



New England Fishery Management Council

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C.M. "Rip" Cunningham, Jr., *Chairman* | Thomas A. Nies, *Executive Director*

MEMORANDUM

DATE: July 26, 2013
TO: Groundfish Oversight Committee
FROM: Groundfish Plan Development Team (PDT)
SUBJECT: **PDT Conference Call, June 17, 2013**

The PDT held a conference call to discuss (1) **haddock spillover** (whether Georges Bank haddock spill over into the Gulf of Maine haddock stock area), (2) **Amendment 18** (fleet diversity and accumulation limits) and (3) **other business**.

Participants

NEFMC Staff	Jamie Cournane, PhD (PDT Chair), Fiona Hogan, PhD, and Rachel Feeney (A18 lead)
NMFS NERO	Michael Ruccio, Sarah Heil, Dan Caless, and Will Whitmore, PhD
NEFSC	Paul Nitschke and Michael Palmer
State	Sally Sherman (ME DMR) and Steven Correia (MA DMF)

1. Haddock Spillover

At the April, 2013 NEFMC meeting, the Council passed a motion:

To task the PDT and SSC to examine the issue of GB haddock spillover into the GOM stock area, provide an estimate of the amount of spillover when large year classes of GB haddock occur, and provide suggestions as to how the anticipated spill over of the strong 2010 year class can be used to adjust the GOM haddock ABC for FY 2013, 2014 and 2015.

The PDT explored whether there is evidence of haddock spillover from the Georges Bank (GB) haddock stock to the Gulf of Maine (GOM) haddock stock. The PDT is concerned that spillover is an inexact term than can cover a broad range of mechanisms (i.e., some synchrony with year-class strength, movement of haddock from one stock area to another).

The PDT completed a literature review and several analyses (projections scenarios, survey diagnostics, year class analyses, survey and assessment cohort tracking, assessment diagnostics,

and assessment results with regards to the strong GB 2003 year class) in order to address the question of haddock spillover. These are summarized below, with more detailed analyses, including tables and figures of results, in the appendices.

1.1. Literature Review (see Appendix A)

The literature indicates movement occurs between the GB and GOM stocks. However, none of the research set out to quantify the magnitude of the movement. Haddock tagging studies extend back to the early 1900s and have primarily been used in terms of stock identification and general movement patterns. Needler (1930) determined that temperature was significant in determining movement. Few Maine haddock went east; they moved more to the south and west. Nantucket Shoals haddock were thought to move south of the banks in the winter and were replaced by haddock from the north or shallow water on GB in the winter. There was no definitive evidence but some mixing or wandering occurred in New England. Growth patterns were different between GB and Nantucket Shoals; based on summer samples, GB grew more slowly indicating that in the summer this is a distinct stock to that of Nantucket Shoals.

Grosslein (1962) considered offshore migration to be limited. Mixing occurred between Passamaquoddy Bay and Subarea 5. Based on unpublished tagging data, 4X – 5Y stock moved south to Jeffrey’s ledge in the winter; some go to South Channel and northwest GB. McCracken (1960) concluded that the Passamaquoddy Bay haddock population was supported by spring recruitment from haddock migrating northward along the coast of the GOM and Bay of Fundy.

Halliday and McCracken (1970) tagged haddock off Digby, Nova Scotia; the majority of the recaptures occurred within 4X with a small number of recaptures on GB (5Z). Based on age estimates, Colton (1955) concluded based on distribution of age 0 haddock and strong year classes in 1948 and 1950 that “the recruitment of the Georges Bank stock is dependent upon fish spawned in or inhabiting, during their first year of life, areas outside the limits of Georges Bank, as well as those fish spending their complete life cycle on the bank proper.”

Begg (1998) reviewed literature on stock identification of haddock in the Northwest Atlantic Ocean. The studies reviewed generally agreed on three broad stock areas, New England, Nova Scotia and Newfoundland, but the level of separation varied with technique utilized. Begg concluded that the management units may include multiple discrete populations and recommended the use of more recently developed stock identification techniques or a combination of techniques to improve knowledge of haddock stock structure.

More recent tagging studies focused tagging effort around the closed areas (Brodziak and Col, 2006) and noted movements in all directions; GB haddock moved north and east while GOM haddock moved to the northwest. The vast majority of haddock tagged on GB remained on GB but some movement to the GOM was observed; this study suggests a ten percent transfer from GB to GOM (Brodziak and Col, 2006). However, the same estimate is not provided in the later study after more tag returns had been received (Brodziak et al., 2008a). A similar pattern was observed for WGOM tagged haddock; the majority stayed in the GOM but some moved to GB. Brodziak et al. (2008b) determined recruitment on GB and GOM age 0 survey catch were correlated between 1963 and 2004. Only one year in the survey time series, 2003, showed a

change in the trend of synchronous large year classes on GB and GOM; in that year the GOM stock remained small and the center of focus for the GB stock was more southwest on GB than in previous large year classes. Grosslein and Hennemuth (1973) also found evidence for such a link although there have been exceptions, e.g. 1978 year class was strong on GB but not in GOM.

1.2. Revisiting Brodziak et al. (2008a) (see Appendix B)

Recruitment on GB and GOM age 0 survey catches were correlated between 1963 and 2004 ($R=0.53$) (Brodziak et al. 2008a). This means that the synchrony of the recruitment events (covariance of GOM recruitment and GB recruitment) accounts for 28% of the total variance, leaving 72% unexplained. Although the correlation is significant, any correlation above 0.3 would be statistically significant given the length of the time series (1963-2004). From a linear model perspective, the regression's prediction of GOM recruitment from GB age 1 explains more variation than using the mean GOM recruitment.

It was suspected that Brodziak et al. was using the Spearman rank correlation method (although not specified in the paper). In this case, a correlation coefficient of 0.53 is moderate at best, and therefore it is unclear whether 2003 was atypical because the association is not a particularly strong one. It would be expected that that association would be much stronger if only 2003 year class was the only not synchronous point.

Furthermore at the time that Brodziak et al. wrote their paper, the GOM haddock assessment was index based. They had no way to assess the influence of recruitment on GB on GOM stock recruitment. In the context of interpreting the meaningfulness of the age 0 association to the spillover question, a better question may be how well does the age 0 index predict recruitment to the fishery?

Therefore, an examination of age 0 indices was conducted to check the robustness of the estimate of the correlation coefficient. On the question of spill-over, is the mechanism synchrony at age 0 indices or migration of adults from GB into GOM?

Using alternative methods, the rank of the 2003 year class does not seem to be atypical. The ranks of 2003 (36 in GOM, 42 on GB) would be supportive of relative synchrony at age 0. GB index was high and GOM low in several years (1966, 1983, 1985, and 1972) and the GOM index ranked higher than the GB index in other years (1979, 1982, and 1997). Using different ranking methods, it was concluded that tight synchrony at age 0 was not apparent. Furthermore, 2003 does not stand out as atypical of a synchrony pattern.

1.3. Consequence Analysis (see Appendix C)

Diagnostic issues should be evident in the GOM haddock assessment if spillover occurs since the two haddock assessments assume no movement between the stocks. Clear diagnostic issues due to a possible influx of the 2003 GB year class were not observed in either the survey residual pattern or the age-1 retrospective of the 2012 updated GOM haddock assessment. The surveys show very strong cohort signals which would not be expected if spillover was occurring since spillover would tend to obscure the cohort signal. There is also a relatively small decrease in the

estimate of the 2003 year class as years are omitted from the model. If spillover was occurring and the strong 2003 GB year class was moving into the GOM then one would expect a large continual increase in the estimated GOM 2003 year class with time.

There is little evidence from the NMFS trawl survey distribution that supports movement from one stock to the other. The deep central part of the GOM appears to provide a barrier for stock separation which was also evident in the tagging studies. There was little evidence for movement in the survey data but updated indices at age suggest that the 2010 (t+1 age-1) year class may be stronger than the geometric mean assumption used in the 2012 groundfish update.

Any spillover effects of the 2010 year class have relatively minor effects on the catch estimates in 2013 since selectivity on age 3 fish is relatively low (9%) in the projections. The consequence projections suggest that most of the catch in the GOM would be coming from GB fish comprised of the single 2010 year class from 2014 to 2018 with net movement rates greater than 2% from GB to the GOM. The consequences of setting catch based on movement rates, if in fact movement was not occurring, would be severe for the GOM stock. Maturity, weights at age and selectivity difference between the haddock stocks also suggests there is separation between the stocks.

1.4. Year Class Analyses (see Appendices D- F)

Year class signals (see Appendix D).

The change in minimum size applied to both GB and GOM haddock stocks (see Framework 48 to the Groundfish FMP). There is a strong discard signal for the 2003 year class on GOM, but not for the 2000 year class. The strongest year class signal in the discards-at-age comes from the 1998 year class which was the largest year class within the assessment time series. There is some consistency in the recruitment between the two stocks, but the relationship is weak. Furthermore, NEFSC fall survey data indicates very strong cohort tracking over time and the cohort signal from some of the stronger year classes (1998 and 2003) tracks quite well with the size of the cohort decreasing over time. This seems to run contrary to the expectation if the GOM haddock signal was being overwhelmed by even a very small amount of GB haddock.

Predicting age 3 abundance in the GOM from age 1 recruitment on GB (see Appendix E).

One might expect to see strong relationship of cohorts between GB and GOM stocks under the hypothesis of spill-over of large year classes. Linear regression of GB age 1 abundance to predict GOM abundance at age 3, was lagged forward 2 years. Both response and predictor variables were log transformed. The regression was statistically significant ($p < 0.001$). Based on the GB age 1 abundance estimate of 748,016 fish in 2011, the GOM abundance at age 3 in 2013 is predicted to be 6,037,000 fish with 95% prediction limits of 609,000 to 59,849,000. The expected value of approximately 6 million haddock would be the 2nd highest value in the time series. The 95% prediction limits are relatively wide, covering values that are below the long term median to a value that is approximately 5 times higher than the maximum abundance in the assessment.

Predictions of age 3 abundance in the GOM from age 1 abundance in GB appear to be highly uncertain. The size of age 1 abundance on GB does not seem to be a reliable way to predict

future cohort strength in the GOM. Altering the GOM ABC as a result of a large year class on GB does not seem reasonable given the weak predicative power of the relationship between year class abundance in the two assessments.

Concordance among abundance at age indices from two stock areas (see Appendix F).

A comparison of the concordance of survey haddock indices at ages from GB stock area and GOM stock area with survey abundance at age indices from the GOM was conducted. Under the hypothesis that older GB fish spill-over into the GOM, it might be expected that younger age GOM abundance at age indices would not track cohorts at older ages within the GOM as younger GB abundance at age indices do. It was found that GOM abundance at age indices had higher correlations with older GOM abundance at age indices than corresponding GB abundance at age indices. Paired comparisons of Kendall rank correlation coefficients indicated that differences between GB and GOM indices were statistically significant. GOM indices had higher concordance with older GOM indices than GB indices.

1.5. Do Georges Bank haddock move into the Gulf of Maine? (see Appendix G)

If spillover of GB haddock into the GOM occurs then some evidence for this should be seen in the 2012 updated Gulf of Maine (GOM) haddock assessment, since a strong 2003 year class occurred on Georges Bank while a moderate 2003 year class was seen in the Gulf of Maine. Furthermore, diagnostic issues should be evident in the GOM haddock assessment if spillover occurs since the two assessments assume no movement between the stocks. Clear diagnostic issues due to a possible influx of the 2003 GB year class were not observed in either the survey residual pattern or in the age 1 retrospective of the 2012 updated GOM haddock assessment. There is a relatively small decrease in the estimate of the 2003 year class as years are omitted from the model. However, if the strong 2003 GB year class resulted in some movement of fish into the GOM then one would expect a large continual increase in the estimated 2003 year class with time.

Examination of the model diagnostics and updated survey data suggests spillover was not a large issue with the strong 2003 year class on GB. Updated survey data suggests the 2010 year class may be stronger than the geometric mean estimate (1977-2010).

1.6. Additional Information about Haddock Stock Assessments

The haddock spillover problem statement document by the Associated Fisheries of Maine submitted to the Council contains this quote from Brown's (2001) stock assessment document:

"The Gulf of Maine haddock stock was last assessed at SAW/SARC 2 in 1986 (NMFS-NEFSC 1986). At the time of the 1986 assessment, landings had declined from 7,600 mt in 1983 to 3,000 mt in 1985. Although no formal analysis of fishing mortality was attempted, fishing mortality was assumed to be relatively high. The fishery in the mid-1980s was being supported by spill over of large year classes from Georges Bank, and research vessel surveys indicated that recruitment in the Gulf of Maine was extremely poor. The Gulf of Maine haddock stock was not updated during the 1999 assessment process for groundfish stocks (NDWG 2000)."

This statement was made in the absence of an age-based assessment for the GOM haddock stock, so despite the specificity, it should be considered in the context of the information available at the time. The age-based assessments first developed for GOM haddock in 2008 do not support this statement. The statement is correct that there was poor recruitment in the mid-1980s, but the GOM haddock fishery during mid-1980s was not exploiting those year classes. The majority of the GOM haddock catch in the mid-1980s was of fish spawned in the late 1970s and early 1980s. The partial recruitment patterns from both the 2008 and 2012 assessment show that in the mid-1980s the fully selected ages ranged from age 3 to 6. Prior to the poor recruitment in the mid-1980s there was a five year consecutive period of moderate to strong recruitment during 1976-1980. The strong recruitment during this five year period is generally supported by the NEFSC spring and fall survey indices. The 1978 year class is the second largest year class within the assessment time series and was a major contributor to the catch in the mid-1980s.

In summary, the poor recruitment of GOM haddock in the mid-1980s would have had negligible impact on the fishery catches during this period and there is strong evidence in the catch-at-age information that fishery catch was directly related to moderate to strong GOM haddock year classes in the late 1970s and early 1980s. The evidence does not support the statement that the GOM haddock fishery was supported by 'spillover' from the adjacent GB haddock stock.

1.7. PDT Consensus Statement on Haddock Spillover Issue

The PDT explored whether there is evidence of haddock spillover from the GB haddock stock to the GOM haddock stock. The PDT is concerned that spillover is an inexact term that can cover a broad range of mechanisms (i.e., some synchrony with year-class strength, movement of haddock from one stock area to another).

The PDT completed a literature review and several analyses (projections scenarios, survey diagnostics, year class analyses, survey and assessment cohort tracking, assessment diagnostics, and assessment results with regards to the strong GB 2003 year class) in order to address the question of haddock spillover. From the literature and tagging studies, there is evidence of some movement of haddock stocks between GB and the GOM areas, and in particular fishery statistical area 521; however the exchange rates between these areas are not well characterized.

Projection scenarios conducted by the PDT reveal that net movement rates greater than 2% of just the 2010 GB year class into the GOM would quickly inundate the GOM stock with GB haddock due to large differences in stock sizes between GB and GOM. Assuming relatively small percentages of net movement into the GOM will have large consequences for the GOM stock if spillover is not occurring. These projections suggest that ad-hoc adjustments of quota for spillover increase the risk of overfishing and spawning biomass decline for the GOM stock in 2014 and beyond.

The PDT also investigated the 2003 GB year class. Spillover of just 1% of the large 2003 GB year class would have approximately doubled the size of the GOM 2003 year class and obscured cohort signals within the survey indices. If spillover of GB haddock were occurring in these large quantities, it would add considerable variability to survey indices, making the tracking of cohorts within the GOM stock difficult and introduce diagnostic issues into the stock assessment model.

Examination of the tracking of cohorts within survey indices at age as well as assessment model diagnostics (survey residuals, retrospective patterns) yielded no evidence to support a spillover of a detectable magnitude. In addition, the PDT finds some synchrony in year classes, although the association is positive, the strength of the association is weak to moderate (with only 4 to 26% explanatory power), generally explaining a small amount of variation in Gulf of Maine recruitment. Furthermore, some correlation in year class strength could be due to similar environmental conditions in both stock areas.

Based on the PDT's literature review and analyses on the potential for haddock spillover from the Georges Bank haddock stock to the Gulf of Maine haddock stock, the PDT is unable to provide a technical basis for adjusting the quota between the two stocks.

2. Amendment 18

Ms. Feeney provided an update on Amendment 18 and an overview on its development. The PDT reviewed the draft analyses conducted by PDT members on identifying trends in fleet diversity and concentration of holdings in the groundfish fishery, as well as the preliminary review of the impact of permit banks on fleet diversity. The analysis of fleet diversity tracked "species" of fishermen, 1994-2011, defined by unique combinations of gear type, vessel size, primary landing port county, and primarily fishing inshore and offshore. Generally, fleet diversity has declined through the time series, but it is outpaced by the rate of fleet size decline. Further analysis could include dependency on groundfish as a species attribute. The work on fishery concentration has a number of caveats related to treatment of the data. However, the data generally show increasing concentration in the years leading up to catch share implementation, and a leveling off period since. Collectively, permit banks are fostering fleet diversity due to the diversity of industry segments that they support individually. A more thorough analysis may help quantify to what extent.

The PDT also discussed the recommendations made by the Advisory Panel on June 10 for revising the goals and objectives of the action, as well as the related motions made by the Groundfish Committee on June 12. Several of the Committee motions task the PDT with analyses related to the development of Amendment 18. The PDT did not delegate tasks, pending the outcome of the Amendment 18 discussions at the June 19 Council meeting.

3. Other Business

Sector Concerns

The PDT discussed the issue of "assumed discards". Several PDT members pointed out that a sector manager has the ability to assign discard rates to members of the sector. Dr. Whitmore suggested that sector managers might benefit from additional training on applying these rates. It could however be done on an individual basis.

Dr. Whitmore also noted that NERO is working on a solution to the Eastern GB cod reporting issue.

Mr. Ruccio informed the PDT that in response to the letter from David Goethel, that NERO is working through confidentiality issues but aims to get closer to prices for leasing. He also informed the PDT that there are currently 4 lawsuits on the May 1, 2013 actions.

APPENDICES

Appendix A: Literature review of haddock spillover, Fiona Hogan, PhD

The two haddock stocks, in 2013, have largely differing ABCs with Georges Bank (GB) being approximately 100 times the size of the Gulf of Maine (GOM) stock size. This prompted the Council to pass the following motion:

{To} recommend the Council request NMFS implement by Emergency Action a measure that will attribute up to 10% of GB haddock quota to the GOM haddock quota and up to 10% of the GOM haddock quota to GB haddock quota.

The PDT was tasked with identifying an appropriate percentage that adequately reflects the current level of mixing between GB and GOM management areas.

A literature review indicated that mixing on some level occurs between the two stocks but no studies were found that were able to quantify mixing between management areas based on tagging data. Haddock tagging studies extend back to the early 1900s and have primarily been used in terms of stock identification and general movement patterns.

Needler (1930) determined that temperature was significant in determining movement; seasonal migrations, sometimes over considerable distances, were thought to be temperature related as haddock try to avoid temperatures between 0 and 12 C, based on catch. Needler (1930) identified three stock regions, the Nova Scotian, the New England and the Newfoundland regions. The New England region consisted of GB, the South Channel and inshore grounds of the New England coast. "The greatest area in the 'New England region' is on Georges Bank, in the South channel and on Nantucket shoals. This is connected with an area to the west supporting only a small haddock community for part of the year, and with a narrower but well-populated belt along the west and north shores of the Gulf of Maine." Based on two percent tag returns in waters adjacent to Mount Desert island, the findings suggested haddock leave that area in the coldest months but return in warmer months; movement was thought to be to the southwest in winter. The GB recapture was considered to have strayed from the Mount Desert area. Some mixing was noted between GB and near White Island, ME. There was no mixing between New England and Nova Scotian region; this was attributed to the deep water separating the two regions. Few Maine haddock went east; they moved more to the south and west. Nantucket Shoals haddock were thought to move south of the banks in the winter and were replaced by haddock from the north or shallow water on GB in the winter. There was no definitive evidence but Needler speculated that some mixing or wandering occurred in New England. Growth patterns were different between GB and Nantucket Shoals; based on summer samples, GB grew more slowly indicating that in the summer this is a distinct stock to that of Nantucket Shoals.

Grosslein (1962) considered offshore migration to be limited. Mixing occurred between Passamaquoddy Bay and Subarea 5. Based on unpublished tagging data, 4X-5Y stock moved south to Jeffrey's Ledge in the winter, while some go to South Channel and northwest GB. Three stocks were identified in subarea 5, the 4X-5Y stock, GB stock east of the south channel, and one inshore extending from Nantucket Shoals just south of Cape Cod to Jeffrey's Ledge.

Based on tagging data, McCracken (1960) concluded that the Passamaquoddy Bay haddock population was supported by spring recruitment from haddock migrating northward along the coast of the GOM and Bay of Fundy.

Halliday and McCracken (1970) tagged haddock off Digby, Nova Scotia; the majority of the recaptures occurred within 4X with a small number of recaptures on GB (5Z). Roughly 15% of haddock were recaptured (148 out of 981) tagged in 1963 and 1966.

Based on age estimates, Colton (1955) concluded based on distribution of age 0 haddock and strong year classes in 1948 and 1950 that “the recruitment of the Georges Bank stock is dependent upon fish spawned in or inhabiting, during their first year of life, areas outside the limits of Georges Bank, as well as those fish spending their complete life cycle on the bank proper.”

Begg (1998) reviewed literature on stock identification of haddock in the Northwest Atlantic Ocean. Begg outlined the general life history and geographic distribution for the species. Various techniques have been used to identify stocks of haddock in this region including tagging, demographics, spawning and recruitment patterns, meristics, parasites and genetics. The studies reviewed generally agreed on three broad stock areas, New England, Nova Scotia and Newfoundland, but the level of separation varied with technique utilized. Begg concluded that the management units may include multiple discrete populations and recommends the use of more recently developed stock identification techniques or a combination of techniques to improve knowledge of haddock stock structure.

More recent tagging studies focused tagging effort around the closed areas and noted movements in all direction; GB haddock moved north and east while GOM haddock moved to the northwest (Brodziak and Col, 2006; Brodziak et al., 2008a). The vast majority of haddock tagged on GB remained on GB but some movement to the GOM was observed; this study suggests a ten percent transfer from GB to GOM (Brodziak and Col, 2006).

However, the same estimate is not provided in the later study after more tag returns had been received (Brodziak et al., 2008a). A similar pattern was observed for WGOM tagged haddock; the majority stayed in the GOM but some moved to GB. It is unclear what effect age/length has on movement patterns (i.e., the haddock tagged in this study were scrod size). Brodziak et al. (2008a) indicated a low growth rate using growth estimations from tagging data. Movement rates could not be estimated from this study based on low tag returns. Brodziak et al. (2008a) concluded there was movement between GB and GOM and vice versa haddock also move between EGB and WGB management units.

Brodziak et al. 2008a wrote :

“The available tag-recapture data also indicate that some haddock move between Georges Bank and the Gulf of Maine. Further, if fishing effort and reporting rates were homogeneous in time and space, the available data would suggest that the probability of individual fish movement between regions may be on the order of 10% per year. This is a crude approximation and the assumption of homogeneous effort is not likely met since recent average fishing mortality during

2005-2007 differed between the Georges Bank (FAVG=0.26, unweighted average of ages 5-8, Brooks et al. (2008)) and the Gulf of Maine (FAVG=0.36, unweighted average of ages 6-8, Palmer et al. (2008)) regions. Overall, the application of finer scale analyses using an appropriately modified tag-recapture model (e.g., Miller and Andersen (2008)) would be necessary to directly estimate movement rates.”

And in the conclusions section:

“Given the limited number of tag recaptures available and lack of information on fishing effort, reporting rates and haddock mortality rates, no attempt was made to estimate movement rates in this report.”

Brodziak et al. (2008b) also examined NEFSC survey data and noted that the exceptional 1963 year class grew slower than the 1961-1996 average. Recruitment on GB and GOM age 0 survey catch were moderately correlated between 1963 and 2004 ($R=0.53$). Only one year in the survey time series, 2003, showed a change in the trend of synchronous large year classes on GB and GOM; in that year the GOM stock remained small and the center of distribution for the GB stock was more southwest on GB than in previous large year classes. Grosslein and Hennemuth (1973) also found evidence for such a link although there have been exceptions (e.g., 1978 year class was strong on GB but not in GOM). Hypotheses for this synchrony include increased (or decreased) larval survival because of uniform favorable (or unfavorable) environmental conditions and larval transport between the two areas (Clark et al. 1982).

References:

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Appendix B: Revisiting Brodziak et al. (2008a), Steven J. Correia and Mike Palmer

Brodziak et al 2008a wrote :

Spatial distribution plots of the 1963 and 2003 year classes at age-0 (Fig. 9) show that the 2003 YC had amore southwesterly distribution than the comparably abundant 1963 YC. In particular, the distance between the centroids of distribution of the 2003 and 1963 YCs was about 177 km. In 1963, age-0 haddock were abundant in the Gulf of Maine, but in 2003, they were largely absent. This difference in abundance of age-0 haddock in the Gulf of Maine and Georges Bank is atypical since recruitment of Georges Bank haddock was significantly positively correlated with NEFSC age-0 survey catch number per tow in the Gulf of Maine during 1963–2004 ($R = 0.53$). This suggested that haddock recruitment strength in the Gulf of Maine and Georges Bank regions was typically synchronous, but that this pattern did not occur in 2003.

Recruitment on GB and GOM age 0 survey catch were correlated between 1963 and 2004 ($R=0.53$) (Brodziak et al. 2008a). This means that the synchrony of the recruitment events (covariance of GOM recruitment and GB recruitment) accounts for 28% of the total variance, leaving 72% unexplained. Although the correlation is significant, any correlation above 0.3 would be statistically significant given the length of the time series (1963-2004). From a linear model perspective, the regression's prediction of GOM recruitment from GB age 1 explains more variation than using the mean GOM recruitment.

Brodziak et al. (2008a) did not clearly identify their correlation method; however they indicate using rho when describing the correlation. It was suspected that Brodziak et al. was using the Spearman rank correlation method (although not specified in the paper). In this case, a correlation coefficient of 0.53 is moderate at best, and therefore it is unclear whether 2003 was atypical because the association is not a particularly strong one. It would be expected that that association would be much stronger if only 2003 year class was the only not synchronous point. In addition, the 1963 year-class may have high leverage in the estimation of rho, although this information was not provided in the figures in the paper. Figure B1 displays the Spearman ranks of age 0 abundance indices for GOM and GB haddock, 1963-2004. This figure was not provided by Brodziak et al. (2008) but it was assumed that this was their approach.

Furthermore at the time that Brodziak et al. wrote their paper, the GOM haddock assessment was index based. They had no way to assess the influence of recruitment on GB on GOM stock recruitment. In the context of interpreting the meaningfulness of the age 0 association to the spillover question, a better question may be how well does the age 0 index predict recruitment to the fishery?

Therefore, an examination of age 0 indices was conducted to check the robustness of the estimate of the correlation coefficient. Perhaps, the relationship is not strong (as might be expected with age 0 indices), since the age 0 survey index in 2010 was above the 1977-2010 average. However, predicting how well this translates into adult fish is difficult. On the question of spill-over, is the mechanism synchrony at age 0 indices or migration of adults from GB into GOM?

Below is a plot of the ranks of GOM and GB age 0 abundances (Figure B2). In this ranking method, the lowest value gets rank 1, the highest rank 42. The rank mechanism ranks the ties in order of encounter. We have 13 zero observations in the GOM index, so these take on ranks 1-13. The red line is the 1:1 line (perfect correlation). Using this method, the rank of the 2003 year class does not seem to be atypical. The ranks of 2003 (36 in GOM, 42 on GB) would be supportive of relative synchrony at age 0. GB index was high and GOM low in several years (1966, 1983, 1985, and 1972) and the GOM index ranked higher than the GB index in other years (1979, 1982, and 1997). In addition using the same comparison, the Bland-Altman plot (an approach used for paired data) resulted in a similar conclusion (Figure B3).

Brodziak et al. found a correlation coefficient of 0.53. However here using different ranking methods, it was concluded that tight synchrony at age 0 was not apparent. Furthermore, 2003 does not stand out as atypical of a synchrony pattern.

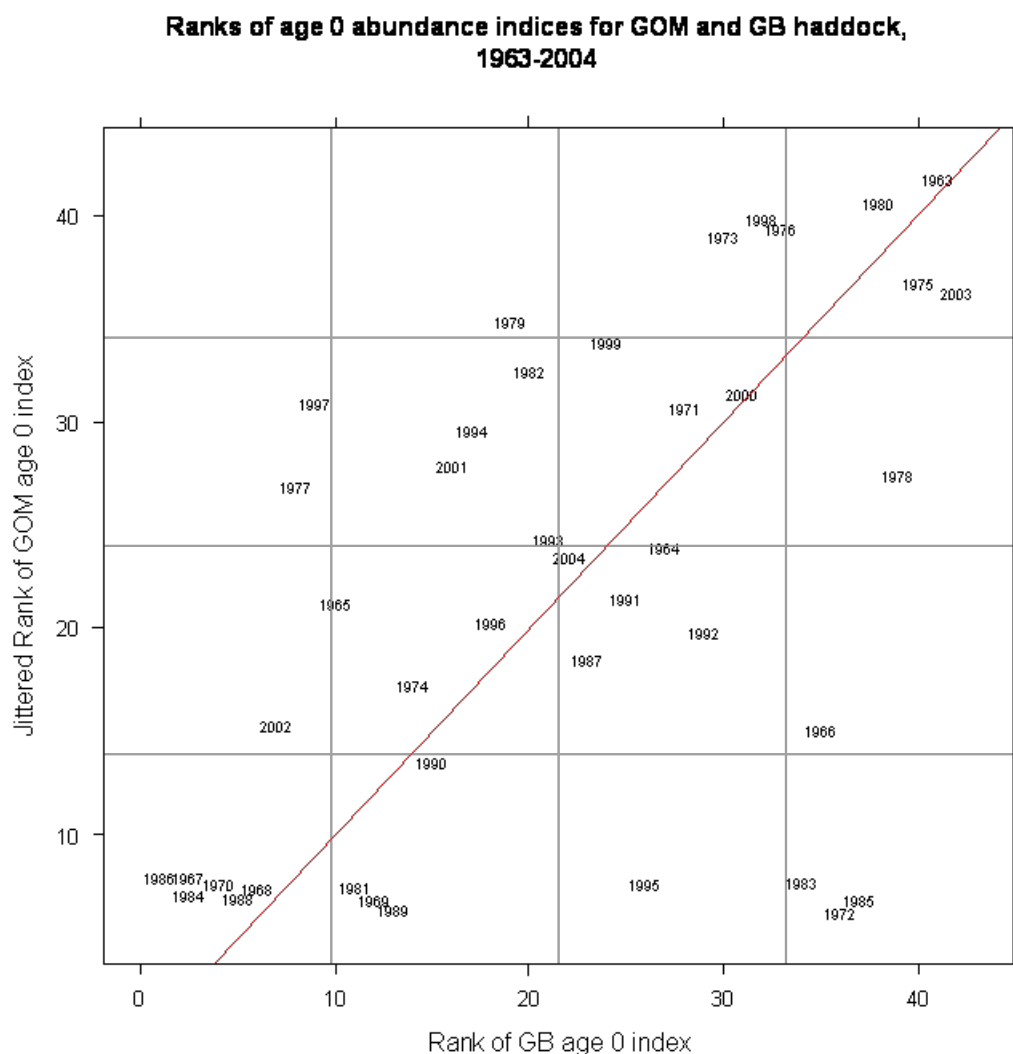


Figure B1: Spearman ranks of age 0 abundance indices for GOM and GB haddock, 1963-2004 (based on Brodziak et al. 2008).

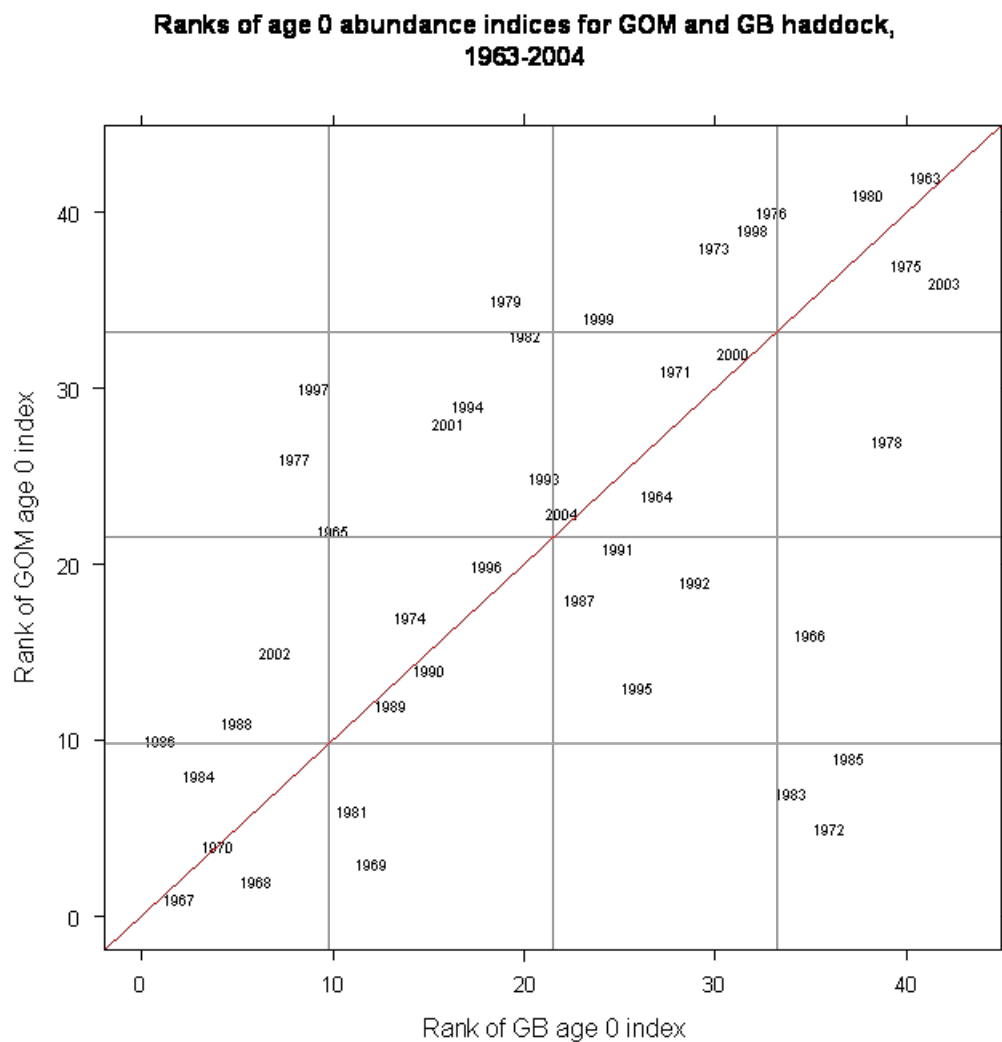


Figure B2: Ranks of age 0 abundance indices for GOM and GB haddock, 1963-2004

Bland-Altman plot of ranks of age 0 abundance indices for GOM and GB haddock, 1963-2004

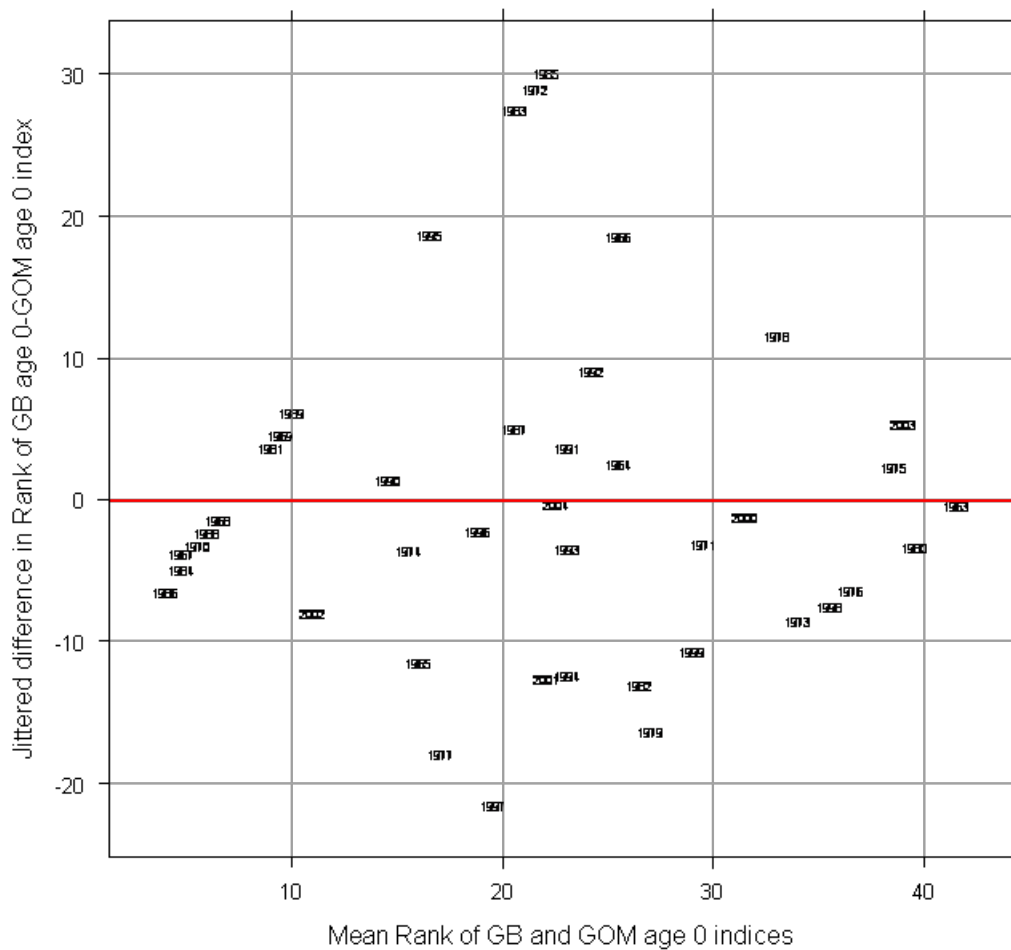


Figure B3: Bland-Altman plot of ranks of age 0 abundance indices for GOM and GB haddock, 1963-2004.

Appendix C: Consequence Analysis, Paul Nitschke

A consequence exercise using AGEPRO projections was conducted that assumed net movement of only the single strong Georges Bank (GB) 2010 year class into the Gulf of Maine (GOM) ranging from 1% to 10%. The 2010 year class was the t+1 age-1 recruitment estimate from the 2012 updated groundfish assessments. Therefore, the t+1 age-1 recruitment estimate tends to be the most uncertain due to the lack information available with age-0 fish in the terminal year of the assessment. The 2012 groundfish update implemented a 59% reduction for the strong direct 2010 Georges Bank haddock estimate (t+1 age-1 recruitment in 2011) which was based on the retrospective changes in the estimate observed for the strong 2003 year class in the past. This consequence exercise also used the same adjusted t+1 Georges Bank haddock estimate (317,433 fish). For the purposes of this analysis, only net movement of the 2010 Georges Bank haddock year class into the Gulf of Maine was considered, since movement of the 2010 Gulf of Maine year class would be insignificant (1,127 fish from the geo-mean estimate) due to the large difference in the stock size estimates.

An exploration of the implications for a range of net age-1 movement rates (1%, 3%, 5%, 8% and 10%) of GB haddock into the GOM stock was examined. The same catch assumptions were used for 2011 and 2012 (as in the original ABC projections), with 75% Fmsy assumed after 2012. Catch implication in 2013 are minor relative to 2014-2015, because of the relatively low selectivity of age 3 fish in 2013 (0.09). The GOM stock is quickly overwhelmed by Georges Bank fish even at low percentages of GB spillover from 2014 to 2018 (Table C1; Figure C1). Most of the catch in the GOM would be coming from Georges Bank fish comprised of this single 2010 year class from 2014 to 2018 with net assumed movement rates at 3% and greater (Table C2). A comparison was also made with the direct estimate of the t+1 recruitment in the GOM haddock assessment. A 1% net movement projection was similar to this projection which assumed a direct estimate of t+1 for the GOM stock.

If spillover was occurring at a higher percentage, it might be apparent in the data, considering how quickly the effect of the GB spillover is seen in the projections. However, the relationship between age 1 haddock from both stocks is weak ($R^2 = 0.004$ and $R^2 = 0.25$ ln transformed; Figure C2).

Additional consequence projections were made by assuming spillover catches were taken from the GOM stock compared to projections that assumed no spillover had occurred. These projections assume the original geo-mean projection is a more accurate reflection of the truth. Not surprising most of the iterations go extinct with high estimates of fishing mortality as the net spillover increases, since most of the catch was originally coming from spillover of Georges Bank fish (Table C3; Figure C3).

Brodziak & Col (2006) suggest a ten percent transfer from GB to GOM, however, this level is not apparent in the surveys (NEFSC & DMF); no major diagnostic issues with the stock assessments have been observed. It should be noted that the earlier assessments were not age-based making it difficult to compare with the current assessment or conclude definitively that the GOM stock was solely supported by the GB spillover. Comparison of assessment estimates of stock numbers at age suggests the 1988 year class was relatively weak in both stocks but the GB

stock had a strong 2003 year class and in the GOM it was estimated as a moderate year class. The GOM stock had a relatively strong 1998 year class and on GB it was estimated as a moderate year class (Figure C1 and Figure C2). The consequence of picking an inappropriate percentage of spillover is evident from the probability of driving a stock to extinction (Table C3).

Potential Conclusion: Based on the projections scenarios, small changes in the assumed spillover can have very large consequences due to the large differences in stock size. No evidence is apparent in the survey and assessment diagnostics, which suggests that if spillover is occurring then it is low.

SSB	abc	direct					
year	geo mean abc	1%	est t+1	3%	5%	8%	10%
2011	2.127	2.136	2.173	2.154	2.172	2.198	2.216
2012	1.711	1.894	2.052	2.254	2.616	3.158	3.511
2013	1.686	2.783	2.987	4.979	7.183	10.48	12.642
2014	2.227	3.718	4.168	6.726	9.731	14.232	17.208
2015	3.023	4.34	4.989	7.015	9.715	13.746	16.402
2016	3.851	4.918	5.544	7.088	9.243	12.467	14.622
2017	4.478	5.257	5.802	6.76	8.285	10.548	12.053
2018	4.951	5.41	5.891	6.348	7.294	8.725	9.66
2019	5.248	5.52	5.922	6.118	6.729	7.632	8.224
2020	5.432	5.576	5.88	5.925	6.276	6.8	7.144
2021	5.54	5.657	5.839	5.857	6.063	6.365	6.565
2022	5.606	5.711	5.79	5.827	5.946	6.125	6.242
2023	5.648	5.708	5.757	5.777	5.845	5.946	6.014
2024	5.658	5.735	5.726	5.774	5.815	5.875	5.915
2025	5.67	5.764	5.711	5.786	5.808	5.842	5.865
2026	5.657	5.694	5.68	5.707	5.72	5.741	5.754
2027	5.677	5.697	5.691	5.705	5.712	5.724	5.732
2028	5.691	5.732	5.698	5.736	5.741	5.747	5.751
2029	5.689	5.718	5.693	5.72	5.723	5.727	5.729
2030	5.699	5.729	5.701	5.73	5.732	5.734	5.735

Table C1: Projected SSB of GOM haddock under varying spillover scenarios assuming 75% Fmsy from 2013-2025.

<u>Total Catch</u>	abc	direct						
	geo mean							
year	abc	1%	est t+1	3%	5%	8%	10%	
2011	0.696	0.696	0.696	0.696	0.696	0.696	0.696	
2012	0.727	0.727	0.727	0.727	0.727	0.727	0.727	
2013	0.289	0.347	0.388	0.463	0.577	0.749	0.86	
2014	0.341	0.504	0.544	0.828	1.15	1.633	1.952	
2015	0.434	0.749	0.823	1.385	2.023	2.979	3.611	
2016	0.585	0.821	0.95	1.309	1.795	2.532	3.014	
2017	0.74	0.975	1.107	1.447	1.92	2.631	3.103	
2018	0.881	1.04	1.146	1.343	1.646	2.1	2.403	
2019	0.974	1.059	1.157	1.242	1.427	1.703	1.888	
2020	1.032	1.079	1.154	1.186	1.293	1.453	1.559	
2021	1.066	1.093	1.147	1.155	1.216	1.309	1.371	
2022	1.083	1.102	1.137	1.138	1.174	1.227	1.262	
2023	1.096	1.117	1.129	1.138	1.159	1.19	1.211	
2024	1.104	1.115	1.123	1.127	1.139	1.157	1.169	
2025	1.105	1.121	1.116	1.128	1.136	1.146	1.152	
2026	1.106	1.125	1.113	1.129	1.133	1.139	1.143	
2027	1.104	1.113	1.109	1.115	1.118	1.121	1.124	
2028	1.108	1.113	1.11	1.114	1.115	1.118	1.119	
2029	1.11	1.114	1.111	1.115	1.116	1.117	1.118	
2030	1.11	1.12	1.11	1.121	1.121	1.122	1.122	

Table C2: Projected catches of GOM haddock under varying spillover scenarios assuming 75% Fmsy from 2013-2025.

Percent of iterations that go extinct (F=5 hits a bound)							
geo mean abc	1%	est t+1	3%	5%	8%	10%	
17%	28%	36%	60%	81%	94%	97%	

Table C3: Percent of iterations that go extinct.

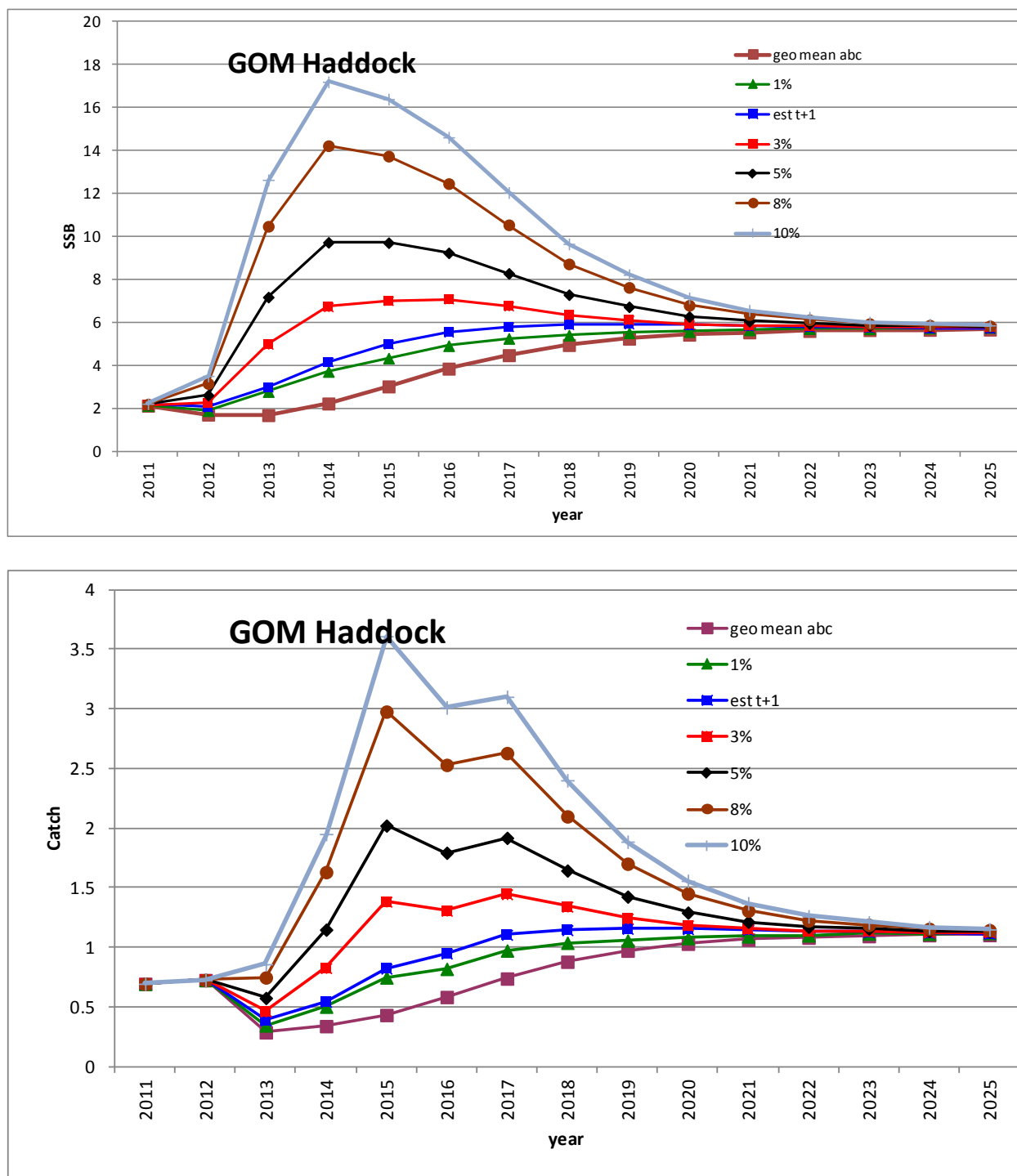


Figure C1: Projected SSB (top) and catch (bottom) of GOM haddock under varying spillover scenarios assuming 75% Fmsy from 2013-2025.

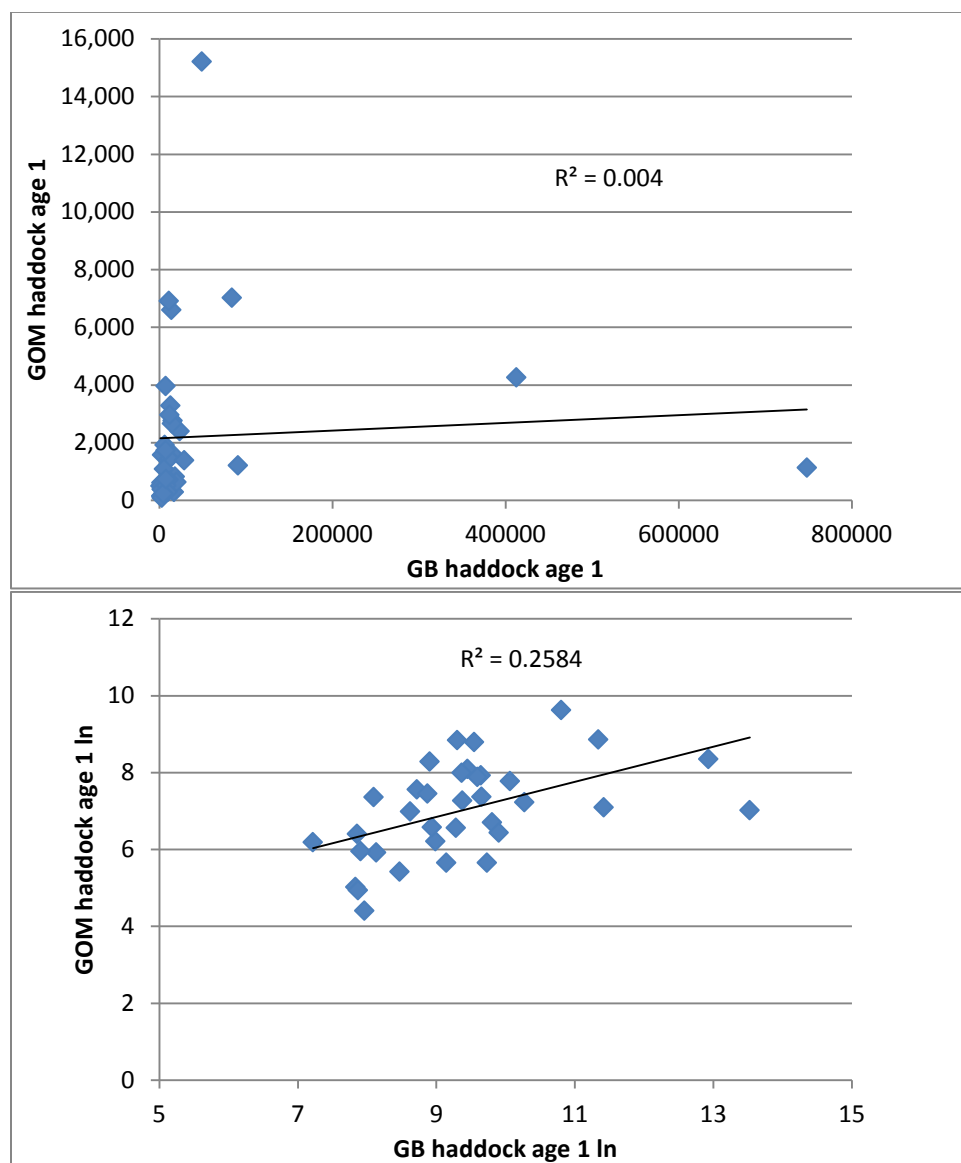


Figure C2: Relationship between age 1 GB and GOM haddock.

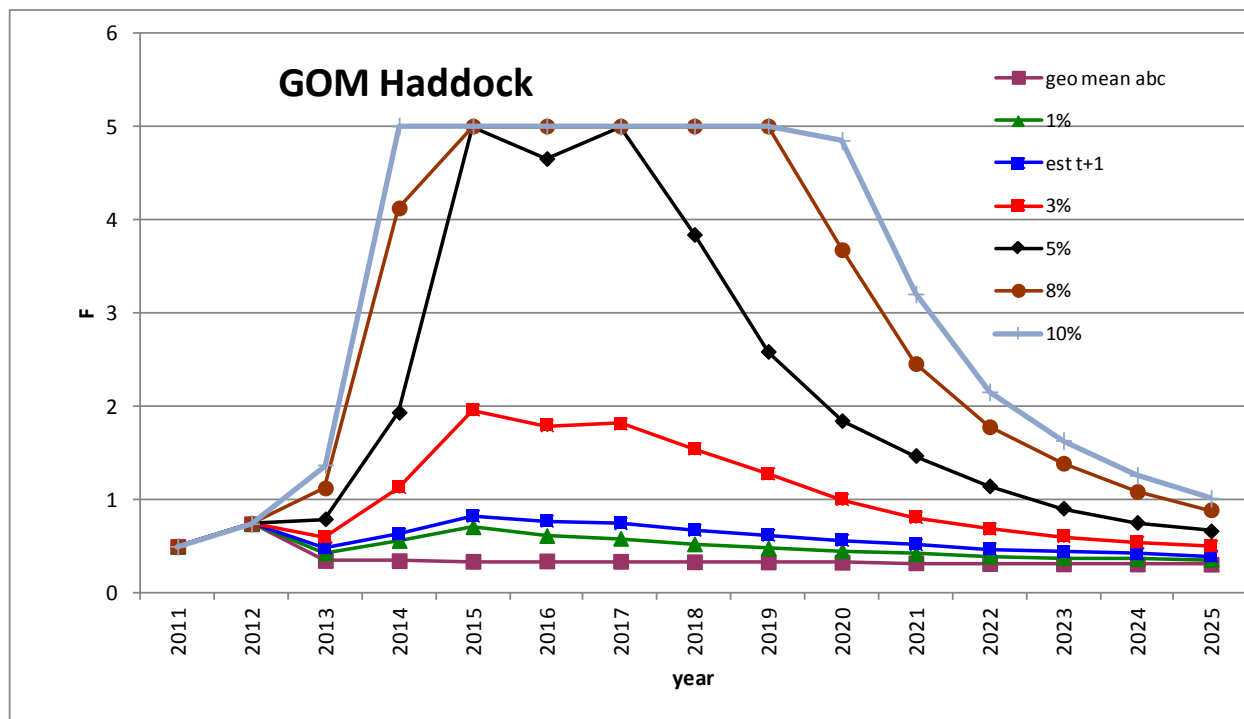


Figure C3: Estimated fishing mortality rates assuming spillover does not occur with removals based on assumed net movement of the 2010 GB year class into the GOM.

Appendix D: Year Class Signals, Mike Palmer

The change in minimum size applied to both GB and GOM haddock stocks in 2013 fishing year (see Framework 48). There is a strong discard signal for the 2003 year class on GOM, but not for the 2000 year class (Table D1). The 2003 year class was a moderately large year class in the GOM (5th largest in the assessment time series). The 2000 year class, while not weak, does not show strong patterns in the discards-at-age. The strongest year class signal in the discards-at-age comes from the 1998 year class which was the largest year class within the assessment time series (Table D1). The 1998 year class was not a very strong year class for GB and subsequently not a strong signal in the GB discards-at-age.

Shown are plots of how well the age1 GOM and GB estimates compare for a) the VPA model output b) NEFSC spring and c) NEFSC fall surveys (see below, Pearson's r values at the top of each plot) (Figure D1). There is some consistency in the recruitment between the two stocks, but it is not as strong as previously considered elsewhere.

Given the very large relative differences between the size of the two stocks (GOM 2003 year class was estimated at 1% the size of the GB year class) then would we be able to track cohorts sufficiently well within the GOM if spillover were occurring? It might be expected that the size of the GOM haddock cohort could continually increase, particularly at exchange rates near 10%. An examination of the NEFSC fall and spring survey data shows very strong cohort tracking over time and the cohort signal from some of the stronger year classes (1998 and 2003) tracks quite well with the size of the cohort decreasing over time (Figures D2-D4). This seems to run contrary to the expectation if the GOM haddock signal was being overwhelmed by even a very small amount of GB haddock.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9+	Total
1977	8.2	504.6	44.2	0	0	0	0	0	0	0	557
1978	9.9	3.1	95.8	1.2	0	0	0	0	0	1	110.9
1979	46.5	62	6	1.2	0	0	0	0	0	0	115.7
1980	76.6	121.9	3.7	0.2	0	0	0	0	0	0	202.4
1981	3.8	164	2.8	0	0	0	0	0	0	0	170.7
1982	178.9	10.8	15.5	0.8	0	0	0	0	0	0	206
1983	2.5	76.1	10	7.3	0.1	0	0	0	0	0	96
1984	0	11.4	43.2	1	1.9	0	0	0	0	0	57.4
1985	0.2	3.1	8.3	21.4	0	0	0	0	0	0	33
1986	10	19.9	0	0	0	0	0	0	0	0	29.9
1987	14.6	8.1	0	0	0	0	0	0	0	0	22.8
1988	0	18.5	0	0	0	0	0	0	0	0	18.5
1989	0	3.4	7.1	0.8	1.7	0	0	0	0	0	13
1990	4.5	4.5	0	1.8	0	0	0	0	0	0	10.8
1991	9.2	7.9	2.2	0.4	0	0	0	0	0	0	19.8
1992	4.8	20.4	11	4.8	0.1	0	0	0	0	0	41
1993	15.7	12.4	17.8	3.1	1.8	0.2	0.6	0.1	0.4	0.6	52.7
1994	60.4	89.9	17.8	21.4	3.9	1.5	3.2	2	0.3	0.4	200.8
1995	0.9	50.1	58.5	42	14.5	1.6	0.9	0.6	0	0	169.1
1996	47.7	9.9	32.4	85.8	10.3	1.7	0.4	0.4	0.2	0	189
1997	0.2	2.9	5.7	87.4	123.1	23.9	4.4	1.5	0.5	0.2	249.8
1998	107.6	13.3	13.8	1.5	4.7	5	0	0	0	0	145.9
1999	1.1	8.4	0.7	0.2	0.1	0.1	0.1	0	0	0	10.8
2000	1.1	5.4	47	14.2	1.7	0.2	0.4	0.1	0	0	70.1
2001	1.2	1.6	11.2	21.1	2.3	0.4	0.4	0.3	0	0	38.6
2002	0	2.1	1.3	6.6	17.3	1.8	0.3	0	0.1	0.1	29.5
2003	0	0.1	3.9	1	3.6	14.3	1.5	0.3	0.2	0.1	25
2004	0.3	7.8	0.4	4.9	1.1	2.9	12.1	1	0.4	0.5	31.4
2005	0	0.3	15.6	1	5.1	4.3	4.1	10.1	0.6	0.5	41.5
2006	5.2	9.4	1.6	35.9	3.8	3.7	1.6	2.8	9.2	0.4	73.6
2007	0	1.8	13.4	4.6	30.7	0.3	2.1	0.5	1.5	5.4	60.3
2008	0	0	4.4	3.1	0.6	6.5	0.2	0.4	0	0.9	16
2009	0.4	0.1	0.7	6.8	3.4	0.5	3.3	0.1	0.2	0.5	15.9
2010	0.1	1.6	0.8	0.9	1.7	0.4	0.1	0.7	0	0.1	6.3

Table D1: GOM haddock discards at age, 1977-2010.

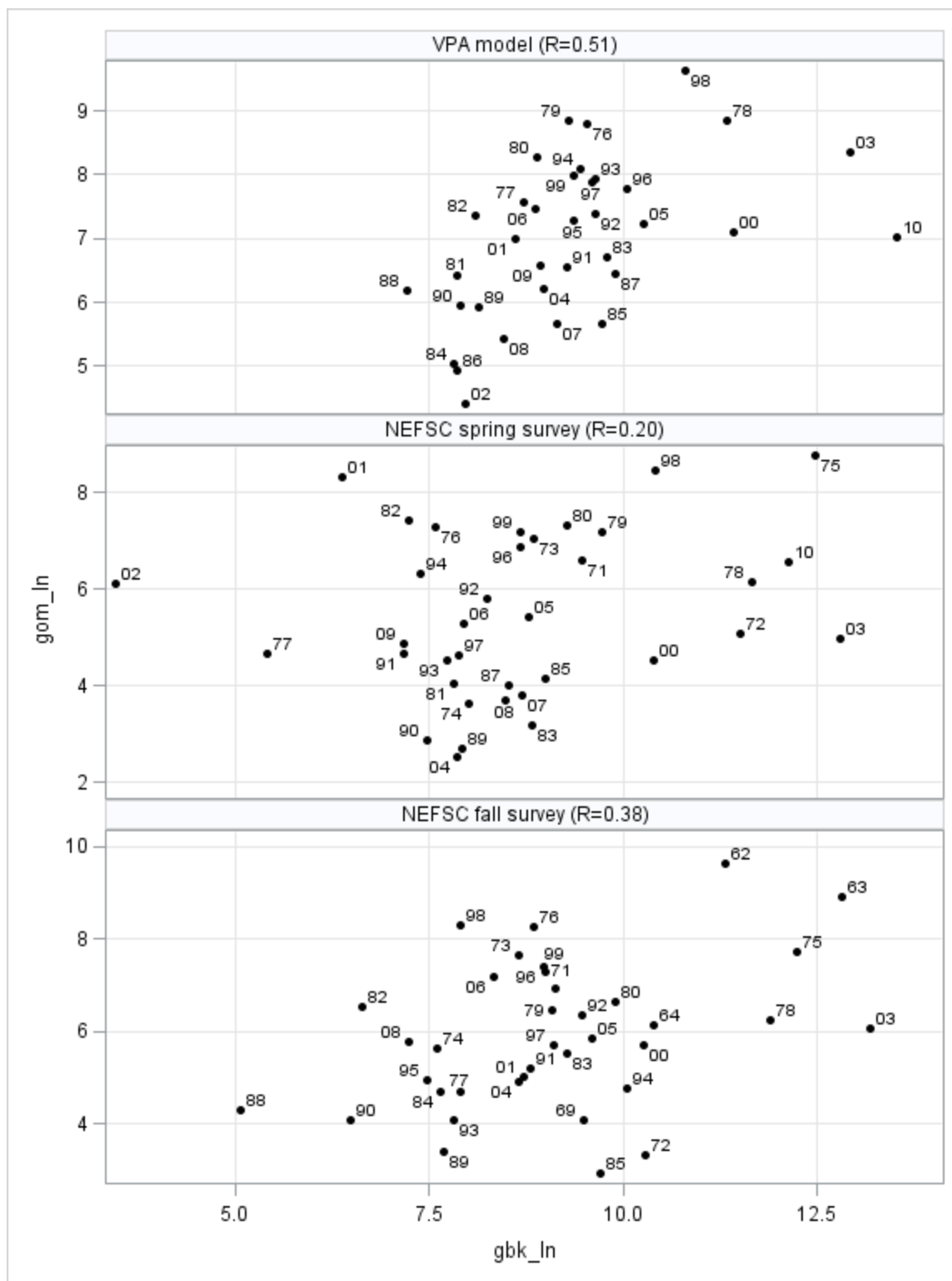


Figure D1: Comparison of \ln age1 GOM and GB estimates for the VPA model output (top), NEFSC spring (middle) and NEFSC fall surveys (bottom), with Pearson's r values at the top of each plot.

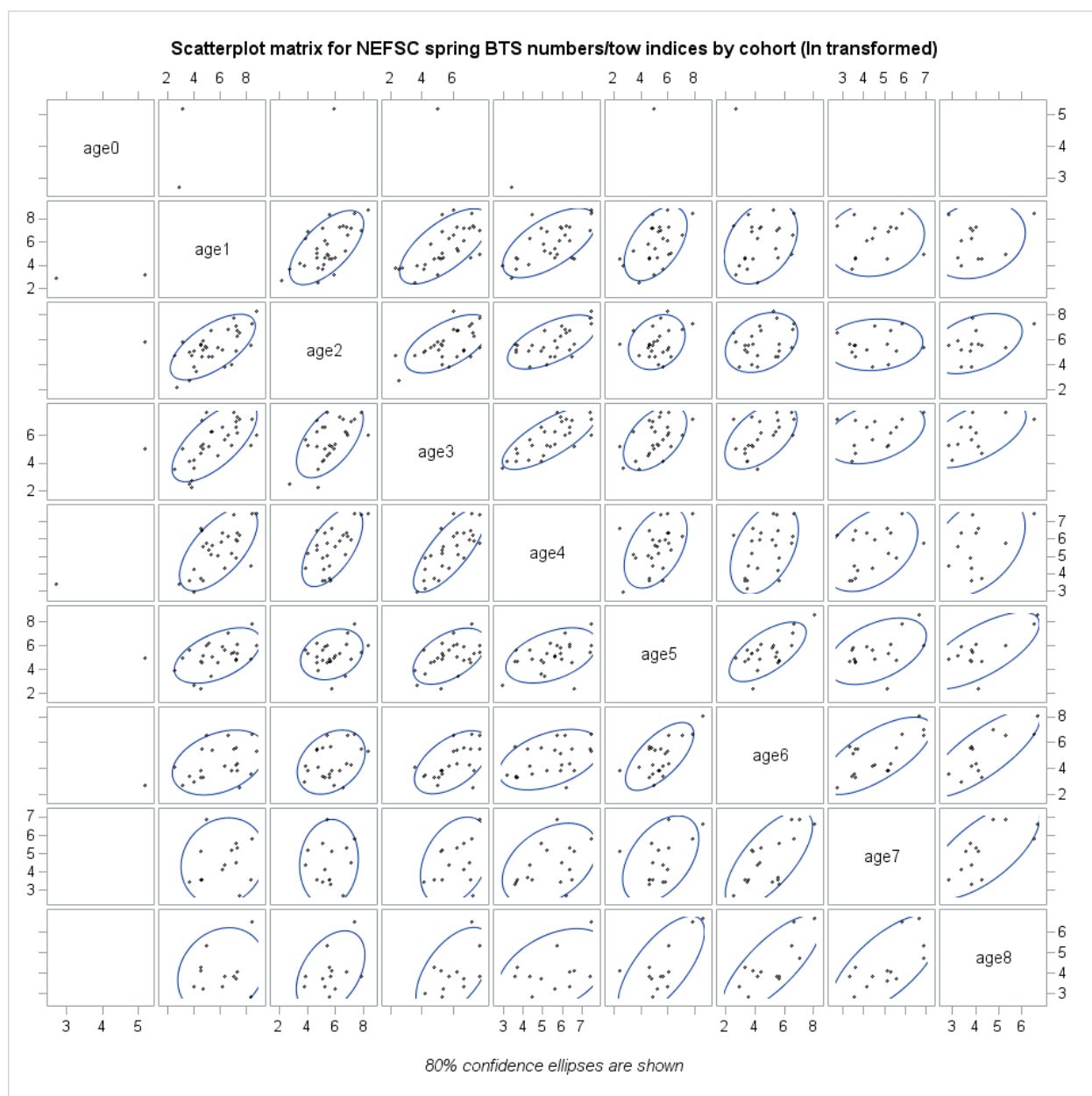


Figure D2: Scatterplot matrix for Gulf of Maine haddock NEFSC spring bottom-trawl survey numbers per tow indices by cohort (log transformed). 80% confidence ellipses are shown.

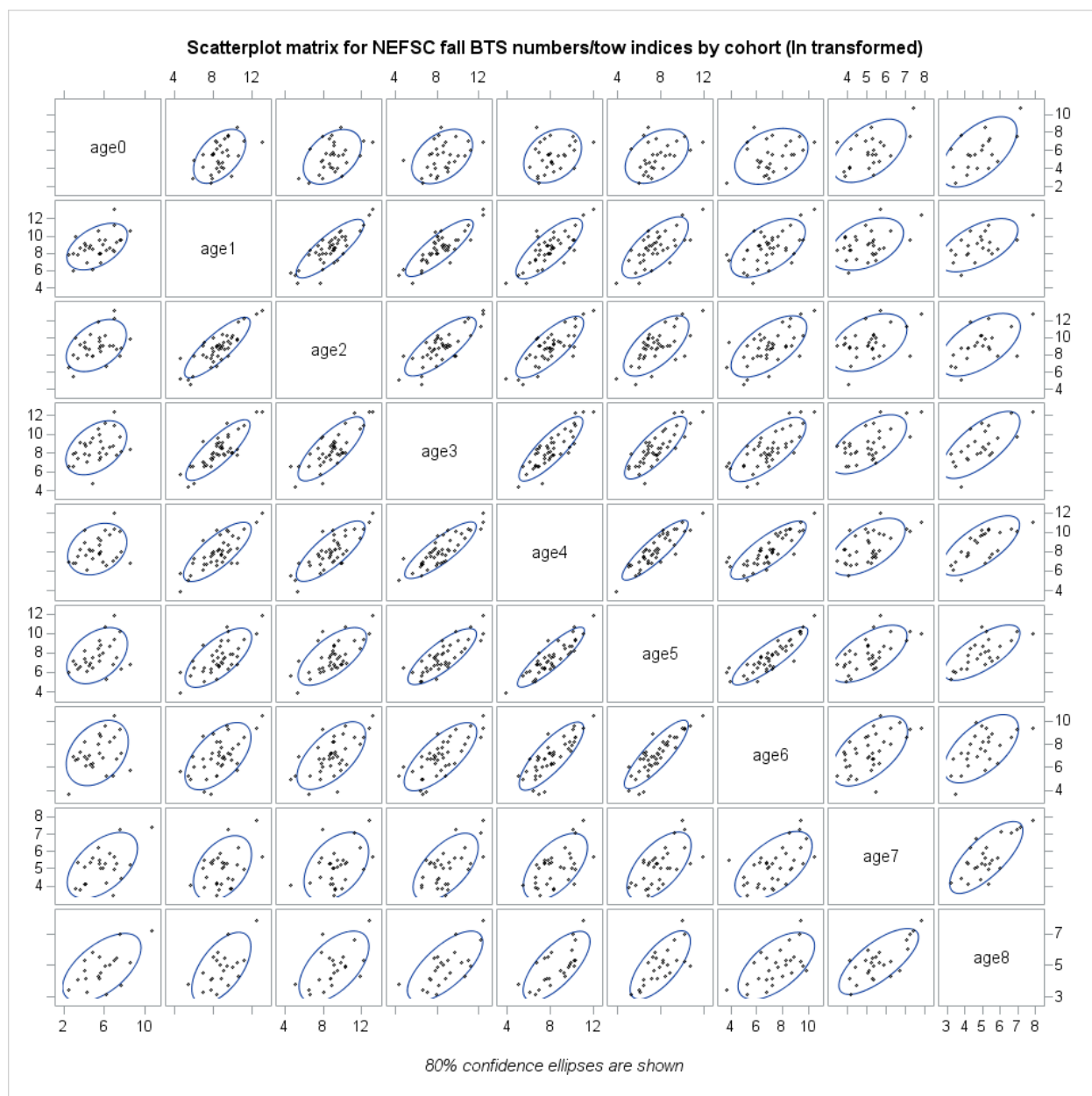


Figure D3: Scatterplot matrix for Gulf of Maine haddock NEFSC fall bottom-trawl survey numbers per tow indices by cohort (log transformed). 80% confidence ellipses are shown.

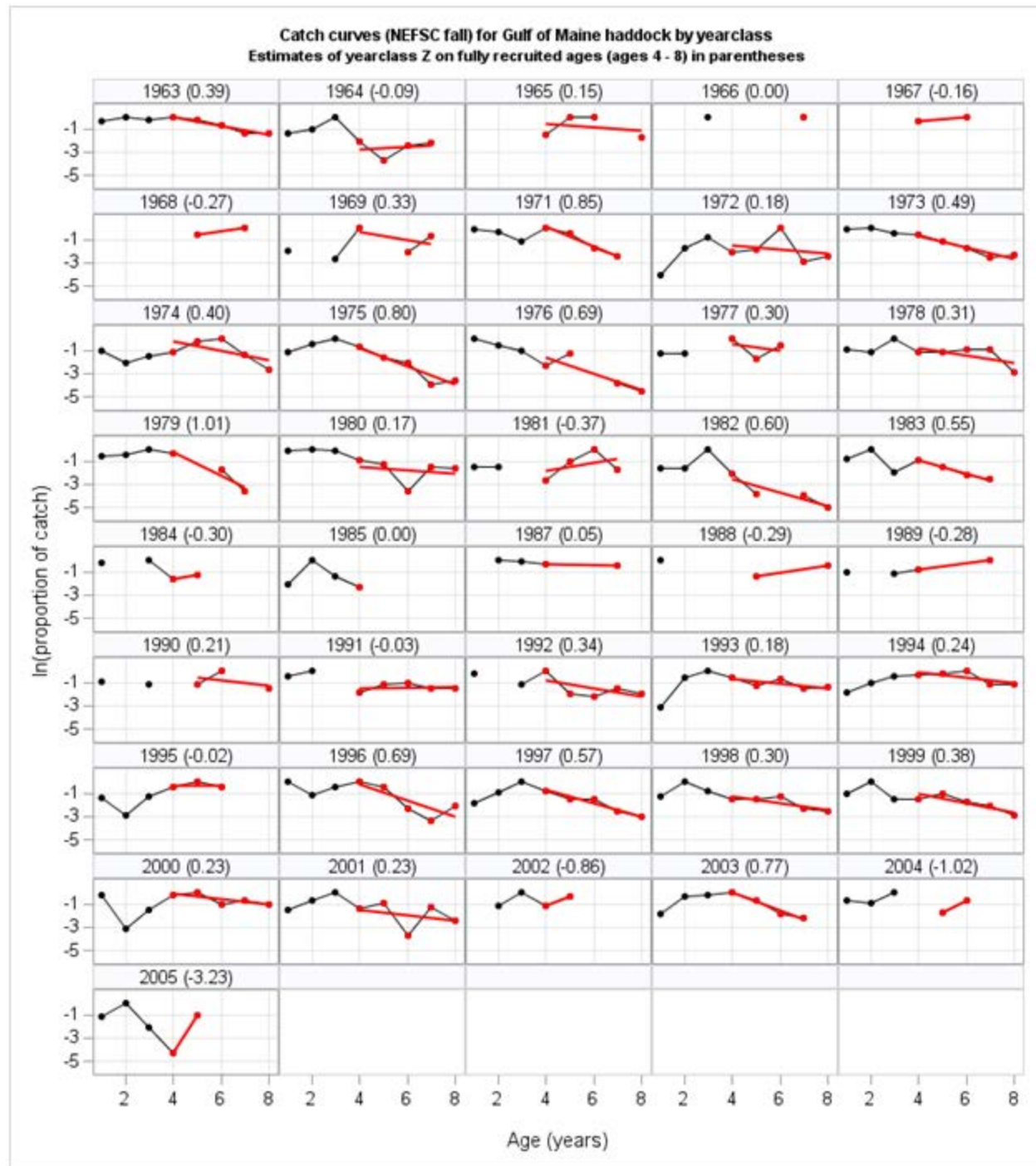


Figure D4: Catch curves (NEFSC fall) for GOM haddock by year class. Estimates of year class, Z, on fully recruited ages (age 4-8) shown in parentheses.

Appendix E: Predicting age 3 abundance at age in the Gulf of Maine from age 1 abundance at age on Georges Bank assessment with a forward lag of two years, Steven J. Correia

Introduction

The 2010 year class at age 1 in the 2012 GB assessment (NEFSC 2012) is potentially large, but the estimate has high uncertainty (84% CV). The GOM haddock stock (2,868 mt SSB) is estimated to be much smaller than the GB haddock stock (167,278 mt SSB). Similarly, the ABC's for 2013 reflect the disparity in estimated exploitable biomass between the two stocks: GOM haddock ABC=290 mt and GB haddock ABC=29,335 mt. Tagging studies indicate mixing occurs between the GB, GOM, and 4X haddock stocks, although the mixing rate is highly uncertain.

The NEFMC passed a motion to “recommend the Council request NMFS implement by Emergency Action a measure that will attribute up to 10% of GB haddock quota to the GOM haddock quota and up to 10% of the GOM haddock quota to GB haddock quota.” As noted in other PDT analyses, a weak to moderate correlation exists in cohort size between the GOM and GB stocks. An important question is how well can cohort size in the GOM haddock stock be predicted from age 1 abundance estimates in the GB haddock stock?

Methods

Log10 GOM age 3 abundance were regressed on log10 GB age 1 abundance for the 1976 through 2008 cohorts. Abundance at age estimates were taken from the 2012 updated groundfish assessments (NEFSC 2012). Regression and prediction were conducted using the *lm* and *predict.lm* functions using R statistical software.

Results

The scatterplot of GOM abundance at age 3 against GB abundance at age (matched for cohort) is shown in Figure D1. The regression (Table E1; Figure E1) was statistically significant ($P < 0.001$). Diagnostics were unremarkable (Figure E2). Jackknifed estimates of slope suggested that the slope was generally well estimated. The prediction of age 3 abundance in the GOM in 2013 from the 2010 year class at age 1 on GB is shown in Table E2

Based on the GB age 1 abundance estimate of 748,016 fish in 2011, the GOM abundance at age 3 in 2013 is predicted to be 6,037,000 fish with 95% prediction limits of 609,000 to 59,849,000. The expected value of approximately 6 million haddock would be the 2nd highest value in the time series. The 95% prediction limits are relatively wide, covering values that are below the long term median to a value that is approximately 5 times higher than the maximum abundance in the assessment (Table E3). Clearly, much uncertainty exists in predicting age 3 abundance in the GOM from age 1 abundance in the GB stock.

Conclusions

Predictions of age 3 abundance in the GOM from age 1 abundance in GB appear to be highly uncertain. The size of age 1 abundance on GB does not seem to be a reliable way to predict future cohort strength in the GOM. Altering the GOM ABC as a result of a large year class on GB does not seem reasonable given the weak predicative power of the relationship between year class abundance in the two assessments.

References

NEFSC. 2012. Assessment or Data Updates of 13 Northeast Groundfish Stocks through 2010. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 12-06; 789 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at <http://nefsc.noaa.gov/publications/>

Coefficients	estimate	Std error	T	Pr(> t)	
(Intercept)	0.2904	0.5967	0.487	0.630	
log10(gb.age.1)	0.6362	0.147	4.329	<0.001	***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Residual standard error: 0.4324 on 31 degrees of freedom					
Multiple R-squared: 0.3767, Adjusted R-squared: 0.3566					
F-statistic: 18.74 on 1 and 31 DF, p-value: 0.0001454					

Table E1. Results from regressing Gulf of Maine log10 abundance at age 3 on Georges Bank log10 abundance at age 1 (lagged 2 years).

	95%	95%
mean	LL	UL
6037	609	59849

Table E2. Predicted abundance of age 3 (000's) in Gulf of Maine from 2010 yearclass at age 1 on Georges Banks. LL and UL are lower and upper 95% prediction limits on the estimate.

	25 th			75 th	
minimum	quantile	median	mean	quantile	maximum
55	324	904	1399	1771	10140

Table E3: Summary statistics for distribution of age 3 abundance (000's) in GOM haddock.

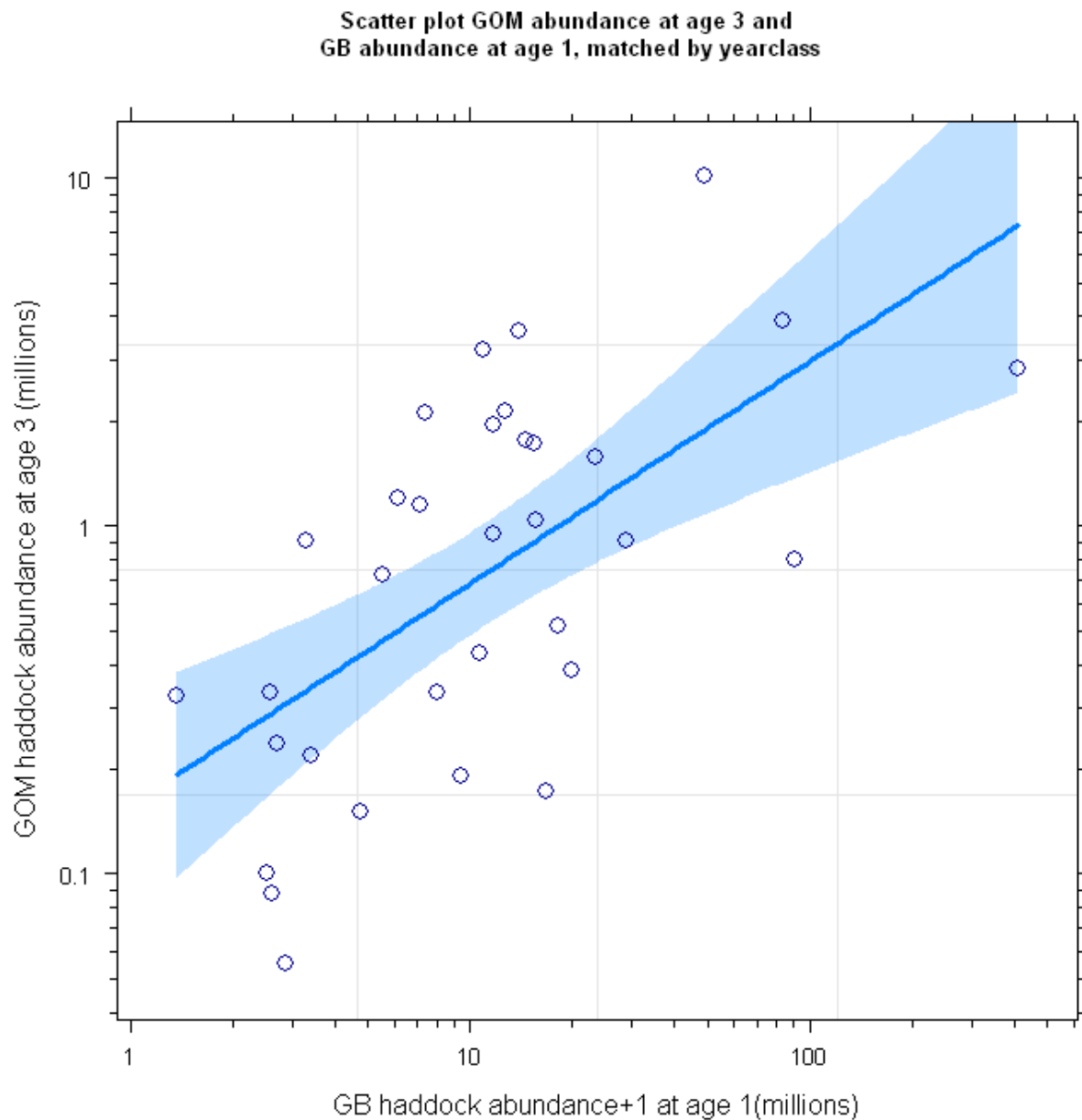


Figure E1: Scatterplot of Gulf of Maine abundance at age 3 against Georges Bank abundance at age 1 (lagged two years). Note that both X and Y axis scales are logarithmic. Blue line is predicted age 3 from linear regression. Blue shaded area is 95% confidence limits on regression line.

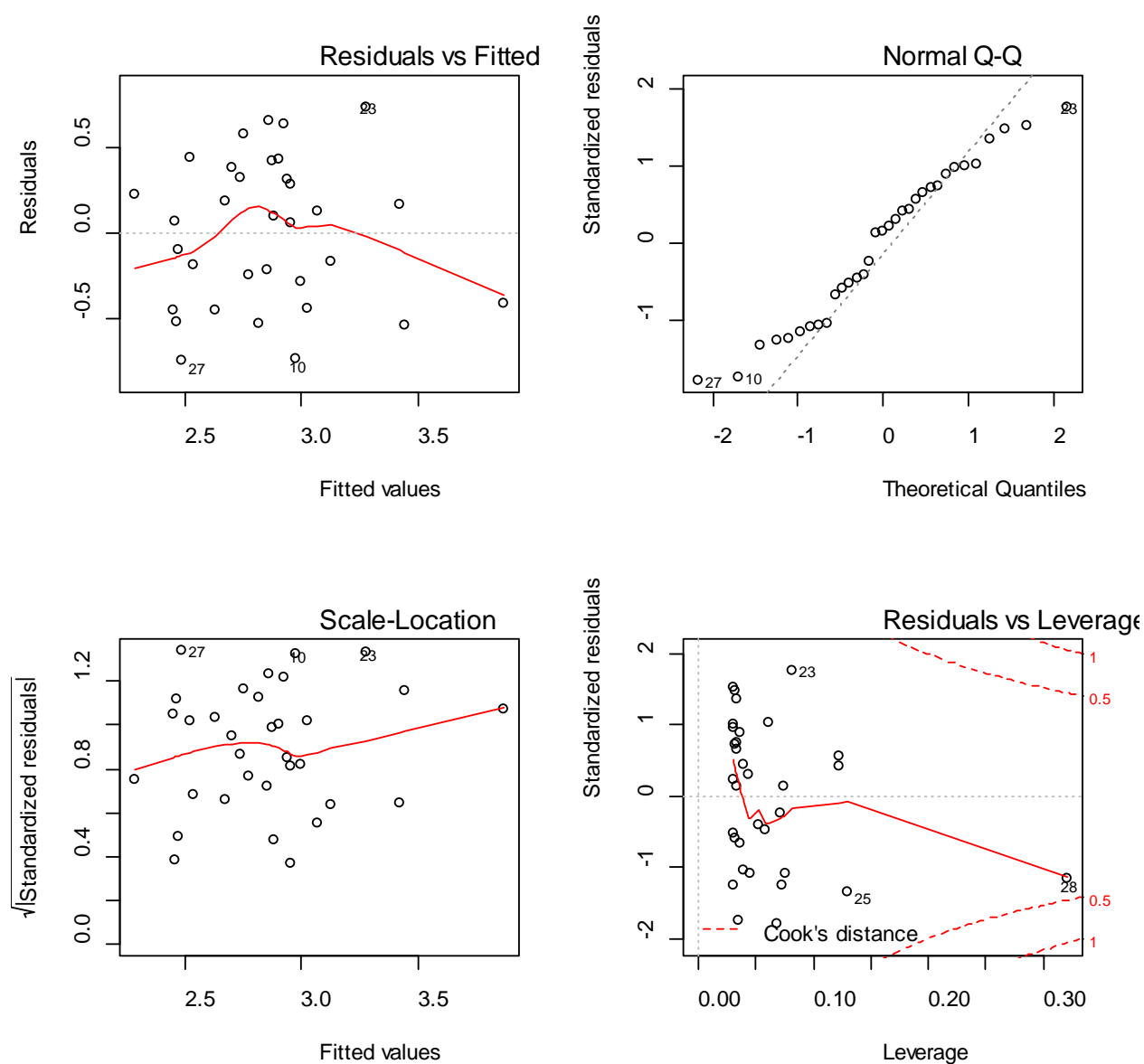


Figure E2: Diagnostic plots from regression of Gulf of Maine log10 abundance at age 3 on Georges Bank log10 abundance at age 1 (lagged 2 years).

Appendix F: Comparing correlation strength among haddock number at age survey indices to Gulf of Maine haddock number at age survey indices, Steven J. Correia and Mike Palmer

Introduction

The 2010 year class at age 1 in the GB assessment is potentially large, but the estimate has high uncertainty (84% CV). The GOM haddock stock (2,868 mt SSB) is estimated to be much smaller than GB haddock stock (167,278 mt SSB). Similarly, the ABC's for 2013 reflect the disparity in estimated exploitable biomass between the two stocks: GOM haddock ABC=290 mt and GB haddock ABC=29,335 mt. Tagging studies indicate mixing occurs across stock boundaries (between GB, GOM, and 4X), although the mixing rate is highly uncertain.

The NEFMC passed a motion to “recommend the Council request NMFS implement by Emergency Action a measure that will attribute up to 10% of GB haddock quota to the GOM haddock quota and up to 10% of the GOM haddock quota to GB haddock quota.” As noted in other PDT analyses, a weak to moderate correlation exists in cohort size between the GOM and GB stocks. From 1977-2010, the ratio of SSB in the GOM stock to GB SSB (Figure F1) has been relatively small (median ratio=0.10, range: 0.02 to 0.27).

The size of the 2010 year class at age 1 in the GB haddock assessment is highly dependent upon NEFSC survey. In addition to the GOM haddock assessment, other sources of information on the size of the GOM haddock stock include numerous trawl surveys. Here, we evaluate the various sources of information by comparing the correlation of survey indices measurement of cohort strength over time. Survey indices with stronger association with cohort size will perform better at predicting future cohort size than surveys with weaker associations. Spillover events of adult fish will add variability to indices, making the tracking of cohorts more difficult. We then compare the capacity of age based indices from the GB and GOM stock areas to track cohorts in the GOM using correlation analysis. We used Kendall's Tau coefficient of rank correlation to measure association, due to concerns that by choosing another method we would not meet the bivariate normal distribution assumption.

Methods

The purpose of the analysis was to determine which set of indices were better at tracking cohorts in GOM survey indices. NEFSC fall survey number per tow by age indices for GOM (ages 0-5) and GB (ages 0-5) strata sets were compared using Kendall's coefficient of rank correlation (Tau). Correlation coefficients were estimated between all pairs of indices (except correlations were not determined for pairs of the same index). Results are shown in Table F1 and Figure F2 and Figure F3.

Results

There are 30 paired comparisons where correlation coefficients were estimated for a GOM index by both a GB and GOM index. We conducted a paired T-test to test for systematic differences between correlation estimates. On average, GB correlation coefficients were 0.16 units smaller than the corresponding GOM correlation coefficients. The paired T-test indicated that paired differences were significantly different from zero (mean difference=0.16, $P<0.001$). A normal

quantile-quantile plot indicated that the distribution of paired differences were not markedly different from normal.

Conclusions

GOM survey indices have stronger associations with cohort size in GOM survey indices than the GB survey indices. This is generally consistent with other work suggesting good ability to track cohorts in the GOM survey age indices for haddock. Strong cohesion among survey indices within a stock area would not be expected if spillover from strong GB year classes was an important contributor to haddock abundance within the GOM stock area.

	GB index	GOM index	gm index	GOM	GB	difference
	GBA0	gmA0	gmA0	NA	0.41	NA
	GBA0	gmA0	gmA1	0.60	0.42	0.18
	GBA0	gmA0	gmA2	0.66	0.47	0.19
	GBA0	gmA0	gmA3	0.59	0.43	0.16
	GBA0	gmA0	gmA4	0.55	0.37	0.18
	GBA0	gmA0	gmA5	0.52	0.39	0.13
	GBA1	gm1	gmA0	0.60	0.35	0.25
	GBA1	gm1	gmA1	NA	0.31	NA
	GBA1	gm1	gmA2	0.65	0.35	0.30
	GBA1	gm1	gmA3	0.58	0.38	0.20
	GBA1	gm1	gmA4	0.61	0.37	0.24
	GBA1	gm1	gmA5	0.58	0.27	0.31
	GBA2	gm2	gmA0	0.66	0.49	0.17
	GBA2	gm2	gmA1	0.65	0.45	0.20
	GBA2	gm2	gmA2	NA	0.53	NA
	GBA2	gm2	gmA3	0.66	0.57	0.09
	GBA2	gm2	gmA4	0.61	0.51	0.10
	GBA2	gm2	gmA5	0.57	0.46	0.11
	GBA3	gm3	gmA0	0.59	0.36	0.23
	GBA3	gm3	gmA1	0.58	0.41	0.17
	GBA3	gm3	gmA2	0.66	0.46	0.20
	GBA3	gm3	gmA3	NA	0.48	NA
	GBA3	gm3	gmA4	0.59	0.46	0.13
	GBA3	gm3	gmA5	0.50	0.46	0.04
	GBA4	gm4	gmA0	0.55	0.41	0.14
	GBA4	gm4	gmA1	0.61	0.4	0.21
	GBA4	gm4	gmA2	0.61	0.5	0.11
	GBA4	gm4	gmA3	0.59	0.48	0.11
	GBA4	gm4	gmA4	NA	0.52	NA
	GBA4	gm4	gmA5	0.59	0.57	0.02
	GBA5	gm5	gmA0	0.52	0.39	0.13
	GBA5	gm5	gmA1	0.58	0.37	0.21
	GBA5	gm5	gmA2	0.57	0.43	0.14
	GBA5	gm5	gmA3	0.50	0.43	0.07
	GBA5	gm5	gmA4	0.59	0.44	0.15
	GBA5	gm5	gmA5	NA	0.6	NA
mean difference GOM-GB	95% confidence limit of mean difference		T-value		df	P-value
0.16	0.14 to 0.19		13.0		29	<0.001

Table F1: Kendall coefficient of rank correlation (Tau) between survey abundance at age indices. Bottom two rows summarize results of paired T-test.

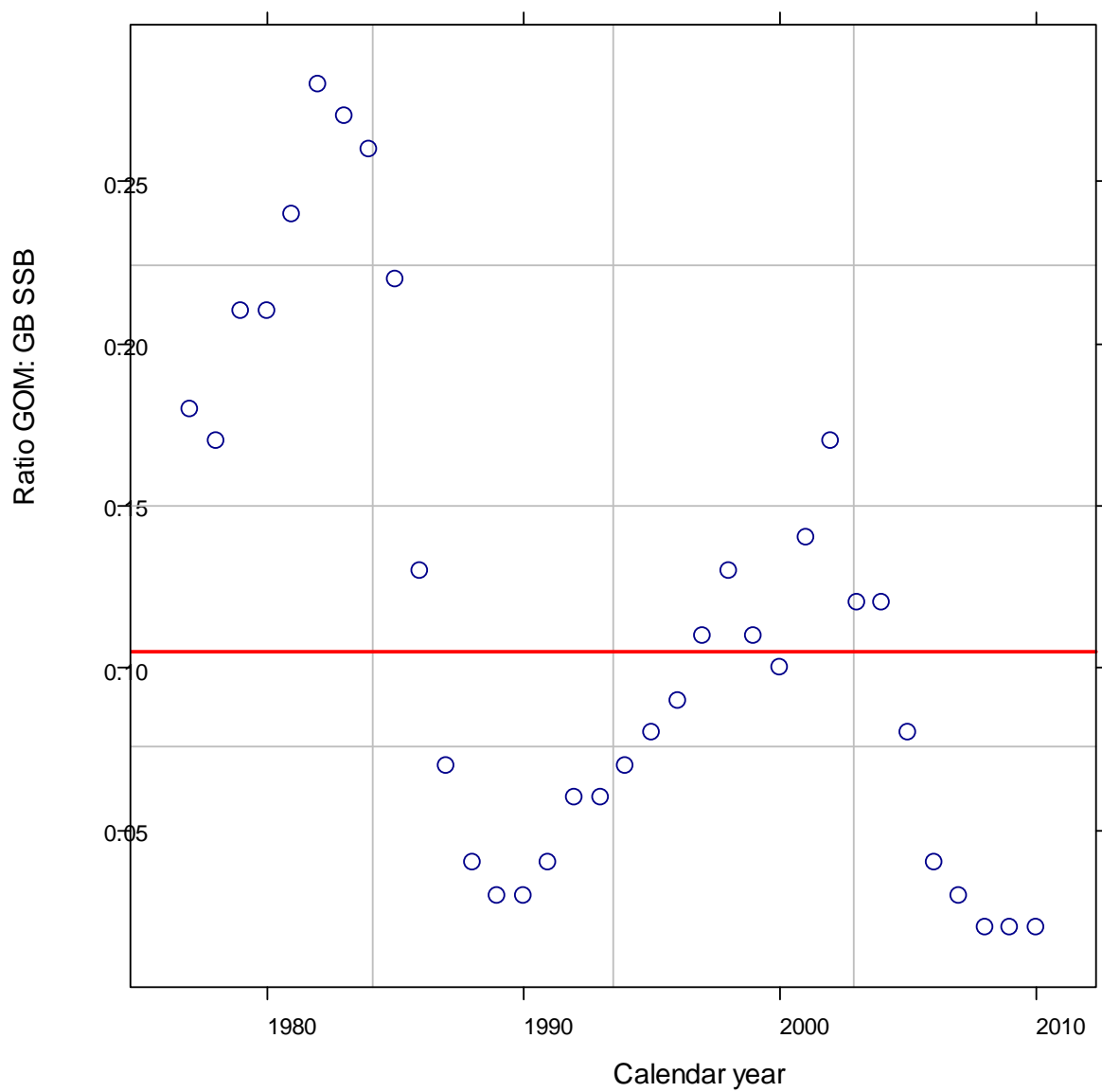


Figure F1: Ratio of Gulf of Maine haddock SSB to Georges Bank haddock SSB, 1977-2010. Redline is median ratio over the time series.

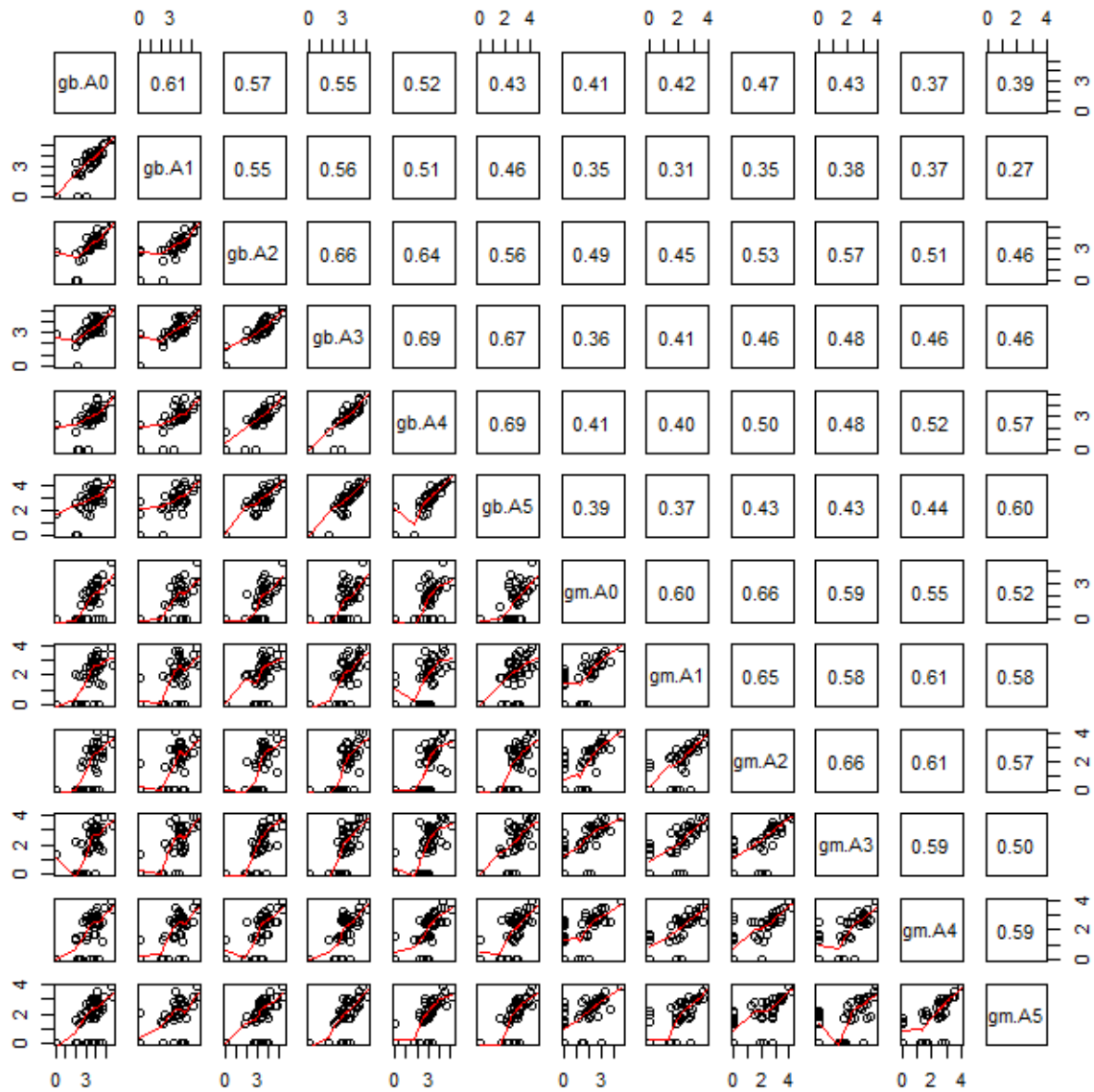


Figure F2: Scatterplot matrix of NEFSC survey indices at age. Values above the diagonal are Kendall's Tau. The main diagonal provides the codes for the survey indices.

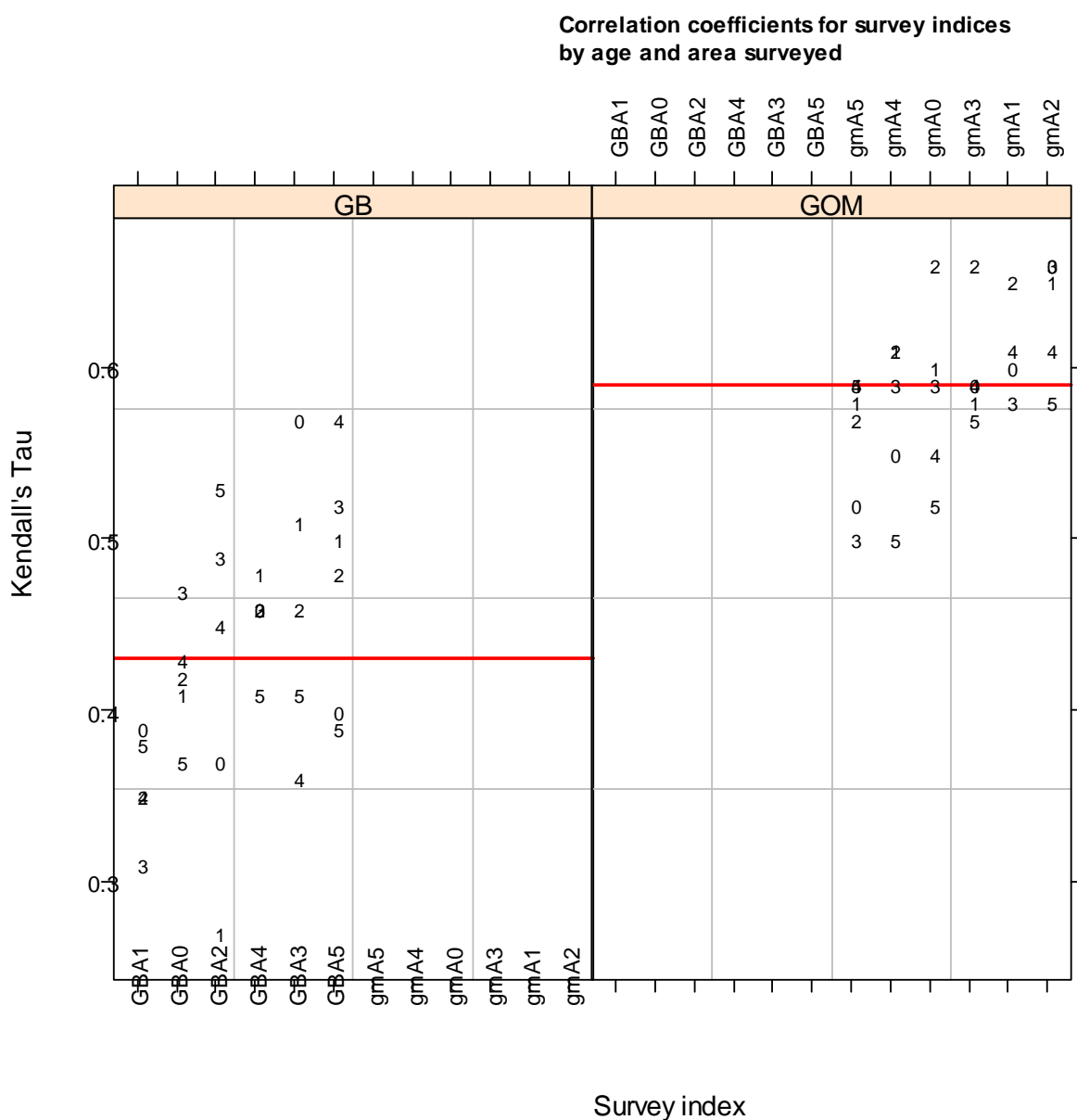


Figure F3: Scatterplot of Kendall's rank correlation coefficient (Tau) of survey indices from stock area (GB= survey indices from Georges Bank, GOM= gulf of Maine stock area. X-axis is age based survey indices correlated with the Gulf of Maine GOM age indices. Red line is median correlation coefficient within the panel. Points are identified with the age of the GOM index.

Appendix G: Do Georges Bank haddock move into the Gulf of Maine? Mike Palmer

If spillover of GB haddock into the GOM occurs then some evidence for this should be seen in the 2012 updated Gulf of Maine (GOM) haddock assessment, since a strong 2003 year class occurred on Georges Bank while a moderate 2003 year class was seen in the Gulf of Maine. Diagnostic issues should be evident in the GOM haddock assessment if spillover occurs since the two assessments assume no movement between the stocks. Clear diagnostic issues due to a possible influx of the 2003 GB year class were not observed in either the survey residual pattern or in the age 1 retrospective of the 2012 updated GOM haddock assessment (Figures G1 and G2). There is a relatively small decrease in the estimate of the 2003 year class as years are omitted from the model. However, if the strong 2003 GB year class resulted in some movement of fish into the GOM then one would expect a large continual increase in the estimated 2003 year class with time.

The 2012 GOM haddock update assessment assumed a geometric mean (1977-2010) for $t+1$ recruitment (2011) due to the lack of information available for this estimate at the time of the update. The geometric mean is estimated at 1.124 million fish for the $t+1$ age 1 recruitment (Figure G3). The direct $t+1$ recruitment estimated from the limited survey information at the 2012 update is estimated at 4.362 million fish which is slightly higher than the estimated moderate 2003 year class of 4.251 million fish at age 1 in 2004 (Figure G3). The relatively low age 1 recruitment estimates from 2008-2010 resulted in reductions in the ABC from 2013 and 2014.

Updated survey information since the 2012 update suggests the 2010 year class may be stronger than the geometric mean estimate (Figures G4-G6). The 2010 year class appears to be similar in size to the moderate 2003 year class. Updated survey data since the GARM update shows continued tracking of the 2010 year class in 2011 and 2012 in both the Spring and Fall surveys, although historically the fall survey appears to be a better index of abundance for GOM haddock (Figures G6 and G7). However, uncertainty surrounding this estimate still remains since this year class has just begun to enter the catch.

The 2010 year class is estimated to be selected at only 9% in 2013. There are some anecdotal signs from the fishery for this incoming year class which may not be the result of spillover from the GB stock. The ABC at 75%Fmsy would increase 98 metric tons in 2013 and 203 metric tons in 2014 if the 2010 year class is a moderate year class similar in size to the 2003 year class (based on a VPA model with a direct estimate of $t+1$). If the 2010 year class is estimated at the geometric mean and if one assumes that 1% of the projected Georges Bank age 1 recruitment (large Georges Bank 2010 year class) moved into the gulf of Maine then the projected catch would increase by 57 metric tons in 2013 and 163 mt in 2014. One percent of the Georges Bank age 1 recruitment would result in a 3.8 fold increase in $t+1$ recruitment which is slightly lower than the direct $t+1$ estimate for the GOM haddock assessment.

In addition, the survey distribution of higher catches also showed the larger haddock tows near shore and not near the stock boundary with Georges Bank which would be expected if spillover was a big issue. Concurrently, the ME/NH survey also saw an increase of small haddock in the survey in 2012.

Conclusions

Examination of the model diagnostics and updated survey data suggests spillover was not a large issue with the strong 2003 year class on GB. Updated survey data suggests the 2010 year class may be stronger than the geometric mean estimate (1977-2010).

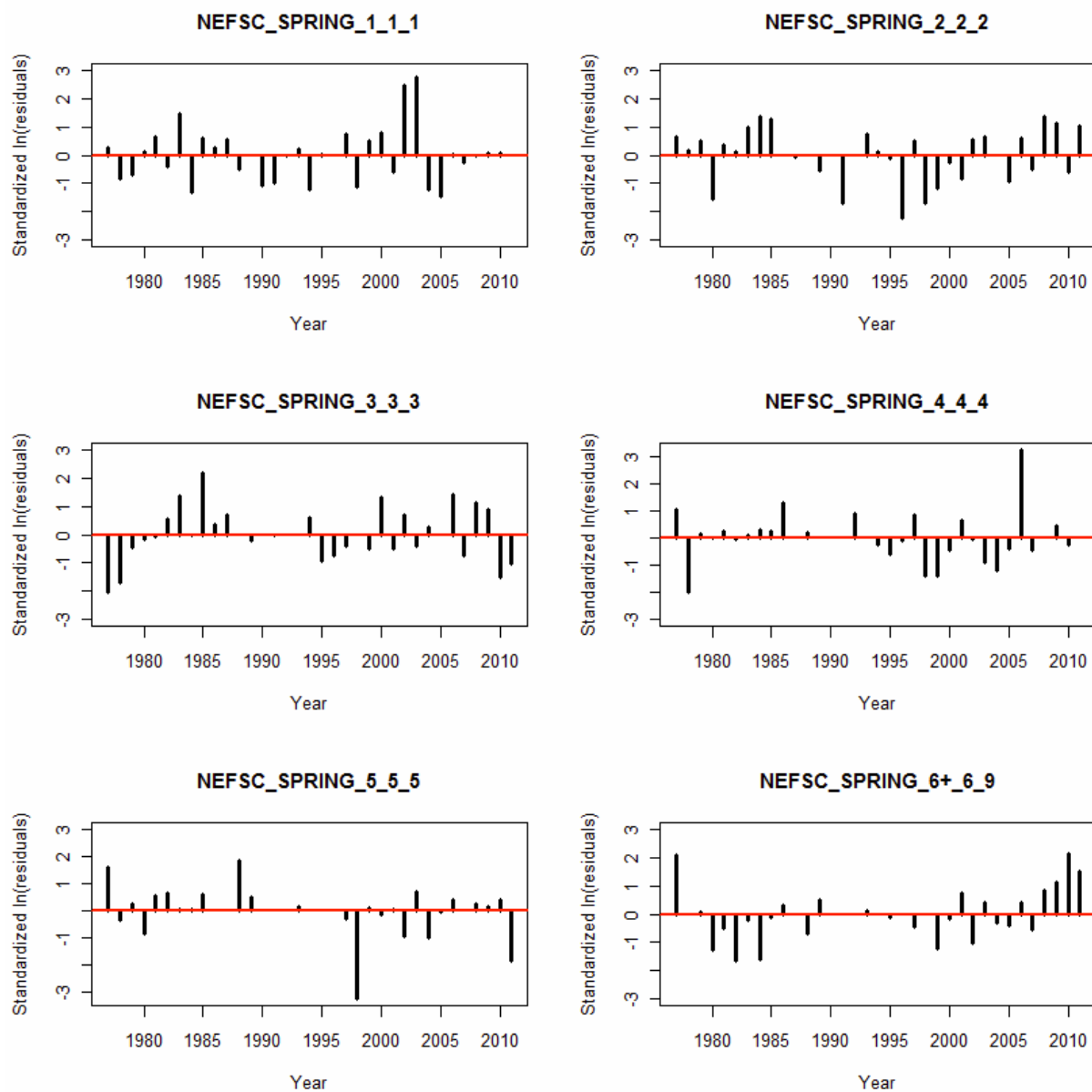


Figure G1: ADAPT-VPA model residuals to the survey fits of the Northeast Fisheries Science Center spring Gulf of Maine haddock survey ages 1 (NEFSC_SPRING_1_1_1) through 6+ (NEFSC_SPRING_6+_6_9).

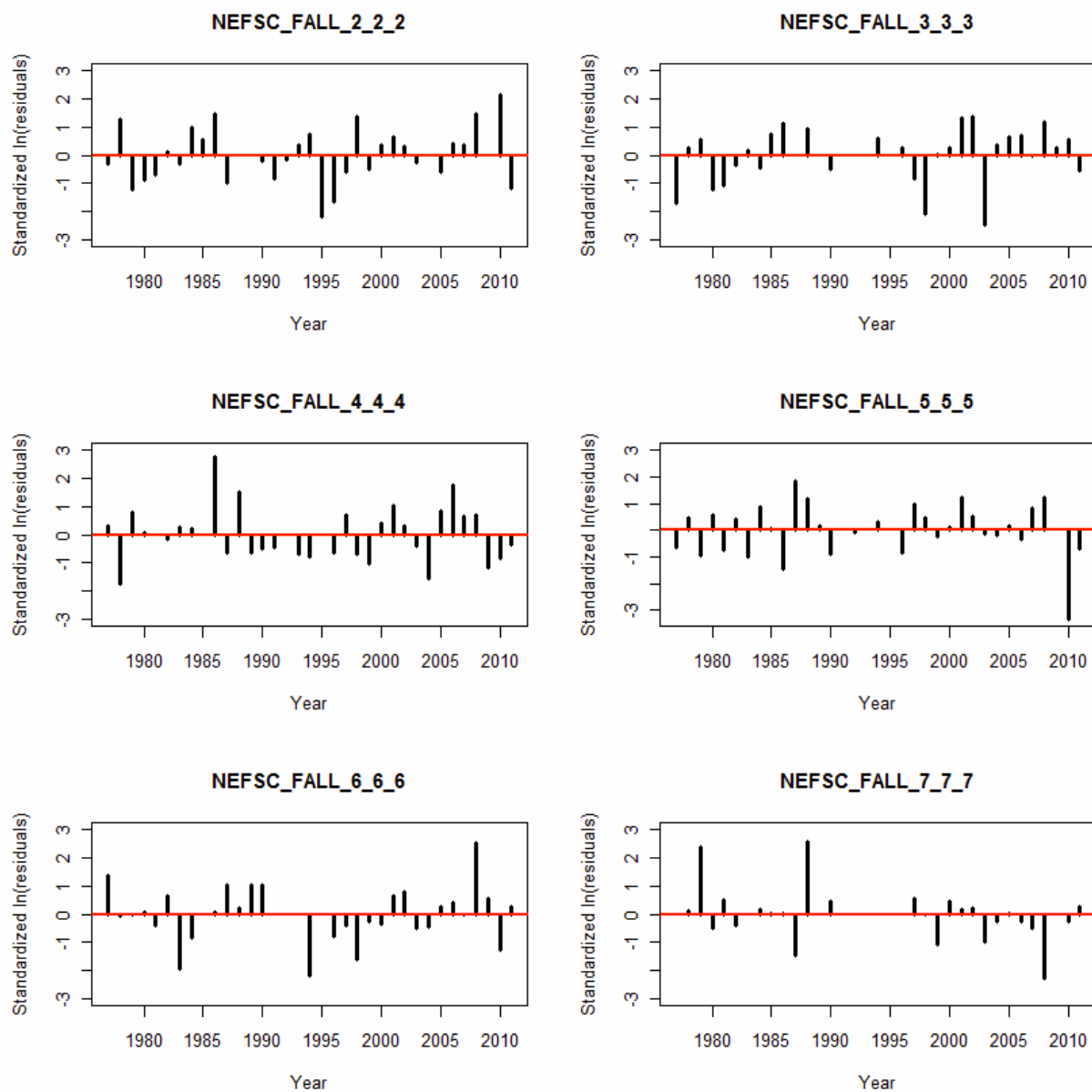


Figure G2a: ADAPT-VPA model residuals to the survey fits of the Northeast Fisheries Science Center spring Gulf of Maine haddock survey ages 1 (NEFSC_FALL_2_2_2) through 6 (NEFSC_FALL_7_7_7). **Note: fall surveys have been lagged forward a year and an age (e.g., 2008 age 1 index was modeled as 2009 age 2).*

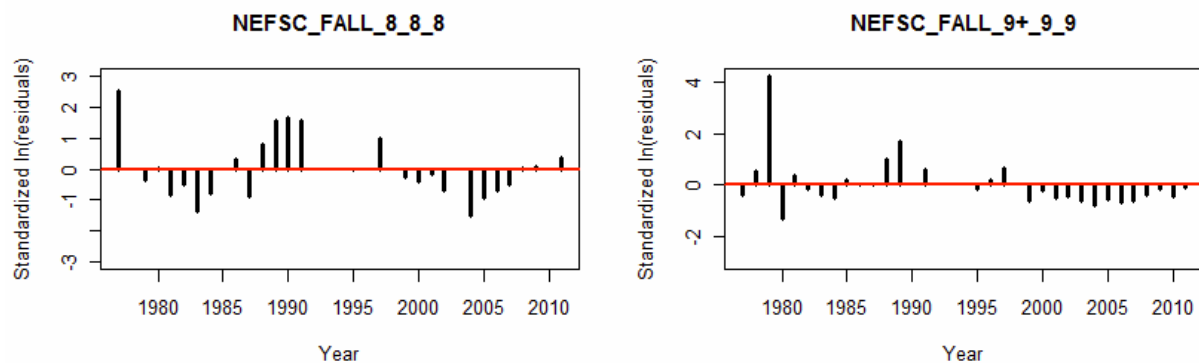


Figure G2b: ADAPT-VPA model residuals to the survey fits of the Northeast Fisheries Science Center spring Gulf of Maine haddock survey ages 7 (NEFSC_FALL_8_8_8) through 8+ (NEFSC_FALL_9_9_9). **Note: fall surveys have been lagged forward a year and an age (e.g., 2008 age 1 index was modeled as 2009 age 2).*

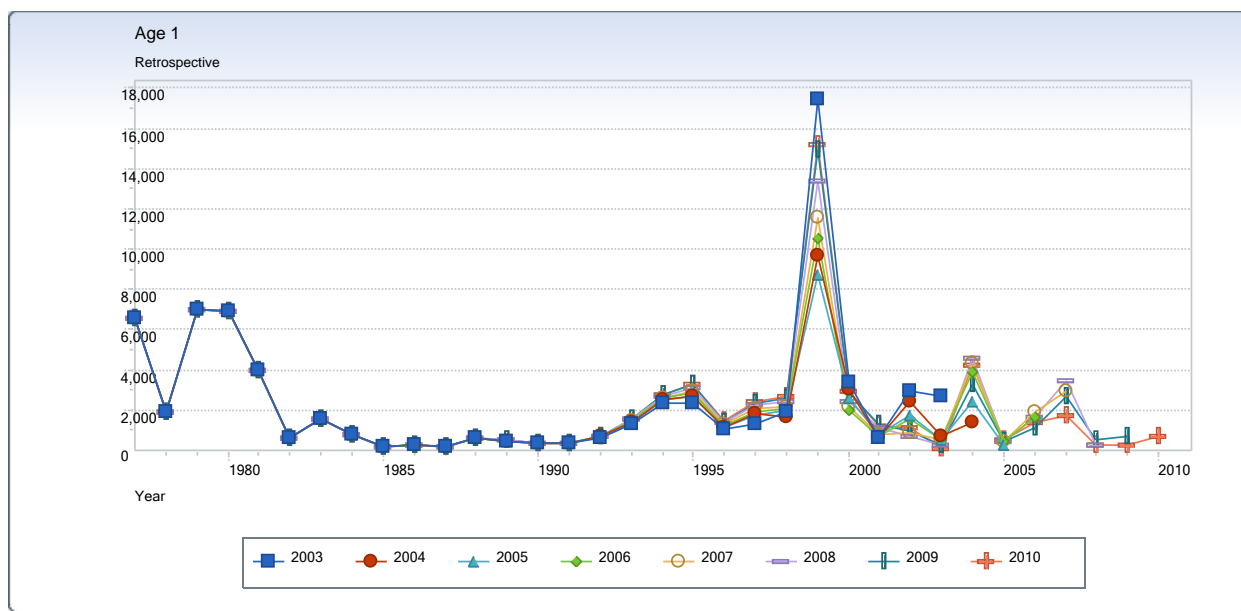


Figure G3: ADAPT-VPA model retrospective patterns for Gulf of Maine haddock age-1 recruitment in absolute terms.

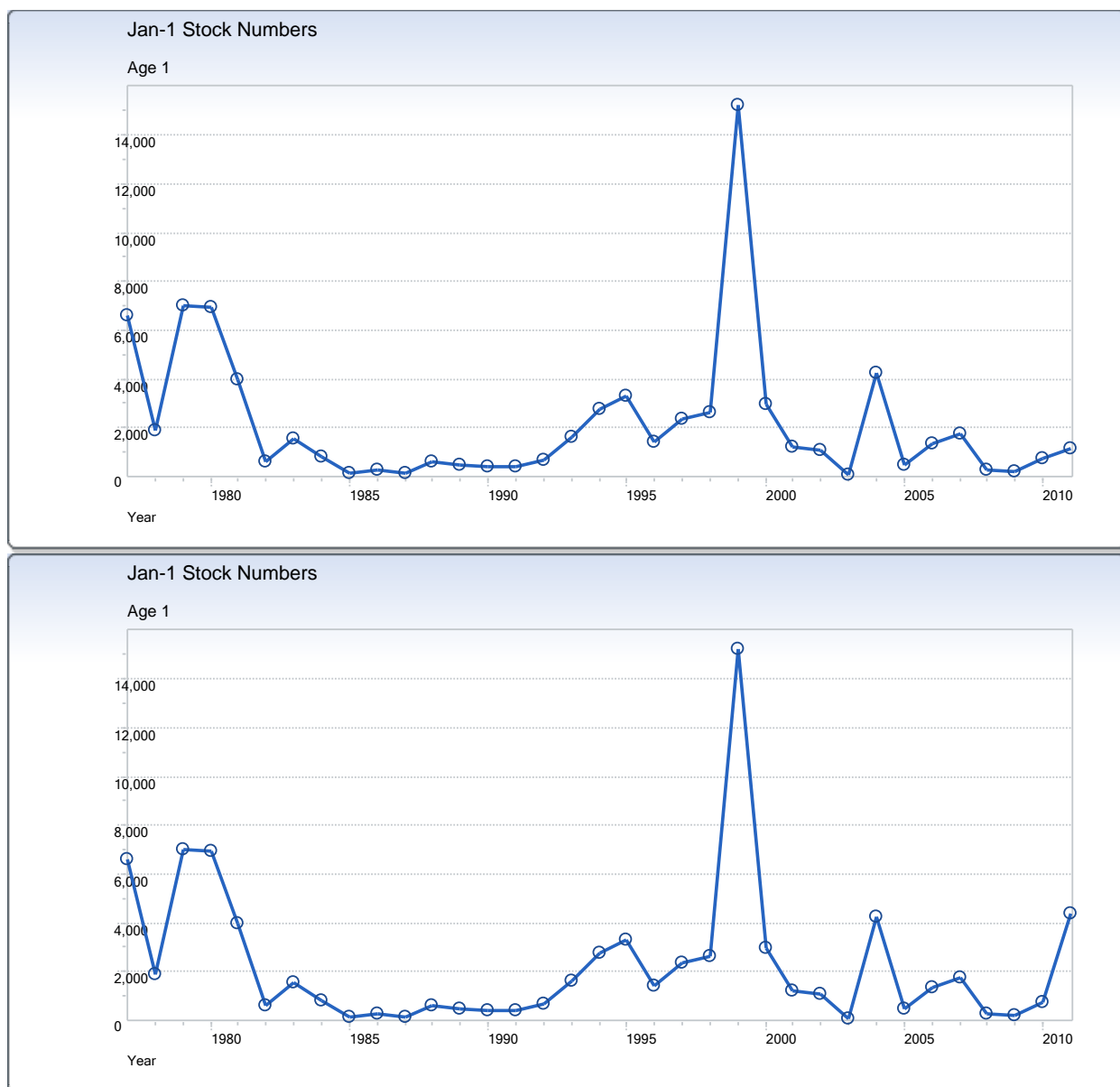


Figure G4: ADAPT-VPA model estimate of age 1 recruitment. Top used a geometric mean recruitment estimate (1977-2010) for 2011 and bottom is the direct estimate from the limited survey information available at the time of the update.

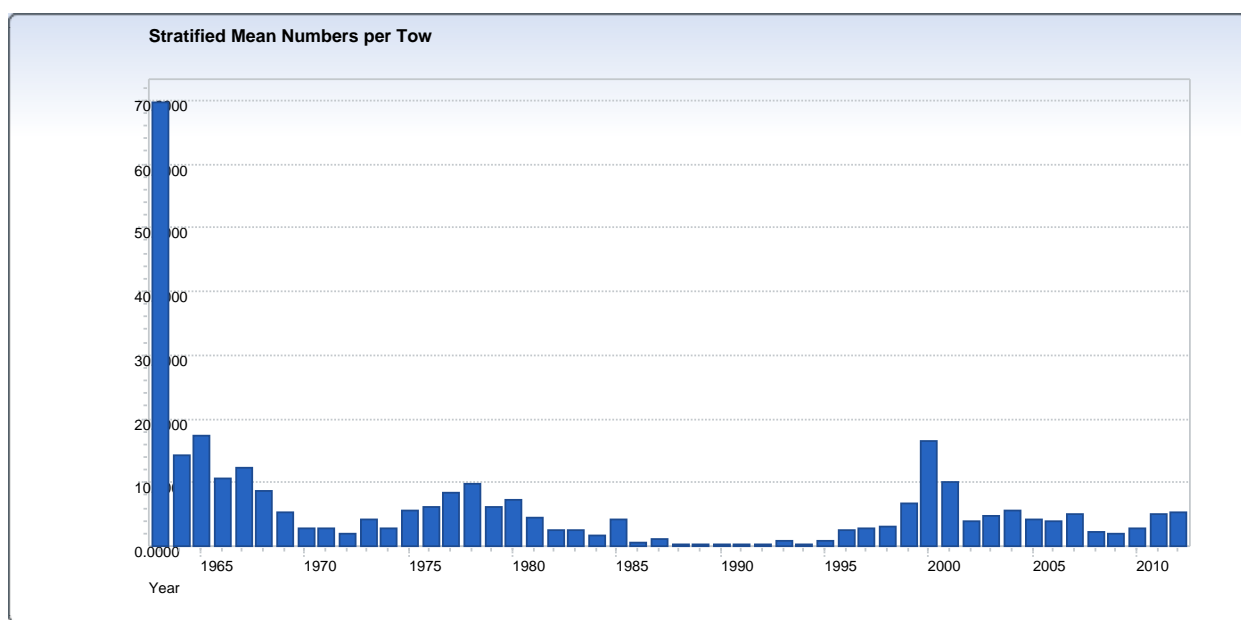
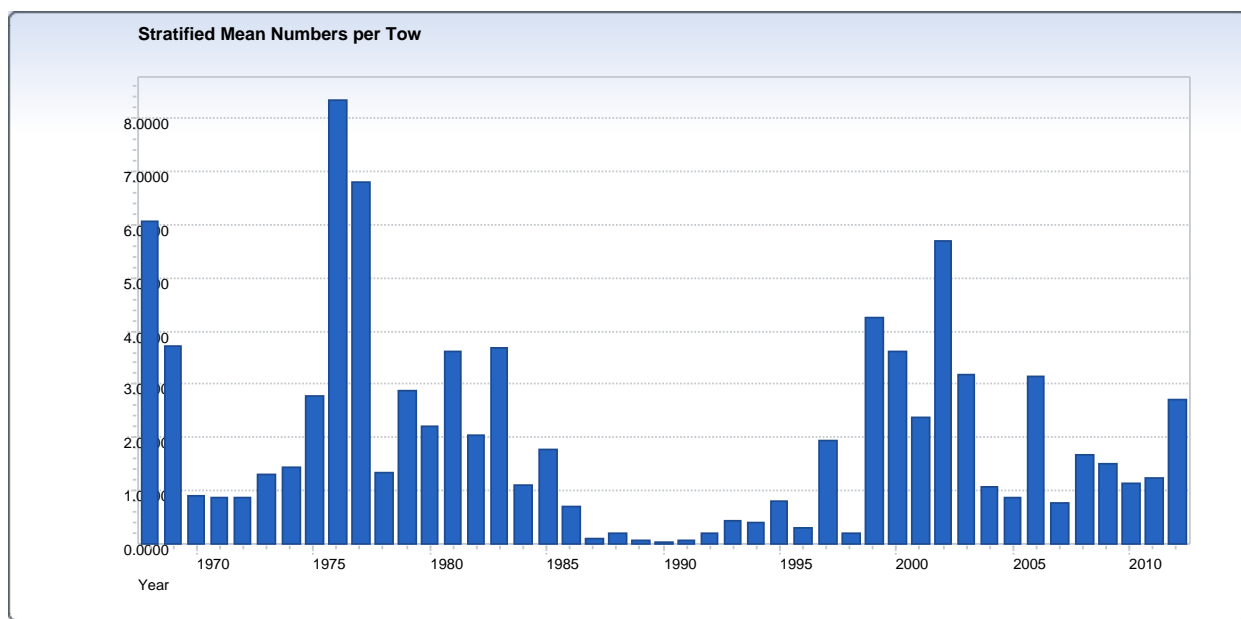


Figure G5: Updated Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl survey abundance (numbers/tow) indices for Gulf of Maine haddock. Vessel and gear conversion factors were applied. Length based conversion was used for the Bigelow years (2009-2012).

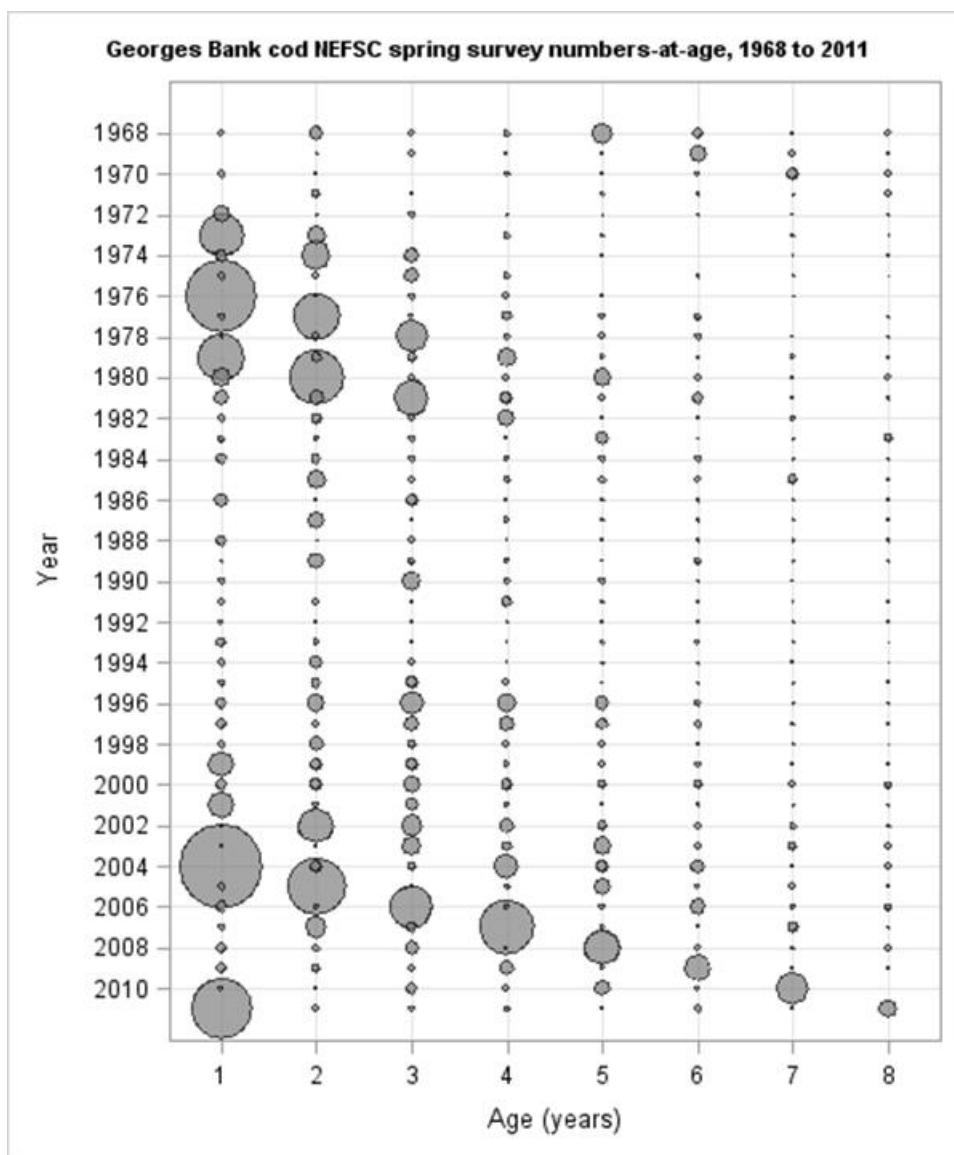


Figure G6: Gulf of Maine haddock numbers-at-age from the NEFSC spring bottom trawl survey, 1968-2011. *Note that age 9 is a plus group.

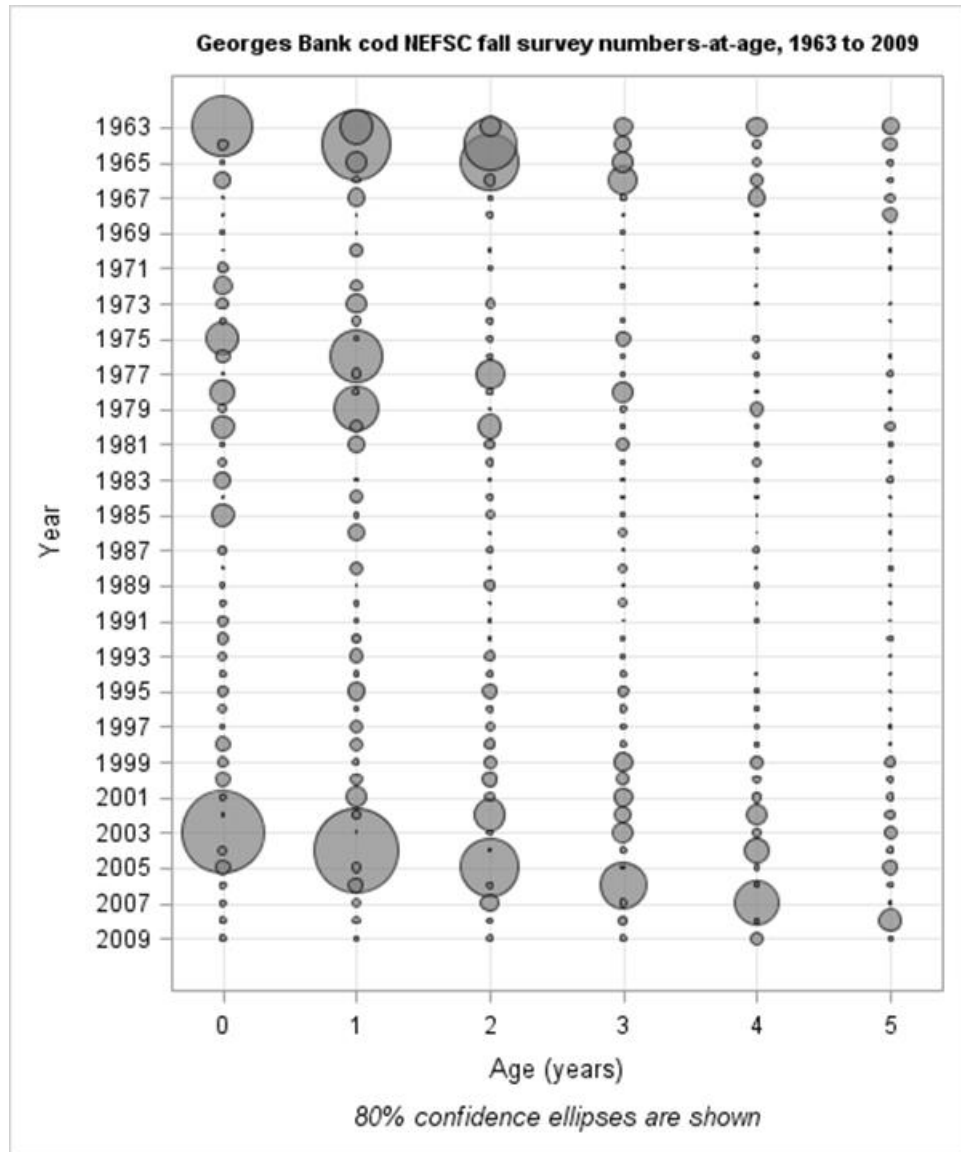


Figure G7: Gulf of Maine haddock numbers-at-age from the NEFSC fall bottom trawl survey, 1963-2009. *Note that age 9 is a plus group.