Management Unit

For the purpose of the sharing agreement, the USA and Canada designated cod on eastern Georges Bank [5Zjm; 551&552&561&562] as the transboundary management unit (Figure 1).

The USA has a requirement for management advice on Georges Bank cod. The status quo has been to use an assessment of cod on eastern Georges Bank for transboundary management advice and an assessment of cod in NAFO Divisions 5Z+6 for USA domestic management advice. While other options could be followed, this option is less disruptive to the existing processes. However, this approach requires concurrent assessment reviews of eastern Georges Bank and of NAFO Divisions 5Z+6 to harmonize results.

Consensus on Basis for Management Advice of Eastern Georges Bank Cod

A basic VPA calibration, where abundance at age in the terminal year is estimated and fishing mortality on the oldest age is calculated as the average of adjacent younger ages, displayed notable trends in residuals and an appreciable retrospective pattern. The current estimate of past biomass was consistently lower than previously estimated and the magnitude of that discrepancy was cause for concern.

A benchmark assessment review was conducted in 2002 to address concerns about the residual patterns and the retrospective patterns from the basic VPA calibration. The benchmark formulation was otherwise similar to the basic formulation except that it also estimated population abundance at age 11 for 1999 onwards. This model formulation did not display any appreciable retrospective pattern but it resulted in a domed shaped fishery partial recruitment. At the time, this was not a concern because the decline in partial recruitment at older ages was modest and the survey catchability was relatively flat for older ages. The dome shaped fishery partial recruitment was thought to be the result of elimination of a fishery in the first quarter of the year when larger/older cod were more prevalent.

In recent assessments that apply the 2002 benchmark formulation, with the inclusion of information for additional years, the descending limb of the fishery partial recruitment became increasingly steeper and the survey catchability pattern at age displayed a notable dome shape. The resulting assessment generated appreciable ‘cryptic biomass’ at older ages that could not be observed by either the fisheries or the surveys. Further, examination of the implications of eliminating the first quarter fishery indicated that the magnitude of those removals was not large enough to appreciably alter the annual size composition. Therefore, a marked change in fishery partial recruitment after the mid 1990s, a key feature of the 2002 benchmark model formulation, was not supported. In principle, it is considered good practice to favour a flat age pattern at older ages for fishery partial recruitment and survey catchability unless there is compelling evidence to suggest otherwise.

Alternative models will be faced with accommodating challenging, and sometimes incongruent, data features.

- The trends in survey abundance, coupled with the fishery catches, suggest that the relationship between survey abundance indices and population abundance changed during the mid 1990s, particularly at ages 4-6.
- Total mortality calculations indicate some decline around the mid 1990s, but total mortality remains high. Total mortality appears higher for ages 6+ compared to ages 4-5.
- Relative exploitation calculations, which assume survey catchability is constant over the time series, indicate a decline beginning in the mid 1990s.
- The indications for total mortality, coupled with relative exploitation (i.e. survey and catch data), imply that natural mortality (or aspects that might alias natural mortality, e.g. emigration) increased since the mid 1990s and that M may be higher at ages 6+.
- Composite tag recovery data, extending from Bay of Fundy to Southern New England, but largely based on returns of larger cod from the adjacent Gulf of Maine stock with limited amount from Georges Bank, did not show a marked decline in percentage recovered by age, therefore not supporting a difference in either natural mortality or fishery partial recruitment by age for recent years. Analyses of the same tagging data resulted in similar estimates of natural mortality for three size ranges, but the robustness of these results could not be evaluated during the meeting.

While the 2002 benchmark model formulation did not display a retrospective pattern, this model was not supported due to generation of ‘cryptic biomass’. The basic VPA model continues to display a strong retrospective. Alternative models that can remove the retrospective pattern will be challenged with discriminating between competing hypotheses about processes. Having ruled out a change in fishery partial recruitment as an option, the approaches considered for addressing retrospective patterns are changes in survey catchability, changes in natural mortality, and ‘missing’ or ‘extra’ catch. The effect of each of these options is often very similar and simulation studies have shown that determining the appropriate corrective measure needs to rely on corroborative information and expert judgement. It is possible, and even likely, that a combination of these options occurred. Specifying the appropriate ‘mix’ is even more challenging.

Given an unexplained intervention occurred in 1994, the retrospective pattern indicates that any bias in catch reporting would have to be due to ‘missing’ catch post 1994 or ‘extra’ catch prior to 1994. Fishery monitoring systems are considered to have improved since the mid 1990s, though there may have been increased sampling bias during the transition. While some ‘missing’ or ‘extra’ catch is thought to have occurred, the large magnitude implied by the retrospective, for this option to be the sole factor, was not considered likely. Further, early ‘extra’ catch does not affect current estimates but may have implications for historical productivity. In conclusion, there was less support for this option. Therefore it was not explicitly explored, but it was recognized that incorporating changes in natural mortality could be interpreted as aliasing some 'missing' catch, i.e. the higher natural mortality could represent some non-reported fishery induced mortality.

Exploration of models that allowed M to change from 1994 onwards but did not split the survey time series gave better fits, flatter survey catchability at older ages, flatter fishery partial recruitment at older ages, fishing mortality time trends that were intuitively more consistent with effort regulations, and improvement of retrospective patterns when natural mortality for ages 6-10+ during 1994-2007 was set to 0.7. Fit statistics (AIC and BIC) also favoured natural mortality of 0.7 over 0.2 for this age/time block. Natural mortality between 0.6-0.8 accounted for about 99% of the probability in the fit statistics However, strong trends in annual survey catchability persisted and were considered problematic.

Splitting the survey time series in 1994 while keeping M fixed at 0.2 for all years and ages, appreciably improved the time trends in residuals and addressed the strong trends in annual surveys. The configuration gave better fits, flatter survey catchability at older ages, flatter fishery partial recruitment at older ages, and reduction of retrospective patterns as compared to the basic VPA.

Further exploration of models that split the survey time series as well as fixing M at 0.5 for ages 6+ during 1994-2007 gave better fits, flatter survey catchability at older ages, smaller changes in survey catchability at all ages, flatter fishery partial recruitment at older ages, fishing mortality time trends that were intuitively more consistent with effort regulations and reduction of retrospective patterns. Fit statistics (AIC and BIC) favoured natural mortality of 0.5 over 0.2 for this age/time block. Natural mortality between 0.4-0.6 accounted for about 80% of the probability in the fit statistics.

A model that incorporated 'random walk' for natural mortality and survey catchability was presented to examine the timing and magnitude of their changes. Results indicated that there were indeed abrupt effects at about 1994 and that increases in both survey catchability and natural mortality were estimated. Estimating both resulted in smaller changes than either estimated alone. In addition, if changes in catch were also incorporated, the expectation is that the change in each factor would be smaller still. The 'random walk' model was not presented as an assessment as it did not incorporate all the indices, but it corroborated the conclusion that the survey and catch data indicate a split in survey catchability and/or an increase in natural mortality at older ages.

There was consensus that splitting the survey time series addressed the strong time trends in annual survey catchability and residuals. Reliable estimation of natural mortality or even changes in natural mortality is challenging. Higher natural mortality for ages 6+ during 1994-2007 was favoured by the survey and fishery catch data and was reflected in the model selection. Tagging data, though not informative about a change over time did not support a difference in natural mortality by age for recent years. Models that split the survey time series did not display appreciable retrospective patterns regardless of whether natural mortality was set to 0.2 or 0.5. While models with higher natural mortality for ages 6+ during 1994-2007 were supported, persistence of higher natural mortality is questionable. Documenting the fate of the 2003 year class, the only year class above average since the 1990 year class, over the next few years should be informative about natural mortality at older ages.

Mechanisms that explain changes in either survey catchability or natural mortality could not be established. Possible differences in vertical structure of cod aggregations in relation to changes in abundance could cause changes in catchability. Changes in natural mortality could be aliasing ‘missing’ catch, particularly during the regulatory and reporting changes of the mid 1990s, and could also be aliasing emigration or imperfect designation of the boundaries for this component, though an excess of larger/older fish is not apparent in adjacent cod components.

A model with split survey time series and natural mortality of 0.5 for ages 6+ during 1994 to the current year is indicated by fit diagnostics as the basis for management advice. However, it is recommended that the results from a comparable model using a constant natural mortality of 0.2 also be considered. Until the fate of the 2003 year class has been documented (ages 6+) it will be necessary to use these two models to adequately account for uncertainty in the assessment. Doing so acknowledges that there is considerable uncertainty about selection of a single appropriate model. It is also notable that domestic USA management of NAFO Divisions 5Z+6 will be based on a model with split survey time series and natural mortality of 0.2.

Reference Points for Harvest Strategy

The Transboundary Management Guidance Committee has adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality limit reference, $F_{ref} = 0.18$. When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding.

Inability to adequately characterize a stock-recruitment relationship and uncertainty about the magnitude and persistence of any changes in natural mortality and weight at age suggests that it is inappropriate to change F_{ref} until these model uncertainties are resolved. While stock recruitment data are not fit well by conventional models, the data suggest that chances of good recruitment are lower when biomass is less than about 25,000 mt regardless of what model was examined.

Procedures for Projection

Projections require specification of future fishery partial recruitment, weights at age and natural mortality. In principle, an average of a suitable time period, say the most recent five years, should be used to derive fishery partial recruitment and weights at age when there are no persistent trends. When trends are present, the time period may be reduced to three years or even the most recent observed value. In the case of extreme trends, it may be necessary to extrapolate the trend. The future natural mortality used for projection should be consistent with the natural mortality used in the model to determine stock status.

The outlook should be provided in terms of consequences with respect to the harvest reference points for alternative catch quotas. Uncertainty about standing stock generates uncertainty in forecast results, which can be expressed as the risk of exceeding F_{ref} =0.18 or the risk that biomass will not increase by a given percentage. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. However, they are dependent on the data and model assumptions and do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect stock dynamics closely enough. To address the uncertainty about selecting among plausible models, i.e. states of nature, the risk from alternative models should be presented and the consequences on basing actions on a ‘wrong’ model should be discussed. For this assessment, risk analyses for models that set natural mortality at 0.5 and 0.2 should be considered as plausible alternative states.