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Proceedings of a Maritimes Regional Advisory Process Meeting on Assessment Frameworks and Decision Rules for 4X - 5Y Cod and Haddock

Compte rendu d'une réunion du Processus consultatif régional des provinces Maritimes sur les cadres d'évaluation et les règles décisionnelles concernant la morue et l'aiglefin de 4X - 5Y

10-14 June 2002
Conference Centre
St. Andrews Biological Station
St. Andrews, New Brunswick

du 10 au 14 juin 2002
Centre des conférences de la
Station biologique de St. Andrews
St. Andrews, (N.-B.)

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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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ABSTRACT

A meeting of the Maritimes Regional Advisory Process was held in St. Andrew's, NB during 10 – 14 June 2002 to review of the assessment approaches to be used on 4X - 5Y cod and haddock over the next three or more years. The approaches considered not only indicators of the state of the stock but also indicators of the productivity regime within which these resources reside. The meeting did not undertake an assessment of these two stocks as this was planned for the fall of 2002. The meeting also provided comment, on a long-term planning framework developed for these stocks by the Fisheries Resource Conservation Council (FRCC).

RÉSUMÉ

Une réunion du PCR a eu lieu à St. Andrews (N.-B.) du 10 au 14 juin 2002, afin d'examiner les approches à utiliser pour évaluer les stocks de morue et d'aiglefin de 4X au cours des trois prochaines années, voire pendant une plus longue période. Les approches envisagées comprenaient non seulement des indicateurs de l'état des stocks, mais aussi des indicateurs du régime de productivité dans lequel se situent ces ressources. La réunion n'a pas donné lieu à une évaluation de ces deux stocks, celle-ci devant être effectuée en automne 2002. On a également étudié un ensemble de règles décisionnelles élaboré par le Conseil pour la conservation des ressources halieutiques (CCRH) et visant à s'assurer que les cadres d'évaluation répondent aux besoins d'information.

INTRODUCTION

The 2001 DFO National Stock Assessment Program Review (Anon., 2001) noted that the Regional Advisory Process (RAP) was having difficulty in ensuring adequate scientific peer review and recommended that, at routine intervals, an intensive evaluation of the assessment data, models and approaches (herein termed assessment framework) be undertaken. These frameworks would then be used in the interim years to determine the status of the stocks. In the Maritimes Region, the RAP has taken this process one step further with a separation of the assessment framework meeting from that used to peer review the assessments themselves. This allows focused discussion on the assessment frameworks without concern for the provision of scientific advice, which would hopefully lead to not only better peer review of the technical issues but also more effective participant input at RAP meetings. Assessment framework meetings have already been conducted on Bay of Fundy scallop and 5Z cod, with further meetings planned for other stocks.

The current RAP meeting was convened to consider a number of technical issues relating to 4X - 5 Y cod and haddock (Appendix 1). First, it was to consider the assessment frameworks, which would be applied to determine the status of these stocks. This was to involve examination of the indicators of stock status, exploitation and productivity, both of the stocks and the ecosystem. To allow identification of reference points, the relationship among stock status, productivity and exploitation was to be examined. This information was to be used to respond to a request for information from the FRCC (5 September 2001).

The meeting was also to discuss ways to measure the impact of the fishery on the ecosystem.

Finally, the RAP was to examine the performance of proposed decision rule (e.g. in the FRCP of FRCC) formulations for establishing a recommended TAC and to provide guidance on their strengths and weaknesses for use in management.

An issue that the meeting could not address was the implications of 4X cod and haddock stock structure for assessment and management. While recognized as being important, research programs currently were underway examining the stock structure issue, the results of which were not available. It is planned that the next 4X - 5 Y cod & haddock assessment framework review would address stock structure questions.

In his opening remarks, the chair (R. O'Boyle) noted that the agenda was very ambitious, a function of the need to review the assessment frameworks used by DFO and the information needs of the FRCC's long-term planning framework to ensure that they are complementary. The meeting schedule (Appendix 2) was structured so as to have all background document and analyses tabled on the first two days (assessment frameworks on first day and decision-rule related analyses on the second day) in order to allow further consideration of these analyses on the next two days. On Thursday, the meeting was to consider the form of the scientific advice provided to the FRCC and what issues would trigger the next assessment framework meeting. The last day was to be devoted to report compilation.

The meeting was attended by DFO scientists from Maritimes (BIO and ST. Andrew's Biological Station), Gulf and Quebec Regions (Appendix 3). C. Annand, a DFO fisheries manager, attended from Maritimes Region. The FRCC was well represented, with the attendance of J. Pope, J.-G. D'Entremont, D. Lane, B. Chapman, and D. Gillis (ex-officio DFO). C. Reardon, N.S. provincial representative, was also in attendance for part of the meeting. Dr. J. Caddy and D. Kehler were specifically invited for their expertise to facilitate the review. Industry participants were invited who had been involved in the FRCC's FRCP consultations. Representatives from the provincial governments of Nova Scotia and New Brunswick also attended. The letter of invite to participants is provided in Appendix 4.

A list of the tabled documents is given in Appendix 5. Subsequent to the meeting, non-FRCC authors were encouraged to upgrade their working papers and submit theseto the CSAS Research Document series.

These Proceedings first document the presentation highlights and subsequent discussion on the background, current assessment frameworks, potential fishery and ecosystem indicators and decision rule – related analyses covered in the first two days. Following each of these meeting sections, there is a summary of the main points made during that session. The discussion during the next two days was structured around re-consideration of analyses presented during the first two days. These sometimes touched upon different topics of the remit in no particular sequence. Thus, the comments are amalgamated into three sections – management objectives and strategies, assessment frameworks and decision rules. The report ends with consideration of the form of the scientific advice and what issue would trigger the next assessment framework review.

BACKGROUND

DFO's Objective-Based Fisheries Management (C. Annand)

Working Papers:

> Anon, 2002a. Executive Summary of Groundfish Management Plan. Scotia-Fundy Fisheries Maritimes Region.
>
> Halliday, R.G. 2002. Fishery Management Decision Frameworks: A Case Study for Scotian Shelf Groundfish. Maritimes RAP Working Paper 2002/32: 12p.

Rapporteur: C. Annand

Presentation Highlights

In early 2000, DFO decided to address a number of issues related to the Integrated Fisheries Management Planning process (IFMP) which had been introduced in 1995. The new initiative was labeled Objective Based Fisheries Management (OBFM) and was designed to emphasize the importance of having clear and achievable objectives that could be quantified and measured, and to introduce risk management practices (including the precautionary approach) and performance measurement, based on system monitoring. Scotia-Fundy Groundfish is the first OBFM pilot for the Maritimes Region, with Bay of Fundy inshore scallops to follow. The 5-year comprehensive groundfish OBFM plan was implemented on April 1, 2002. The multi-year aspect of the plan was seen as important, recognizing that the development of an effective team and products for both conservation (e.g. indicators and decision rules) and operations (performance measurement and risk management) would take some time. The plan includes not just catch and effort regulations but also, for the first time, recognizes the requirement to include an ecosystem approach in planning, as well as a broadening of the plan scope to include social, economic and co-management elements. These make it quite different from earlier plans.

The plan documents where we are (history), what factors are pertinent to the plan and what data are available. Once that was developed, it was easier for industry to contribute to where we want to go (objectives) and how we want to get there (strategies). The plan was developed with an awareness and in the context of the Atlantic Fisheries Policy Review (AFPR), using its hierarchy of objectives (i.e. conservation, social economic and shared stewardship).

Annex 1 of the plan deals with conservation approaches and recognizes the strong overlap between DFO and FRCC initiatives (i.e. FRCPs) and the need to harmonize the differences between the two (i.e. an agreement with the FRCC to resolve these differences). It proposes that the FRCC and DFO Science explore ways to formulate decision rules that are scientifically defensible while meeting FRCC needs, using 4X cod and haddock as test cases. It also proposes that reopening criteria be considered during 2002 with 4TVW haddock as the test case, for two reasons:

1. Considerable interest by industry in this stock as a result of improvements in the status of the stock and,
2. The FRCC has indicated its intention to develop a FRCP for this stock as well as the 4X cod and haddock.

Both the FRCC and DFO plans have a number of interrelated themes, including the requirement to take an ecosystem approach to resource management and a risk management approach to decision making, along with the need for improvements in management plan implementation, which should pave the way for reconciliation of the two approaches.

The plan suggests a new process for making conservation decisions on Scotian Shelf stocks, based on a modified relationship between DFO Science and Fisheries Management, the FRCC and stakeholders. Essentially, it requires an agreement to specific sets of decision rules that the FRCC can utilize in meeting its mandate and responsibilities, for which DFO Science and Fisheries Management will provide support and industry will commit to accept.

The FRCC was seen as providing an oversight and facilitating role in providing advice to the Minister, but must be satisfied that the decision rules developed meet their guidelines. The intention is to have agreement by all parties on a decision process that is consistent with the risk management approach within the timeframe of this plan. Without this cooperation, it is difficult to outline a long-term implementation program.

Annex 2 looks at ecosystem considerations related to the protection of susceptible coral, MPA implementation, benthic communities and minimization of incidental mortalities on non-target species, particularly species at risk. It proposes an ecological profile in terms of bycatch spectra and that bycatch rates be developed from existing data. Ecosystem objectives are seen in large part as multi-plan and multi-industry issues that require a forum to facilitate a common strategic direction. The groundfish plan is one implementation mechanism for agreed-to solutions.

The social and economic considerations (Annex 3) encompass the quota transfer system, vessel replacement rules, industry capacity, risk evaluation of invertebrate stock collapses, and the development and evaluation of performance indicators. This will require considerable ingenuity.

The section on co-management (Annex 4) considers the Code of Conduct, cooperative projects with industry on both science and management and how these can be achieved. The current ad-hoc nature of many of these arrangements leads to unrealistic expectations as well as possibility of resource expenditure that could be better directed elsewhere.

Annex 5 on Management Measures of the Operational Plan relates to operationalization of the conservation strategies by developing Risk Management indicators from existing data sources i.e. cross comparisons among data elements both within and between data sets. It also relates to finding ways to improve risk management capabilities by determining what changes to present practices offer improvements to risk management capabilities, (i.e. sampling design).

Annex 6 on Performance review identifies a team to manage the development of tools for risk management and performance evaluation to implement the plan.

Each year, the plan will be reviewed, considering the elements of plan performance in relation to objectives. Year four will include a fundamental review of all plan aspects, which will form the basis of the next 5-year plan.

Discussion

There was only limited discussion following the presentation. It was pointed out that the groundfish plan’s executive summary was available at the meeting for information.

FRCC’s Fisheries Resource Conservation Plans (D. Lane)

Working Papers:

> Anon. 2002b. Fisheries Resource Conservation Plan. 4X5Y Cod and Haddock. Draft Revised 17/10/01. FRCC Report: 13p.
>
> Anon. 2002c. FRCC Terms of Reference.

Rapporteur: D. Lane

Presentation Highlights

On behalf of the Southern Team of the FRCC, D. Lane presented background information to the FRCP document that was referred to in the meeting remit and included in the documents sent to participants.

The context for the development of FRCP document by the FRCC was described in terms of the specific mandate of the FRCC, copies of which had also been distributed to meeting participants. The FRCC mandate explicitly calls for the Council to prepare a “comprehensive long-term plan”. The draft FRCP for 4X - 5Y cod and haddock represents a first attempt at developing such a plan to guide the Council in preparing its recommendations for these stocks. Moreover, the FRCC was under pressure in some areas (e.g., the Gulf of

St. Lawrence) to become more strategic and to demonstrate its capacity to rebuild stocks through effective longer-term planning.

It was noted that the development of the FRCPs had been ongoing since the Council was reorganized in October 1999 into "ecosystem teams" (Scotia-Fundy, Gulf and Newfoundland). At that time, each team was assigned to develop long-term plans for the groundfish stocks within their ecosystems. In the case of DFO Scotia-Fundy Region, it was described how the Council, since early 2000, provided input and feedback on the form and content of the FRCPs to the team, and how the team developed its draft plans. This involved extensive consultation with industry, including meeting with member associations and their fishermen, culminating in the formation of a working group selected from the Scotia-Fundy Groundfish Advisory Committee (SFGAC). The FRCC team has worked with this industry group since January 2001 to obtain industry input into the planning process and early drafts of the FRCPs. DFO Science and Fisheries Management were invited to provide input into the contents of the FRCP draft in June 2001. This was followed by a formal request to DFO Science from the FRCC in September 2001 for specific feedback on the technical contents of the plan.

Among the issues to be discussed with DFO include the need for coordination of the integration of several ongoing initiatives into the FRCP planning process and document. These initiatives include: implementation of a risk management approach, implementation of the Ecosystem Approach, correspondence with the OBFM initiative, inclusion of aspects of Intensive Fisheries Evaluations, and the full consideration of the Oceans Act. It is recognized that while many of these initiatives are either in current development or awaiting to be defined and implemented, that the parallel development of an FRCP for the FRCC needs would require a more direct role in the understanding of these complementary initiatives. Thus, the FRCPs were drafted with full knowledge that until such time as the DFO initiatives are more fully realized, some steps need to be taken to begin the longer-term planning process.

The contents of the 4X - 5Y cod and haddock FRCP were presented as:

- I Ecosystem Considerations
- II Plan Objectives
- III Plan Guidelines and Strategies
- IV Research and Information Gathering
- V Summaries of Plan Strategies and History of Cod and Haddock Stocks and Fisheries

Section I of the FRCP provides a description of the 4X - 5Y ecosystem, including groundfish habitat, groundfish biology, food sources, predation and competition and a brief overview of the fishery.

Section II itemizes the general objectives (stock conservation and rebuilding, and sustainable use and relative policy stability) and the associated specific objectives of the plan. The specific objectives provide further direction toward more detailed strategies for implementation in the cod and haddock fisheries.

Section III provides the main operating elements of the FRCP. Described as "strategies", these provide the context for developing decision rules and for making recommendations on these stocks. The FRCP strategies:

- State TACs for a 5-year rolling horizon and allow for possible change after a fixed TAC for 2 years
- Specify stock absolute indicator targets forbiomass, condition, age structure, productive capacity, spawning components, desirable long-run TAC, and moderate fishing mortality
- Specify “unacceptable” values for the stock indicators
- Establish “base” TAC levels below which the commercial fishery could operate only on a restricted by-catch basis
- Set stepwise TAC changes in accordance with indicators moving into defined ranges
- Protect juvenile fish
- Close fishing on known spawning areas at peak times
- Reinforce Conservation Harvest Plans and License Condition

The process for making recommendations will also incorporate, as far as possible, the following measures:

- Environmental conditions, e.g., water temperature and salinity
- Information on predator and prey interactions
- Other biological indicators about current stock status
- Indicators pertaining to the stock’s potential productivity, e.g., recruitment and growth rate, fish condition and age/length at maturity, geographic distribution
- Estimates of abundance, spawning stock biomass, and mortality

The FRCP proposes to consolidate all information on current stock status and on potential future productivity into an environmental / biological “Consideration Matrix” that categorizes these dimensions and provides the rationale for adjusting the TAC recommendation for each stock. Thus, the Consideration Matrix is a decision table that is to be used to assist the FRCC in defending its TAC recommendations and other conservation measures for the stock (the details of the decision framework were discussed later in the meeting.

Section IV described the ongoing research and information needs in support of the FRCP. These needs address the as yet unresolved issues of how environmental factors impact stock status, how stock components and their dynamics impact the perception of the aggregate stock status, how the reproductive capacity of the stock can be determined, and how industry and DFO can cooperate to ensure reliable stock information.

The presentation ended as it began with a listing of the desirable outcomes of the meeting. From the FRCC perspective, these would include the list of appropriate stock indicators for describing current stock status as well as the stock’s anticipated productivity regime, and a decision on how these indicators would be presented in DFO’s Stock Status Reports (SSRs).

Discussion

Following the presentation, several questions were raised. These included:

1) Why does the FRCP not include socio-economic considerations?

It was explained that the main focus of the FRCP was conservation and developing rationale for the FRCC’s recommendations to the Minister. While, admittedly, the FRCC is mandated to take account of socio-economic realities in the fishery, the ways and means of doing so are not straightforward, i.e., there is a lack of any regular source of information coming to the FRCC on the social and economic returns to fishing. Moreover, the FRCC does not have the means to acquire such information on its own. Thus, until such time as regular sources of these indicators can be provided, the FRCC cannot take these measures into account in anything but an *ad hoc* manner.

2) How does the proposed 5-year rolling horizon work?

The 5-year rolling horizon provides a ‘look ahead’ to the end of the planning period, when the specified stock targets are expected to be reached. Coupled with the 2-year TAC commitment, the 5-year horizon provides the strategic view of the fishery system and sets the pace at which realizable objectives are determined. The 5-year horizon shifts out as each year passes so that the strategic view and targets of the plan evolve according to the latest information. The commitment to planning out 5 years does not constitute an obligation to fix TACs for 5 years. Rather, it permits a review of strategic management capabilities and the possible need for adjusting strategic capabilities based on actual versus predicted and adjusted performance.

3) Does the FRCP take into account optimal ages to fish along with the protection of juveniles?

Not directly. The FRCP assumes that ages of first capture (relative to the yield per recruit curve) and catchability at age are endogenous to the existing structure of the fishery, the gears and technologies in place, and the fisheries regulations (e.g., small fish protocol, mesh and hook size restrictions, etc.). Thus, insofar as these determine a specific fishing mortality at age, it is assumed that the age distribution of catches does not deter growth in the stock and, as such, probably represents a “second best” solution. Whether these conditions may collectively result in optimal catches at age in a dynamically changing environment is extremely doubtful, difficult to determine, and impossible to control.

4) How will the FRCP follow-up enable it to connect with emerging initiatives?

The question seemed to imply that the FRCP was considered to be an independent planning initiative that might not be linked to parallel initiatives being developed within DFO. It was noted that the FRCC was mandated to do long-term planning and has been requested to do so in specific cases. The 4X cod – haddock FRCP has been developed in the absence of anything else in place at the time to respond to these requests for long-term stock rebuilding plans. The FRCC is seeking to partner with industry and DFO in order to make progress on developing a more strategic outlook. To date, the industry have been helpful in providing their points of view and there is a need to have DFO Science and Fisheries Management provide technical feedback. This is what the FRCC has been seeking since the fall of 2001. If new initiatives under development require DFO to take a position on relevant technical issues for stocks, then merging with these initiatives will provide information needed for FRCPs. This obviously will be to the benefit of the FRCC.

The Traffic Light Method (P. Fanning)

Working Papers:

Halliday, R.G., L.P. Fanning, and R.K. Mohn. 2001. Use of the Traffic Light Method in Fishery Management Planning. CSAS Research Document 2001/108: 41p.

Rapporteur: P. Fanning

Presentation Highlights

Indicator-based approaches to management decision-making are becoming more common in resource and environmental applications (Caddy, 2002). Systems of indicators to monitor progress towards national goals of sustainable development are routinely used in national accounting. They are particularly appropriate in situations where mechanistic descriptions of processes of interest do not exist or are inadequate. They are also useful in hybrid situations where mechanistic models exist, to compare information, which is expected to be related to the processes of interest but is not considered in the modeled framework. This appears to be the case in fisheries stock assessment.

The concept of a Sustainable Development Reference System (SDRS) has been described (Garcia and Staples, 2000) as a means to incorporate a broad range of social and economic objectives with conventional biological objectives for fisheries management. In most cases, these non-biological objectives are assessed qualitatively and never in strictly biological terms. An SDRS must integrate across the different scales of interest in time, space and species. Indicators appropriate for use in a SDRS is an area of active research. Although the traffic light method (TLM) has potential as a full-fledged SDRS, the application presented at this meeting was solely as a means of consolidating and representing the many indicators of stock status into three or more characteristics of interest to fisheries management. A later presentation at this meeting considered the application of TLM to evaluating decision rules as may be specified in a precautionary, risk-management framework. The example decision rules were based on the FRCP (although perhaps not interpreted as the FRCC intended).

The TLM fits within a larger context of decision-making. The strategic objectives determined as a matter of policy are typically too general or high-level to be directly implemented or even evaluated. A process of ‘unpacking’ has been described elsewhere (Jamieson et al, 2001). Unpacking specifies more precise operational objectives, which are implied as sub-objectives of broad, conceptual objectives. This may require several steps of unpacking until an operational objective is recognized. An operational objective is one for which a specific characteristic and a desired state for it can be defined. As an example, the objective of ‘healthy fish stocks for the benefit of Canadians’ could be unpacked to include, amongst other operational objectives, ‘restore abundance to levels in the 1960’s’. In this example, the population characteristic abundance is one which we can measure by a variety of means.

In the context of stock assessment, the characteristics of a biological stock related to the productive capacity of the stock are typically called abundance, production and fishing mortality. The TLM uses indicators, which are measurable aspects of the fisheries system that are related to the underlying characteristics of the stock. Model-based estimates of these three characteristics can be included along with direct estimates and indirect or correlated indicators. All indicators, regardless of source or type are treated in the same ‘currency’ of colours i.e. red equating to the low or bad range and green for the good range. Yellow is used to represent indicators in intermediate ranges although, strictly speaking from a mathematical perspective, it is not required. Indicator accounts have been prepared for a variety of indicators so far. In each case, a description of the nature of the indicator, its technical features and the interpretation of it is included. Whenever new indicators are proposed, an account is required.

Initially, the traffic light boundaries between colour regions were sharp edges and were conceptually related to conventional reference points, i.e. targets and limits. The sharp boundaries produced unacceptable changes in TL response for small changes in the indicator, i.e. the small change crossed a boundary and hence the TL switched from ‘green’ to ‘yellow’. The concept of fuzzy transitions was introduced as one of several means of addressing the sharp boundary problem. Fuzzy sets and corresponding fuzzy logic are an extension of conventional (binary) set theory and logic. A simple fuzzy set of three colours is able to capture all the information in an indicator, at least over the range of the transition zone. The definitions applied in the method here are constrained so that a given indicator value can belong to two colour sets within the transition zone (either red-yellow or yellow-green) and outside the transition zone, it will belong to only one, i.e. pure red or pure green.

The TL indicators are combined into the characteristics using a simple weighted average of the colour proportions. As a result, even though the individual indicators are limited to two colours and cannot include red and green at the same time, the characteristic in question will include all three colours if all three colours are in the set of all the indicators related to the characteristic. Thus conflicting signals, red in one indicator but green in another, will be reflected in the mix of colours present in the characteristic. In addition to the ability to reflect uncertainties arising from the conflicting signals from different indicators, the TL provides two other means to reflect uncertainty. The indicator weights that are applied to different indicators when they are combined to a TL characteristic reflect our relative confidence in the indicators. The selection of colour boundaries is also a means of reflecting uncertainty as indicators about which we have little information to judge its performance (e.g. short time series). In this instance, we may give the indicator equal weight to other indicators but the colour boundaries may be set quite wide (i.e. a wide yellow zone), reflecting uncertainty about the eventual range of values the indicator may take.

The ability to extend the TL method is given in the example applications to 4TVW haddock and white hake, each including additional characteristics. In the 4TVW haddock example, a ‘management’ characteristic was demonstrated to reflect the potential for management issues to arise as a result of the state of the stock(s). In white hake, an ‘environment’ characteristic was derived from a single indicator, the area of suitable bottom water temperatures. Another important contrast in the two example assessments is that the 4TVW haddock included indicators derived from the population model (i.e. VPA results) while in white hake, no population model was applied. In both cases, the form of the assessment is the same although the information sources obviously differed.

The TL method, as presented here, provides a means of summarizing and integrating a wide variety of information sources into a consistent framework. To this extent, it is a means of presenting information on the status of the biological stock. It can be extended to include non-biological elements (e.g. management, economic or social) . Progress with the TL method will require many of the same elements called for by Objectives-Based Fisheries Management such as explicit objectives and indicators of progress towards them. Then, it can also provide a means of evaluating decision rules, determining the implied outcomes of a set of decision rules with respect to advancing towards objectives or not.

Discussion

It was pointed out that the example used in the presentation for 4TVW haddock was not identical with the TL table in the most recent (2001) assessment. The specific changes were the inclusion of the example ‘management’ characteristic and the ‘environment’ characteristic. The changes were solely for the purposes of this presentation and were not intended to reflect a change in the TL information in the current assessment.

The TL tables considered here have reflected only the biological information usually produced in stock assessments. Inclusion of the socio-economic elements is essential to improving the success of fisheries management and some at the meeting felt that the ability to include socio-economic considerations through the Traffic Light Method is one of its most valuable features.

There were questions on the loss of information in going from a continuous to a discrete indicator. The conversion of quantitative indicators to fuzzy traffic lights does lose information about the exact value of the original indicator. This effect is limited to data values in the highest and lowest ranges i.e. pure green or pure red. It was argued that those colour boundaries should be set at levels beyond which we would not be concerned about the exact value. The exact value of any given indicator within the transition ranges i.e. between pure green and pure red, is recoverable from the fuzzy traffic light data. It is however not possible to disentangle the individual indicators once they have been integrated into a characteristic. The integration process includes the selection of relative weights given to each indicator within a characteristic. The choice of weights is subjective and is based on consensus views of the relative importance and precision of the indicators. It is important to give weight to multiple indicators as, to the degree that they are independent, they provide a redundant source of decision-making information. This has to be balanced against the risk of adding multiple indicators, which are so closely related that they merely duplicate the information of one indicator. True redundancy adds strength to the basis of decision making while duplication adds nothing and possibly obscures some sources of uncertainty.

The Traffic Light Method, in the absence of decision rules, can be used as a presentation system to provide a context for other information. It can also be used as the basis for decision making directly. A subsequent presentation developed an example of this approach.

The ability to extend the Traffic Light Method to additional objectives such as ecosystem objectives and others was noted. The meaning of indicators becomes more complex under these broader considerations as what may be red for seals may be green for cod. Indicator systems, similar to traffic lights, have been considered for this broader, ecosystem, context (Garcia and Staples, 2000).

CURRENT ASSESSMENT FRAMEWORKS

4X Haddock Assessment Framework (P. Hurley)

Working Papers:

> Anon. 2002d. Inputs into the Evaluation of Division 4X5Y Haddock. Maritimes RAP Working Paper 2002/18: 50p.
>
> Anon. 2002e. 4X Haddock Stock Status Indicators and Traffic Light Table. Maritimes RAP Working Paper 2002/39: 14p.

Hurley, P.C.F., G.A.P. Black, P.A. Comeau, and R.K. Mohn. 1999. Assessment of 4X Haddock in 1998 and the First Half of 1999. CSAS Research Document 1999/147: 80p.

Rapporteur: P. Hurley

Presentation Highlights

The details of the 4X haddock assessment framework were contained in two working papers. The presentation described the Virtual Population Analysis (VPA) formulation used and the stock status indicators proposed for use in a TLM. The results of two VPA formulations for 4X haddock were presented. The first formulation was the same as was used in the previous assessment of this resource (Hurley et al. 1999), using updated input data. This included a full year catch-at-age for 1999 (where only a half-year catch-at-age had been used previously) and 2000, constructed from age-length keys and length frequencies stratified by quarter, gear, and area. A half-year catch-at-age for 2001 for use as a placeholder was constructed by scaling the half year landings for 2001 by the 2000 catch-at-age. The results were consistent with the previous assessment. Several other formulations had been explored and that considered the best calibrated ages 2-10 rather than ages 2-7, as in the previous assessment. A comparison of results from the two formulations showed very little differences. An examination of the age by age residuals from the ages 2-10 formulation showed some year effects, but no cohort trends. It was felt that the residual pattern was acceptable. Past assessments of this resource have shown a strong retrospective pattern in estimates of fishing mortality and biomass. The retrospective pattern from this formulation was similar to the previous assessment and considerably better than earlier assessments. A comparison of q-adjusted survey numbers and bias-corrected population numbers was good although less so in the late 1970s and early 1980s. This same pattern was seen in the previous assessment. The trends in fishing mortality estimates were consistent with total mortality estimates calculated from the research vessel survey. Overall, results were comparable with the previous assessment. Exploitation increased through the 1970s to more than twice $F_{0.1}$ in the early 1980s, decreased in 1985-86 but remained above $F_{0.1}$ until 1993, and has been below $F_{0.1}$ since. Recruitment was below average from 1983 to 1992, but the 1993 and 1994 year-classes were strong, the 1996 year-class was average, the 1997 year-class was strong and the 1998 and 1999 year-classes are estimated to be very strong. Age 4+ biomass, the spawning stock biomass (SSB) proxy, increased from a low in 1974 to a high in 1979, then decreased to a series low in 1990, and has increased since to about the long-term average. Neither the research vessel (RV) survey data nor SPA results indicate any stock/recruit relationship.

A number of stock status indicators were presented as candidates for a TLM table, with proposed boundaries. It was stressed that these were proposals only, as a starting point for discussion at this meeting. The TLM had not been applied to 4X haddock previously. Several new indicators were presented to address requests to include age structure.

Discussion

A question was raised as to whether the retrospective pattern in the SPA result represented a problem. Some of the pattern may be associated with large year-classes but this required further investigation. It was observed that RV age one and two catch per tow were being used as a recruitment indicators but that age one was not included in the model calibration; it was suggested, and agreed, that age one not be used as an index. It was noted that the

TLM indicator boundaries were almost all based on informed opinions from examining the data. It was concluded that expert opinion was an acceptable means of establishing boundary levels. Inclusion of the rationale for these in the TLM table would be very informative. There was a comment that it wasn't appropriate to include management indicators in the TLM table and that the table should only deal with stock status. It was observed that there were no environmental indicators or characteristic and that there should be. If no significant environmental influences had been determined, then this was an area that required work. The trends in fish condition and growth from the RV data were alarming, possibly indicating a regime shift. There was a comment that the condition indicator shouldn't be red, and the suggestion made that the indicator was not reflective of any negative biological response, or that the index had not yet reached a critical level. It was also noted that there seemed to be duplication and redundancy in the indicators presented. For example, area occupied and density appeared to be measuring the same thing. Also, many of the indicators are implicitly incorporated into the VPA. It was considered that some degree of redundancy, particularly with the VPA indicators, was beneficial and we should not rely on the VPA completely. It was felt that duplication was a bigger issue than redundancy. There was a question as to whether we would conclude the same stock status if the model-generated (mechanistic-based) indicators were considered separately from the non-model generated (mechanistic-free) indicators. A concern was voiced that we were focusing on indicators other than stock status. It was countered that using a wider suite of indicators than just the VPA outputs allows a broader view of stock status.

4X Cod Assessment Framework (D. Clark / P. Fanning)

Working Papers:

Clark, D.S. 2002. 4X Cod Assessment Draft June 10, 2002. Maritimes RAP Working Paper 2002/40: 47p..

Clark, D.S., S. Gavaris, and S.D. Paul. 2000. Assessment of Cod in Division 4X in 2000. CSAS Research Document 2000/139: 72p.

Fanning, P., and D. Clark. 2002. 4X Cod Traffic Light Table. Assembly of Existing Indicators Maritimes RAP Working Paper 2002/42: 6p.

Rapporteur: D. Clark

Presentation Highlights

A similar presentation to that for haddock was made for cod. Some of the background on the cod assessment is given in Appendix 7.

Discussion

The presence of a domed partial recruitment (PR) was noted. It was clarified that this is only used for projection, as the current year fishing mortalities at age are all estimated. Mention was also made of the ITQ survey, which is used in both the cod and haddock assessments. It could be more informative than the DFO survey in that 184 versus 68 sets are made. Its biggest value is in being an independent indicator from that of DFO survey. It was felt that it would be worthwhile computing recruiting indicators based on this survey for both cod and haddock. During this discussion, it was noted that the ITQ survey preferentially captures small fish as opposed to the DFO survey. Was this an area, gear or some other effect? The explanation could be that the ITQ survey samples the inshore area of 4X, whereas the DFO survey can't. Discussion followed on the need to consider the spatial dynamics of cod in management (e.g. Bay of Fundy vs. Scotian Shelf).

POTENTIAL FISHERY AND ECOSYSTEM INDICATORS

Fishery Interactions and Impacts (K. Zwanenburg)

Working Papers:

> Zwanenburg, K., and M. Showell. 2002. Ecosystem–Based Management of Human Activities in Marine Ecosystems: Context and Estimation of Catch Profiles and Ecological Footprints for Fisheries – Preliminary Analyses. Maritimes RAP Working Paper 2002/43: 39p.

Rapporteur: K. Zwanenburg

Presentation Highlights

Ongoing work estimating ecological footprints of fisheries on the Scotian Shelf was presented. The report included the framework of international agreements that Canada has entered into that apply to the manner in which our natural resources are exploited. It was pointed out that the Convention on Biological Diversity, the FAO Code of Conduct for responsible fisheries, and a number of other accords establish national responsibilities that Canada has accepted to fulfill. The Convention on Biological Diversity obliges Canada to make inventories of, to monitor changes in, and make plans to conserve biological diversity. The FAO Code of Conduct and a number of other agreements obliges Canada to take into consideration relationships among species in exploited systems, to promote the development of selective fishing gears, to minimize waste in target species and minimize by-catch of non-target species, to protect and restore endangered marine species, and to preserve rare or fragile ecosystems.

The general knowledge requirements to move from the single species approach (that has dominated Canada's resource assessment science sector) to a more ecosystem based approach were laid out. Jamieson et al. (2001) lay out the over-arching objectives that moves management from single species assessment toward operationalizing the ecosystem approach, and give overviews of some existing ecosystem management initiative.

Focus was put on the development of ecological footprints (*sensu* terrestrial ecology). As an initial step towards developing these footprints, an approach to developing catch profiles for a number of fisheries on the Scotian Shelf was presented. Catch profiles give insight into the manner in which these ecosystems are being exploited, and the manner in which these fisheries are interacting with or effecting the general biological diversity of the Scotian Shelf. They may also provide information on how fisheries interact, particularly with regard to the regulation of catch limits in mixed species fisheries.

Catch profiles were developed from a number of available data sources - from species composition of trip by trip landings (Figure 1) to information collected by on-board observers for each fishing set (Figure 2). The bulk of the presentation focussed on the approach to the development of catch profiles for the 4X cod, haddock, pollock fishery for NAFO Division 4X.

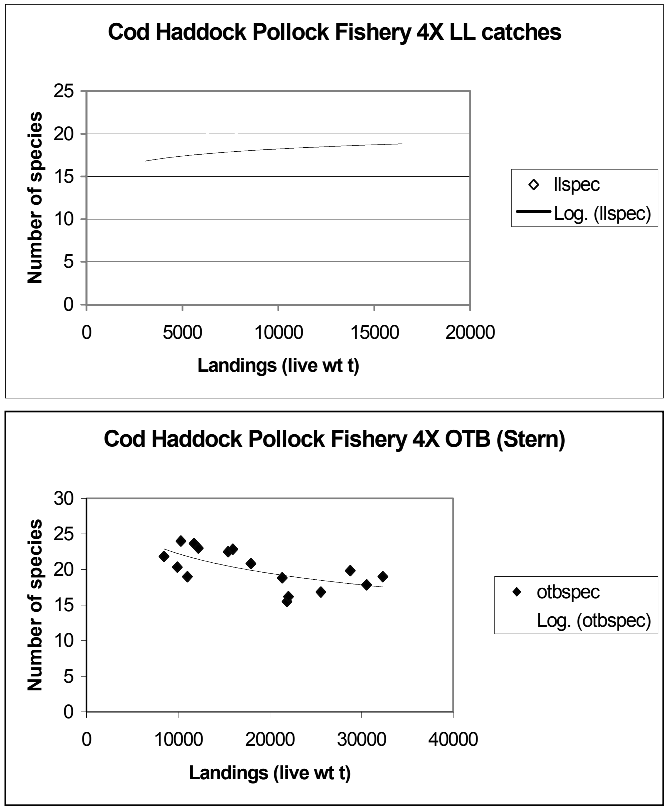

Figure 1. Relationship between the number of species landed in the 4X cod/haddock/pollock fishery as a function of total landings.

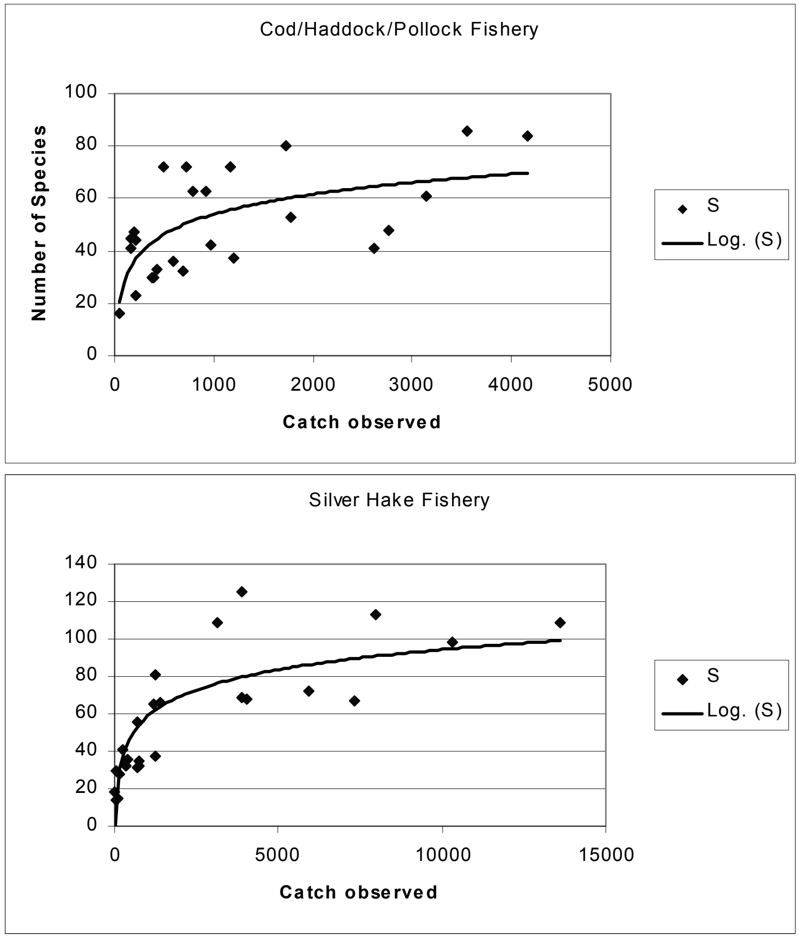

Figure 2. Relationship between the number of species observed in the 4X cod/haddock/pollock fisheries (OTB–Stern) as a function of total catches observed; note the increase in the number of species observed as a function of increasing amounts of observed catch; note also that no asymptote is reached for either fishery.

As a first step, the available catch profiles were aggregated into annual year/gear/fishery type categories. These categories were treated as samples from the 4X fishery. Multidimensional Scaling (MDS) was then used to examine which of these factors (year, gear, and fishery type) have the greatest impact on catch profiles. Apparent differences were investigated more formally as using Analysis of Similarity to establish the recognizable fisheries categories. These tests showed that catch profiles within gear and fishery types have remained relatively constant over time (at least at this level of aggregation) and that catch profiles from gear types and fishery types are readily distinguishable using either of the major data sources (landings or catch).

The differences between catch profiles using landings and onboard-observed catch profiles are evident (Figure 3). Catch profiles derived from landings data show no relationship between the amount landed and the number of species observed. This is inconsistent with the underlying species - area curves known to apply in most ecosystems and indicate that the species composition of these profiles has been significantly altered before landing (discarding, culling, etc). The relationship between species observed and amount of observed catch is quite evident in the onboard data. A comparison of these species-area curves to a species-area curve derived from fishery independent surveys would provide some insight into the overall selectivity of these fisheries. Most notably, the catch profiles derived from onboard observer data are significantly broader than those derived from landings data (broader in the sense of including a significantly larger number of species. The other notable difference is that the catch profiles for stern trawlers and longliners are easily distinguished with the onboard data while from landings, the catch profiles appear much more similar.

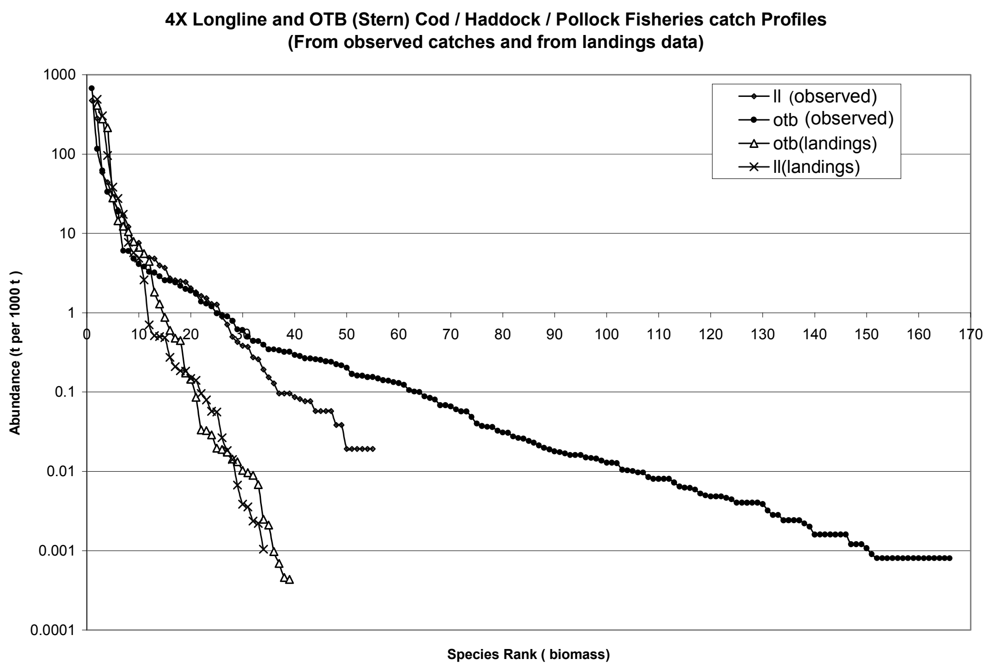

Figure 3. Catch profiles for the 4X cod/haddock/pollock fishery derived from landings and onboard observed data. Each line represents the log abundance of the each species in the catch profile for that gear type and data source ordered by rank (on biomass) of that species in the catch profile. These represent profiles based on data averaged for the 1977-2002 (observer) and 1986-2001 (landings).

Discussion

It was asked whether or not observed trips that use small mesh (e.g. ITQ survey trips) were included in the analysis, to which was replied no, only the commercial trips were included. It was noted that it would be interesting to analyze the DFO survey data in the same way as this dataset is free of the biases potentially present in the commercial data. It was suggested to relate these analyses to size spectrum studies, for which there are a number of examples, particularly documented by the ICES WG on the Ecosystem Effects of Fishing.

The discussion then moved to the fishing impacts on specific species. The analyses indicated the occurrence of some very rare species. It would be important to assess the fishery impacts on these species, which infers some analysis of fleet-specific mortality estimation. For some of these species, even their identification can be problematical, with a suggestion made that a colour atlas be made available for on-board usage. It was pointed out that all unknown species are to go the Atlantic Reference Centre for correct identification.

The presentation raised the issue of indicators of the impacts of human activity on the ecosystem. This not only involves target and by-catch species, as examined here, but also the broader ecosystem impacts on diversity, food chain relationships, the habitat, etc. There are also inter-fleet interactions (e.g. cod in lobster traps) that need to be considered. Some participants queried as to how such a suite of indicators would be developed and peer reviewed. Research will be incremental and it is planned that indicators would be peer reviewed through RAP before being incorporated into management plans. It was pointed out that this meeting would later consider indicators of biological productivity. Indicators of the environment are available in the haddock working paper (Anon, 2002e) and in Colbourne et al. (2002), which was circulated to participants prior to the meeting.

In summary, the presentation described work in progress on the measurement of fishery impacts and stimulated a number of suggestions for further work, including:

1. Comparison of the trajectories of species in the research vessel survey time series to their rank in the by-catch profiles over time to determine which are the most likely to have been influenced by the fisheries
2. Examination of the catch profiles for the fishery in the most disaggregated form and consideration of the effects of:
    - Spatial heterogeneity
    - Tonnage class
    - Mesh sizes (in the trawler fishery)
3. Examination of the RV survey data to establish a baseline species spectrum that would allow judgement of the degree to which each of the fishery selects particular species.
4. Exploration of the relative vulnerability of species of interest
5. Relationship of this work to that previously reported in the ICES WG on Ecosystem Effects of Fishing.

General Discussion

Rapporteur: R. O'Boyle

Following the day's presentations and discussion, the meeting chair presented some of the main themes and points made.

A concern had been raised that the objectives outlined in the OBFM plan and FRCP might be different, whereas they should be as equivalent as possible. The same objectives structure facilitates association of stock and productivity indicators with the appropriate objectives in a consistent manner. A small group of DFO and FRCC meeting participants offered to conduct a comparison of the objectives for the meeting report. Their comparison is provided in the section on Objectives and Strategies below.

Much of the discussion focused on the appropriate indicators that could be associated with the various objectives of the plans. When defining indicators, it is important to understand their signal content. For example, when presenting the survey numbers per tow at age one as an index of recruitment in the TLM table, it would be worthwhile examining the continuity of year-class strengths in the survey to ensure that the indicator is not mostly composed of noise. Typically, this check is done before using these data in a population model and results in a more limited age span of survey indicators being used.

Another concern raised was the aggregation of many indicators into a characteristic, such as abundance, in the TLM tables. One must be careful to ensure that two or more indicators are not being summarized that are highly correlated (e.g. duplication). This might happen when two indicators are derived for the same characteristic from the same dataset. This is as opposed to having two indicators developed from separate datasets (e.g. redundancy), which was considered a positive feature of any assessment.

The day's presentations also highlighted the need for new indicators, one example being one on age structure. This is particularly true of fishery and ecosystem-level indicators, for which further research was encouraged.

To address the points made on indicators in the TLM tables, it was agreed that an expert group, chaired by P. Fanning, would convene to review the 4X cod and haddock TLM tables. This group would validate the indicators being proposed, consider any new indicators, and outline the rationale for the red, yellow and green boundaries. It was intended that the group would report back to the plenary later in the week. However, due to time constraints, the results of the discussion could not be presented in plenary and were not formally reviewed by the meeting. Thus, the results of this group are provided in Appendix 6.

DECISION RULE – RELATED ANALYSES

FRCC Approach to Decision Rules: the FRCP (D. Lane)

Working Papers:

> Anon. 2002f. Fisheries Resource Conservation Plan. 4X5Y Cod and Haddock. TAC Rules and Historical Application Test of the Plan. FRCC Report: 11p.

Rappporteur: D. Lane

Presentation Highlights

On day one of the meeting, a description of a decision rule for rationalizing FRCC recommendations on stocks was presented. The decision rule was described by a two-dimensional "consideration matrix" that attempted to capture the scientific perspective on the current state of the target resource ("stock condition") and the forward-looking productivity prospects for that stock ("productivity regime"). The decision table used the stock condition and productivity regime to identify relative change (stable, adjust up, adjust down) in the TAC management measure, given a current TAC.

The presentation illustrated the proposed draft FRCP decision rule for 4X - 5Y cod. It was tested by application to the historical and projected data to evaluate its performance vis-à-vis pre-specified management targets. For simplicity, the test used the historical series of spawning stock biomass (SSB, cod biomass ages 4+) as the indicator of the stock condition, which was discretized into categories based on empirical actions and historical observations. The test implicitly assumed a constant productivity regime over time. Thus, the simple TAC decision rule in the test was determined directly in terms of the estimate of the SSB over time and the predefined discrete category into which it fell. The decision table assigned relative change values (stable, adjust up, adjust down) to the current TAC dependent on the SSB category, as noted above.

The recommended TAC's were intended to allow a maximum exploitation rate of 20%, corresponding to a moderate fishing mortality (F) strategy for each possible stock status/productivity combination.

It was understood that a real application of the consideration matrix would require a more complex scientific perspective on the definition of stock condition and the productivity regime, and should include a mechanism for incorporating uncertainty. The FRCC is seeking scientific advice from DFO Science and Fisheries Management on 1) how best to describe these two states, i.e. the suite of indicators needed to describe stock condition and productivity regime, 2) how to define relative categories (e.g. "good", "moderate", "bad") for each of these two states, and 3) the potential consequences of management policies adopted, given the various combinations of stock condition and productivity.

Thus, the FRCP decision rule involves defining the following elements of the consideration matrix:

1. Stock condition or the status of the stock (in 3 or 4 categories) – determined from traditional VPA sources, the proposed Traffic Light Method, or other aggregate estimation procedures such as the AD Model Builder approach.

2. Productivity regime (in 3 or 4 categories) – measured in terms of growth rates, recruitment, and other metrics that provide a forward-looking view to stock status.

3. Management action – the pairwise set of stock condition positions and productivity regime positions that determine a decision point. These can be written in terms of a relative TAC strategy, e.g., stable, adjust up, or adjust down in predetermined step sizes.

Discussion

It was suggested that a time series approach could be taken to defining the indicators of the productivity regime. In relation to productivity, there was concern that all the models discussed assumed that natural mortality (M) was constant over age. Rather, M is likely to be high at age one, drop off at middle ages and increases again at older ages. It was argued that assuming lower than likely M on the recruiting ages makes the situation seem better than it actually is. It was pointed out that VPA smoothes the size of incoming year-classes, which might in fact be more variable. It was countered that unless account of predator-prey dynamics can be made at these younger ages, as has been done in some North Sea examples, M is only a scalar of abundance.

This discussion raised the issue of the reliability of the historical VPA-related indicators. VPA typically produces converged estimates of population abundance and fishing mortality as the analysis proceeds backward in time but is this reality, given the problems in the catch information? This is important to keep in mind when using VPA as the basis for management decisions.

It was noted that during the development of Management Procedures, as being considered in the Southern Ocean, simulations are conducted based on history to examine future states. In international fora, where negotiations can sometimes be difficult, having pre-defined rules based on simulation is an advantage. Here, some felt that we have more flexibility and perhaps don't require the best rules – only ones that are sensible. One should endeavour to have relatively simple and unencumbered decision rules. This is the philosophy behind the FRCP. The question is, then, are the rules adequate?

The complication of a 4X-mixed fishery was raised i.e. what management activities targeted on cod will impact haddock and vice versa. Establishing relative harvest rates for both species did not appear to be a part of the FRCP. As the industry desires stability of catch, TACs were being considered based on the binning of stock condition, not exploitation rate. However, the desire to seek stable catches might result in instability of exploitation rate ratios of the two stocks. It was felt that the decision rule needs to consider the cod and haddock exploitation rate ratio. Ways of considering this were discussed and are presented later in this report.

Fuzzy Logic Approach to Decision Rules (P. Fanning)

Working papers:

> Fanning, P. 2002. Application of Decision Rules in 4X Cod Traffic Light Assessment. Based on FRCC Fisheries Resource Conservation Plan. Maritimes RAP Working Paper 2002/30: 11p.

Rapporteur: P. Fanning

Presentation Highlights

The draft Fisheries Resource Conservation Plan (FRCP) includes decision rules based on stock condition (e.g. spawning stock biomass) and a qualitative assessment of the productivity regime. An example of implementing decision rules based on the TLM tables was presented. While the FRCP was written in terms of the spawning stock biomass (SSB), a VPA output, the TLM evaluates stock size (abundance) as the integration of several indicators. One of the indicators is generally the stock biomass where VPA results are available but other sources of information are included. For purposes of this example, the SSB in the FRCP has been replaced with the Abundance characteristic of the TLM. In the FRCP consideration matrix, the productivity regime is simply the TLM production characteristic. The three components of the FRCP considered in this example are i) the base TAC derived from the Abundance, ii) the consideration matrix which relates both Abundance and Production, and iii) an ‘unacceptable situation’ identified when the Abundance is low and declining. Discussion with the FRCC members indicated that the intent of the base TAC was different from the interpretation used in this example. However, as this is an example, this does not matter greatly and could be revised to accommodate their intent.

In fuzzy logic, decision rules are written in the form IF x THEN y. In this example, the antecedents (x) are defined in terms of the colour values of the Abundance and Production characteristics and the Abundance trend. The consideration matrix was simplified to include only three levels of Abundance as well as the three levels of Production. The resulting nine cells in the matrix yield nine rules to determine the adjustment to apply to the base TAC. Similarly, a total of six other rules were derived from the Abundance and Abundance trend considerations to determine the base TAC. Once the rules are defined, the current values of the input data are applied and the outcomes of the rules evaluated. The evaluation process was described in some detail but is not reported here. The fuzzy responses for TAC and TAC adjustment are reduced to single values (defuzzified) and then combined to give the TAC implied by the given rule set and input data.

The performance of the sample decision rules was compared to the actual catches for the period 1973 to the present (Figure 4). These rules are much more conservative than actual catch levels were. It is likely that there would be a great deal of yield foregone under this rule. This representation does not consider the gains that have also been foregone as a result of non-conservative actions in the past. The intent of the FRCC to re-visit the rules on a regular basis would allow them to be adaptive to the changing underlying stock.

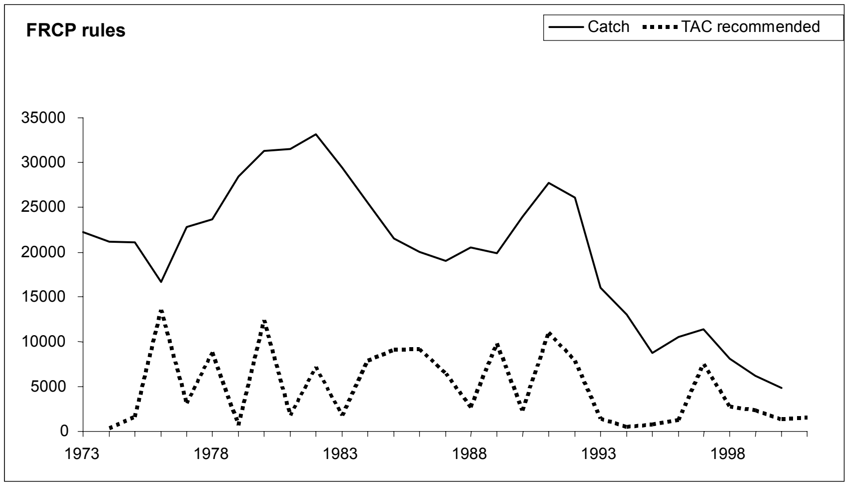

Figure 4. Performance of Decision Rule using FRCP-related approach.

An alternative approach to setting the base TAC was briefly explored in the presentation. In this case, the new TAC is derived from the recent catches and changes detected in the population characteristics. The rule set for this example considers only the current value of the Abundance, Production and Fishing Mortality characteristics. Inclusion of trend considerations would be an obvious way to improve the responsiveness of the decision rule. Recommended TACs with these alternate rules appear to rise slower and decline sooner than the actual catches did (Figure 5). Although they may be more conservative, there is much less evidence of yield foregone. What neither of these examples of decision rule performance reflects is the response of the stock to the different catch that would have resulted.

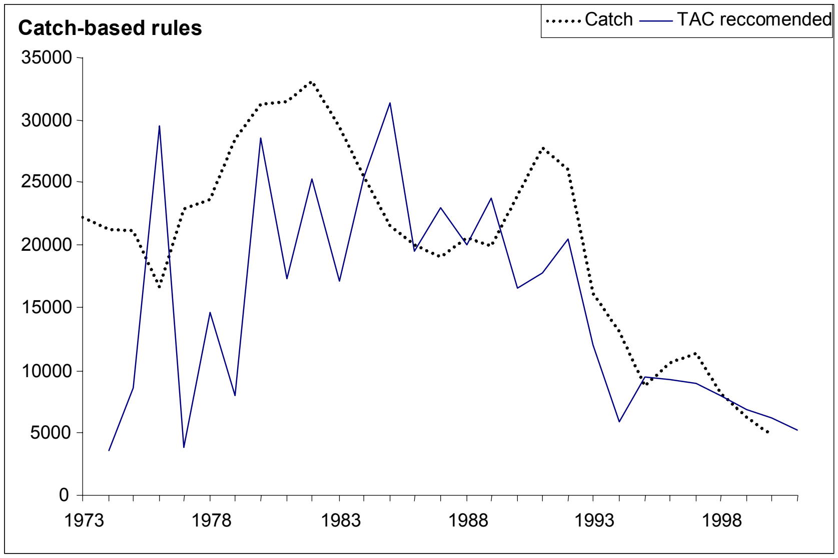

Figure 5. Performance of Decision Rule based upon recent catches.

Discussion

The development of decision rules as a basis of fisheries management introduces a number of new issues separate from the specifics of stock assessment. First is the inclusion of additional dimensions such as ecological, economic or social characteristics. Another is that decision rules need to consider the impact of decisions regarding one resource on another. As noted above, views at the meeting as to the degree to which decision rules are rules leading to specified management responses varied from hard and fast prescriptions through to apparent guidelines whereby management decisions may be considerably different from the 'rules'. The difficulties include the challenges of pre-specifying the rules as well as the desire to leave advisors and decision-makers room to address unspecified issues in a more ad hoc manner. It was noted that the firmer the rules, the more transparent and reproducible the management responses would be. The question remains, for any set of decision rules, how do we validate the performance of the process (stock assessment, other dimensions and decision rules) in achieving the management goals?

It was queried as to how well the fuzzy implementation of the FRCP captures the intent or essence of the FRCP. This implementation separates the decision rules from the indicators by evaluating the rules in terms of the characteristics. A strength of the inclusion of characteristics is that one can explicitly consider the impact of contradictory signals from the various indicators on a given characteristic. Weighting is a means to control how much a given indicator affects the outcome. While it was observed that similar rule evaluation could be done in continuous modeling rather than fuzzy, no example was offered. There was discussion of what was gained from the fuzzy method and whether to pursue it. It was suggested that D. Lane and P. Fanning meet to compare and contrast the details of their FRCP and TLM implementations respectively.

There was considerable discussion on the decision framework of the FRCP. The FRCP operates from a fixed base catch and adjusts this as considerations permit. The FRCP is not targeting a constant exploitation rate but rather a variable but moderate F tied to a TAC in fixed increments. This produces a 'sawtooth' pattern in exploitation rate varying from 16-20%

over a range of estimated biomass. While the base TAC in the FRCP would be established for the plan period, it would updated regularly.

The consideration matrix proposed by the FRCP includes an axis in stock condition. It was questioned how this differs from spawning stock biomass (SSB). Stock condition is supposed to identify the state of the stock, as opposed to the possible direction of the change of state, which is identified by the productivity axis. It would be up to the RAP meeting to decide what are the most appropriate indicators of the two axises of the consideration matrix. Other aspects of stock condition (e.g. age composition) would be value-added.

Alternatives to the FRCP rules were discussed although none were specifically recommended or rejected by the meeting. For instance, it was suggested that the mean of recent catches could be used as the TAC in the current year. Adjustments would be made to this starting TAC based on the consideration matrix in order to move the stock condition in the desired direction. The starting TAC to this decision rule could also be drawn from a longer time period.

There was consensus that adjustments to the TAC based upon the consideration matrix should be asymmetric - reductions in catch are larger or easier to invoke than increases.

Production Modeling and Decision Rules (S. Gavaris)

Working Papers:

> Gavaris, S. 2002b. Formulation of Fisheries Management Advice for Keeping Fishing Mortality at Moderate Levels. Maritimes RAP Working Paper 2002/28: 13p.

Rapporteur: S. Gavaris

Presentation Highlights

One strategy to achieve conservation is to keep fishing mortality, F, at a moderate level, this achieved through total allowable catches (TAC). A decision rule, which measures the forecasted F of alternative quotas against a reference F, aids determination of the TAC. The presentation made the distinction between indicators of the state of the resource and those that pertain to its productivity and thus can influence the reference level. The impact of the latter on F reference levels was investigated for 4X cod.

One way to study production dynamics of a resource is to integrate the results of a yield per recruit (Y/R) analysis with those from a stock / recruitment (S/R) analysis (Shepherd, 1982). A number of F reference points were derived from Y/R analysis: e.g. F_{max} = 0.25, $F_{0.1}$ = 0.14 and $F_{40\%}$ = 0.15. Establishing a stock / recruit relationship is more challenging, with extrapolation beyond the range of observation and inference of the shape of the stock / recruit curve often employed. Here, steeply increasing or declining recruitment at higher SSB was not assumed and the shape of the S/R relationship was assumed to be asymptotic. This approach constrains predicted recruitment within the range of observation and the associated reference points are then a reasonable consequence of mortality, growth and fishery exploitation pattern at age processes. To avoid results greatly influenced by the choice of a specific S/R model, a robust locally weighted smoothing procedure was used. The catch at age used in the recent assessment was augmented with that for 1948 to 1982 to reconstruct the historical trends of age one recruitment and adult biomass (ages 3+) from a VPA. The

S/R analysis resulted in recruitment of about 19 million recruits at age one for adult biomass over about 75,000t, with indication that recruitment is impaired at lower biomass (Figure 6).

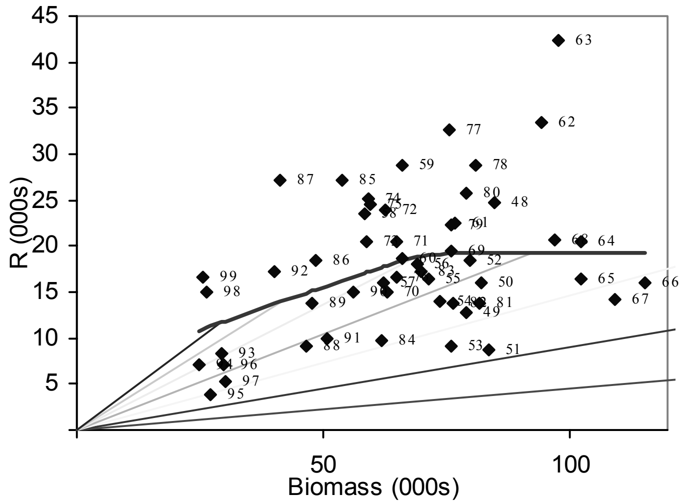

Figure 6. 4X cod stock/recruitment relationship based upon 1948–2000 VPA output.

The S/R relationship was then integrated with the Y/R analysis to allow examination of how yield and biomass respond to F. A candidate for an F reference is the fishing mortality that achieves maximum sustainable yield, F_{MSY}, which is 0.25, the same as F_{max} from the Y/R analysis. However, many yield – F relations are not noticeably peaked; adoption of F_{MSY} as a reference point may gain yield at the expense of a substantially reduced biomass, sacrificing stability and resulting in lower catch rates. Equilibrium biomass at $F_{0.1}$ and $F_{40\%}$ is about 160,000t, compared to about 110,000t at F_{max} =0.25 while the yield is similar, 22,500t versus 23,500t.

While exploiting a resource at some F reference level should result in the greatest yield and a stable biomass, improved recovery and latitude for errors of assessment or environmentally driven fluctuations is afforded by reducing the F reference proportional to the reduction in biomass below some threshold or upper sill. The smallest value of the F reference will be referred to as the lower sill, and the region where the F reference reduces as a function of decreasing biomass will be called the transition zone.

The presentation outlined an illustrative decision rule (Figure 7) for 4X cod, accepting that the specifics would be subject to consensus among stakeholders. F would be maintained below 0.2 for adult biomass above 75,000t. The lower sill F reference would be 0.1 because all observed stock / recruit observations lie above the F = 0.1 replacement line (Figure 6). The population could have successfully rebuilt from low biomass using a strategy of F = 0.1 even under the most unfavorable of conditions that were observed. Lacking information about stock dynamics below the lowest observed biomass (about 25,000t), it would be prudent to maintain fishing mortality below F = 0.1, for biomass below this. Between 75,000t and 25,000t, F would be maintained below an F reference corresponding to a linear decline in fishing mortality rate from 0.2 to 0.1.

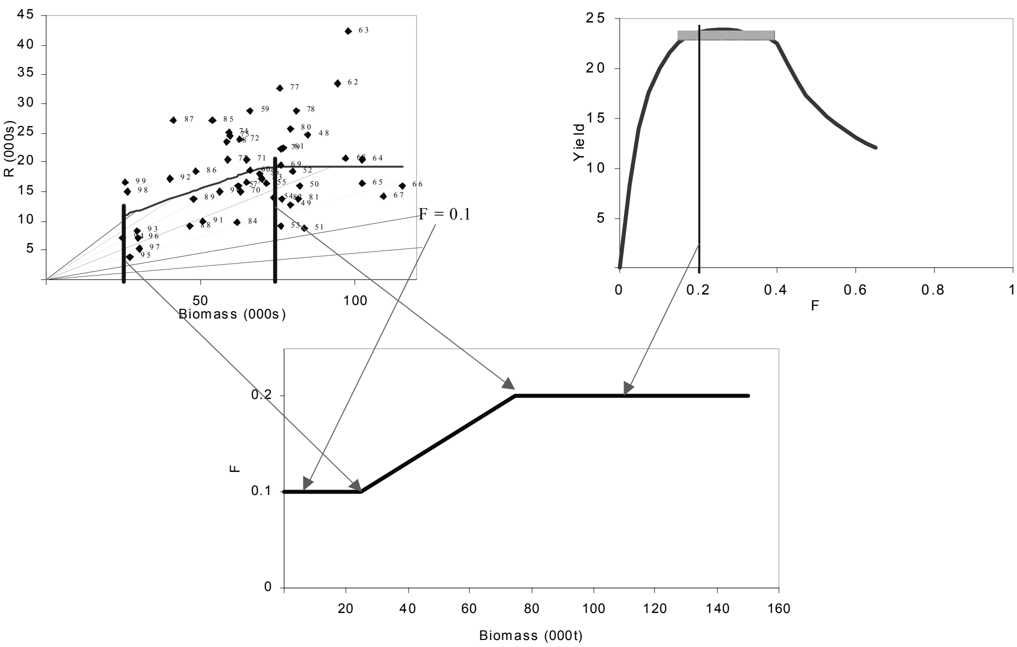

Figure 7. Illustrative SSB – F based Decision Rule for 4X Cod using Arbitrary but Reasonable F and SSB Reference Points.

Consideration was given to additional population attributes that may influence productivity but for which mechanistic relationships cannot be proposed, although hypotheses on cause and effect are postulated. For example, recruitment may be impaired when fish condition is poor. Three biological attributes (age structure, condition and area occupancy) were entertained. It was suggested that these could be used to adjust the F reference post hoc, by specifying by how much the lower sill should be reduced if the attribute is worse than a reference condition. The upper sill is not adjusted. When more than one attribute is used to adjust the lower sill, they are assumed to have a multiplicative effect.

The presentation also discussed various forms of advice (see Figure 8 in discussion section), illustrating the consequences of forecast F relative to the F reference for alternative TAC options. Accounting for uncertainty is facilitated by framing a decision rule in terms of bounds rather than targets e.g. characterizing the risk of the forecast F exceeding the F reference for alternative TAC options. It was pointed out that management guidance based on these types of risk analyses should be qualified by acknowledging the assumptions on which the calculations are based and the aspects of uncertainty that were not incorporated.

Discussion

There was discussion on what level of F was considered moderate and the utility of the production analysis to identify useful reference points for this purpose. The FRCP proposed a constant exploitation rate in the range of 16-20% over all biomass levels above 30,000t for cod in Division 4X. The production analysis presented here indicated that the difference in yield was marginal for F between 0.15 and 0.25 but biomass, and consequently catch rate, declined substantially at higher F. It was generally agreed that a reference F around 0.2 could be considered moderate for higher biomass.

There was support for the notion of reducing the F reference when biomass declined, contrary to the proposed FRCP decision rule. This analysis indicated that reductions of the reference F could be initiated when biomass declined below about 75,000t. It was noted that an accelerated rebuilding strategy afforded by the reduction in F reference was a policy decision. Therefore, advice should be framed in terms of both the moderate reference F and the reduced reference F.

Evidence of time trends in productivity could be used to guide judgement between applying the moderate F, F_{mod}, and the accelerated rebuilding F, F_{reb}. Explicit rebuilding strategies are not operationally defined, though evaluation of forecast change in biomass are often considered. Further, stock dynamics below the lowest observed biomass are unknown and the strategy could be for lowest possible F without specifying a lower sill. The author suggested that the advice be provided in the following forms (Figure 8):

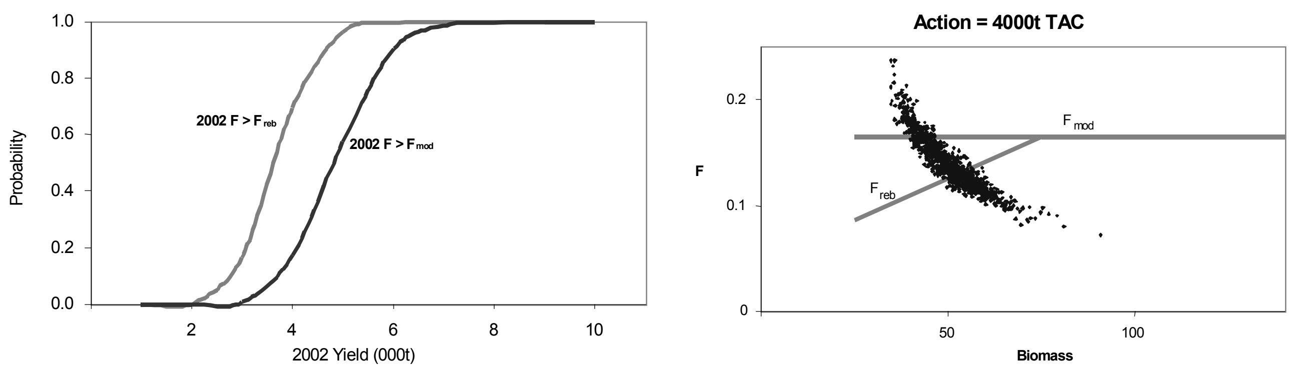

Figure 8. Suggested Depiction of Annual Forecast Advice.

There was debate on the wisdom of utilizing an approach in which advice depends on the output of the model assumed to be absolute measures of stock size and F. Violations of the assumptions of the model (e.g. large-scale historical inaccuracies in fishery statistics, changes in natural mortality, problems with the stock definition), as sometimes exemplified by severe retrospective patterns, would seriously impact the quality of the advice and make estimates of current stock size and F very uncertain. An alternative approach that does not use mechanistic relationships of population dynamics was suggested. In this, the absolute estimates of current F are not necessary for TAC setting. TAC decisions could be made by classifying the status of the resource and the productivity regime. This is similar to what is being proposed by the FRCP. Stock condition constituted more than the 'state', i.e. amount of fish, of the stock. TAC adjustments from the current level could be made based on positive or negative trends in the stock condition and productivity regime. Performance in relation to F could be measured retrospectively, using a variety of methods, and adjustments could be made to the decision rules if necessary.

Others did not accept that the current estimates of F were completely uninformative and that the historical reconstruction of population development could not give guidance on an absolute magnitude of a moderate F. They pointed to the negative correlation between F and biomass as evidence that fishing did impact the resource and that this effect was measurable. In the mechanistic approach, the 'state' of the stock is a key determinant of the evaluation against an F reference. They argued that many of the indicators considered in the alternate approach bore little or no connection to the resulting exploitation rate. Accordingly, if this non-mechanistic approach to managing fisheries were adopted, it would necessitate definition of a strategy other than maintaining F at moderate levels. It was further argued that if the catch statistics were inaccurate, a strategy to regulate exploitation was not meaningful, regardless of how stock condition was determined.

There was debate about whether the decision rule should be F or TAC based. Some argued that the decision rule should set the TAC and then the response in F evaluated. It was noted that the 'management measure' was indeed the TAC but that a strategic F reference was needed to evaluate the consequences of alternative TAC options. The disagreement might be a case of semantics where ‘decision rule’ was being associated with 'strategy' by some and with 'management measure' by others. It is noteworthy that the form of advice proposed by the FRCP would permit evaluation of the response in F for alternative TAC options. It was acknowledged that the reference points depicted in the form of advice were not intended to be prescriptive. The final choice of TAC may need to be based on considerations other than keeping F at moderate levels.

Concern was expressed that the production analysis did not take spatial structure into account. It was noted that the objective of the TAC management measure was to achieve a moderate F globally for the stock. Other measures would have to be invoked to accommodate concerns about stock spatial structure. The examination of stock-recruit residuals against biological indicators like condition was commended and examination against environmental variables was encouraged.

Production Modeling and Decision Rules (R. Mohn)

Working Papers:

> Mohn, R. 2002. Production Modeling and Decision Rules. Maritimes RAP Working Paper 2002/31: 14p.

Rapporteur: R. Mohn

Presentation Highlights

Two concepts essential to resource management were presented - production and productivity. Production is a characteristic of a resource that measures the observed balance between inputs (growth and recruitment) and outputs (yield and natural deaths); it is related to the familiar concept of surplus production. Productivity is a characteristic that measures the longer-term potential production of a resource, as influenced by an environmental or ecological regime. Using data for 4TVW haddock (due to observed large changes in productivity), methods were presented to estimate both of these and their relevance to management discussed.

Methods were presented to partition production into that due to growth and that due to recruitment. Growth production takes account of the increase in biomass and yield in a given year, while recruitment contributes to production over the life of the cohort; it was presented as the probable contribution over the life of the cohort but shifted ahead to approximate the mean age of the cohort, somewhat analogous to a net present value calculation in economics. Also examined were how decadal changes in age-dependent characteristics such as partial recruitment, weights at age and maturity at age have influenced production and productivity.

The trends in 4TVW haddock production were then analyzed by decade, through a conventional Sissenwine-Shepherd (1987) analysis and estimates of the maximum production, or productivity, derived for each decade (Figure 9). If these decades are thought of as regimes, the productivity change from the 1970s to the 1990s is evident.

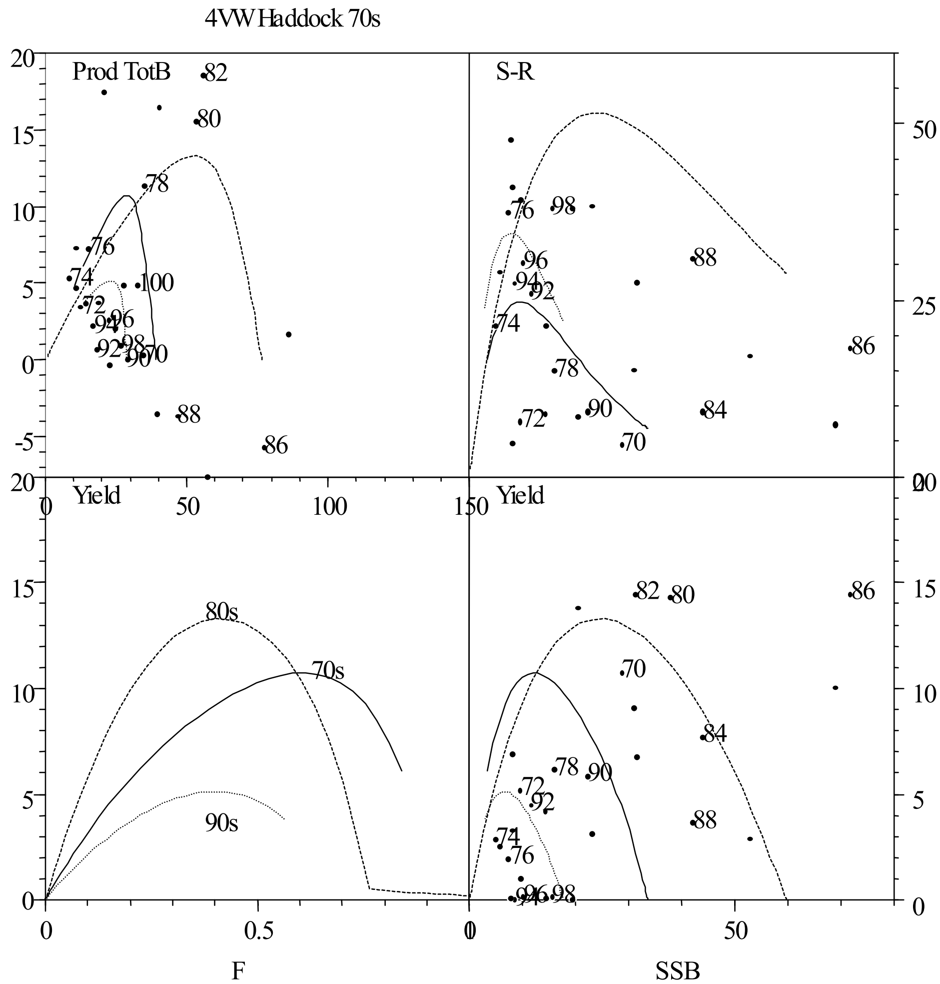

Figure 9. Decadal Sissenwine Shepherd plots for 4TVW haddock. The upper panels show the production (upper left) and stock recruit (upper right) data as well as the model fits. The lower panels shows estimates of equilibrium production for each of the decades in the analysis. On the left, the yield is a function of fishing mortality and on the right, it is in terms of SSB.

The implications of these concepts for management were presented. Currently, only biomass is considered in setting yield. If, as well as biomass, regime productivity has been estimated, the recent production may be compared to it. If the production were near equilibrium values, no adjustment in yield would be required. If the stock were below equilibrium production, the yield could be scaled down to take this into account. Decision rule schemes, for either a rebuilt or rebuilding situations, on how this might be done were presented. For example, if rebuilding was the objective, one would presumably want a larger proportion of the annual production to go into stock growth.

Discussion

It was noted that both the production and productivity for 4VW haddock were depressed. Similar, but less complete, analyses were presented for 4X cod and haddock. The general feeling was that these methods had potential to improve the assessments and the resultant advice. It was observed that they fit well into the general framework discussed at this meeting. Time was not available to explore the details of the techniques and thus it was recommended that they receive a more thorough subsequent review.

Integrated Assessment and Production Modeling (D. Kehler)

Working Papers:

> Gibson, A.J.F., D.G. Kehler, and R.A. Myers. 2002. An Integrated Stock Assessment and Risk Analysis Framework for 4X Haddock. Maritimes RAP Working Paper 2002/27: 36p.

Rapporteur: D. Kehler

Presentation Highlights

As an alternative framework for evaluating stock status, a statistical, age-structured stock assessment model for 4X haddock was presented that allows for the estimation of fishery reference points, population projections and risk analysis simultaneously with the historical catch-at-age analysis. Uncertainty in the estimated parameters, reference points and biomass projections are assessed in a Bayesian context using Markov chain Monte Carlo simulations. Using this method, errors in the population reconstruction, reference point estimation and biomass projections are carried through the analysis. The intention was to provide an overview of the modeling framework as well as the use of Bayesian methods for the evaluation of reference points and decision rules. The use of Bayesian methods in fisheries is becoming increasingly popular (e.g. McAllister et al. 1994, Punt and Hilborn 1997), and in particular, used in risk assessment. Risk assessment involves the evaluation of the outcomes of alternative management decisions given uncertainty in the state of knowledge.

As the proposed model has yet to undergo a thorough sensitivity analysis, the results were provided for illustrative purposes only. Agreement between the predicted and observed total catches and catch-at-age for the commercial data was very good, although fits to the mean RV catch per tow and mean RV catch-at-age per tow, however, were considerably looser, reflecting the greater variability in the RV data in both the total mean catch per tow and the mean catch-at-age per tow.

A comparison of the estimated numbers in age classes 1 to 10 with those from the most recent SPA match quite closely. This was somewhat surprising, given the different structures of the models. For the 2001 projections, numbers begin to differ substantially in years 8-10 where the model estimated twice as many fish as the VPA. As the VPA does not produce estimates for fish older than 10, a comparison of the projections for fish in these age classes was not possible.

Some of the most useful outputs of this modeling approach are posterior distributions for the parameters of interest, as well as the risk analysis for alternative management actions, examples of which were presented. The posterior distributions used in the risk analysis capture the uncertainty in the model and the data, thus providing the best reflection of the precision of the resulting advice. An example of how the model results could be used in risk analysis was also presented. This analysis incorporated uncertainty into the reference point estimates as well as in the fishable biomass projection for the following year.

Discussion

It was noted that the presented model was not yet at a stage to compare the results with other assessment models, but would be useful in the future. In particular, the selectivities of the recent research gear seemed suspect. Amongst other sensitivity analyses, it would be important to undertake retrospective analyses, as done with VPAs. The modeling framework is flexible enough to incorporate dependence on environmental factors, predator and prey species, and potentially a multi-species fishery as well as the modeling of discarding. The risk curves appear fairly gentle, reflecting the large level of uncertainty in some of the parameter estimates. Treating the total commercial catch as a random variable may be problematic, as it is intended as a census, not a sample, and errors in the census are likely to be unidirectional (underreporting of catches). Nonetheless, the errors in the catch-at-age and total catch can be examined for patterns.

General Discussion

Rapporteur: R. O'Boyle

The meeting chair offered some observations on the day's discussion.

Early in the day, the need for taking a broader view of the management system was noted, with a working paper (Halliday, 2002) pointing out that decision rules on specific elements such as TACs needed to be made in the context of an overall fishery management decision framework. It was decided, however, that this meeting's focus was to be the biological components of the management system. Nonetheless, the need for rules that governed exploitation on both 4X cod and haddock as part of a mixed fishery was noted and further examination during the meeting of this particular element of fishery interactions encouraged.

There was discussion following many of the presentations on the need, under a risk management framework, to have pre-agreed decision rules. The FRCP was viewed as a step in the right direction. The considerable industry input to the FRCP was considered an important element of the plan, as decision rules must have wide industry support. However, opinions varied on how specific these rules should be, with some saying quite specific and others saying to allow more flexibility. There remained fundamental unresolved differences in views as to how the decision rules should be structured and used.

Notwithstanding the ability of the TLM to incorporate a broad scope of biological and management indicators not included in mechanistic approaches, a number of issues were raised that required resolution. Also, there was considerable debate on the need for absolute vs relative indicators of stock condition, exploitation and productivity. Some argued that TAC management requires an absolute estimate of SSB and F, something that the TLM could not provide as it combines indicators from different sources. However, the view that mechanistic approaches provided such absolute estimates was contested and the issue was seen as one of scaling. The alternative viewpoint was given that, given a starting TAC, as with the FRCP, subsequent changes to this can be made using relative indicators. This led to discussion on how one could compare and contrast the two approaches. One suggestion was to create a TLM table with only input data (mechanistic-free formulation) and compare the derived states with those from a VPA (mechanistic-based). It was also suggested to do a comparison, using the historical dataset, of 3-year forecasts from both approaches. How much of this could be done at the meeting would depend on the activities of the expert working group established on the first day. This group had at that point not completed its review of the 4X cod and haddock TLM tables, which were planned to be reviewed in plenary in the morning of the third day.

There was agreement that the next part of the meeting should focus on the assessment frameworks – the evaluation of the indicators and their boundary conditions that make up to two marginals (stock condition and productivity) of the consideration matrices of 4X cod and haddock. In addition, S. Gavaris offered to apply his model to 4X haddock and R. Mohn and J. Pope offered further consideration of the stock state – productivity relationships.

MANAGEMENT OBJECTIVES AND STRATEGIES

FRCP / OBFM Objectives Comparison

Rapporteur: R. Halliday

A small working group (Annand, D'Entremont, Gavaris, Halliday, Lane) compared the structure and content of the conservation elements in the 2002-07 Scotia-Fundy Groundfish Management Plan with the FRCC draft Fisheries Resource Conservation Plan for 4X cod and haddock (Table 1). The terminology used for the Objectives Hierarchy differs between plans but there is a close correspondence in hierarchical structure. It was proposed that the OBFM terminology - General Objectives, Strategies and Management Measures - be adopted. The primary differences in content are:

1. The OBFM plan develops some objectives for non-target species to second (Strategy) and third (Management Measure) levels whereas the FRCP does not take these beyond the first level. This reflects the greater possibilities for addressing ecosystem issues in a multi-species fishery plan compared to one for one or two species.

2. Objectives for the target species are comparable with regard to F and both plans include maintenance of population diversity, regulation of size at first capture and protection of fish during spawning as conservation strategies. However, there are substantive differences between plans in the rationales for these last three strategies, which could result in quite different decisions on management measures. It was proposed that there be further discussions on these points between DFO Science and the FRCC to explore whether their different perspectives can be reconciled.

3. Fishery interactions are addressed in the OBFM plan but not specifically in the FRCP. This reflects the difficulties in addressing interactions in what is essentially a single species plan.

It was agreed that, ultimately, there can be only one plan and the participants were optimistic that outstanding differences could be resolved through further discussions.

Table 1. Comparison of conservation elements in Objectives Hierarchies in DFO 2002-07 Scotia-Fundy Groundfish Management Plan (OBFM) and the draft FRCC Fisheries Resource Conservation Plan for 4X5Y Cod and Haddock (FRCP).

OBFM	**FRCP**
GENERAL OBJECTIVES	OBJECTIVES
1.1 Maintaining community diversity by protecting benthic communities susceptible to disturbance	A.a Ecosystem health
1.2 Maintaining species diversity	A.a Ecosystem health
1.3 Maintaining population diversity	A.c Conserve: avoid over-exploitation of individual stock components
1.4 Maintaining trophic structure	A.a Ecosystem health
1.5 Maintaining productivity of populations by managing exploitation of target species	A.b Rebuild: SSB to target range B. Sustainable utilization and relative stability
(Not considered to be a conservation objective)	A.d Research
STRATEGIES	GUIDELINES
1.1 Protect high diversity coral beds and communities in the Gully	*(No guidelines for protecting benthic communities/habitat)*
1.2 Minimize incidental mortalities on non-target species, particularly species at risk	*(No guidelines for non-target species)*
1.3 Maintain spawning components of target species	#4 Conserve biodiversity through protection of spawning components and spawning areas
1.4 *(Insufficient knowledge at this time to establish strategies on trophic structure)*	*(No guidelines for maintaining trophic structure)*
1.5 Keep exploitation rates at moderate levels	#2 Precautionary decision making: conservative Fs
1.5 Avoid wastage by managing size and species selection during fishing	#3 Protect juvenile (pre-spawning) fish
1.5 Prevent disturbance of fish during spawning	#4 Conserve biodiversity through protection of spawning components and spawning areas
(not considered to be a conservation strategy)	#1 Planning horizon
(not considered to be a conservation strategy)	#5 Effective control
MANAGEMENT MEASURES	STRATEGIES
1.1 Close area in Fundian Channel and establish The Gully as a Marine Protected Area	*(No strategies for protecting benthic communities/habitat)*
1.2 *(No measures to protect non-target species)*	*(No strategies for protecting non-target species)*
1.3 Define management areas that correspond to stock distributions	Spawning closures
1.4 *(Insufficient knowledge at this time to establish management measures on trophic structure)*	*(No strategies for protecting trophic structure)*
1.5 Control fishing mortality (F) through annual TACs and bycatch rules	Biomass targets and schedules; base TACs, annual adjustments
1.5 - Specify aspects of gear construction, principally mesh size - Implement temporary and permanent closures of areas of small fish concentration - Restrict small-mesh groundfish fisheries to specified areas - Establish minimum fish size limits	Gear controls; small fish protocol
1.5 Prohibit fishing for haddock during the spawning season in spawning areas on Browns and Georges banks	Spawning closures and spawning protocol

Strategic Issues Relevant to Division 4X - 5Y Groundfish Management Advice

Author and Rapporteau: J. Caddy

Throughout the meeting, a number of issues were raised by Dr. Caddy that bore on the strategies employed in controlling resource harvesting. These have been compiled below. While the meeting did not explicitly endorse these comments, they are included here for future consideration.

Recruitment

Currently, groundfish fisheries in Divisions 4X-5Y, as elsewhere, are far from equilibrium and are heavily dependent on recruitment. As such, discussions on fishing strategy depend critically on obtaining reliable estimates of recruitment or of favourable conditions for reproduction, as early as possible, but for obvious reasons, the information database is much more certain with respect to age 3+ fish already in the population. This does not seem possible for 4X-5Y groundfish to obtain earlier estimates of recruitment, which seems a major deficiency scientifically, and in terms of advice to management. A critical part of the debate has related to the TLM versus VPA approaches, an important component of which is what the two approaches can say about recent (within last one-two years) recruitment; the answer seems to be ‘not much’. Both approaches ultimately have the limitation that they provide a measure of recruitment at least two years after they have entered the surveys. In general, fine mesh resource surveys might give the first indication of an incoming year class but the variability of the signal is quite high.

This lack of age 0 – 1 recruitment estimates provides serious problems in offering advice to management on these stocks on what is likely to happen in future years. However, establishing recruitment of cod, for example, at age 0 + to 1 would require inshore (e.g. beach seine) surveys, and would be too expensive or manpower intensive. Could correlates with environmental information be useful? From preliminary analyses, these do not appear to explain or correlate with the index of recruitment coming from VPAs. Based on climatic forcing factors shown to be important in other fisheries, both in the Pacific and the Atlantic (see literature by Beamish, Bakun and others), this seems, at first sight, a scientifically improbable result. One explanation could be that in 4X-5Y, we are not looking at a single spawning population or stock. If there is a unit spawning stock in the Bay of Fundy, which is in a warmer water regime, and others on Browns and the Scotian Shelf in a colder water regime, then one environmental signal is not likely to reflect the combined recruitment from the two stocks. If so, this raises the question as to whether or not these sub-groups in 4X-5Y should not be managed separately.

Natural Mortality (M)

The decline in M over the first two years of life, as shown for the North Sea gadoids by MSVPA shows that the natural mortality rate of ages 1-2 gadoids is higher than the 0.2 value used in the VPA, and typically is closer to 0.5-1.0. As explained by several meeting participants, since both VPA and forward projections also use M=0.2, this conscious bias may not introduce errors in retrospective analyses. It does, however, tend to create false optimism as to survival of new recruits to commercial recruitment at age 3+. Extending age-structured analyses to include trophic relationships would also require higher M-values to be acknowledged, so it seems that the main reason for using these values seems to be ‘tradition’. Several indications suggest that currently M values are higher than previously – is this due to a higher M for a younger population, or due to increased predation? If so, the question is, by what species? Unfortunately, no multispecies information was presented that might show whether the apparent 'regime shift' on the central Scotian Shelf suggested by changing growth rates and condition factors is related to changes in predator abundance or that of forage species.

Stock Rebuilding

More debate would have been desirable on the priorities for survival of different age groups in an early stock recovery situation, as currently appears to be the case. Assuming a low natural mortality for young individuals tends to lead to higher priority being given for conservation of juveniles versus conservation of older spawners. Is this appropriate in an early recovery situation? A high juvenile M implies that old fish become much more 'improbable' in terms of their chance of survival from the age of settlement from the plankton. This suggests support for some sort of refugium management strategy for older spawners. Promoting differential survival of large spawners seems appropriate in terms of their likely higher reproductive / market value, as well as from an evolutionary point of view. Interestingly, the European Community recently subscribed to this view with proposed closures to some groundfish spawning areas in the northeast Atlantic.

Parental Age

In evolutionary terms, spawning in a virgin population (prior to commencement of commercial fishing) is almost certainly heavily dominated by very large old fish. In fact, the species life cycle evolved in a situation of high parental age. Currently, mean parental age is closer to age 5+ for both cod and haddock. Can we assume that eggs from young parents are as viable as those produced at the evolutionarily-tested older parental ages? Evidence with salmonids and gadoids suggest not, casting doubt on the assumption that 'letting them spawn once before capture' is a good strategy. Genetic studies also suggest that targeting older spawners will eventually lead to earlier maturity of stunted fish. Interestingly, the opposite strategy to 'fishing out' after allowing one spawning might be to allow capture of some part of the pre-mature fish as long as escapement to a spawning refugium of a small proportion of old fish is allowed to occur. Which areas to select for closure might be aided by spatial analysis of early survey data prior to stock collapse, say in the 1950's to 1960's, should these data exist.

Mixed-Fishery Effects

Author and Rapporteur: J. Pope

On the first day of the meeting, there was discussion on the overall impacts of the fishery on the ecosystem. Related to this was the interaction between the fisheries directed on cod and haddock. While indicators of broader fishery impacts (e.g. ecological footprints) are under research, the group considered what could be done to document inter-fishery interactions with existing indicators of exploitation. The illustrative analysis below was undertaken using the fishing mortalities taken from the cod and haddock VPAs.

In Divisions 4X-5Y, decisions of the levels of fishing mortality (F) to adopt one species clearly have to consider the level of fishing mortality of other species caught in the mixed fishery. Such problems can be investigated by considering a vector diagram formed by the fishing mortality of each species in each year connected to the origin. The envelopes of this diagram indicate the most extreme ratios so far achieved between various species. This is illustrated by Figure 10 for total fishing mortality on 4X-5Y cod and haddock.

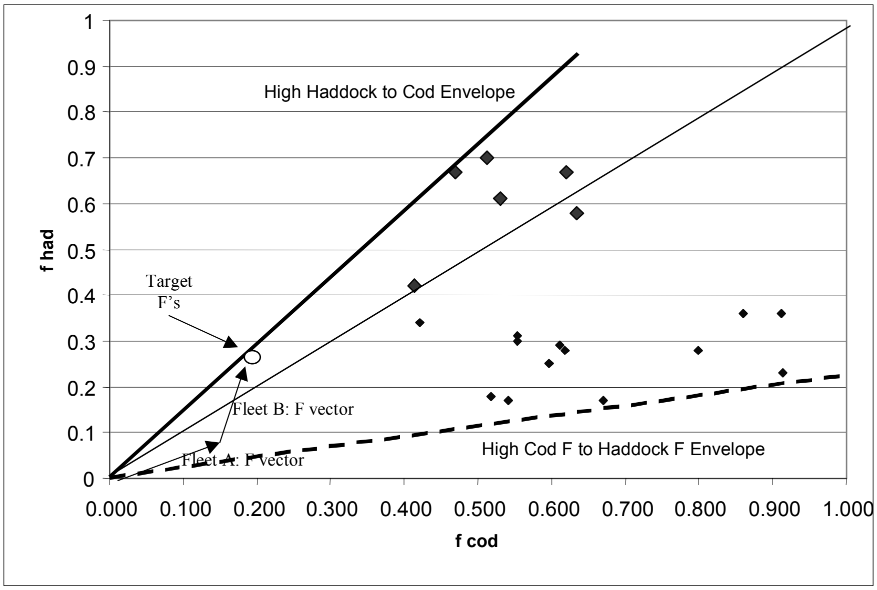

Figure 10. Fishing mortality vectors for 4X cod and haddock.

The heavier points show the fishing mortality rates in earlier years (with more even ratios) and the lighter points the more recent years (heavily slanted towards cod F). The high haddock F to cod F envelope is indicated by the heavy solid line and the high cod F to haddock F indicated by the heavy dashed line. The ellipse indicates a possible target level of cod and haddock fishing mortality.

Clearly, this figure indicates that a target of haddock F= 0.25 and cod F=0.2 is pushing the boundary of the ratio of F haddock to F cod achieved in past years, particularly recent years. While higher ratios might be possible, these would require either the development of more selective fishing gears (e.g. separator trawls), more selective fishing pattern (e.g. fishing only in places and times with relatively high haddock and low cod catches) or changes in fleet allocations. The former approaches may have implications for catches of other species in the mixed fishery (e.g. flatfish) while the latter would clearly disrupt current allocations of rights. Thus, there maybe difficulty in pushing the envelope very far and this indicates a possible constraint on how far cod fishing mortality can be reduced relative to fishing mortality on haddock.

Such diagrams could also be produced to show fleet components of the fishing mortality. Vectors of fleet partial mortality rates might be a useful way of illustrating where components of the annual fishing mortality are generated and thus the scope for ratio reductions in the various component fleets. This is illustrated in Figure 10 by the sum of sub-vectors for hypothetical fleet A and fleet B for the target mortalities.

Both forms of diagram would be useful elements of overviews of the fisheries in an area. They would help chose target fishing mortality consistent with the existing fisheries. The group discussed how best to document these inter-fleet effects at assessment time. As these involve more than one stock, it is inefficient to include the results of these analyses in both Stock Status Reports. Rather, the Fisheries Status Report (FSR) series might be usefully employed. Some stated concern for the workload in doing these analyses and favoured inclusion of these analyses in the research documents of each stock, rather than producing a separate FSR. The form of documentation of these inter-fishery effects was unresolved and will need to be so prior to the fall RAP meeting.

POTENTAIL ASSESSMENT FRAMEWORKS

Indicator Development

Rapporteur: R. O'Boyle

Two assessment frameworks were considered at the meeting, each of which might supply the indicators for the consideration matrices. The first was that of the Traffic Light Method (TLM), which proposed the summarization of all useful indicators for stock state and productivity, using a broader range of available and pertinent indicators than available to VPA. It was referred to as a mechanistic-free framework as explicit processes do not associate the indicators within the TLM tables. The second framework, as exemplified by the VPA and Forward Projection models (using AD Model Builder), were referred to as mechanistic – based because the indicators in these framework are linked through explicitly defined associations. Examples of how both frameworks could link to the FRCP decision rules were presented.

While the TLM frameworks for both 4X-5Y cod and haddock were reviewed in an expert group at the meeting, they were not presented and discussed in plenary due to time constraints. Similarly, while the VPA formulations were presented in plenary, they did not undergo a rigorous review (although no major problems were identified). These frameworks are provided in appendices 6 and 7 respectively. On the other hand, the Forward Projection Model was recognized as work in progress, and needs development before being used as a basis for assessment.

There was considerable debate on which framework should be used as the basis for assessment. It was argued that if spawning biomass (SSB) and fishing mortality (F) are key components of a management strategy, one should know, to the degree possible, their absolute levels as these relate to the biological processes of the population. For instance, one should know absolutely what a moderate level of F is. The counter argument was that management decision rules could be developed using relative indicators. Indeed, for many of the stocks on the East Coast of Canada, only relative indicators (e.g. survey number per tow) are available and management appears to be able to handle this. The advantage of the TLM approach is that it allows incorporation of indicators not easily considered in a model framework (e.g. ecosystem indicators). It was countered that, while relative indicators can be used to move an established TAC up or down, one needs to determine what the initial TAC is, which is an issue of scaling. It was also argued that models can incorporate other forms of information, the advantage being that this is then explicitly linked to some modeled process.

This led to further debate on just how absolute model results are, given previously documented problems in their behaviour (e.g. retrospective issue). Natural mortality is in itself a scalar for which there is limited information. Thus, it was argued, estimates of absolute SSB and F from models are an illusion. It was recognized that previous models had suffered problems but it was claimed that the current formulations of the two VPAs had been improved and that diagnostics were now available to assist in the determination of their adequacy.

A number of proposals were made to resolve this debate. Currently, the TLM framework incorporates indicators based on direct observations as well as model derived indicators. It was suggested that the TLM framework restrict itself to only indicators based on input data (i.e. exclude mechanistic – based indicators). A broad suite of indicators would thus be available that would put the mechanistic-based results into context. The main advantage is that such an approach can be used for all assessments, even those for which mechanistic-based assessments are unavailable. In cases where both approaches are available, their results can be compared and inferences to mechanistic-free situations made. It was argued, however, that this proposal gets away from a philosophy of the TLM approach of including as many sources of information as possible.

A related proposal was to compare the management advice produced by the two approaches over a five-year period. If in year one, the results are the same, then the TLM could be used over the longer term. Otherwise, we should understand why the results are different. However, some felt that five years was too long a period of comparison. The FRCC participants suggested a two-year comparison, again with the idea of one approach corroborating the results of the other. The counter view was held that we should be presenting one view of the resource status – our best one.

Throughout this discussion, workload of DFO science staff was stated as a constraint. The intent of establishing the assessment frameworks now was to reduce workload, not increase it, as these proposals appeared to imply. It was countered that no matter what approach is taken, the infrastructure costs (e.g. sampling and surveys) are the same. Once the framework is established, there is not a big time expenditure. What takes the time is agreeing to the framework.

The FRCC participants were asked their preferences. They stated their desire to see model (e.g. VPA) results for SSB and F. However, they were also interested in having the broader context for these data, as highlighted by the request for information on the productivity regime for the consideration matrices.

Some considered the TLM a work in progress, for which further study and research is required. For instance, along with concerns raised at this meeting, some mentioned that a number of issues had been previously raised by the RAP FMSWG and required resolution. The chairman of the pertinent FMSWG meetings however considered that the issues had been addressed. Further, there were calls for the validation of the approach through simulation study, although it was difficult to see how this could be undertaken. A contrary view was that the VPA method had been in use for about 35 years and, given the history of the east coast groundfish fishery, did not appear to provide a reliable basis for establishing the current state of stocks and future expectations. The TLM is being increasingly used in other fields, particularly environmental assessment, and the suggestion that the method was not yet well enough developed for application was challenged.

While there was not consensus, the majority opinion appeared to be that models (i.e. VPA) should be used to provide estimates of SSB and F for RAP meetings, with the TLM providing the broader context for this information.

It was agreed that DFO Marine Fish Division conduct internal meetings to resolve the issues raised with the TLM before the fall RAP meeting, as well as encourage validation efforts.

Further Consideration of the Productivity Indicators

Model – Based Indicators

Rapporteurs: J. Pope and R. Mohn

Two analytical approaches to calculating productivity indicators were considered at the meeting. The first has already been described above (see section on Production Modeling and Decision Rules by R. Mohn) and is only briefly summarized here. Another approach, which partitions productivity into its components, which facilitates comparison with the TLM Production characteristic discussed in the next section, is also presented.

Net productivity is defined as the sum of the increase in biomass (decreases taken as negative increases) between two years and the catch weight in the first year. These may be readily calculated from the results of an analytical assessment method such as VPA and displayed as productivity levels or as production rates (production divided by biomass). The former may be more appropriate if the consideration matrix is interpreted to yield TACs while the latter might be more useful if the consideration matrix is to be interpreted in terms of a harvest rate. Such measures might also be projected a few years if estimates of upcoming recruitment are available. Indeed, it is the production to be expected during the years for which TACs are to be set and perhaps subsequent years, which are most appropriate to management decisions. Hence some modest forecasting of production is desirable and indicators that might signal its trend or turning points are worth considering.

As an alternative to overall estimates of productivity, it is possible to decompose the measure into its components. Following an approach similar to that of Deriso (1980), we can write a recursive relationship for weight at age as

$$Wt(a+1,t+1)= A*Wt(a,t)+B$$

where A and B are constants.

Effectively, this is a Ford-Walford plot applied to weight at age rather than length at age. Multiplying both sides by equivalent estimates of population (using the cohort analysis formula of Pope, 1972) leads to an equation for biomass

$$\begin{aligned}Bio(t+1)= A*\{&Bio(t)exp(-M)-CatchWt(t)exp(-M/2)\} + \\ &B*\{Num(t)exp(-M)-CatchNo(t)exp(-M/2)\} + \\ &Wt(2)*Recruits(yc\ t-1) \ldots\ldots\ldots\ldots \text{Eqn. 1}\end{aligned}$$

This may then be adapted to give a formula for production

$$Production = Bio(t+1)-Bio(t)+CatchWt(t) \ldots\ldots\ldots\ldots \text{Eqn. 2}$$

Equation 1 and hence equation 2 contains elements of production as:

- Growth (A, B and W(2))
- Biomass, and its relative size composition (Bio(t) versus Number(t))
- Recruitment (t-1).
- Natural mortality rate (M)

The importance of these various factors varies between years and it is possible that observation based indices of production (e.g. in the TLM) might usefully reflect these components and their varying impacts on production. Each element could be studied in isolation with a mind to its forward prediction. Preliminary examinations suggested little systematic variation in A and B but substantial variation in W(2) as measured from commercial catches. This might not be the case for population estimates. Biomass and Number typically have persistence over a number of years when mortality rates are low. Recruitment estimates also appear to show some persistence and might perhaps be estimated up to the current year's recruitment using a combination of stock recruitment, environmental or perhaps time series predictors. Natural mortality might be linked to the abundance of known predators.

All these factors might usefully be investigated with a mind to their prediction.

Traffic Light Indicators

Rapporteur: P. Fanning

The TLM tables for both 4X-5Y cod and 4X haddock contain a characteristic termed Production, which summarize a number of indicators related to production and productivity. It was proposed to use this characteristic to define the productivity regime of the consideration matrix. The discussion focused primarily on the specifics of the cod example although much of it was applicable to both stocks. The 4X-5Y cod production characteristic includes VPA recruitment at age 3 (revised from age 1 during the meeting), RV index of recruitment (<33cm), mean weight at age 4 **,** fish condition (K) and total mortality (RV Z for ages 4-8). The mechanistic-based proposals above contained three components of production (recruitment, growth and mortality), all of which are included within the TLM Production characteristic. The two approaches are thus similar, as are the production time series. One difference was that the mechanistic-based productivity was based on rates (e.g. R, G and Z), while those of the TLM were not. It was suggested that the TLM Production characteristic could also be based in indicators that are rates rather than states. Others did not share this concern, given that all indicators are transformed into a common scale of good to bad (green to red). Further dialogue on this is required.

Recognizing that there are three components to production, there was discussion as to whether or not the weighting should be structured to give equal weight to each component (e.g. 0.33 for each of R, G and Z). Thus, if for instance, additional recruitment indicators were added to the production characteristic, the overall contribution of the recruitment component to this characteristic would remain the same. This would also provide better coherence in the interpretation of production amongst different stocks. The practice has been to weight the indicators within a characteristic by the subjective evaluation of the relevance of the indicator to the characteristic. It was felt that variability is better accounted for in the colour boundaries although it could be a factor in assigning weights as well. It was agreed that the impact of alternative weighting decisions should be examined.

Area of occupancy was proposed as a production indicator but did not garner much support. It was not evident what the biological rationale for its inclusion would be. An indicator of age structure was also proposed for inclusion in the production characteristic (one was already included in the abundance characteristic). No specific indicator was examined although various fractions in age classes were mentioned. It was noted that the FRCC considered this a significant issue. It felt that, with weighting of 0.5, it was underrated.

While a number of issues with the TLM production characteristic require further discussion, it was considered that both the TLM production characteristic, and the mechanistic-based productivity, as described in the previous section, could form the basis of a narrative on the Productivity Regime.

DECISION RULES

4X-5Y Cod Consideration Matrix

Rapporteur: D. Clark

There was considerable discussion on the implications of a TAC, established in each cell of the consideration matrix, on fishing mortality. As noted earlier, a constant TAC over a given biomass range implies a saw-toothed F, peaking at about 0.2 in each cell. It was argued however that, given the uncertainty of F, such as sawtooth would be an illusion and that the 16 – 20% range proposed by the FRCC was appropriate. An F in the order of 0.2 was considered moderate at higher biomass.

At lower biomass, the minimum 6kt TAC proposed by the FRCC was felt to be contrary to the goal of rapid growth when biomass is low. It was generally considered appropriate to reduce F at low population biomass to increase population growth rate. It was suggested that the benefit of ramping down F when appropriate be noted in the assessments. The assessments would state the implications on F of both a constant and ramped F strategy at lower biomass. The ‘banana plots’ showing the two F strategies - one flat and one ramped (Figure 8b) might be useful in this regard. Cod in 4X are largely mature by age 3, and thus, contrary to the FRCP proposal, it was suggested that age 3+ rather than age 4+ biomass from the VPA should be used for stock condition. Given the historical use of age 4+ biomass, the FRCC was concerned in this change. Further dialogue with the FRCC on the rationale for this change is warranted.

As noted during the presentation on the second day, knowledge of stock dynamics below 25kt age 3+ biomass is rudimentary; it is uncertain what would happen to the resource at these levels. Thus, below this, it was suggested that fishing should be minimal by closing the directed fishery (i.e. by-catch fishery only) as proposed by the FRCC. At the higher end, 75kt was suggested as an end point for the ramp.

It was noted that projection calculations explicitly account for population age structure, something the consideration matrix is not designed to address. Projections would have to be done in terms of fishing mortality rate and a TAC calculated from this. Projections using the results of mechanistic models are only relatively reliable for one-two years into the future. Beyond that, it might be better to rely on narratives of the general trends in stock condition and productivity.

A number of suggestions were made relating to the productivity regime. It could be characterized by a narrative based on:

- Production Characteristic from the TLM: A number of indicators were proposed for this characteristic although further work is required (see section above on TLM productivity indicators).

- Current production from population model e.g. VPA or Forward Projection Model: 1) relative production (rate) and 2) production over time giving current state in relation to historical levels. There appears to be 'memory' in the production regime, so recent past production may be a reasonable predictor of short-term expected production

The indicators below were also discussed for possible inclusion in this narrative. However, some are already included in the TLM and could perhaps be included in its Production characteristic:

- Age structure: Lack of older fish in the population would be considered negative, given their contribution to recruitment. Cod population structure at equilibrium (assuming F=0.2) gives 5% age7+. The observed age structure would be considered in relation to this.

- Area of occupancy: Design weighted area of occupancy, as measured for the RV survey has generally fluctuated around 60% for the past two decades while SSB has been 30-50kt. For the past 5 years, the ITQ survey area of occupancy (% non-zero sets) has been 70-80%. Below 60% for the RV and 75% for the ITQ would be considered indicative of low productivity.

- Temporal trends in R/SSB: Periods of low or high relative productivity would be detected from the R/SSB plots and in residuals of R/SSB from S/R plot.(perhaps related to changes in environmental regime).

- Condition: It has been proposed that poor condition has resulted in increased mortality or impaired recruitment in other cod stocks. This has not been observed for 4X-5Y cod. A large drop in condition below the observed range would be interpreted as a warning of poor productivity.

4X-5Y Haddock Consideration Matrix

Rapporteur: P. Hurley

The production analysis presented at the meeting suggested that haddock spawning biomass and yield did not vary with fishing mortality as markedly as it did for cod. Choosing a reference F would be more subjective for haddock because the Y/R is less peaked than for cod. The analyses suggested that a moderate F was in the range of 0.2-0.25, about the same used in the FRCP.

There was agreement that age 4+ biomass from the VPA could be used for stock condition. As our knowledge of stock dynamics below 20kt biomass is rudimentary, below this, fishing should be minimal by closing the directed fishery (i.e. bycatch fishery only), as proposed by the FRCC. There was no support for a ramped F approaching this level, in contrast to cod, and there appeared to be no need for stock condition binning – two biomass ranges appeared sufficient. Exploitation rate would be the same across the bins, using 2kt TAC increments. The FRCC could choose to use bins as it wished. There were comments suggesting that we should not fixate on F; we did not need to get it "right" every year. It was pointed out that this was to be a five-year plan and that if rebuilding was successful and the 2kt increments proved to be too small, they could be revisited.

Regarding productivity, there was a suggestion that recruitment variability of haddock was likely defined by environment, not SSB, and that we should consider using environment to adjust production levels in the consideration matrix. It was noted that we need to watch growth very carefully in this resource, given the disturbing trends in size at age. Otherwise, the comments made above on 4X cod could also apply to 4X haddock.

FORM OF SCIENTIFIC ADVICE

This section provides comments made on the display of the scientific advice that could be made in the assessments of 4X-5Y cod and haddock.

Stock Condition and Productivity

The consideration matrix is a tool that the FRCC may use to guide its decisions. The role of the scientific advice is to quantify or at least qualify the implications of alternative TACs in relation to the stated strategy of keeping fishing mortality at moderate levels. For the mechanistic-based approaches, that information could be summarized in a form illustrated by Figure 8 or similar representations. This shows how key indicators respond to alternative TACs.

Another form discussed at the meeting is to display the most recent period's stock condition and productivity information (the marginals of the consideration matrix) in three dimensions (Figure 11). This allows an impression of the variability of the perceived stock condition/productivity status

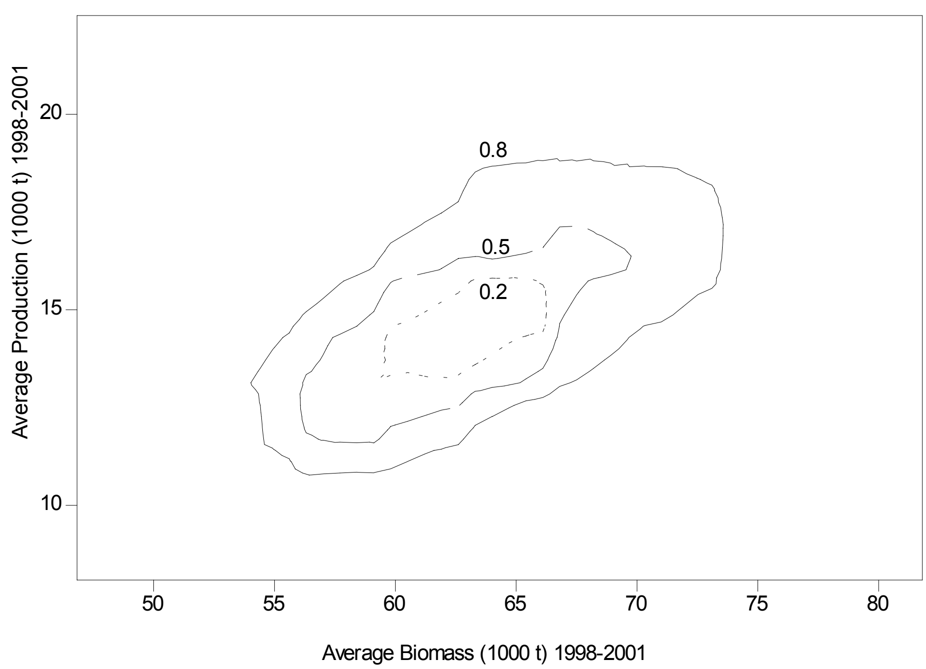

Figure 11. Average surplus production and total biomass for 4X haddock for the last 4 years; contours are 20%, 50% and 80% of the total volume.

Diagnostics for Assessment Methodologies

Rapporteurs: R. Mohn and D. Kehler

The meeting considered the diagnostics that could be examined on a routine basis to ensure that the assessment frameworks are behaving appropriately. The assessment methodologies considered included age-structured analytical models using VPA and AD Model Builder technology, and the Traffic Light Method.

There are two levels of diagnosis to be considered -- the amount needed for scientific review and the amount needed to assess the quality of the assessment. For scientific review, alternative model formulations need to be examined, as well as sensitivity to particular data inputs.

To evaluate internal model consistency, useful measures from the mechanistic-based models would include:

1. Time series of
   - SSB
   - F
   - Recruitment
   - Production (change in biomass + yield)
   - Projected biomass in the next year

These time series would include an estimate of the error. For the VPA, these estimates are based on non-parametric or semi-parametric bootstrapping of residuals. For the ADMB approach, the time series would consist of the mode and 80% credible intervals from the posterior of the parameter in each year. For two-dimensional data, joint confidence regions (halo plots) can be produced.

2. Residual plots of fits to the total catch and catch-at-age RV and commercial (where applicable) data. Two examples of residual plots are given. The first (Figure 12) shows the residuals as expanded symbols, + for positive residuals and filled circles for negative.

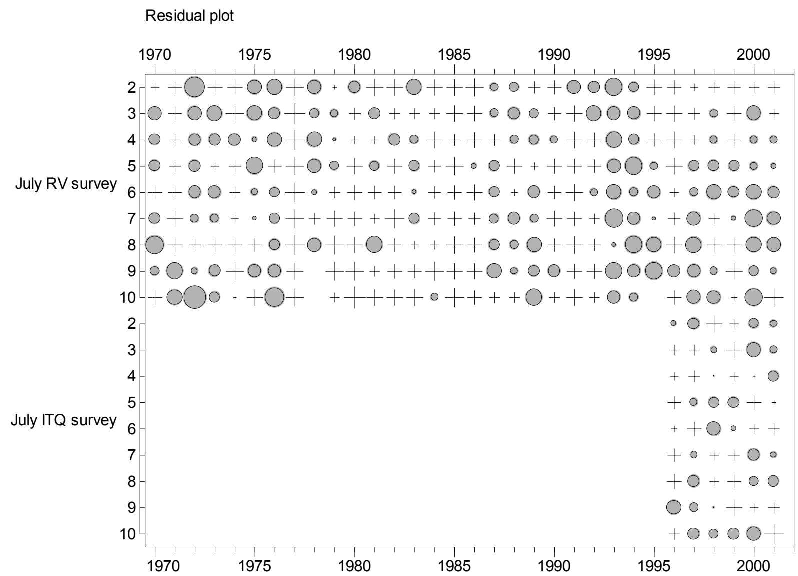

Figure 12. Sample residual plots for 4X-5Y haddock using expanded symbols. The upper panel is average F over ages 2-10 and the lower is biomass summed over the same ages.

Similarly, if the survey data at age are divided by the q for each age-survey they may be compared to the population estimates. In Figure 13, the surveys and model population numbers are summed over ages 2-10 to show how well the model fits the data.

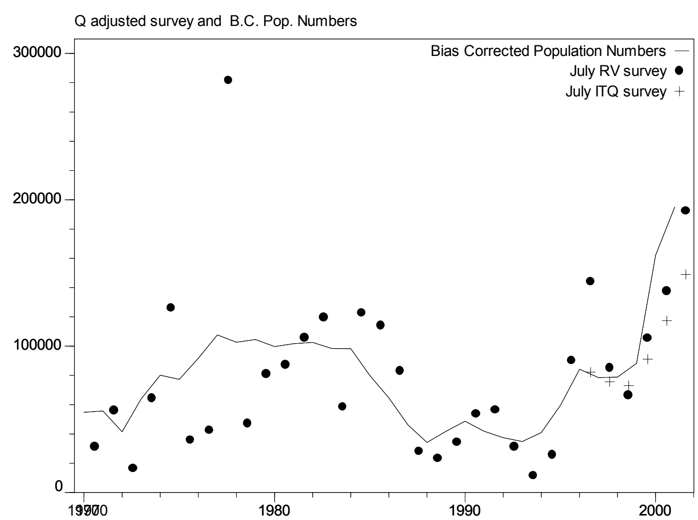

Figure 13. Sample diagnostic plots of the model fit to q for 4X haddock. The upper panel is average F over ages 2-10 and the lower is biomass summed over the same ages.

3. Retrospective plots that include the next year's projections. This will identify any retrospective problems, and in particular, biases in the projections for next year.

Retrospective plots include "spaghetti" and "lasagna" plots. Sample of spaghetti plots are shown in Figure 14.

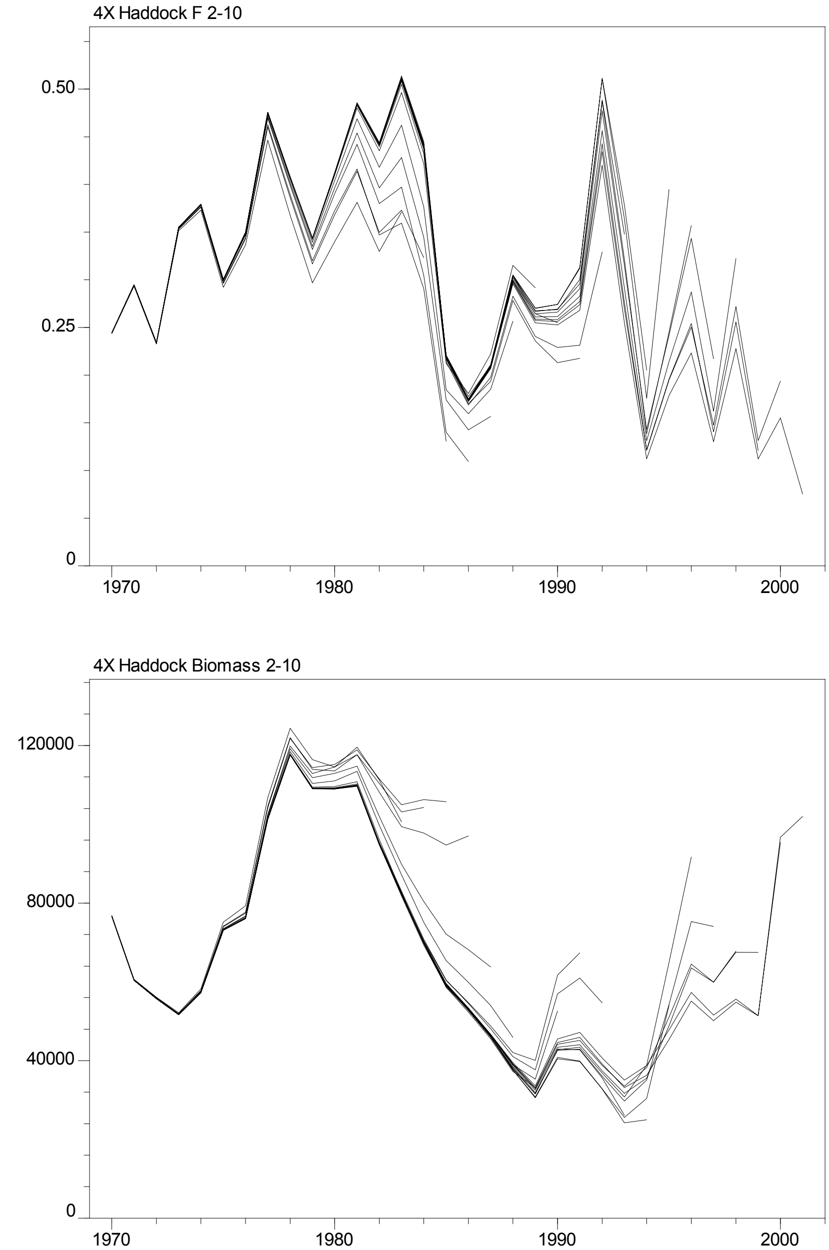

Figure 14. Sample retrospective plots for 4X-5Y haddock. The upper panel is average F over ages 2-10 and the lower is biomass summed over the same ages.

The question of diagnostics for the Traffic Light Method still needs consideration. One approach would be a sensitivity analysis on inclusion/exclusion of indicators. Another would be scatter plots of pairs of indicators to see how they interact. As the TLM is largely an additive model, another consideration might be some sort of analysis of variance. Also, there may be established methods that have been derived for Fuzzy Logic, but were not presented at this meeting.

Content of the Stock Status Report

Rapporteur: D. Gillis

On behalf of the FRCC, J.-G. d'Entremont tabled a list of additional SSR information products for consideration (Appendix 8), which included a series of indicators for judging the current productivity regime, further information on spawning activities, and an extended outlook/projection provision. He explained that these items would benefit the Council in implementing those parts of the FRCP leading to conservation and TAC recommendations, particularly the consideration matrix.

In the ensuing discussion, it was noted that a number of the specific items, such as the recruitment plots, age structure comparisons, reproductive indices and other biological indicators, were either already available or could be readily produced from existing datasets and spreadsheets. Also, as a consequence of this meeting, much of this information would be provided through the assessments.

Regarding Environmental Factors (#4), several researchers questioned whether the Council expected the Department to provide answers or just the data; and if the latter, were concerned with how the Council would use that data. Science staff indicated a preference for them providing the answers based on critical analysis, albeit it may take time and additional resources to do so. Council members noted that few results were now available in spite of DFO efforts to date, and suggested the environmental data could be used directly by them to help characterize and understand what fishermen were saying to the Council about the environment during consultations. It was pointed out by the Chair that the annual review of environmental conditions produced by K. Drinkwater would provide much of what was needed for that purpose, however, he feared the intra-specific information (ie: predator/prey) requested may exceed what is available.

Regarding the request for extended outlooks, the Council clarified that the purpose was not to support multi-year advice on TACs, but to provide a longer-term context for current recommendations. A distinction was made between 3-year quantitative projections (which would be highly uncertain), and a more qualitative extended outlook based on recent trends in parameters such as growth, recruitment and mortality (which it was agreed was likely feasible).

Opinion was offered that unless the Council had a clear rational for why extra information is needed and how it will be used, it would be difficult to make any additional analysis a priority.

It was agreed that an FRCC / MFD working group review this list in more detail before the fall RAP meeting to develop a mutually agreed list of information products necessary for the FRCC to properly deliberate these stocks. W. Stobo and J.-G. D'Entremont were to interact on setting this up.

ASSESSMENT FRAMEWORK TRIGGERS

Rapporteur: R. Stephenson

The intent of the benchmark or intensive stock assessment process is to review and agree upon methods that would be used for several years. It would be logical, then, that the next benchmark for these stocks not take place for several years (2005 at the earliest) unless:

1) the assessment was performing poorly, or
2) a benchmark meeting was deemed necessary after consultation between the RAP office and clients

It was recognized (when the terms of reference were being developed) that several elements of a full benchmark evaluation could not be covered in this meeting, and that this would likely result in the need for an earlier review of some aspects of the 4X-5Y cod and haddock assessments.

CONCLUDING REMARKS

This RAP meeting was a first in that it considered both the decision rules proposed by a DFO client (the FRCC) to provide advice on two resources and the assessment frameworks to supply the indicators for these rules. It was an ambitious agenda with many issues discussed and debate on points of contention. While all components of the remit were discussed, few of the issues were resolved, requiring follow-up work. Nevertheless, the meeting was successful in bringing many of these issues to the table, discussing and debating as many as it could and indicating areas of further work.

REFERENCES

Anon. 2001. Fisheries and Oceans. National Stock Assessment Review. Final Report. Manuscript: 79pp.

Caddy, J.F. 2002. Limit Reference Points, traffic lights, and holistic approaches tp fisheries management with minimal stock assessment input. Fisheries Research. 56: 133–137.

Campana, S. and J. Simon. 1986. Assessment of the 4X Cod Fishery in 1985. CAFSAC Res Doc. 86/35.

Clark, D.S., S. Gavaris, and S.D. Paul. 2000. Assessment of Cod in Division 4X in 2000. CSAS Research Document 2000/139. 72p.

Deriso, R.B. 1980. Harvesting Strategies and Parameter Estimation for an Age-Structured Model. Can. J. Fish. Aquat. Sci. 37: 268-282p.

Garcia, S. M., and D.J. Staples. 2000. Sustainability Reference Systems and Indicators for Responsible Marine Capture Fisheries: a review of concepts and elements for a set of guidelines. Mar. Freshwater Res. 51: 385-426.

Jamieson, G., R. O'Boyle, J. Arbour, D. Cobb, S. Courtenay, R. Gregory, C. Levings, J. Munro, I. Perry, and H. Vandermeulen. 2001. Proceedings of the National Workshop on Objectives and Indicators For Ecosystem-based Management. Sidney, British Columbia, 27 February – 2 March 2001. CSAS Proceedings 2001/009.

McAllister, M.K., E.K. Pikitch, A.F. Punt, and R. Hilborn. 1994. A Bayesian approach to stock assessment and harvest decisions using the sampling/importance resampling algorithm. Can. J. Fish. Aquat. Sci. 51: 2673-2687.

Pope, J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. ICNAF Research Bulletin 9: 65–74.

Punt, A.E, and R. Hilborn. 1997. Fisheries stock assessment and decision analysis: the Bayesian approach. Rev. Fish Biol. Fish. 7: 35-63.

Shepherd, J.C. 1982. A Versatile New Stock-Recruitment Relationship for Fisheries, and the Construction of Sustainable Yield Curves. J. Cons. Int. Explor. Mer. 40: 67-75.

Sissenwine, M.P. and J.G Shepherd. 1987. An Alternative Perspective on Recruitment Overfishing and Biological Reference Points. Can. J. Fish. Aquat. Sci. 44: 913–918.

APPENDICES

Appendix 1. Meeting Remit

Objectives

The RAP will

- Review relevant information on 4X cod and haddock to develop the stock assessment frameworks to be used until the next review. These frameworks will be first used in the fall 2002 RAP to provide assessments in support of the 2003/04 fishery.

- Review relevant information to respond to a request made by the FRCC (5 September 2001) to DFO Maritimes Science for feedback on proposed indicators of stock and ecosystem system status.

For both 4X cod and haddock, the review will:

- Characterize the relationships among stock status, productivity and exploitation, by

  - Reviewing existing and / or developing new indicators used to characterize stock status and productivity and examining how these vary over a range of stock conditions

  - Reviewing indicators that measure the impact of ecosystem (i.e. abiotic and biotic) and human (i.e. non-groundfish fisheries) factors on the productivity of these stocks

  - Relating the agreed set of indicators to indicators of exploitation, identifying conservation limits and other reference points (e.g. closing and re-opening criteria)

  - Examining the performance of proposed decision rule (e.g. in the FRCP of FRCC and DFO) formulations and providing guidance on their strengths and weaknesses for use in management

- Provide a suite of indicators to measure the extent of impact of 4X cod and haddock fisheries on the ecosystem, by

  - Considering indicators of the mortality of non-target species, particularly species at risk

  - Considering indicators that measure the disturbance of benthic communities

- Describe the stock assessment framework to be used until the next review and identify factors that would trigger a review ahead of schedule

Products

A Proceedings will be produced, which will document the details of the 4X cod and haddock assessment frameworks and summarize the discussion of the meeting. This will also include an outline of the Stock Status Reports that would be produced.

Participation

Participation will be solicited from the following:

- DFO Science & Fisheries Management
- FRCC
- Industry
- Non-DFO scientists

Appendix 2. Meeting Agenda

Monday, 10 June 2002

Background

09:00-09:20 Introduction, Remit, agenda (O'Boyle)

09:20-09:40 Background: DFO's Objective-Based Fisheries Management (Annand)

09:40–10:00 Background: FRCC's Fisheries Resource Conservation Plans (Lane)

10:00-10:15 Break

Assessment Frameworks

10:15-12:00 4X Haddock Assessment Framework (Hurley)

12:00-13:00 Lunch

13:00-15:00 4X Cod Assessment Framework (Clark / Fanning)

15:00-15:15 Break

Fishery & Ecosystem Indicators

15:15-17:00 Fishery Interactions & Impacts (Zwanenburg)

16:00-17:00 Discussion

Tuesday, 11 June 2002

Decision Rule - Related Analyses

08:30-09:30 FRCC Approach to Decision Rules: the FRCP (Lane)

09:30-10:30 Fuzzy Logic Approach to Decision Rules (Fanning)

10:30–11:00 Break

11:00-12:00 Production Modeling & Decision Rules (Gavaris)

12:00-13:00 Lunch

13:00-14:00 Production Modeling & Decision Rules (Mohn)

14:00-15:00 Integrated Assessment & Production Modeling (Gibson & Kehler)

15:00-15:15 Break

15:15-17:00 Discussion

Wednesday, 12 June 2002

Re-Analyses

0830-10:00 Analyses & Discussion on Frameworks & Decision Rules

10:00–10:15 Break

10:15-12:00 Analyses & Discussion on Frameworks & Decision Rules

12:00-13:00 Lunch

13:00-15:00 Analyses & Discussion on Frameworks & Decision Rules

15:00-15:15 Break

15:15-17:00 Analyses & Discussion on Frameworks & Decision Rules

Thursday, 13 June 2002

Re-Analyses

08:30-10:15 Reconsideration of Assessment Frameworks & Fishery Interactions

10:15–10:30 Break

10:30-1200 Reconsideration of Assessment Frameworks & Fishery Interactions

12:00-13:00 Lunch

13:00-15:00 Reconsideration of Assessment Frameworks & Fishery Interactions

15:00-15:15 Break

15:15-16:00 Form of Scientific Advice

16:00-17:00 What Triggers Next Assessment Framework Review

Friday, 14 June 2002

Report Preparation

08:30-10:00 Report Compilation

10:00–10:15 Break

10:15-12:00 Report Review

12:00-13:00 Lunch

13:00-15:00 Report Review

15:00 Meeting Adjournment

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Appendix 4. Letter of Invitation to Participants

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17 May 2002

Subject: <u>4X Cod & Haddock RAP in St. Andrew's, NB</u>

Dear X,

First let me start by thanking you for accepting my invitation to participate in the Regional Advisory Process (RAP) meeting to review the assessment frameworks of 4X cod and haddock, to be held during 10 – 14 June 2002 at the Conference Centre of the Biological Station, St. Andrew's, NB. The meeting promises to be quite interesting, as it will delve into the inner workings of the approaches to be used to assess these two valuable resources off Southwest Nova Scotia.

The remit of the meeting is attached. You will note that we are not conducting the assessments of these resources at this meeting but rather considering the approaches on how they are to be assessed. As well, we will be examining the performance of proposed decision rule systems. The results of the meeting will also be used to respond to a request made by the FRCC last September.

The agenda is still being developed and will be available within the next week or so. Please note that the meeting will start at 9:00am sharp on Monday morning, June 10th . Generally, the meeting will start on the first two days with presentations on the proposed assessment approaches and decision rule systems, with the last day devoted to report drafting. The middle two days will further investigate the issues raised during the first two days. We expect to end on Friday afternoon (June 14th) at 3:00pm to allow travel time.

I enclose a number of documents as background for the meeting.

Stock Assessments

The latest complete or full assessments of cod and haddock were conducted in 2000 and 1999 respectively. I enclose the two research documents describing these assessments.

Over the last few years, scientists in the Maritimes Region have been investigating use of the Traffic Light approach as the basis for the assessments. I enclose a research document prepared by Ralph Halliday, Paul Fanning and Bob Mohn, which outlines regional progress on this approach so far. While it has not been used in 4X cod or haddock so far, it has been used most recently (fall 2001) for 4TVW haddock, which is probably its most extensive application to date. I thus enclose the 4TVW haddock Stock Status Report and supporting Research Document to provide an idea of the potential applications to be considered at this meeting.

Decision Rules

As part of its Fisheries Management Plan initiative, DFO has committed itself to outlining the objectives, strategies and management measures used to control harvesting. Decision rule approaches are being considered as a part of this. In its Fisheries Resource Conservation Plan (FRCP) initiative, the Fisheries Resource Conservation Council (FRCC) has been considering and developing, jointly with industry, such decision support systems. The latest draft FRCP for 4X cod and haddock is enclosed, along with a background document describing a simulation based on 4X cod. The enclosed disc has the excel files used in the simulation. The Council has made great progress in this area and it will be very instructive to consider its work at this meeting.

The issue of conservation limits and other reference points will be raised at the meeting, subjects discussed at a December 2001 national DFO workshop. I therefore enclose the Proceedings of this meeting for background.

Working papers to address the various parts of the remit are currently under preparation. As these become available, I will circulate to you as soon as possible. I can't emphasize too much the importance of participants familiarizing themselves with the content of these reports and the background documents prior to the meeting. We have a lot of material to cover in the week and the more preparation before the meeting, the better.

If you have any logistical questions on the meeting, please don't hesitate to contact Valerie Myra at the RAP Office (902.426.7070).

I look forward to seeing you in St. Andrew's

Sincerely,

Original Signed by:

Robert O'Boyle

Appendix 5. List of Documents

Anon. 2002a. Executive Summary of Groundfish Management Plan. Scotia-Fundy Fisheries Maritimes Region.

Anon. 2002b. Fisheries Resource Conservation Plan. 4X5Y Cod & Haddock. Draft revised 171001. FRCC Report: 13p.

Anon. 2002c. FRCC Terms of Reference.

Anon. 2002d. Inputs into the Evaluation of Division 4X5Y Haddock. Maritimes RAP Working Paper 2002/18: 50p.

Anon. 2002e. 4X Haddock Stock Status Indicators and Traffic Light Table. Maritimes RAP Working Paper 2002/39: 14p.

Anon. 2002f. Fisheries Resource Conservation Plan. 4X5Y Cod & Haddock. TAC Rules and Historical Application Test of the Plan. FRCC Report: 11p.

Clark, D.S. 2002. 4X Cod Assessment Draft June 10, 2002. Maritimes RAP Working Paper 2002/40: 47p.

Clark, D.S., S. Gavaris, and S.D. Paul. 2000. Assessment of Cod in Division 4X in 2000. CSAS Research Document 2000/139: 72p.

Colbourne, E.B., K. Drinkwater, and D. Gilbert. 2002. Environmental Data and Climate Indices for the Northwest Atlantic. A Fisheries Oceanography Committee (FOC) CSAS Research Document 2002/086: 35p

Fanning, P. 2002. Application of Decision Rules in 4X Cod Traffic Light Assessment. Based on FRCC Fisheries Resource Conservation Plan. Maritimes RAP Working Paper 2002/30: 11p.

Fanning, P., and D. Clark. 2002. 4X Cod Traffic Light Table. Assembly of Existing Indicators Maritimes RAP Working Paper 2002/42: 6p.

Gavaris, S. 2002b. Formulation of Fisheries Management Advice for Keeping Fishing Mortality at Moderate Levels. Maritimes RAP Working Paper 2002/28: 13p.

Gibson, A.J.F., D.G. Kehler, and R.A. Myers. 2002. An Integrated Stock Assessment and Risk Analysis Framework for 4X Haddock. Maritimes RAP Working Paper 2002/27: 36p.

Halliday, R.G. 2002. Fishery Management Decision Frameworks: A Case Study for Scotian Shelf Groundfish. Maritimes RAP Working Paper 2002/32: 12p.

Halliday, R.G., L.P. Fanning, and R. K. Mohn. 2001. Use of the Traffic Light Method in Fishery Management Planning. CSAS Research Document 2001/108: 41p.

Hurley, P.C.F., G.A.P. Black, P.A. Comeau, and R.K. Mohn. 1999. Assessment of 4X Haddock in 1998 and the first half of 1999. CSAS Research Document 1999/147: 80p.

Mohn, R. 2002. Production Modeling and Decision Rules. Maritimes RAP Working Paper 2002/31: 14p.

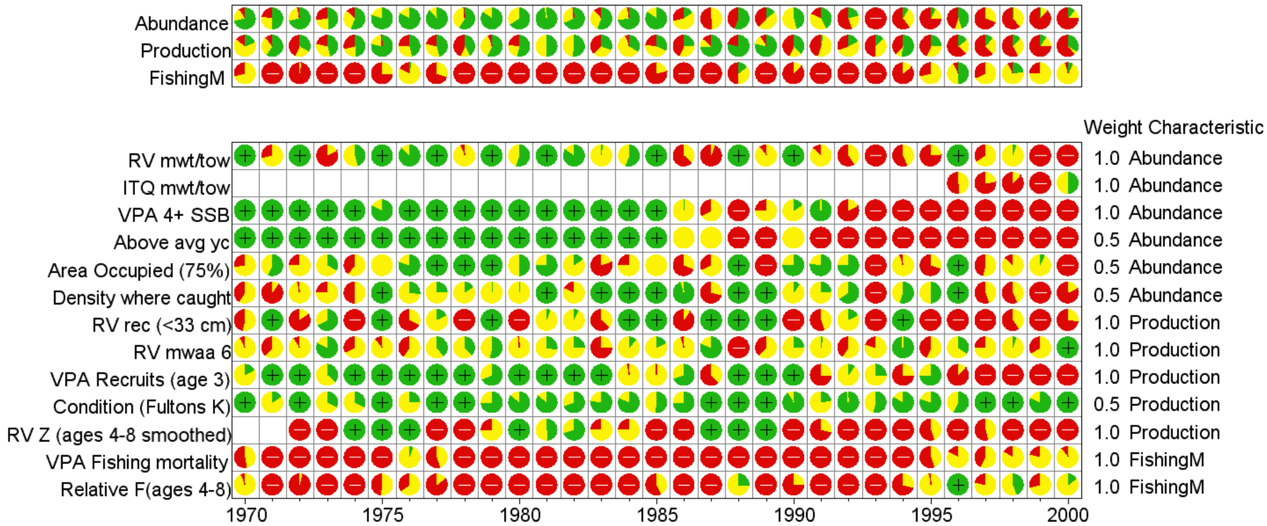
Zwanenburg, K., and M. Showell. 2002. Ecosystem–Based Management of Human Activities in Marine Ecosystems: Context and estimation of catch profiles and ecological footprints for fisheries – preliminary analyses. Maritimes RAP Working Paper 2002/43: 39p.

Appendix 6. Traffic Light Tables for 4X Cod and Haddock

4X Cod
Rapporteur: D. Clark

A description of the TLM table for 4X cod including stock status indicators, the boundary points, and the weighting used for integrating indicators into characteristics are given in the following table and figure. These were developed by the Expert Group during the meeting.

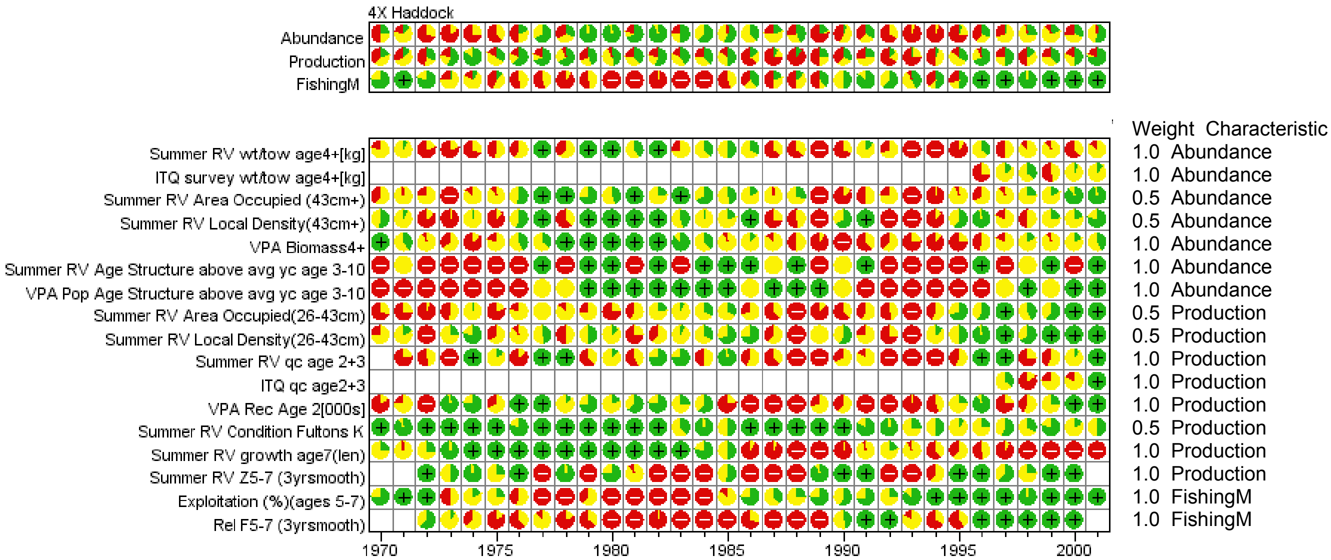
Indicator	Green Boundary	Red Boundary	Characteristic	Weight
Summer RV mean wt per tow	18: Consistent with the highest values	10: Consistent with the low abundance years in the 1990s.	Abundance	1
ITQ mean catch per tow	55: This is a short time series and thus its true range is uncertain. The green value was set a little above the highest observed in the time series in order to make this uncertainty explicit	15: Consistent the low end of the data series.	Abundance	1
VPA SSB (3+)	45000: Target SSB specified in FRCP	25000: Unacceptable limit SSB	Abundance	1
Above Avg yc (VPA)	4: As specified in FRCP	2: Set at half the FRCP target	Abundance	0.5
Area Occupied by 75% of survey numbers	0.45: Consistent with widest distribution	0.35: Consistent with narrowest distribution	Abundance	0.5
Density where caught	2: Consistent with highest density	1.5: Consistent with lowest density	Abundance	0.5
RV recruitment (<33cm)	1.0: Consistent with the largest recruitment pulses	0.4: Consistent with the smallest observed values	Production	1
RV mean weight at age 4	3.0: Consistent with the largest observed sizes	1.5: Consistent with the smallest observed sizes	Production	1
VPA recruits	16,000: Consistent with the largest recruitment pulses	10,000: Consistent with the smallest observed values	Production	1
Condition (Fultons K)	1.0: Consistent with largest observed	0.90: Set to ensure there is no red in this indicators (ie no critical impact)	Production	0.5
RV Z (ages 4-8) smoothed	0.4: FRCP Limit F + Assumed M	0.6: Twice FRCP limit F + assumed M	Production	1
Relative F (ages 4-8)	0.2: Boundary chosen for consistency in the 90's with the VPA F	0.8: Boundary chosen for consistency in the 90's with the VPA F	Fishing Mortality	1


Abundance
Production
FishingM
Weight Characteristic
RV mwt/tow
ITQ mwt/tow
VPA 4+ SSB
Above avg yc
Area Occupied (75%)
Density where caught
RV rec (<33 cm)
RV mwaa 6
VPA Recruits (age 3)
Condition (Fultons K)
RV Z (ages 4-8 smoothed)
VPA Fishing mortality
Relative F(ages 4-8)
1.0 Abundance
1.0 Abundance
1.0 Abundance
0.5 Abundance
0.5 Abundance
0.5 Abundance
1.0 Production
1.0 Production
1.0 Production
0.5 Production
1.0 Production
1.0 FishingM
1.0 FishingM
1970
1975
1980
1985
1990
1995
2000

4X Haddock
Rapporteur: P. Hurley

A description of TLM table for 4X haddock, including stock status indicators in the TLM table for 4X haddock, the boundary points, and the weighting used for integrating indicators into characteristics are given in the following table and figure. These were developed by the Expert Group during the meeting.

Indicator	Green Boundary	Red Boundary	Characteristic	Weight
Summer RV wt per tow age 4+ (kg)	40: Consistent with highest observed	10: Consistent with lowest observed	Abundance	1
ITQ survey wt per tow age 4+	30: This is a short time series and thus its true range is uncertain. The boundaries were set wide in order to make this uncertainty explicit	20	Abundance	1
Summer RV Area Occupied 43cm+	0.48: Consistent with highest observed	0.3: Consistent with lowest observed	Abundance	0.5
Summer RV Local Density 43cm+	2.5: Consistent with highest observed	2: Consistent with lowest observed	Abundance	0.5
VPA biomass age 4+	55000: Target SSB specified in FRCP	20000: Unacceptable limit SSB	Abundance	1
Summer RV Age Structure above avg yc age 3-10	4: Target specified in FRCP	2: Set at half FRCP target	Abundance	1
VPA pop Age Structure above avg yc age 3-10	4: Target specified in FRCP	2: Set at half FRCP target	Abundance	1
Summer RV Area Occupied (26-43cm)	0.4: Consistent with highest observed	0.2: Consistent with lowest observed	Production	0.5
Summer RV Local Density (26-43cm)	3.2: Consistent with highest observed	1.6: Consistent with lowest observed	Production	0.5
Summer RV q-corrected numbers age 2+3	100,000: Consistent with highest observed	10,000: Consistent with lowest observed	Production	1
ITQ survey q-corrected numbers age 2+3	100,000: Consistent with highest observed	10,000: Consistent with lowest observed	Production	1
VPA Rec age 2	40,000,000: Consistent with highest observed	10,000,000: Consistent with lowest observed	Production	1
Summer RV Condition Fultons K	1.04: It is unlikely that K values in the range observed were low enough to have affected reproductive success or mortality, but they do reflect reductions in production	0.98	Production	0.5
Summer RV length at age 7 (cm)	60: Consistent with highest observed	50: Consistent with lowest observed		1
Summer RV Z age 5-7 3yr smooth	0.45: Based on Target F + M (0.2)	0.65: Twice Target F + M (0.2)	Production	1
Exploitation (%) (age 5-7)	0.2: Moderate F level	0.4: Twice F limit	Fishing Mortality	1
Relative F (Age 5-7) 3yr smooth	0.25: Consistent with lowest observed	0.45: Consistent with lowest observed	Fishing Mortality	1


4X Haddock
Abundance
Production
FishingM
Summer RV wt/tow age4+[kg]
ITQ survey wt/tow age4+[kg]
Summer RV Area Occupied (43cm+)
Summer RV Local Density(43cm+)
VPA Biomass4+
Summer RV Age Structure above avg yc age 3-10
VPA Pop Age Structure above avg yc age 3-10
Summer RV Area Occupied(26-43cm)
Summer RV Local Density(26-43cm)
Summer RV qc age 2+3
ITQ qc age2+3
VPA Rec Age 2[000s]
Summer RV Condition Fultons K
Summer RV growth age7(len)
Summer RV Z5-7 (3yrsmooth)
Exploitation (%)(ages 5-7)
Rel F5-7 (3yrsmooth)
1970
1975
1980
1985
1990
1995
2000
Weight Characteristic
1.0 Abundance
1.0 Abundance
0.5 Abundance
0.5 Abundance
1.0 Abundance
1.0 Abundance
1.0 Abundance
0.5 Production
0.5 Production
1.0 Production
1.0 Production
1.0 Production
0.5 Production
1.0 Production
1.0 Production
1.0 FishingM
1.0 FishingM

Appendix 7. VPA Assessment Frameworks for 4X Cod and Haddock

4X Cod
Rapporteur: D. Clark

The management unit is defined as 4X and Canadian portions of 5Y. Growth differences and results from tagging studies distinguish cod in 4X from those to the east. Stock structure information available on Western Atlantic cod stocks was summarized in the 1962 NAFO Redbook (Templeman 1962). Information from tagging studies, along with vertebral counts and parasite studies were used to identify six cod spawning populations in 4X. Templeman (1962) concluded that stocks in the 4X area, apart from the Halifax harbour spawning stock, were largely distinct from those in adjacent NAFO areas. Coastal stocks in 5Y, along with coastal Nova Scotian stocks were considered to be largely sedentary. Browns Bank cod (offshore 4X) were thought to be distinct from coastal cod (including the Bay of Fundy). Georges Bank spawning cod were also considered separate, although with some variable degree of mixing into 4X. Due to the apparently high degree of mixing among 4X spawning populations, and the difficulty in resolving landings among these groups, cod in 4X and Canadian portions of 5Y were assessed as a single stock for management purposes beginning in 1985 (Campana and Simon, 1986). More recent analyses of tagging data support the conclusion that cod populations within this management area are fairly discrete from adjacent areas, although there is clearly some mixing with cod in Division 5. Studies are ongoing on the amount of mixing among populations within the management area.

Characteristics of the fishery, including commercial landings and sampling for length and age have been summarized in Clark et al (2000). Commercial samples are available for 4X cod from all years since1947. Sampling intensity, however, was very low in the 1960’s and 1970’s, with no samples available from the Bay of Fundy in many of these years, and has been considered insufficient to derive a reliable catch at age. While estimates of individual year-class strengths through this time-period may be imprecise, they are sufficient for examining long-term trends in recruitment. Sampling since 1980 has been sufficient for characterizing the landings.

Throughout this period age-length keys have been derived by quarter separately for the Scotian Shelf (4Xmnop) and Bay of Fundy (4Xqrs5Y) in recognition of the differences in length at age and partial recruitment of cod in these areas. Cod in the Bay of Fundy are fully recruited by age 3, but do not recruit fully on the Scotian Shelf until age 4 or 5. When samples are available from 4Xm, separate age-length keys are also prepared for this area. Particularly in summer the length at age for cod in this area is lower than in other parts of the 4X Scotian Shelf. Given the very low landings in this area, commercial samples are rarely available.

With the increase in landings from 4Xp in recent years, and the shift in the distribution of landings in 4Xp into the deep basins, separate age-length keys have also been used in this area starting in 1998. This reflects the uncertainty in which growth type will be caught in 4Xp given the diverse fishery in this area.

DFO bottom trawl surveys from 1983 to the present and the joint ITQ/DFO bottom trawl survey from 1986 to the present have been employed as indices of abundance (Clark et al 2000). The DFO survey is conducted according to stratified random designs and the indices are calculated using standard design based estimators. The ITQ survey employs a fixed station design, and indices are calculated as simple averages of catch per tow.

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

<u>Observations</u>

$C_{a,y}$ = catch at age for a = 0 to 14 and y = 1980 to terminal year.

$I_{s,a,t}$ = survey abundance index for:

s= RV survey ages a=2 to 8, years t = 1983.5 to present

ITQ survey ages a = 2 to 8, years t = 1996.5 to present

<u>Parameters</u>

$\theta_{a,y}$ = ln abundance for a = 2 to 14 in y = terminal year, and for a = 14 in y = 1998 to terminal year.

κ_{sa} = calibration constants for RV and ITQ surveys for ages a = 2,3,4-8.

<u>Structural Conditioning</u>

Natural mortality assumed to be 0.2 for all ages and years.

Fishing mortality on age 14 for 1980 to 1997 assumed to be equal to the population number weighted average fishing mortality on ages 10-12.

<u>Error Conditioning</u>

Catch at age error was assumed negligible compared to the index error.

Error on the *ln* index observations was assumed to be independent and identically distributed

<u>Estimation</u>

Parameters were obtained by minimizing the objective function

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

For short-term projections, catch and stock weights at age and partial recruitment to the fishery should be averaged over a suitable recent period of stable patterns if there are no trends over time. Fish are assumed to be mature at age 3. If trends are detected, suitable measures to reflect the most recent patterns should be applied. For short-term projections, recruitment should be based on draws from the most recent years with similar SSB or from the entire time period if an SSB threshold is not evident.

4X Haddock
Rapporteur: P. Hurley

The management unit for this resource is NAFO Division 4X plus the Canadian portion of Division 5Y.

Characteristics of the fishery, including commercial landings and sampling for length and age have been summarized in Hurley et al. (1999). The age composition is derived by the application of age length keys to length frequencies, stratified by quarter and gear. Due to differences in growth rates between haddock on the Scotian Shelf and in the Bay of Fundy, landings are separated into 4Xmnop and 4Xqrs5Y and separate age length keys are used for these areas.

The July bottom trawl surveys conducted by DFO research vessels since 1970 and bottom trawl surveys conducted in July by the mobile gear < 65' (ITQ) fleet since 1995 have been employed as indices of abundance (Hurley et al. 1999). A vessel conversion factor of 1.2 was used for the *A.T. Cameron* surveys. The research vessel surveys used a stratified random design while the ITQ surveys used a fixed station design. The 1995 ITQ survey was not used due to survey changes after that first survey year. Separate age length keys are applied to catches from strata 470-481 and 482-495 in the research vessel surveys. These same research vessel age length keys are applied to ITQ survey catches separated by the same strata groupings.

The assessment framework for this resource used a traditional age-based Sequential Population Analysis to produce estimates of population abundance in numbers. The SPA model used is as follows:

<u>Observations</u>

$C_{i,t}$ i = 1-10; t = 1970 to 2001 - catch-at-age for entire year (half year for 2001)
$J_{i,t}$ i = 2-10; t = 1970 to 2001 - July RV survey index
$ITQ_{i,t}$ i = 2-10; t = 1996 to 2001 - ITQ survey index

<u>Parameters</u>

Population numbers at mid-year $N_{i,2001}$ i = 2-10
Calibration coefficients $q_{1,i}$ i = ages 2-10 for July RV survey
$q_{2,i}$ i = ages 2-10 for ITQ survey

<u>Structural Conditioning</u>

Natural mortality assumed to be 0.2 for all ages and years.
Partial recruitment fixed for age 1 in 2001
F on oldest age (10) set as average F of ages 8-9 adjusted by the partial recruitment of age 10 in 2001

<u>Error Conditioning</u>

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

<u>Estimation</u>

Parameters were obtained by minimizing the objective function

$$\{ \sum(\ln J_{i,t} - \ln q_{1,i} N_{i,t})^2 \} + \{ \sum(\ln ITQ_{i,t} - \ln q_{2,i} N_{i,t})^2 \}$$

For short-term projections, catch and stock weights at age and partial recruitment to the fishery should be averaged over a suitable recent period of stable patterns if there are no trends over time. Fish are assumed to be mature at age 3. If trends are detected, suitable measures to reflect the most recent patterns should be applied. For short-term projections, recruitment should be based on draws from the most recent years with similar SSB or from the entire time period if an SSB threshold is not evident.

Appendix 8. Proposal by FRCC on Content of the 4X Cod and Haddock Stock Status Reports (Presented by J.-G. D'Entremont)

At the meeting of the Regional Advisory Process on 4X-5Y Cod and Haddock Assessment Framework, in St. Andrews, N.B., on June 14th, the FRCC was tasked to review the 2001 Eastern Scotian Shelf Haddock Stock Status Report and indicate changes to the current format that were needed to satisfy the request for planning data, especially for the developing FRCP. Some of the following requests may be attached as an annex to the SSR for the FRCC because of the Council's need for more "in depth" information on the stocks and the ecosystem.

Under the section **Resource Status**:
The FRCC request that DFO science state their view of the "productivity regime" of the stock (historical perspective, recent trend, short term expectation). Also we ask that DFO characterize the recent "productivity regime" including the following elements:

1. The Bob/John graph.
2. TLM characteristics of productivity including weights and categories.
3. The RV and ITQ survey age 1 #'s/tow as a recruitment indicator.

Under the section **Population Considerations**:

4. Annual updates of Environmental Factors: For these indicators; water temperatures, water salinity, availability of prey (zooplankton, other…), availability of predators, what are the (i) average, (ii) minimum, and (iii) maximum values observed in the most recent relevant time period for the areas in 4X5Y designated as:
    - the Inner Bay of Fundy
    - the Outer Bay of Fundy
    - the Western Scotian Shelf
5. Similarly for the Biological Indicators; specifically, growth rate, fish condition, age/length at 50% maturity, and geographical distribution, what are the (i) average, (ii) minimum, and (iii) maximum values observed in the most recent relevant time period for the areas in 4X5Y designated as:
    - the Inner Bay of Fundy
    - the Outer Bay of Fundy
    - the Western Scotian Shelf
6. The FRCP contains a target of 4 average abundance/or better year classes in the population. (the FRCC not sure how to capture this?)
7. A Reproductive Capacity index included in the SSR.
8. Identification of Individual Spawning Stock Components. To the best of our current information, identify known and hypothesized individual spawning components, their spawning location and periods of peak spawning activity.

Under the **Outlook** section:

9. The current SSR provides an outlook for the coming year, the FRCC would like to see an additional 2 year projection for a total of 3 years.