Fisheries and Oceans Canada / Pêches et Océans Canada
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Canadian Science Advisory Secretariat / **Secrétariat canadien de consultation scientifique**

Proceedings Series 2003/014 / **Série des compte rendus 2003/014**

Transboundary Resource Assessment Committee (TRAC)

Comité d'évaluation des ressources transfrontalières (CERT)

Report of Meeting held 10-14 February 2003

Rapport de la réunion du 10 au 14 février 2003

Conference Center St. Andrews Biological Station

Centre des conférences Station biologique de St. Andrews

Stratis Gavaris
Meeting Chairperson / Président de réunion

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May 2003 / Mai 2003

Canada

Foreword

The purpose of these proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or mis-leading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

Avant-propos

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s'est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s'il est clairement indiqué qu'elle l'est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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ISSN 1701-1272 (Printed)

Published and available free from:
Une publication gratuite de:

Fisheries and Oceans Canada / Pêches et Océans Canada
Canadian Science Advisory Secretariat / Secrétariat canadien de consultation scientifique
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Ottawa, Ontario
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Printed on recycled paper.
Imprimé sur papier recyclé.

Correct citation for this publication:
On doit citer cette publication comme suit:

Gavaris, S. 2003. Transboundary Resource Assessment Committee (TRAC): Report of Meeting held 10-14 February 2003. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2003/014.

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ABSTRACT

A meeting of the Transboundary Resource Assessment Committee (TRAC) was held at St. Andrews, NB during 10-14 February 2003 to review the assessment approaches and results for the herring complex of the Gulf of Maine and Georges Bank. Information on stock structure and resolution of survey and fishery information were reviewed to reaffirm the basis of the management unit definition. Fishery catch at age information and indices of abundance from bottom trawl and acoustic surveys were used to estimate the contemporary state of the resource. The results were sensitive to model structure and assumptions. A principal difference was the use of age specific information by one model and age aggregated information by the other. Information on growth, natural mortality, exploitation pattern by age and the relationship between stock and recruitment was used to characterize the productivity of the resource. Fishing mortality reference points were better determined than biomass reference points. The uncertainty in the contemporary state of the resource translated into substantial uncertainty in the forecast projections.

RÉSUMÉ

Le Comité d'évaluation des ressources transfrontalières s'est réuni à St. Andrews (N.-B.) du 10 au 14 février 2003 afin d'examiner les méthodes d'évaluation du complexe de stocks de hareng du golfe du Maine et du banc Georges, et leurs résultats. On a passé en revue l'information sur la structure de ces stocks, les résultats des relevés et l'information provenant de la pêche pour étayer à nouveau la définition des unités de gestion. On s'est fondé sur les données de prises selon l'âge dans la pêche et sur les indices d'abondance dans les relevés acoustiques et au chalut de fond pour estimer l'état actuel de la ressource. Les résultats se sont avérés sensibles à la structure et aux hypothèses des modèles. Une différence fondamentale résidait dans l'utilisation d'une information spécifique par âge dans un modèle et d'une information portant sur une combinaison d'âges dans l'autre. L'information sur la croissance, la mortalité naturelle, le régime d'exploitation par âge et la relation entre le stock et le recrutement a servi à caractériser la productivité de la ressource. Les points de référence de la mortalité par pêche ont été mieux déterminés que les points de référence de la biomasse. L'incertitude au sujet de l'état actuel de la ressource s'est traduite par une incertitude importante dans les projections prévisionnelles.

The Transboundary Resource Assessment Committee (TRAC) met during 10-14 February 2003 in the Conference Center, Biological Station, St. Andrews, NB, Canada, to address the Remit in Annex 1 following the Agenda in Annex 2. Participants are listed in Annex 3. The list of working papers is given in Annex 4. The consensus report on the status of the stock complex is attached as Annex 5.

1. INTRODUCTION

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.

While scientists from both countries have participated in each other's peer review of the Gulf of Maine/Georges Bank herring assessments, there has not been a joint peer review meeting, as there has been since 1998 for Georges Bank cod, haddock and yellowtail. On 26 June 2000, P. Kurkul (Northeast Regional Administrator, NMFS) and N. Bellefontaine (Regional Director General, DFO Maritimes Region) received a joint request from the US and Canadian herring fishing industries to undertake a Canada / US peer review of Gulf of Maine herring under the auspices of TRAC. Due to data availability and workload, this meeting could not be undertaken earlier. This meeting responds to that request.

TRAC conducts appraisals of "benchmark reviews" and of "assessment reviews". Benchmark reviews examine the methodologies that may be most suited for assessment of a particular stock and establish an approach to be followed. Assessment reviews examine the results and interpretation of conclusions arising from application of a "benchmark" approach. The aim is to conduct benchmark reviews periodically, say every few years, at meetings dedicated to this task alone. The schedule of assessment reviews is tailored to the fisheries management planning process. The schedule for herring did not permit such a separation. This meeting addresses both a benchmark review and an assessment review.

2. DEFINITION OF MANAGEMENT UNIT

Melvin, G.D. et al. 2003. Review of geographical range, seasonal composition, and management units for the Gulf of Maine/Georges Bank stock complex. TRAC Working Paper 2003/01.

A synthesis review of herring stock structure indicated that three major spawning components have been identified in the Gulf of Maine/Georges Bank area. These are coastal Gulf of Maine, Georges Bank and Nantucket Shoals. While these components are considered relatively distinct during spawning, intermixing during other seasons, including when fisheries or surveys are prosecuted, is presumed to occur. Due to the impracticality of separating spawning components for the catch and survey indices, the resource must be assessed as a complex of the three components.

Melvin, G.D. et al. 2003. Management of the stock complex. TRAC Working Paper 2003/02.

An objective of fisheries management for herring is to prevent overfishing of the resource. This implies that fishing effort should be distributed over the components of the complex roughly proportionate to their biomass by defining a suitable partitioning of the complex into management areas. Two pieces of information are needed to implement such a strategy, the relative biomass of each component and the contribution that each component makes to the various fisheries conducted in each management area.

Rapporteur: L. Jacobson

TRAC did not review all the data and observations on which the prevailing view of stock structure has been based, though some larval and adult herring survey distributions were examined. Spawning groups appear to mix seasonally and are taken in the same fisheries. One of the primary difficulties was in separating U.S. catches of the Georges Bank taken in the Gulf of Maine. There was concensus to combine the three major spawning groups into a single stock complex for assessment purposes. The decision was pragmatic and based on biological interactions, the location and seasonality of fisheries, and difficulties in obtaining separate catch and survey data for each spawning group.

In lieu of spawning group-specific assessments, the group agreed that spawning groups should be considered carefully in crafting management advice. Potential differences in productivity are important. Some components may be very productive, and capable of sustaining high fishing mortality rates, while other components may be relatively unproductive. The average F_{msy} value for the whole stock may, for example, be high enough to deplete unproductive components.

Management should endeavor to maintain spawning on all grounds in order to maintain significant production from all spawning groups. Production in different seasons and areas would be the basis for advice regarding potential harvest levels in different areas. There is little or no new information in this assessment about the seasonal distribution of herring catches by area, beyond what was used in previous assessments. There is, however, new hydroacoustic survey information that could be used to refine estimates of relative abundance in the inshore and offshore areas of the Gulf of Maine. The latter may be important because the proportion of the stock offshore in the Georges Bank has likely increased as biomass has increased offshore.

It was **recommended** that the boundaries between management areas in the US Fishery Management Plan be reviewed for possible realignment in order to correspond better with the defined spawning components, the fishery patterns and the resolution of the data. Three changes should be considered; (1) moving the boundary between Area 1B and area 2; (2) moving the area 2/3 boundary from its current position (`69:00) further west to about `70:00, and (3) including the Canadian portion of Georges Bank in area 3. It was further **recommended** that the results of the tagging initiative in the coastal New Brunswick weir fishery be examined to refine the understanding of stock structure and the affinity of those juvenile catches with this stock complex. Finally, it was **recommended** that a large scale morphometrics study be initiated to study mixing rates and distributions of herring from 4X, 5Y, and 5Z components in seasonal fisheries in the region.

3. ESTIMATION OF CONTEMPORARY STATE

3.1. Overview and Fishery Data

Melvin, G.D. et al. 2003. A general overview of the fishery and past assessments. TRAC Working Paper 2003/03.

Principal fisheries on the stock complex over the years have included US coastal fisheries in Div. 5Y, Canadian weir fisheries off the coast of New Brunswick in Div. 4X, foreign fisheries mostly in Div. 5Z prior to 1977 and, more recently, US coastal and offshore fisheries in Div. 5Z and Subarea 6. Since 1991, herring in the Gulf of Maine/Georges Bank area have been assessed as a stock complex, in recognition of the impracticality of partitioning the catch by spawning component.

Cieri, M. et al. 2003. Landings, samples, and the catch at age matrix for the Atlantic herring fishery: 2002. TRAC Working Paper 2003/04.

Landings and samples data, length frequency and age length key, are processed by unit, defined as month/geographical area/gear, to derive catch at age in both weight and number. The results reveal strong 1994, 1998 year-classes and moderate recruitment for other years. The catch shows a higher prevalence of older herring after the 1980s, roughly coinciding with a change from fixed gear to purse seine and subsequently midwater trawl gears in US fisheries. There has been a reduction in length and weight at age for herring ages 3 and older since the mid 1980s.

Rapporteur: R. Mohn

The magnitude of landings data for the late 1960s and early 1970s are probably an underestimate, perhaps by about a factor of two in some years. Landings data since then are considered more reliable and from 1994 to the present, data were audited by cross-referencing three distinct reporting systems. Nonetheless, some industry representatives commented that the recent landings did not represent all the herring that suffered mortality due to fishing operations. The magnitude of any additional mortality could not be quantified. Weir fishermen observed that although their catches were low in 2002, this was partly due to low effort.

Furthermore, herring were seen outside the weirs and perhaps the relative absence of predators altered their behavior, making them less vulnerable to the weirs.

Sampling of the fishery for length and age composition was extensive and representative of the spatial and temporal patterns in the fishery. Unsampled units were few and were readily accommodated by borrowing from adjacent units.

The average weight at age in the fishery declined since the mid 1980s. There was concern that the change might have been due to a shift in markets or gear and seasonal changes in the fishery. Calibration of age determinations is done routinely and there is no indication that the reduction in size at age in the late 1980s is an artifact caused by drift in interpretation. Subsequent checking using consistent area/season strata confirmed a decline in weight at age. This was corroborated by NMFS and DFO survey observations. The pattern also displays an apparent change in growth as a function of age. In recent years age two herring are getting larger while older fish are getting smaller. The pattern was noted in both fishery and survey results. There was speculation that this could be an age specific density dependent effect coincident with stock recovery in the early 1980s.

Comparisons of age determinations by readers with DMR, NMFS and DFO indicated poor agreement for ages greater than about five. It has been observed that otoliths are harder to interpret recently with compression of outer zones. It was **recommended** to conduct a workshop on age determination involving staff from the three laboratories.

3.2. Survey Indices

Melvin, G.D. et al. 2003. Overview of assessment surveys. TRAC Working Paper 2003/05.

Surveys of early stage larvae are taken as an indicator of the spawning stock biomass that gave rise to them but are not considered reflective of year-class strength. The larval surveys were terminated in the mid 1990s but they indicated an increase in spawning stock biomass after the mid 1980s. Bottom trawl surveys also indicate an increase in biomass after the mid 1980s. Bottom trawl survey indices are substantially higher in recent years than at any other time since the inception of the surveys. This same pattern is evident for bottom trawl surveys in Div. 4WX and in Div. 4T. Mean length at age, calculated from survey observations, is lower for 1987-91 year-classes compared to 1983-85 year-classes. Agreement, between US and Canadian readers, in age interpretation is not very good beyond about age 5.

Overholtz, W. et al. 2003. Acoustic surveys and results. TRAC Working Paper 2003/06.

Acoustic surveys in 1998 were focused on locating spawning and pre-spawning concentrations in the Gulf of Maine and on Georges Bank. During 1999-2002, the objectives of acoustic surveys included estimation of herring abundance. Zigzag and parallel systematic as well as stratified random transect designs have been used over these years. Kriging was used to estimate mean herring backscatter. Intercepts from eleven target strength equations were applied to each survey and the results were averaged. A weighted average of the various designs used in each year indicated a gradual increase in biomass from 1999 to 2001 and a substantial decline in 2002.

Rapporteur: C. LeBlanc

The larval herring surveys have not been used as indices of abundance in the most recent assessment. This was because the series were terminated in the mid 1990s and high annual variability had been observed. It was noted though that the trends appeared to reflect some aspects of recent population developments and that they may be useful for bridging a period in the mid to late 1980s when the catchability of trawl surveys appeared to change. The group decided to incorporate these indices into the assessment.

The bottom-trawl surveys were designed for groundfish, but indices of abundance for herring have been developed based on them. There were concerns that a bottom trawl may not sample herring effectively if they were distributed in the water column above the headline. Reports of commercial mid-water operations suggested that herring were often fairly close to bottom. There were also doubts raised about the reliability and comparability of these indices during the early part of the 1970's when large amounts of herring were removed off George's Bank but the indices indicated very low abundance. It was noted that adjustments to NMFS surveys (spring and autumn) have previously been made for vessel changes but not for the door replacement in 1985. Remedial steps will be taken to introduce corrections for survey timing and for gear change in the assessment. It was noted that there appears to be a change in survey catchability coincident with the door replacement in 1985. Year-class tracking was best in the NMFS spring survey. Surveys do not track year-classes well after about age 6. The abundance of herring of ages 6 and older declines rapidly and may be indicative of a catchability problem or may be confounded by the difficulty in interpreting the age of older herring. A similar increase in bottom trawl survey abundance during the mid 1980s was observed for herring on the Scotian Shelf and in the Gulf of St. Lawrence. It could not be established if those changes were due to increased abundance, alteration in behavior or vessel changes.

The use of stratified arithmetic means for calculating the bottom trawl survey indices was discussed. It was suggested that the calculation of the index be done on log scale or assuming a Poisson distribution in order to account for the nature of the variability. It was noted that log-transform of the data does not adequately address year effects and raises concerns about proper treatment of the large number of zero tows where no herring are caught. Transformations of data may be worth pursuing in specific cases but past experience suggests that they can not be considered an automatic improvement for routine application. It was noted that the design based estimates of variance were not used in weighting observations for the assessment. Further, the design based estimates would not be appropriate because they are not reflective of the variation in the catchability process.

Acoustic surveys have been conducted in the inshore Gulf of Maine since 1998. Surveys are conducted at night to minimize target strength variability. The decline in biomass estimates from 2001 to 2002 was thought to be due to timing of surveys. Spawning is very punctual and could easily be missed if the survey is conducted at the wrong time.

Acoustic surveys have also been conducted on Georges Bank since 1998. Each offshore survey was completed in 5 to 6 days prior to 2002 and in 9 to 10 days in 2002, due to increase in sampling intensity. The duration is short enough to ensure that double counting and movement of migrating herring should be minimal. Herring were distributed from the Great South Channel to the Northern Edge of Georges Bank along the 100 meter contour. They were close to bottom in mostly continuous schools with some patchiness. Vessel avoidance is not thought to be a problem since the distribution was in deep water near the bottom. Herring did not show any diel movement and did not appear to be feeding at the time of the surveys. Aggregations seem to disperse in early October soon after spawning. Survey timing in 2002 was similar to the previous years, but indications, confirmed by fishery sampling data, were that spawning occurred earlier and part of the spawning aggregation might have been missed, resulting in the low biomass estimate.

Biological sampling was done during the acoustic survey using a mid-water trawl, generally towed near the bottom. The predominant species was herring with a bycatch of mostly silver hake and redfish. Post-survey processing was done to account for acoustic backscatter of non-target species. The length and age composition data from mid-water trawl samples for herring have not been analyzed. Age 2 immature herring are mixed with adults.

Stock specific target strength values are not available. Eleven target strength equations from herring stocks in the North Atlantic were used in the analysis. The range of target strength relationship intercepts that were used in the calculations implied a range in biomass that varied by a factor of five. The biomass calculation is done for the area of aggregation only and does not include the peripheral area surveyed but where herring were consistently absent. This practice should not bias the estimate of biomass but its effect on the variance calculation was unknown. Means and variance of herring backscatter were estimated with geostatistical methods and a correction for geometric anisotropy was done from east to west. It was noted that the Kriging variance was not representative of the repeatability of surveys and is not comparable to design based estimates of variance. Design based variance calculations are based on between transect variability. Neither the kriging nor design based variances are the appropriate variance for observations used in assessment model.

Attempts to compare results from the inshore (GOMAQ_DMR) and offshore (NMFS) acoustic surveys in 2002 failed due to equipment problems on the contracted vessel. It is **recommended** that experiments aimed at calibrating the inshore and offshore acoustic surveys should be pursued.

3.3. Assessment

Overholtz, W., et al. 2003. VPA/FPA analysis and results + Appendix: KLAMZ model. TRAC Working Paper 2003/07.

An updated (adding additional catch at age and survey data for 1998-2001) US VPA calibration continued to show a severe retrospective pattern and the same problems that were recognized in the previous assessment. Because of the severe retrospective pattern, problems with aging, and recognition of major problems in the previous assessment, an age aggregated assessment was pursued. A biomass dynamic delay-difference model using only two age classes, age 2 recruits and ages 3+ aggregated, was investigated. The fishing mortality rate is assumed to be the same for both age groups but otherwise the mortality dynamics are similar to VPA. A von-Bertalanfy relationship is used to model annual changes in the growth of herring. . A recruitment parameter is estimated for each year-class. NMFS winter, spring and autumn bottom trawl surveys, and DFO bottom trawl surveys were used as indices of biomass for age 2 and for ages 3+. NMFS and DFO larval surveys were used as indices of spawning biomass. NMFS acoustic surveys were used as indices of total biomass. Survey covariates were used to account for catchability changes associated with change in timing (via temperature anomaly) of the autumn survey and with change of the trawl doors in 1985 for both the spring and autumn surveys.

The acoustic surveys were also used to scale the absolute biomass, after adjusting for the proportion on Georges Bank, as the acoustic surveys did not cover the Gulf of Maine. The results indicated that fishing mortality was very high from the late 1960s to the mid 1980s, exceeding 1.0 in several years, followed by an abrupt decline over about a two year period to about 0.2 and a subsequent decline during the 1990s to a low of 0.06 in 2002. Biomass declined to a low in the early 1980s and has since progressively increased to about 1.8 million mt.

Power, M.J., et al. 2003. Gulf of Maine herring complex VPA analysis. TRAC Working Paper 2003/08.

Examination of an updated VPA calibration continued to display a severe retrospective pattern and had troublesome patterns in residuals. Most of the concerns related to an apparent change in catchability at about the mid 1980s. A truncated VPA calibration, using only ages showing acceptably low variation for the ln index residuals, resulted in improved diagnostics but only a moderate amelioration of the restrospective pattern. Concern remains also about the catchability pattern by age for the surveys and about the fishery partial recruitment pattern by age, particularly in the most recent years. The results indicate that the fishing mortality was very high at about 0.8 between the early 1970s and the early 1980s, declined to about 0.2 by the mid 1980s, fluctuated between 0.2 and 0.4 until the late 1990s when it declined again to about 0.2. Biomass decreased progressively between 1967 and 1977, remained low until the mid 1980s when it increased with the recruitment of the 1983 year-class, remained at that level until the late 1990s when it increases progressively, due to improved recruitment, to about 0.8 million mt, about two thirds of the high biomass in 1967.

Rapporteurs: R. Conser and G. Stefansson

KLAMZ is a forward projecting delay-difference model, which estimates initial stock size (in 1960), recruitment and fishing mortality for each year in the model (1960-2002), and the parameters for a Beverton-Holt stock recruitment curve. Appoximately 100 parameters were estimated in this model application of KLAMZ. AD Model Builder libraries were used for optimization and parameter estimation. A full suit of 11 surveys were used in the model and a set of dummy variables and temperature covariates were incorporated to adjust nominal survey observations when needed, e.g. to adjust for trawl door changes. As the model is new to this assessment, additional documentation was requested, e.g. a full list of model parameters along with their point estimates and standard errors, the correlation matrix for estimated parameters, etc.

Surplus production calculations were carried out using stock biomass estimates from the KLAMZ model:

$$S_y = B_{y+1} - B_y + C_y$$

where:

S_y is the surplus production during year y
B_y is the stock biomass at the beginning of year y
B_{y+1} is the stock biomass at the beginning of year y+1
C_y is the catch in weight during year y

S_y and B_y were then used to estimate MSY reference points using the Fox model. Although this was done within the KLAMZ model, the weight given to this likelihood component was near zero and as such, had no effect on other parameters estimated in the model. Estimates of reference points using the Shaefer model were completed after the fact. Although this approach is reasonable, some internal inconsistency may be result from using the Beverton-Holt stock recruitment relationship to model herring compensation within the estimation model, while using the Schaefer production functions to model compensation for the reference point calculations.

In several cases, the combination of dummy variables and temperature covariates resulted in pronounced adjustments to nominal survey time series. While it was agreed in principal that adjustments were necessary, the magnitude of the adjustment was questioned in some cases, e.g. a 70-fold increase in efficiency of the NMFS fall survey due to door changes and environmental effects. It was suggested that plots of each survey time series be provided illustrating the original and adjusted time series.

A table of likelihood components from the fitted model was presented. With many surveys, an estimated stock recruitment relationship, priors, weights, and penalty functions, KLAMZ has many likelihood components that sometimes “pull” the optimal solution in differing directions, e.g. toward low survey catchability/high biomass or toward high survey catchability/low biomass. While the table of likelihood components at the solution was quite helpful in illustrating this model tension, additional runs were requested that explicitly weight a key component very high (e.g. lambda=1000) while all other weights were low (e.g. lambda=1). In this way, the effect of each component on the fishery management results would become more clearly evident.

With many estimated parameters, the possibility of parameter confounding was raised. In particular, model estimates of important management state variables (e.g. abundance and fishing mortality in recent years) may be confounded with estimates of survey catchability. Additional diagnostics should be examined, e.g. from the Hessian matrix and bootstrap results.

Although KLAMZ is not as highly parameterized as some assessment models used in other fora, the estimation of 100+ parameters via a highly nonlinear objective function does raise the possibility of a relatively flat response surface with multiple local minima. This is of practical importance if several different local minima have similar likelihoods but different fisheries management implications. KLAMZ runs should be made using a variety of initial value vectors for the estimated parameters and these results should be reported with the final model run.

KLAMZ results are somewhat difficult to compare to the results of a fully age-structure model (e.g. ADAPT). It would be useful to forward project KLAMZ recruitment estimates into an age structure using the model’s assumptions of fixed F and M to compare the resulting age structure with other results. Further, it would be helpful if this could be done in a numbers-based mode as well as the weight-based mode that is inherent to KLAMZ

After extended discussion of the model and results, it was agreed to:

- test fixed growth parameters
- change maturity parameters
- look at dropping covariates in some submodels in accordance with significance level

- test effect of not including temperature
- revise the prior on recruitment variance
- carry out bias-correction using the bootstrap results

Final analyses with the KLAMZ model also used a revised prior for the variance of log recruitment. Reducing the emphasis on the likelihood components for the stock recruitment and its variance resulted in substantially higher estimates of recent recruitment.

ADAPT is an age structured VPA calibration model that typically estimates terminal year abundance and index catchabilities. The ADAPT model formulation used in the previous stock assessment (SAW27, 1998) was updated with the new catch-at-age and survey data that have become available post-1998. Retrospective patterns continued to be pronounced. Subsequent exploration with ADAPT included index selection and weighting, truncation of time series to exclude pre-1983 indices and aggregation to an age 6 plus-group.

A mean-squared-error (MSE) criterion of MSE<3 was initially used to include survey series. These MSE values were based on an initial VPA with all surveys included. Truncating survey series to include only post-1983 data resulted in much lower MSE but still high at around and over 1.0. Subsequently, survey series were weighted proportional to the inverse of MSE, internally updated. It was decided that the exclusion criterion, MSE>=3, was not sufficiently well founded since the internal weighting scheme should provide the appropriate relative variability between series. On the other hand it is possible that the inclusion of very noisy series could give undue high weighting to one series leading to inappropriate down-weighting of better series. Since the initial MSE values and selection scheme were derived from a VPA fitted to all series it is also possible that the MSE values for one series are overestimates due to the inclusion of other series. It is therefore desirable to fit to each series separately first and investigate the results. The exclusion of series should ideally be either done a priori using independent criteria, such as stock area coverage. A posteriori the series can be selected based on residual patterns or other consistency checks rather than only based on raw MSE values.

Initially, fishing mortality on the oldest age (10) was initially set equal to that on the next to oldest age (9), i.e. not as an average of several younger ages. Subsequently it was set to the average of ages 5-9. Recent recruitment estimates from KLAMZ were very high and imply a high abundance of old fish. ADAPT results suggested increasing fishing mortality with age, resulting in reduced abundance of old fish. This inconsistency gives cause for loosening up the ADAPT assumptions on fishing mortality for the oldest age, yet without resorting to setting it based on a single age group. Fishermen indicated that they do not avoid large fish so the reason for large fish to exist but not appear in the catch would be due to location of the fishery. It is presumed that older fish tends to be more prevalent on Georges Bank rather than in-shore in the Gulf of Maine where much of the fishery is located. It was concluded that for final ADAPT results the fishing mortality on age 10 would be set to the average of ages 7-9 and the resulting fishery partial recruitment patterns will be examined. Estimation of abundance at all ages over age 2 could be attempted in the terminal year.

The utility of and criteria for exclusion of various survey series were discussed at length. The aim was to specify a common set of indices to be used in both KLAMZ and ADAPT in final analyses. It was determined to exclude DFO survey results for 1993 and 1994 because the western portion of the survey area was not covered due to operational difficulties. Larval surveys were included since they might help bridge across the year 1985 and hence link together the periods before and after the door change on the NMFS bottom trawl surveys. A break for the NMFS larval survey in 1988 was introduced to account for a marked change in the magnitude of the index that may be associated with differences in processing. NMFS and DFO bottom trawl surveys were included as were NMFS offshore acoustic surveys. The entire time series for the NMFS spring and fall surveys would be included but with a break in 1985 that allows estimation of distinct catchability coefficients. The reference run will thus include all available surveys, unweighted. In addition, analyses with internally weighted time series would also be presented. Other options, e.g. analyses including survey series one-at-a-time, will be considered for diagnostics.

The ADAPT and KLAMZ models differed in population dynamics, complicating comparisons. However, both models assumed that the natural mortality rate was equal to 0.2 and constant over time for all ages and that the total catch was assumed known without error. Comparability of assessment results was enhanced by ensuring that the same survey indices were used and that they were treated in a similar manner. For example the door effect was included in ADAPT runs and the temperature covariate can be eliminate from a KLAMZ run.

One of the principal differences between the population dynamics in the KLAMZ and ADAPT models pertained to aggregation of ages. In recognition of possible age mis-specification for older ages, an ADAPT formulation using an age 6 plus-group may be a practical intermediate approach that can shed some insight. Since the delay-difference model aggregates all ages except the youngest, this will be a move towards making these models somewhat more similar, possibly illustrating the cause of some differences. It may also be worth while to move the plus-group to younger ages so as to move closer to the delay-difference model. Initial exploration with an ADAPT formulation using an age 6 plus-group indicated that the choice of weighting schemes seriously affected the biomass estimates. Analyses using internal weighting of survey series were not stable, suggesting that one or more survey series was attracting undue weighting. There was not sufficient time to explore this further during the meeting. This remains a potential avenue for exploration.

It was noted that assessment results should be broadly consistent with the acoustic estimates of total biomass, after adjusting for the fraction in the stock complex covered by the offshore acoustic survey.

Subsequent diagnostic evaluations of KLAMZ model results indicated that the change in catchability in 1985 was very large, particularly for the fall survey. The effect of this change for the age 3 plus-group in the spring was marginal. Many of the survey likelihood components tended to pull the biomass estimates towards higher values, but particularly the NMFS spring survey at age 2. Changes in the weighting given to the NMFS spring age 3 plus-group index had a considerable effect on the perceived accuracy of this series. The temperature/timing effect, which accounts for a drift in about one month in survey timing, was significant for the NMFS fall age 3 plus group index but, surprisingly was not significant for the same survey at age 2. The increasing trend in residuals for the DFO survey might be due to an increasing portion of the herring stock complex occurring on Georges Bank, as the DFO survey does not cover the remainder of the geographic range. A few of the correlations were surprisingly surprising and cause for concern, notably the correlations between recruitment estimates in early years and important management parameters, e.g. biomass in the terminal year, were around and over 0.6. Bootstrap results indicated that biomass estimates had a large bias in the early years but in recent years the bias was negative and on the order of about 10%.

Subsequent diagnostic evaluations of ADAPT indicated that biomass values ranged from 624,000t to 1,183,000t when the NMFS bottom trawl surveys were used one-at-a-time (analysis using DFO survey did not converge, larval surveys terminated in 1995 and could not be used on their own, acoustic survey series too short). Partial recruitment to the fishery for recent years in these runs appears to be strictly increasing with age from age 5. Biomass estimates resulting from runs with weighting are quite similar to the converged runs. When including all fleets, with weighting (or ML estimation of variances), there are no indications that individual indices may pull estimates influentially and hence it was agreed that final results would include all fleets in a weighted manner. Differences in catchability between the early and latter time series for the NMFS spring and fall surveys was greatest at younger ages and was particularly large for the NMFS fall survey. The retrospective pattern for the final three years was not as pronounced, but there was a marked shift in the results for years prior to that, suggesting an abrupt change in survey catchability between 1999 and 2000.

Even when KLAMZ and ADAPT were based on as similar assumptions as possible and used the same sources for indices of abundance, the resulting biomass estimates differed by a factor greater than two.

4. CHARACTERIZATION OF PRODUCTIVITY

Clark, K.J., et al. 2003. Biological reference points for Gulf of Maine herring. TRAC Working Paper 2003/09.

One of the objectives of fisheries management is to keep fishing mortality rate moderate. FMSY proxies were investigated using per recruit analyses and productivity analyses. The productivity analyses explored various parametric and nonparametric stock recruit relationships. The range of F reference points was between 0.15 and 0.35 with the majority being in the vicinity of 0.2.

Overholtz, W., et al. 2003. Biological reference points. TRAC Working paper 2003/10.

Yield per recruit and SSB per recruit reference points were updated and gave results of F0.1=0.18, F40%=0.15 and Fmax=0.40. Updated surplus production reference points were FMSY=0.25, BMSY=896,000 mt, and MSY=222,000 mt.

Rapporteur: J. Gibson

Selection of a functional relationship is a principal consideration. Other analyses suggest the Beverton-Holt model provides a better fit to herring data than the Ricker and debatably could be given preference. The Ricker analysis should be included for comparison. The non-parametric model doesn't require a functional form and also provides a useful comparison. Some thought that it should be constrained to pass through the origin (recruitment>0 at SSB=0 is an impossibility) while others argued that an unconstrained fit provides an empirical description over the observed range without making extrapolation assumptions about where the bend to the origin begins.

Selection of an appropriate error distribution can influence results. In principle, a symmetric additive error structure, e.g. Gaussian, is not justifiable either statistically (does not constrain recruitment to be positive), or biologically (multiplicative error arising from survival probabilities between ages/life stages) and could therefore be dismissed. The use of lognormal or gamma distributions is more appropriate. Some argued that log recruits should be used for any fit, whether it is a functional parametric form or a non-parametric smooth, with transformation bias correction applied.

Further diagnostic analyses could be useful. Sensitivity analysis of assumed constants in the yield/spawner per recruit components could be explored, as well as for the slope at the origin of the stock recruitment relationship. Meta-analyses can be used to examine the plausibility of the stock recruitment parameter estimates. Some assessment of the goodness of fit of the stock recruitment model would also be beneficial. Non-stationarity in the stock recruitment relationship should be examined.

Other reference points follow directly from these types of analyses and could be examined, e.g. F_{crash}, F_{ssbmsy}, $SSB_{F=0}$, etc. This led to a discussion about whether the slope at the origin of the stock recruitment relationship could be estimated reliably. Some observed that many herring datasets have observations near the origin. Bayesian methods could be used to include information from other populations. The view was expressed that F_{crash} is an important reference point and uncertainty in its estimate can be assessed.

Reference points are often derived from a yield/spawner per recruit model with a reproductive component. A surplus production model could be fit to production results from assessments for comparison, as was done with the KLAMZ approach.

5. PROJECTION

Only short term projections to 2004 were provided, therefore assumptions about future recruitment have no impact. Projections were conducted from the results of both the KLAMZ and ADAPT models assuming that the catch in 2003 would be 100,000t, approximately equal to that in 2002. Natural mortality was assumed to be 0.2 as in the assessment. Two F scenarios were considered, F = 0.2, approximating the F estimated by the VPA in recent years and corresponding roughly to an F_{MSY} proxy reference points, as well as F = 0.1.

KLAMZ projections are dependent on the internally estimated dynamics and the externally estimated growth relationship. The results from the KLAMZ projections indicated that a catch of about 323,000t in 2004 corresponds to an F = 0.2 and results in a decrease in 2+ biomass from about 1,800,000t in 2004 to about 1,640,000t in 2005. With an F = 0.1, the resulting catch is about 170,000t and the 2+ biomass decreases from about 1,800,000t to about 1,790,000t.

The ADAPT projections were done from the bias adjusted VPA results and assumed that the fishery partial recruitment to be fully recruited for ages 2 and older and 0.01 at age 1. The fishery and population weights at age were taken as the average from 1992 to 2002. The results indicated that a catch of about 100,000t in 2004 corresponds to an F = 0.2 and results in a decrease in 3+ biomass from about 550,000t in 2004 to about 500,000t in 2005. With an F = 0.1, the resulting catch is about 60,000t and the 3+ biomass stays constant at about 550,000t.

6. GUIDANCE FOR SUBSEQUENT ASSESSMENTS

It will be some years before sufficient new and revised data can be assembled to attempt again to discriminate between the results of these and other competing models. In the ensuing period, it is considered prudent to report the results of both the delay-difference and the fully age structured VPA models. If progress is made with intermediate models which aggregate data to, say a 6 plus group, these results could also be considered.

Annex 1. Remit

Transboundary Resources Assessment Committee
Biological Station
St. Andrew's, NB, Canada
10 - 14 February 2003

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.

While scientists from both countries have participated in each other's peer review of the Gulf of Maine herring assessments, there has not been a joint peer review meeting, as there has been since 1998 for Georges Bank cod, haddock and yellowtail. On 26 June 2000, P. Kurkul (Northeast Regional Administrator, NMFS) and N. Bellefontaine (Regional Director General, DFO Maritimes Region) received a joint request from the US and Canadian herring fishing industries to undertake a Canada / US peer review of Gulf of Maine herring under the auspices of TRAC. Due to data availability and workload, this meeting could not be undertaken before at least spring 2002. This meeting is to address this request.

Objectives

Definition of the Management Unit

- Review the geographical range and seasonal composition of the coastal stock complex.

- Develop consensus on management units for provision of advice

Estimation of Contemporary State

- Review the assessment framework (s) for the Gulf of Maine herring management units. The agreed approach would be used to provide the management agencies of each country with stock status information.

  - The landings and catch at age will be accepted as presented i.e. will not include evaluation of methods of analysis for catch at age

  - The methods and results of developing indices from surveys and for conducting population analyses of herring will be reviewed and evaluated

  - Information regarding the relative status of the various components within the stock complex, including basic input data will be provided to the extent possible

- Using the agreed assessment framework, update the status of the coastal stock complex of Atlantic herring through 2002 and characterize the variability of estimates of stock size and fishing mortality rates.

Characterization of Productivity to Determine Harvest Strategy

- Review biological reference points for Atlantic herring to meet management requirements of both countries.

Procedure for Projection to Evaluate Tactics

- Review framework for the provision of projections to meet the requirements of both countries

- For Canadian management purposes, for a range of yield quotas in 2003, evaluate the consequences on exploitation rate in 2003 and on spawning stock biomass (or its proxy) in 2004

- For US management purposes, provide projected estimates of catch for 2003- 2004 and spawning stock biomass for 2004 - 2005 at various levels of Fishing Mortality for the coastal complex.

Guidance on Activities

- 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

Products

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

- Canadian Stock Status Report for Georges Bank herring stock

- US Advisory Report for Gulf of Maine herring complex

Annex 2. DRAFT AGENDA

Transboundary Resources Assessment Committee
Biological Station
St. Andrew's, NB, Canada
10 - 14 February 2003

Definition of Management Unit

- Overview & context (Gary Melvin)

Estimation of Contemporary State

- Overview, history & context (Gary Melvin)
- Fishery data (Matthew Cieri)
- Bottom trawl surveys (Gary Melvin)
- Acoustic Surveys (Bill Overholtz)
- Assessment
    - Coastal Complex
        - ADAPT (Bill Overholtz, Mike Power, Gary Melvin, Stratis Gavaris)
        - Likelihood (Larry Jacobson, Bill Overholtz)
    - Georges Bank
        - ADAPT (Mike Power, Gary Melvin, Stratis Gavaris)

Characterization of Productivity

- Context for biological reference points in herring (Kirsten Clark)
- Biological reference points (Bill Overholtz, Gary Melvin, Larry Jacobson)

Projection

- Framework for conducting projections (Bill Overholtz, Gary Melvin)
- Projected estimates of catch for 2003-2004 and SSB for 2004-2005 (Bill Overholtz)
- Overview of partitioning of coastal complex catch (Bill Overholtz)
- For a range of catch in 2003, evaluate consequences for F in 2003 and SSB in 2004 (Gary Melvin)

Review Stock Status Report/Advisory Report

Annex 3. List of Participants

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Annex 4. List of Working Papers

Cieri, M., et al. 2003. Landings, samples, and the catch at age matrix for the Atlantic herring fishery: 2002. TRAC Working Paper 2003/04.

Clark, K.J., et al. 2003. Biological reference points for Gulf of Maine herring. TRAC Working Paper 2003/09.

Melvin, G.D., et al. 2003. Review of geographical range, seasonal composition, and management units for the Gulf of Maine/Georges Bank stock complex. TRAC Working Paper 2003/01.

Melvin, G.D., et al. 2003. Management of the stock complex. TRAC Working Paper 2003/02.

Melvin, G.D., et al. 2003. A general overview of the fishery and past assessments TRAC Working Paper 2003/03.

Melvin, G.D., et al. 2003. Overview of assessment surveys. TRAC Working Paper 2003/05.

Overholtz, W., et al. 2003. Acoustic surveys and results. TRAC Working Paper 2003/06.

Overholtz, W., et al. 2003. VPA/FPA analysis and results + Appendix: KLAMZ model. TRAC Working Paper 2003/07.

Overholtz, W., et al. 2003. Biological reference points. TRAC Working Paper 2003/10.

Power, M.J., et al. 2003. Gulf of Maine herring complex VPA analysis. TRAC Working Paper 2003/08.

Annex 5. Consensus Report

Atlantic Herring: Georges Bank, Nantucket Shoals, Gulf of Maine Stock Complex

Stock Complex and Management Units

Atlantic herring spawn in discrete locations to which they are presumed to return. In the Gulf of Maine and Georges Bank there are major herring spawning grounds on the northern edge of Georges Bank, on Nantucket shoals and in the coastal waters of Cape Cod through Maine. Herring from these spawning areas migrate and mix outside of the spawning season, and are mixed in most fisheries and in research surveys. As a result, the herring of the Gulf of Maine and Georges Bank are considered to be a complex made up of three major distinct but seasonally intermixing components (Georges Bank, Nantucket Shoals and the coastal Gulf of Maine).

While it would normally be considered desirable to treat components separately in assessment and management, intermixing of components in the fishery and in surveys preclude separate assessment and management. It was therefore deemed necessary (as has been done in recent years) to undertake an evaluation of the entire complex with subsequent consideration of the individual components.

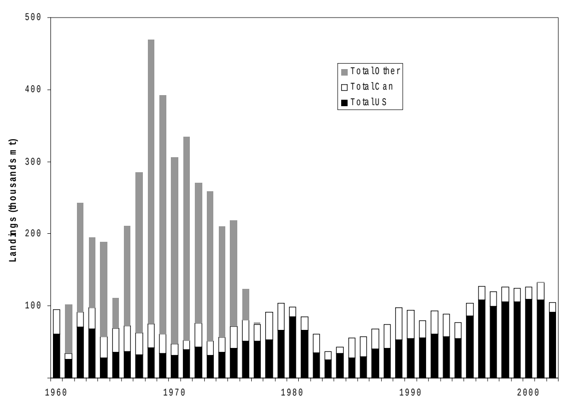
Management boundaries in the US Federal-Atlantic States Marine Fisheries Commission (ASMFC) fisheries management plan for herring were based on the current distribution of seasonal fisheries during the summer in the Gulf of Maine (GOM), on Georges Bank and in southern New England (SNE) during the winter. These boundary lines correspond to a rough demarcation between the coastal and Georges Bank/Nantucket Shoals components and to the spatial/seasonal components of the fisheries on the stock complex. The GOM, Georges Bank and the area south of Cape Cod were divided into three major management areas (areas 1-3) for the purpose of allocation of catch from the various seasonal components of the fishery.

In previous assessments the relative proportions between the inshore GOM and Georges Bank were determined from an analysis of the National Marine Fisheries Service (NMFS) autumn bottom trawl survey indices allocated to inshore and offshore strata. Since 1996 these relative proportions from the autumn survey became more variable and gave results that were contrary to other information suggesting that the Georges Bank component is currently much larger than the inshore component. An analysis of comparisons between the relative size of the two components using hydroacoustics results from both the inshore and offshore areas and previous assessments (Stevenson 1998) suggest that the current proportion in the GOM is much smaller. A summary of these results suggested that the percentage of the total stock in the inshore GOM is currently somewhere near 10-15% in contrast to the 25% that was used in recent years. These reflect available results at the present time, but require confirmation from subsequent calibrations of NMFS and inshore surveys.

Fisheries and Landings

The coastal herring fisheries of Division 5Y are among the oldest in the western Atlantic, dating back over a century. These fisheries have evolved from traps (weirs and shutoffs) through gillnet to purse seine and midwater trawl. Landings in these fisheries peaked at 94,200t in 1950 and have averaged about 50,000t since 1951. Landings in the contiguous New Brunswick weir fishery, which has historically been considered to take fish from this stock complex, have averaged 26,000t over the same period.

Herring landings increased dramatically in the early 1960's with the development of a predominantly foreign fleet fishery, first using gillnets then trawls and purse seines, in the (then) international waters of Georges Bank and southern New England. Landings in this fishery increased from 68,000t in 1961 to at least 373,000t in 1968, but then decreased rapidly as the stock collapsed and as management measures were introduced in the early 1970's. Limited directed fishing for herring occurred on Georges Bank between 1979 and 1995. Since 1996 landings have increased to almost 40,000t in 2001 and were about 17,000 in 2002.

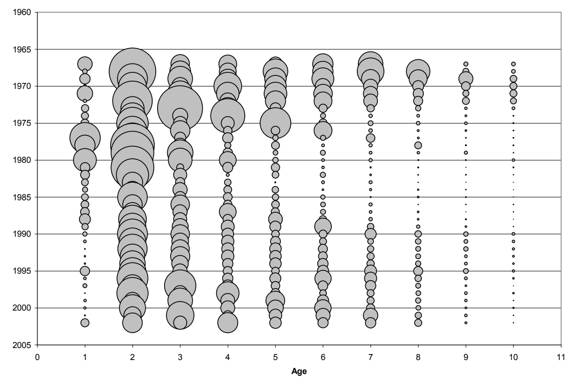


State of the Stock

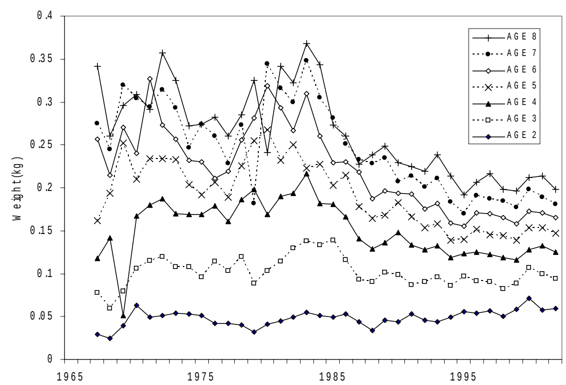
Commercial fishery information

Commercial landings compiled for the period since 1959 from Maine Department of Marine Resources (DMR), Fisheries and Oceans Canada (DFO) and the International Commission for Northwest Atlantic Fisheries (ICNAF) sources (1961-1978), are considered to be reliable in recent years but may represent a minimum catch in the early period.

Age composition of the commercial catch is available since 1967. A comparison of age determinations by NMFS and DFO readers showed consistency in age determination to age 5, but reduced agreement on older ages. Examination of the catch at age indicated some misallocation to adjacent ages. The size of the bubbles in the accompanying graph corresponds to the magnitude of the catch at age.



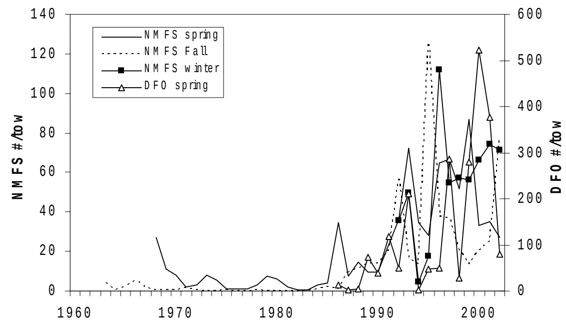
The growth rate of herring in the Georges Bank/Gulf of Maine complex has changed. Size at age of mature herring has decreased coincident with expansion of the population since about 1982.



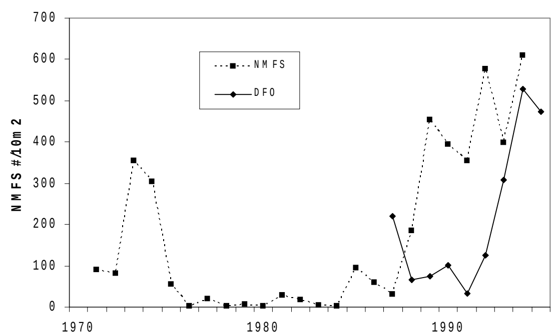
Research Surveys

Several bottom trawl surveys have been undertaken by both NMFS and DFO in this area. While designed primarily for groundfish, these surveys also take herring, and provide some of the longest time series of survey information. These differ in season and length of time series and there is uncertainty regarding the consistency of herring catchability. The NMFS spring (1968-2002) and NMFS autumn (1963-2002) surveys cover the complete distribution of herring, while the NMFS winter includes mostly the over-wintering area in Southern New England. The DFO spring survey covers only Georges Bank and represents a small portion of the northern distribution during that time of year. Timing of the surveys is relatively constant for each of the time series, except for the fall survey where the mean survey date has changed by about one month becoming progressively earlier. Indices of abundance were developed using the strata defined in the 27th NMFS Stock Assessment Workshop. Both the NMFS spring and autumn surveys imply that a change in catchability occurred around

1985, coincident with a bottom trawl door change. The surveys indices were subsequently divided into two time periods pre-1985 and 1985- present.



Larval surveys undertaken by both the NMFS (1971-1994) and by DFO (1987-1995) which covered Georges Bank and Nantucket, were terminated in the mid 1990’s. Statistical analysis of the NMFS survey suggested a difference in catchability between two time periods, 1971-1988 and 1989-1994.



The NMFS hydroacoustic program began in 1998 with a series of surveys on inshore locations and a broad scale survey of the entirety of the GOM. Surveys on Georges Bank in 1998 were of a pilot nature and were useful in pinpointing the location of spawning fish. During subsequent years (1999-2002) larger scale surveys were conducted on Georges Bank with the intent of covering the entire spawning distribution of herring. Three surveys in each year (1999-2001) were completed on Georges Bank, utilizing systematic zigzag, parallel and stratified random designs. One parallel design survey was completed in 2002. An analysis of acoustic information was completed using 11 available TS equations for herring stocks in the North Atlantic. Results suggest that the average 2+ biomass increased from about 1.2 million mt in 1999 to about 1.8 million mt in 2001 on Georges Bank. The survey during 2002 suggested a 2+ biomass of 0.8 million mt, but other information suggests that the peak spawning time on Georges Bank may have occurred prior to the survey.

The hydroacoustic program in the inshore area of the GOM has been conducted by the DMR-Gulf of Maine Aquarium during 1999-2002. Surveys from this program were conducted at frequent intervals during September-November, utilizing a systematic zigzag design. Results suggest that the spawning biomass during this period increased from 200,000t in 1999 to 350,000t in 2001, and decreased to 200,000t in 2002.

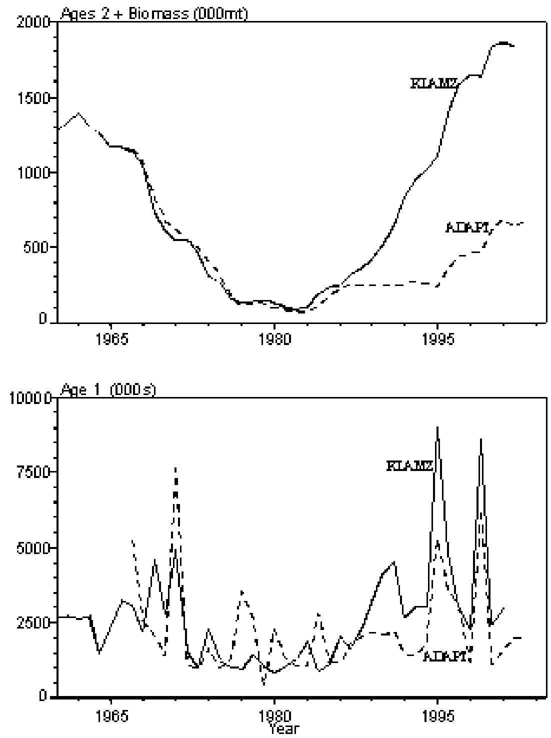
Assessments

Two approaches, a delay-difference model (KLAMZ) and a calibrated VPA model (ADAPT) were used to evaluate stock status. Both models assumed that the natural mortality rate was equal to 0.2 and constant over time for all ages. The total catch was assumed known without error in both models and all available indices were used, though given different weightings according to their variability.

KLAMZ partitions the herring stock into two age groups (age 2 and age 3+). All delay-difference calculations for herring were in units of biomass assuming von Bertalanffy growth. The delay-difference model is “foreward-casting” and simulates the herring stock starting with the first year in the analysis. Model parameters, biomass, recruitment biomass and fishing mortality rates are estimated from survey data and other information including hydroacoustic biomass estimates and a spawner-recruit constraint.

For ADAPT, the survey indices were used to calibrate a VPA with the following further assumptions; error in the catch at age is negligible and the fishing mortality on age 10 is equal to the weighted average for ages 7-9. This approach places greater emphasis on the catch at age observations, particularly in earlier years. Inconsistencies between the catch at age information and trends in the survey indices can give rise to retrospective patterns (systematic positive or negative differences in estimates as additional years of data are used) and this assessment displays a marked retrospective pattern.

Results from the primary methods used for the assessment differ considerably in some regards, reflecting uncertainties in input data sets, but several important agreements are also seen. Historical biomass trends until 1985 are very similar. Differences between model estimates appear in the mid-1980s, when the biomass and recruitment estimates diverge. This is due to the combined effects of divergent mortality and recruitment estimates.



Estimates of the current stock biomass are quite dependent on model assumptions and weightings given to data sets. This application of ADAPT, tends to give estimates of mortality rates which correspond to catch at age data (indicating higher mortality rates and lower biomasses). KLAMZ leans towards the scaling implied by the acoustic survey biomass estimates and the stock recruit constraint (indicating higher biomass and lower fishing mortality). The KLAMZ results seemed to track trends in recent survey data more closely than did the ADAPT results, implying more older fish in the population during recent years and a different recent recruitment pattern. Evidence for higher proportions of older fish in the catch at age or surveys is not strong.

To verify and compare models, new and revised data need to be considered. Thus a continuation of the hydroacoustic survey is likely to elucidate trends in biomass when they appear and improved age determinations for older fish should give a better indication of the total mortality in the stock. While results are substantially different, the estimation error internal to each model is considerable, blurring the statistical significance of those differences. This is a reflection of the great variation in the observed survey indices. An additional complicating factor that contributes to this statistical uncertainty is the apparent change in survey catchability before and after 1985, particularly for the NMFS autumn survey. The KLAMZ model estimated the magnitude of this effect to be a factor of 68 times for age 2 and 10 times for ages 3+ while the ADAPT model estimated it to be a factor of about 60 times at age 2 and decrease to about a factor of 10 at age 8.

A possible way to resolve the discrepancy between model results, is to use hydroacoustics to directly estimate abundance (with accompanying target strength verification).

Productivity and Biological Reference Points

Biological reference points (BRP's) based on the KLAMZ assessment were updated from the last assessment and are based on a yield per recruit model (Thompson-Bell) for $F_{40\%}$, $F_{0.1}$ and F_{max}, and a surplus production model for F_{msy}, MSY and B_{msy}. The yield per recruit model results gave an F_{max} =0.40, an $F_{0.1}$ =0.18 and an $F_{40\%}$ =0.15. The new F_{max} is the same and the $F_{0.1}$ is slightly lower than values from the last assessment. Reference points from the production model were also re-estimated, using a formulation that is consistent with the KLAMZ model. The new biological reference points for the herring complex were estimated as F_{msy} =0.25, MSY =222,000 mt and B_{msy} =896,000 mt. These reference points are all less than those from the previous assessment, which used a conditioned ASPIC model to estimate the BRP's.

BRP's were also estimated using a yield/spawner per recruit model with a reproductive component fitted to ADAPT model output. $F_{0.1}$ and $F_{40\%}$ estimates were similar to those estimated in the KLAMZ assessment. $F_{95\%MSY}$, was estimated to be in the range of 0.20 - 0.22 using a parametric and nonparametric stock recruitment relationship.

Although the ADAPT and KLAMZ assessments suggest different levels of production and biomass at MSY, the reference fishing mortality rates produced by the two approaches were similar. There is greater uncertainty about biomass reference points than the fishing mortality reference points.

Projections/Forecast

Projections were conducted from the results of both the KLAMZ and ADAPT models assuming that the catch in 2003 would be 100,000t, approximately equal to that in 2002. Natural mortality was assumed to be 0.2 as in the assessment. Two F scenarios were considered, F = 0.2, approximating the F estimated by the VPA in recent years and corresponding roughly to an F_{MSY} proxy reference points, as well as F = 0.1.

The results from the KLAMZ projections indicated that a catch of about 323,000t in 2004 corresponds to an F = 0.2 and results in a decrease in 2+ biomass from about 1,800,000t in 2004 to about 1,640,000t in 2005. With an F = 0.1, the resulting catch is about 170,000t and the 2+ biomass decreases from about 1,800,000t to about 1,790,000t.

The ADAPT projections were done from the bias adjusted VPA results and assumed that the fishery partial recruitment to be fully recruited for ages 2 and older and 0.01 at age 1. The fishery and population weights at age were taken as the average from 1992 to 2002. The results indicated that a catch of about 100,000t in 2004 corresponds to an F = 0.2 and results in a decrease in 3+ biomass from about 550,000t in 2004 to about 500,000t in 2005. With an F = 0.1, the resulting catch is about 60,000t and the 3+ biomass stays constant at about 550,000t.