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Proceedings of the Maritimes Region Science Advisory Process on the Assessment Framework for Southwest Nova Scotia/Bay of Fundy Herring

Compte rendu d'une réunion tenue dans le cadre du processus de consultation scientifique de la Région des Maritimes au sujet du hareng du sud-ouest de la Nouvelle-Écosse et de la baie de Fundy

January 24-28, 2011 / **24-28 janvier 2011**

Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Institut océanographique de Bedford,
Dartmouth (Nouvelle-Écosse)

Ross Claytor
Meeting Chair

Ross Claytor
président de la réunion

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September 2011 / **Septembre 2011**

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenues dans le présent rapport puissent être inexactes ou propres à induire en erreur, elles sont quand même reproduites aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considérée en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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SUMMARY

A Maritimes Region Science Regional Advisory Process (RAP) was conducted on January 24-28, 2011 at the Ramada Inn, Dartmouth, Nova Scotia to conduct a framework assessment for SW Nova Scotia / Bay of Fundy Herring. Participation in this meeting included Fisheries and Oceans Canada (DFO), Province of Nova Scotia, Province of New Brunswick, and the fishing industry. The results of this meeting will form the basis for the subsequent assessments of SW Nova Scotia / Bay of Fundy Herring.

SOMMAIRE

Dans le cadre du Processus de consultation régional (PCR) scientifique de la Région des Maritimes, on a tenu une réunion du 24 au 28 janvier 2011, au Ramada Inn de Dartmouth (Nouvelle-Écosse), pour procéder à une évaluation du cadre de référence applicable au hareng du sud-ouest de la Nouvelle-Écosse et de la baie de Fundy. Les résultats de cette réunion, à laquelle ont pris part Pêches et Océans Canada (le MPO), les gouvernements de la Nouvelle-Écosse et du Nouveau-Brunswick ainsi que l'industrie de la pêche, serviront de base aux évaluations subséquentes du hareng du sud-ouest de la Nouvelle-Écosse et de la baie de Fundy.

Science Advisory Process on Assessment Framework for SW Nova Scotia / Bay of Fundy Herring

Fall 2006 – Winter 2011

MEETING III: 24-28 JANUARY 2011

Background

The 2005 and 2006 assessments of the status of the SW Nova Scotia / Bay of Fundy Management Unit (SWNS/BoF) of the 4VWX stock complex highlighted the need for an in-depth review of the data and models used to provide advice on current stock status and forecasts for fishery management.

Two review meetings were held in 2006/07 to: 1) define the management unit and fishery data inputs (31 October – 1 November 2006), and 2) to review the indices of abundance (9 – 11 January 2007). Proceedings for these meetings are available at: http://www.dfo-mpo.gc.ca/csas/Csas/Proceedings/2007/PRO2007_002_E.pdf). During this review process a serious error in ageing was uncovered and a third meeting was postponed until the age issue could be resolved. The catch at age and the age disaggregated index of abundance for the past 10 years were corrected. The third and final framework meeting to review the issues identified during the first and second frameworks was held 24-28 January 2011.

These proceedings outline the findings of this third meeting with the overall objectives to review the current ADAPT formulation and to investigate alternative assessment models for providing advice on current stock status. The proceedings also outline the assessment procedure to follow until the next framework review. The framework will be used for the first time in March/April 2011 in support of the 2010/11 fishery.

The framework meeting had three main objectives:
1. Determine the methodology, exploring a range of models, to estimate the current state of the stock.
2. Determine the methodology to provide short, medium and long-term yield forecasts.
3. Provide guidance on the assessment procedure to be used during subsequent years, recommended timing of future framework reviews, as well as procedures to verify the on-going efficacy of the framework.

To achieve these objectives, national and international experts were engaged to use the input data and explore assessment formulations with a suite of models from a simple model using the acoustic surveys, a length-based approach, and various age-based models (Tables 1 and 2). The complete Terms of Reference, Agenda, and list of invited participants is provided in Appendices 1 -3.

Table 1. Brief description of models examined during the framework meeting.

Model	Brief Description of Model
Acoustic approach additive model	Calibrated acoustic surveys are conducted using industry vessels. These surveys are completed every 10 -14 days on major spawning grounds in SWNS/BoF. The sum of these estimates is used as a spawning stock biomass index for this portion of the 4VWX stock.
Acoustic approach maximum biomass model	Calibrated acoustic surveys conducted using industry vessels are completed every 10-14 days on major spawning grounds in SWNS/BoF. The maximum of these individual survey estimates on each spawning ground is used as a biomass index for each spawning component of the 4VWX stock.
Length Based models	Length based assessment models are used to estimate biomass for stocks where fish age is difficult to obtain or unknown. The method is generally premised on modal progression of annual cohorts as they move through the fishery. The approach is relatively good for rapid growing short lived species where there is some separation of length modes with age.
ADAPT-VPA	In the ADAPT-VPA model the abundance index is treated as observed values and a sequential population analysis (SPA) is used to produce predicted abundance values. An objective function which minimizes the sum of squares between the predicted and observed values is used to determine best fits and subsequent parameter estimates. By fitting the ages simultaneously in one objective function, the ad hoc nature of finding the best fit through separate age by age plots is avoided.
SSAM	A statistically rigorous state-space assessment model (SSAM) assumes there is measurement error in catches. SSAM has been adopted as the primary assessment model for Western Baltic Cod, Kattegat Cod, and Sole in 3A. SSAM generally produces trend estimates that are smoother than ADAPT-VPA estimates.
iSCAM	iSCAM is an integrated statistical catch age model that is currently under development for the assessment of Pacific herring stocks off the coast of British Columbia, Canada. The software is very flexible and can incorporate any number of surveys or abundance indices in conjunction with the catch at age data. The model uses a maximum likelihood fitting procedure.
TASACS	TASACS is a set of programs consisting of a VPA and a separable model applied to a time series of catch and numbers at age. These time-series are tuned to an abundance index (acoustic measurements in this framework, which is regarded as a relative measure of the stock numbers at age. The main computer program is a package called TASACS, which is a collection of standard assessment routines together with a collection of diagnostics and a working environment.

Table 2. Main references that describe the methodology of each of the models examined during the framework.

Model	Main Reference
Acoustic approach additive model	Power, M.J., G.D. Melvin, and A. Clay. 2011. Summary of 2009 Herring Acoustic Surveys in NAFO Divisions 4VWX. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/098: vi + 97 p.
Acoustic approach maximum biomass model	See Power et al. 2011 above
Length Based models	Kimura, D.K. and S. Chikuni. 1987. Mixtures of Empirical distributions: An iterative application of the age-length key. Biometrics 43: 23-35.
ADAPT - VPA	Gavaris, S. 1988. An adaptive framework for the estimation of population size. Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 88/29: 12 p. Power, M.J., F.J. Fife, D. Knox, and G.D. Melvin. 2010a. 2009 evaluation of 4VWX herring. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/111
SSAM	ICES. 2010. Report of the Working Group on Methods of Fish Stock Assessment (WGMG), 20–29 October 2009, Nantes, France. ICES CM 2009/RMC:12. 85 pp.
iSCAM	Documentation, program and user guide can be obtained from: https://sites.google.com/site/iscamproject/home
TASCAS	Skagen, D. W. and Skålevik, Å. A Toolbox for Age-structured Stock Assessment using Catch and Survey data (TASACS) Institute of Marine Research: Fisken og Havet FH2009-1. http://www.imr.no/publikasjoner/andre_publikasjoner/fisken_og_havet/2009/nb-no

Note: Documents from the Canadian Science Advisory Secretariat are available from:
http://www.isdm-gdsi.gc.ca/csas-sccs/applications/events-evenements/index-eng.asp

The inputs, assumptions, strengths, and weaknesses for each model were identified and are presented in Appendices 4-5

A multi-species virtual population analysis (MSVPA) model to estimate natural mortality for ages 1-2 and 3+ was also presented by Sylvie Guénette. A primary paper on this topic is being prepared by Dr. Guénette.

Note: Throughout the document unless otherwise indicated, survey refers to acoustic surveys undertaken using industry vessels to estimate spawning stock biomass (SSB).

CONCLUSIONS

Objective #1 - Determine the methodology, exploring a range of models, to estimate the current state of the stock.

For the following reasons it was concluded that it is not possible, at this time, to develop a framework for estimating the current state of the stock that uses an analytical model.

1. There is a basic conflict between the scale of the acoustic survey biomass index and the age composition information from both the fishery and the survey. The commercial catch-at-age compositions and the survey-at-age compositions (derived from commercial catches associated with individual surveys) suggests higher fishing mortality rates than directly estimated exploitation rates from the survey (e.g. catch divided by Spawning Stock Biomass (SSB) from the sum of the acoustic surveys).
2. The model examinations undertaken during the review indicate that this estimation difference is due to biases in either the age compositions and / or the scale and trends in the survey biomass index.
3. Sampling to determine the age composition of the population during the acoustic surveys is derived from the commercial catch.
4. Age composition for a survey is obtained using age-length keys from the monthly commercial catch and is applied to length-frequencies from the commercial catch which occurs during a survey. Using length-frequencies from the commercial fishery will create a bias if the commercial fishery selects for certain sizes on the nights when a survey takes place.
5. For example, market demand for certain sizes are likely creating survey-at-age compositions that do not reflect stock age compositions. Selection for small fish will cause large fish to be under-represented in the catch-at-age; consequently mortality rates estimated from cohort catch-curves will be over-estimated. Selection for large fish will cause small fish to be under-represented in the age compositions and mortality rates would be under-estimated.
6. The acoustic survey does not consistently cover the stock in time and space. Variability in survey dead zones (depths or areas where fish are not detectable by the acoustic gear), components outside survey box, and the presence of fish in other smaller spawning areas alters the percentage of the stock covered in these surveys. In addition, the potential that the survey counts some fish more than once adds to the bias. If the net effect of these biases is to over-estimate SSB then the implied exploitation rates (i.e. catch divided by acoustic survey SSB) would be too low, and if the net effect is to under-estimate SSB then the implied exploitation rates would be too high. It is not possible to determine which is more likely with current data.
7. If the percent of the stock covered in the survey varies with size then the catch-curve estimates of mortality rate could be biased.
8. Most assessment methods examined (ADAPT-VPA, SSAM, TASACS) estimated age-based catchabilities for the acoustic survey index of total stock size which were high (averaged around 5). This indicates a 5-fold difference in stock size estimated by the models and the survey, the reason for which could not be determined at the meeting. The exception was iSCAM which estimated a higher SSB but poorly fit the survey biomass time series.
9. Model explorations indicated sensitivity to model fitting criteria. When an exploratory model (developed during the meeting for illustrative purposes) was fit to the survey and commercial catch-at-age data using log error sum of squares, estimates of fishing mortality were higher, and SSB lower, than when the model was fit to the catches and survey age-compositions using multinomial likelihoods and to the total catch and survey abundance estimates using lognormal likelihoods, an approach that better matches the data collection. In comparison

with the use of log sum of squares, the multinomial likelihood places less emphasis on the age classes with lower abundance, typically the older ages. Further exploration of this issue may lead to an improved understanding of the influence of the abundance of older fish on the model results.

10. The model estimated that catchability substantially increased with age approximately linearly, however, this pattern seemed implausible. The reasons for this pattern were not determined during the meeting. This pattern could be accounting for the differences in the mortality rates implied by the age-compositions of the commercial and survey catches.

As a result of the difficulties in using an analytical framework to provide estimates of current stock size, it was decided to develop an assessment methodology that would partly rely on the model identified as Acoustic approach additive model in Appendices 4 – 5. To facilitate this development the characteristics of a good abundance index were identified with specifics related to the acoustic surveys for Southwest Nova / Bay of Fundy herring assessment.

First, a series of measurements or criteria that would be reported in each assessment were identified. These measurements would be used to assess the degree to which surveys in any given year satisfy the criteria for a good abundance index. A proposal was made to rank surveys with a scale that would provide an annual summary index of whether or not surveys were aligned with the characteristics of a good survey.

Second, a subgroup of the meeting consisting of industry and DFO Science representatives developed a set of ideal survey protocols that would help to ensure the surveys in any given year met the identified criteria. Many of these are already in place and it was often a matter of making a slight change in order to increase the likelihood of meeting the criteria.

The measurements and proposed survey protocols are described in Table 3 and the ideal survey to meet these objectives given the practical constraints is given in Table 4.

Table 3. Properties of a good abundance index (survey covers consistent proportion of stock and is proportional to abundance) and the acoustic and biological sampling characteristics that measure consistency among years.

1. Survey covers consistent proportion of stock
    a. Geography
        i. Proportion of biomass outside boxes (Scot's Bay and German) (tests the assumption that what is inside the box represents a consistent proportion of the stock)
        ii. Include qualitative information from Scot's Bay scout boat sonar to assess proportion of the stock covered in the survey (tests the assumption that what is inside the box represents a consistent proportion of the stock)
        iii. Proportion of catches outside survey area (tests the assumption that what is inside the box represents a consistent proportion of the stock)
        iv. Measure of survey design – distance between transects (measures uncertainty associated with any survey design changes)
    b. Behaviour – varying portion in dead zones (surface and bottom)
        i. Allen Clay's depth index (depth at which the centre of the distribution occurs, measure of fish not available to the survey)
        ii. Profile of signal versus depth (acoustic signal versus depth plot, measure of fish available to the survey)
        iii. Research on surface and bottom dead zone is occurring and would be incorporated into the criteria when it is finished (measure of fish not

available to the survey).
   iv. Aggregated biomass (above some density, representing spawning aggregations) versus dispersed biomass (proportions, represent non-spawning aggregations). The aggregated biomass might be more representative of spawning biomass on the night of the survey and less prone to multiple counting.
 c. Spawning timing and location
   i. Scot's Bay: Report first day of surveying relative to first identification of when Scot's bay scout boat observes spawning fish (a measure to determine if Scot's Bay survey are covering a consistent proportion of the SSB)
   ii. German Bank
     1. Percentage of stage 6 in the catch that occurs before survey starts (contributes to the assessment that a constant proportion of the stock is surveyed)
   iii. All Banks
     1. Timing of survey: report first and last day of sampling, and average survey intervals (helps to assess uncertainty contributed by changing survey design)
     2. When tagging study is finished then correction for multiple counting based on tagging could be shown annually.
 d. Biological characteristics (influence on Target Strength (TS))
   i. All Banks
     1. Spawning stock : Proportion of stage 5 and 6 in samples (variation may have implications on TS)
     2. Report on percentage of samples that are +/- 2 days of survey compared to those more distant from the survey in time (measures uncertainty associated with selection)
     3. Report on geographical location of samples (used to help estimate any selectivity effects)
   ii. German Bank: Report on geography of samples: percentage from key areas of German Bank (related to evidence of size segregation on the bank)

2. Proportional to abundance (requires an analytical model to test)
 a. Test in model (consistency with other data)
 b. Assumption accepted unless contrary evidence found

Table 4. Ideal survey to meet the criteria for a good abundance index. Note: surveys are valid only if sampling shows them to be spawners.

Category	Issue	Survey Protocol
Geography	Scot's Bay: We may be missing fish by keeping to the box.	Scot's Bay only: Retain box and adjust survey to take in other areas. Consider two phase design with overall then detailed coverage of schools. Would require a DFO or HSC person on each survey to co-ordinate.
		Discussion point: Test the box using a pre-survey 'scout boat' and then cover the area with fish with more intensity. This could also be tested by varying the size of existing boxes and re-running the analysis.
	German	No change: Discuss how to deal with fish outside the box on an annual basis. Fish are sampled outside the box if they are observed on the transect. Default is to exclude

Category	Issue	Survey Protocol
		them unless sampling shows they are spawners (see important note in caption)
Transects	Number and distance	German: 4 boats minimum (8 transects) Scots: 3 boats minimum (6 transects)
Timing	Tidal Time of day	Scout boat to monitor (Scot's bay). Flexibility to allow adjustment for timing of 1st survey to coincide with tides in/out of the area which affects fish movement and steaming time (3-5kt tides) (this represent a change toward consistency) Survey needs to be at night for comparability btw years (Scot's and German) Scout boat under contract for Scot's Bay, Wednesday Night. Plan a survey for Saturday, this starts survey (usually around July 14) (if no scout boat is available we might have to rely more on the July 14 date) German Bank fishing starts prior to the spawning season on feeding fish. Sampling during this fishery determines when spawners start to arrive on the bank. Surveys start at first sign of stage 6 roe fish on German (normally around Aug. 15th)
Survey interval	10-14 days	Maintain a 14 day interval +/- 1 day
Weather	Interference with signal due to poor weather	Don't survey on poor weather nights Too rough to fish, too rough to survey
Biological samples	Spatial:	Would like to sample all the fish seen on a survey especially for different concentrations seen in different parts of the Bank. RV survey using the Needler this year will test whether or not this occurs at this time of year. Starting in 2010 every boat is sampled for length frequency.
	Temporal:	Prefer to have samples on the night of the survey plus or minus 2 days.
	Must have samples to verify a survey	The last survey of year is generally not included because of difficulty in getting samples. The use of the ITQ survey to obtain these samples was considered but it is not possible as the dates for the ITQ survey are typically first 2 weeks of July.
Survey season	When do we stop surveying	Surveys require samples to confirm spawning fish in order to be counted or from within the same location by 3-4 days.

The final assessment methodology Table 5 adopted consisted of the following elements that would describe the trends in the stock. These could inform management decisions.

Table 5. The elements of the assessment methodology developed by the SW Nova Scotia / Bay of Fundy Herring.

1. Report on criteria for survey and sampling (Table 3) and identify anomalies
2. Rank with respect to criteria for an abundance index that consistently covers the stock. Use past data to determine a method and usefulness of this approach.
3. Signs of change indicators
    a. Survey biomass trends
        i. Overall survey biomass trends – add all biomass estimates
        ii. Individual bank surveys
    b. Fishermen input
    c. Numbers or proportion at age in catch : it would not be possible to separate changes in population from changes in fishery but would identify change
    d. Trends in exploitation rates from survey
        i. Total SSB catch / Overall survey biomass trends
        ii. Total juvenile catch/ Overall survey biomass trends
            1. Relative exploitation rates – the main interest is in overall direction more than following ups and downs
            2. Use a smoothing model to identify the trends
    e. Mortality rate trends based on age composition , F=Z-M (the assessment team will justify their choice of M)
        i. Numbers at age estimated in the survey
        ii. The main interest is in overall direction more than following ups and downs
        iii. Follow true cohorts, Z at each age, average over range of ages
        iv. Use a smoothing model to identify the trends (SURBA is one example)
        v. Assumptions: All ages are fully or equally recruited to survey; catchability is the same and has not changed from year to year.
        vi. Treat Z as relative, but large trend values should be a concern and accounted for in management advice. Some examples of information that would be used to assess the degree of concern are given below:
            1. The selectivity that occurred in fishery (industry input)
            2. The percentage of fish in the dead zone (if large fish tend to be in the dead zone).
            3. Age distribution in acoustic survey (see conservation objective #1, Terms of reference Appendix 1)
            4. A model like SURBA can be used to examine the impacts of varying selectivity on mortality rates

CONCLUSIONS

Objective #2 - Determine the methodology to provide short, medium and long-term yield forecasts.

The following points were concluded with respect to objective #2 of the framework.

1. An analytical method for providing forecasts could not be developed at this meeting and currently there is no analytical method for providing forecasts.
2. Short-term (next year) forecasts of stock direction will rely on interpreting indicator levels and trends (Table 5).

3. For example, if recruitment is constant and F increasing over a series of years this would be a clear indicator for reduction in TAC.
4. No method was developed that would apply to medium term (life-span of fish) forecasts.
5. An evaluation of the degree to which conservation objectives are being met would provide a qualitative assessment of long-term forecasts. A summary table of these is currently provided in the assessment each year.

CONCLUSIONS

Objective #3 - Provide guidance on the assessment procedure to be used during subsequent years, recommended timing of future framework reviews, as well as procedures to verify the on-going efficacy of the framework

Guidance on the assessment procedure is in the answer to conclusion #1.

Research recommendations focusing on model improvement and exploration will need a 3 - 5 year time period before another examination of the framework is warranted.

Procedures to verify the on-going efficacy of the framework are identified in the methodology (Tables 3 and 5) and research recommendations (see below).

RESEARCH RECOMMENDATIONS

The following research recommendations are provided without priority. Where there is a specific link to a decision made during the framework it has been identified in parentheses.

Objective #1 - Determine the methodology, exploring a range of models, to estimate the current state of the stock.

1. Use bootstrapping approach to assess the uncertainty that changing distance between transects adds to estimate% du poids (see survey protocols, Table 4).
2. Determine the difference in length-frequency between spawning locations on German Bank. This will be a test for selectivity in the commercial catch during acoustic surveys. One aspect of this test will occur using the Needler in late August to early September (Table 4).
3. Check to see if ranking method of categorizing surveys is useful by examining the past (Table 5).
4. Explore methods to infer the size of stock components not included in the survey (i.e. dead zone, outside survey area). This could be used to provide a more accurate acoustic survey estimate of total stock size. This research is on-going (Table 3).
5. Simulations and hindcasts to see how well the method (Table 5) identified in conclusion #1 would perform.
6. Model herring behaviour on spawning grounds to help interpret trends and numbers and evaluate or develop future analytical models.
7. Recruitment survey (1 and 2 year olds, sample from weirs) is under way at Grand Manaan, wolves, juvenile fish using Acoustic surveys from small vessels making a series of transects June to Oct.
   a. 2010 is the first year
   b. fish and target id is an issue,
   c. sampling method is being worked out
   d. July RV survey could also be investigated

8. Explore methods to estimate the potential for multiple counting.
   a. Tracking of acoustic tagged fish in the acoustic survey is a possible approach.
   b. Modelling of spawning behavior on banks is another approach.
   c. Completing the on-going tagging study.
9. Explore the impact of separating scattered and aggregated biomass in acoustic estimates (Table 3).
10. Research on the effect of selectivity on reference fishing mortality rates
11. Research on using qualitative information and decision making using Bayesian belief networks.

Objective #2 - Determine the methodology to provide short, medium and long-term yield forecasts.

1. Determine the methodology to provide short, medium and long-term yield forecasts based on the framework (Table 5).
2. Develop operating model and explore the MSE approach

Objective #3 - Provide guidance on the assessment procedure to be used during subsequent years, recommended timing of future framework reviews, as well as procedures to verify the on-going efficacy of the framework.

No additional recommendations.

Appendix 1. Terms of Reference for Science Advisory Process on Assessment Framework for SW Nova Scotia / Bay of Fundy Herring

Science Advisory Process on Assessment Framework
for SW Nova Scotia / Bay of Fundy Herring
Fall 2006 – Winter 2011

Meeting III: 24-28 January 2011

Ramada Park Place Hotel and Conference Centre
240 Brownlow Avenue
Dartmouth, NS

Chair: Ross Claytor

Terms of Reference

Context

The current management plan for the 4VWX Herring stock complex pursues three conservation objectives:

1. To maintain the reproductive capacity of Herring in each management unit through:
   - persistence of all spawning components in the management unit
   - maintenance of biomass of each spawning component above a minimum threshold
   - maintenance of a broad age composition for each spawning component
   - maintenance of a long spawning period for each spawning component
2. To prevent growth overfishing
   - continue to strive for fishing mortality at or below F0.1
3. To maintain ecosystem integrity/ ecological relationships ("ecosystem balance")
   - maintain spatial and temporal diversity of spawning
   - maintain Herring biomass at moderate to high levels

If during the current review, biological processes become apparent for which additional objectives might be required, these would be proposed to the Scotia-Fundy Herring Advisory Committee for approval.

The 2005 and 2006 assessments of the status of the SW Nova Scotia / Bay of Fundy Management Unit (SWNS/BoF) of the 4VWX stock complex highlighted the need for an in-depth review of the data and models used to assess progress against these objectives. For instance, the population model (VPA) and acoustic surveys estimates of current biomass differ substantially, which has focused attention on whether or not the acoustic survey biomass estimates should be considered absolute or relative as well as the veracity of the VPA.

This framework review was to be conducted over three sequential meetings scheduled to ensure that modifications identified in a meeting can be incorporated into the preparations and deliberations of the following meeting. Two review meetings were held in 2006/07 to: 1) Define the management unit and fishery data inputs (31 October – 1 November 2006), and 2) to review the indices of abundance (9 – 11 January 2007). Proceedings: http://www.dfo-mpo.gc.ca/csas/Csas/Proceedings/2007/PRO2007_002_E.pdf). During this review process a serious error in ageing was uncovered and the third meeting, the assessment review, was postponed until the age issue could be resolved. The catch at age and the age disaggregated index of abundance for the past 10 years are now corrected so that the third and final framework meeting can proceed

The main objective of the third framework meeting will be to review the current ADAPT formulation and to investigate alternative assessment models for providing advice on stock status. This meeting will also outline the assessment procedure to follow until the next framework review. The framework will be used for the first time in March/April 2011 in support of the 2010/11 fishery.

The hope is that a range of assessment models can be explored, including ADAPT, to recommend a modelling approach for future evaluations. In this context there will be a comparison of the output and diagnostics of models commonly used for the assessment of pelagic fish stocks. To achieve this goal a number of national and international experts have been engaged to take the input data and explore assessment formulations using a suite of models from a simple no-catch model, to a length-based approach, in addition to various age-based models.

Objectives

Review of Models to Assess Status and Productivity (24-28 January 2011)

- Determine the methodology, exploring a range of models, to estimate the current state of the stock.
- Determine the methodology to provide short, medium and long-term yield forecasts.
- Provide guidance on the assessment procedure to be used during subsequent years, recommended timing of future framework reviews, as well as procedures to verify the on-going efficacy of the framework.

Outputs

CSAS Proceedings of the discussion of the third framework meeting
CSAS Research Documents (none are required as a result of this meeting)

Participation

DFO Science Maritimes and other regions
DFO Maritimes FAM
Scotia-Fundy Herring Advisory Committee
Provincial representatives
National and International modelling experts
External/Internal reviewers

Appendix 2. Agenda for Science Advisory Process on Assessment Framework for SW Nova Scotia / Bay of Fundy Herring.

Science Advisory Process on Assessment Framework for SW Nova Scotia / Bay of Fundy Herring

Fall 2006 – Winter 2011

Meeting III: 24-28 January 2011
Ramada Plaza Park Place Hotel
240 Brownlow Ave, Dartmouth, NS

Agenda

24 January 2010 – Monday

08:30 - 09:00 Welcome and Introduction (Chair, Ross Claytor)

09:00 - 11:00 Review of model-less approach - Evaluation of stock status based on trends in acoustic biomass estimates (Gary Melvin)

11:00 - 12:00 Review of previous analyses and discussion on why a length-based model is not appropriate for this stock (Gary Melvin)

12:00 - 13:00 Lunch

13:00 - 15:00 Review of current VPA (Mike Power)

1500 - 16:30 Review of MSVPA (Sylvie Guénette)

16:30 - 17:00 Summary and discussion of Day 1 and plan for Day 2

25 January 2010 - Tuesday

08:30 - 09:00 Summary of Day 1 and plan for Day 2

09:00 - 11:00 Review of state space assessment model (Noel Cadigan)

11:00 - 12:00 Review of Statistical catch at age model (Jake Schweigert)

12:00 - 13:00 Lunch

13:00 - 14:00 Review of Schweigert Statistical catch at age model continued

14:00 - 16:00 Review of Skagen Statistical catch at age model + VPA models (Dankert Skagen)

16:00 - 17:00 Summary and discussion of Day 2 and plan for Day 3

26 January 2010 – Wednesday

08:30 - 09:00 Summary of Day 2 and plan for Day 3

08:30 - 12:00 Discussion of the most appropriate methodology, exploring the range of models presented on Days 1 and 2, to estimate the current state of the stock.

12:00 - 13:00 Lunch

13:00 - 16:00 Possible breakout groups for additional analyses

16:00 - 17:00 Discussion and conclusions from Day 3 and plan for Day 4

27 January 2010 – Thursday

08:30 - 09:00 Summary of Day 3 and plan for Day 4

09:00 - 12:00 Discussion of the methodology to provide short, medium and long-term yield forecasts

12:00 - 13:00 Lunch

13:00 - 16:00 Possible breakout groups for additional analyses

16:00 - 17:00 Discussion and conclusions from Day 4 and plan for Day 5

28 January 2010 - Friday

08:30 - 09:00 Summary of Day 4 and plan for final day

09:00 - 12:00 Discussion of provision of guidance on the assessment procedure to be used during subsequent years, recommended timing of future framework reviews, as well as procedures to verify the on-going efficacy of the framework.

12:00 - 13:00 Lunch

13:00 - 16:00 Review of meeting conclusions

16:00 Adjournment

Appendix 3. List of invited participants for Science Advisory Process on Assessment Framework for SW Nova Scotia / Bay of Fundy Herring.

Name	Category	Affiliation
Don Aldous	Industry	Herring Science Council
Noel Cadigan	External Reviewer	DFO Newfoundland
Alan Chandler	Provincial	NS Dept of Fisheries and Aquaculture
Allen Clay	Other	Femto Electronics Limited
Ross Claytor	DFO	DFO Maritimes/PED
Kim d’Entremont	Industry	Comeau’s Sea Foods Limited
Sherman d’Eon	Industry	Cape Breeze Seafoods Ltd.
Delma Doucette	Industry	Vonndel II Fisheries Ltd.
Jamie Gibson	DFO Maritimes/PED	DFO Maritimes/PED
Sylvie Guenette	DFO Reviewer	DFO Maritimes/SABS
Tony Hooper	Industry	CONNORS Bros. Clover Leaf
Tim Kaiser	Industry	Scotia Garden Seafoods Inc.
Claude LeBlanc	DFO	DFO/Gulf
Gary Melvin	DFO	DFO Maritimes/SABS
Denny Morrow	Industry	Nova Scotia Fish Packers Assoc.
Julie Porter	DFO	DFO Maritimes/SABS
Michael Power	DFO	DFO Maritimes/SABS
Billy Saulnier	Industry	Comeau’s Seafoods Limited
Jake Schweigert	External Reviewer (DFO)	External
Dankert Skagen	External Reviewer	External
Dick Stewart	Industry	Atlantic Herring Fishermen’s Marketing Co-op
Roger Stirling	Industry	Seafood Producers Association of Nova Scotia (SPANS)
Christa Waters	DFO	DFO Maritimes/FAM
Julio Araujo	DFO	DFO Maritimes/PED
Tara McIntyre	DFO	
Alida Bundy	DFO	
Chris Murphy	WM R Murphy Fisheries Ltd	

Appendix 4. Data inputs, assumptions, and notes for models examined in 4VWX Herring Framework Assessment meeting.

Model	**Data Inputs**	**Assumptions**	**Input and Assumption Notes**
Acoustic approach additive model	1. Acoustic biomass Scots Bay, Trinity Ledge German Bank without integration calibration factor includes survey biomass outside area. 2. Age length keys from sampling during survey – commercial sampling day before, day, or day after are used to divide survey biomass into ages. 3. Sample design 6 -10 , 12 – 20 transects gives backscatter mean of transects lth weighted 4. Vessel calibration 5. TS length of samples – mean lth TS uses same age lth keys for commercial and survey	1. In the past this was assumed to be an absolute abundance currently it is considered to be a relative index of population trends 2. Represents fish that are present 3. Turnover time is 10-14 days 4. TS is accurate 5. Age length sampling represents age distribution among lengths same for all areas 6. Surveying all spawning fish in area but others may be outside- spent fish may have left spawning area but be in survey area 7. After spawning fish disappear.	1. Estimate downgraded by proportion of juvenile or non-mature fish (< 5%) 2. What if spent fish don't aggregate, we would have no samples of these fish. This effect will be tested by examining these targets with mid-water trawl. Currently they are assumed to be part of spawning fish
Acoustic approach maximum biomass model	1. Maximum individual survey –	1. What if all assumptions are incorrect except that they are representative of what is there. 2. Implicit is the assumption that no fish from previous surveys have left.	1. Not an acceptable method under these survey protocols and assumptions, see strength and weakness table.
Length Based	1. Modal length analysis 2. Length frequency	1. Modal length describes progression of cohorts through fishery	1. Uncertainty in ages plus group 5+ on. Fitting to length freq. may have multiple year classes, but would work as equivalent to plus group. 2. Age data should be done and is preferred. 3. Confounding of many factors, makes it difficult to separate out sources of mortality. 4. If have age structure it should be used because it is so valuable
ADAPT - VPA Models in general	1. Survey index either overall trend or by age 2. Catch at age for fishery from stock	1. Survey index reflects changes in population from year to year in an overall sense and age by age. 2. Catch at age is for this stock and	General assumptions are: 1. There are no fish alive at some age (see specifics 1, 4, and 5) 2. Total catch at age is known without error

Model	Data Inputs	Assumptions	Input and Assumption Notes
		there is no error (all catches are accounted for)	(see data input 2). 3. The natural mortality rate is known (see specifics 2). 4. There is no net immigration or emigration (closed population). 5. Abundance index satisfies the requirements of a good abundance index (given below: also see input 1 and Table 3) a. Survey covers consistent proportion of stock b. Proportional to abundance Specifics of assumptions: 1. Estimate population by age in final year using either initial estimates or PR's by age based on fully recruited F 2. M = 0.2 for all ages and years (except MSADAPT - VPA model) 3. Recruitment estimate for age 1 in final year(s) based on average in last 'x' years. 4. Oldest age (10) for population calculated as a weighted F on a set of fully recruited ages 5. If there is a plus group then calculate (using either FIRST method to going forward or FRATIO method going backward)
ADAPT - VPA Model A	1. German Bank acoustic index ages 4 – 8 2. Catch at age 2 – 11+ 3. Estimate a singe age, age 7 in 2010	1. M = 0.2 for all ages and years 2. Recruitment estimate 1 billion 3. Oldest age 11 in 1965 = 500; Use FIRST method to calculate 11 plus group: 4. Oldest age 10 for 1965-2009 calculated as population weighted F for all fully recuited is calculated on 6 - 9 5. PR age 2 = 0.2 as directed in 2006 6. PR age 3 = .4, age 4=.7, age 5=.9,	1. Need to define FIRST method: First method defines population in oldest age 11 in 1965 set to 500. Method calculates population estimate for that year.

Model	Data Inputs	Assumptions	Input and Assumption Notes
		6+ were = 1	
ADAPT - VPA Model B	1. Same as A and 2. German bank acoustic 3-7 and 10 (8 and 9 not significant) 3. Estimates ages 4 – 8 in 2010 and age 10 in 2009	1. Same as Model A and 2. PR for ages 3,4 = 0.4 and 0.7 used if not estimated terminal year population numbers age 5 = .9 3. Use PR for age 2 only as 0.4 based on recent 10 year average	1. How are ages 9 and 10 estimated in terminal year (used PR as fully recruited) 2. Testing model using simulated data: are we capturing reality with the data. Is needed for this model and Model M.
ADAPT - VPA Model B2	1. An identical version of the German Bank model B was run using the option for intrinsic weighting of the indices.	1. Same as Model A and 2. Same as Model B	
ADAPT - VPA Model C	1. All acoustic areas – German Bank, Scots Bay, Trinity 2. Same basic model inputs as model B	1. Initial run with ages 3-10 showed ages 3-5 & 9 not significant 2. Re-run with only ages 6-8 & 10 used in final run	
ADAPT - VPA Model D	1. Same as Model A with 2. Add larval index with 2009 included	1. Same as Model A	
Model E	1. Illustrative run with addition of 50% by number for 1995-2009 2. Attempt to account for unaccounted mortality in other areas	1. Same as Model A	
ADAPT - VPA Model M	1. Same as Model B 2. Use PR for age 2 only as 0.4 based on recent 10 year average 3. Natural mortality age 1=0.7, age 2=0.35, age 3+=0.27	1. The MSADAPT - VPA used to derive mortalities follows the formulation described in Magnússon (1995) in which the number of herring of age a eaten by a predator in year y (predation deaths) is the result of the biomass of prey available to the predator divided by the total biomass of prey including age groups not available to predators and the biomass of other prey biomass in the ecosystem:	

Model	Data Inputs	Assumptions	Input and Assumption Notes
Model NB	1. Same as model A with 2. Add all NB weir catch to catch at age	1. Same as model A 2. NB weir catch part of same stock as German, Trinity, and Scot's Bay	1. Stock structure assumption is not supported by any data, model not used.
State Space Assessment Model (SSAM)	1. Catches for ages 1-11+ and years 1965-2009, with age 11+ as a plus group. 2. Acoustic indices for ages 3-10 and years 1999-2009 3. catch weights for for ages 1-11+ and years 1965-2009 used as beginning of year stock weights. 4. Stock maturities were constant over time. The age at 50% maturity was three, and all herring of ages five and older were fully mature. 5. Natural mortalities M_{ay} =0 for all ages and years.	1. Uses a time-series component for fishing mortality, which is called a random walk model. 2. SSAM is a nonlinear Kalman filter. 3. Stock indices assumed to be measured with error, and error are iid Gaussian 4. Commercial catches are assumed to measured with Gaussian error, and modelled with the Baranov catch equations 5. Includes process error in the cohort population dynamics equations 6. Recruitment is derived from a stock-recruitment relationship, *R(SSB)*, plus process error. The Beverton-Holt model was used in this application. 7. Survey catchabilities (Q) were modeled separately by age, except Q9 = Q10 = Q9+. This is a common assumption and reasonable if the survey equally selects ages 9 and 10 herring. 8. Fishing mortalities (F) at ages 9-11 assumed to be equal, F9 = F10 = F11+. I ages were modeled separately, but 9. the F random walk variance was assumed to be the same for all ages. 10. Break in random walk for age 1 F, in 1970. 11. The catch measurement error was the same for ages 2-11, but different for age 1.	Coded in ADMB basic parameters are 1. Numbers at age in the first model year, Fishing mortality at age in the first year, 2. Survey catchabilities, 3. Catch and survey measurement error variances, 4. Random walk and population dynamics process error variances. 5. Stock-recruit parameters, 6. Many of these parameters can be grouped for sets of ages. In a preliminary run, the population dynamics process error variance for ages 2-11 was estimated to be large and measurement error variance in catch was estimated to be very low. It was concluded there was not enough information to separate these two variance components. The process error variance was bounded to have a standard deviation of 0.2, which is a large but not unreasonable amount of error.

		12. The acoustic survey measurement error variance was the same for ages 3-10. 13. The population dynamics process error variance was the same for ages 2-11, but different for the recruitment age 1 (as usual). 14. This is because the stock-recruit process error is usually much larger than the cohort population dynamics process error. I bounded the process error variance to have a standard deviation of 0.2, which is a large but not unreasonable amount of error.	
iSCAM	1. Acoustic biomass index for German Bank 2. Total catch biomass 3. Age composition of catch 4. Acoustic age composition	1. In the absence of empirical weight at age data, growth is assumed to follow von Bertalanffy 2. Mean fecundity-at-age is assumed to be proportional to the mean weight-at-age of mature fish 3. maturity at age is specified by a logistic function. 4. Includes Baranov catch equations and stock recruitment function (Ricker or Beverton-Holt), fixed or estimated natural mortality. Selectivity can be fixed over age or time using either logistic or spline functions. 5. Objective function is minimized using maximum likelihood estimation with three components: the likelihood of the data, prior distributions and penalty functions that regularize the solution during phases of the non-linear parameter estimation. 6. Measurement errors in the catch are assumed to be log-normally distributed. 7. The relative abundance data are	1. Integrated statistical catch-age model 2. Developed by Dr. Martell at UBC using ADMB software and planned to be open source 3. Provides MSY based reference points that are appropriate for DFO harvest policy 4. Bayesian framework that utilizes Markov Chain Monte Carlo (mcmc) procedures to investigate model and policy parameter uncertainties. 5. Significant flexibility in allowing weighting of input data and including multiple abundance index series.

		assumed proportional to biomass that is vulnerable to the sampling gear: 8. Initial numbers-at-age in the first year and the annual recruits are treated as estimated parameters and initialize the numbers-at-age matrix 9. Annual fishing mortality for each gear is average fishing mortality and annual fishing mortality deviation	
TASACS	1. Yearly catches in numbers at age 2. Survey indices in numbers at age from: 3. Survey covering 'all areas' 4. Survey covering 'German bight', presumably a subset of the former	1. Two models were applied and compared, a separable model and a VPA. In addition, some exploratory runs were ade with the ISVPA, for comparison. The following was common to all models: 2. Time range 1965 – 2009. Age range 1-11+. Spawning stock biomass (SSB) was calculated at 1. Jan. 3. The plus roup was modeled as a dynamic pool which is depleted according to mortality and supplemented with survivors from the oldest true age. 4. The catches in the plus group were given full weight in the objective function. The survey observations were used for ages 3-11, but from age 9 onwards they were down-weighted by a factor of 0.1. 5. The survey observation at age 11 in 2001 was regarded as an outlier and excluded. All other data were given equal weights in the objective function unless stated otherwise. 6. The objective function was the weighted sum of squared log residuals with the weightings as described.	

		Parameters estimated: 7. Selectivity at ages 1-5, older ages equal to age 5. Three periods were used, with a change in 1983 and 1995 (separable model only) 8. Survey catchability at age (assuming Index = catchability * Abundance): Assumed constant over years but dependent on age. Survey catchabilities for ages 9 – 11 were assumed equal to age 8. 9. Stock numbers in the last year and at oldest age. In the VPA, numbers at oldest age were estimated for all years with survey data.	

Appendix 5. Strengths, Weaknesses, and Diagnostic notes for models examined in 4VWX Herring Framework Assessment meeting.

Model	Strengths	Weaknesses (Including Uncertainties)	Diagnostic Notes
Acoustic approach additive model	1. Allows consideration to meet protection of spawning component objective Defines trends on spawning grounds 2. Represent what is present at time of survey (survey is done quickly, acoustic protocols followed, work ongoing refine, covers entire spawning season) 3. In-season adjustment 4. Industry confidence and that they are part of it 5. Allow assessment of changes in behaviour 6. Geographic area of survey is standardized 7. The surveys begin when fish occur on the bank.	1. Turnover time assumption 10-14 days is variable. Turnover has been found to occur prior to 10 – 14 days and after. 2. If over-estimating biomass no diagnostic to tell that it is occurring. 3. Estimates are affected by behaviour 4. Needs a method for scaling to provide annual 5. Little predictive capability need absolute 6. Cannot estimate F unless it is established as an absolute index 7. Uncertainty with respect to absolute estimate 8. There has been variability in survey start and end times from year to year 9. No recruitment estimates 10. Small spawning areas are not covered 11. Uncertainty of biological charactistics of fish not in aggregations	1. Representative assumption (the following work is being done in order to obtain an absolute index of abundance): a. In situ target strength studies on-going. TS accuracy for large fish similar to Foote equation b. TS accuracy for absolute biomass estimate is not known for small fish is different from previously estimated c. Estimate fish that are unavailable to acoustic system, hard on bottom and at the surface d. Camera work to look at fish hard on bottom e. Sonar looking up to detect at surface 2. Abundance estimation (the following work is being done to allow the individual surveys to be combined to estimate population size or trends): a. tagging to look at turnover time – current results indicate that SSB should be reduced on average by approximately 20% on German bank. b. Tagging in Scot's Bay occurred in 2005 and 2006 but has not yet been analyzed. c. Acoustics estimates of known juvenile numbers in weirs of nursery area of Grand Manaan and Campobello are in progress d. Sampling of fish outside aggregations will need to occur in order to determine their contribution to SSB

Model	Strengths	Weaknesses (Including Uncertainties)	Diagnostic Notes
			An important question to include in future work is: Which of these or additional diagnostics need to be continued or developed to provide annual diagnostics?
Acoustic approach maximum biomass model	1. If all else wrong would be a baseline	1. Contrary to biological knowledge and spawning events.	
Length Based models	1. Usually only good for short-lived species with mode separated first 2 – 3 years 2. has worked in other situations, porbeagle for example halibut 3. if aging data not available	1. Herring growth decreases after age 3 blending modes, plus 2. Herring have two modes, 1) 2 year olds, 2) ages 3 – 10 impossible to separate 3. Annual changes in length at age are known to occur less preferable when ages are available	Does not follow cohorts
ADAPT- VPA in general	1. VPA: Virtual Population Analysis- virtual as reconstructed catch only sees fished portion of population 2. Catch: lots of data, unknown biases real units (tonnes) 3. Surveys: less data, less biases, consistent methods, relative units (q)	1. Not a stock 2. Survey and catch from different portions of stock - spatially or size/age 3. Catch too small a portion of stock 4. Change in M 5. Change in reporting	1. Error in the compilation of the numbers caught at age can cause problems 2. Choice of values for M. Fixed M assumes changes are proportional for all ages and at some fixed ratio of the true level 3. VPA has inability to estimate any year class that is not fished almost to extinction (not a problem)
ADAPT - VPA Model A	1. Accepted in 2006	1. Only estimates age 7 2. Diagnostics identify problems needing resolution before adoption of this model. 3. Model not to be considered because of limitations and assumptions required for estimating only age 7s. 4. Uncertainty in historical data with respect to attempts to correct mis-	1. Q's increasing with peak at age 7. Indicates a problem in data or model formulation and needs to be resolved. 2. Residuals: obs and pred. acoustic survey series. Primarily negative residuals after 2005. Survey biomass estimates are below average for this period. 3. Acoustic index ages 8-9 not significant based on correlations significant at 5% level.

Model	Strengths	Weaknesses (Including Uncertainties)	Diagnostic Notes
		reporting. Minor uncertainty at this point.	
ADAPT - VPA Model B	1. Improvement on Model A as additional ages are estimated. 2. Retain as potential candidate if diagnostics can be explained or improved.	1. Data is eliminated because it does not fit observed and predicted.(apply to all) Information from these ages is lost. 2. Diagnostics identify problems needing resolution before adoption of this model. 3. Uncertainty in historical data with respect to attempts to correct mis-reporting. Minor uncertainty at this point.	1. Q's increasing with peak at age 7. Indicates a problem in data or model formulation and needs to be resolved. 2. Residuals: obs and pred. acoustic survey series. Primarily negative residuals after 2005. Survey biomass estimates are below average for this period. 3. Acoustic index ages 8-9 not significant
ADAPT - VPA Model B2	1. Examines intrinsic weighting	1. Data is eliminated because it does not fit observed and predicted, (apply to all). Information from these ages is lost. 2. Diagnostics identify problems needing resolution before adoption of this model. 3. Uncertainty in historical data with respect to attempts to correct mis-reporting. Minor uncertainty at this point 4. Provides no benefit over Model B which is simpler, exclude from additional consideration	1. Q's increasing with peak at age 7. Indicates a problem in data or model formulation and needs to be resolved. 2. Residuals: obs and pred. acoustic survey series. Primarily negative residuals after 2005. Survey biomass estimates are below average for this period. 3. Acoustic index ages 8-9 not significant
ADAPT - VPA Model C	1. None	1. This ADAPT - VPA was considered good with better diagnostics than Model B but uses a limited subset of older ages which do not reflect the overall population structure which predominates with ages less than 6. 2. Not to be considered as assessment model. 3. Uncertainty in historical data with respect to attempts to correct mis-	1. Q's increasing with peak at age 7. Indicates a problem in data or model formulation and needs to be resolved. 2. Residuals: obs and pred. acoustic survey series. Primarily negative residuals after 2005. Survey biomass estimates are below average for this period. 3. Acoustic index ages 8-9 not significant

Model	Strengths	Weaknesses (Including Uncertainties)	Diagnostic Notes
		reporting. Minor uncertainty at this point	
ADAPT - VPA Model D	1. None	1. The ADAPT - VPA was rejected because of the poor fit with the larval data and high MSR.	1. LAI vs SSB was not significant with 2009 included 2. Observed and predicted annual trends do not correspond; especially large increase and declines
ADAPT - VPA Model E	1. None	1. The model was not explored further due to the lack of evidence for missing catch or unaccounted mortality. 2. No improvement of fit over other formulations. 3. Do not consider further.	1. Not needed, model rejected on basic assumption.
ADAPT - VPA ADAPT - VPA Model M	1. Estimates of natural mortality for younger ages are acquired 2. M for older ages (0.25) is similar to 0.2 assumption 3. Use of information about all sources of mortality 4. Retain as potential candidate if diagnostics can be explained or improved	1. Data is eliminated because it does not fit observed and predicted.(apply to all) Information from these ages is lost. 2. Diagnostics identify problems needing resolution before adoption of this model. 3. Uncertainty in historical data with respect to attempts to correct mis-reporting. Minor uncertainty at this point	1. Q's increasing with peak at age 7. Indicates a problem in data or model formulation and needs to be resolved. 2. Residuals: obs and pred. acoustic survey series. Primarily negative residuals after 2005. Survey biomass estimates are below average for this period. 3. Acoustic index ages 8-9 not significant
ADAPT - VPA Model NB	1. None	1. This ADAPT - VPA model was rejected because current stock structure is considered adequate	1. Not needed, model rejected on basic assumption.
State Space Assessment Model. (SSAM)	1. Includes information from all data and is a statistically rigorous assessment model 2. Random walk assumption is flexible, if you know something has really changed in the fishery you can make a break in the model 3. Random error terms change every year	1. The catch measurement error and population dynamics process error parameters were confounded in this assessment; therefore, bounded the process error variance at 0.2 (std) 2. Mortality rates from catches and surveys disagreed in this assessment. 3. The model was not easy to modify.	1. Survey catchabilities increase with age, and are much greater than one (observed in every model) 2. No well-defined plateau in selection 3. SSAM estimates of SSB usually lower than ADAPT estimates, but with similar trends 4. The smoothness in F is due to the random walk, and measurement errors in catch and process errors in population dynamics

Model	Strengths	Weaknesses (Including Uncertainties)	Diagnostic Notes
	4. Estimating size of each cohort separately but penalizing deviations from a stock-recruit model. 5. If catch is perfect can tell the model it is (constrain measurement error to zero; example of flexibility) 6. Stock recruitment parameters are estimated within model.	4. Needs additional diagnostics to describe how the data and assumptions are influencing results.	5. spikes in SSAM estimates of recruitments (Fig 17). were lower than ADAPT estimates 6. Selection at ages 2-4 has increased recently Exploratory analysis 1. Cohort fanning and switching of dominant year class was observed (May indicate ageing error or changes in selectivity) 2. Changes in catch at age over time indicate changes in selectivity 3. Decline in weights at age indicates a change in the growth aspect of stock productivity 4. Possible dependence of commercial CAA and Acoustic CAA identified (a problem may be created by using CAA to determine Acoustic CAA)
iSCAM	1. Flexibility – allows incorporation of other data sources 2. Bayesian framework allows evaluation of uncertainty in key model parameters 3. Allows for up or down weighting of individual year's data 4. Stock recruitment parameters are estimated within the model. 5. Readily incorporates additional survey indices and weighting of data sets. 6. Can provide natural mortality estimates 7. Allows for alternative assumptions about priors, penalty weights on key parameters during model fitting.	1. Needs additional diagnostics to describe how the data and assumptions are influencing results.	1. Appears to be conflict between the age data and the acoustic index 2. Sensitive to the selectivity assumption 3. Limited contrast in the data might benefit from additional indicators 4. Estimates of SSB higher than for ADAPT and unable to fit to the acoustic index.
TASACS	1. Incorporates a variety of VPA and statistical catch-at-age models	1. The signal indicating high mortality that triggers the steep increase in selection and catchability with age as well as the high survey	1. The results are somewhat different with the two methods. The reason may be that the quite large variation in the catch numbers at age is interpreted differently by the two methods.

Model	Strengths	Weaknesses (Including Uncertainties)	Diagnostic Notes
		catchability have not been identified so far	2. The separable model translates this variation to variation in annual fishing mortality, while the VPA places the variation directly in individual yearly fishing mortalities at age. 3. The overall impression is that the analyzes with different methods give the same overall picture, but with some variation in the detail, in particular in the past. This variation is more prominent than for most stocks that I have looked at. It may perhaps be ascribed to noise in the catch data relative to a separable model, which may not be just random noise. 4. Both the selection (or F) at age and the catchability at age tends to rise with age. 5. One relevant question is whether it is realistic for the survey catchability at ages 8 and upwards to be more than the double of the catchability at age 4, as is the case both with the VPA and the Separable model.