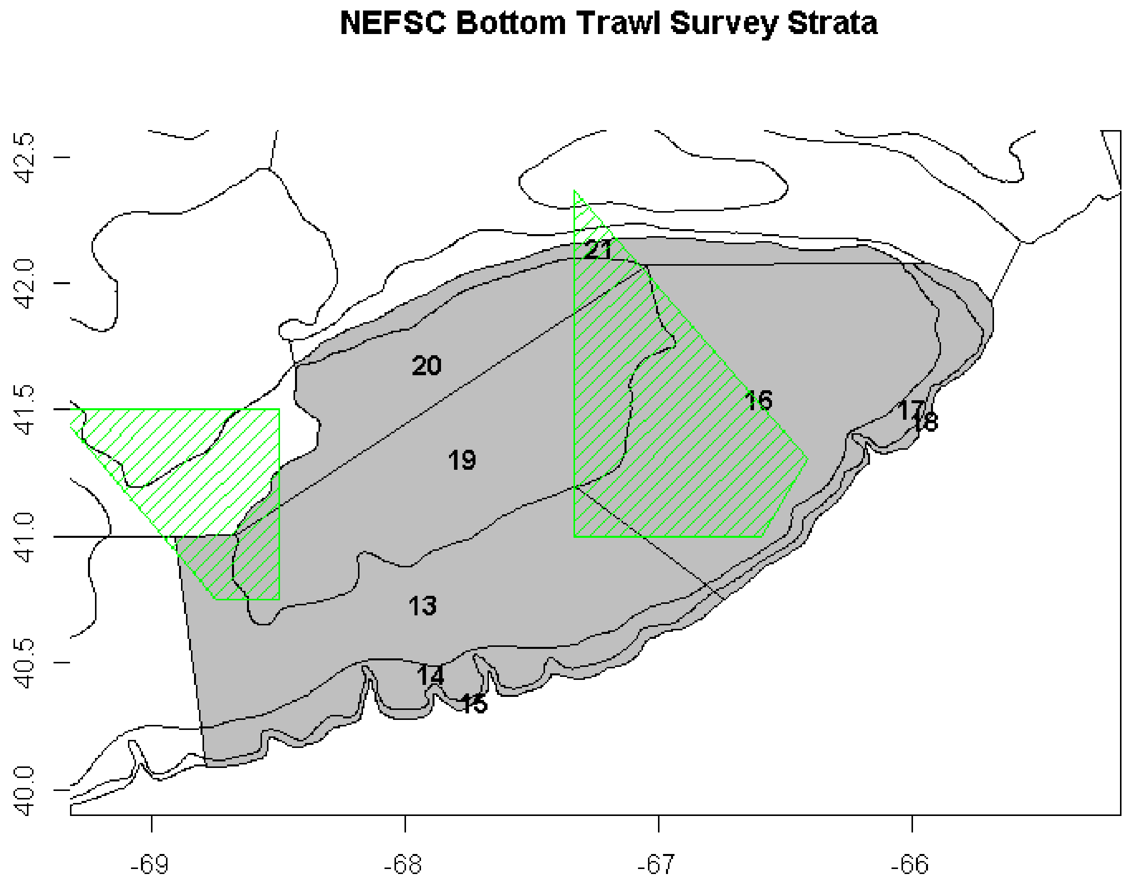

Figure 1. Northeast Fisheries Science Center bottom trawl survey strata used for Georges Bank yellowtail flounder (13-21). The green shaded regions denote Closed Area I (to the west) and Closed Area II (to the east).

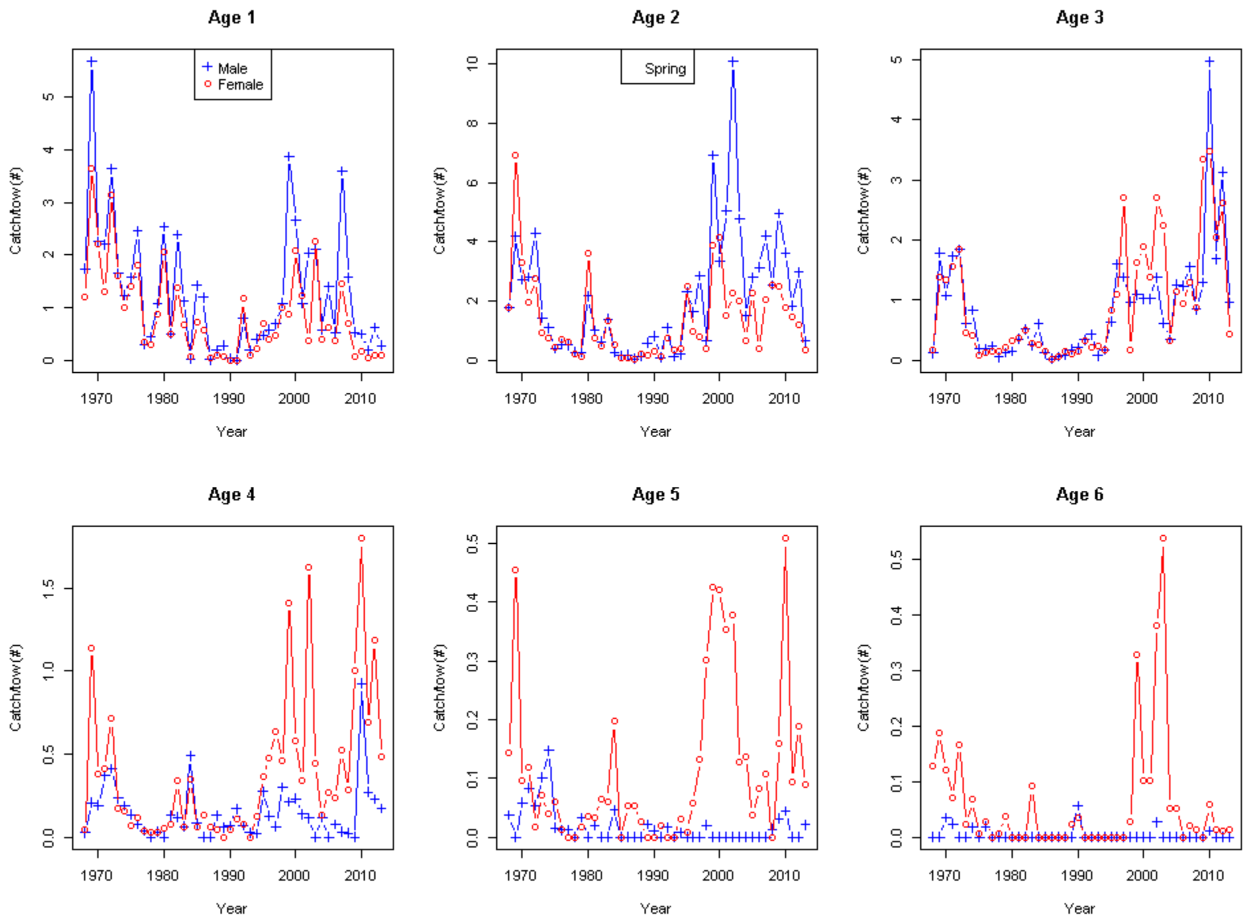

Figure 2. Catch per tow (numbers of yellowtail flounder) by sex over time for ages 1-6 from the NEFSC spring bottom trawl survey.

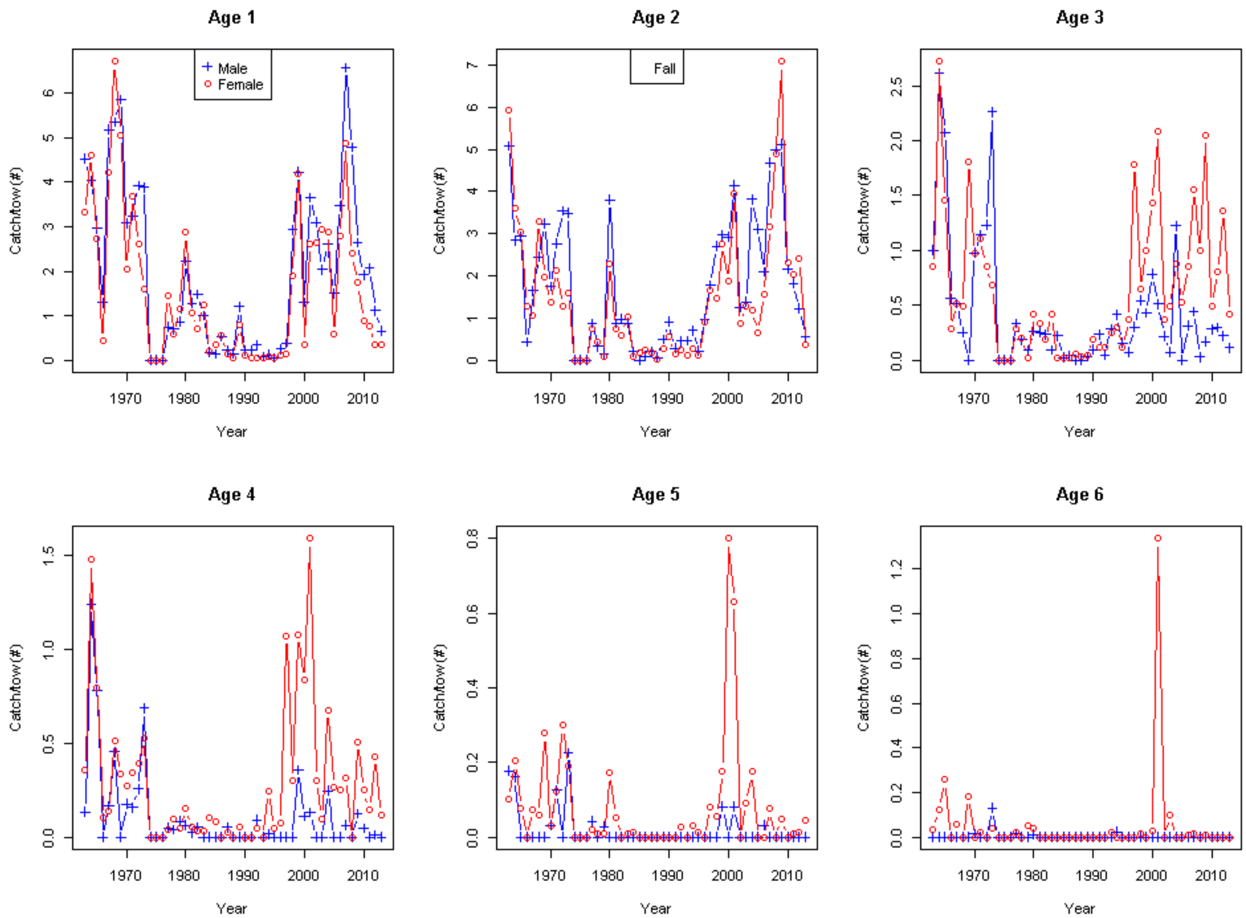

Figure 3. Catch per tow (numbers of yellowtail flounder) by sex over time for ages 1-6 from the NEFSC fall bottom trawl survey.

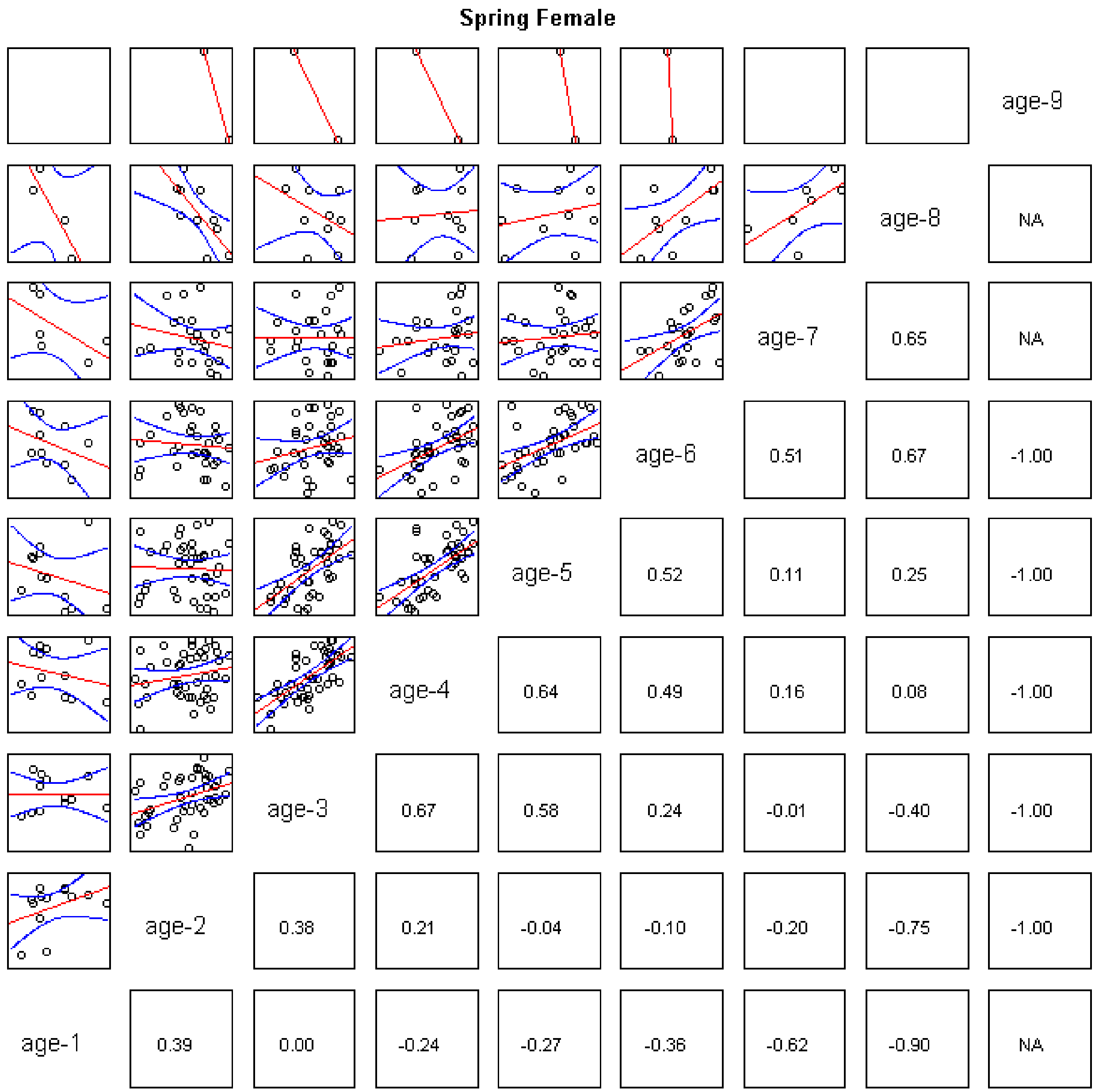

Figure 4. Cohort age matrices for females in the NEFSC spring survey. Each dot in the upper left plots is a cohort at one age plotted against that same cohort at another age on natural log scale. The red line is a linear regression and the blue lines are prediction intervals. The numbers in the lower right triangle are the correlations among the ages.

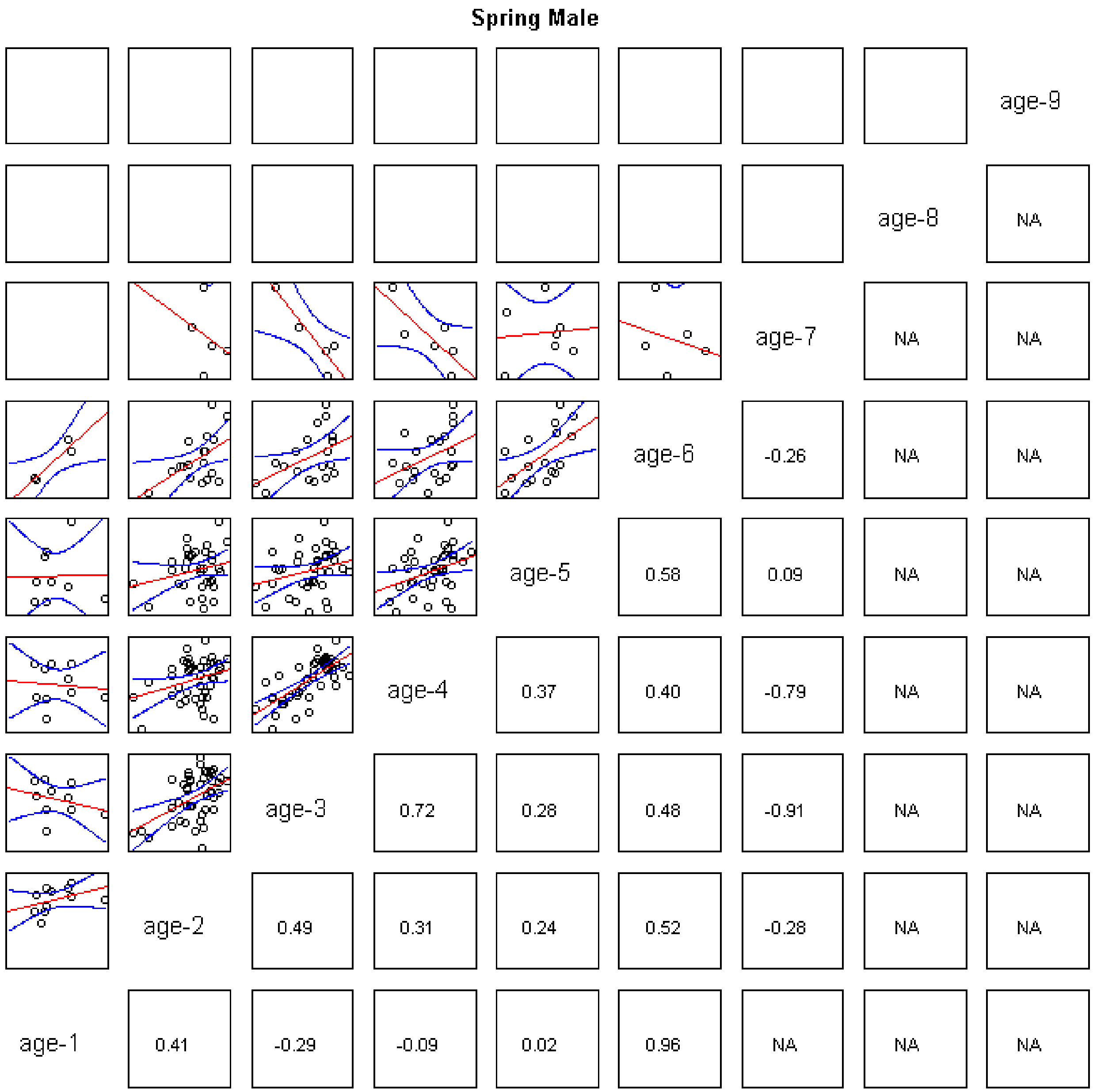

Figure 5. Cohort age matrices for males in the NEFSC spring bottom trawl survey. See Fig.4 for an explanation of the symbols, lines, and numbers.

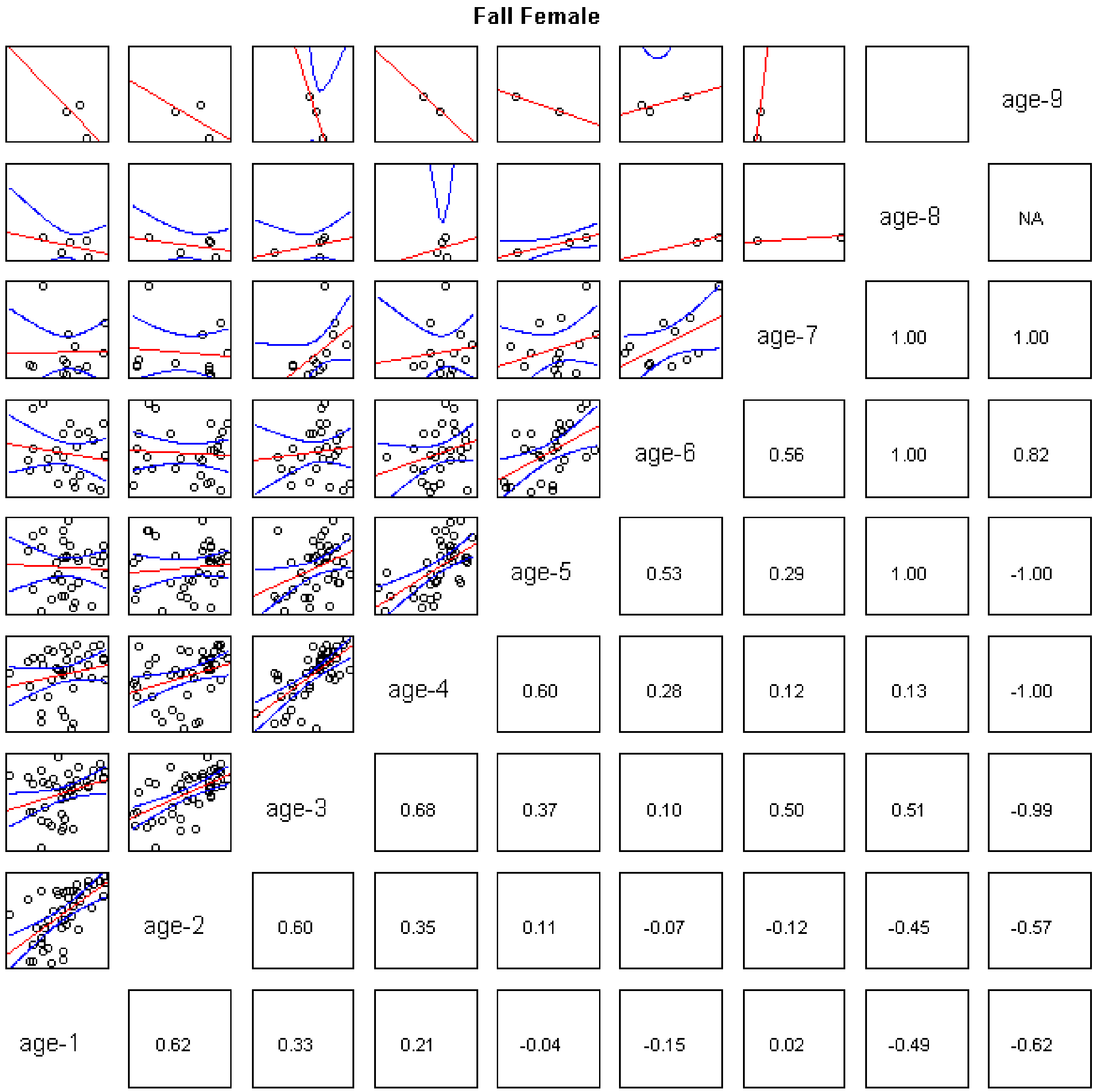

Figure 6. Cohort age matrices for females in the NEFSC fall bottom trawl survey. See Fig.4 for an explanation of the symbols, lines, and numbers.

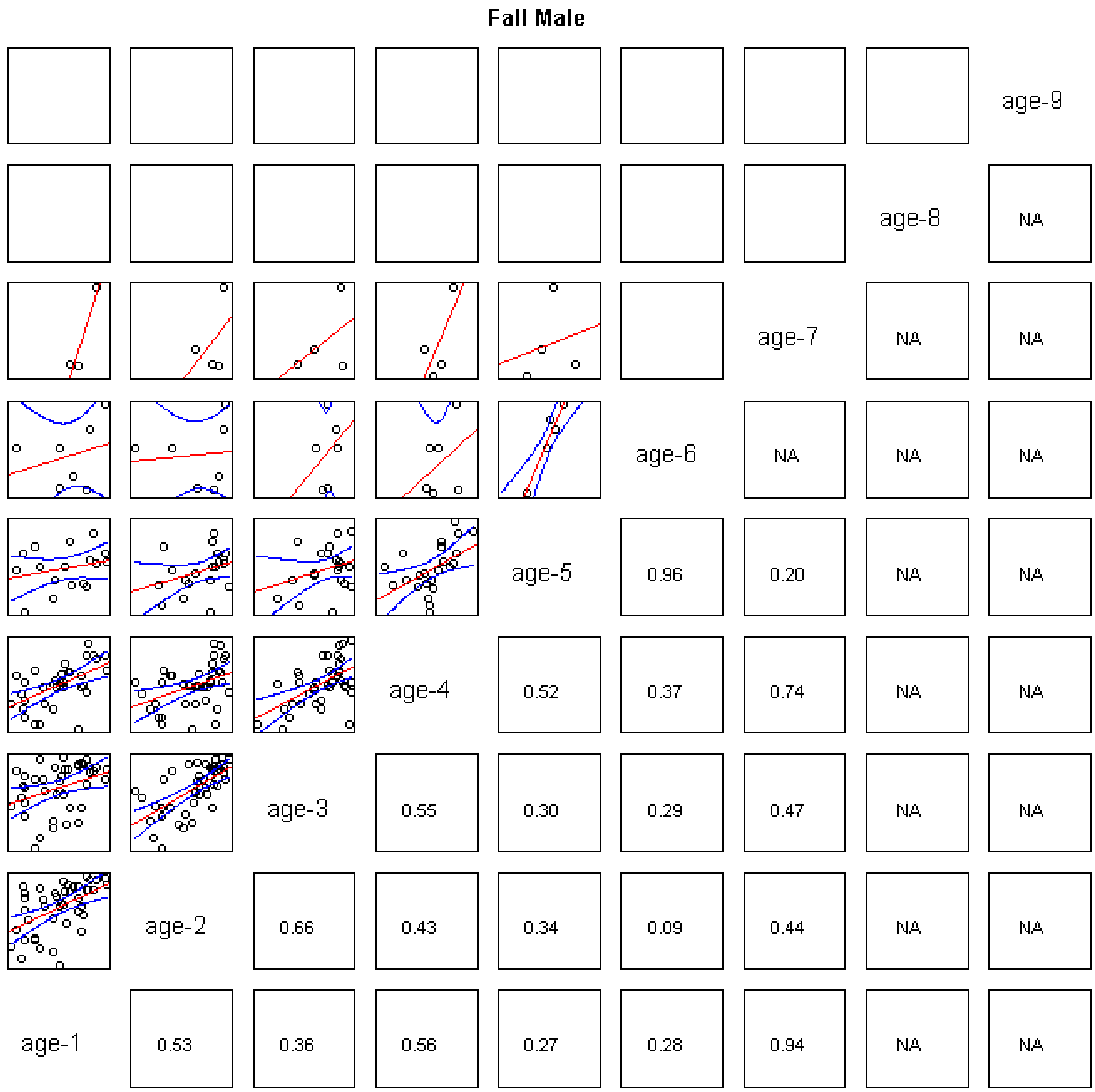

Figure 7. Cohort age matrices for males in the NEFSC fall bottom trawl survey. See Fig.4 for an explanation of the symbols, lines, and numbers.

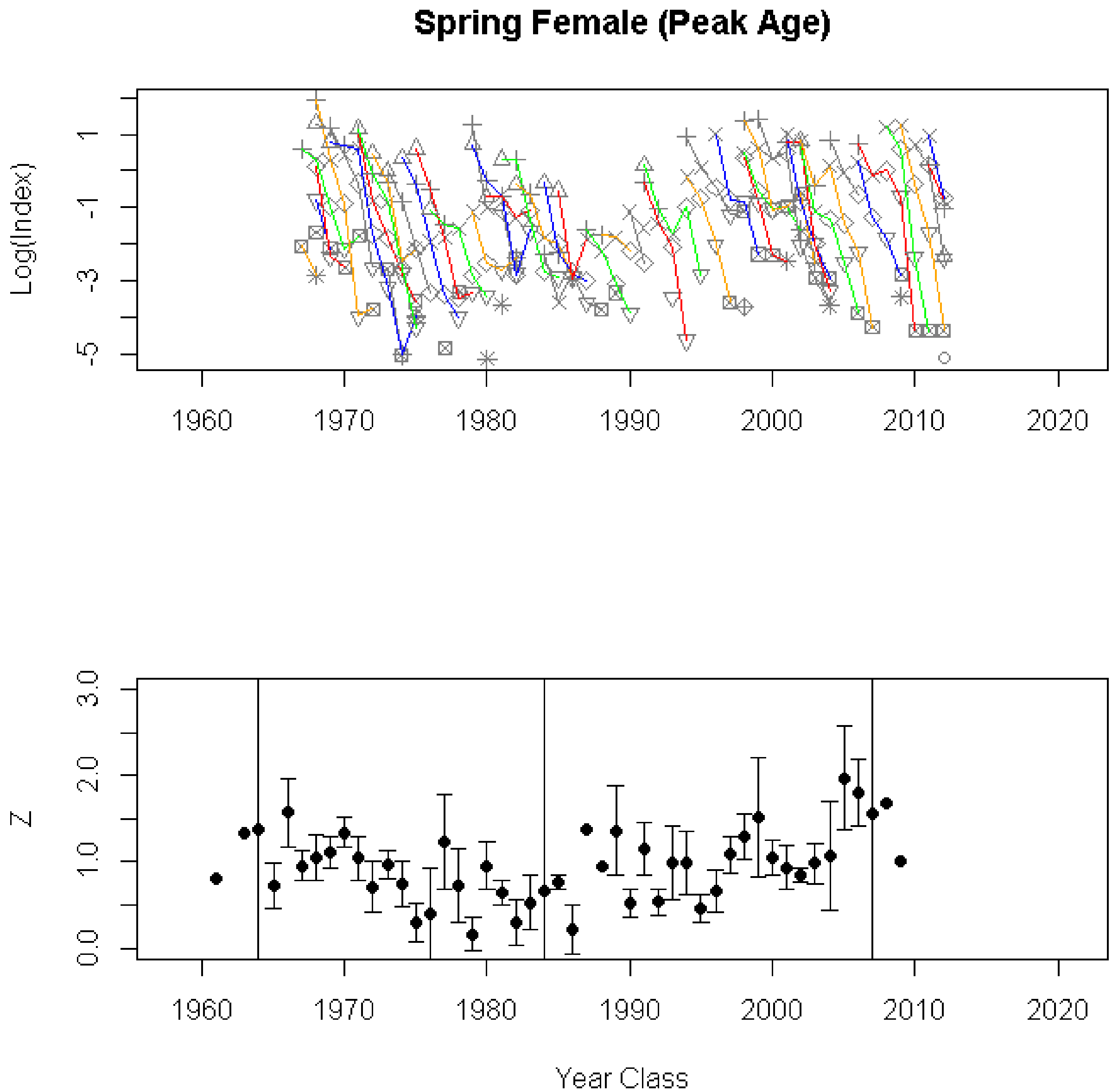

Figure 8. Cohort catch curves (top panel) and total mortality estimates by year class (bottom panel) for females in the NEFSC spring bottom trawl survey when peak age is selected by cohort for the estimation of Z. The symbols in the top panel denote different ages and the colored lines connect the cohorts. The error bars in the bottom panel denote 80% confidence intervals.

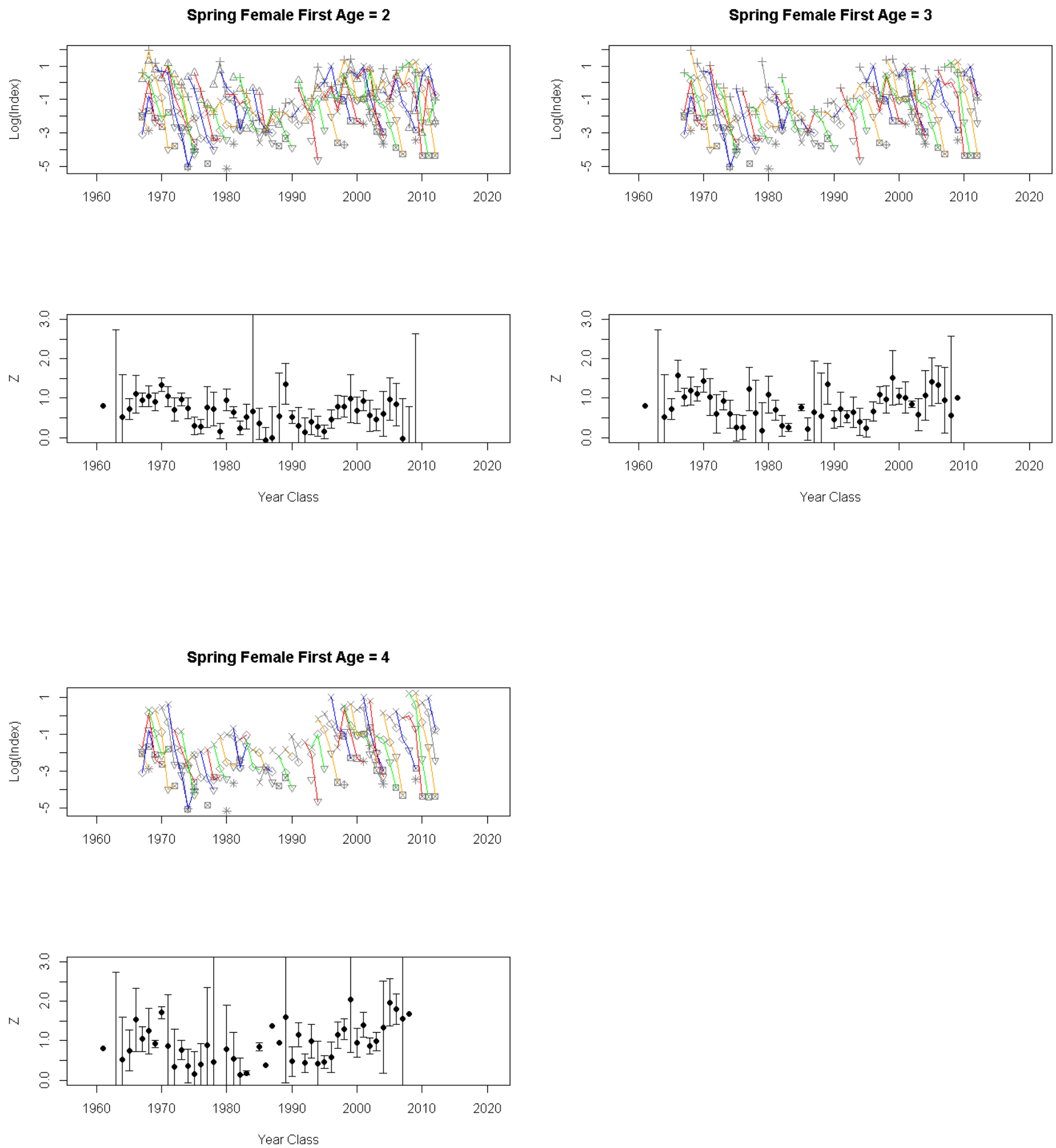

Figure 9. Cohort catch curves and total mortality estimates by year class for females in the NEFSC spring bottom trawl survey when the first age used in estimation of Z is 2, 3, or 4. See Figure 8 for description of symbols and error bars.

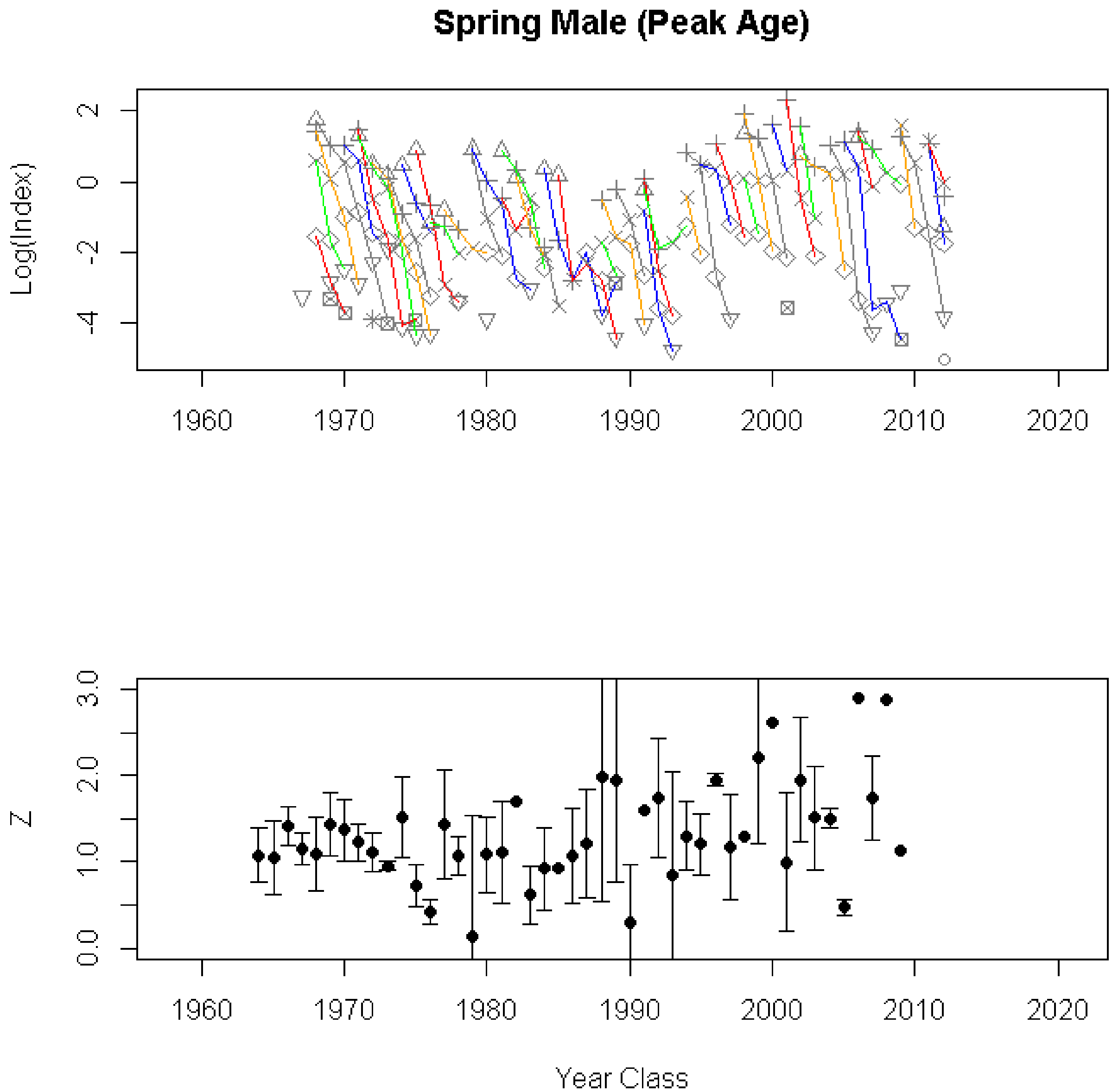

Figure 10. Cohort catch curves (top panel) and total mortality estimates by year class (bottom panel) for males in the NEFSC spring bottom trawl survey when peak age is selected by cohort for the estimation of Z. The symbols in the top panel denote different ages and the colored lines connect the cohorts. The error bars in the bottom panel denote 80% confidence intervals.

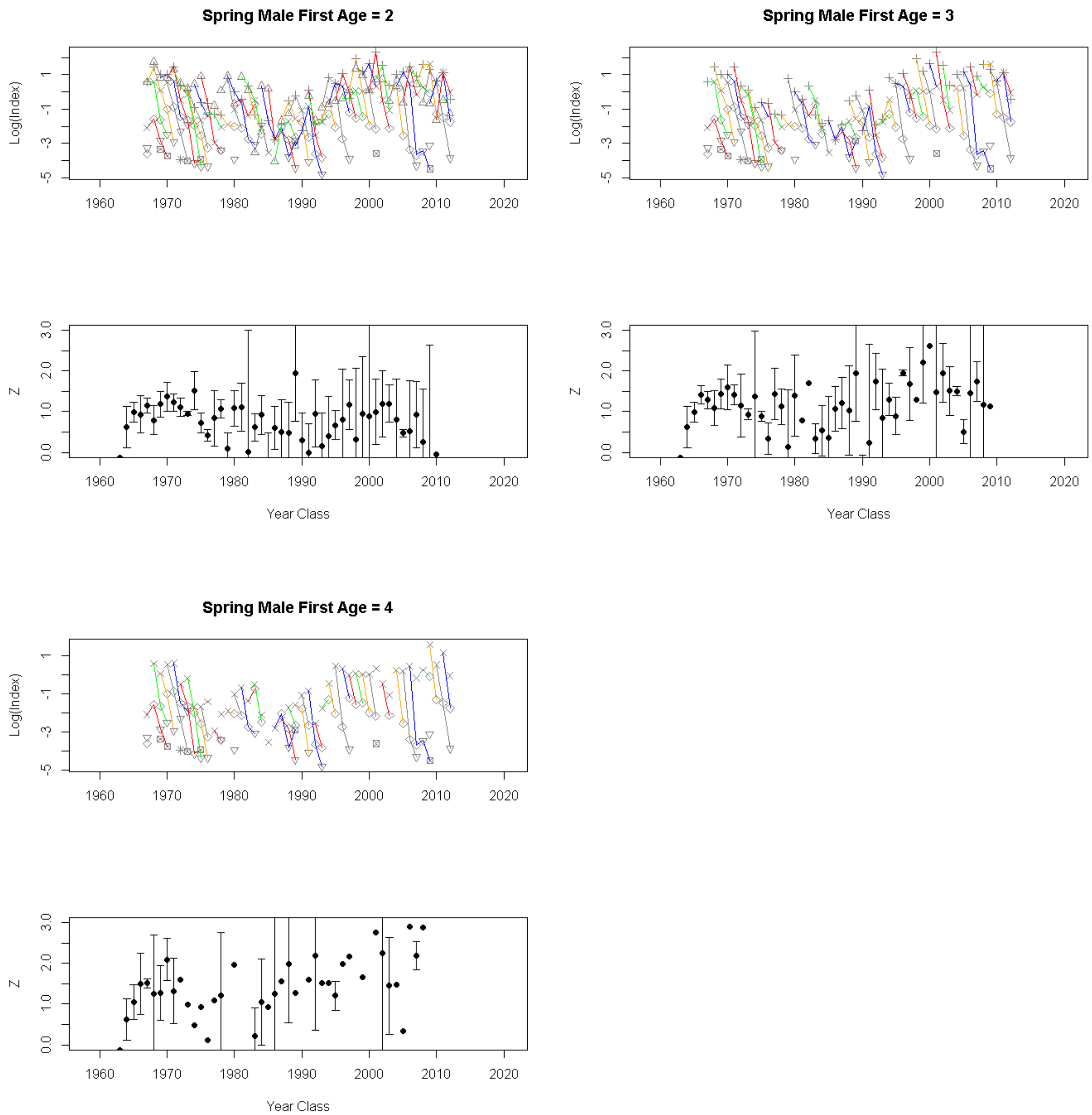

Figure 11. Cohort catch curves and total mortality estimates by year class for males in the NEFSC spring bottom trawl survey when the first age used in estimation of Z is 2, 3, or 4. See Figure 8 for description of symbols and error bars.

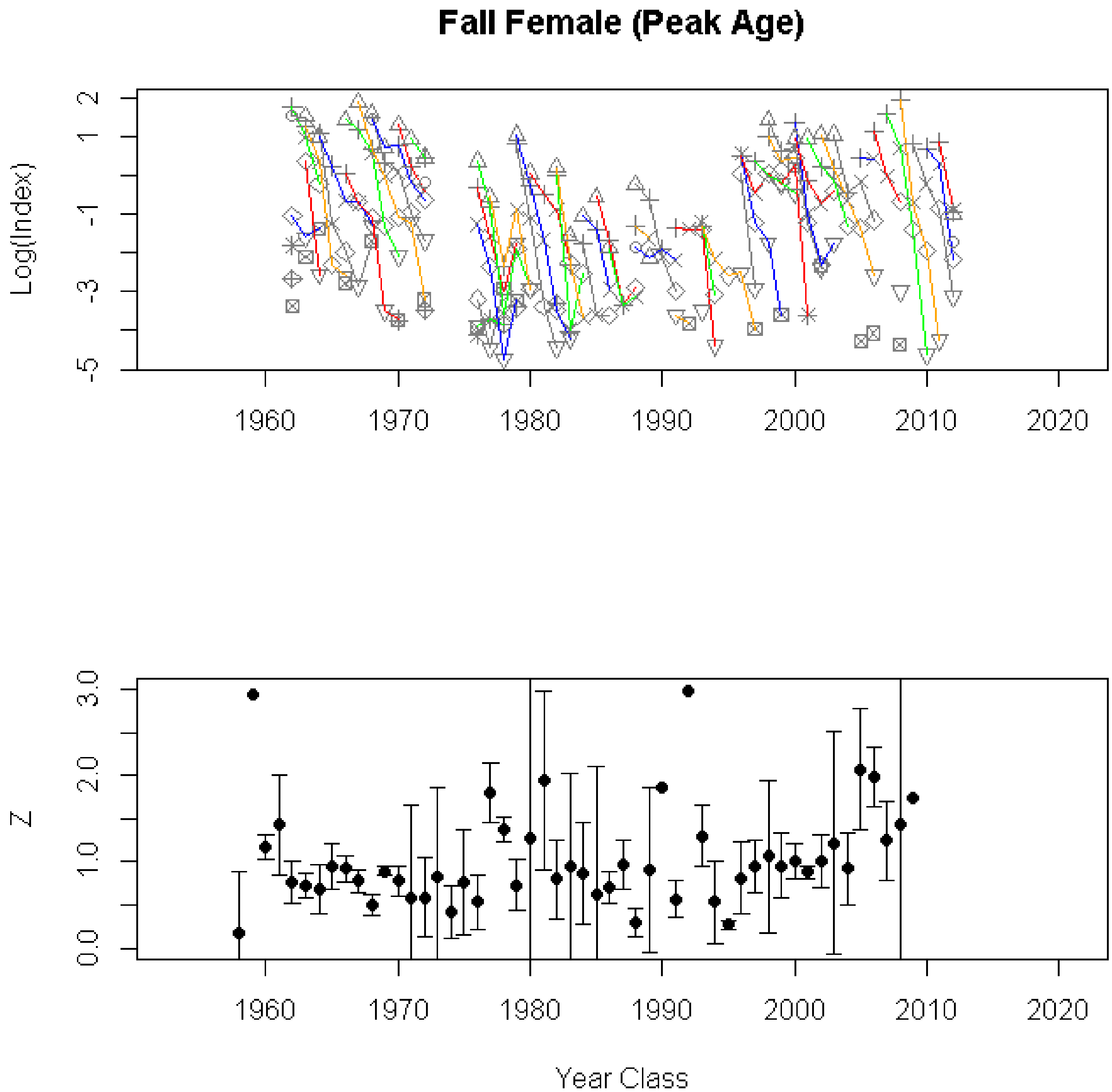

Figure 12. Cohort catch curves (top panel) and total mortality estimates by year class (bottom panel) for females in the NEFSC fall bottom trawl survey when peak age is selected by cohort for the estimation of Z. The symbols in the top panel denote different ages and the colored lines connect the cohorts. The error bars in the bottom panel denote 80% confidence intervals.

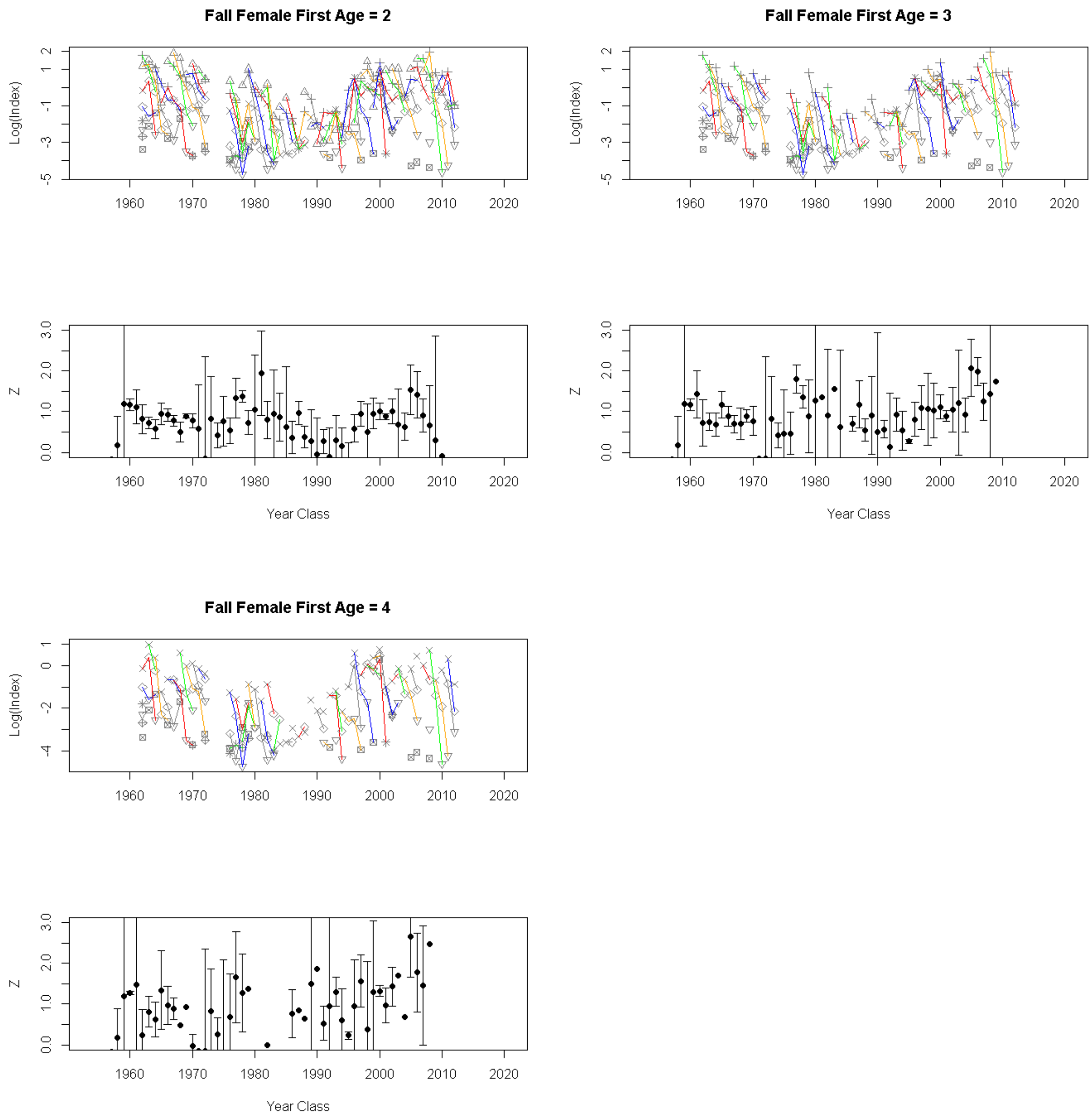

Figure 13. Cohort catch curves and total mortality estimates by year class for females in the NEFSC fall bottom trawl survey when the first age used in estimation of Z is 2, 3, or 4. See Figure 8 for description of symbols and error bars.

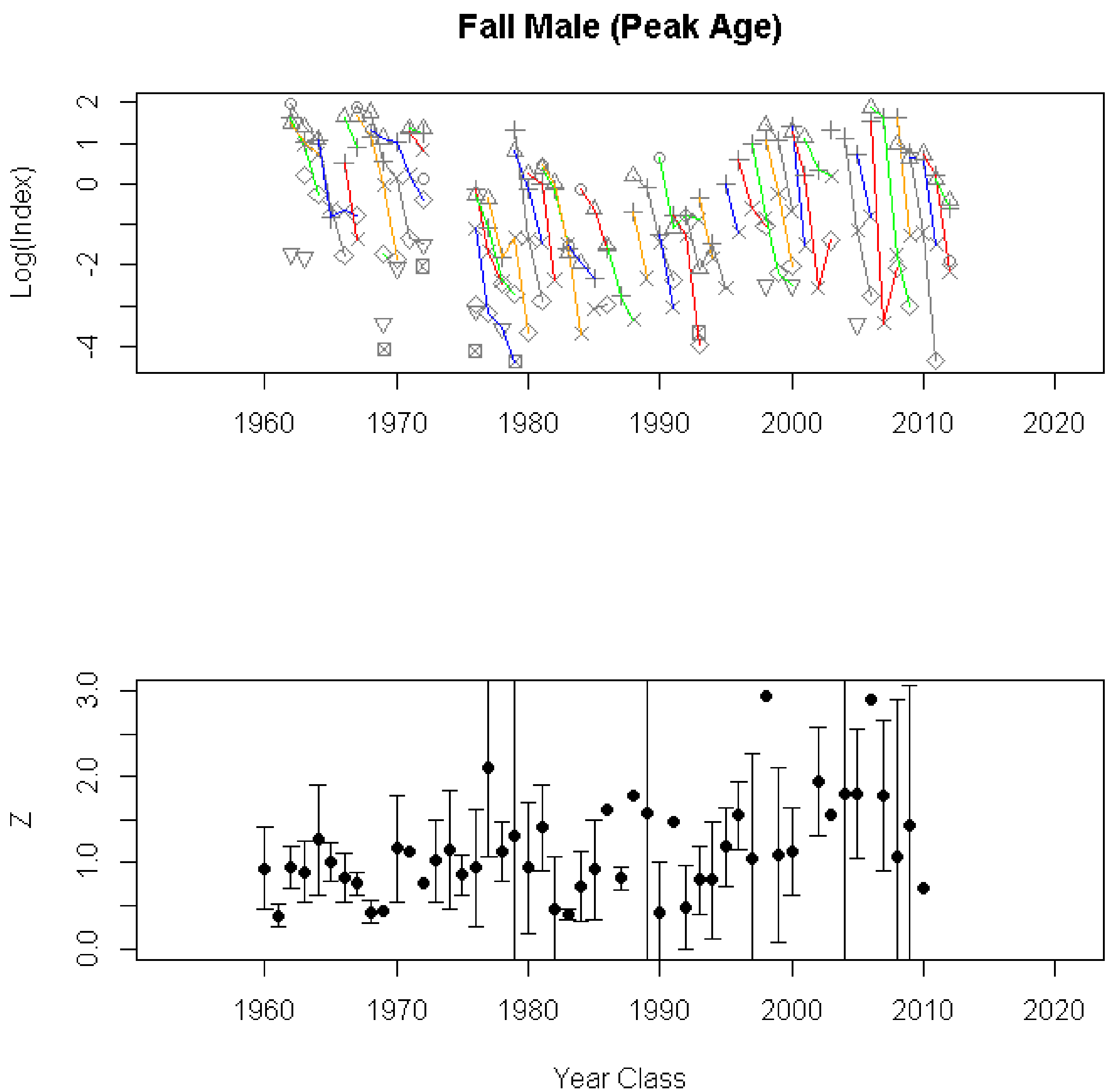

Figure 14. Cohort catch curves (top panel) and total mortality estimates by year class (bottom panel) for males in the NEFSC fall bottom trawl survey when peak age is selected by cohort for the estimation of Z. The symbols in the top panel denote different ages and the colored lines connect the cohorts. The error bars in the bottom panel denote 80% confidence intervals.

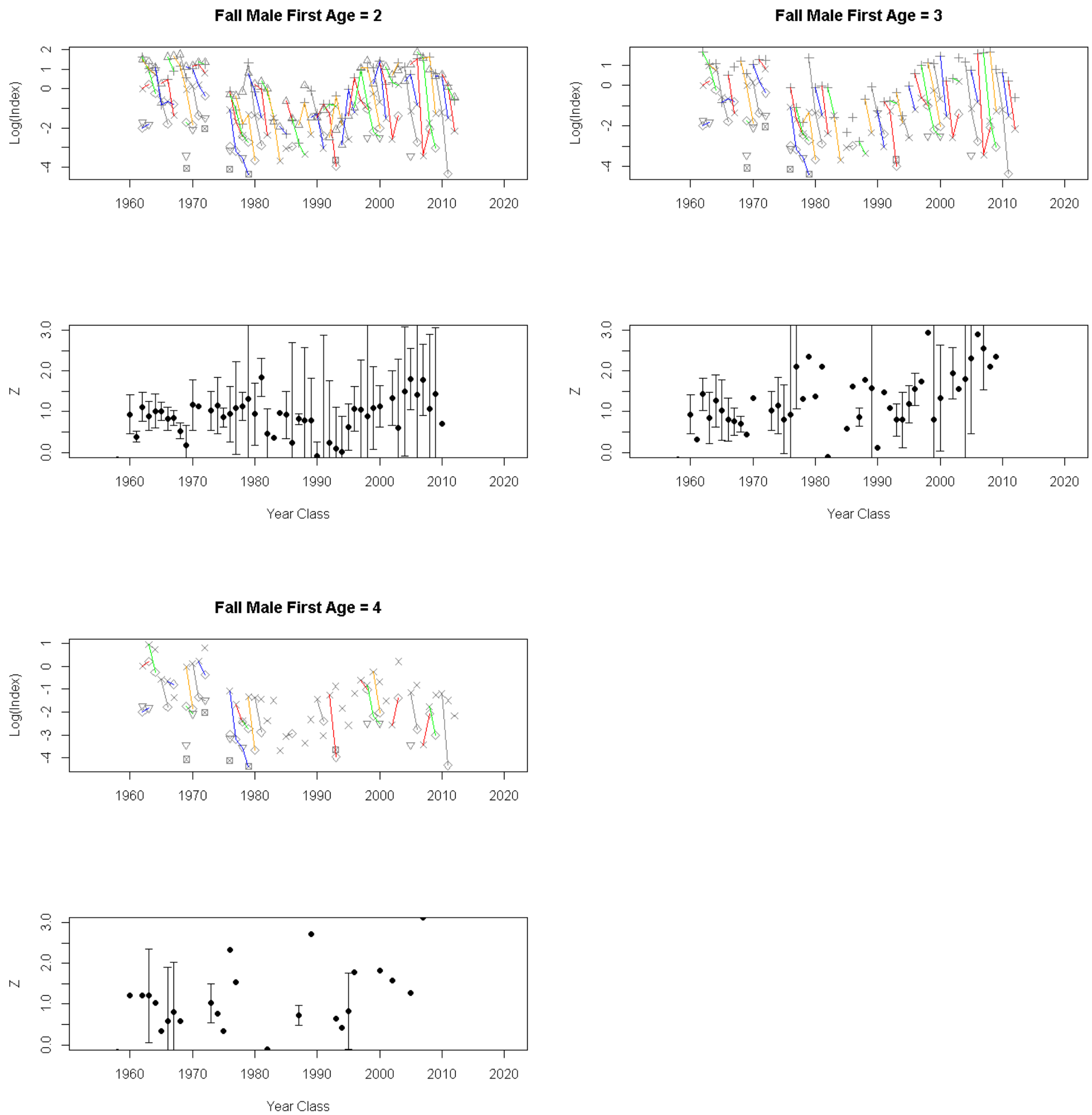

Figure 15. Cohort catch curves and total mortality estimates by year class for males in the NEFSC fall bottom trawl survey when the first age used in estimation of Z is 2, 3, or 4. See Figure 8 for description of symbols and error bars.

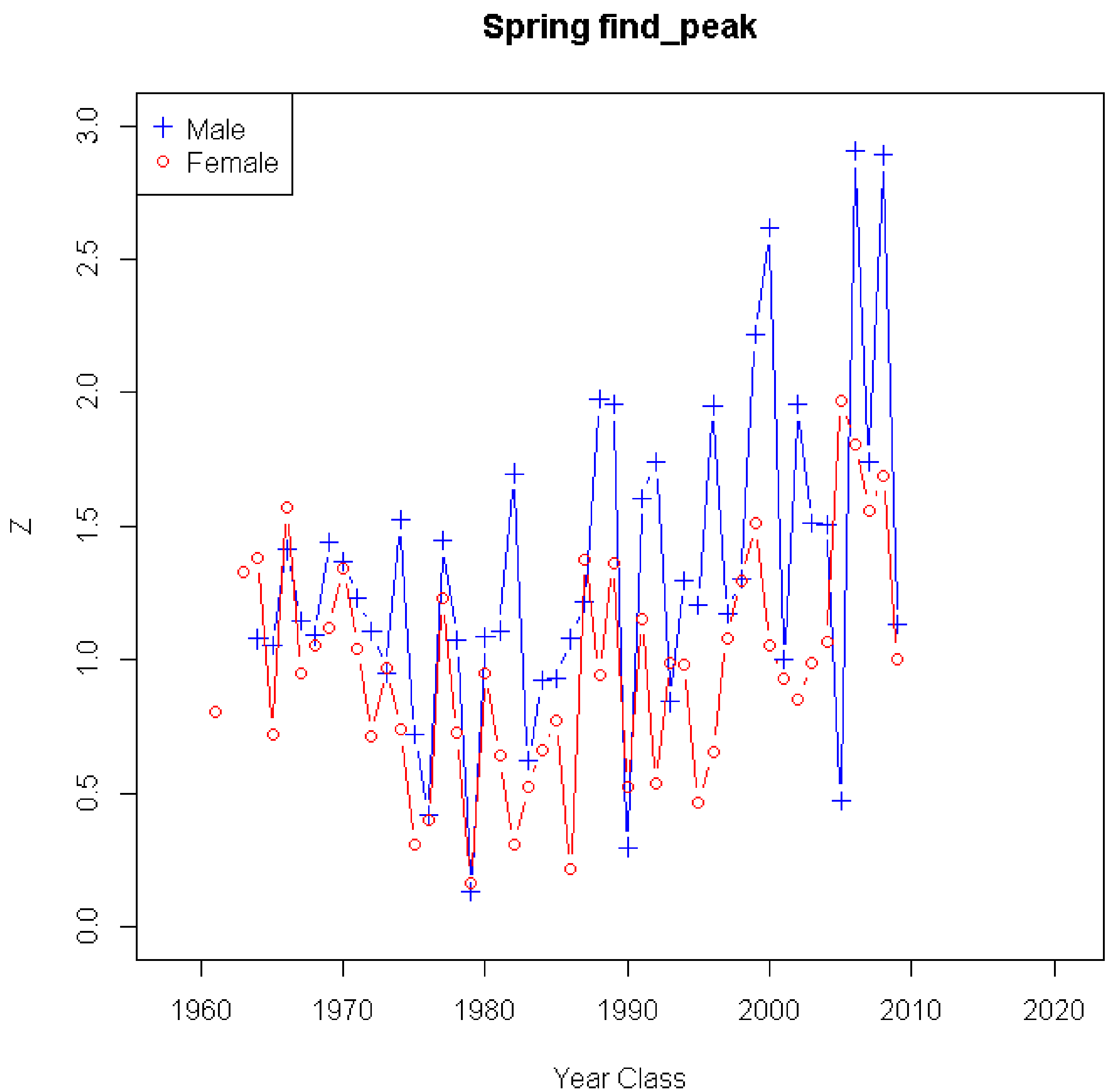

Figure 16. Point estimates of annual total mortality rates by sex from cohort catch curves using NEFSC spring bottom trawl survey catches when peak age is selected by cohort for the estimation of Z.

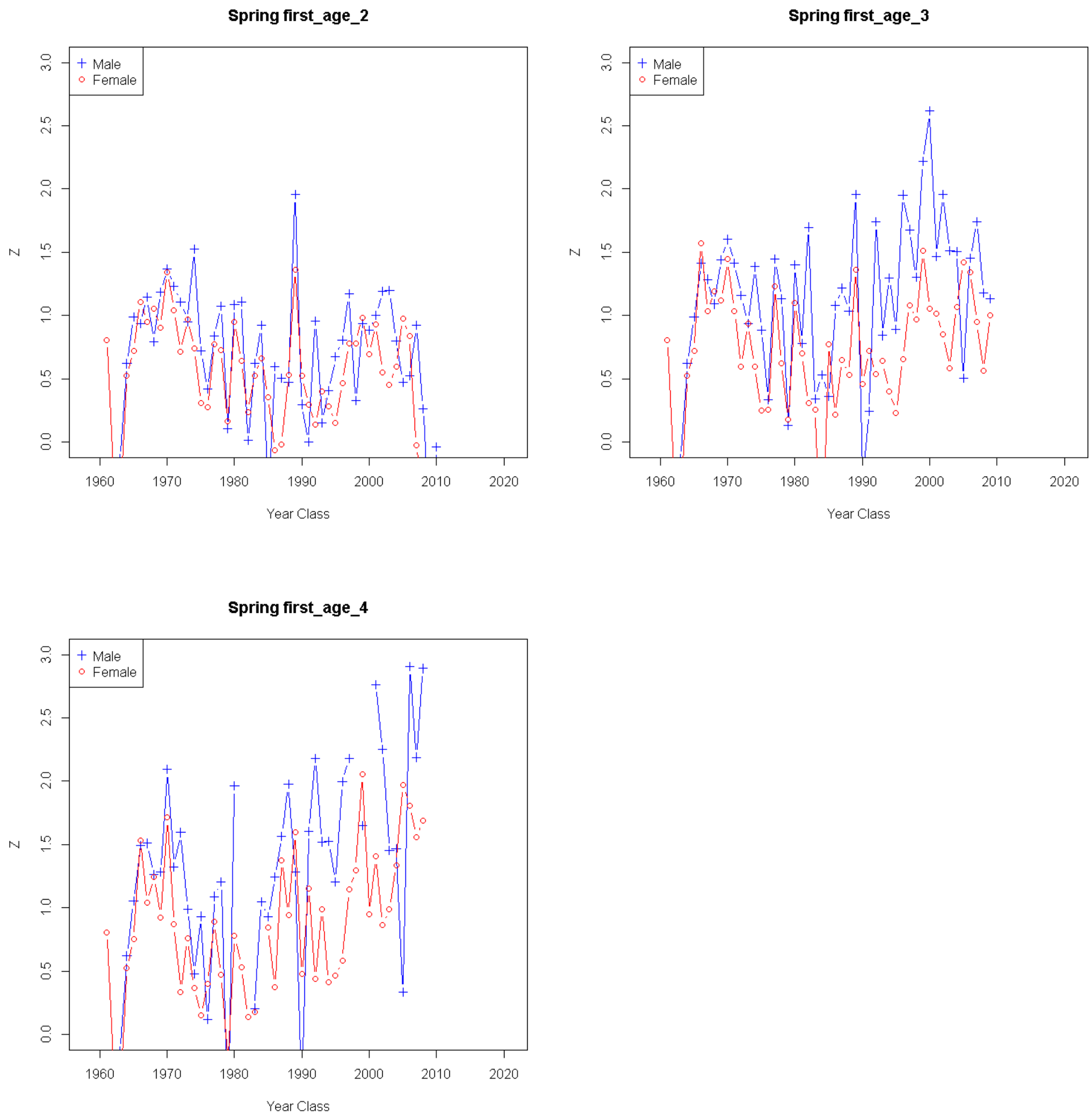

Figure 17. Point estimates of annual total mortality rates by sex from cohort catch curves using NEFSC spring bottom trawl survey catches when the first age used in the estimation of Z is 2, 3, or 4.

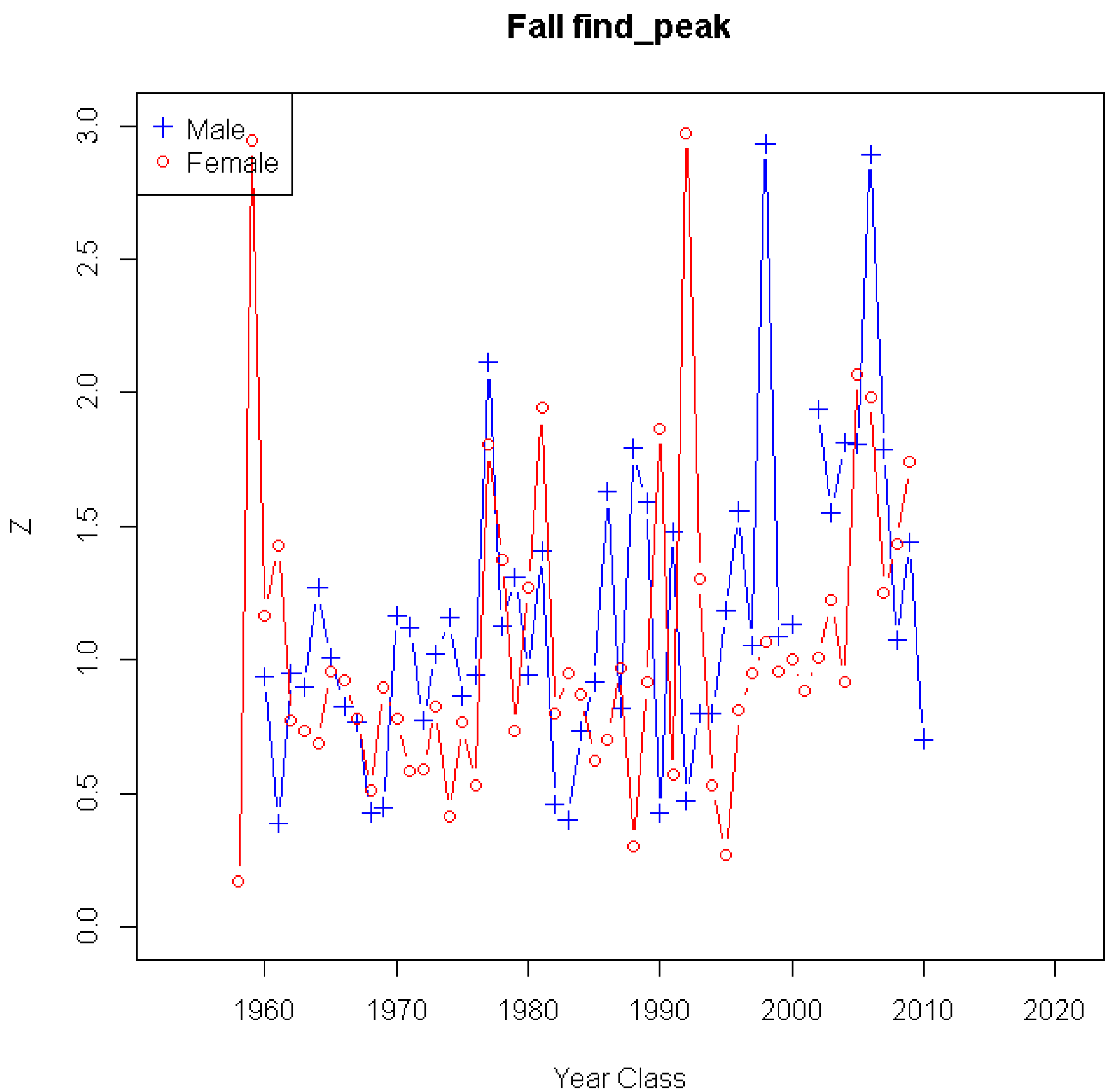

Figure 18. Point estimates of annual total mortality rates by sex from cohort catch curves using NEFSC fall bottom trawl survey catches when peak age is selected by cohort for the estimation of Z.

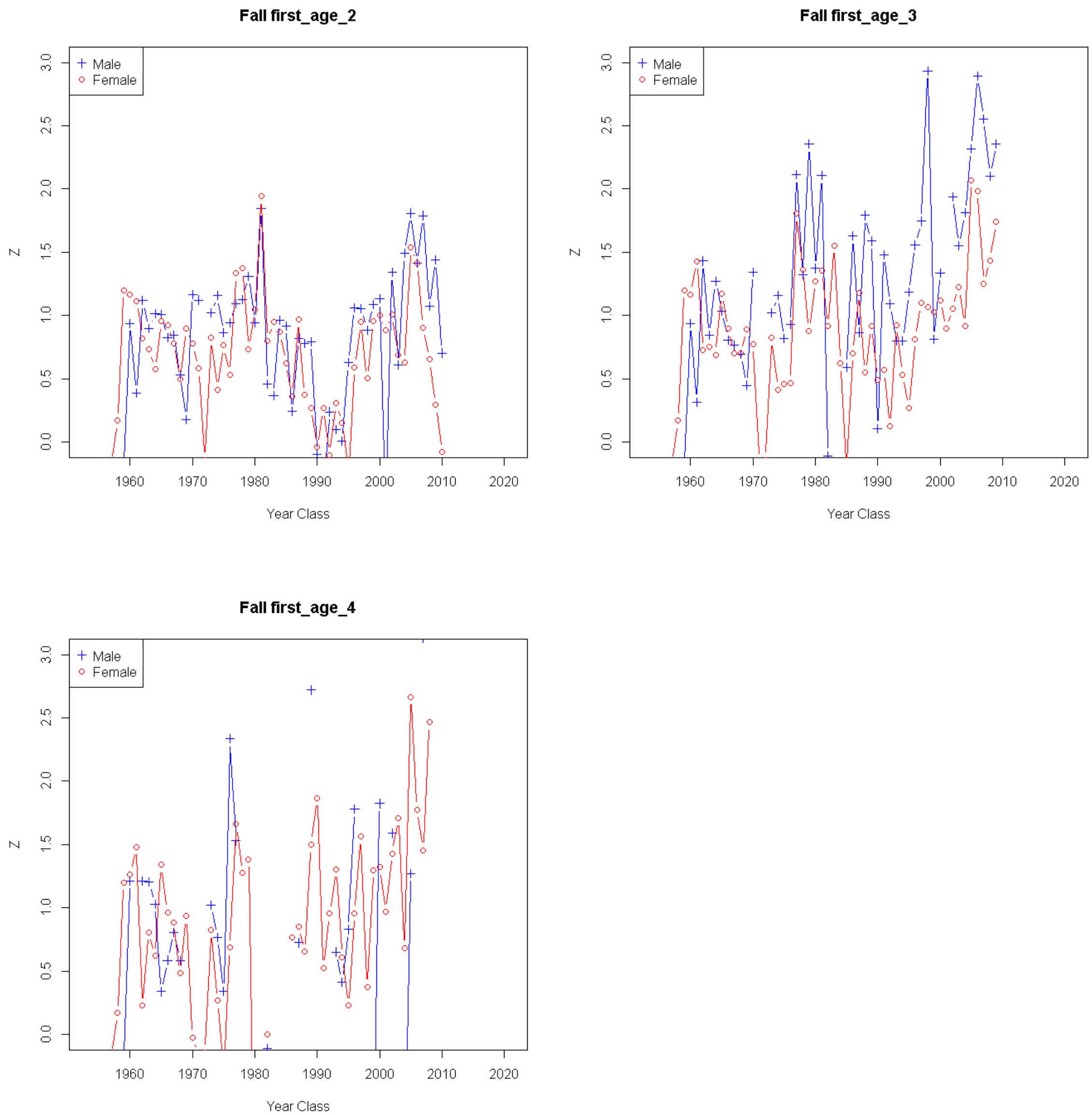

Figure 19. Point estimates of annual total mortality rates by sex from cohort catch curves using NEFSC fall bottom trawl survey catches when the first age used in the estimation of Z is 2, 3, or 4.

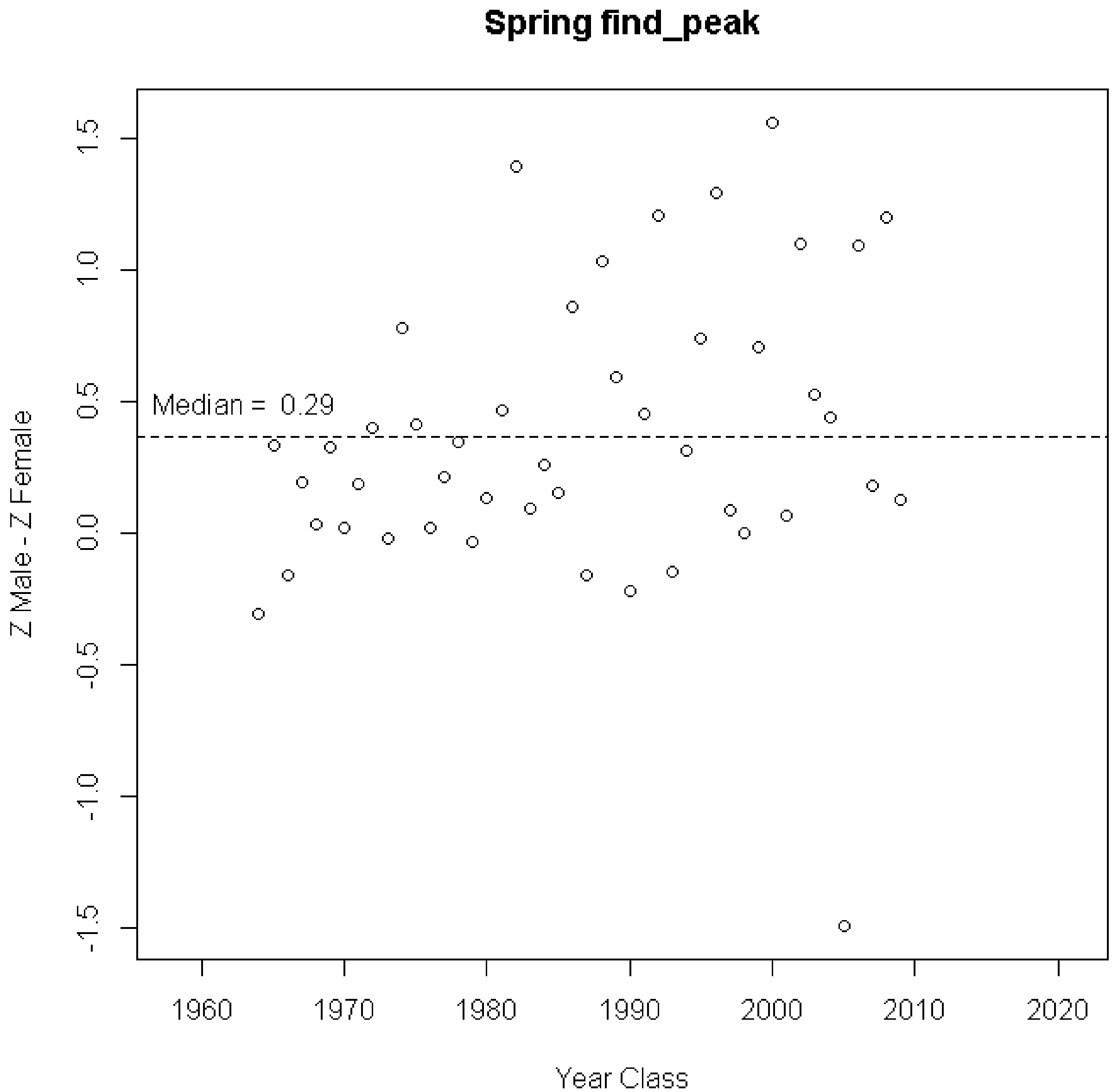

Figure 20. Differences in point estimates of annual total mortality rates between the sexes (males minus females) from cohort catch curves using NEFSC spring bottom trawl survey catches when peak age is selected by cohort for the estimation of Z. The horizontal dashed line denoted the median difference, which is labeled on the graph.

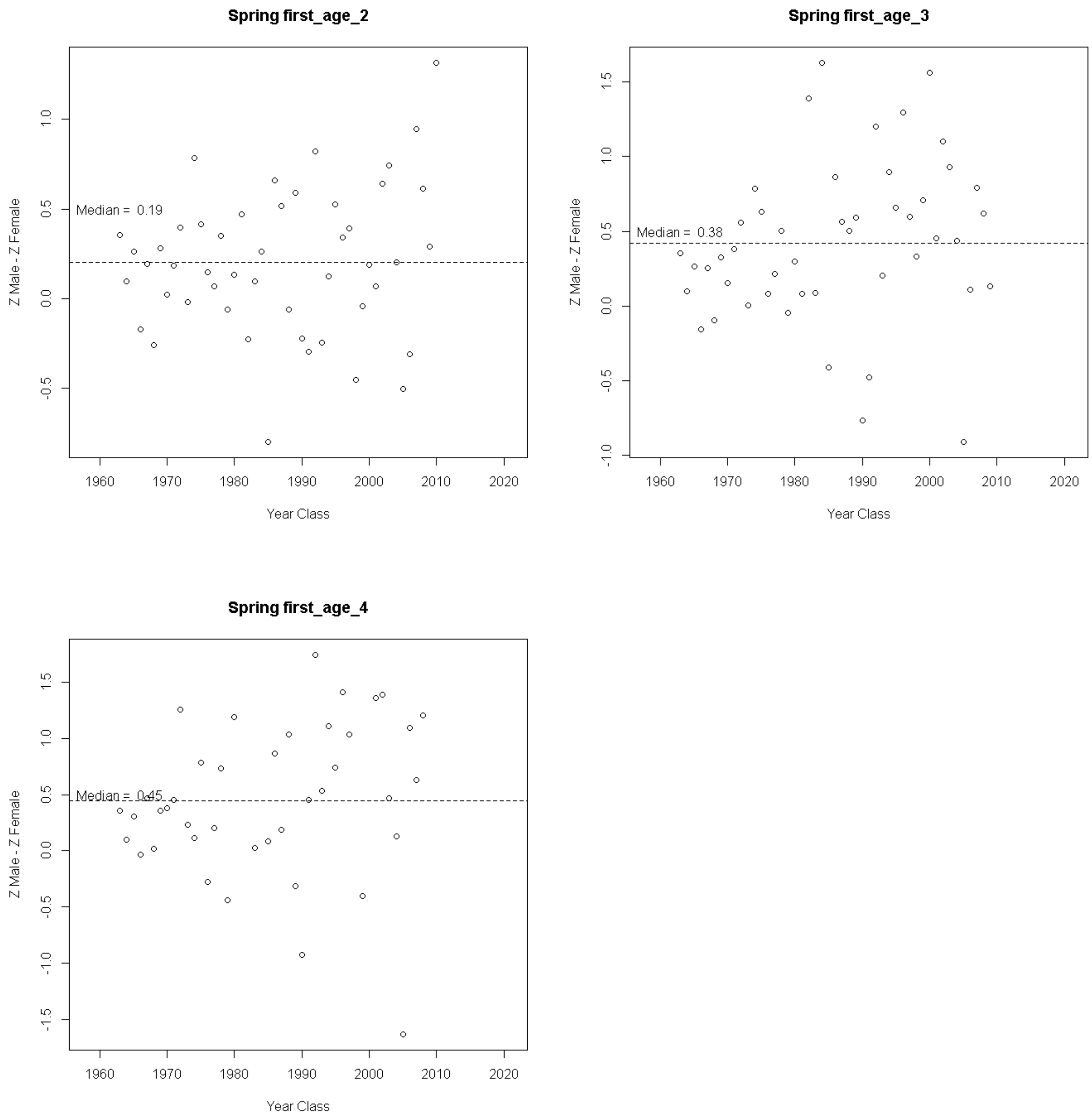

Figure 21. Differences in point estimates of annual total mortality rates between the sexes (males minus females) from cohort catch curves using NEFSC spring bottom trawl survey catches when the first age used in the estimation of Z is 2, 3, or 4. The horizontal dashed lines denoted the median difference, which is labeled on each graph.

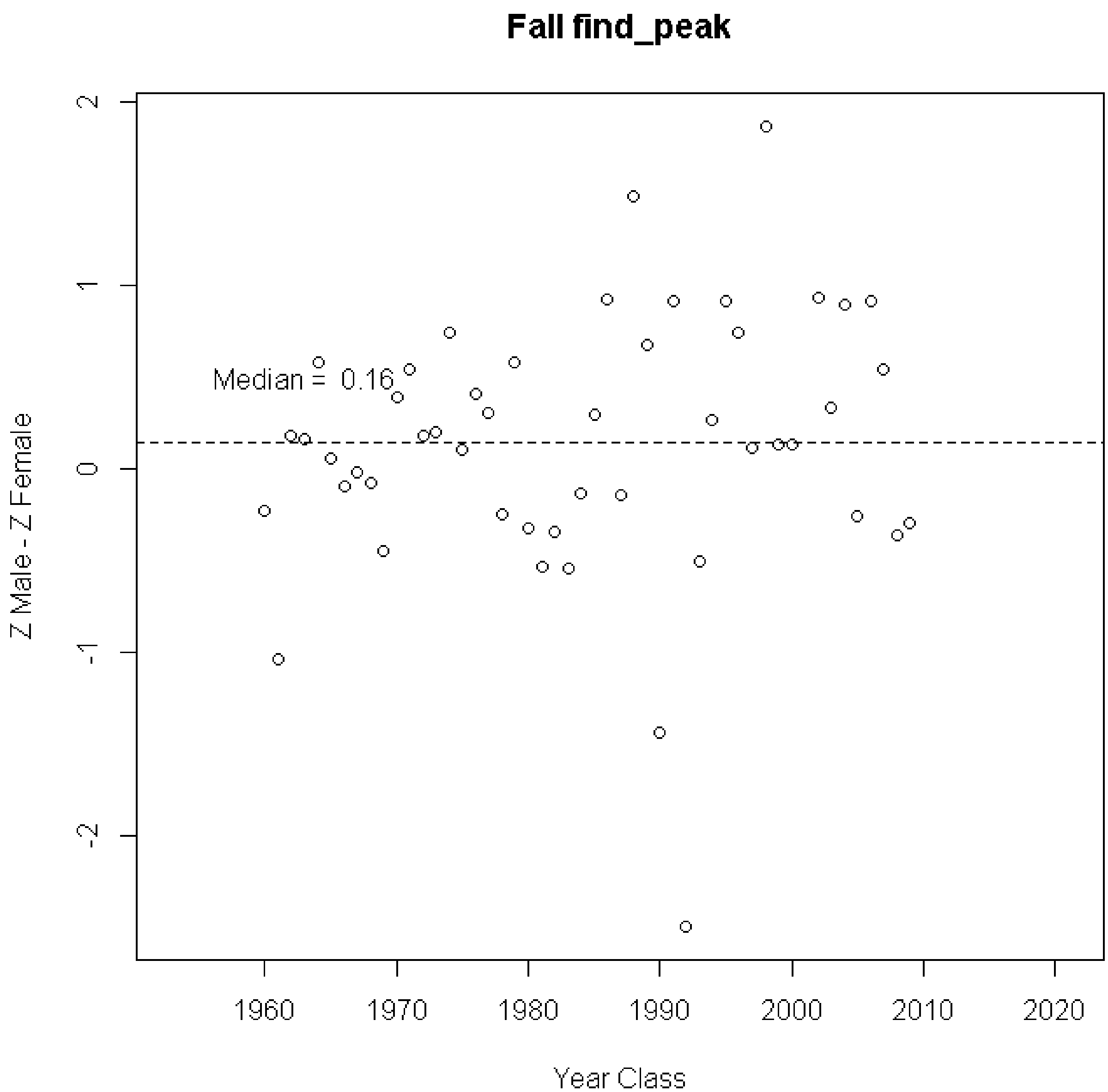

Figure 22. Differences in point estimates of annual total mortality rates between the sexes (males minus females) from cohort catch curves using NEFSC fall bottom trawl survey catches when peak age is selected by cohort for the estimation of Z. The horizontal dashed line denoted the median difference, which is labeled on the graph.

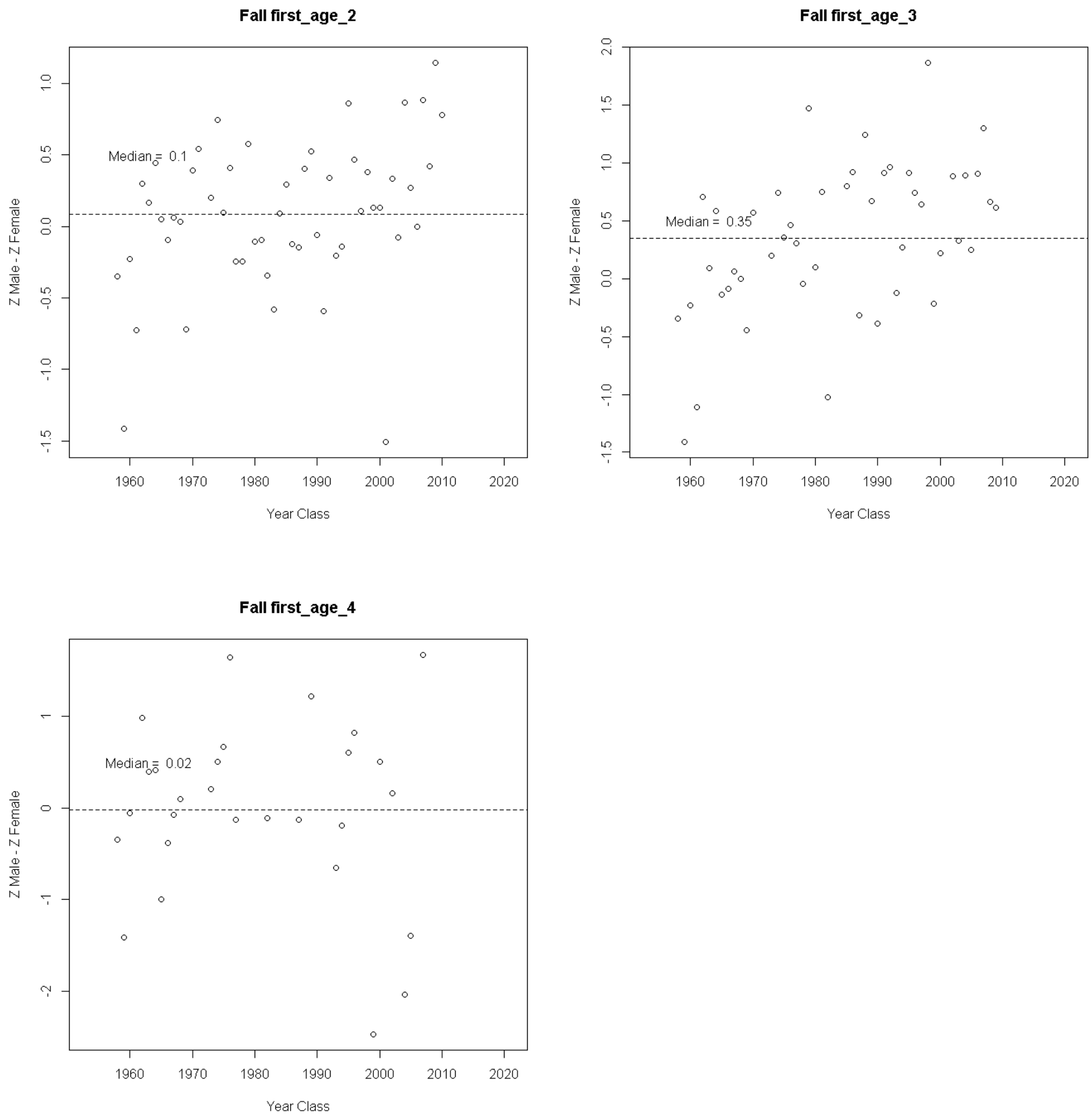

Figure 23. Differences in point estimates of annual total mortality rates between the sexes (males minus females) from cohort catch curves using NEFSC fall bottom trawl survey catches when the first age used in the estimation of Z is 2, 3, or 4. The horizontal dashed lines denoted the median difference, which is labeled on each graph.

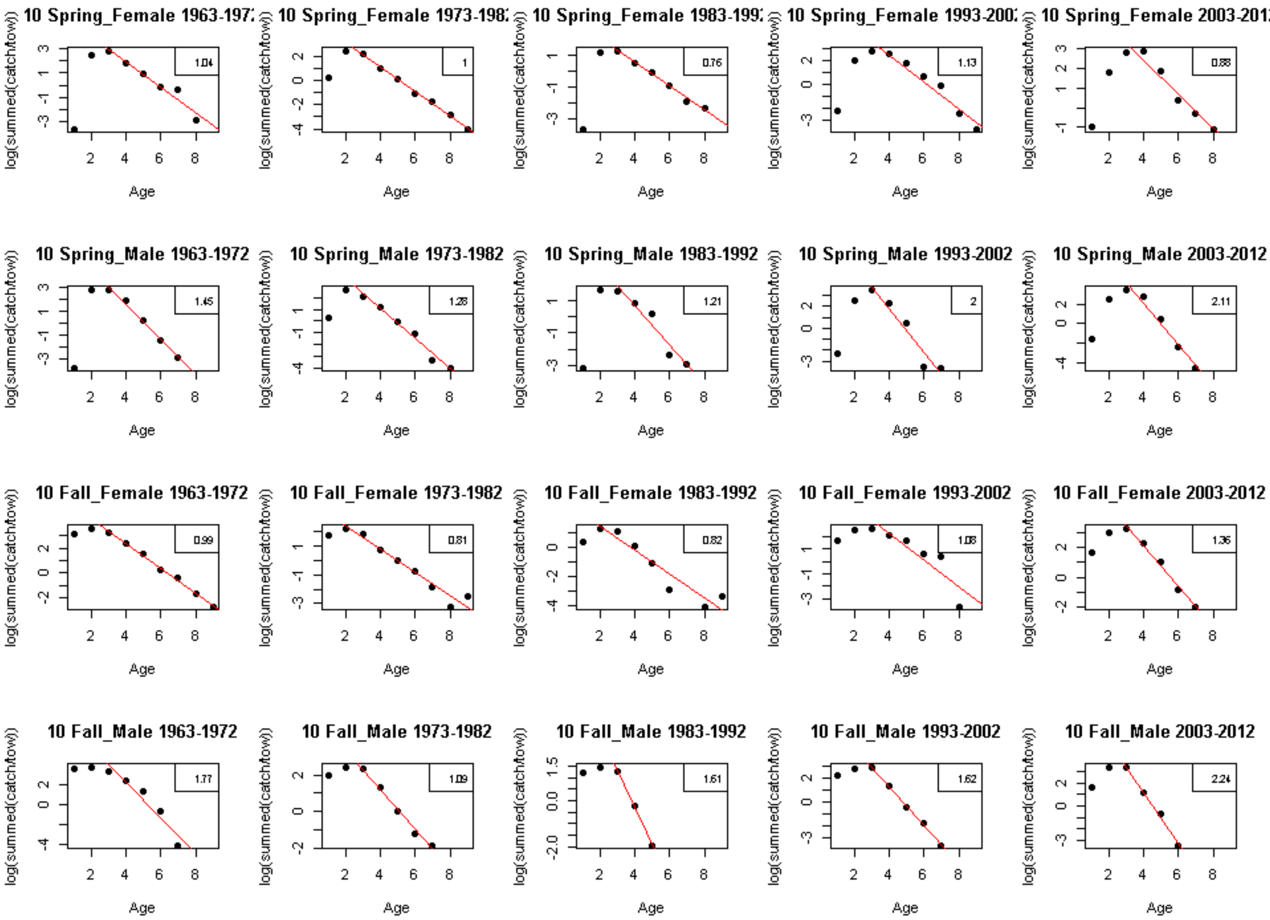

Figure 24. Static catch curves for blocks of 10 years by season and sex. The red lines show regressions beginning at age 3 and the numbers in the upper right corner of each plot is the corresponding total mortality estimate.

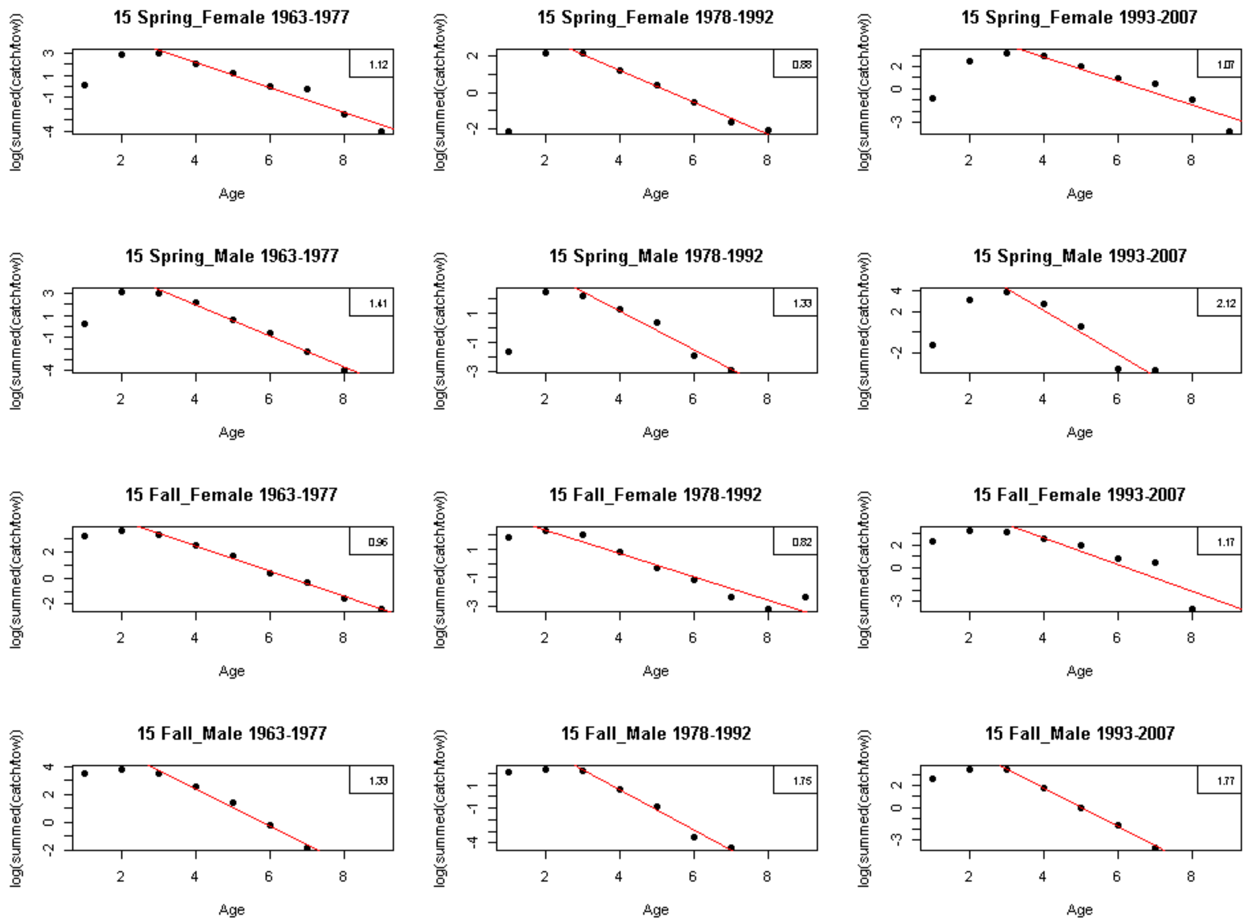

Figure 25. Static catch curves for blocks of 15 years by season and sex. The red lines show regressions beginning at age 3 and the numbers in the upper right corner of each plot is the corresponding total mortality estimate.

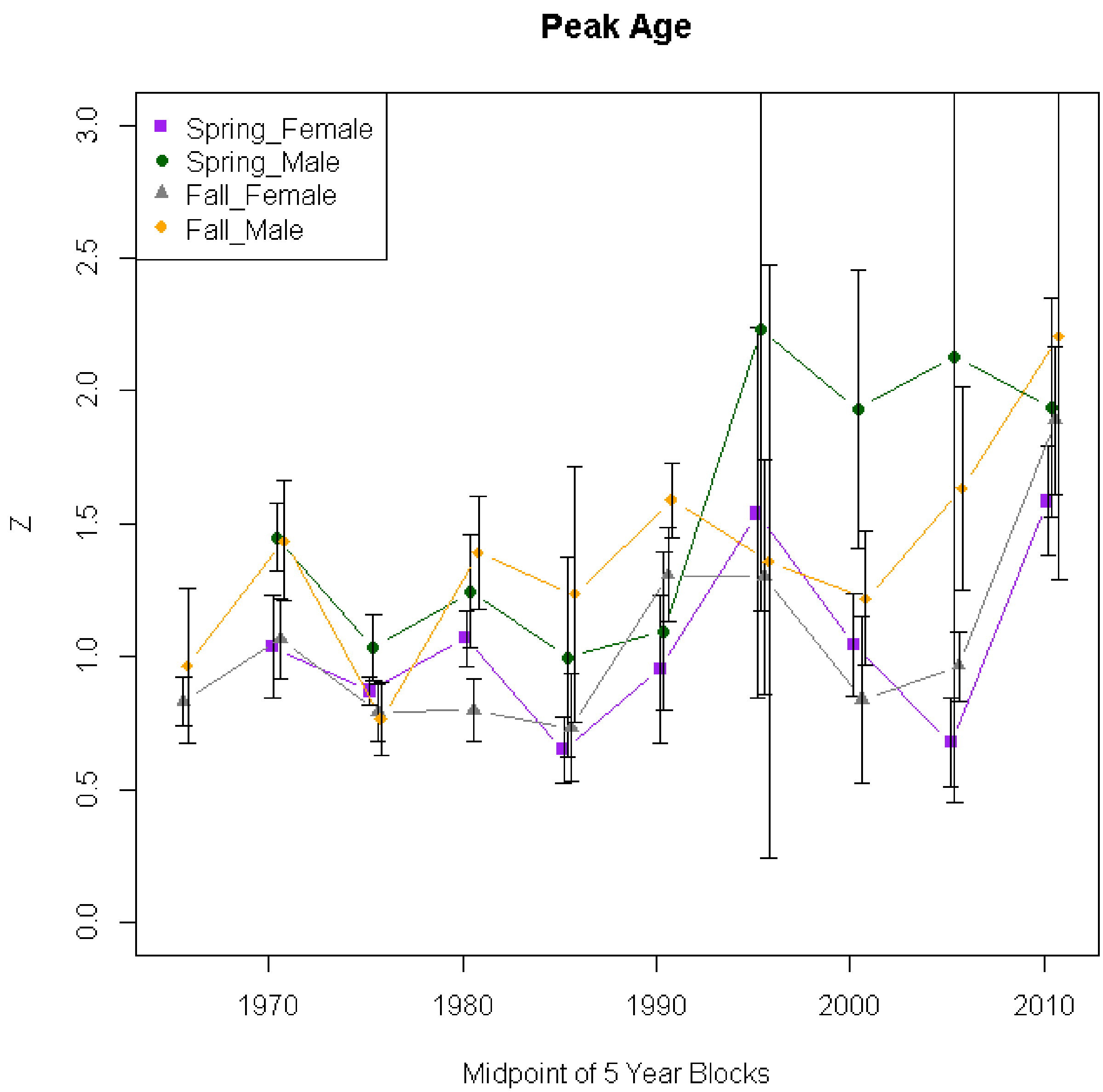

Figure 26. Static catch curve estimates of total mortality (error bars denote 80% confidence intervals) for blocks of 5 years by season and sex from the NEFSC bottom trawl surveys when the peak age is used to in the estimation of Z.

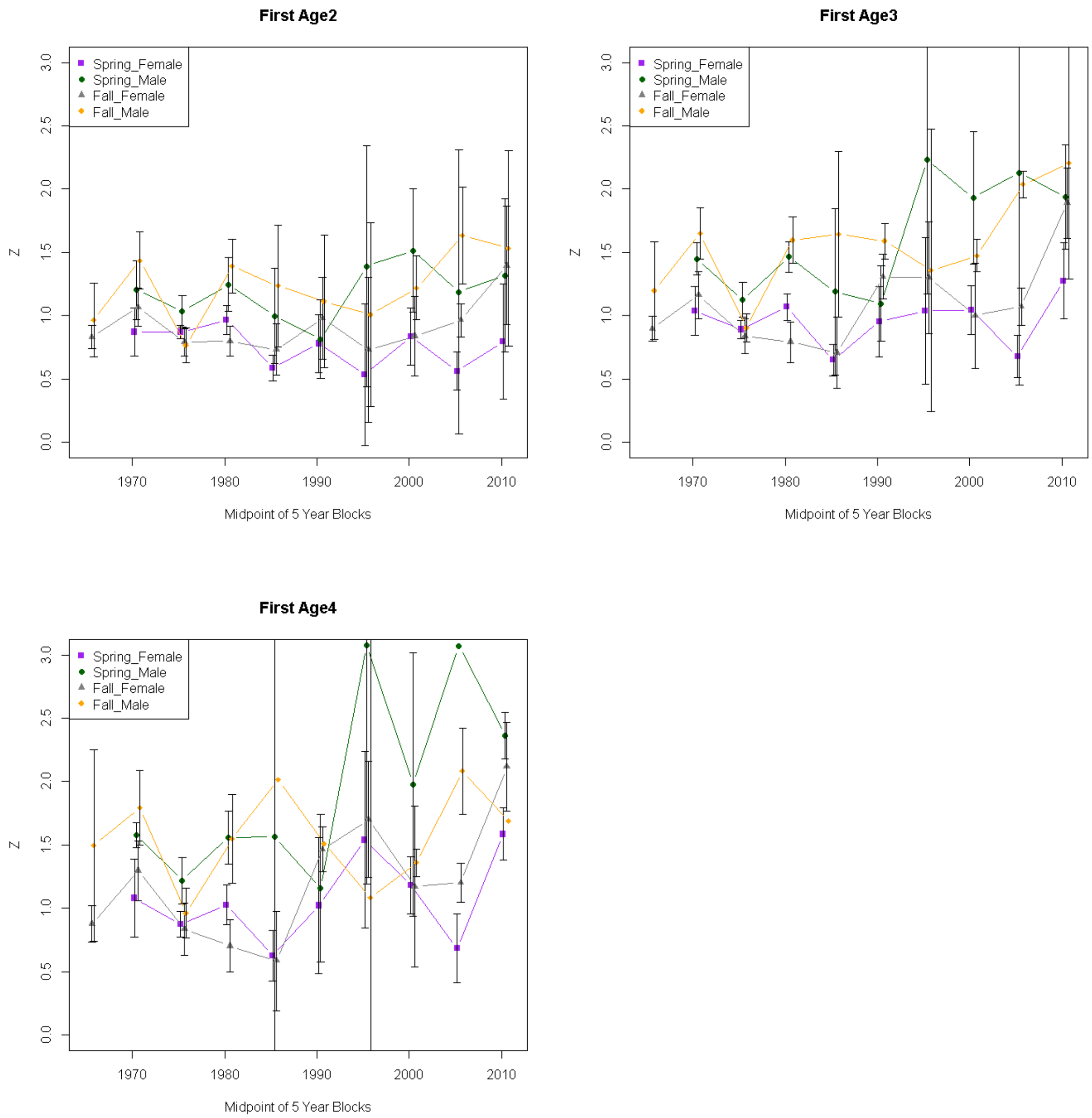

Figure 27. Static catch curve estimates of total mortality (error bars denote 80% confidence intervals) for blocks of 5 years by season and sex from the NEFSC bottom trawl surveys when the first age used in the estimation of Z is 2, 3, or 4.

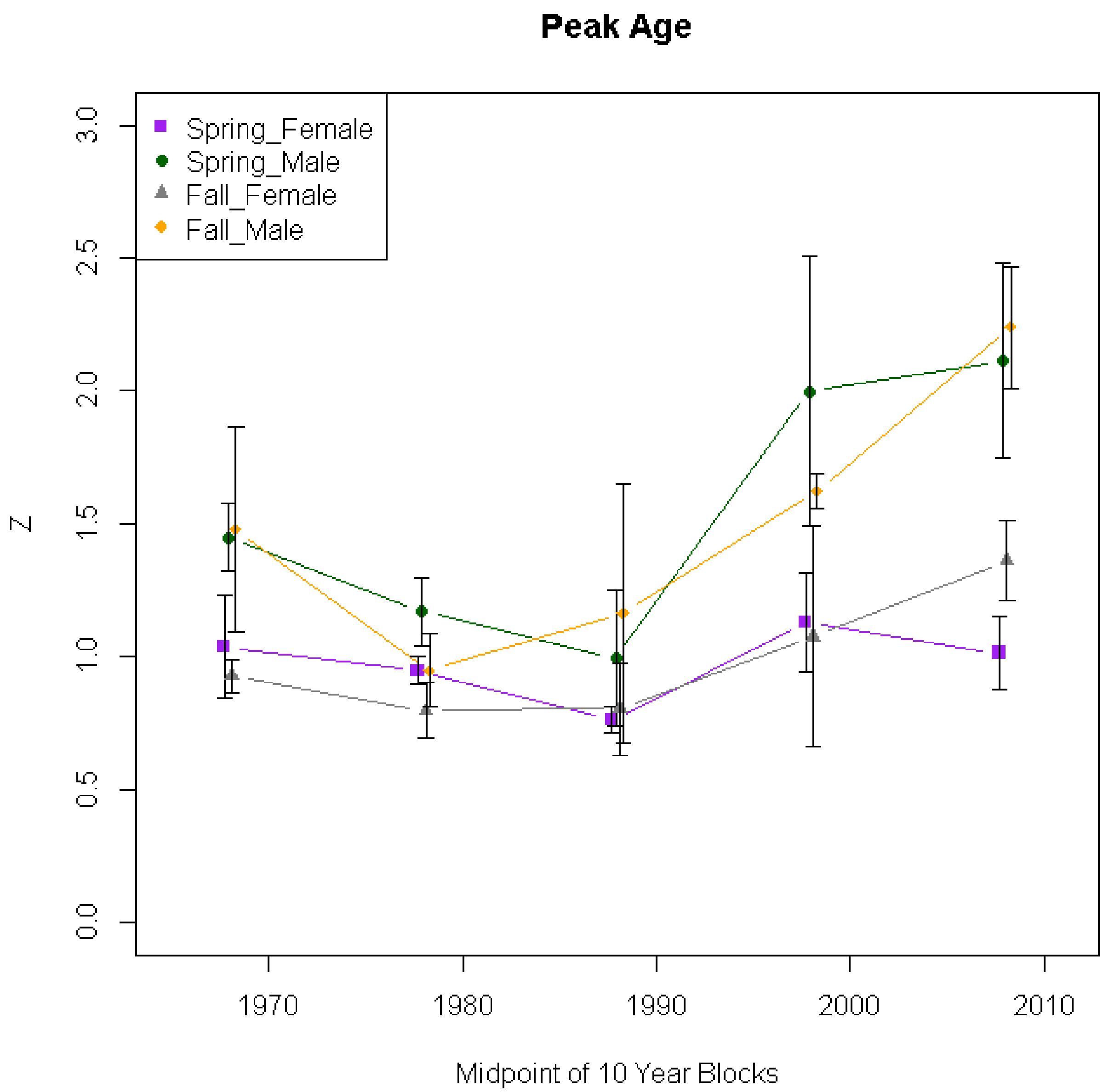

Figure 28. Static catch curve estimates of total mortality (error bars denote 80% confidence intervals) for blocks of 10 years by season and sex from the NEFSC bottom trawl surveys when the peak age is used to in the estimation of Z.

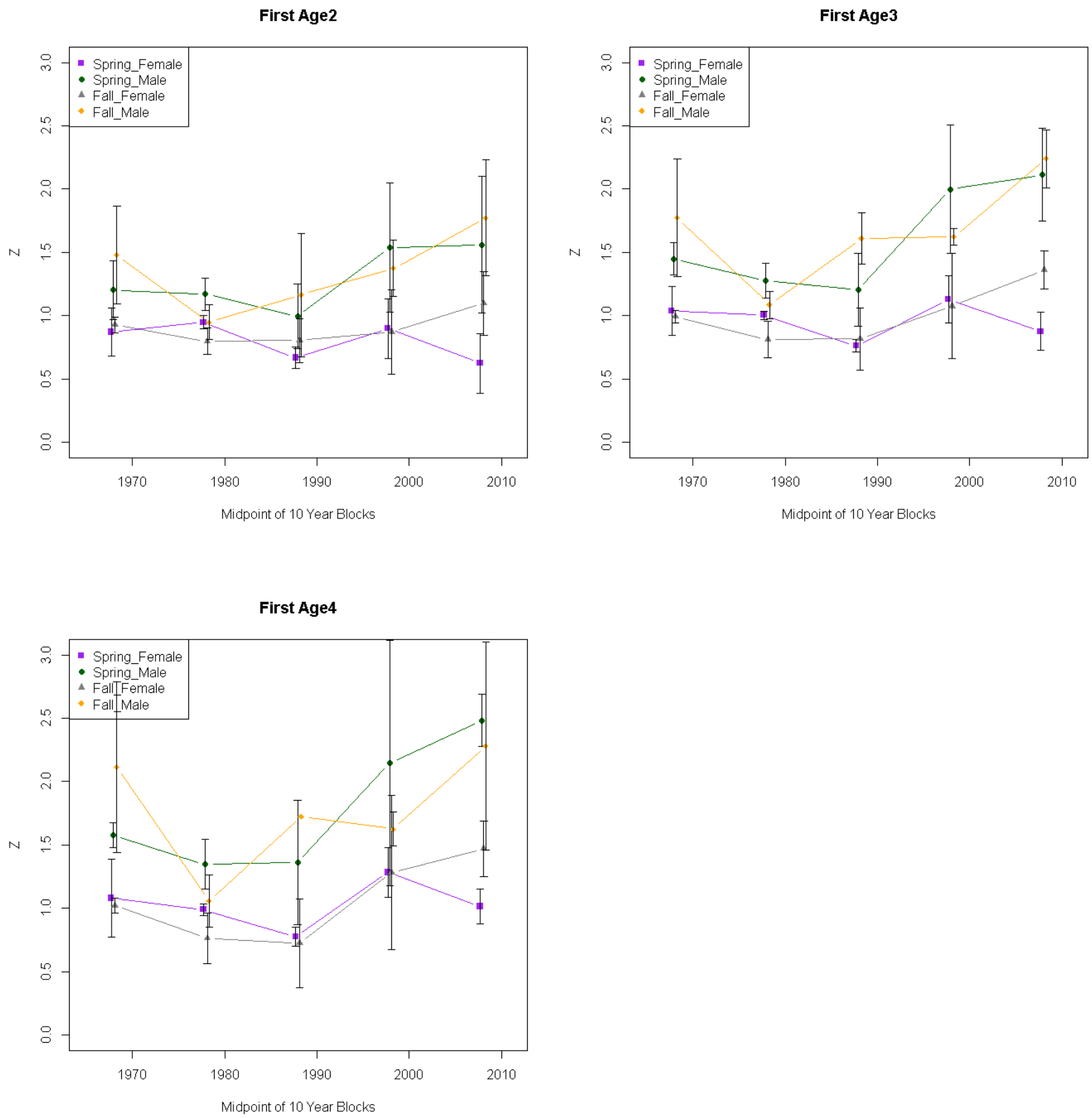

Figure 29. Static catch curve estimates of total mortality (error bars denote 80% confidence intervals) for blocks of 10 years by season and sex from the NEFSC bottom trawl surveys when the first age used in the estimation of Z is 2, 3, or 4.

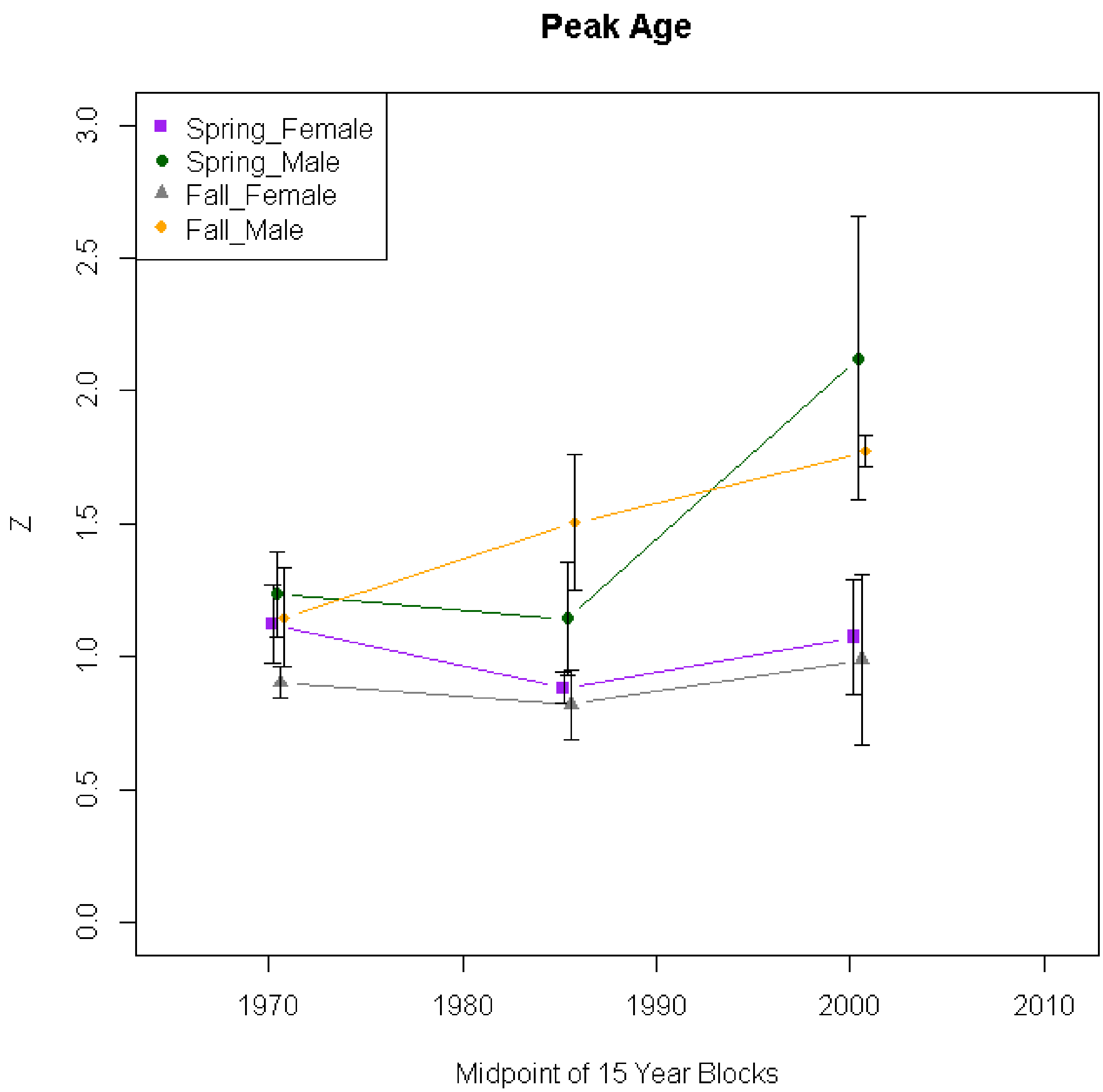

Figure 30. Static catch curve estimates of total mortality (error bars denote 80% confidence intervals) for blocks of 15 years by season and sex from the NEFSC bottom trawl surveys when the peak age is used to in the estimation of Z.

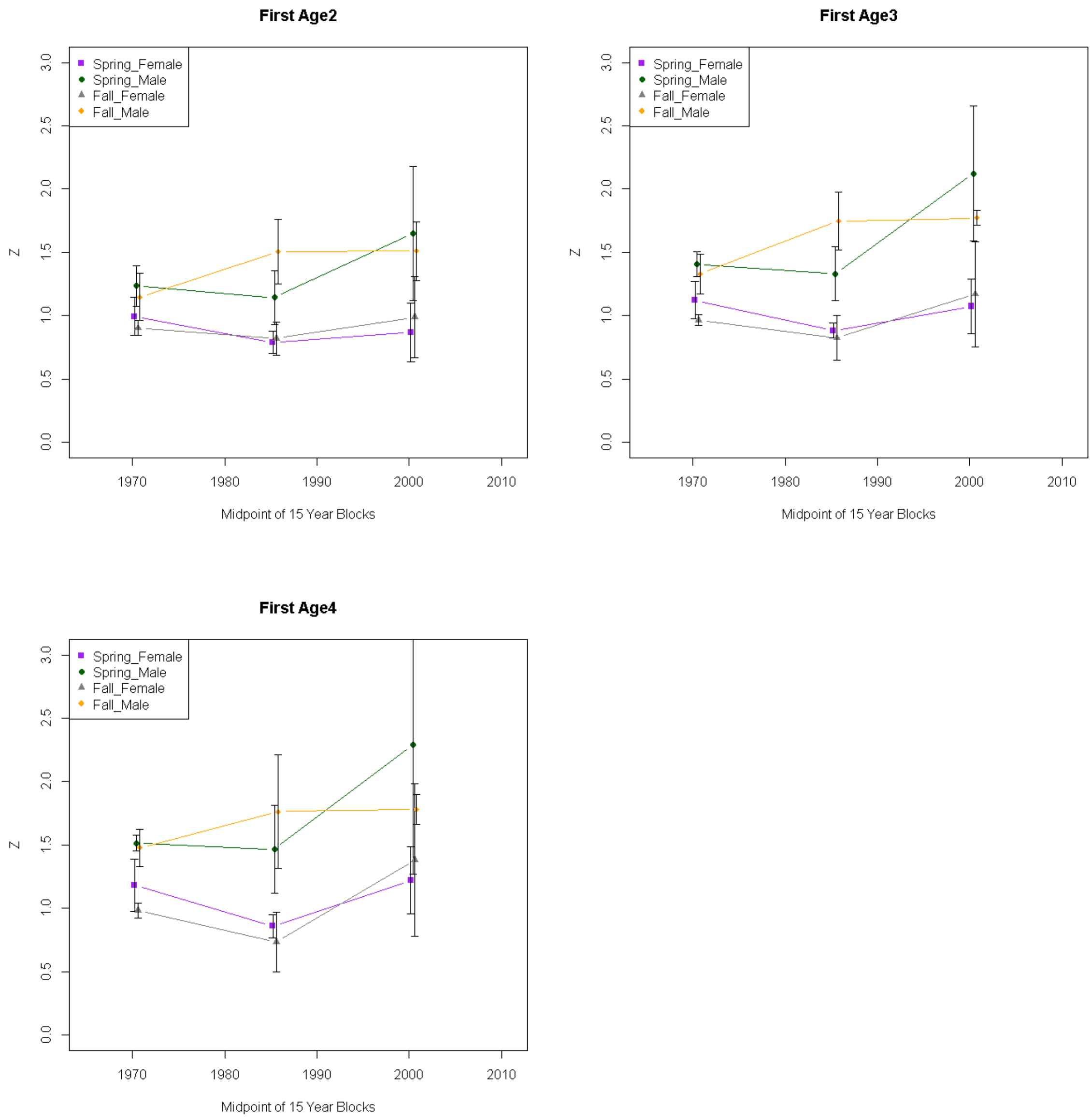

Figure 31. Static catch curve estimates of total mortality (error bars denote 80% confidence intervals) for blocks of 15 years by season and sex from the NEFSC bottom trawl surveys when the first age used in the estimation of Z is 2, 3, or 4.