Northeast Fisheries Science Center Reference Document 02-12

Proceedings of the Fifth Meeting of the Transboundary Resources Assessment Committee (TRAC), Woods Hole, Massachusetts, February 5-8, 2002

Robert N. O'Boyle and William J. Overholtz,
TRAC Co-Chairmen

September 2002

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ABSTRACT

The fifth meeting of the Transboundary Resources Assessment Committee (TRAC) was held during 5 – 8 February 2002 in Woods Hole, Ma., USA to review the assessment models for 5Z+6 cod and 5Zjm cod to be used over the next 3 – 4 years. The assessment meetings will be held for Canadian management units in mid - April 2002 and for US management units sometime during the summer of 2002. This was the first time that TRAC had undertaken benchmark reviews separate from the provision of assessments and was generally considered a positive development. The meeting also discussed issues related to yield and stock production.

INTRODUCTION

The co-chairs, R. O'Boyle and W. Overholtz, welcomed the meeting participants (Appendix 1). It was noted that this was the 5th TRAC meeting since 1998, the last one being held in St. Andrew's, N.B. in 2001.

The TRAC process was briefly summarized. It consists of the Transboundary Assessment Working Group (TAWG) compiling the assessment working papers, which are then peer reviewed by the TRAC. At the 14th Canada-USA Scientific Discussions (Clark and O'Boyle, 2001), a proposal was made to separate the review of assessment frameworks, termed benchmarks, from application of these frameworks to data as part of the annual management cycle. This proposal was made not only to improve the depth of the scientific review but also to allow each nation to provide the most timely advice to their respective management systems. After further development, the proposal was accepted (Appendix 2). The present meeting was a benchmark review of the 5Z+6 and 5Zjm cod assessments.

During 2001 and 2002, negotiations between Canada and the USA on sharing allocation formulas have been underway in the bilateral Transboundary Management Guidance Committee (TMGC). Until the details of how the TRAC is related to the outcome of this negotiation, the TAWG will annually review the assessments. In 2002, the TAWG will review the Canadian management units in mid-April while the US management units would be reviewed during the summer of 2002.

The Terms of Reference of the meeting (Appendix 3) were briefly reviewed. The meeting sought to address various benchmark assessment themes (Appendix 2). The focus of the meeting was on the definition of management units and estimation of contemporary stock status of 5Z+6 and 5Zjm cod. The discussion on exploration of production dynamics was not as extensive as planned. Implementation of Amendments 7 and 9 to the Northeast Multispecies Fishery Management Plan has been legally challenged, necessitating a review by NMFS of biological reference points the week of 11 February 2002. Therefore, discussion at the present meeting was undertaken to provide general observations on Georges Bank groundfish production dynamics, which might be of use to the NMFS meeting. The current meeting did not extensively consider procedures for projection to evaluate TAC's, relying instead on previous TRAC discussions. It did however formulate assessment activities to be undertaken by TRAC between benchmarks.

This report provides a summary of the presentations and associated discussion and the consensus on the benchmark formulations to be used in annual assessments.

The meeting schedule was kept flexible to allow full discussion on the benchmarks, with day one devoted to presentations and the remaining time to discussion, analysis and report writing. The list of documents considered, minutes of TAWG meetings, and recommendations made are provided in Appendices 4 to 6 respectively.

5Z+6 COD

Working Paper: **O'Brien, L. 2002. 5Z+6 Cod Presentation: Atlantic Cod, Simulated Data Analyzed by ASAP, retrospective Analysis of Cod Using a Forward Approach. TRAC Working Paper 2002/01.**

L. O'Brien presented the main issues encountered in the 2001 assessment and tabled the minutes of a TAWG meeting (Appendix 5) held in preparation for this meeting.

Diagnostic plots from the current Georges Bank cod assessment (O'Brien and Munroe 2001) were presented that demonstrate the strong retrospective pattern underestimating fishing mortality (F) and the domed partial recruitment (PR) pattern since 1994. Patterns in PR prior to 1994 were flat-topped. An additional Virtual Population Analysis (VPA) was conducted, using Extended Survivors Analysis (XSA), without F shrinkage, that also demonstrated a similar retrospective pattern in F. In addition, log-log plots of survey abundance indices and population numbers from the VPA indicated that survey catchability (q) in the most recent years (1994-2000) was generally higher than that in earlier years (1978-1993). A shift in survey q was not expected and it was speculated that this was perhaps due to the model formulation used in the VPA, to be investigated at this meeting.

Definition of the Management Unit

Georges Bank cod in the US is managed and assessed using NAFO Division 5Z and Subarea 6 catch and survey index data. The assessment is conducted on a calendar year basis although the fishing year is May-April.

Estimation of Contemporary State

Fishery

In 1994, the collection and processing of commercial catch and effort data changed from a system of personal interviews of vessel captains to a mandatory reporting system of logbooks and dealer reports. The procedures for collection of biological data also changed at this time and the numbers of samples declined for the large market category catch, although sampling has since improved.

Since December 1994, year-round closures have been in effect for Areas I and II (Figure 1).

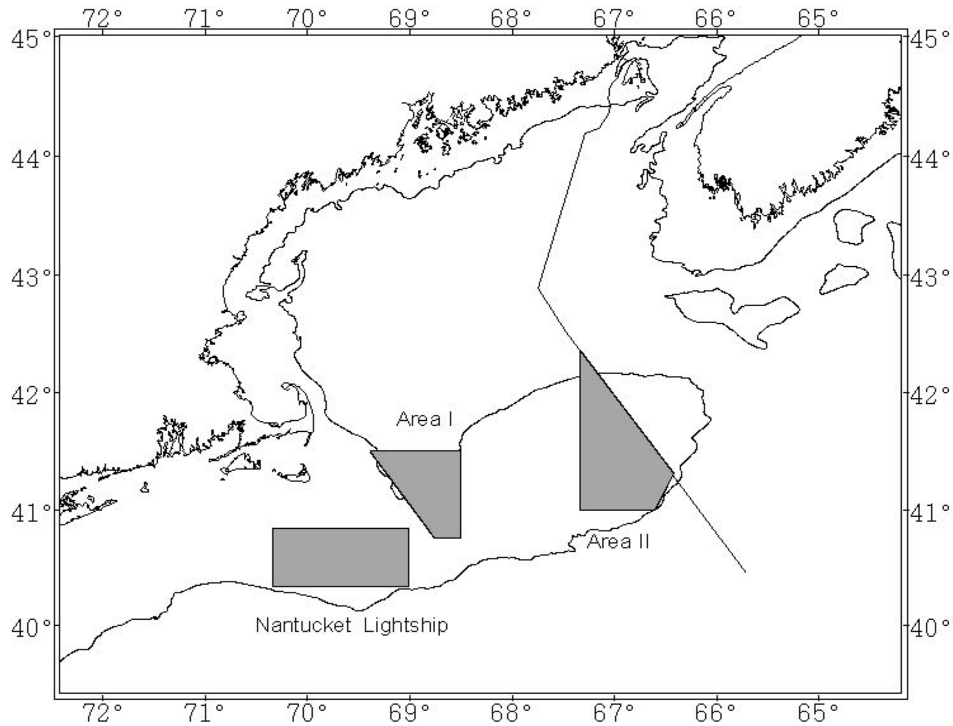


Figure 1. Georges Bank with Year-Round Area Closures indicated.

Recent vessel tracking of about 40 USA offshore vessels that account for about one third of the total groundfish landings indicates that effort in recent years has been focused on the northwest edge of Area II and to the west and north of Area I. Lack of access to Closed Area II since 1994 has decreased the catch of larger fish (Figure 2) that aggregate in this area prior to spawning in the spring. Displaced effort may have also resulted in the catch of smaller fish in areas nearer to shore. The shifts in effort and the reduced availability of larger fish in the spring are consistent with the domed PR observed in recent years.

In 1994, the regulated mesh size increased to 6" diamond. Since August 1999, there has been a trip limit for vessels fishing for cod on Georges Bank, however, discarding of small fish remains at historical levels of about 5-8% (discard/kept ratio). Recreational landings of Georges Bank cod have averaged about 7% of the total catch in recent years (1996-2000). Sampling of these landings is minimal and insufficient to characterize the catch-at-age. Sensitivity analyses that include the recreational landings in the catch-at-age, apportioned to age using commercial samples, result in an upward scaling of the biomass. This increase in biomass results because of an overall increase in catch in recreational numbers-at-age.

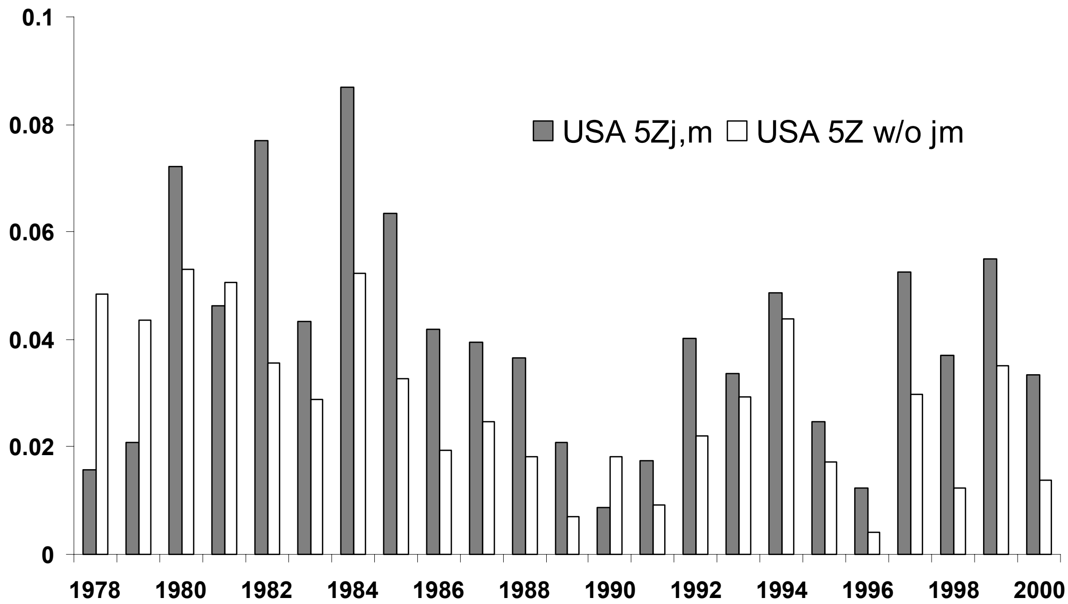


Figure 2. Proportion of Age 7+ Cod in the 5Z Catch.

The catch-at-age used in the assessment includes ages one to 10+. Further decomposition of the plus group was not possible due to data limitations. The number of age samples for ages 10 and older represent only 1% of the total age samples collected during 1982-1988 and less than 1% for all other years.

Abundance

Survey abundance indices available for calibrating the VPA include: NEFSC spring and DFO spring survey ages 1 – 8 and NEFSC autumn survey ages 0 - 5. Data for the DFO survey are not available for 1993-1994 because the entirety of Georges Bank was not surveyed in those years. Spawning stock biomass weights (January 1st weights) were estimated from catch weights (Rivard, 1982), although spawning stock biomass (SSB) might well be better estimated using NEFSC weights-at-age from the spring survey. There are some minor differences in the maturity-at-age between the NEFSC and DFO surveys that need to be reconciled. The meeting recommended that the TAWG address these data changes.

Recommendation: TAWG should recalculate stock weights at age, consider how to best fill in the DFO 1993 & 94 DFO RV information, and reconcile the differences in DFO and NMFS maturity-at-age data.

Several differences exist between the NMFS and DFO ADAPT software for VPA analysis. The NEFSC FACT (Fisheries Assessment Computation Toolbox) software requires that the autumn survey indices be moved forward a year to match beginning of the year VPA population estimates, whereas the DFO software allows for the timing of the survey to be implemented directly. Also, FACT uses Cohort Analysis and the DFO software uses the catch equation.

Recommendation: The FACT software should be amended to allow appropriate time matching of RV & VPA population estimates, and FACT should be modified to use the full catch equation instead of the Pope (1972) approximation.

The NEFSC assessment, to be conducted in late summer 2002, will allow for the use of the NEFSC spring survey for calibration in the VPA. This will be a change in the formulation from previous years when the spring survey was not available for the terminal year.

Apart from fleet distribution changes, differences in the spatial distribution of length classes of fish may explain both the domed PR patterns observed in recent years and the retrospective pattern in F. Spatial patterns of Georges Bank cod in the spring and autumn surveys were examined by 10 cm groupings to investigate differences between length groups and to determine if cod were concentrated in the closed areas since 1994. Young fish, less than 30 cm, tended to occur inshore, larger sized fish were evenly dispersed in the spring, and in the autumn inhabited deeper water on the Northern edge of the Bank and in the Great South Channel. No changes in cod distribution were detected after 1994, when the year-round closed areas went into effect. No more than 10% of each length group occurred inside of Closed Area I or II, i.e. 90% of the 51-60 cm fish occurred outside of the closed areas during 1978-2000.

The NEFSC spring survey is conducted after the period of peak spawning of cod on Georges Bank. Older haddock are known to preferentially inhabit deeper water (Overholtz 1985). If this behavior is also true for Atlantic cod, cod may move off the Bank after spawning and not be available to the Canadian fishery because of current Canadian fishing practices and regulations. Prior to 1993, spawning aggregations in Area II could be fished in January, but the Northeast Peak is now closed to the Canadian groundfish fleet from January to June. Commercial length frequency samples were examined during 1978-1993, by quarter and area (Div 52 and Div. 56), to determine if larger fish were landed in quarter 1 from Div. 56 compared to the remainder of the year, but no significant difference was evident in the length of fish landed between areas or quarters. However, the trends were hard to detect and the TRAC suggested averaging the data across years and, examining the proportion of older fish landed by quarter and area.

Simulation Investigations

A number of simulation exercises were conducted to determine how the VPA results were influenced by varying data input and assumptions. An alternate model was also examined that used forward projection instead of the backward calculation of VPA.

<u>VPA Simulations: Can VPA recover domed PRs from simulated data – Part I?</u>

An age-structured simulation model was developed to investigate the performance of various estimation methods to detect an underlying domed shaped PR pattern from simulated data. The purpose of this exercise was to examine the effect of model mis-specification and changes in model parameters. The Working Group noted that the retrospective patterns in fishing mortality and spawning biomass in the 5Zjm and 5Z+6 cod assessments could arise from a number of sources, and concern was expressed that the domed PR might be an artifact of the modeling process.

Trial analyses were performed using the DFO Contouring Package (ACON) software. The analysis was divided into two components: the first using simulated data, and the second using actual data from the Georges Bank cod assessment.

In the simulations, the catches were generated using a flat-topped PR for the first 16 years and a domed PR for the last seven. This pattern mimicked the perceived pattern in the Georges Bank cod assessment. The simulated data were plotted as if the first year was 1978, to match the empirical data used in the second analysis.

Although four survey time-series were available, only two were used in the simulations because similar trends and low variability made two of them superfluous for fitting the VPAs. All ages (1-9) were estimated in the terminal year. VPAs were performed using two different scenarios. The first assumed that fishing mortality on the oldest age (F9) was equal to that at age eight. If a dome existed, this formulation would be most appropriate. In the second scenario F on age 9 was assumed to be the average (weighted by numbers) of F 4-7. This implies that the partial recruitment is flat-topped.

In the following figures, the upper plot shows the simulation runs with the F on the oldest age (F9) set equal to F8. The lower plots present the simulation results assuming F 9 is equal to the average (weighted by numbers) of ages 4-7.

Figure 3 shows the PR patterns by year. In general, when the model is allowed to find a dome (assumption 1), it does, whereas a mis-specified model (assumption 2) does not detect the PR very well. This also has consequences for the retrospective pattern (Figure 4). These patterns are also evident in the survey catchabilities derived from a moving window analysis (Mohn 1999) (Figure 5) where the mis-specified model shows an increase in age 7 q when the PR is simulated as a dome.

Figure 6 shows a strong relationship between survey catchabilities and model residuals.

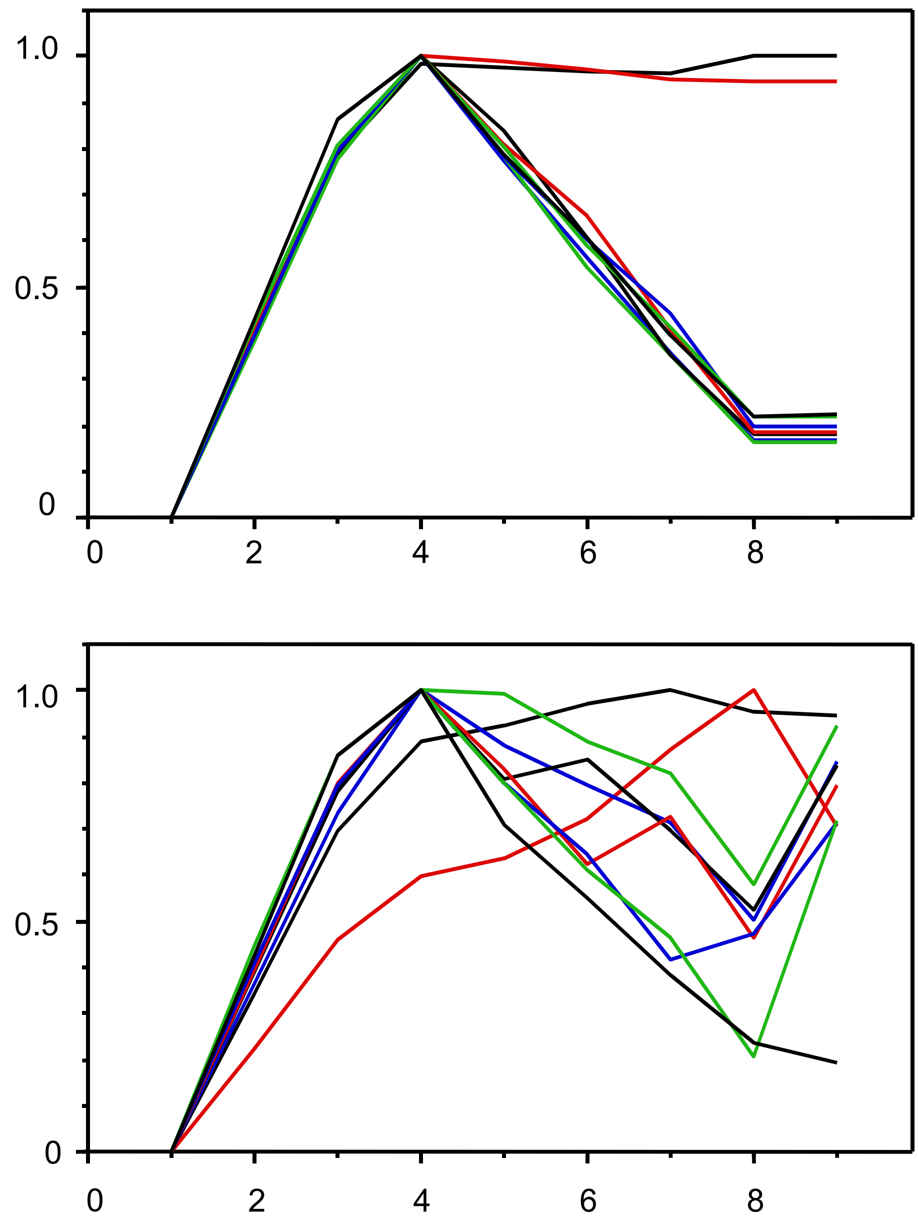


Figure 3. Comparison of selectivity patterns of Atlantic cod, areas 5Z+6. The lines are the estimates of PR for the most recent 9 years. The upper plot captures the dome-shaped. The lower plot (F9 = F4-7), estimates the terminal year well (the line with the lowest PR on age 9), but does not do well for the most of the proceeding years.

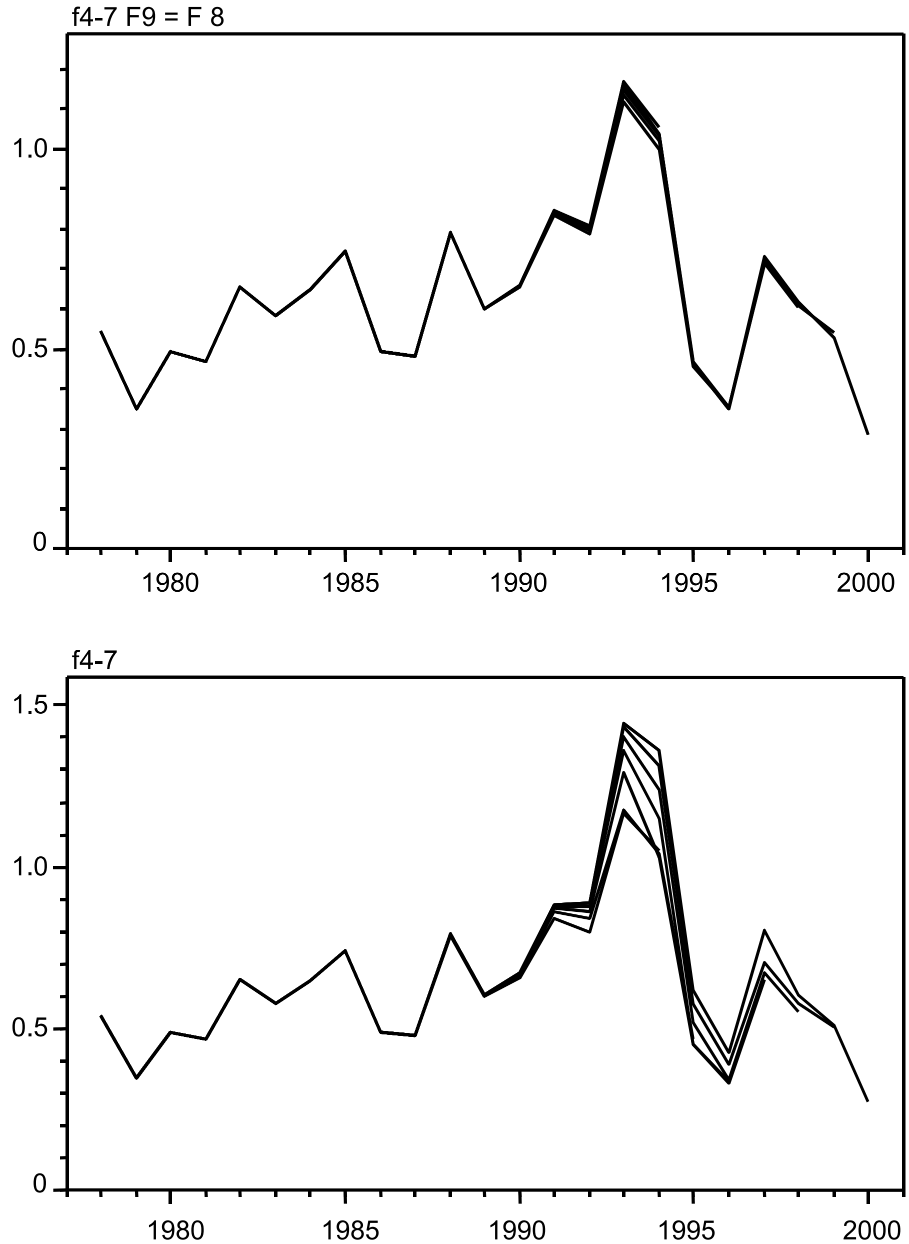
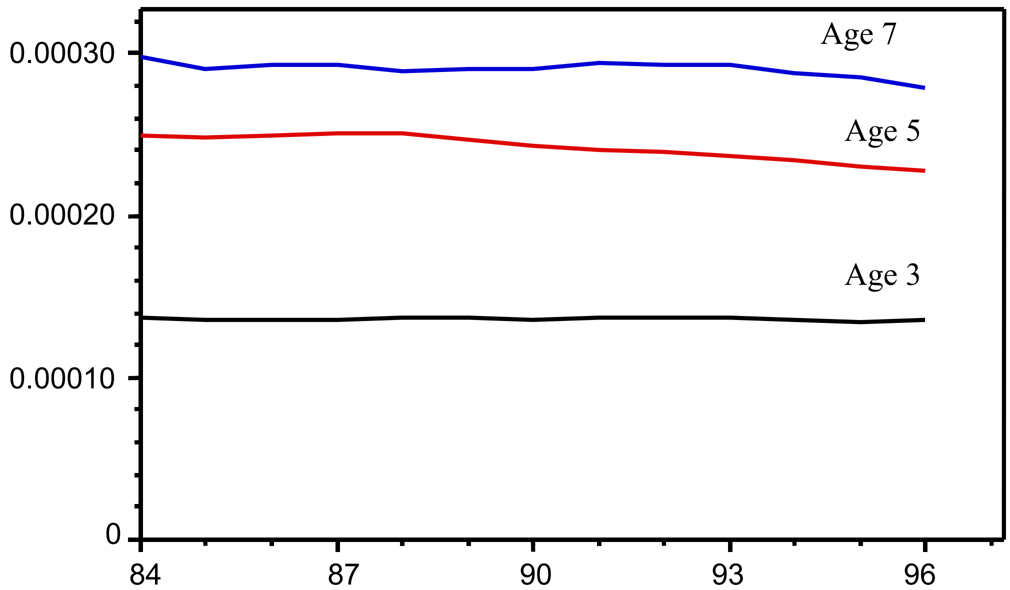


Figure 4. Comparison of retrospective patterns (F4-7) for Georges Bank cod. Seven years were successively removed (starting in 2000) and the VPA re-estimated. The (almost) properly specified model (upper plot) did not exhibit a retrospective pattern while the mis-specified PR model in the lower plot (F9 = average (F4-7)) shows a significant retrospective pattern.



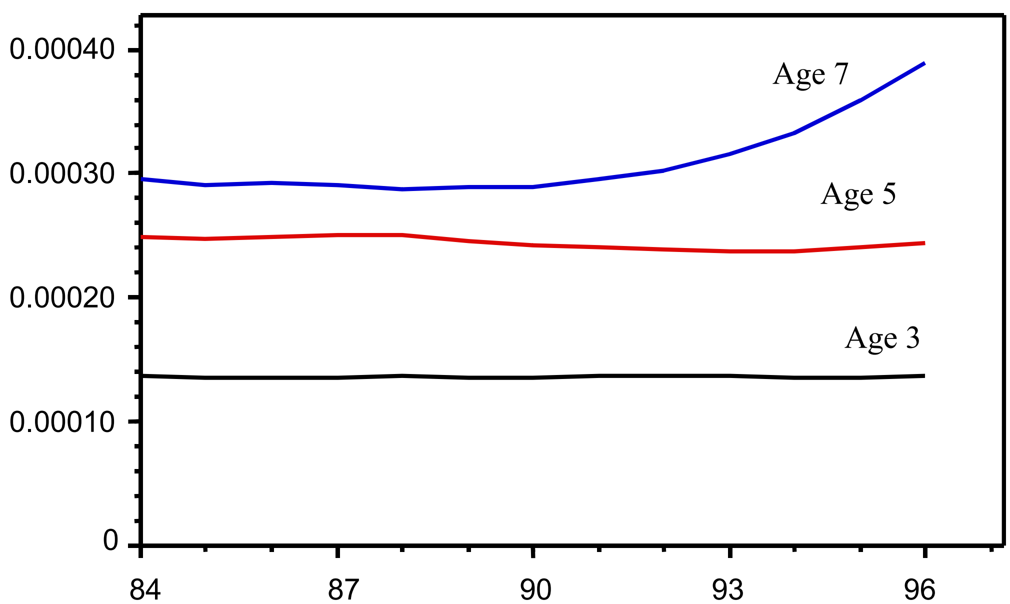


Figure 5. Comparison of RV catchability coefficients (q s) of Georges Bank cod from a moving window analysis (Mohn 1999). The data were partitioned into 11-year blocks (1-11, 2-12, etc) and VPAs performed and qs estimated. Longer windows gave better convergence but less resolution in the detection of timing of changes. The figures show an increasing trend in q for ages 3, 5 and 7. The upper figure shows a small trend in time, especially for the 7-year-old q (upper or blue line). This may be an artifact and in part be due to difficulty in convergence using the short time series. The lower plot shows a time trend in the 7-year-olds, which approximately coincides with the change in the PR.

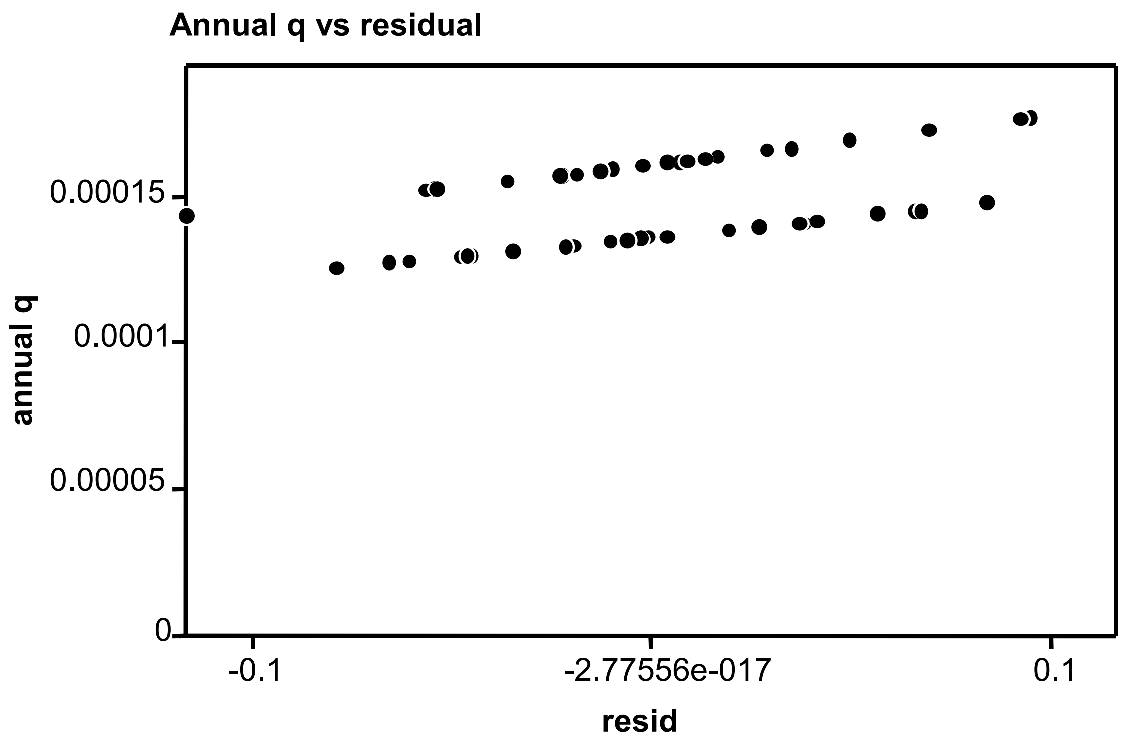


Figure 6. Relationship of annual research vessel catchability coefficients of age 3 Georges Bank cod and residuals (log(observed) – log(predicted)) in simulated survey analyses.

Analyses using the actual Georges Bank cod data differed from those used in the benchmark formulation in the following ways:

- the spring survey was not separated into separate periods for the Yankee 36 and 41 trawls ,
- the survey timing was estimated to the nearest month – e.g. similar to 5Zjm formulation; and
- the age 0 NMFS fall RV indices were not used

As before, the upper plot of each figure shows the VPA runs with the F on the oldest age (F9) set equal to F8, the lower plot presents the results when F9 was set equal to the average (weighted on numbers) of ages 4-7.

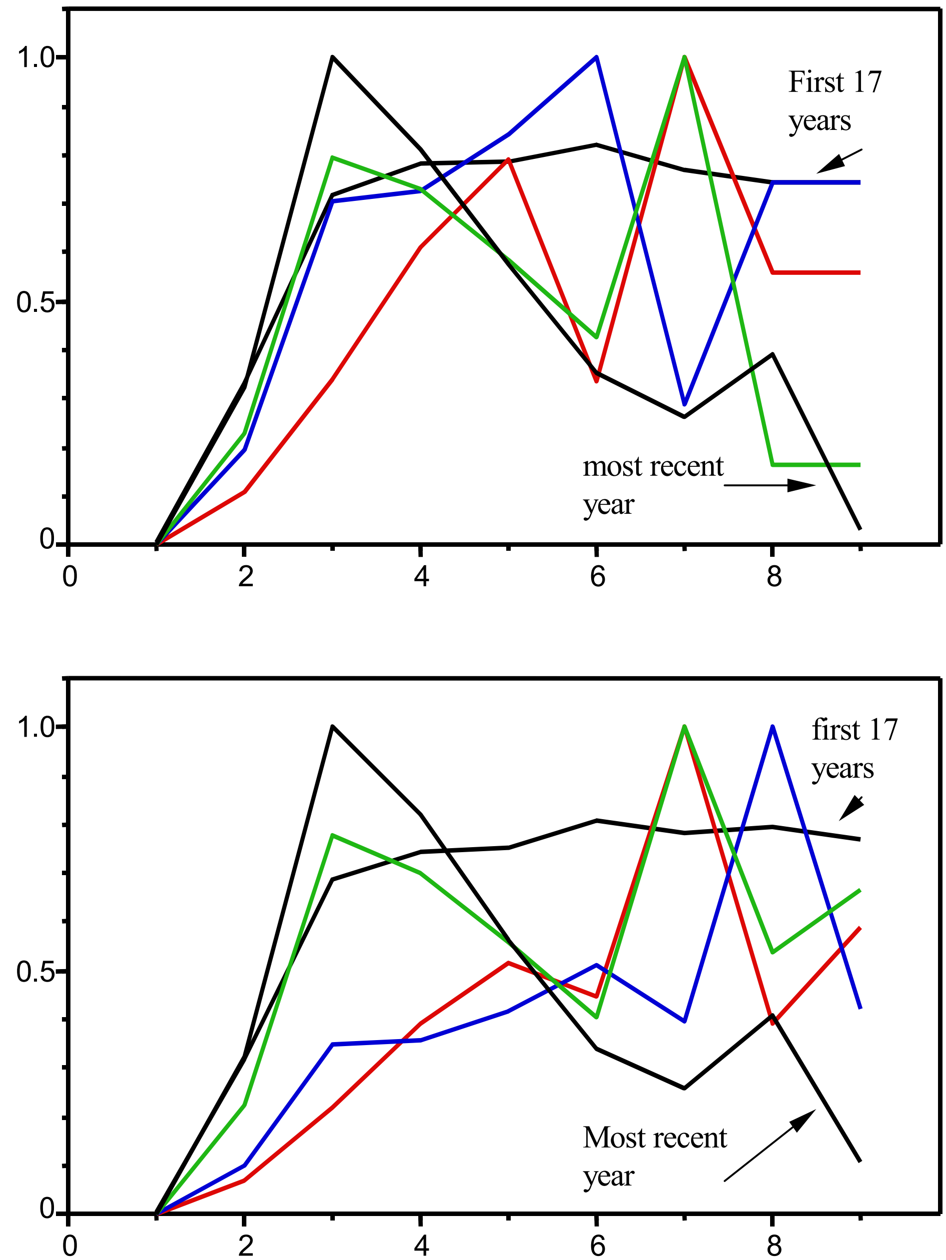


Figure 7. Comparison of selectivity patterns for Georges Bank cod using empirical catch data. The most recent year shows the strongest domed PR. The average for the first 17 years is displayed as an asymptotic pattern.

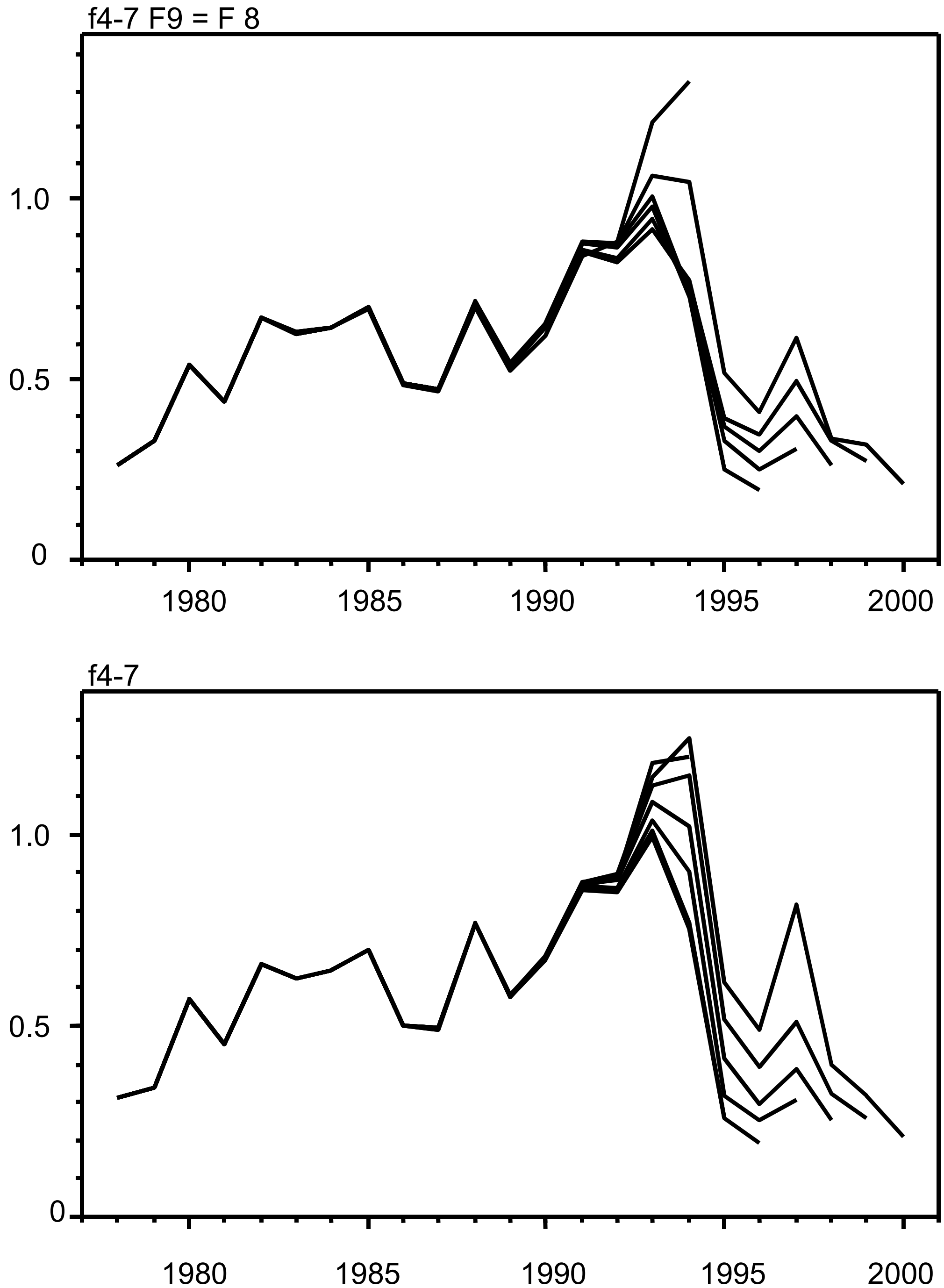


Figure 8. Comparison of retrospective patterns of fishing mortality (F4-7) for Georges Bank cod using F9 = F8 (top panel) and F9 = average (F4-7)(bottom panel). Seven years were sequentially removed (starting in 2000) and the VPA re-run for each data set.

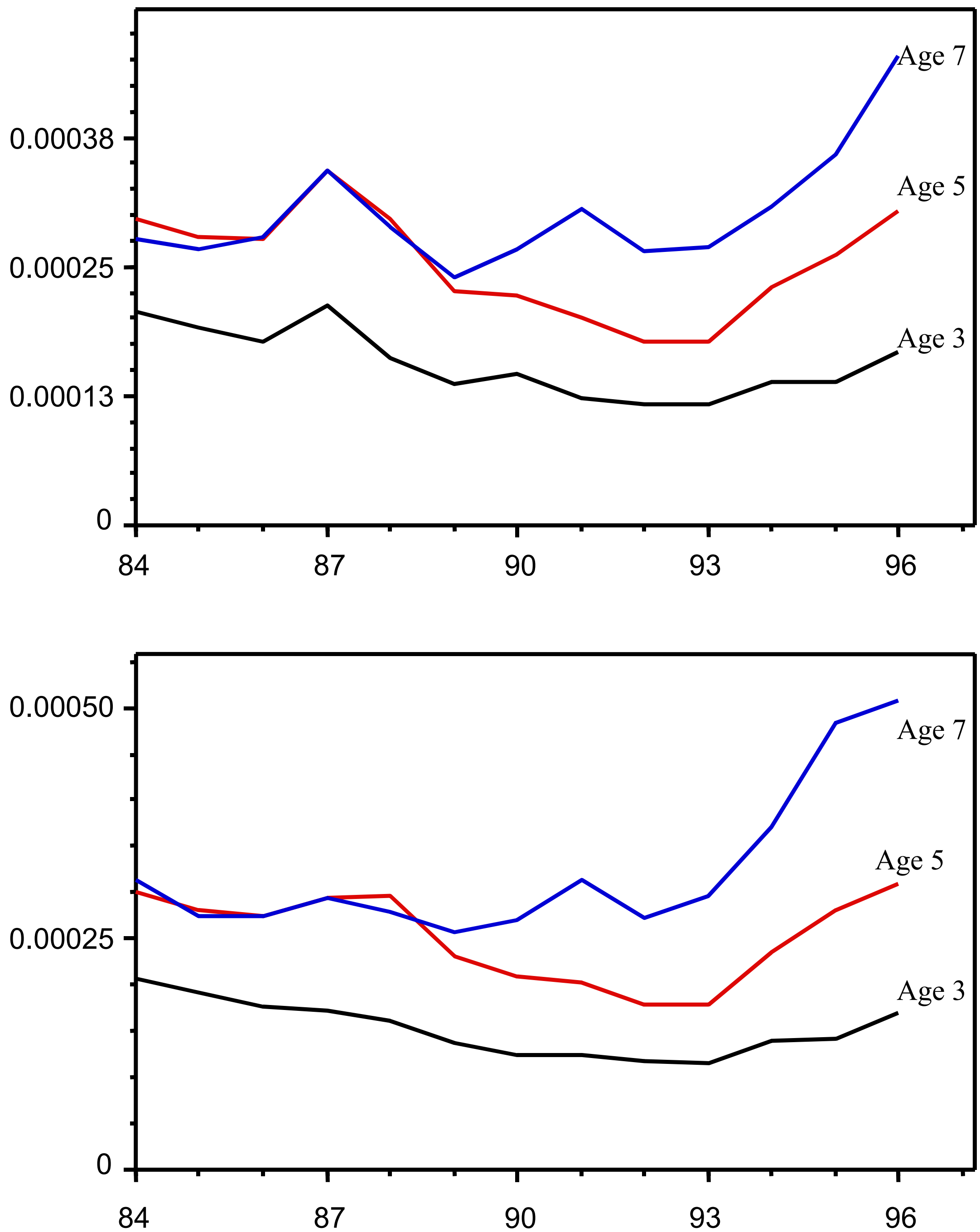


Figure 9. Comparison of moving window analysis (Mohn 1999) for Georges Bank cod using empirical catch data. The data were partitioned into 11-year blocks (1-11, 2-12, etc) and VPAs performed and qs estimated. The above plots shows qs for ages 3 (lower), 5 (middle) and 7 (upper).

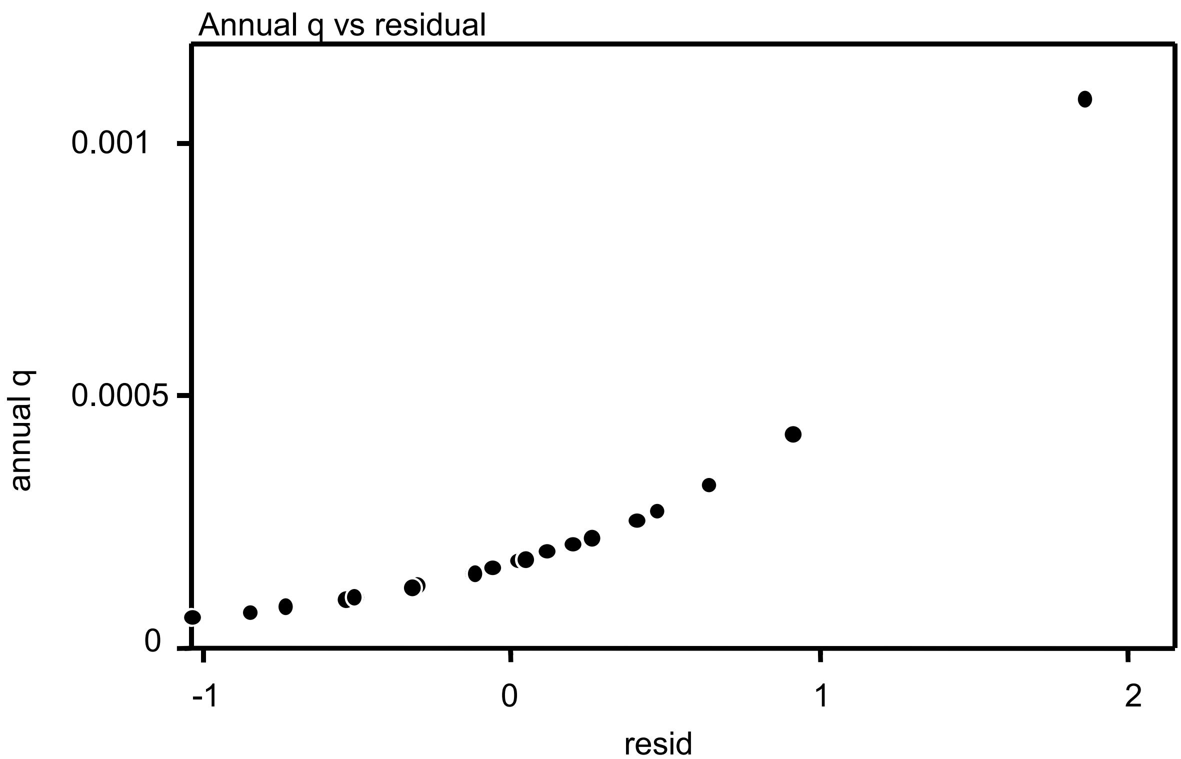


Figure 10. Relationship of US spring survey catchability coefficients (q s) of age 3 Georges Bank cod and the annual residuals using empirical data. Note x-axis and y-axis scales are more than 10 x greater than those in Figure 6.

The analysis of simulated data indicated that VPA could produce the 'true' population selectivity pattern but that it was better to use a minimally constrained estimate of F on the oldest age in cases where partial recruitment changes over time. This conclusion might be compromised if noise were added to the data. The retrospective and moving window analyses behaved as expected. The actual Georges Bank cod data also showed that the less constrained PR fit the data better. The moving window analysis showed a discontinuity occurring around 1994 in both scenarios, which was more pronounced for the q s for older age groups.

<u>VPA Simulations: Can VPA recover domed PRs from simulated data? – Part II</u>

A simulated population was created from average weights, initial population sizes (N) and annual recruitment levels similar to those in the USA Georges Bank (5Z+6) cod assessment. Fishing morality on the fully recruited age classes varied by year but the pattern of partial recruitment had two distinct phases. Prior to 1994, the pattern was flat-topped; from 1994 onward, the pattern was assumed to be domed. Catches, computed using the catch equation, were infused with a small amount of uniformly distributed error equal to + / - 0.1% of the predicted value. Thirty simulated abundance indices were generated as I = qN with population sizes N and the q parameters derived from the actual Georges Bank cod assessment. A small error term, uniformly distributed between + / - 1% of the predicted value, was added to each simulated index. The addition of small error terms in the catch and tuning indices was intended to reduce convergence problems in the numerical optimization procedures. The use of negligible error terms was also intended to isolate problems of model configuration from problems of observational error.

Analyses of the simulated data sets using the U.S. and Canadian implementations of ADAPT revealed that recovery of the known parameters was highly dependent on the model formulation. In particular, the models were sensitive to the range and number of age groups used to estimate the average F on the oldest true age group. If the true PR pattern is domed, then averaging Fs on younger ages (say 3-7) will result to an incorrect estimate of the F on the oldest true age. This leads to a transient behavior whereby the Fs are underestimated in the terminal year. Retrospective analyses revealed a pattern of consistent underestimation of Fs on the older age groups. When the model parameterization was modified to restrict estimation of fishing mortality (F_{old}) on the oldest age groups, then both the U.S. and Canadian formulations of ADAPT led to nearly correct and identical estimates of F and elimination of the severe retrospective pattern in F.

Overall, a domed PR presents particular challenges to the models and ancillary information is required to resolve whether or not such a pattern is present. The ancillary information could include examination of RV trends by age and year. One would expect the RV q s to asymptote (i.e. become flat) at a given age and not monotonically increase. Survey mensuration research could be brought to bear on this issue (i.e. what is the expected shape of the q – age/size relationship for survey gear)? One would also expect that RV q by year would vary without trend (similar to residual pattern). Further, examination of fleet and or population spatial patterns and partial Fs by country and or fleet might provide insight on changes in exploitation patterns. Some of these were examined at this meeting (as described below).

If a domed PR is present, then sooner or later, the surveys should record increases in abundance of large cod although this might take a number of years depending on recruitment and F.

Forward Projection Model using Actual Data

A forward projection model was applied to the cod data to determine if a different model structure could shed light on the retrospective problem. The ASAP [age structured assessment program, Legault and Restrepo (1999)] model uses a forward solving approach to estimate population abundance and fishing mortality rates from catch at age and tuning indices. The model is based on a separable approach for fishing mortality and estimates a stock - recruitment relationship to determine the strength of each cohort. Flexibility in the model is facilitated by allowing selectivity to vary annually and by allowing predicted recruitments to vary from the stock recruitment relationship. Flexibility can be constrained by placing penalties on the parameters that determine the amount of variance in the estimates)so that the model does not become over-parameterized). The model is written using AD Model Builder software. Parameters are found rapidly through automatic differentiation and subsets of parameters can be estimated in phases, which stabilizes the estimation procedure.

Five model formulations were used in ASAP based on the same cod data used in the VPA analyses. All five models assumed total annual catch in weight was known without error while the catch-at-age data were assumed to have error rates corresponding to effective sample sizes of 50-200 fish per year. The first two formulations had recruitment exactly follow the stock recruitment relationship, while the remaining three formulations allowed deviations in recruitment from the S-R curve. Four of the models held selectivity constant in all years while the most complex model allowed selectivity to vary from year to year, subject to constraints.

Model	Recruitment	Selectivity
1. Minimal, Flat PR	SRR	Flat topped all years
2. Minimal, Dome PR	SRR	Dome all years
3. Recruitment, Flat PR	Deviations	Flat topped all years
4. Recruitment, Estimated curve.	Deviations	One curve estimated for all years
5. Recruitment,PR estimated yearly	Deviations	Estimated for each year

All models produced trends in SSB and F that were similar to the VPA, but, different in magnitude. When selectivity was estimated, it was strongly domed, even for an additional run when selectivity in the first year was fixed as flat topped. All five models were examined for retrospective patterns in SSB, recruitment and average F (ages 4-8 unweighted). Flat topped selectivity models (1 and 3) had more pronounced retrospective patterns in SSB and F than domed selectivity models. The simple models (1 and 2) had more pronounced retrospective patterns in recruitment than the complex models. Use of the asymptotic variances provided by AD Model Builder demonstrated that in general the retrospective patterns were not “statistically significant” from one year to the next; between when a unidirectional pattern was present, the accumulation of change produced significantly different changes in estimates of SSB, recruitment and average F.

The types of changes generated by the retrospective analyses of a forward projecting model demonstrate that model formulation plays an important role in affecting retrospective patterns. The same may be true ofVPA, but is not generally observed due to the limited range of formulations typically examined. One avenue for future research is to use the results from VPA results as the starting conditions for the ASAP model under the hypothesis that the range of solutions under different model configurations will differ less in magnitude.

Recommendation: Pursue research on using VPA results as starting conditions for the ASAP so that initial conditions for the ASAP model will be consistent across different model runs.

Forward Projecting Model using Simulated Data

As with VPA, a simulated data set was prepared that incorporated a flat-topped selectivity pattern for years 1978-1993, switching to a dome during 1994-2000. The simulated data included 30 tuning indices with minor observation error. Three model formulations were explored which each contained recruitment deviations but differed in the treatment of the selectivity pattern. In the first formulation, selectivity was assumed to be flat-topped in all years. In the second formulation, a single pattern was estimated for all years. In the final formulation, the first year was assumed to be flat-topped, with selectivity in subsequent years estimated under a constraint on change from one year to the next.

The forward projection modeling results failed to recover the true population size but the trends were consistent with the VPA. One reason for the lack of agreement was the dependency of the forward simulation on the estimated stock-recruitment function. Since the simulated data were not generated from a specific S-R function, the forward projection method estimates the S-R parameters. If the underlying simulated data do not support a particular model formulation, then the lack of a good S-R fit will induce population size errors that are not considered in VPA-based approaches. Under these circumstances, a better test of the forward projection model approach would be to initiate the simulated population with the VPA results and generate the recruits (and therefore, subsequent population estimates) with a known underlying S-R function.

When selectivity was estimated, a strong dome resulted, and when selectivity changes over time, a stronger dome is estimated in the most recent years. In contrast with the VPA, however, was absent. This may be due to the small amount of observation error allowing the ASAP model to fit the data consistently while the larger amount of noise in the real data allow for a retrospective pattern to be expressed in the VPA output.

One possible explanation for the strong dome estimated by ASAP is that there was no tuning information for the plus group. To examine this possibility, an additional run was performed which linked the selectivity at ages 8 through 10+. A dome selectivity pattern was still obtained, with selectivity at ages 8 to 10+ approximately the midpoint of the individual estimates from the full model.

Patterns in Relative Fishing Mortalities

Patterns in the partial recruitment and relative fishing mortality were evaluated using relative indices obtained from the ratio of catch-at-age divided by the catch rate-at-age from each of the RV surveys. This type of analysis is useful in examining changes in exploitation when there are uncertainties in VPA results. However, trends from this analysis will be affected by changes in the rate of catch reporting and/or changes in survey catchability.

The analysis was conducted with the 5Z+6 cod data. The ratio of catch-at-age to the RV catch rate at age was calculated for the US spring survey and the Canadian winter surveys for ages 1 to 8. To examine partial recruitment over time, this ratio was normalized by year (highest value set equal to 1) and averaged over the time period. Averages were then calculated over three periods (1978-1985, 1986-1992 and 1995-2000).

The resulting trends from each of the survey indices indicate that the partial recruitment pattern is somewhat domed over the entire period (Figure 11). However, this could be due to an increasing pattern of survey catchability up to an asymptotic age. Because fish of younger ages are likely not fully recruited to the survey, the peak of the dome is shifted to younger ages and not representative of the PR in absolute terms. However, the relative change in PR should be representative of temporal changes that have occurred either in survey catchability or in the fishery. The dome in the partial recruitment is more pronounced (steeper descending limb) in the post-1994 period.

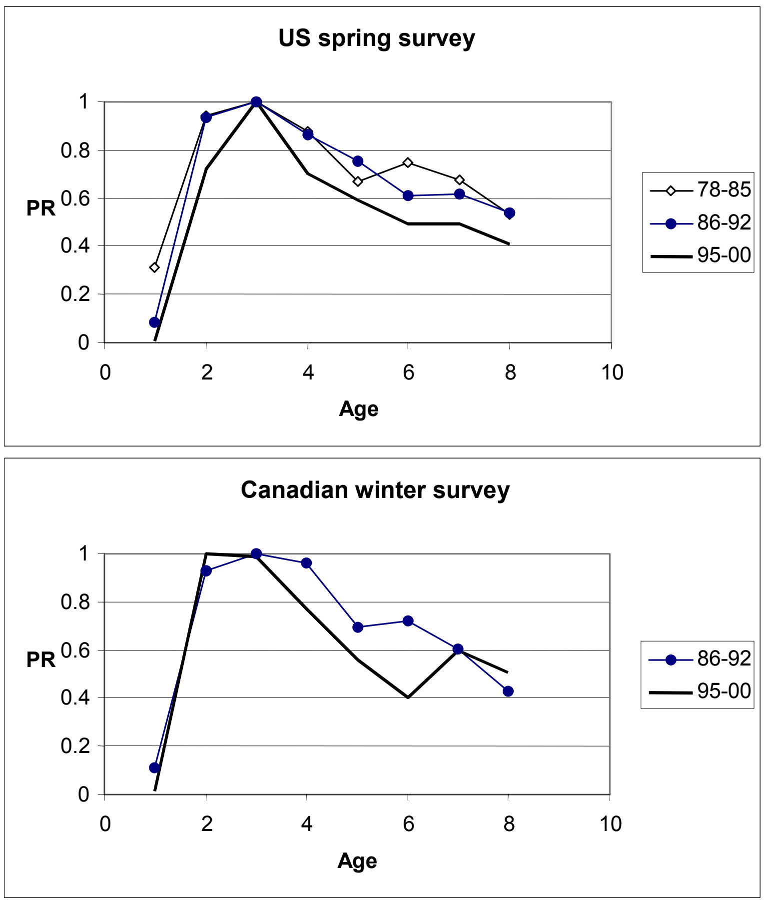


Figure 11. Temporal Pattern in Relative Fishing Mortality.

The trend in relative F was further examined by normalizing by age the catch-at-age to survey indices ratios over the entire time period. The resulting values were averaged for ages 4 to 6, the age groups considered fully recruited to the fishery.

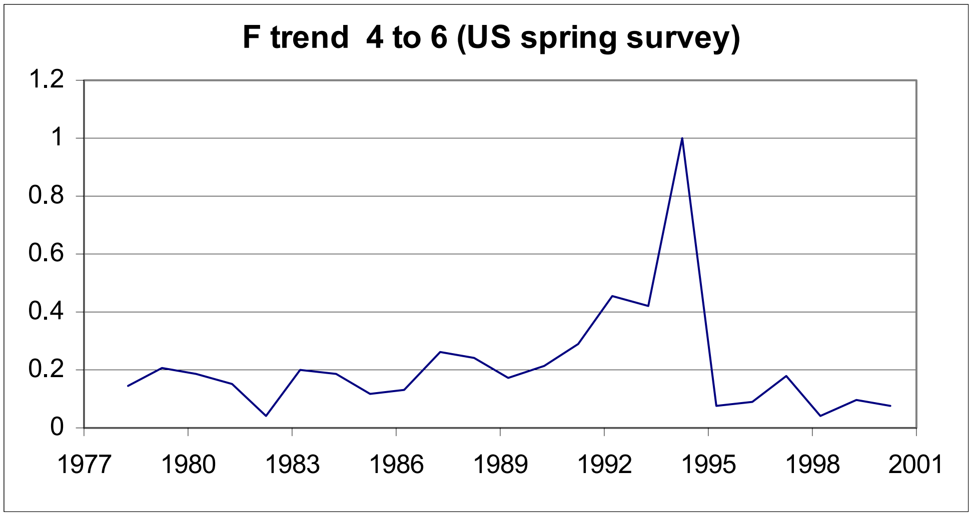


Figure 12. Trend in Age 4 – 6 Relative Fishing Mortality from NMFS Spring Survey.

The results (Figure 12) indicate an increasing trend in fishing mortality in the late 1980s and early 1990s, followed by a sharp decline in 1995 an low F afterward. This is consistent with the decline in fishing effort that occurred in these years.

Given the variability in the survey indices, the results are relatively consistent with the VPA. The VPA suggested a flat-top PR in the early time-series and a shift to a dome since 1994. The relative F's also suggest a decline in PR at older ages in recent years. It would thus appear that the dome PR in recent times is not an artifact of the VPA calibration.

Estimation

<u>Virtual Population Analysis</u>

Catch-at-age for Georges Bank 5Z+6 cod includes ages 1-9 with a 10+ age group from 1978-2000. Further decomposition of the 10+ age group is not possible due to lack of sufficient age data prior to 1982 and after 1988.

All survey indices (NEFSC spring and DFO ages 1-8, NEFSC autumn ages 0-5) are used in the calibration of the VPA. Although the 5Zjm benchmark assessment excluded the DFO age 1 and 8 indices and the NEFSC autumn 0 indices (see below), this was not necessary in the 5Z+6 assessment. Examination of the indices shows no lack of fit between the survey values and the VPA estimates that was observed in the 5Zjm assessment. This is perhaps due to the difference in the number of strata used in the estimation of abundance indices for 5Z vs. 5Zjm.

Stock sizes were estimated for ages 1-8 in the terminal year plus one and in the corresponding unweighted F estimates for ages 1-7 in the terminal year. Full recruitment was assumed at age 4 and F on ages 8 and 9 in the terminal year was an unweighted average of ages 4-8. The F on age 9 for all years prior to the terminal year was derived from a weighted average (by numbers) of ages 4-8. Age 10+ F was set equivalent to age 9 F in all years.

The model is sensitive to the choice of age groups used in estimating F on the oldest age (9). Different combinations of age groups to estimate F on age 9 were applied to determine if the choice of ages influenced the retrospective pattern. The retrospective pattern in F still persists regardless of the F assigned to the oldest age (9), although the magnitude shifts slightly in some cases (Figure 13).

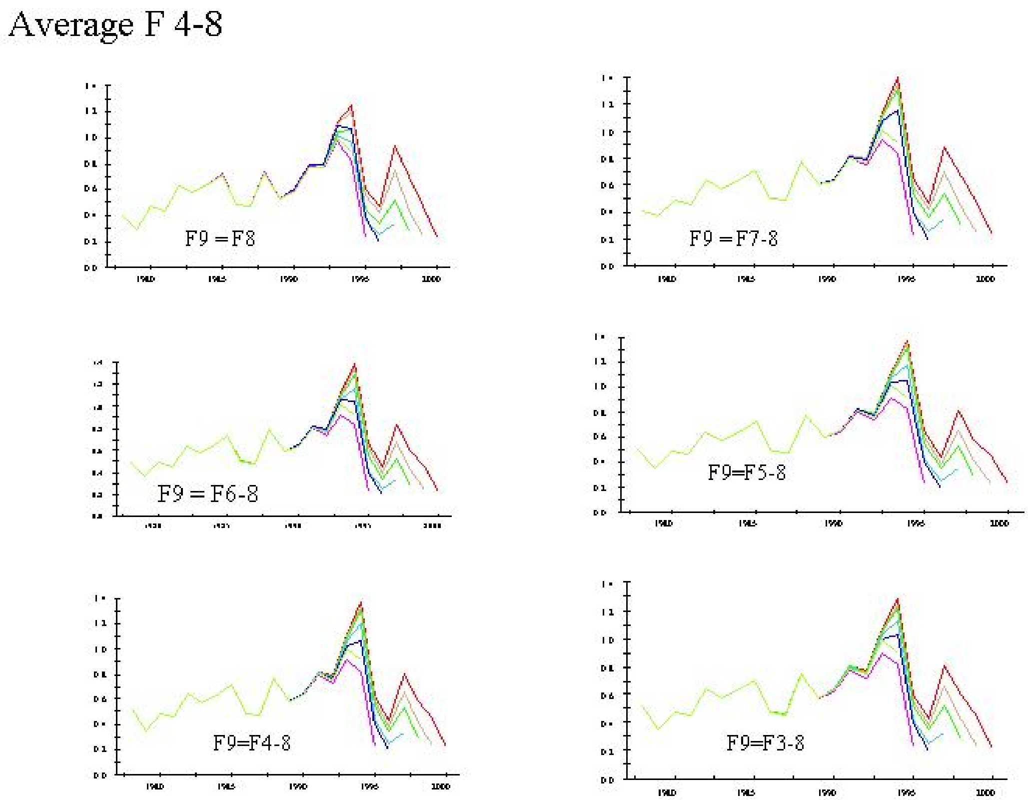


Figure 13. Retrospective analysis (starting in 2000 and proceeding back to 1995) of average F (4-8, unweighted) with F on the oldest age (9) derived by setting F9 equal to F8 (top left), F7-8 (top right), F6-8 (middle left), F5-8 (middle right), F4-8 (bottom left), and F3-8 (bottom right).

Exploratory analyses were conducted to determine if weighting of cohorts in the catch at age (CAA) would influence the retrospective pattern, based on the assumption that since less information is known about the incomplete cohorts then less weight should be given to their contribution in the analysis. A weighting factor was derived for each year and age of the cohort based on the number of years of catch data available to derive the estimate. In the terminal year, all cohorts were assigned a value of 1, in terminal year -1, each cohort was assigned a value of 2, etc. All complete cohorts were assigned a weight of 10. All weights were then divided by the maximum weight in that age group across all years and multiplied by 10. The retrospective pattern in F still persisted using either an average F on ages 4-8 or an average F on ages 6-8. The magnitude of F shifts depending on the F assigned to the oldest age 9 (Figures 14 and 15) and these shifts are slightly more than that observed in the unweighted CAA analysis (Figure 13).

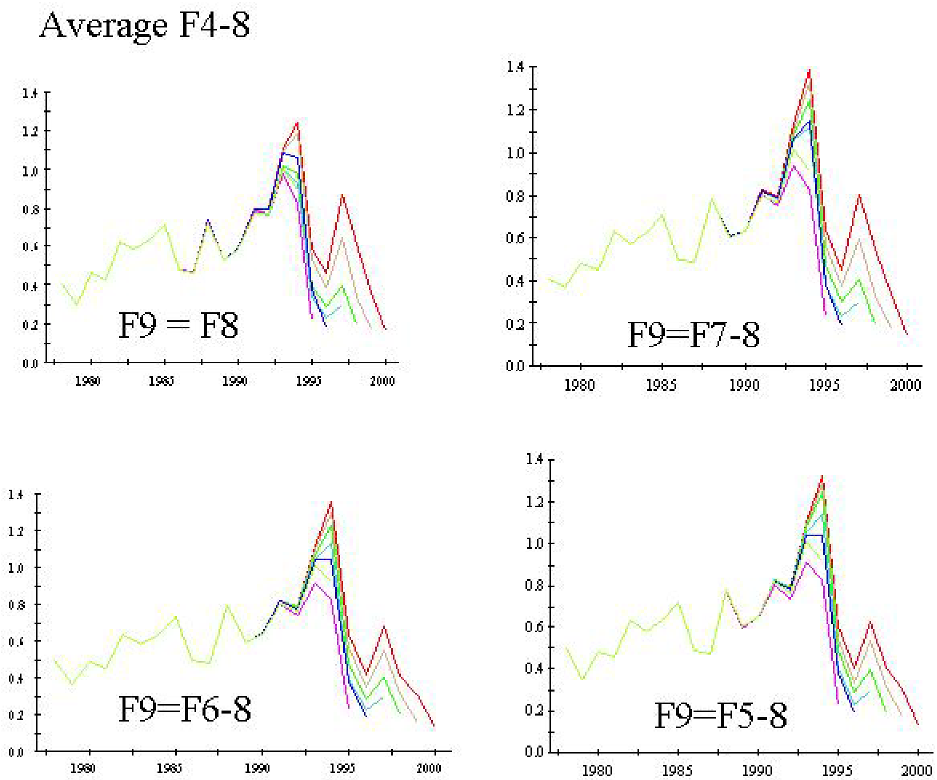


Figure 14. Retrospective analysis (starting in 2000 and proceeding back to 1995) of average F (4-8, unweighted) with F on the oldest age (9) derived by setting F 9 equal to F8 (top left) and to the average of F7-8 (top right), F6-8 (bottom left), and F5-8 (bottom right).

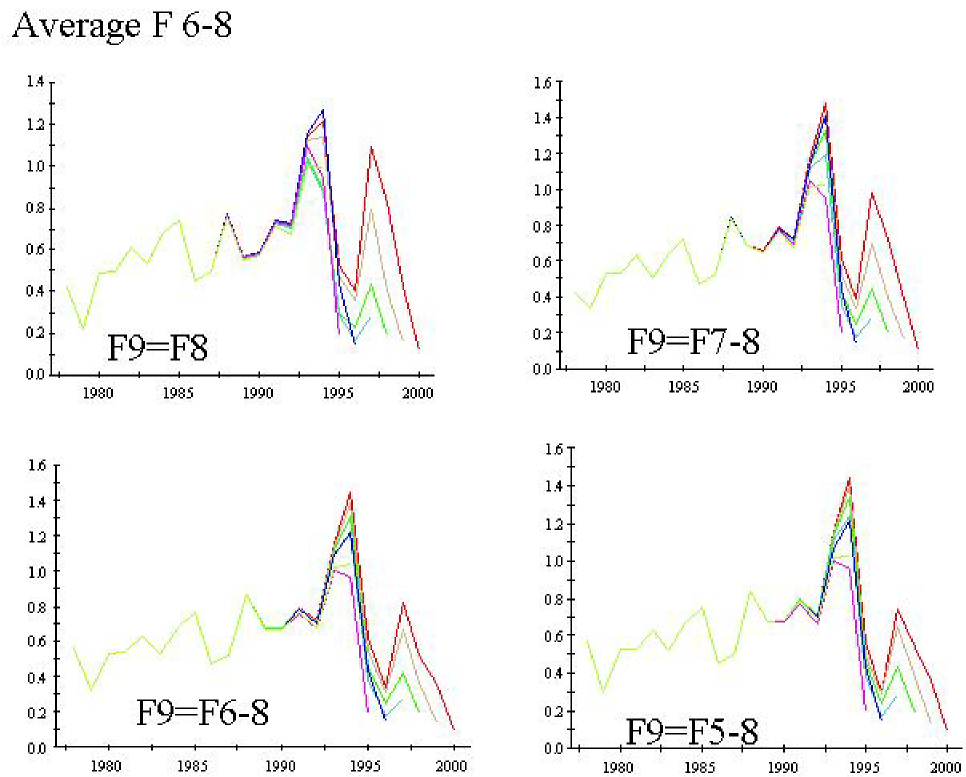


Figure 15. Retrospective analysis (starting in 2000 and proceeding back to 1995) of average F (6-8, unweighted) with F on the oldest age (9) derived by setting F9 equal to F8 (top left) and to the average of F7-8 (top right), F6-8 (bottom left), and F5-8 (bottom right).

The ADAPT formulation for 5Z+6 cod differed from the benchmark ADAPT formulation for 5Zjm. The 5Zjm benchmark calculated F10 as a weighted F of ages 7-8 for 1978-1996 and population sizes were estimated for 1997-2001 (see below). This could not be done using FACT for 5Z+6 due to required changes to NMFS software (FACT)

Recommendation: Modify FACT to allow more flexibility in estimating F on older ages in the terminal year and most recent years.

The TRAC recommended that the 5Z+6 cod be assessed using the same model formulation as used for 5Zjm cod to eliminate confusion and produce comparable results. The 5Z+6 formulation was then run using the DFO software (ADAPT). The age 10+ calculations were not performed but were generated outside the final analysis.

For 5Z+6 cod, population sizes were estimated for ages 1-9 in the terminal year and for age 9 in 1997-2000 for 1978-1996, fishing mortality at age 9 was set equal to a weighted F of ages 7-8. Results showed the PR was flat-topped from 1978-94 and was domed after 1994, consistent with FACT runs (Figure 16). Population size for ages 1-9 were estimated reasonably well and the correlation matrix was acceptable. The survey q s were asymptotic at age 5+ (Figure 17) and average F at ages 4-6 showed no persistent retrospective patterns (Figure 18). This formulation of ADAPT largely addressed the retrospective pattern seen in the FACT runs.

TRAC agreed that this formulation should be used for the 5Z+6 benchmark.

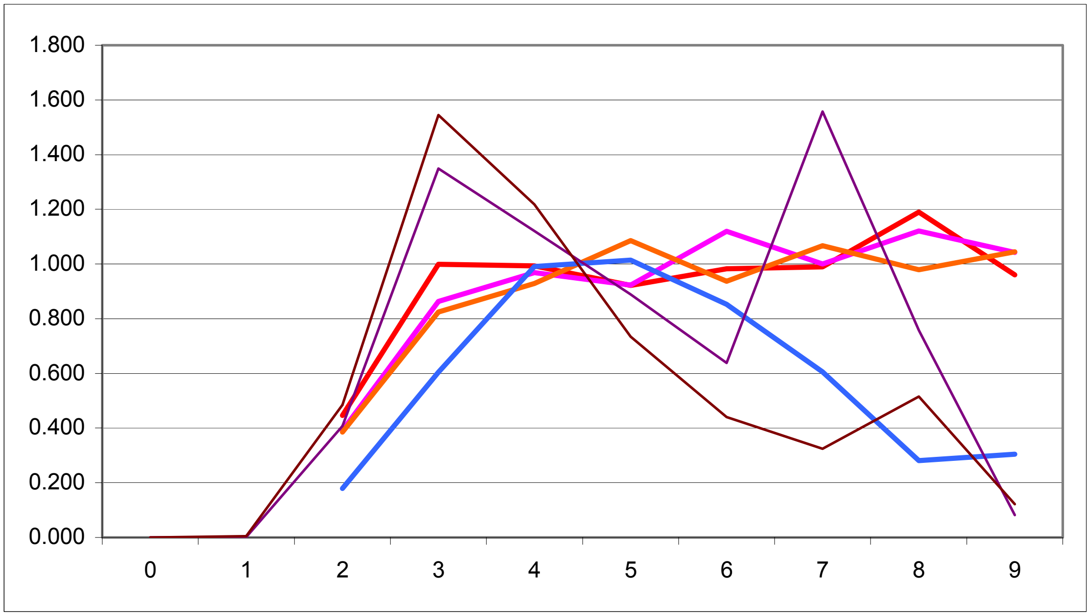


Figure 16. Partial recruitment pattern for 78-94 (flat curves), 95-98 (domed curve), 1999 (steep curve with peak at age 7), and 2000 (steep curve) for ages 1–9 for 5Z+6 Georges Bank cod.

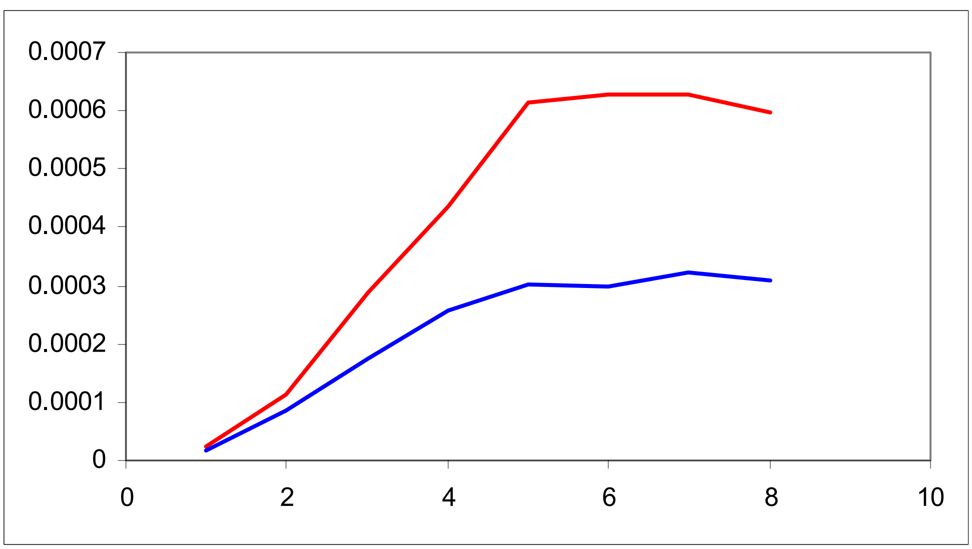


Figure 17. Catchability for NMFS (lower line) and DFO (upper line) spring survey for ages 1-8 for 5Z+6 Georges Bank cod.

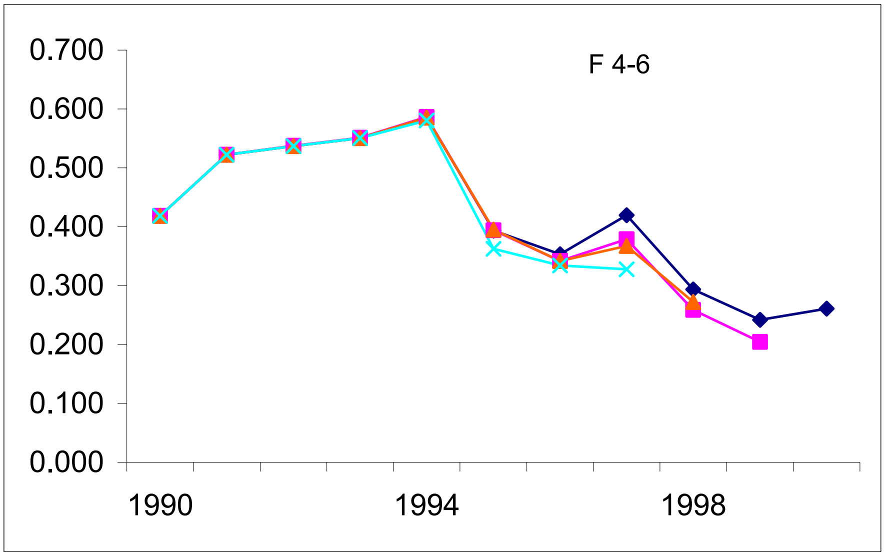


Figure 18. Retrospective analysis (starting in 2000) for F ages 4-6 using the 5Zjm benchmark formulation for 5Z+6 Georges Bank cod.

Alternate Explanations for Dome-Shaped Partial Recruitment

While partial recruitment (PR) in the Georges Bank cod fisheries was flat-topped prior to 1995, since then a dome-shaped PR appears to be more consistent with catch-at-age data (CAA) and with research survey indices of abundance. Changes in fishing practices due to management regulations, instituted about 1994, appear to be the primary causal factor. If this is indeed the case, changes in CAA patterns relative to survey indices (for older fish) should emerge clearly within the next 5 years or so. However at this point in time, it is difficult to know with certainty that a change in PR has occurred.

Scenarios other than a change in PR that may be also be consistent with the CAA and survey indices. These involve influences on the catch and on the population (i.e., affecting the numerator and denominator of the fishing mortality equation respectively). Alternative explanations were discussed briefly, but were not considered to be really viable options by the TRAC. Some of the hypothetical scenarios discussed include:

[Alternative 1] Migration out of Area 5Z:

PR in 5Z has not changed (i.e. PR remains flat-topped) but significant movement of older cod out of 5Z and into the Gulf of Maine (GOM) has been occurring. This movement occurs seasonally after the time of the spring survey but before the height of the fishery occurs. High fishing mortality rates (F) in the GOM results in the capture of nearly all of these cod within a year or two of their out migration. While such a scenario may be consistent with the observed data from Area 5Z, there is not much evidence of movement into the GOM (from tagging data). Further although large cod are thought to move into deeper water, this deeper habitat is still part of Area 5Z.

[Alternative 2] Spatial misreporting of the catch

PR in 5Z has not changed (i.e. PR remains flat-topped) but a significant spatial misreporting of older cod has occurred since 1994. A major restructuring of the USA sampling program occurred in 1994. Proper area allocation of the catch to stock area is thought to be less reliable as a result of this change. However, if the catch of older 5Z cod has been misreported to other stock areas (such as the GOM), it is not apparent in the statistics from these other areas. In addition, similar evidence for a change in PR can be seen in the Canadian data even though no change has occurred in the Canadian sampling program.

[Alternative 3] Discarding older cod

PR in 5Z has not changed (i.e. PR remains flat-topped) but a significant increase in discarding of older cod has occurred since 1994. Since discards are not routinely reported, such a scenario may be consistent with the observed data from Area 5Z. However, there does not appear to be any economic (or other) incentive for fishermen to discard older (larger) cod.

[Alternative 4] Change in natural mortality

PR in 5Z has not changed (i.e. PR remains flat-topped) but natural mortality (M) on older cod has increased since 1995. An increase in M on older cod would affect the observed 5Z CAA data in a fashion similar to the out migration described in Alternative 1, above. However, the survey indices should also be likewise affected, and this does not appear to be the case in either the NMFS spring or fall surveys.

Although these alternative explanations are mentioned and were discussed, they are not considered to be useful explanations for the change in PR since 1994. The benchmark assumes that fishing effort changes have resulted in a change in PR (flat-topped to domed) beginning about 1994. This appears to be the scenario that is most consistent with the observed data and general knowledge of the cod fisheries. However, a more complete understanding of the the spatial and temporal effort patterns in cod fisheries is important in refining this understanding.

5Zjm COD

Working Paper: Hunt, J. and B. Hatte. 2002. Eastern Georges Bank Cod in 5Zjm Assessment Evaluation. TRAC Working Paper 2002/02.

J. Hunt presented issues from the 2001 TRAC and noted interim changes from the last benchmark formulation, including expansion of the catch at age to age 10 and using ages 7-9 (rather than ages 4-9) to estimate fishing mortality on the oldest ages. Issues and concerns identified in the 2001 TRAC included calculation of F on oldest age method, lack of improved recruits with increasing SSB, utility of an industry longline survey, ability of the survey to sample ages zero and one, and a relatively strong retrospective pattern.

Two TAWG meetings at Saint Andrews Biological Station were conducted and minutes of discussions were tabled (Appendix 5).

Definition of the Management Unit

The operational management unit for this resource consists of unit areas 5Zj and 5Zm. Several ongoing projects are presently considering transboundary management issues. A major cod tagging program is underway including releases by Canada, NMFS and State agencies in the Inner Gulf of Maine, Bay of Fundy, Scotian Shelf and Georges Bank. Results will be available after 2004 and have implications for timing of the next benchmark.

Estimation of Contemporary State

Fishery

Input data available for the ADAPT formulation included combined 1978-2000 Canada and USA catch at age for ages 1-10 without a plus group.

Abundance

RV abundance indices consisted of ages 1 – 8 spring (NMFS 1978-1981, NMFS 1982-2000 and DFO 1986-2001), 0-5 fall (NMFS 1978-2000) and ages 2-8 for a 1996-2000 Canadian industry longline survey. The longline survey was considered a new index and an evaluation was made after development of a formulation with the previously used indices.

Estimation

The updated catch at age (ages 1 – 10) incorporating revised landings statistics, assignment of decimal year to RV indices and a numbers-weighted average F on ages 7-9 for F on the oldest age groups were used in the TRAC 2001 ADAPT formulation as a baseline model. Comparison of results from this formulation with those from the last assessment revealed no significant differences in population estimates or exploitation rate.

Examination of the relationship between RV indices and population estimates (Figure 19) identified three potential candidate indices for exclusion. The DFO RV age 1 index vs. VPA age 1 seems to have a power relationship rather than proportional, with RV q increasing with N.

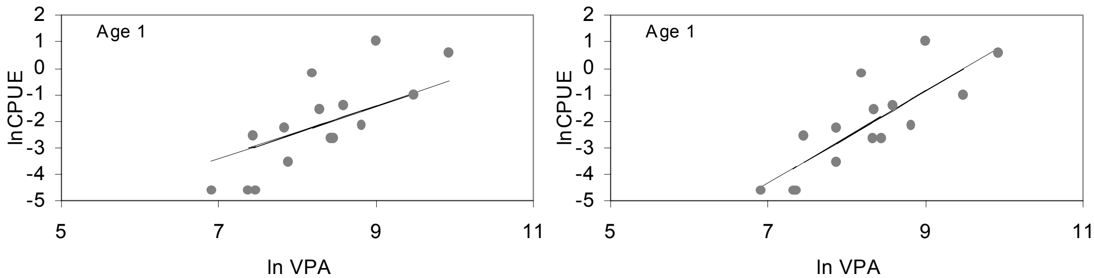


Figure 19. Relationship between the DFO age 1 index and VPA population showing a proportional fit (left) and power fit (right).

This effect was not apparent in the NMFS RV spring age 1 index and use of a smaller/lighter footrope on the 36 trawl for the NMFS survey might be the reason. Given the lack of a proportional relationship and poor precision for parameter estimates of a power relationship, it was decided that the best option was to exclude the DFO age 1 index. A similar lack of fit for the DFO age 8 index was accepted as the basis for its exclusion.

The NMFS RV fall age 0 index has seven zero values in the last 10 years and substitution of proxy values based on a relationship between 5Zj,m and 5Z was examined. Inclusion of proxy values resulted in only marginal improvement in precision and it was concluded that this index for 5Zj,m did not contain sufficient information to justify inclusion in the formulation.

The Canadian longline survey has been conducted in late August since 1996 using five commercial vessels. Problems in adhering to the design have been noted but consistency with the RV indices for ages 2-8 has been observed. Inclusion of the index in the formulation gave similar parameter estimates and some improvement in parameter precision. However, it was noted that this index was a short time series, with coverage restricted to Canadian side. The time series is too short to discern shifts in distribution and, if distribution changes, this series could be misleading. Trends in the proportion of the total 5Zj,m biomass within the Canadian zone show about 80% in recent years and about 50% in the early time period (Figure 20).

Therefore, it was concluded the index is not useful as an index within the ADAPT formulation but it could be of use as an independent index after assessment to corroborate trends.

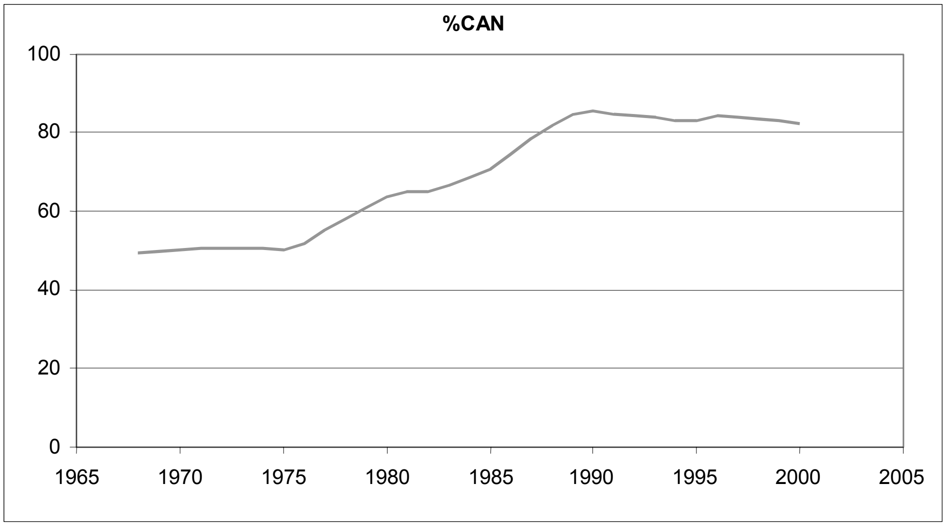


Figure 20. Proportion of the 5Zj,m biomass found in the Canadian zone (curve smoothed in EXCEL).

The effect of intrinsic (inverse of internally calculated mean squared residual) and extrinsic (RV proportions at age) weighting on RV indices was examined and, based on examination of mean square residuals (MSR) for each index and age, homogeneous blocks were identified. Results showed slightly more even distribution and balance of residuals with intrinsic weighting having the most influence. It was noted that as years are added to the analysis, the perception of variability of RV indices might change, necessitating a change in the groupings by block; this is primarily a problem with short data sets. The influence of year effects was discussed and an example using the 1982 NMFS spring survey showed that inappropriate weight might be given to an index if a strong residual pattern existed in the series. In this specific case the MSR between the three RV indices was comparable when the 1982 values were excluded, negating the potential benefit of weighting. It was therefore concluded that weighting in this formulation would not be an improvement. However, it was recognized that the merit of weighting should be considered on a case by case basis in developing model formulations.

Three options for estimating fishing mortality or population size at the oldest age were considered.

1. F 10 = weighted mean of F 8 – 9 for 1978 – 1999; all ages estimated in 2000
2. Imposed Flat-topped PR (4-10) in 2000; 4 – 6 estimated and 7 – 10 calculated
3. Estimation of N10 in 1997-2001 with F10 = weighted mean F 8-9 for 1978 - 1996

Partial recruitment patterns and trends in RV q were used to evaluate each option. The first option produced a dome PR for 1999 and 2000 but an unrealistic pattern for 1995-1999 and Rv q’s that increased monotonically. The second option also had an unrealistic PR for 1999 and 1994-1998 to an even more pronounced monotonic increase in RV q’s. The third option gave results that seemed more consistent with fishery trends (Figure 21) and an asymptotic pattern in RV q’s (Figure 22). Correlation among variables of the matrix was examined as an influencing effect but was considered not to be a problem.

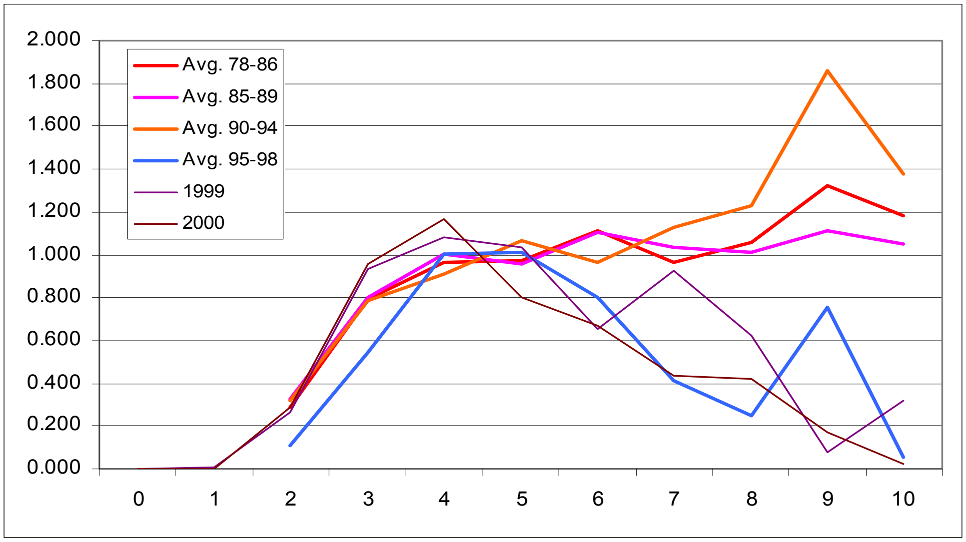
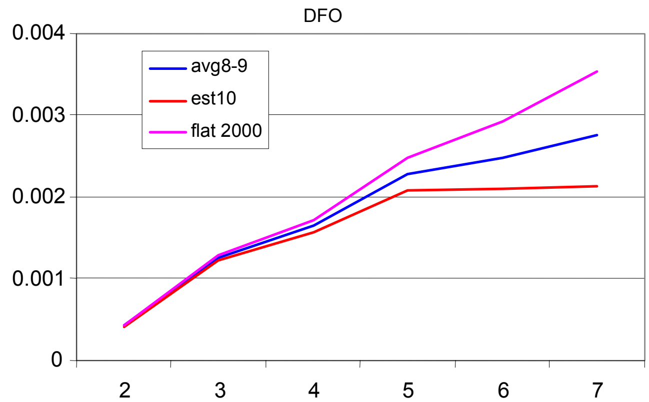


Figure 21. Partial recruitment for 1999 (steep curve), 2000 (steep curve with peak at age 7), 95-98 (steep curve with peak at age 9), and averaged time blocks (78-94, flat curves) estimated from fishing mortalities derived using option 3.



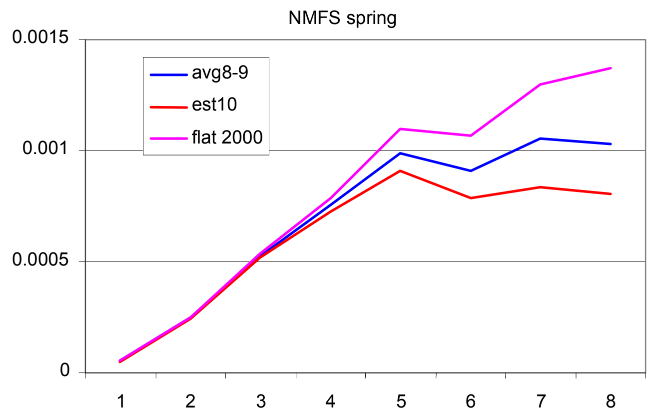


Figure 22. RV survey catchabilities for DFO and NMFS spring surveys estimated from three formulation options.

The apparent dome-shaped partial recruitment from option 3 required explanation. Cod distribution in relation to Canadian and USA fleet distributions could have induced a reduction in exploitation of large cod. Prior to 1994, about 50% of the annual landings of age 7+ was caught during the winter (Jan-Mar) fishery. The fishery harvests large spawners and after spawning, cod move into deeper water. Since 1994, the Canadian fishery has been closed between January 1 and June 1, which is consistent with reduced exploitation of large cod. Since December 1994, the USA has closed these areas on Georges Bank year round including Closed Area II on the Northeast Peak. Also, the Canadian fishery avoids areas of cod abundance to avoid overruns of limiting cod allocations while directing for haddock,. Both fishery and survey observations suggest that large cod are not in commercial aggregations after spawning, making it uneconomic to direct for them.

Under option 3 of the ADAPT assessment formulation the retrospective pattern showed significantly less effect (Figure 23), and there was also less of a trend to under-estimate recruitment.

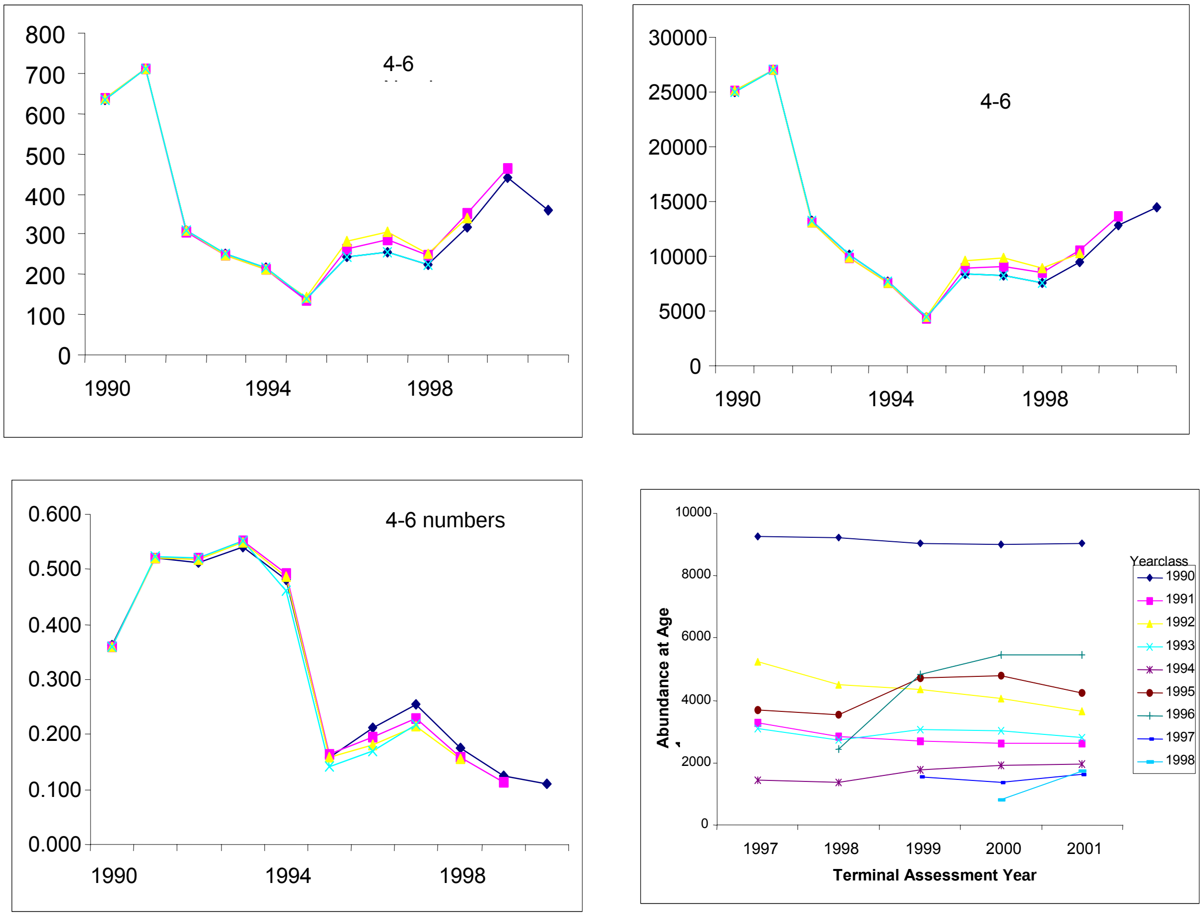


Figure 23. Retrospective pattern estimated with option 3 in the ADAPT formulation.

Overall, it is considered that estimation of age 10 stock size during 1997-2001 with F10 = weighted mean F 8-9 for 1978 – 1996 gave results that were consistent with fishery trends, and thus should be used for the 5Zjm benchmark.

Partial Fishing Mortality by Country

Partial F's by age and year were calculated for the 5Z and 5Zjm areas to examine patterns during 1978-2000. These analyses were accomplished by dividing the catch at age by country by the total catch at age for the assessment area.

The pattern in the US fishery indicated that partial F's were relatively flat for ages 4-9 during 1978-1988 (Figure 24a). This pattern began to change in the early 1990s and partial F for the oldest ages (7-9) started to decline. During the 1990s, the pattern was variable but generally indicated lower partial F on the older age groups (Figure 24d).

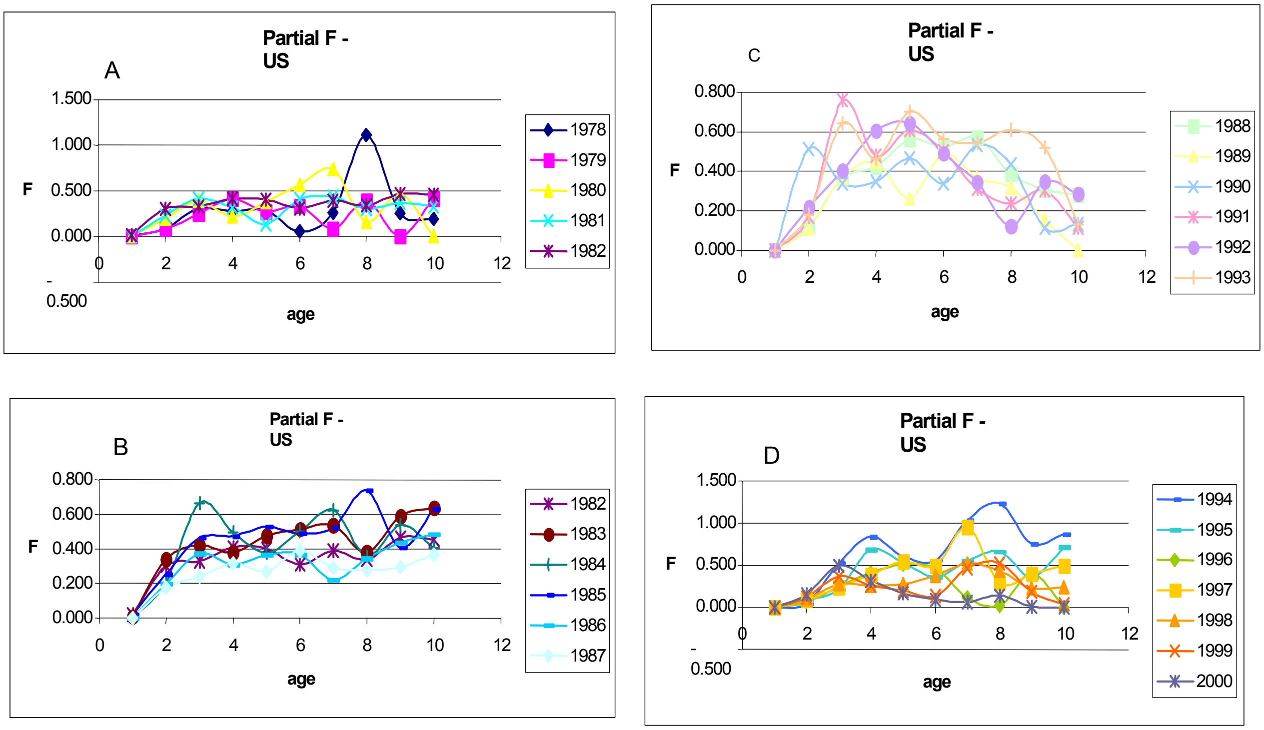


Figure 24. Partial fishing mortalities by country, age, and year during 1978-2000 for the 5Z assessment area.

Analyses for the 5Zjm assessment area indicated similar trends by year. Partial F for the Canadian portion of the catch at age showed a flat trend during 1978-1987, a relatively increasing trend during 1988-1994, and a dome shaped trend during 1995-2000 (Figure 25a). The pattern in the US fishery in 5Zjm was similar to the 5Z trends with a relatively flat trend during 1978-1987, a slight dome in 1988-1994, and a more pronounced dome during 1995-2000 (Figure 25b).

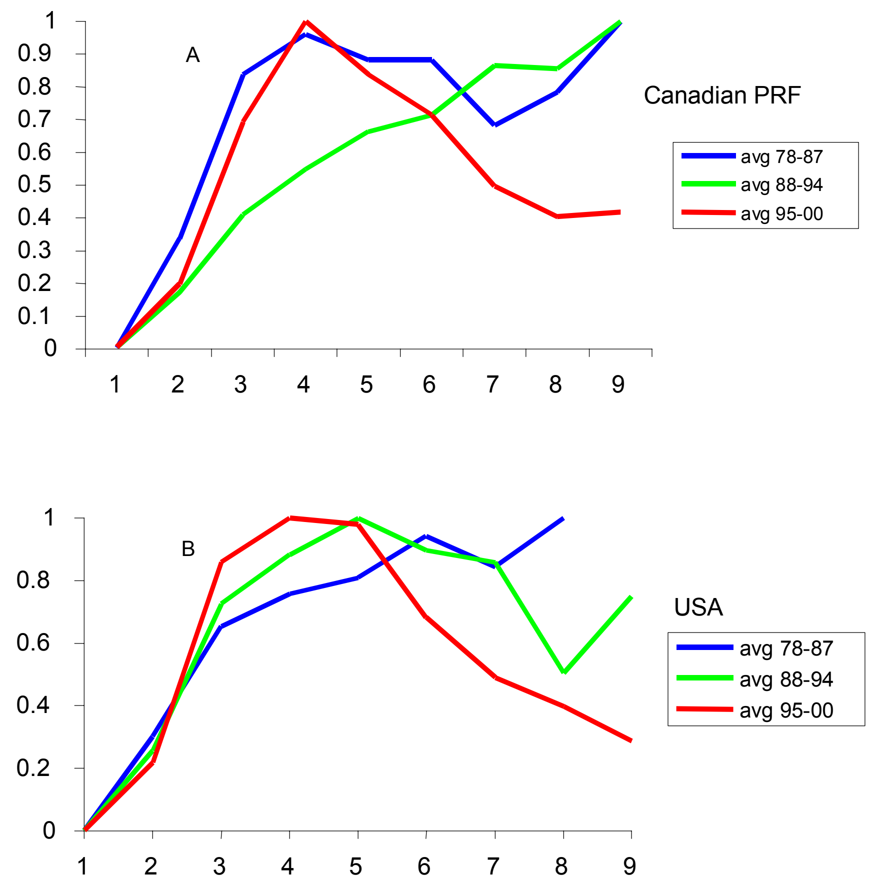


Figure 25. Partial fishing mortalities by country, age, and year during 1978-2000 for the 5Zjm assessment area.

Discussion centered on potential reasons for a dome in 1995-2000 in the US fishery. Several ideas were discussed including a change in fleet distribution and composition, a decline in the proportion of otter trawl landings (was 80%, now 60%), and various seasonal effects. No single factor is likely responsible, so the TRAC concluded that further investigation was necessary to better define the mechanism for the dome in the recent US fishery.

CHARACTERIZATION OF PRODUCTIVITY TO DETERMINE HARVEST STRATEGY

Fisheries management harvest strategies are typically operationalized through reference points. Reference points may be used as signposts against which forecasted outcomes for specified management actions are compared or they may underpin the specification of harvest control rules. Reference points serve as a gauge of resource productivity, therefore their derivation is implicitly based on an understanding of the production dynamics. Fisheries production dynamics can be summarized by mortality, by growth and fishery selectivity processes which are captured by yield per recruit analyses, and by the recruitment process which is described by a stock recruitment relationship. Yield per recruit analysis can be combined with a stock recruitment relationship to characterize the response of yield to fishing mortality and the associated biomass implications. However, concern was expressed about using the yield response to identify reference points associated with maximum sustainable yield (or suitable proxies).

Various parametric forms of stock recruit relationships have been proposed and it is generally not possible to convincingly demonstrate a better fit to one form than another (particularly for chronically overfished stocks). Reference point estimates can be sensitive to the choice of parametric form. Stock recruit forms of the Ricker type have been criticized because the mechanisms that can cause over-compensation are not thought to be common in the marine environment. Stock recruit forms of the Beverton-Holt type have been criticized because they typically imply very high biomass for the unfished state compared to the maximum sustainable yield biomass. Non-parametric scatterplot smoothers can be used to summarize the stock recruit relationship without having to specify a model form. Estimates of reference points can be sensitive to subtle differences in the shape of a smoothed relationship that may be caused by the choice of the smoothing criteria or by peculiarities of the observed data.

For maximum sustainable yield reference points, the zone of interest for the stock recruitment relationship is at moderate to high biomass, and often outside the range of observation. In these instances, reference points derived using either parametric or non-parametric approaches are highly dependent on behavior in the extrapolated zone.

In the absence of an objective statistical estimation procedure, fishery and population dynamic principles and meta-analyses may be employed to constrain the domain of possibilities. However, it is important to clearly identify the limitations of the data and the reliance on expert subjective judgment. Bounding the range of plausible subjective choices and characterizing the consequences of selecting the wrong hypothesis could further enhance the decision process. The implications for conservation, economic opportunity and the potential to learn more about the productive capacity of the resource should be examined for alternative hypotheses. It is not obvious that meaningful quantification of uncertainty can be carried out when results are highly conditioned by subjective judgment. All of these results are also conditioned on the assumption that these production dynamic processes are stationary and not subject to regime shifts.

A presentation was made which demonstrated the use of multiple models to compare measurement, process and model uncertainty. Measurement and process error were estimated in the usual way, with conditioned bootstrapping. Within the Sissenwine - Shepherd (S-S) framework, fitting a Ricker stock-recruitment curve was considered to be process error, which is subsequently re-expressed as error in MSY estimation. MSY as a process was also estimated directly from production data in a Schaefer model and bootstrapped to estimated confidence regions. The direct and the Sissenwine-Shepherd process errors were of similar magnitude and both were much greater than the errors in estimation for a population via VPA. The model uncertainty, that is the difference between the S-S and Schaefer MSY-BMSY estimates, was about the same magnitude as the process errors. This approach seemed promising and it was recommended that it be applied to ther stocks.

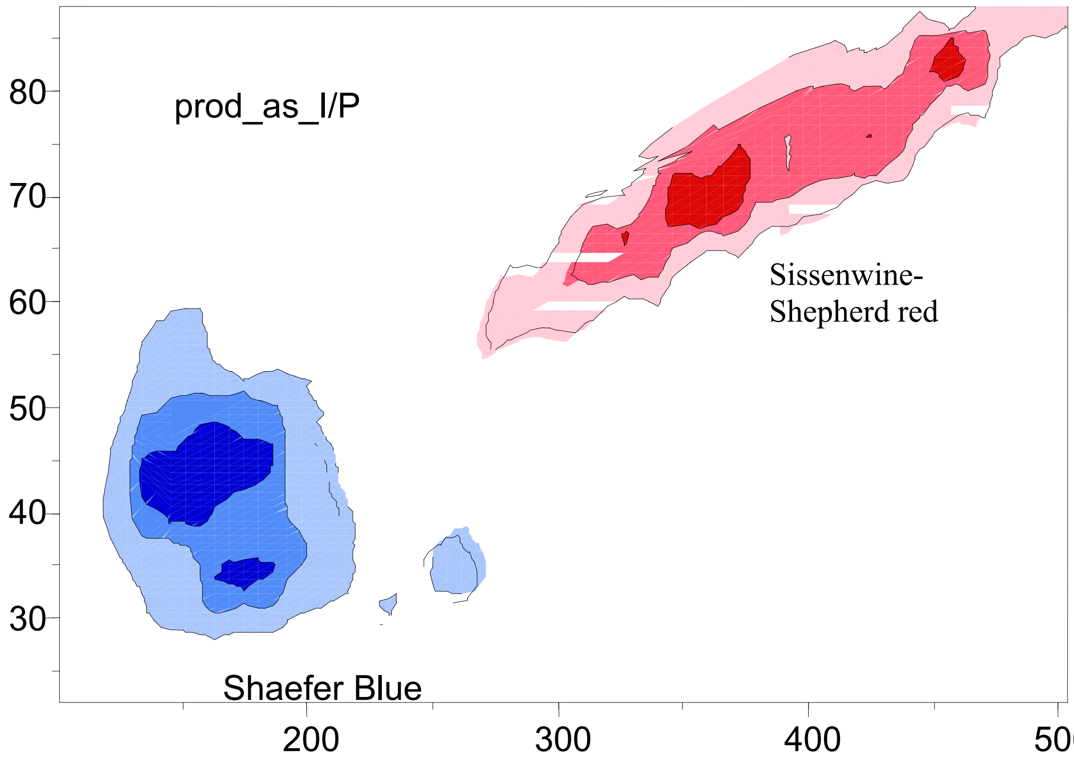


Figure 26. Uncertainty in process estimation. The x-axis is BMSY and the y-axis is MSY. The contours of process error are the 25, 50 and 75th percentiles.

These presentations and the ensuing discussion highlighted the prudence, for medium term projections, of sampling from stock/recruitment data, rather than using parametric forms, to derive estimates of recruitment and this prevents extrapolating recruitment outside the range of observations. How the sampling is conducted is very important and should be carefully considered. Conceptually, the approach can be used to derive biological reference points. Where the uncertainty of stock productivity processes is high, it is probably worthwhile to establish biomass and fishing mortality reference points based on direct examination of the data rather than using derived parametric models.

There was a discussion on the use of flat top and dome PRs in short, medium and long-term projections. For short and medium-term projections, it was agreed that the dome PR should be used as this is most reflective of current conditions. Further, it was agreed to use the modal ages to calculate fishing mortality for both indicator and reference points.

However, it is not obvious what PR to use for long-term forcasts, potentially causing inconsistency in approach to these projections. If the fleet behavior reacting to management measures is causing the dome PR, then depending on management activities, a flat top PR might return. It was therefore considered prudent to examine the consequences of using both flat top and dome PRs in long-term projections.

GUIDANCE ON ACTIVITIES

The TRAC discussed procedures for undertaking assessments on an annual or as needed basis. The application of the benchmark, as outlined in the next section, to the latest information constitutes an assessment update. The sensitivity of the assessment to any suggested modifications to the assessment framework needs to be examined. The TAWG can undertake these modifications if they are judged to be straightforward. Otherwise, the TAWG should discuss with TRAC the need for a benchmark review.

Participants also discussed additional that might require a benchmark review. If it becomes evident that the assessment model is performing poorly (e.g., increasing retrospective pattern), a benchmark review would be warranted. Consideration of new data or research results would not automatically require a benchmark, unless deemed necessary after consultation between the TAWG and TRAC.

The meeting also considered that, notwithstanding the above, a benchmark review of the 5Z+6 and 5Zjm cod assessment frameworks should be held in February 2006 (e.g. at 5 year intervals).

CONSENSUS BENCHMARK FORMULATIONS

5Z+6 Cod

Definition of the Management Unit

The management units employed for cod in the USA is primarily based on the findings of Wise (1963) who concluded that four distinct stocks could be recognized within the New England area, Georges Bank, Gulf of Maine, Southern New England and the South Channel, and the New Jersey coastal cod. Operationally, the Georges Bank management unit is defined as comprising cod in NAFO Division 5Z and Subarea 6 (Serchuk and Wigley 1992).

Estimation of Contemporary State

Characteristics of the fishery, including commercial landings and discards, recreational catch, and sampling for length and age are summarized in O'Brien and Munroe (2001). Sampling prior to 1978 is not considered sufficient to derive a catch at age. Concern had been expressed about low sampling intensity of the USA fisheries during the late 1990s. Although sampling intensity increased to satisfactory levels in 2000, the market category, spatial and temporal pattern of sampling needs some attention to ensure adequate coverage of all components. The age composition is derived by the application of age length keys to length frequencies, stratified by quarter and market category (USA fishery) or gear (Canadian fishery).

While catch rates from the commercial fishery are examined, only the NMFS fall, NMFS spring and DFO bottom trawl surveys are employed as indices of abundance (O'Brien and Munroe 2001). The NMFS spring survey used a Yankee 41 net during 1978 to 1981 and a Yankee 36 net since 1982 and is treated as two distinct series. All three surveys are conducted according to stratified random designs and the indices are calculated using standard design based estimators.

Estimates of population abundance in numbers at the beginning of the year following the terminal year (the last year for which catch at age is available) are obtained by calibrating a simple Virtual Population Analysis with the three bottom trawl surveys. VPA models assume that errors in the observed catch at age are negligible compared to errors in the abundance indices. Such an assumption allows a deterministic application of the catch equation recursively to derive the abundance of a year-class at any time given the observed catch at age and an estimate of abundance for that year-class at one point in time. The following formulation produced results that were most consistent with observations and expected biological and fishery processes (a indexes age and y indexes year):

Observations

$C_{a,y}$ = catch at age for a = 1 to 9 and 10+ and y = 1978 to terminal year
$I_{1,a,y}$ = NMFS fall survey for a = 0 to 5 and y = 1977 to terminal year
$I_{2,a,y}$ = NMFS spring survey for a = 1 to 8 and y = 1978 to 1981
$I_{3,a,y}$ = NMFS spring survey for a = 1 to 8 and y = 1982 to terminal year +1
$I_{4,a,y}$ = DFO survey for a = 1 to 8 and y = 1986 to terminal year +1
Spring survey abundance is related to the beginning of year VPA abundance while the fall survey abundance is related to the subsequent year's VPA abundance.

Parameters

$\theta_{a,y}$ = *ln* abundance for a = 1 to 9 in y = terminal year +1, and for a = 9 in y = 1997 to terminal year.
$\kappa_{1,a}$ = *ln* NMFS fall survey catchability for a = 0 to 5.
$\kappa_{2,a}$ = *ln* NMFS spring survey catchability for a = 1 to 8.
$\kappa_{3,a}$ = *ln* NMFS spring survey catchability for a = 1 to 8.
$\kappa_{4,a}$ = *ln* DFO survey catchability for a = 1 to 8.

Structural Conditioning

Natural mortality was assumed to be 0.2 for all ages and years.
Fishing mortality on age 9 for 1978 to 1996 was assumed to be equal to the population number weighted average fishing mortality on ages 7 and 8.
Age 10+ was calculated using the catch equation and the fishing mortality on age 9.

Error Conditioning

Catch at age error was assumed negligible compared to the index error.
Error on the *ln* index observations was assumed to be independent and identically distributed.

Estimation

Parameters were obtained by minimizing the objective function

$$\sum_{i,a,y}\left(I_{i,a,y} - \hat{I}_{i,a,y}\left[\theta,\kappa\right]\right)^2$$

Characterization of Productivity to Determine Harvest Strategy

Yield per recruit analysis has been used to derive fishing mortality reference points. Analyses using age aggregated surplus production models have also been used to derive MSY reference points. Concerns were expressed about the comparability of reference points derived from age aggregated models to the estimates of current stock status derived from VPA. Age disaggregated analyses of productivity and associated reference points are currently being investigated.

Procedure for Projections

Implementation of the bias corrected percentile method in the NMFS FACT software and the use of survey weights to calculate population biomass would make DFO and NMFS analyses more compatible and allow assessment results to be more easily compared.

For short term projections, catch and stock weights at age, maturity ogives and partial recruitment to the fishery should be averaged over a recent period of stable patterns if there are no trends over time. If trends are detected, suitable measures to reflect the most recent patterns should be applied. For short-term projections, recruitment should be based on observations from the most recent years with similar SSB or from the entire time period if an SSB threshold is not evident.

Medium to long term projections were considered most useful for for evaluating the relative performance of alternative harvest strategies. The utility of long term projections for establishing explicit annual measures to achieve rebuilding is considered less certain. Probability statements about medium term forecasts should be considered conditional and not be taken as representing the actual probabilities of eventual outcomes.

5Zjm Cod

Definition of the Management Unit

A review of tagging results and geographic distribution of survey catch and commercial fishery catch indicated that some discontinuity between the cod aggregations on eastern Georges Bank and those in the Great South Channel and Cape Cod area. Operationally, the management unit was defined to be unit areas 5Zj and 5Zm (Hunt 1990).

Estimation of Contemporary State

Characteristics of the fishery, including commercial landings and discards, and sampling for length and age are summarized in Hunt and Hatte (2001). Sampling prior to 1978 is not considered sufficient to derive a catch at age. Concern has been expressed about low sampling intensity of the USA fisheries during the late 1990s. Although sampling intensity increased to satisfactory levels in 2000, the market category, spatial and temporal pattern of sampling needs some attention to ensure adequate coverage of all components. The age composition is derived by the application of age length keys to length frequencies, stratified by quarter and market category (USA fishery) or gear (Canadian fishery).

While catch rates from the commercial fishery and a longline industry survey have been examined, only the NMFS fall, NMFS spring and DFO bottom trawl surveys are employed as indices of abundance (Hunt and Hatte 2001). The NMFS spring survey used a Yankee 41 net during 1978 to 1981 and a Yankee 36 net since 1982 and is treated as two distinct series. All three surveys are conducted according to stratified random designs and the indices are calculated using standard design based estimators.

Estimates of population abundance in numbers at the beginning of the year following the terminal year (the last year for which catch at age data are available) were obtained by calibrating a simple Virtual Population Analysis with the three bottom trawl surveys. VPA models assume that errors in the observed catch at age are negligible compared to the errors in the abundance indices. Such an assumption allows a deterministic application of the catch equation recursively to derive the abundance of a year-class at any time given the observed catch at age and an estimate of abundance for that year-class at one point in time. The following formulation produced results that were most consistent with observations and expected biological and fishery processes (a indexes age and y indexes year):

Observations

$C_{a,y}$ = catch at age for a = 1 to 10 and y = 1978 to terminal year.
$I_{1,a,y}$ = NMFS fall survey for a = 1 to 5 and y = 1978 to terminal year, occurring about 0.69 into each year.
$I_{2,a,y}$ = NMFS spring survey for a = 1 to 8 and y = 1978 to 1981, occurring about 0.29 into each year.
$I_{3,a,y}$ = NMFS spring survey for a = 1 to 8 and y = 1982 to terminal year, occurring about 0.29 into each year.
$I_{4,a,y}$ = DFO survey for a = 2 to 7 and y = 1986 to terminal year +1, occurring about 0.16 into each year. Since projections for entire calendar years are required, the index in terminal year + 1 was taken as occurring at the beginning of the year.

This is a departure from the previous assessments in that DFO age 1 and 8 and NMFS fall age 0 are not used as indices.

Parameters

$\theta_{a,y}$ = *ln* abundance for a = 2 to 10 in y = terminal year +1, and for a = 10 in y = 1997 to terminal year.
$\kappa_{1,a}$ = *ln* NMFS fall survey catchability for a = 1 to 5.
$\kappa_{2,a}$ = *ln* NMFS spring survey catchability for a = 1 to 8.
$\kappa_{3,a}$ = *ln* NMFS spring survey catchability for a = 1 to 8.
$\kappa_{4,a}$ = *ln* DFO survey catchability for a = 2 to 7.

Structural Conditioning

Natural mortality was assumed to be 0.2 for all ages and years.
Fishing mortality on age 10 for 1978 to 1996 was assumed to be equal to the population number weighted average fishing mortality on ages 8 and 9.
Age 10+ was calculated using the catch equation and fishing mortality on age 9.

Error Conditioning

Catch at age error was assumed negligible compared to the index error.
Error on the *ln* index observations was assumed to be independent and identically distributed.

Estimation

Parameters were obtained by minimizing the objective function

$$\sum_{i,a,y}\left(I_{i,a,y} - \hat{I}_{i,a,y}[\theta,\kappa]\right)^2$$

Characterization of Productivity to Determine Harvest Strategy

Yield per recruit analysis has been used to derive fishing mortality reference points for the cod in management unit 5Zjm. Historically, the chance of good recruitment (more than 5 million fish at age 1) has been higher when the adult biomass is greater than a 25,000 t threshold. The objective of management has been to rebuild the resource to be above this threshold.

Procedure for Projection to Evaluate Tactics

For short term projections, catch and stock weights at age, maturity ogives and partial recruitment to the fishery should be averaged over a recent period of stable patterns if there are no trends over time. If trends are detected, suitable measures to reflect the most recent patterns should be applied.

Alternative TAC tactics are evaluated through risk analysis.

APPENDICES

Appendix 1. List of Participants

USA	Canada
C. Legault	R. Mohn
L. O'Brien	S. Gavaris
P. Rago	G. Chouinard
R. Conser	J. Hunt
R. Mayo	B. Hatte
S. Murawski	R. O'Boyle
S. Wigley	
W. Overholtz	

Appendix 2. Topics to be considered in Benchmark Assessment.

The following five themes are to be addressed in a benchmark assessment. Characteristic elements associated with these themes are identified for illustration and as a guide. This is not intended as an exhaustive or exclusive list of elements. In any benchmark, not all themes may be subjected to evaluation. Similarly, emphasis may be given to only some elements of a theme. The extent of evaluation of a theme or element is defined by the terms of reference of the benchmark assessment. However, the basis of accepted practice for all themes and elements should be documented. For example, the information on management unit definition may not be re-evaluated if there are no new data or analyses, but a summary of previous deliberations should be given.

1. **Definition of the management unit**
   Stock structure and complexity elements
   - Distribution and movement
   - Morphometrics and meristics
   - Growth

   Management consideration elements
   - governance institutions
   - political boundaries
   - administrative convenience

2. **Estimation of Contemporary State**
   Typically the stock status is expressed in terms of population abundance at the beginning of the period following the terminal period for which removals are available. This may be derived by analyzing information from the fishery together with information on trends in abundance. Alternatively, stock status may be expressed as a summary of variety of indicators that are related to abundance.
   Fishery elements
   - Removals
   - Size and age composition
   - Weight at age

   Abundance/mortality trend elements
   - Surveys
   - Fishery CPUE
   - Tagging

   Estimation elements
   - Model dynamics, assumptions and formulation used to integrate information
   - Observation and/or process error assumptions
   - Uncertainty and consistency (retrospective) of results

3. **Characterization of Productivity to Determine Harvest Strategy**
   Typically this culminates in identification of undesirable states for quantities of interest for fisheries management such as exploitation rate or abundance. Fishing mortality based

strategies are common. The analysis may be based on characterizing the response of yield to exploitation and the associated biomass implications. Alternatively, it may be based on establishing break points for the historically observed range.

Process elements

- Growth (size at age, condition, etc.) and maturation
- Partial recruitment to the fisheries
- Natural mortality
- Stock biomass and recruitment
- Contrasts with related stocks and species
- Patterns of change in demographic parameters
- Linkages of environmental factors to stock productivity

Estimation elements

- Model dynamics, assumptions and formulation
- Observation and/or process error assumptions
- Derivation of candidate reference points or decision break points
- Uncertainty of results

4. Procedure for Projection to Evaluate Tactics

Process elements

- Growth and maturation
- Partial recruitment to the fisheries
- Natural mortality
- Recruitment

Procedure elements

- Projection calculations
- Incorporating uncertainty and stochasticity
- Evaluation of tactics if candidate tactics (e.g. TAC) are identified

5. Guidance on Activities

Specification of assessment procedures during interim years and recommended timing of subsequent benchmarks, recognizing that unusual events may trigger a benchmark prematurely. Identification of key issues for assessment and recommended research.

Appendix 3. Terms of Reference

Background

The TRAC was established in 1998 to peer review assessments of transboundary resources in the Georges Bank area and thus to ensure that the management efforts of both Canada and USA, pursued either independently or cooperatively, are founded on a common understanding of resource status.

`For the Canadian management system, the stock status advice is required in May for a fishery that opens in June. For the US management system, the stock status advice is required in November for a fishery opening in May the following year. While stock assessment results are needed routinely to serve the management system, it is not practical or meaningful to evaluate the assessment framework each time the assessment is conducted.

The 1998 TRAC meeting provided an in-depth review of the assessments and thus has been considered a 'benchmark', with subsequent assessments applying the models developed in 1998. At that meeting, technical expert reviewers noted the competing demands to fully investigate the assessments and to develop the stock status advice during a one-week meeting. They could better contribute to the process of evaluating the formation of the assessment model.

It was agreed that a separation of the review of the assessment framework from its application to provide routine stock status advice would address concerns.

Objectives

1. To review the assessment frameworks for the two Georges Bank cod management units (5Z+6 for USA and 5Zjm for Canada). The agreed approach would be used in April 2002 (Canada) and September 2002 (USA) to provide the management agencies of each country with stock status information.

   The landings, fishery catch at age and survey indices at age are accepted as presented at the 2001 TRAC meeting, i.e. will not include evaluation of methods of analysis for catch at age or survey data. Therefore, given the catch at age (if possible, include all available ages) for years 1978-2000 and survey indices at age (also all available ages if possible) for 1963-2000 (NMFS fall), 1968-2000 (NMFS spring) and 1986-2001 (DFO spring), for the two management units

   - Determine the abundance at age at the beginning of the terminal year plus one and associated uncertainty
   - Develop consensus on an approach to be applied for routine assessment of stock evaluation until the next "benchmark" is conducted
   - Suggest schedule for next benchmark and identify factors that would trigger a benchmark ahead of schedule

2. To explore the production dynamics for Georges Bank cod (as well as haddock and yellowtail if time is available), which will be used to evaluate common harvest strategies.

   The natural mortality rate, weight at age, maturity at age, exploitation pattern at age and the historical stock-recruitment time series are accepted as presented at the 2001 TRAC meeting or the last yield per recruit analysis. Therefore, given this,

   - for each management unit, characterize the relationship of yield and biomass to fishing mortality and evaluate MSY quantities or their candidate proxies

Products

A Proceedings, which will document the details of the assessment framework and summarize the results of the production dynamics analyses.

Participation

NEFSC and DFO Stock Assessment teams and other laboratory scientists (approx. 12)
Invited external (not from NEFSC or DFO Scotia Fundy) reviewers (2)
Representatives from US and Canadian management agencies (2 – 4)
US State and Canadian Provincial representatives (2 - 4)
US and Canadian fishing industry participants (2 – 4)

Appendix 4. List of Documents

Anon. 2002. TAWG Meeting Minutes. Woods Hole. 30 January 2002, St. Andrews Biological Station, 22 and 30 January 2002.

Clark, S. and R. O'Boyle. 2001. Proceedings of the 14th Canada – USA Scientific Discussions, January 22 – 25, 2001, MBL Conference Center, Woods Hole, Massachusetts. Northeast Fish. Sci. Cent. Ref. Doc. 01-07, 52p.

Hunt, J. 1990. Status of the Atlantic cod stock on Georges Bank in unit areas 5Zj and 5Zm, 1978-89. CAFSAC Res. Doc. 80, 37 pp.

Hunt, J. and B. Hatte. 2002. Eastern Georges Bank Cod in 5Zejm: Assessment Evaluation. TRAC Working Paper 2002/02.

Hunt, J. and B. Hatte. 2002. Population status of Eastern Georges Bank cod (Unit areas 5Zj, m) for 1978-2002. Canadian Stock Assess. Sec. Res. Doc. 2002/072, 48p.

Legault, C.M. and V.R. Restrepo. 1999. A flexible forward age-structured assessment program. Int. Comm. Cons. Atl. Tunas, Coll. Vol. Sci. Pap. 49(2): 246-253.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES Journal of Marine Science. 56:473-488.

O'Brien, L. 2002. 5Z+6 Cod Presentation: Atlantic Cod, Simulated Data Analyzed by ASAP, Retrospective Analysis of Cod Using a Forward Approach. TRAC Working Paper 2002/01.

O'Brien, L. and N. J. Monroe. 2001. Assessment of the Georges Bank Atlantic Cod Stock for 2001. Northeast Fisheries Science Center Reference Document 01 – 10.

Overholtz, W.J. 1985. Seasonal and age specific distribution of the 1975 and 1978 year-classes of haddock on Georges Bank. NAFO scientific studies. 8:77-82.

Rivard, D. 1982. APL programs for stock assessment. Canadian Technical Report of Fisheries and Aquatic Sciences. 1091. 146p.

Serchuk, F.M. and S.E. Wigley. 1992. Assessment and management of the Georges Bank cod fishery: an historical review and evaluation. J. Northw. Atl. Fish. Sci. 13:25-52.

Wise, J.P. 1963. Cod groups in the New England area. Fish. Bull. U.S. 63:189-203.

Appendix 5. TAWG Meeting Minutes

TAWG Meeting
30 January 2002
Woods Hole

Attendees: Loretta O'Brien, Bill Overholtz, Paul Rago, Susan Wigley , Steve Correia, Chris Legault.

The focus of this meeting was on exploring/reviewing how either data or model specification contribute to the retrospective pattern in estimates of F and the domed partial recruitment observed in recent years for Georges Bank cod (5Z). The implication from these results are that larger fish are not being accounted for in the Catch at age, perhaps due to poor sampling, unavailability to the gear (refuge in closed areas, movement off Bank to deeper water), or model mis-specification.

Data issues:

We reviewed the spatial distribution of Georges Bank cod for two time periods before and after the implementation of the closed areas in 1994 to determine if a greater proportion of the larger fish were using the closed areas as refuge post 1994 vs. pre-1994. Distribution plots by 10 cm groupings do not appear to reflect a differential distribution of fish in the closed areas in recent years. Examination of proportion of fish at length from the NEFSC spring and autumn bottom trawl survey within and outside the closed areas also did not indicate any persistent trends.

Sampling of larger fish has clearly been poor during the 1994-2000 period and most likely do contribute to the retrospective pattern and the domed PR. These same patterns appear in the 5Zjm assessment, where sampling is adequate, so the implications of poor sampling were not pursued for this TAWG.

Model issues:

A review of back calculated partial recruitment (PR) vectors indicated a flat top pattern for most of the time series, except for the most recent years (1994-2000). The domed PR in more recent years seems to occur partially due to targeting of year classes. However, the domed PR is also possibly induced by the model specifications.

Plots of catchability (survey index vs. VPA population numbers) for three time periods (1978-2000, 1978-1993, 1994-2000) indicated that the q in the most recent time period (1994-2000) is very different than that of the complete time series or the 1978-1982 time period. The divergent q's were most apparent in ages 4-8 for both NEFSC and DFO surveys and for ages 3-4 in the NEFSC autumn survey.

The ages for population numbers chosen to estimate the average F on the oldest true age (9) influence the PR pattern in the more recent years. Retrospective plots of F averaged over different ages (3-8, 3-7,3-6,3-5, 4-8,4-7,4-6) to determine F on age 9 all showed same retrospective pattern as the original assessment formulation of average F 4-8. The TAWG suggested further runs be performed using age 8 only, ages 7-8, 6-8, etc.

A simulated data set generated by VPAsim (Paul Rago) will be used to ascertain how well ADAPT in FACT can recover the original PR pattern. The first data set simulated will have a flat topped PR for 1978-1993 and a domed PR from 1994-2000. Additional runs will be made to compare the behavior of the model (retrospective plots) when using different ages for estimating average F on age 9.

We discussed weighting of residuals using a weighting index based on how many years of catch data are available for the estimation of each N at age. This is essentially a cohort specific downweighting, so that cohorts with full information in the converged part of the VPA receive more weight than the most current year classes. Currently, FACT cannot handle a user supplied matrix of weighting factors but will be modified in the near future to investigate the feasibility of this type of weighting.

A forward projecting model using AD model builder was presented for 5 different model formulations. The ASAP (age structured assessment program, Legault and Restrepo 1999) model uses a forward solving approach to estimate population abundance and fishing mortality rates from catch at age and tuning index data. In essence, the model is based on a separable approach for fishing mortality and estimates a stock recruitment relationship to determine the strength of each cohort. Flexibility in the model is added by allowing selectivity in each year to vary and by allowing predicted recruitments to vary from the stock recruitment relationship. This flexibility can be constrained by placing penalties on the parameters that determine the amount of variance in these estimates, such that the model does not become over-parameterized. The model is written using the AD Model Builder software such that parameters are found rapidly through automatic differentiation and subsets of parameters can be estimated in phases, which stabilizes the estimation procedure.

The 5 model formulations used for cod in ASAP are listed below. The first two models forced recruitment to exactly follow the stock recruitment relationship while the remaining three models allowed deviations in recruitment away from the expected curve. Four of the models held selectivity fixed for all years while the most complex model allowed selectivity to vary from year to year, subject to constraint. In general, all models produced lower estimates of F than the VPA but followed similar trends in SSB and F, differing in magnitude. When selectivity was estimated, it was strongly domed, even for an additional run when selectivity in the first year was held fixed as flat topped. All five models were examined for retrospective patterns in SSB, recruitment and average F (ages 4-8 unweighted). It was found that the flat topped selectivity models (1 and 3) had the more pronounced retrospective patterns in SSB and F than dome selectivity models. The simple models (1 and 2) had more pronounced retrospective patterns in recruitment than the complex models. Use of the asymptotic variances provided by AD Model Builder demonstrated that in general the retrospective patterns were not "statistically significant" from one year to the next, but that when a unidirectional pattern was present the accumulation of change produced significant changes in estimates of SSB, recruitment and average F. The amount and pattern of changes seen in these retrospective analyses demonstrate that the model formulation plays an important role in determining retrospective patterns. It is hypothesized that the same effect is present in VPA, but not readily seen due to the limited range of formulations usually examined.

Model	Recruitment	Selectivity
1. Min Flat	SRR	Flat topped all years
2. Min Dome	SRR	Dome all years
3. Rec Flat	Deviations	Flat topped all years
4. Rec Est	Deviations	One curve estimated for all years
5. Full	Deviations	Estimated for each year

TAWG Meeting
22 January 2002
St. Andrews Biological Station

Attendees: Rob Stephenson, Heath Stone, John Neilson, Stacy Paul, Lou Van Eeckhaute, Don Clark, Kent Smedbol, Stratis Gavaris (chairperson), Betty Hatte, Joe Hunt

The TAWG/TRAC process leading to the 5-8 February 2002 TRAC meeting was described. The TAWG is used to prepare material for the TRAC and provides preliminary review and feedback on work in progress. All matters are open for review at the TRAC and no final conclusions are drawn at the TAWG meetings. It is desirable to have TAWG meetings with participants from both DFO and NMFS in attendance. This is not operationally practical for the upcoming TRAC. TAWG meetings will be conducted within each lab at St. Andrews and at Woods Hole with the two co-chairs (Loretta O'Brien and Stratis Gavaris) exchanging meeting summaries. Working material may also be exchanged as needed. If required, a teleconference can be used to discuss specific issues.

Guidelines for a benchmark assessment have been distributed. It is noted that while all themes and elements of a benchmark may not be subject to intensive evaluation during a benchmark review, the basis for accepted practice should be documented for all themes. The February 2002 TRAC benchmark review for Georges Bank cod is focused on the model formulation for estimating stock status and on the methodologies for determining production dynamics.

This TAWG meeting will review preliminary explorations of model formulations for estimating stock status. The model formulation issues were grouped into 2 classes of related subjects.

1. Index weighting, index inclusion/exclusion, form of relationship for index catchability
2. Partial recruitment at the oldest age, common index catchability at the oldest age, estimating changes in M

These will be addressed sequentially. The first step was to establish a base formulation, closely matching the 2001 assessment results. The base formulation used revised catch at age (minor updates), compared survey indices to population numbers decremented to the time of year the survey was conducted (rather than approximating to the beginning of year) and applied weighted F on ages 7-9 for age 10 rather than unweighted (as a safeguard against wild Fs for small year-classes). These modifications, which will be retained for the new benchmark, did not result in substantive differences. Comparisons of biomass, recruitment and F between the 2001 assessment results and the new base should be presented at TRAC.

Two types of weighting were considered.

1. Intrinsic weighting: to account for heterogeneity between index series is based on the inverse of internally calculated mean squared residuals
2. Extrinsic weighting: to account for heterogeneity within index series is provided from external sources

Internally calculated intrinsic weights may be sensitive to anomalous residuals. Short time series are particularly suspect. To guard against this type of problem, mean squared residual were examined for meaningful patterns. Generally, older ages appear more variable and this is attributed to patchiness associated with lower abundance. Younger ages may also display more variance if the gear does not capture small fish consistently. Common weighting across selected ages within a survey series that appeared homogeneous was proposed to mitigate against potential spurious results. The following groupings for common weighting were subsequently used:

- DFO age 1
- DFO ages 2-5
- DFO ages 6-8
- NMFS fall ages 0-5
- NMFS spring ages 1-6
- NMFS spring ages 7-8

It was also noted that wide disparity in weighting where one or a few indices draws an inordinate amount of weighting must be watched for. This is a peculiarity of VPA calibration but did not occur here.

Extrinsic weighting can be based on externally calculated variance, e.g. based on survey design, but the reliability of such variances is suspect due to small sample size within strata. An alternative that has been proposed is that weaker year-classes are not sampled as reliably. External weighting based on proportion at age in each year of a survey were calculated and applied.

Residual diagnostics were examined to compare the fit between unweighted, intrinsically weighted, extrinsically weighted and both intrinsically and extrinsically weighted. The unweighted residuals tended to show a wedge type pattern with larger residuals at smaller index values, particularly for the DFO survey. Extrinsically weighted residuals showed some improvement but the most appealing pattern (horizontal band) was obtained with intrinsic weighting. Using both intrinsic and extrinsic weighting appeared to overcompensate and made residuals at low index values too small (note that small index values tend to occur more at older ages which get lower intrinsic weight as well). Intrinsic weighting, according to the grouping indicated above, was preferred.

It was noted that weighting did not have a great impact on parameter estimates. This raised the question of whether weighting should not be applied. The qualified response was that weighting could always be applied. If the homogeneity between index series were small, then the differences in weighting would be small with little impact on estimates. By applying weighting routinely though, cases with greater heterogeneity are automatically handled. The qualification pertained to checking the patterns in mean squared residuals to ensure that anomalous residuals were not unduly influential and to check that individual series were not drawing inordinate weight. The improvement in homogeneity, while not impacting parameter estimates greatly, should improve the reliability of uncertainty calculations.

Examination of observed and predicted index versus population indicated support for a proportional relationship for most indices. DFO age 1 index was an obvious case of a poor fit. It was speculated that this could be due to the high roller foot gear used during the DFO survey. An alternative suggestion was that the age 1 cod were not available in the survey area, but this was contradicted by the good fit for age 1 with the NMFS spring survey, conducted roughly one month after the DFO survey. An exploratory fit with a power relationship resulted in a very large exponent, almost 2, and poorly estimated coefficients. Given the difficulty with reliably estimating power catchability relationships and the obvious lack of fit, it was proposed that the DFO age 1 index should be excluded. It was pointed out that the DFO age 8 relationship was also poor and its utility could be explored. Also, the impact of frequent zeroes for the NMFS fall age 0 index was questioned. These two aspects will be investigated.

Only cursory examination of the issues in the second class of modeling issues was completed. These results indicated that forcing a flat toped PR at older ages resulted in an increasing trend for survey catchability at older ages. Freely estimating abundance at age 10 in recent years suggests a dome shaped PR and results in nearly constant survey catchability at older ages. Subsequent exploration will focus on these concerns.

TAWG Meeting
30 January 2002
St. Andrews Biological Station

Attendees: Rob Stephenson, Heath Stone, Stacy Paul, Lou Van Eeckhaute, Kent Smedbol, Stratis Gavaris (chairperson), Betty Hatte, Joe Hunt, Lei Harris

The model formulation issues were grouped into 2 classes of related subjects. Aspects of the first class were considered at the 22 January TAWG meeting. In relation to the 2 defined classes of subject, the focus of this second TAWG in St. Andrews was:

1. Index weighting, index inclusion/exclusion, form of relationship for index catchability
   - review of concerns raised about utility of DFO age 8 and NMFS fall age 0 indices
   - revisiting of proposal for weighting after accounting for excluded indices and investigating potential causes of differences in average mean square residuals
2. Partial recruitment at the oldest age, common index catchability at the oldest age, estimating changes in M
   - alternative PR formulations
   - changes to age composition of fishery catch since 1994
   - implications to survey catchability patterns by age and time
   - handling of plus group
   - any preliminary results on retrospective patterns (if available)

In addition, a review of Sissenwine-Shepherd type of analyses for production and preliminary results will be considered.

Closer examination of the relationship between population abundance and DFO age 8 survey index suggested that the index was relatively constant over a wide range of population abundance. The fit to a proportional relation was not satisfactory. The NMFS fall survey has a frequent occurrence of zeroes, especially in recent years. It was proposed that the poor fit for DFO ages 1 and 8 and the frequent lack of information for NMFS age 0 justified excluding these from the analyses.

With the exclusion of these 3 indices, the pattern in mean square residuals was re-examined. In addition, the impact of the anomalous 1982 NMFS spring survey results on the mean square residuals was considered. It was observed that the mean squared residual for the remaining indices were fairly comparable when the 1982 NMFS spring survey residuals were omitted. The exception was NMFS fall survey at age 4, which displayed some larger residuals. It was suggested that the mean squared residuals were similar enough and the residual diagnostic patterns were satisfactory enough to proceed with an unweighted analysis. If a weighted analysis were pursued, the 1982 NMFS spring survey would have to be excluded because of undue influence on the calculated weighting. Recall that weighting did not have a great impact on parameter estimates.

The base assessment calculated F on age 10 as the weighted average of F on ages 7 to 9. Given indications of domed shape partial recruitment, this was modified to be the weighted average of ages 8 and 9. Partial recruitment patterns resulting from such a formulation suggested domed PR in 1999 and 2000 and flat PR for earlier years. This pattern might be taken as an indication that the estimation of survivors in 2001 for older ages was not reliable. To check this, a formulation where survivors in 2001 for older ages were not estimated and the F for ages 7 and older in 2000 was calculated as the weighted average on ages 4 to 6, i.e. assuming flat top PR in 2000, was investigated. This resulted in an anomalous increasing PR pattern at older ages in preceding years. Another alternative was to permit the abundance at age 10 in the latter years of the VPA to be freely estimated. An exploratory analysis indicated that the estimates for years prior to 1997 were poorly determined. An analysis that estimated abundance at age 10 for 1997 to 2000 resulted in domed PR after 1994.

There were substantial changes to the fisheries after 1994. The USA expanded Closed Area II and extended it year round. The Canadian quota was severely reduced and the spawning closure period was extended from 1 January to 31 May. With increasing haddock abundance, Canadian fisheries are now more directed at haddock and avoid cod concentrations. Examination of the age composition for the Canadian fishery indicated that about 50% of cod over 7+ were caught in the first quarter as opposed to an expected 25%. This suggests that the changes to the fisheries are consistent with a reduced PR at older ages after 1994.

The pattern of survey catchability at age for the DFO and NMFS spring surveys was compared for the alternative PR formulations. Assuming a flat PR in 2000 and the base formulation resulted in increasing catchability for ages 5 and older. The formulation where age 10 for 1997 to 2000 was estimated and resulted in domed PR gave constant catchability for ages 5 and older. Plausible mechanisms for increasing survey catchability at older ages are not easily identified.

It was suggested that time trends in survey catchability could be compared for the alternative PR formulations.

A model formulation with age 10 estimated for 1997-2000, which results in domed PR after 1994, was used for further exploration. Preliminary retrospective analysis suggests that there may still be a retrospective pattern, but it did not appear to be severe. It was suggested that the retrospective analysis focus on ages 4-6 biomass and on recruitment.

Results of the response of yield to F, for cod using parametric Beverton-Holt, Ricker and non-parametric LOESS stock recruitment relationships were compared. While F_{MSY} may be very stable for a given parametric form, its value is sensitive to the choice of parametric form. More specifically, its value is sensitive to the slope of the relationship at moderate to high biomass. This means that even non-parametric approaches will give poorly defined F_{MSY} if the observed recruitment does not extend sufficiently over the biomass range to define the slope well. Examination of data for cod, haddock and yellowtail suggest that even for these stocks, considered to be data rich, the observed values are likely to be insufficient to resolve the shape of stock recruitment relationship in this biomass range. It was speculated that a practical and parsimonious option would be to assume constant recruitment (zero slope) for moderate to high biomass range.

Appendix 6. List of Recommendations

- TAWG to recalculate stock weights at age, consider how best to fill in the DFO 1993 & 94 DFO RV information and to confirm the maturity data for consistency.
- FACT software should be modified to allow appropriate time matching of RV & VPA population estimates, and modified to use VPA equations.
- Pursue research on using VPA results as starting conditions for the ASAP model under the hypothesis that the range of solutions under different model configurations will differ less in magnitude.
- Modify FACT to allow flexibility in estimating F old in the terminal year & most recent years.
- Investigate other model formulations such as the ASAP for use in assessing Georges Bank cod.

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