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Proceedings of the Fisheries Management Studies Working Group

25-29 June 2001

Bedford Institute of Oceanography
Dartmouth, Nova Scotia

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Foreword

The purpose of this 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

The Working Group met on 25-29 June 2001 to discuss the use of the Traffic Light method for application of the Precautionary Approach to fishery management planning and the concept of Intensive Fishery Evaluations (IFEs). Specifically, the intentions were to:

- Thoroughly air and provide a sound basis for solutions to the technical problems raised during pilot applications of the Traffic Light method in groundfish stock assessments in November 2000.

- Further elaborate the conceptual basis for using the method as a precautionary framework for fishery management by exploring the interface between stock assessment and the rest of the management system and making proposals for decision rule formulations.

- Review the format of IFEs, as proposed by the National Stock Assessment Review.

- Discuss IFE – like approaches used elsewhere and locally to better describe what an IFE consists of and what issues need to be considered.

- Consider the current assessment review process and discuss what changes would be required to move to an IFE framework in the Maritimes and Gulf Regions.

RÉSUMÉ

Le Groupe de travail s'est réuni du 25 au 29 juin 2001 pour discuter de l'utilisation de la méthode des feux de circulation dans l'application de l'approche de précaution à la planification de la gestion des pêches et de la notion d'évaluation de pêche intensive (EPI). Cette réunion visait les buts suivants :

- Examiner à fond les problèmes techniques rencontrés lors de l'application expérimentale de la méthode des feux de circulation aux évaluations des stocks de poisson de fond, en novembre 2000, et réunir une base solide d'éléments de solution à ces problèmes.

- Développer davantage la base conceptuelle d'utilisation de la méthode comme approche de précaution dans la gestion des pêches, par l'examen des interrelations entre l'évaluation d'un stock et le reste du système de gestion, et présenter des propositions sur la formulation de règles décisionnelles.

- Revoir la forme des EPI, selon la proposition découlant de l'examen national des évaluations de stock.

- Discuter des approches comparables aux EPI utilisées ailleurs et localement, afin de mieux décrire en quoi consiste une EPI et quels sont les éléments à considérer.

- Examiner le processus actuel d'examen des évaluations et discuter des changements à y apporter pour passer à un régime d'EPI dans les Régions du Golfe et des Maritimes.

FISHERIES MANAGEMENT STUDIES WORKING GROUP

REPORT OF MEETING of 25-29 June 2001

The Fisheries Management Studies Working Group (FMSWG) met on 25-29 June 2001 in the Hayes Boardroom, Bedford Institute of Oceanography, Dartmouth, to address Advances in the Traffic Light Method and Intensive Fishery Evaluations. Two separate sessions were held on these topics on 25-27 June and 28-29 June, respectively. The agendas for, lists of participants in, and lists of working papers presented at these two sessions are in Annexes 1 and 2, respectively. The first session was chaired by R. G. Halliday and the second by R. N. O'Boyle.

1. Advances in the Traffic Light Method

1.1 Introduction

The session was planned with two general objectives in mind:

- To thoroughly air and provide a sound basis for solutions to the technical problems raised during pilot applications of the Traffic Light method in groundfish stock assessments in November 2000. As a result of this meeting, the necessary tools should be available to support application of the method in the next round of stock assessments.
- The broader purpose was to elaborate the conceptual basis for using the method as a precautionary framework for fishery management by exploring the interface between stock assessment and the rest of the management system and making proposals for decision rule formulations.

The main issues on the agenda stemmed from recommendations made at the 8-11 January 2001 meeting (CSAS Proc. Ser. 2001/08). These issues were development of indicator descriptions, methods for integrating indicators in a Traffic Light table, and decision rules for translating traffic lights into management actions. Stock assessment indicator descriptions were addressed in the May 2001 meeting (CSAS Proc. Ser., this volume) and several recommendations from that meeting also carried forward to the present meeting, specifically: boundary points, scaling of data series and descriptions of characteristics. New items on the agenda were case studies of Traffic Light applications for salmon and shrimp stocks, which broadened the WG considerations from groundfish.

1.2 Indicators

1.2.1 Proceedings of May 2001 Meeting

The report of this meeting, which contained a revised indicator description template and nine indicator descriptions, was presented by the chairman for information. Attention was drawn to the clarification of purpose that these descriptions are essentially a codification of current practice. They describe practical work tools to facilitate application of the method. This in no way inhibits innovation. Rather, it establishes a structured and disciplined way to develop better and new indicators.

1.2.2 More Indicator Descriptions

There were some descriptions identified during the May meeting that could not be prepared in the time frame available. The principal group is comprised of descriptions of indicators from industry surveys, and analysts have made commitments to prepare these. A fifth indicator, or possibly indicators, of population size/age structure has also received some attention and further avenues of investigation were suggested in May. These are indicators that will be required in further applications of the method to groundfish in the assessment RAP in September/October of this year. It was agreed that the WG had done all that it could in this regard and that approval of descriptions for these and any other assessment indicators should be passed on to the RAP assessment committees. The WG was not aware of any progress on development of fishery, economic/social, or compliance indicators.

1.2.3 Case Studies for Salmon and Shrimp Stocks

Salmon

Chaput presented a case study of the application of the Traffic Light method to Atlantic salmon based on the Miramichi River population (Annex 3 and RAP WP 2001/42). The Traffic Light table was composed of six characteristics, three quantitative (adult abundance, freshwater production and marine recruitment) and three qualitative (resilience, environmental and management), for each of which there could be one or more indicators. Boundaries for quantitative indicators were based on modelled relationships with egg production, conservation requirements being defined in terms of egg deposition per m^2. The product was an annual status report in relation to characteristics; no formal decision framework had yet been developed.

Two main issues were raised in discussion. The first related to the scaling of all the quantitative indicators to egg deposition. Egg deposition was proposed as the appropriate means to establish the boundary points for the indicators. This required modelling the relationships of indicators to egg deposition, which invariably requires assumptions about the appropriate model or the borrowing of a model from another stock. The necessity of this was questioned since it makes egg deposition the only important management objective. A larger set of objectives might prove more effective in enhancing the presentation of stock status. The second question raised was the appropriateness of including management attributes in determination of stock status. It was argued, however, that the presentation of stock status should go beyond biology and should incorporate measures of assessment quality and uncertainty, and the ability to manage the factors contributing to mortality (including fishing and all anthropogenic sources of mortality).

Shrimp

Orr presented a case study of the application of the Traffic Light method to shrimp in the Hawke Channel – 3K shrimp fishing area. Various indices of production, exploitation and environment were presented in relation to their long term mean values. The stock appeared healthy with biomass and abundance at all time high levels. The 2000 offshore and inshore catch rates were at the highest levels attained since the mid 1990's. During this time, catches increased from 11,000 tons to over 63,000 tons equating to exploitation rates that have always been maintained below 13% (catch/biomass). However, there was concern that the narrow female size distributions present in both the research and offshore commercial length frequencies meant that females were probably represented by only one or two year classes. This residual biomass would be dying soon and would be replaced by the relatively weak 1995 and 1996 year classes. The 1997 and 1998 year classes appeared strong and were expected to contribute to the spawning stock biomass in 2003 and 2004 respectively. Mean bottom water temperatures in 2J3K and at Station 27 increased between 1992 and 1999 then slightly decreased during 2000. These indices were summarized on a within year detailed spreadsheet and a retrospective spreadsheet. Due to short time series and monotonic increasing nature of the indices, there was no attempt to define either targets or limits. Long-term mean values for each indicator provided a crude reference against which to base the 2000 stock status. In most cases, the indices suggested that the stock was healthy.

In discussion it was noted that Northwest Atlantic shrimp stocks present an unusual assessment problem where data time series are relatively short and represent a period of rapid increase in stock size. The fishery may have little relevance to stock status, as the major abundance changes appear to be environmentally driven. Nonetheless, it is important to provide a forecast to the industry. Although management can perhaps do nothing to prevent a reversal of recent trends, such a downturn will have major economic, social and political repercussions that will need to be addressed. Prior agreement on some arbitrary boundaries for use in decision making could be most useful in this regard.

1.2.4 Boundary Points

The issue of boundary points for individual indicators was discussed at the January, and also at the May, meeting. The deficiencies in the method used so far, of arbitrarily taking percentiles of data series as boundaries, are understood and use of this method is viewed as a last resort. Objective boundaries based on biology are preferred but the science isn't there to do this, with perhaps the rare exception. The next preference is for subjective boundaries based on a reasoned scientific judgement about 'good' and 'bad' states for an indicator. The issue is how to implement this last option. Decision-making techniques such as the Delphi method were thought to have an application here.

The relationship of boundary points to reference points (Agenda item 1.4.1) has yet to be resolved. However, if the Traffic Light method is to provide a precautionary framework for decision-making, there needs to be a link between red lights and precaution. The desire for a scientific, rather than purely statistical, basis for boundaries is consistent with this. What is required, then, is that 'bad' is defined as a state associated with a threat of serious or irreversible damage to the productivity of the resource. The salmon example presented at the meeting was a case where the spawner abundance reference point was used to set boundary points for the traffic lights that were consistent with the precautionary approach.

1.2.5 Scaling Data Series

The issue of short time series and how to best utilize these in Traffic Light analyses was discussed in the January 2001 meeting. The problem was identified as one of setting appropriate boundaries when data series are too short to span the full dynamic range of an attribute. It was suggested that, when there are also long time series available that provide data on the attribute in question, the two data series be scaled and the boundaries for the long series could then be applied to the short series.

Fowler presented the results of an analysis of scaling abundance estimates for Div. 4X cod between July research vessel surveys and the industry-conducted ITQ survey of shorter duration (RAP WP 2001/44). The overall indicators did not correlate well but when the data were restricted to a common survey area by removing data for inshore grounds from the ITQ estimates, the series were strongly correlated. The important insight was the need to ensure that indicators are indeed providing measures of the same thing before calculation of a scaling factor. Calculation of the factor itself for scaling of boundaries is straightforward. Data interpretation in relation to the attribute to be measured, in this case overall stock abundance of cod in 4X, is the complex problem. It was emphasised that this kind of data examination needed to be conducted on a stock by stock basis.

1.3 Integration

1.3.1 Traffic Light Index versus Traffic Light Decision Framework

Halliday presented a brief review of concepts to clarify terminology. He pointed out that John Caddy introduced the Traffic Light method in 1998 as a Precautionary Management Framework. The essential elements of Caddy's approach are:

- A multiplicity of indicators of stock status
- Limit Reference Points for indicators based on red, yellow and green lights, and
- Management response rules associated with some integrative function of light colours.

It was Peter Koeller and other shrimp scientists who introduced the idea of using a 'retrospective' table of lights to communicate recent trends as an aid to decision-making. This was subsequently adopted and extended in groundfish applications. Emphasis in groundfish analyses has been on construction of an historical time series index of stock status.

It might help guide the WG's efforts if it were to distinguish between a **Traffic Light Stock Status Index** and a **Traffic Light Precautionary Management Framework**. The latter is the key element of the method. The uses for an historical index have not yet been clearly articulated.

There was no discussion of this item.

1.3.2 Multi-Criteria Decision Making Techniques

Karasakal provided an overview of Multi-Criteria Decision Making (MCDM) techniques relevant to fishery management planning and specifically in relation to the Traffic Light method (Annex 4 and RAP WP 2001/46).

A key element of the methods described is that they require decision makers to be part of the process. The methods guide the decision makers to make their own choice. Decision makers need to define the goal, assist in determining alternatives and the criteria against which alternatives will be judged.

Discussion focussed on the issue of goals. Goals were equated to objectives in fisheries parlance. The difficulty in defining objectives for fishery management has presented a chronic problem. In actuality, there are implicit goals underlying management plans even if none are recognised explicitly. One aspect of the problem is represented by cases where stakeholders have considered it in their interest that decisions on objectives not be reached. However, decision makers must be able to specify goals to some degree if technical aids such as MCDM techniques are to be of value.

Another aspect of the problem is the existence of multiple objectives in fisheries of an economic, social and biological nature, which may conflict with each other, like in other MCDM problems. In solving an MCDM problem, after defining overall goal and sub-goals, criteria and sub-criteria need to be defined. Goals are useful for clearly identifying a level of achievement to strive toward. However, criteria are more relevant than goals for evaluating alternatives and they represent the different dimensions from which the alternatives can be viewed. It was thought that, in fishery problems, stock status, ecosystem effects of fishing, managerial performance etc. can be defined as criteria and different dimensions of each criterion can be defined as sub-criteria.

It was reported that the Scientific Committee of the International Whaling Commission (IWC) tried to apply some MCDM techniques during the development of its Revised Management Procedure. These techniques were not used formally in the final selection process, although they did help to identify "dominated options" (a "dominated option" is one that is worse on at least one attribute and never better on any attribute that another option).

The IWC experience showed that the use of MCDM techniques can be complicated by several factors:

1. Some of the decision makers may have "hidden agendas" in that they would be satisfied with "no decision" if there is a default option (e.g. close the fishery, do not change the management arrangements) which is preferable to them.

2. Decision makers are often representatives of interest groups and decisions often involve compromise. Some decision makers will have "points of resistance", i.e. options which they could not reasonably expect to "sell" to their constituents.

Control theory approaches to Traffic Light boundary setting were not thought to be appropriate for biological attributes. They may be more appropriate for fishery management attributes.

The nature of alternatives was briefly discussed. One example given was that different TAC levels could be used as alternatives.

It was thought that MCDM had potential for application to fishery management planning but expertise within the DFO regional organization was lacking. Ways to acquire this expertise, perhaps from local universities, to support some demonstration applications were discussed.

Assigning weights in an MCDM problem is a difficult task. A pair-wise comparison method was suggested for use in calculating the weights of criteria. The pair-wise comparisons are done with respect to the criteria at the preceding level. Thus, the alternatives are compared pair-wise with respect to the sub-criteria, the sub-criteria are compared pair-wise with respect to their contribution towards the criteria and the criteria are compared with respect to their importance towards the goal. It was argued that to predict the effects of alternatives on sub-criteria is difficult. However, it was thought that even if an MCDM technique is not used, in order to be able to take measures regarding the fishery problem according to the results of the analysis, one needs to predict the effect of alternatives on criteria. Otherwise, it is impossible to determine a new strategy for the next period.

1.3.3 Descriptions of Characteristics

The term 'characteristic' was adopted at the Traffic Light workshop in September 2000 (CSAS Proc. Ser. 2001/08, Annex 3). It was defined as a conceptual entity based on a number of indicators, the purpose of which was to aggregate similar indictors for further analysis or discussion. **Fanning** addressed the requirement, identified at the May meeting (this volume), for more detailed descriptions of the characteristics that have come into use in a groundfish stock assessment context (RAP WP 2001/43). He defined characteristics as descriptors of the factors of productive capacity of a fish stock. Productive capacity was itself defined as the total losses, in biomass, a stock can withstand from all anthropogenic sources while still maintaining itself. The following descriptions of characteristics were provided:

> **Production –** includes effects of growth, survival and reproduction and recruitment. This is the most direct measure of productive capacity if appropriate consideration is given to non-anthropogenic demands.
>
> **Abundance –** describes the size of the population providing the production. The historical dependence on abundance (biomass) to describe stock status has assumed (implicitly or explicitly) that any given biomass can and will produce with a constant P/B.
>
> **Fishing Mortality –** provides a direct description of the impacts of fishing. A more complete description should include other sources of anthropogenic mortality (habitat, unrecorded fishing effects, etc.).
>
> **Ecosystem/Environment –** may be treated as one or two characteristics. Each describes the external factors affecting the stock, most of the distinction being whether they are biological (ecosystem) or physico-chemical (environment). Each may also reflect some aspects of anthropogenic effects.

A number of points were raised by the presentation. It is anticipated that advice on stock status would be framed in terms of these characteristics. These do not take into account other factors relevant to setting the regulations controlling fishing, e.g. social and economic considerations or implications of bycatches to biodiversity. The appropriate place for these other factors to enter in is at the next level of decision-making; they are not relevant to a decision on the biological status of the stock. The appropriateness of separating fishing mortality from other sources of mortality was questioned, as survival is part of production.

The rational is based on fishing mortality being the primary control variable. It was suggested that it would in fact be useful to have separate ecosystem and environment characteristics to split out biotic from abiotic indicators.

1.3.4 Integration Methods for Formulation of Characteristics

Four different ways of converting data to indicators and combining indicators into a characteristic or some other summary were proposed during the January meeting. These were referred to as the Strict, Ramp-step, Fuzzy Logic and Continuous approaches. It was agreed that these should be tested using common data sets to establish the advantages and limitations of each and how sensitive results are to the method used. **Fanning** made a presentation on behalf of **Mohn**, who was absent (Annex 5 [note that this annex requires colour reproduction]). The author illustrated that there was progressively less information lost in integration from the Strict to the Continuous method. Something is always lost in integration, but this need not be serious. The indicators are still available for decision rules that might require more information than is contained in the characteristics. There is no necessity to pick one system over another. Simplicity and communicability may be served if a consistent analysis was used, but there is no need to throw away any useful attributes on technical grounds.

In discussion, the point was raised that the alternatives to the Strict Traffic Light, when presented in a historical table, gave a more complicated visual impression that made trends difficult to see. As one of the advantages of the method is to facilitate communication, this is an undesirable feature. In counter to this, it was pointed out that this is also an analytical tool and the virtue of the more complex methods is that less information is lost and uncertainties are communicated. One suggestion was to retain the original simple version for presentation of historical summary tables but the complex version for presentation of the decision framework, but there was also a view that this was unnecessary.

Attention was drawn to the similarity of what was being done to utility functions. Some ranges are viewed as good by decision makers, some so – so and others bad. Although using continuous variables, values within some range may mean the same to the decision maker. Before deciding whether there is added value to continuity over discreteness, there is a need to analyze the utility of the alternative approaches to the decision maker. In response it was stated that all integration methods are potentially capable of capturing decision maker 'happiness' as they will come from a Delphi-like process, except maybe for the 'continuous conversion scheme'. For each indicator, Delphi processes will have to lead to the establishment of the indicator boundaries and of the conversion scheme to use.

The fuzzy logic scheme can account for uncertainty. Thus, it presents a way to take account of the fact that some indicator data values are missing or that some indicators are more variable than others.

1.3.5 Integration of Characteristics with regard to Stock Status

Fanning made a presentation (Annex 6) on the use of fuzzy sets to represent the state of an indicator in relation to chosen boundaries. Integration of indicators into characteristics is then achieved based on summation of the areas of each colour. An example fuzzy control system was demonstrated that could provide the technical basis for structuring the decision rules required to translate analytical results into appropriate management actions.

It was clarified in discussion that the context in which this methodology is expected to be used is one requiring a multi-year approach. The precautionary approach calls for pre-agreed decision rules and this is only possible in a multi-year decision framework. The same framework would be applied each year based on the most up-to-date data, providing revised advice annually. The decision framework itself, however, would be reviewed and possibly revised less frequently, perhaps every five years or when it became clear that it could be substantially improved. The view was expressed that this was too prescriptive and would not be acceptable to decision makers, who wanted to reconsider all the management options every year. In rebuttal, it was pointed out that this is precisely what needs to be avoided. There is little if any gain in scientific understanding from one year to the next. Complete re-evaluations every year are not a good use of scientists' or decision makers' time. The thrust of policy is to have decision makers focus on medium to long term strategic decision making, the lack of which is viewed as a major deficiency of planning in the past. Nonetheless, a 'safety valve' could be built into the decision framework in the form of a rule that triggered a review of the framework when certain conditions were met.

Another important issue raised in discussion was how the method could be tested. This kind of feedback system could go into oscillation if corrections were too large. Simulations were suggested but realistic simulation was seen as difficult. Use of a small subset of indicators, e.g. SSB and F, would make simulation more practical, but not necessarily very relevant. An alternative suggestion was to go back in time, e.g. starting in 1990, and see what decisions would have been made with different decision rule formulations. This was thought to be a more tractable proposition. This could be enough to establish what decision rules provide adequate managerial responses.

The inter-relationship between the various steps in the process from the availability of indicators in relation to characteristics to the final step of formulating decision rules was stressed. The interactions between these methodological decisions are not yet fully elucidated but it appears that they cannot be taken in isolation from each other.

In the example presented, no provision was made to account for 'recent trend' as well as present state of indicators and characteristics. It was widely recognized that this is a desirable feature to include in a decision framework and ways to do this should be investigated.

1.4 Using a Traffic Light Precautionary Management Framework

1.4.1 Reference Points and 1.4.2 Decision Rules

These topics were not discussed separately as they were thought to be adequately covered under other items.

1.4.3 Update on the Groundfish Case Study (Objective-Based Fisheries Management [OBFM] Initiative)

At the January meeting, it was decided that the WG should conduct some case studies that addressed the issues of interfacing the Traffic Light output with the rest of the management system. The WG was informed that the Scotia-Fundy Region had put forward groundfish and inshore scallop fisheries for pilot applications of OBFM. This development made the groundfish fishery an obvious choice for a case study for exploring and determining decision rules that link Traffic Light results to managerial actions, as groundfish stocks provide well-worked examples of Traffic Light applications in stock assessment. No arrangements were made for this case study at the January meeting.

The present meeting was informed that progress had been made by both the Fisheries Resource Conservation Council (FRCC) on their initiative to produce long-term groundfish Fisheries Resource Conservation Plans (FRCPs) and by DFO Fisheries Management (FM) on the OBFM pilot Integrated Fisheries Management Plan (IFMP) for groundfish.

Lane presented a summary of the FRCC's development of a long-term planning document for 4X5Y cod and haddock. This first FRCP is being developed by the Southern Team of the FRCC in conjunction with a working group of the Scotia-Fundy Groundfish Advisory Committee (SFGAC). The objectives of the plan are:

- Sustainable utilization and relative stability
- Rebuilding and conservation

These objectives are to be obtained by multi-year but flexible planning, precautionary exploitation, protection of juveniles, maintenance of spawning components and effective monitoring and control. Strategies are:

- Recommend TACs for 5 years on a rolling horizon, allowing for change every 2 years
- Specify absolute stock indicator targets on biomass, condition, ages, productive capacity, spawning components, TAC, F
- Specify "unacceptable indicators"
- Establish "base" TAC levels
- Set stepwise TAC changes in accordance with indicators moving within defined ranges
- Protect juvenile fish
- Close fishing on known spawning at peak times
- Reinforce CHPs, LCs

The plan also specifies in some detail the needs for information gathering and for further research and lays out what are considered to be relevant ecosystem considerations.

It is intended to finalise this planning framework and extend its application to other Scotia-Fundy groundfish stocks in the autumn, with the intention of using the results as the basis for FRCC recommendations for the 2002-03 fishing season.

In discussion it was noted that, although the draft plan itself was not presented to the WG, several DFO staff had attended a presentation of it at an earlier meeting (4 June 2001). At that previous meeting, the draft presented had a decision rule structure similar to the form proposed under the Traffic Light method in that it translated the status of indicators into annual TAC adjustments whereas the framework itself remained set for a number of years. A reservation was expressed, however, about the sole dependence of the decision rule in that plan on spawning stock biomass. The meeting was informed that the FRCC intended to base its decisions on a number of indicators and was not tying itself to pre-determined decision rules.

It was noted that the planning framework continued to take a single species approach and focussed on TAC setting. It did not break any new ground in taking ecosystem considerations onto account. It was noted also that the plan did not make provision to monitor performance in relation to plan elements. With regard to the latter, this was viewed as outside the FRCC mandate.

Halliday, in **Annand**'s absence, gave a status report on the OBFM groundfish pilot (RAP WP 2001/45). The main thrusts of the OBFM initiative are to introduce the precautionary approach, risk analysis and the principles of performance measurement into the IFMP process. The precautionary approach definition adopted by FMSWG at its January 2000 meeting (CSAS Proc. Ser. 2000/02) is proposed for use in the pilot, requiring a definition of unacceptable outcomes for use in decision rules, and that ecosystem considerations be taken into account. The definitions of ecosystem objectives put forward in the report of the Workshop on the Ecosystem Considerations for the Eastern Scotian Shelf Integrated Management (ESSIM) Area (CSAS Proc. Ser. 2000/14), held at BIO in June 2000, were proposed for use in the plan. A hierarchy of fishing plan objectives, based on the recently released Atlantic Fisheries Policy Discussion Paper is being put forward for discussion, covering conservation, economic, social and stewardship issues. A template for plan structure has been drafted that envisages a main text that will give a description of the fundamentals of the plan and likely remain unchanged for its life, presently expected to be the 5 years, April 2002 – March 2007. It will be supported by a series of annexes that present the information and analyses that support the plan. Most of these will likely change annually.

A working group has been established to produce the plan consisting of 6 industry representatives from the Regional Groundfish Advisory Committee, and DFO staff from Fisheries Management (Conservation and Protection, Resource Management), Science and Policy and Economics. Provincial fisheries agencies and FRCC will also have a role. The first meeting of this WG was on 5 June. The next meeting is planned for early September, by which time a first draft plan should be on the table. There is a need for broad interaction between the planning WG and the various interested parties during the planning process but it is not clear yet how to accomplish this.

In discussion of ecosystem considerations, it was pointed out that, subsequent to the regional ESSIM workshop, there had been a national workshop on objectives and indicators for ecosystem-based management (CSAS Proc. Ser. 2001/09) that proposed revised objectives from those at the ESSIM meeting. These revised objectives should be considered. The suggestion that, in this round, the groundfish plan might do little more than codify present ecosystem-related provisions into the plan, while providing an action plan to incorporate new provisions over its 5 year life, was challenged and it was proposed that more could be done now. In particular, it was suggested that bycatch issues could be more closely scrutinised by examining the "ecological footprints" of the various components of the fishery and new provisions introduced.

It is clear that the work of the FMSWG on the Traffic Light Decision Framework, the FRCC on their FRCPs and the OBFM planning group need to come together in a co-ordinated way, but how remains to be resolved. The FMSWG has, to this point, thought primarily about assessment of stock status and decision rules that translate the results into TACs. However, the issues are broader. Decisions on TACs should be conditional on more than stock status, and there are decisions to be made on other management measures also, not just TACs. Reference was made to the Intensive Fisheries Evaluation (IFE) concept and its potential role, but debate was deferred to the upcoming session on that topic. As the plan was to be written in the next few months, it seemed unlikely that IFEs would be of immediate relevance. The question was raised as to when and how the OBFM pilots themselves would be evaluated but there was no information on this.

With regard to the precautionary approach, the meeting was informed that the government was tending to view it as applicable in circumstances of a risk of serious or irreversible harm about which there is significant scientific uncertainty. Thus, precaution is associated with bad (red) situations (unacceptable outcomes) and, conversely, has little or no relevance when situations are good (green). It was pointed out that this would need operational definition and that, in doing so, "hard" boundaries are to be avoided as they could trigger unnecessary closures or restrictions. The problems with hard boundaries have been discussed in several FMSWG meetings and there appears to be general agreement on the need for transition zones. Similarly, in the 1995 United Nations Fisheries Agreement, transition zones are recognized through the introduction of buffer zones and harvest control rules within the concept of precaution.

As precaution is to be related to the risk of serious or irreversible damage, the notion of "target" is disassociated from precaution. This is not foreign to the practices/definitions adopted by many groups which have come to consider "targets" in the context of socio-economic objectives. It was noted, however, that a target zone, if equated with a "safe" place to aim for or stay within, could contribute to precaution and thus could contribute to conservation.

It was noted that the concept of "base" TACs in the FRCC presentation equates to a form of hard boundary where the industry itself defines a minimum TAC that can support directed fishing. Below such base level (or boundary), there would be a cessation of fishing and perhaps a need for special protective measures. It was also noted that the FRCC have introduced the concept of targets for indicators in their FRCPs but the basis for these was not available to the present meeting.

A national DFO Science meeting on the precautionary approach is being planned for December to review past and ongoing initiatives related to precaution and to develop a plan for moving ahead.

2. Intensive Fishery Evaluations

2.1 Introduction and Background

O'Boyle welcomed the participants (Annex 2) and provided background to the session. During June 2000 – March 2001, the DFO undertook a national review of its stock assessment program. One of the main recommendations of the review was for DFO to move from its present stock assessment process (termed the Regional Advisory Process or RAP) to an Intensive Fishery Evaluation (IFE) approach. The latter would be an in-depth analysis of the assessment framework and fishery decision rules outside of the management plan schedule. The products of the IFE would then be used annually to guide management of the fisheries. It was pointed out that the IFE concept was not new, with numerous examples available (e.g. Catch Limit Algorithm of the IWC, krill management by CCAMLR, discussion on Comprehensive Fishery Evaluations in the ICES WGFS, discussions at the 1998 ICES Symposium in South Africa, the 4Vn Herring Decision Rules). Thus, we can and should learn from previous experience. A list of background documents related to IFEs, which was circulated prior to the meeting, is provided in Annex 2.

The overall objective of the session (Annex 2) was to provide an opportunity to discuss what an IFE is intended to be and what changes are required to implement IFEs in DFO Maritimes and Gulf Regions. It was emphasized that this is primarily a regional 'ideas' and investigative meeting, with further deliberations, likely at a national level, to follow. The schedule was briefly reviewed (Annex 2). First, there would be a presentation on what the national stock assessment program review concluded about IFEs. This would be followed by presentations on IFE like approaches both elsewhere in the world and locally. Then, there would be an overview of the current RAP approach, which would lead to a discussion on changes required to implement IFEs.

Rapporteurs for the presentations and discussion were then assigned.

2.2 IFEs – National Stock Assessment Review

Rapporteur: K. Zwanenburg

Presentation Highlights

The national stock assessment program review was initiated by the DFO ADM Science to evaluate the program and its delivery. The review was undertaken during June 2000 – March 2001, with public release of the final report pending.

There were three main parts to the review: 1) definition of the program’s vision, 2) the current situation in relation to the program's structure and funding, and 3) consideration on how the vision can be achieved. Regarding the latter, the review considered seven areas for improvement and change, these being workforce development, resource monitoring, new technologies, data availability, analyses, population/species/ecosystem evaluation and management decision support. Under population/species/ecosystem evaluation, the review recommended that the current assessment and advisory process move to a system of Intensive Fishery Evaluations (IFEs). These would be comprehensive evaluations at a lower frequency than annually and be independent of the management schedule. They would consider both the assessment and decision rules for management, consistent with Objectives Based Fisheries Management (OBFM). The frequency of IFEs would be dependent on the characteristics of the resource and the fishery and would stipulate the mechanism whereby a new IFE would be triggered. Between IFEs, only resource updates would be undertaken.

The review elaborated in some detail each aspect of the IFE. With regards to frequency, it stated that IFEs would be conducted "occasionally", which would for groundfish type stocks and / or fisheries be approximately twice a decade. The frequency of IFEs would have to be sensitive to a resource's life histories and the characteristics of its use. It was felt efficient to link the timing of IFEs to re-evaluations of fishery objectives under the OBFM initiative. As part of the IFE, there would be agreement on a schedule for the IFE, which would include considerations for holding an IFE earlier or postponing a scheduled one. During an IFE, the following activities would be undertaken:

- All potential data sources reviewed for quality
- Information on biological processes reviewed
- Information on fisheries reviewed
- Alternative model formulations explored to fully use available information
- Selection of preferred formulation
- Full description of stock status
- Evaluation of contribution of existing or proposed technical measures (mesh size, closed areas, etc) for achieving conservation and some socio-economic objectives
- Specification of activities for interim years (annually or as appropriate for fishery)

O'Boyle noted that an IFE was thus more than a conventional assessment and indeed considered all elements of the management system. He referred to McAllister et al. (1999) who provided an overview of the elements of an IFE. This separated an Operating Model (composed of population dynamics, observation, harvest decision and implementation models) from a Harvest Control Model (composed of stock assessment and harvest control rule models) and highlighted where the current stock assessment model would fit in under an IFE approach.

The review described the nature of an IFE meeting. There would be participation of technical experts from within DFO (usually multiple Regions) as well as externally. There would also be invited participants (not just observers) from diverse interested parties, such as resource users, environmental groups, other levels of government, etc. Discussion would include traditional ecological knowledge (TEK), technical review of analytical material and everything in between. The meetings would likely last several days and require extensive preparation of materials. As stated earlier, these meetings would not be linked to the timing of the management cycle.

In relation to communications, an IFE meeting would produce a Stock Status Report on the resource in question, and the detailed results would be provided in one or more research documents, as per current practice. As well, there would be proceedings of the meeting. The review stated that a media briefing and press release might also be held.

In the interim years between IFEs, the review stated that the following activities would be undertaken:

- All time-series updated and discussed, and the agreed forecast model(s) run; all formulations & parameters would taken from last IFE (could include risk quantification model); the model diagnostics would not be reviewed
- Preparatory analyses should rarely require more than a day of work
- Data updates may require more time, but are necessary in all approaches, if we are to report status relative to biological objectives – even on multi-year basis
- Results tabled at open and transparent RAP-style forum, where there would be discussion on the relationship of forecast outputs to decision rules agreed at last IFE
- Specification of the biological consequences of proposed new management measures, based on last IFE

Overall, the interim meeting would strive for consensus on resource status relative to conservation objectives, including risk quantification, as per the IFE.

The products in interim years would include:

- For stocks where quantitative results are available, short (1-3 pages) annex to most recent SSR (SSR template may be re-designed to accommodate this)
- For stocks where interim forecast not quantitative, new information for multiple stocks included in overview SSR (SSR produced at last IFE would alert readers to these)
- One Research Document
- One Proceedings from meeting where a number of interim assessments reviewed

Discussion

The rationale underlying the move to an IFE process was discussed. One key factor was that the explanatory power of current assessments does not appear sufficient to adjust our view of resource status annually. We would be better served by developing and agreeing to a management model that could be used to guide harvesting over a number of years, while at the same time undertaking the research necessary to improve this model. It was noted that, by incorporating the stock assessment model into the broader IFE approach, a simpler assessment model might in fact meet management needs. We are not looking for the right model per se. Rather, we are searching for a trade-off between the costs of a particular model versus its benefits. It was queried if the investment of additional resources really would increase our understanding of the management system proportionally. It was felt that adoption of an IFE approach would free up scientific time and energy to expand the view of the fishery into the ecosystem, consistent with the 2010 vision articulated in the national review. However, there would have to be willingness on the part of the management system to move to a new approach. Otherwise, we would be doing exactly what we are doing now but only working harder every five or so years. A concern was that the current East Coast fisheries are exploiting the resources to the limits of sustainability. Perhaps the solution is to 'step back from the edge' and reduce fishing effort to a safe zone. The fact that fishing capacity and thus effort is so high has driven fishing for the last fish and consequently DFO Science to find that last fish. Reduction of fishing effort should lead to reduction in the required scientific effort, which could then be used more profitably investigating other parts of the management system.

There was considerable discussion on what activities are undertaken during an IFE. It was emphasized that it is not just a big assessment. Rather, the status of a fishery is being evaluated more broadly. The question was asked if we were talking about the whole scope of the fishery management process, raising the issue of the mandate of science. Certainly, under an expanded view of an IFE, economics, for instance, would be implicated. This prompted comment that the view of the IFE needs to be even broader. It should be evaluating the fishery in the context of the entire ecosystem. To this was added that one couldn't review the management objectives and decision rules in isolation of regulatory measures.

Concerns were raised about the linkage of the IFE to the annual production of harvest advice. For instance, by what process would annual TACs be established? It was replied that assessments would still be done in the interim. These would use the framework developed during an IFE to provide the annual state of the resource and thus the implications of various harvest rates. It was asked how other management measures would be evaluated. Right now, there is no formal process and adoption of an IFE approach would put these into the formal process. Overall, the IFE should be used to address strategic questions, with the operational questions dealt with through scientists directly or through the interim assessments.

In relation to IFE frequency, it was offered that the review of population status could become extensive each year, with the semi-decadal reviews looking at the fishery in the context of the entire ecosystem. However, it was countered that we cannot do both. We need time to evaluate the broader questions. Multi-year plans could suffice and research done in the interim. It was acknowledged that for some stocks, we might need to produce annual advice, while for others, less frequent assessment might be possible. Whatever schedule is agreed to should be incorporated into the fisheries management plan.

How an IFE review would be undertaken was discussed. As an IFE would be examining the management system, it would be complex, and thus DFO needs to be careful to ensure a comprehensive review. There is a lack of the appropriate expertise within DFO to fully subscribe to the IFE approach, and thus external expertise must be sought. Funds should be identified to contract reviewers to conduct full and independent evaluations, perhaps using different models. It was felt that there would likely not be savings to the department as a whole.

Another issue was how best to document the IFE framework which would be used annually to guide management. One idea was to produce a workbook or guide on how the interim assessments would be conducted.

Discussion then focused on the interim assessments. Concern was raised that these could require a significant amount of time to undertake. While the national stock assessment review stated that model diagnostics would not need to be reviewed, this was debated, raising the specter of full assessment discussions. However, it was offered that the traffic light approach discussed earlier in the meeting could be effective during the interim years. It perhaps could become the only view of the resource in the interim. Under this scenario, workload could be reduced. A critical element of interim assessments would be monitoring the performance of indicators related to the need to re-open the IFE. We need an escape hatch for a failed IFE and should not be locked into a faulty process.

2.3 International Observations on Management Procedures

Rapporteur: K. Zwanenburg

Abstract

Punt gave an overview of some aspects related to the use of Intensive Fishery Evaluations in South Africa, Australia, New Zealand and at the International Whaling Commission. The objective of IFEs within these jurisdictions is primarily as the basis to select decision rules (or management procedures) that are sufficiently robust to uncertainty and that achieve a reasonable balance between the (conflicting) objectives for management. A management procedure is "an algorithm that includes rules for data collection and analysis that determines the management actions and that is tested (by simulation)". Thus, aspects considered during IFEs tend to be those to which the performance of management procedures may be sensitive. The focus to date has been on identifying management procedures for (primarily) single-species fisheries managed using output controls, although, increasingly, emphasis is being placed on cases in which there are substantial technical interactions, e.g. the anchovy-pilchard situation in South Africa. Consideration of "ecosystem" issues remains a weakness, although some effort in New Zealand has been given to evaluating the consequences of restricting fishery activities to promote recovery of a depleted sea lion population. The experience has been that the process of conducting IFEs has led to the decision-makers considering their objectives (and how these should be quantified) to a greater extent. Also, the range of hypotheses considered during IFEs is considerably broader than is conventionally the case. Some of these hypotheses are identified by the stakeholders, e.g. fishers, and, in general, industry is quite supportive of management based on decision rules as it provides security in terms of how future management actions, e.g. TACs, will be determined. In principle, the development and use of management procedures should lead to better utilization of research resources. However, it is hard to prove that this has occurred to date.

Presentation Highlights

The presentation emphasized that the purpose of IFEs was to produce simple decision rules that could be used between IFEs. An algorithm that includes rules for data collection and analysis is developed and tested by simulation and presets management actions. It was highlighted that the aim of the IFE is therefore not to obtain a full understanding of the system being managed but rather to identify decision rules that perform satisfactorily at managing the system. The IFE experience so far is that it has forced decision-makers to be involved in the process and has encouraged the quantification of objectives. A broader range of uncertainties than is usually considered has at least been contemplated. It was pointed out that hypotheses / assessments may come from several sources (government, industry, conservation groups etc.) with no agreement expected. Selection of the right management procedure is not a scientific issue but rather reflects a trade-off between risk and reward (see MCDM techniques). A number of examples were then provided:

New Zealand Rock Lobster

The IFE, which was conducted by scientists contracted by the Ministry of Fisheries, involved developing a decision rule that satisfied the legislative objective for New Zealand fisheries of moving the resource towards BMSY. The decision rule adopted involves conducting an assessment and predicting the time sequence of CPUE expected if the resource is indeed moving towards BMSY as planned. TACs are adjusted depending on how the actual CPUE compares with that expected if the resource was moving as intended towards BMSY. The TACs are changed every second year and the rule should lead to a small number of large jumps in TAC rather than many small jumps in TAC. Assessments of rock lobster stocks continue to be developed but the TACs are set using the decision rule.

South African Hake

The decision rules adopted for this resource have led to lower levels of fishing mortality that before the 200nm EEZ was declared and some resource recovery has occurred. Emphasis has been placed on a decision rule that provides stability in TACs. The ability to set TACs using a decision rule has freed up some resources to look more broadly at hake dynamics, e.g. consideration of inter-specific predation, and at other species.

Anchovy-Pilchard off South Africa

The decision rules initially developed for these species have been modified to take account of technical interactions. Different companies in the South African pelagic fishery have different preferences towards anchovy versus pilchard, and so the decision rule gives each company a share in the fishery rather than in individual species. Part of the IFE process involved examining whether a decision rule that attempted to use environmental indices related to recruitment could lead to improved performance of the management system.

Discussion

Questions were asked on the comprehensiveness of the IFEs. Specifically, it was noted that the IFE experience so far appeared to focus on traditional fishery issues. It was asked if any had taken the Convention for Biological Diversity (CBD) into account. Australia and New Zealand are discharging their responsibilities under the CBD through closed areas in all bio-regions. The importance of both NGOs and industry supporting these areas was highlighted. There was a concern by some that the IFE approach might be incompatible with the desire of ecosystem-based management (EBM). However, it was noted that while we wish to conserve biodiversity, we do not need to understand all the processes that control it, a philosophy not incompatible with the IFE. Thus it is not unreasonable to think that IFEs could serve as a basis for EBM plans.

There was considerable discussion on the role of decision-making in IFEs. In Canada, for instance, it was felt by some that the management system is being undermined through industry lobbying of the minister. This is counter to the decision rule concept. It was noted that this also happened in New Zealand, where industry lobbied the Minister to avoid TAC reductions. It was observed that in order to make decision rules effective, they would have to become a key consideration in the decision framework, which typically includes Fishery Advisory bodies, Conservation Advisory bodies and, ultimately, decisions by the Minister. It was recognized that agreement on the decision rules was one of the most difficult parts of the process. For them to be accepted (and avoid lobbying), there should be broad understanding of them. This led to discussion on the need to have a simplified decision-making process, while recognizing that the system is indeed complex. Certainly, the decision-making rules need to be simplified, as you will have a knowledgeable collective that will make the decisions.

The concern was raised that current Canadian fisheries are 'close to the cliff edge' in terms of fishing effort and that an IFE approach might be incompatible with this state, i.e. we will be forced to find the last fish (and thus have high assessment costs) until effort is reduced). In reply, it was noted that a big advantage of the IFE approach is that it makes all decisions in the management of a fishery transparent, even inappropriate ones. IFEs allow one to start to identify problems in the system, which will hopefully lead to improvements over time.

A number of questions were asked on the models within IFEs. Concerns were raised about how precise these should be. Model uncertainly is presumably a problem. However, the role of models in IFEs is to allow the overall system to work. It is not necessary to create models that fully describe the system. In an IFE, we might not understand the system but the model will still work. The emphasis is on identifying the most robust management approach, rather than the one that is the most scientifically correct. For instance, in the previous presentation, it had been mentioned that IFEs could lead to the adoption of simpler assessment models. The experience to date appears to confirm this, as all the models so far used are relatively simple.

There was interest in how IFEs were actually accomplished in the examples given. For the most part, the process is composed of two parts – a technical part in which all the analytical aspects of the IFE, including the development of different decision rules, are considered, and a "decision" part (typically participatory in nature) in which the decision rule to run the fishery is chosen. In the examples, typically 10s of meetings are required, with the shortest duration being six months and more typically lasting two or more years.

What about the interim process? What is the experience? Once the IFE framework has been accepted, then all that happens is an expert (typically a scientist) undertakes the calculations as per the decision rule and reports the results to the decision-makers. This highlighted the need for the appropriate timing of the IFEs. It was asked if the life history characteristics influence on the effectiveness of IFE, to which was replied that the rate of IFE updating is generally life history dependent, i.e. sardines are updated more frequently than blue whales.

2.4 The ICES Experience

Rapporteur: J. Neilson

Presentation Highlights

Lane presented the history of broader fisheries assessment related studies that have taken place within ICES since 1993. These related studies included sessions at the Annual Science Conferences of: (1) linking fisheries biological considerations with socioeconomic and political concerns (2) long-term management considerations (3) multiple impacts of rights-based fisheries management approach (including ITQs) on fisheries resources (4) the precautionary approach and (5) fisheries as systems.

The progression of Annual Science Conference theme sessions, the establishment of ICES Study Groups and Working Groups and their meetings were reported, along with the linkages among the various related topics that have taken place since 1993.

In summary, it appeared that while several initiatives have been ongoing in ICES since 1993, including a new WG on Fisheries Systems, there seemed to be little clear resolution on where these related initiatives were headed or what improvements they have brought to fisheries decision-making. The 'life history' of these groups within ICES typically began with broad-based discussions about the construction of general frameworks, e.g. for multidisciplinary evaluation of fisheries decisions. This was followed by a process of identifying representative international cases against which to apply the general framework. Finally, the analysis of particular case studies was carried out by knowledgeable and interested parties familiar with the cases.

The analysis of these case studies effectively signaled the end of the "theme" within ICES. Several initiatives in this area were noted as having been revitalized by shifting their emphasis slightly, e.g. from evaluation of ITQs into more general evaluation of fishery systems. These new initiatives would then reconstruct the same dynamic from framework to analysis of cases. It is not clear whether or not the discussion of case studies actually meant that a shift has occurred domestically within those groups who had worked on these projects. What is clear is that most attempts to standardize or generalize principles, i.e. establish general frameworks, typically do so at a high level that could include a wide variety of actual cases. In contrast, the cases normally revealed much more specific, contextual-type variety that it was difficult to make general policy statements about effectiveness and performance.

Under the circumstances, it appears from this experience that more can be learned from the specifics at the 'ground level' of individual pilots or case studies rather than from applying general principles from the top down.

Discussion

During the course of the presentation, it was asked whether fishermen had a significant involvement in ICES meetings dealing with the Precautionary Approach. In general, it appeared that fishermen had only a minor involvement.

It was asked what has been said concerning IFEs in the ICES forum. Lane responded that there has been little discussion specifically dealing with the topic of IFEs. As a follow-up, a participant asked if ICES is considering management by decision rules. Lane responded that the sequence of developments of initiatives within ICES is to develop the technical basis first, then the framework, and finally application through case studies.

Regarding the lack of examples of applications of management by decision rules in the ICES forum, one participant noted that European scientists do not generally work in an environment that supports simulation-based decisions rules. In particular, the political structures do not support this.

2.5 Observations by the Organization for Economic Cooperation and Development (OECD)

Rapporteur: J. Neilson

Presentation Highlights

Lane presented the experience of the Organization for Economic Cooperation and Development (OECD, Paris) that has undertaken significant initiatives within its Fisheries Committee regarding fisheries systems and broad policy implications. He reported that the past two work programs, 1995-1997 and 1997-1999, focused on multidisciplinary studies of fisheries management policy evaluation inspired by the FAO Code of Conduct for Responsible Fisheries, that was published in 1995. The first work program resulted from the casework of Jon Sutinen of the University of Rhode Island and the publication of the OECD document *Towards Sustainable Fisheries (1997)* (http://www.oecd.org/agr/fish/publications.htm). This document describes the results of over 100 fisheries case studies and the evaluation of the economic aspects of their fisheries management programs.

The 1997-1999 work program continued the work of *Towards Sustainable Fisheries* by expanding the evaluation of a limited number of specific cases to include the fisheries system implications of policy on the biological, economic, social, and administrative (management cost) components of the system. The objective was to explore the implications of alternative policy instruments in moving the case studies towards "responsible" fisheries.

The methodology and analysis for these studies was described briefly. The policy models were presented in Excel spreadsheets (http://www.oecd.org/agr/fish/docrespfish.htm) that provide an analysis of policy alternatives with respect to TACs, allocations to gears, capital reduction and/or expansion, and market and environmental effects. The models explore the multidisciplinary transitions of the fishery system under alternative policy and exogenous change to specified target levels.

Discussion

In reference to the OECD publication *Towards Sustainable Fisheries*, it was asked whether social considerations were adequately dealt with. Lane responded that it depends on the region: lots of information available from Canada, but little from Japan, and Oceania, as examples.

Lane noted that it was easier to discuss the implementation of IFEs within the OECD forum compared with ICES. In the ICES environment, other considerations make implementation of IFEs difficult. A participant noted that perhaps that was due to the ICES forum dealing largely with fisheries concerns in the traditional sense, with little input from disciplines apart from biology. Lane agreed, and noted that it was important to have a proper blend of expertise when discussing the IFE concept. Some participants stressed that the IFE process is not fundamentally a science process. Science is part of a much larger picture. It was noted that in Australia, IFEs weighted considerations such as economic efficiency very highly.

The Namibia example of an IFE was raised again. One participant asked if sociologists were involved in the process, and the response was no, the players included primarily biologists and managers.

A participant asked if there had been any attempt to synthesize the many reports pertaining to the Precautionary Process within ICES. Lane responded to the negative.

2.6 4Vn Herring Decision Rules

Rapporteur: J. Neilson

Presentation Highlights

Claytor described how the process of developing and implementing decision rules resolved a mixed-stock herring fishery crisis in Cape Breton, Nova Scotia, Canada. The fishery occurs in an area, which receives a large migrating stock on a set of smaller local stocks. A purse seine fleet follows the migrating stock into the area as part of their autumn and winter fishery. Little is known about the smaller local stocks, which are harvested as by-catch in the seiner fishery and in directed inshore fisheries by local boats. A situation of constantly shifting regulations during the 1996 fishing season led to a series of incidents that included a wharf occupation and prevention of seiner offloading. As a result of these conflicts it was decided to develop decision rules that would allow the fishery to continue in a safe manner and would clearly identify the information and analyses needed to change the rules.

The decision rules were developed by using computer simulations to estimate exploitation rate scenarios on each stock component. These simulations determined the following general guidelines for the decision rules. First, if fishing occurs where mixing of schools from stocks is random and proportional to their abundance, then average exploitation rates will be equal among stocks but exploitation rates will be more variable on the smaller stock(s). Second, if fishing occurs where small stocks are concentrated, then exploitation rates will be higher on the small stocks. A combination of data analysis and computer simulations was used to develop decision rules concerning catch allocation, when and where to start fishing, and size of fish to catch.

The decision rules were formulated in a series of workshops and stock assessment review meetings attended by industry, managers, and scientists. This process was successful because it broke down barriers among these groups and used quantitative general guidelines to develop the decision rules. The process is readily transferable to other fisheries and provides a means of avoiding or resolving fisheries management crises.

Discussion

One participant asked about the legal implications of proceeding with a decision with a weak rationale, i.e. the question of how many fish to catch was based on recent fishery experience. The participant noted that this would be a problem in other jurisdictions.

For clarification, it was asked if the $F_{0.1}$ target was open for debate during the process. Claytor responded that not at that point in time. It was further noted that the herring industry agreed that changing rules had to have a supporting basis in data and analyses.

Participants asked if there were social or economic considerations in this case. Claytor noted that except in a very general way, such considerations were not a part of the discussions.

There was interest in what has happened since the implementation of the decision rules. The presenter noted that the purse seine fleet had a difficult time finding fish and as a consequence, the fishery has not been too active. It is difficult to evaluate the impact of the decision rules given the recent developments.

A participant asked about the responsibility of the RAP participants in the decision making process. Were participants apprised of this additional responsibility (to help generate the decision rules as well as provide scientific review) and were they comfortable with this? Claytor replied that participants were informed of the process, and they seemed comfortable with it.

There was interest in the industry perceptions of the role of DFO scientists. Was a DFO scientist considered a non-partisan participant in the process? Claytor was not sure but noted that purse seine representatives expressed satisfaction in the process. Claytor emphasized that in his view, satisfaction with the process was extremely important, as was frequent involvement of industry in the whole process.

The discussion then turned to invertebrate fishery examples. The Bay of Fundy scallop fishery was considered comparable to the 4Vn herring example. In the case of the scallop fishery, industry and government also worked out a solution. The resource was in difficult shape in the mid-1990s. Decision rules were established to protect small scallops but not in a formal sense. The speaker agreed that the process was important. In contrast, attempts to manage lobster through measures to protect egg production were mentioned as an example of how not to do it: government tried to implement management measures without thorough involvement of the industry. Another session participant agreed that the process was important, but complications arise when issues that cost money to industry are identified. In response, another participant noted that if industry has responsibility for their own actions, they would consider the longer-term consequences. It was generally agreed that if fishermen were both responsible and accountable, their actions might be more consistent with resource conservation.

2.7 <u>The Current RAP Process and Potential Changes</u>

Rapporteur: J. Neilson

Presentation Highlights

O'Boyle described the Regional Advisory Process (RAP) that was established in 1993 to provide peer review science on the status of fisheries and marine mammal resources in the Southern Gulf of St. Lawrence, the Bay of Fundy, and on the Scotian Shelf and Georges Bank. As well, it peer reviews technical analyses relating to regional habitat and fisheries management issues. The RAP consists of a number of steps. First, the issues are defined by the RAP Coordination Committee and the meeting schedule established. Next, analyses are undertaken by individuals and / or working groups which produce draft SSRs and working papers. These are then presented for review at a meeting of experts and invited industry participants. This meeting produces the final SSR, which will be used in management. Lastly, the advice is communicated through public meetings and other fora.

This process has been the same since the establishment of RAP but is not without its problems. To examine these, the criteria developed by O'Boyle et al. (1999) were used:

- Relevance: Does the advice answer the right question; is it the right question?
- Objectivity: Can different groups develop same answer? Is there conflict of interest?
- Reliability: How good is the quality control (precision and bias issues)?
- Credibility: Does advice make sense? Is it credible to clients and experts?
- Clarity: Is advice unambiguous and clearly understandable?

RAP was then compared to these criteria.

Relevance: The timing of these is based upon the timing of management plans and availability of stock indicators, e.g. survey results. This has resulted in many small RAP meetings to meet needs of each management plan. A more flexible approach is required.

Objectivity: The preparation of working papers is not uniform (WGs vs. individual scientist) and has limited external input. At the review meetings, while industry participation is supposed to be based upon expertise, the reality seems to be by organization, which raises the possibility of conflict of interest. There is a need to change the motivation of industry participation.

Reliability: RAP review meetings are typically 1 - 3 day duration, which is too short for major changes to be made. Assessments can only be accepted or rejected. There is a need for more discussion on assessment frameworks and the opportunity to include new expertise and knowledge.

Credibility: There are client concerns with the potential for 'influence peddling' and scientist concerns with the level of technical peer review.

Clarity: There is client confusion between a full and update assessment, with the perception that the quality of the two products is different.

The RAP Coordination Committee discussed these issues (18 June 2001) and concluded that a new process was required. This would be composed of IFE workshops and annual assessments. There would be a series of workshops each year that would focus on key stocks. Initially, the IFEs would consider only the assessment frameworks and leave discussion on decision rules until a later date. Contrary to the national review recommendation, IFEs would not review stock status. Experts from other sectors and regions would be invited. Assessments would be conducted when needed as part of management schedule. It was emphasized that there would only be one assessment product, i.e. no full vs. update assessment. These assessments would apply the IFE – derived framework to the data with divisions responsible for quality control. Participation and document options were also presented, as were the potential benefits of the new approach in relation to the five criteria. A number of issues in relation to the organization, objectives and products of IFE and assessment meetings still need to be resolved, particularly the need to consult with clients, managers and staff to ensure a smooth transition from the old to the new system.

Discussion

Some participants commented that the presentation sounded like an intensive stock assessment evaluation. It was reiterated that IFEs are different, and encompass a broader set of objectives. O'Boyle stressed that, with the benefit of the discussion held this week, his presentation would be quite different. Some participants pointed out the need to consider ecosystem concepts. A session participant suggested that change is a hierarchical process; attempts to include ecosystem features are already being considered.

It was asked what is the best way to proceed? There is a need to define components of the IFE, including players and participants. It is obvious that the products of an IFE will include more than just a stock assessment. It was suggested that a scoping exercise for an IFE is needed. Another participant agreed that the need for a scoping requirement is absolute. However, he cautioned against unrealistic expectations for the planning and implementation of IFEs, noting that in his group, considerable resources were being devoted to the investigation of the Traffic Light Approach and there is not much left over for additional work.

A participant expressed confusion as to where the process is going. The participant had initially thought that IFEs were focussed on stock assessment only. However, IFEs now sound closely related to the OBFM initiative. This point came up frequently in subsequent discussion and appeared to be a point of consensus. Given the overlap between the OBFM and IFE initiatives, coordination of agendas seems critical. It was suggested that a good starting point is to discuss IFEs within the OBFM discussions.

2.8 General Discussion

Rapporteur: G. Chouinard

The session chair presented a summary of the discussion of the previous day. Some of the important points were:

- IFEs include stock assessment as well as complete analyses of economic, social implications, fisheries management measures, decision rules, etc.
- One does not need to understand the dynamics of the system entirely (an analogy was made to a cement factory); this represents a shift from current approaches which aim at understanding of the system
- Success of the IFE approach may be more difficult to achieve with fisheries 'on the edge'; the concern being that the approach may be incompatible with this situation

- IFEs must address objectives (biological & socio-economic), indicators/reference points, and decision rules; simulation of system behavior is a critical part of IFEs
- IFEs should be organized as an iterative series of workshops, which may take 6 – 24 months, perhaps longer; these would involve scientists, managers and industry; a manual describing the IFE could be attached to the fishery management plan

Discussion focused on buy-in, particularly at the policy level. It was pointed out that if the system can be shown to solve problems, then buy-in by the Minister may be straightforward. Generally, scientific input has had a significant impact on government policy, e.g. $F_{0.1}$, but buy-in will require time; it is a progressive and evolutionary process. Some of the challenges include:

- IFEs will require broad agreement on decision rules from stakeholders up to the Minister
- OBFM and IFEs are and must be seen as part of the same process
- IFEs need broad consultation and will require time to implement
- IFEs will be an increased workload in the short-term; there needs to be recognition that workload is important
- IFEs will require expertise in non- traditional areas, e.g. decision analysis, facilitation skills
- IFEs will require new types of data

Despite the challenges, there are also opportunities. The group considered IFEs as the technical support for OBFM, to which the DFO has committed itself, e.g. Scotian Shelf groundfish is an OBFM pilot. It was noted that, in groundfish, the FRCC is also going in a similar direction with their Fishery Resource Conservation Plans (FRCPs). There was, however, discussion on whether or not it would be appropriate to introduce IFEs. Some were concerned that the approach may be too complex and that it may give a 'bad name' to IFEs. It was felt important to recognize that we are in transition and not overstate the impact of IFEs. We should start small and focus on practical issues. It was felt that many initiatives to date have so far not produced tangible results, while a number of relevant issues, e.g. by-catches, are not being addressed. IFEs have a role in making the fisheries management plans work but DFO needs to be strategic in implementing IFEs. IFEs should deal with the fishery level, e.g. keep Scotian Shelf groundfish as focus rather than its stock components, as this is the practical level that needs attention.

There was discussion on the many processes going on within the DFO and how they interact. It was noted that many of these (AFPR, OBFM, ESSIM, GOSLIM, IFMP, FRCP, etc.) deal largely with the same issue, posing a challenge to the implementation of any one of them. There needs to be discussion on how to reconcile these approaches in a unified approach so that industry will become meaningfully involved. IFE needs to fit into OBFM and not be an additional process.

A number of next steps were discussed:

- IFEs should be initiated within the currently planned OBFM pilots (Scotian Shelf groundfish, Bay of Fundy scallop and Area 19 snow crab)

- IFE software mentioned in the session should be investigated; related IFE approaches and methodologies should be discussed at future meetings

- IFEs needs to be further discussed and accepted at senior management level

- DFO needs to continue its efforts to 'move fisheries off the edge'

It was noted that this is a transition period. It is anticipated that assessments will be conducted this year in a similar fashion as last year.

The chair thanked the participants for the discussion in the session.

2.9 Concluding Remarks

From the chair's perspective, the session achieved its intended goal of initiating dialogue on IFEs to broaden understanding of what IFEs could be and to consider the implications for changes to current practices. While the National Stock Assessment Review did consider a broader scope than just stock assessment for IFEs, just how broad this scope could be may not have been fully appreciated until this session. When the session considered IFE-like processes undertaken both locally and elsewhere, it became evident that IFEs, being comprehensive evaluations of a fishery system, could take a significant amount of time and resources to implement. They represent a dramatically different approach to evaluations than are currently undertaken. On the other hand, the link of IFEs to a number of current initiatives, in particular OBFM, was evident and represents an opportunity to effect fundamental change in the right direction. The session was only the start of dialogue on IFEs with further discussion to develop the definition and understanding of IFEs needed. This session has established a solid basis for this continued dialogue on IFEs.

3. Other Business

The WG was concerned about the multiplicity of initiatives that were on-going that had relevance to fishery management science, policy and planning. There are activities in both Fisheries and Oceans sectors of which WG participants need to be more fully aware if FMSWG is to meet its mandate. At the request of the group, R. O'Boyle and P. Fanning agreed to produce a summary of on-going activities with timelines. *[Subsequent to the meeting, R. O'Boyle conducted a round of consultations and produced the Summary of Policy and Planning Initiatives appended as Annex 7.]*

3.1 Future Work of WG

No suggestions were made for further work by the WG. It was considered that the Traffic Light methodology was now in a testing and evaluation phase and that this was best performed in the assessment working groups. There was anticipation that new issues on Traffic Light methodology could arise during the course of assessment meetings in the autumn that would merit convening the WG. There was a suggestion also that the WG could be used to evaluate technical issues arising from the OBFM pilots, also in the autumn.

3.2 Next Meeting

It was decided to await developments. No specific arrangements were made for the next meeting.

Annex 1. Agenda, Participants and Working Papers, 25-27 June 2001

Advances in the Traffic Light Method

AGENDA

1.0 Introduction

- 1.1 Approval of Agenda

2.0 Indicators

- 2.1 Report on meeting of 15-16 and 31 May on indicator descriptions
- 2.2 More indicator descriptions
- 2.3 Case studies for salmon and shrimp stocks (G. Chaput, D. Orr)
- 2.4 Boundary points
- 2.5 Scaling data series of different duration - RV vs. Industry surveys (M. Fowler)

3.0 Integration

- 3.1 Traffic Light Index versus Traffic Light Decision Framework
- 3.2 Multi-criteria decision making techniques (Esra Karasakal)
- 3.3 Descriptions of Characteristics (P. Fanning, R. Mohn)
- 3.4 Integration methods for formulation of Characteristics (R. Mohn)
- 3.5 Integration of Characteristics with regard to stock status (P. Fanning)

4.0 Using a Traffic Light Precautionary Management Framework

- 4.1 Reference Points
- 4.2 Decision rules
- 4.3 Update on the Groundfish Case Study (Objective-Based Fisheries Management [OBFM] Initiative) (C. Annand – FM perspective, D. Lane – FRCC perspective)

5.0 Other Business

- 5.1 Future Work of WG
- 5.2 Next Meeting

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LIST OF WORKING PAPERS

1. Chaput, G. 2001. Stock attributes and traffic light summaries of stock status for Atlantic salmon. RAP WP 2001/42, 20pp.

2. Fanning, P. 2001. Characteristics as indicators of productive capacity. RAP WP 2001/43, 1p.

3. Fowler, M. 2001. Scaling estimates between surveys: a look at some approaches to integrate the summer research vessel and mobile gear survey estimates of cod abundance in 4X. RAP WP 2001/44, 4pp.

4. Halliday, R. 2001. Notes on the Objective-Based Fisheries Management Initiative: pilot application to groundfish management in Scotia-Fundy Region. RAP WP 2001/45, 15pp.

5. Karasakal, E, and O. Karasakal. 2001. Multiple Criteria Decision Making methods. RAP WP 2001/46, 23pp.

Annex 2. Agenda, Participants and Working Papers, 28-29 June 2001

Intensive Fishery Evaluations

AGENDA

Background

One of the issues raised by the 2000 – 2001 DFO National Stock Assessment Review was the frequency of stock assessments and the provision of advice to DFO clients. The recommendation was made to move to a system of Intensive Fishery Evaluations (IFEs), which would be comprehensive evaluations of the stock assessment and decision models outside of the routine management schedule. In other words, the IFE would set up the assessment / decision framework, which would then be provided to scientists, managers and clients to implement on an on-going basis.

Conceptually, the proposed IFE approach is similar to approaches that have been considered by a number of international organizations. It has its roots in the work of De la Mare (1986) on Management Procedures for the IWC, of which Cooke (1999) provides recent efforts. Constable et al. 2000 discusses the approach in CCAMLR's management of the Antarctic marine ecosystem. Various ICES working and study groups have also considered the evaluation of management systems, this work summarized in the 2000 report of its Working Group on Fishery Systems. Butterworth and Punt (1999) provide a nice overview of the use of the IFE approach internationally.

In eastern Canada, the RAP Fisheries Management Studies Working Group (FMSWG) has discussed the need for the evaluation of fisheries systems, not just the biological component. Most recently (Halliday and Mohn, 2001), it has considered an assessment approach (termed the Traffic Light Method) that allows integration of indicators from different parts of the management system. Implementation of the IFE approach has been limited, with the 4Vn herring decision rule system (Claytor, 1998) being an example.

Consideration of an IFE approach in Canada would benefit from the experience of its use elsewhere in the world.

Objectives

The meeting is to provide an opportunity to discuss what an IFE is intended to be and what changes are required to implement IFEs in the Maritimes and Gulf Regions. This is primarily an 'ideas' meeting, as subsequent national level meetings will develop the discussion further. Specific objectives include:

- Review the format of IFEs, as proposed by the National Stock Assessment Review
- Discuss IFE – like approaches used elsewhere and locally to better describe what an IFE consists of and what issues need to be considered.
- Consider the current assessment review process and discuss what changes would be required to move to an IFE framework in the Maritimes and Gulf Regions

Schedule

28 June 2001

09:00 - 09:15	Introduction and Background (O'Boyle)
09:15 – 10:00	IFEs - National Stock Assessment Review (R. O'Boyle)
10:00 – 10:15	Break
10:15 – 11:00	International Observations on Management Procedures (A. Punt)
11:00 – 11:30	The ICES Experience (D. Lane)
11:30 – 12:00	Observations by the OECD (D. Lane)
12:00 – 13:00	Lunch
13:00 – 13:30	4Vn Herring Decision Rules (R. Claytor)
13:30 – 14:00	The management of the 4VW Herring Fishery (R. Stephenson) (tentative)
14:00 – 15:00	The Current RAP Process and Potential Changes (R. O'Boyle)
15:00 – 15:15	Break
15:15 – 17:00	Discussion

29 June 2001

09:00 – 12:00	Discussion (if needed)
12:00	Adjournment

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LIST OF BACKGROUND DOCUMENTS

Anon. 2000. Report of the Working Group on Fishery Systems. ICES CM 2000 / D:02.

Butterworth, D. S. and A. E. Punt. 1999. Experiences in the evaluation and implementation of management procedures. ICES Journal of Marine Science. 56: 985 – 998.

Claytor, R. 1998. Decision Rules: 4T Overwintering Herring Fishery in 4Vn. DFO Maritimes Regional Fisheries Status Report. 98 / 3.

Constable, A. J., W. K. de la Mare, D. J. Agnew, I. Everson and D. Miller. 2000. Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). ICES Journal of Marine Science. 57: 778 – 791.

Cooke, J. G. 1999. Improvement of fishery – management advice through simulation testing of harvest algorithms. ICES Journal of Marine Science. 56: 797 – 810.

De la Mare, W. K. 1986. Simulation studies on management procedures. Report of the International Whaling Commission. 36: 429 – 450.

Halliday, R. G. and R. Mohn. 2001. Proceedings of the Fisheries Management Studies Working Group. 8 – 11 January 2001. Canadian Science Advisory Secretariat Proceedings Series. 2001 / 08.

O’Boyle, R., J. Rice and A. Sinclair. 1999. The Peer Review of Science in the Management of Living Aquatic Resources. ICES C.M. 1999/Q:03.

Annex 3.

Stock Attributes and Traffic Light Summaries of Stock Status for Atlantic Salmon

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DFO Science, Gulf Region
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Moncton, NB

There are approximately 550 Atlantic salmon rivers in eastern Canada and each river is assumed to consist of at least one stock with the larger rivers containing several stocks. Detailed biological information is available from a limited number of rivers. There are clearly articulated management principles for Atlantic salmon in eastern Canada. The highlights are:

1. Priority management to achieve conservation objectives
2. After conservation, priority access given to the Aboriginal fisheries for food, social and ceremonial purposes
3. After conservation and Aboriginal fishing rights, access will be given to recreational and commercial fisheries so as to distribute the benefits among the largest number of Canadians.
4. Protection and improvement of salmon habitat to allow for maximum stock production.

In 1991, CAFSAC (1991) formally defined conservation for Atlantic salmon as a level of egg deposition in individual rivers. A fixed escapement policy with all fish in excess of this requirement considered surplus and available for harvest has been promoted.

For Atlantic salmon, three stock status zones are proposed on the basis of performance relative to both spawning stock abundance and fishing mortality reference points (Fig. 1).

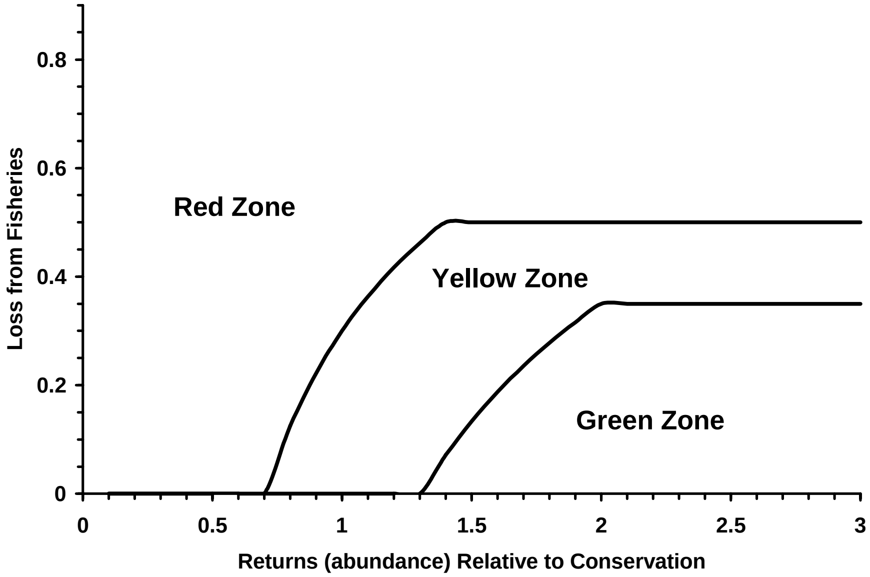


Figure 1. *Performance plot defining the status categories for Atlantic salmon. The plot describes a fixed escapement policy up to a maximum exploitation rate level.*

The three zones are interpreted as follows:

Green Zone: “desired” state in terms of exploitation and stock size. When the resource is above the Stock reference point and removals are below the Removal reference point, then status quo management is acceptable or a different exploitation regime could be considered.

Yellow Zone: caution zone where returns or exploitation rates are are within the uncertainty bounds of the limit reference points. With the fixed escapement policy, as returns decline to the limit reference level, the allowable harvests must also decline. Alternatively, the spawning stock is above the reference level but removal rates are also above the removal reference rate which increases the chances of stock declines below reference levels should recruitment be less than expected, or fisheries harvest more than expected.

Red Zone: This is a danger zone where removal rates are excessively high at all spawning stock levels or spawning stock levels are below the limit reference level.

The yellow zone encompasses the uncertainty in the quantification of the reference points which arises from process error (variations in survival among year classes), observation error (error in the estimates of spawning stock size and recruitment), and model misspecification error (the assumed dynamic of the stock may not be the correct one). In terms of spawner reference levels for Atlantic salmon, the estimation of spawners for MSY have uncertainty of +/- 30% in the best of cases. The removal rate reference points are expected to be similarly poorly defined.

By overlaying the historical pattern of returns and exploitation of a stock, the performance of the stock and the success of the management regime in maintaining the resource within the desired zone can be assessed (Fig. 2).

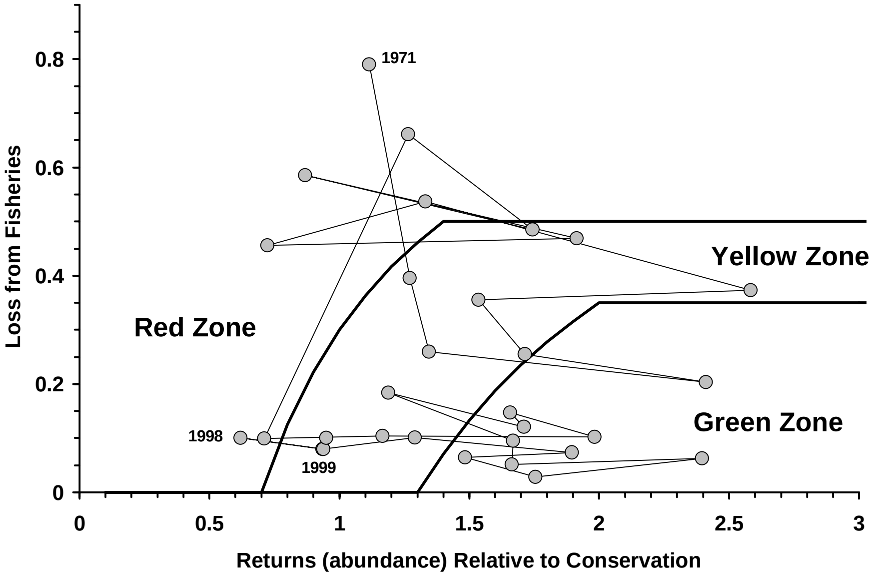


***Figure 2**. Performance plot for the Miramichi River Atlantic salmon stock, 1971 to 1999.*

Development of Stock Attributes for Characterizing Stock Status

Six characteristics are proposed:

1. Quantitative characteristics
- Adult abundance: abundance and trends of adult returns and spawners
- Freshwater production: abundance of juveniles, temporal trends in abundance, spatial distribution
- Marine recruitment: relative abundance of smolts, temporal trends in abundance, trends in sea survivals

2. Qualitative characteristics
- Resilience: biological characteristics such as maximum age, age at maturity, fecundity, semelparity, and stock size
- Environmental: environmental (temperature, discharge) chemical, and physical constraints, disease,
- Management: relevance of reference points, fishing mortality sources directed and incidental, preseason and inseason assessment capabilities, and intervention (hatchery stocking).

The boundary points for the quantitative characteristics are defined relative to the response of the indicators to variations in spawning stock below, at and above the reference points. Although spawning escapements at these reference points should provide recruitment surplus to the parental stock, the size of the exploitable component (surplus to requirement) will be defined by the productivity of the stock.

For common characteristic indicators, uniform weights (or unweighted) are used. The characteristic is constructed sequentially relative to the information available. This is most easily represented as a summation matrix for two indicators.

Summation matrix for two indicators of one characteristic (negative = red, 0 = yellow, positive = green)				
	Indicator B for characteristic			
Indicator A for characteristic		Red	Yellow	Green
	Score	-1	0	1
Red	-1	-2	-1	0
Yellow	0	-1	0	1
Green	1	0	1	2

No weighting across characteristics to derive a single traffic light for overall stock status was proposed.

Quantitative Characteristics

The adult abundance characteristic reflects in some cases overall returns (when fisheries are closed) and the performance of the management system. Returns are estimated for an individual river and escapements are the returns minus known removals. Returns and escapements are translated into eggs and these are evaluated relative to the conservation requirement for the river (defined in terms of eggs).

Summation matrix for the adult attribute (negative = red, 0 = yellow, positive = green)				
	Returns relative to conservation			
Spawners relative to conservation		Red (< 70%)	Yellow (70% to 130%)	Green (> 130%)
	Score	-1	0	1
Red (< 70%)	-1	-2	-1	0
Yellow (70% to 130%)	0		0	1
Green (> 130%)	1			2

The following example is the traffic light summary for adult abundance for the Miramichi River salmon stock for the years 1971 to 2000 (Fig. 3). The traffic light associated with the label "adult" is the result of the summation matrix of the spawner and return indicators.

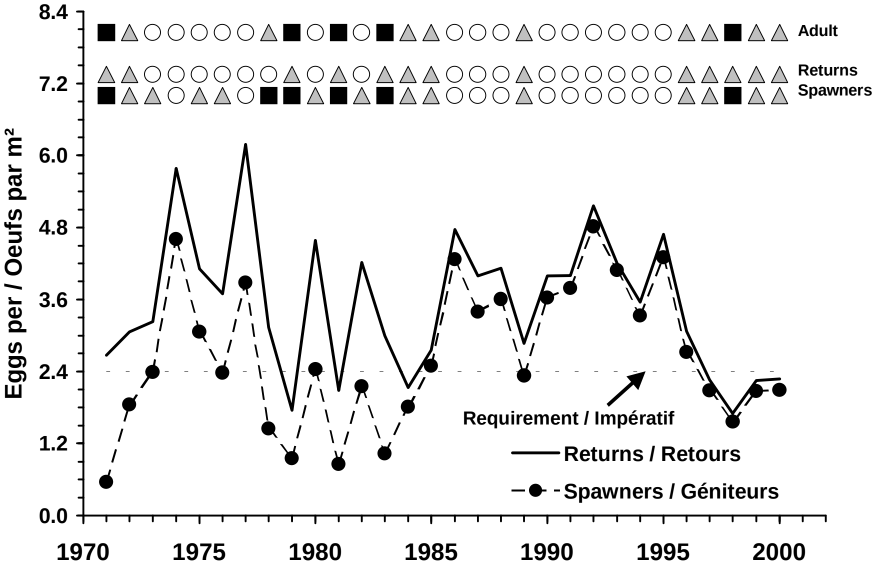


Figure 3. *Adult abundance characteristic from the Miramichi River, 1971 to 2000. The solid square is the red light, the grey triangle is the yellow light and the white circle is the green light.*

The freshwater stages of Atlantic salmon are the source of recruits to the sea and subsequent returns of adults. They are an indication of the recent spawning escapements and freshwater productivity and carrying capacity. As an attribute for stock status, juveniles would be assessed in terms of abundance (average and variance), spatial distribution within accessible area, and trends in abundance.

The relationships between juvenile abundance and egg depositions in the Miramichi River were used to define boundaries for the juvenile abundance indicators.

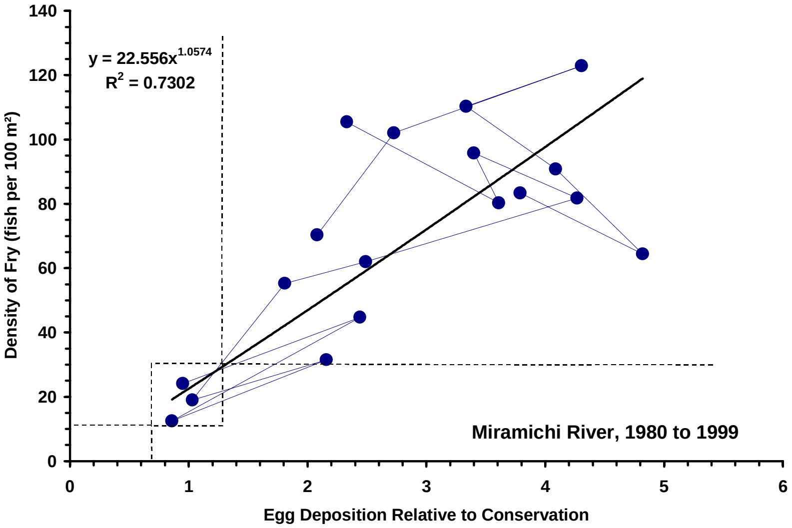


Figure 4. *Juvenile abundance of fry relative to egg depositions from the Miramichi River, 1980 to 1999.*

The combined matrix for juveniles would be:

Summation matrix for the juvenile abundance attribute (negative = red, 0 = yellow, positive = green)				
	Parr Abundance (fish per 100 m^2)			
Fry Abundance (fish per 100 m^2)		Red (< 8)	Yellow (8 to 14)	Green (> 14)
	Score	-1	0	1
Red (< 10)	-1	-2	-1	0
Yellow (10 to 30)	0	-1	0	1
Green (> 30)	1	0	1	2

The spatial distribution of juveniles within the river can be used to infer changes in spawning escapement levels, differences in habitat suitability, and possible loss of population structure. Since salmon are not broadcast spawners, as abundance of spawners declines, spawning areas can remain vacant. As well as indicating the previous year's spawning activity, the constriction of spatial distribution within the river means that the system is. Restricted spawning activity can be detected by distribution of fry the following summer. There were proportionally more sites without fry when spawning escapements were low in the 1970s relative to the 1990s for the Miramichi (Fig. 6).

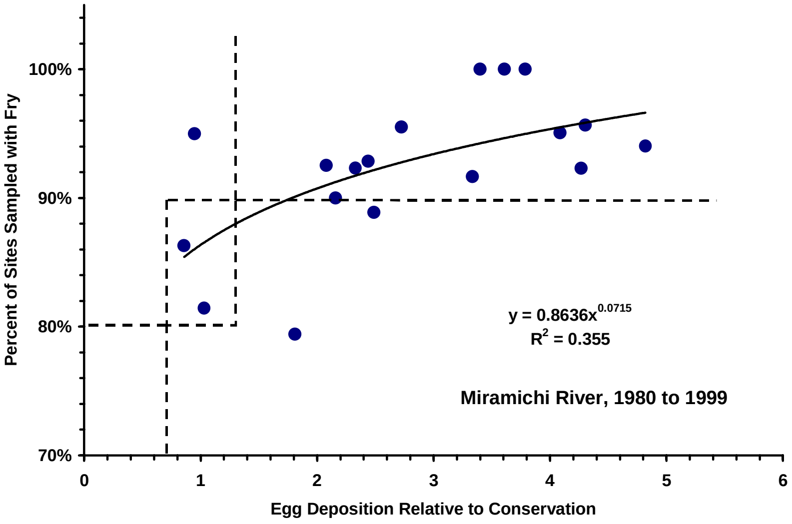


Figure 6. *Spatial distribution of fry relative to egg depositions in the Miramichi River, 1971 to 1999.*

The final freshwater characteristic is defined by the combination of the juvenile abundance matrix and the spatial occupancy matrix.

Summation matrix for the freshwater production attribute (negative = red, 0 = yellow, positive = green)

	Juvenile Abundance Indicator (from summation matrix)			
Spatial Occupancy for fry (% of sites)		Red	Yellow	Green
	Score	-1	0	1
Red (< 80%)	-1	-2	-1	0
Yellow (80% to 90%)	0	-1	0	1
Green (> 90%)	1	0	1	2

The performance of the freshwater characteristic for the Miramichi River, 1971 to 1999 is presented in Fig. 7. Since 1987, all the indicators are green which reflects both high abundance of juveniles and broad distribution of juveniles within the sampled habitat.

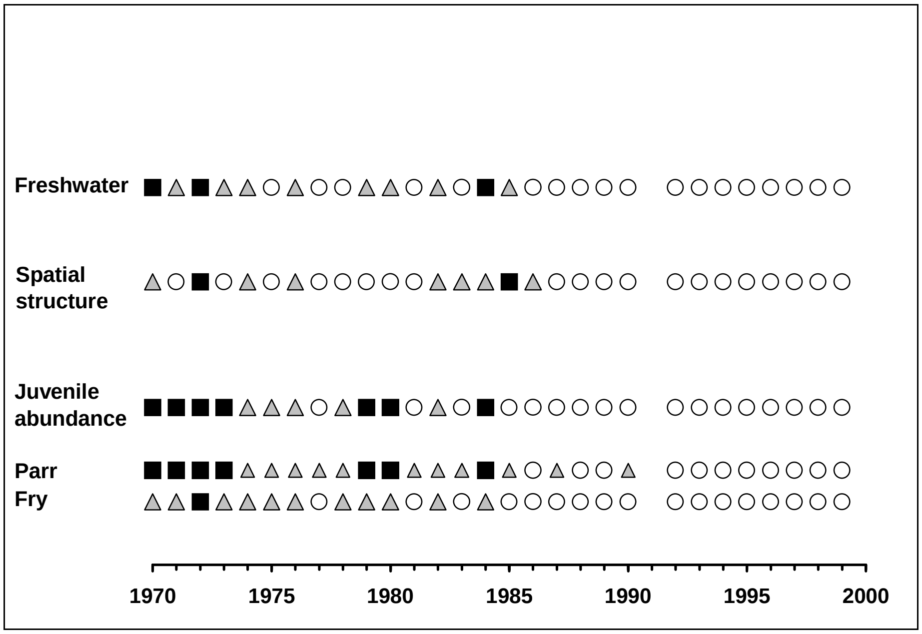


Figure 7. *Freshwater production indicators and overall freshwater characteristic traffic light summaries for the Miramichi River, 1971 to 1999. The solid square is the red light, the grey triangle is the yellow light and the white circle is the green light.*

The marine recruitment stage characteristic measures the smolt production from the river and the sea survival to returns as adults. A commonly used smolt production rate for the fluvial habitat of rivers of eastern Canada is 3 smolts per 100 m^2. Elson (1975) indicated that smolt production rates of 3 to 6 smolts per 100 m^2 should be expected in Maritime rivers.

The boundary points for the sea survival indicator would be defined on the basis of sea survival rates required to produce potential spawners at conservation or replace the spawning stock for different rates of freshwater production. At the default conservation egg deposition rate of 240 eggs per 100 m^2 and a resultant smolt production rate of 3 smolts per 100 m^2, the egg to smolt survival rate is 1.25% (3/240). At this rate of freshwater survival, the parental stock would replace itself or generate surplus recruitment at the conservation reference point if sea survival of the smolts was 3.2% in a 1SW salmon stock (at 2500 eggs per spawner), or 1.5% in a MSW stock (at 5500 eggs per spawner).

Summation matrix for the marine recruitment attribute of a 1SW stock (negative = red, 0 = yellow, positive = green)

	Sea survival rate			
Smolt production rate (smolts per 100m^2)		Red (< 3.2%)	Yellow (3.2% to 9.6%)	Green (> 9.6%)
	Score	-1	0	1
Red (< 1)	-1	-2	-1	0
Yellow (1 to 3)	0	-1	0	1
Green (> 3)	1	0	1	2

Qualitative Characteristics

The general resilience of a population to environmental and demographic perturbations is reflected in the life history characteristics of the species, including population size, lifetime fecundity, age at maturity, maximum age and post-spawning survival. Generally, small rivers have smaller runs of salmon than large rivers. Atlantic salmon runs to rivers of the Maritimes are generally small with only three rivers with run sizes exceeding 10,000 fish annually.

When there are few year-classes simultaneously contributing to reproduction, the stock is more susceptible to catastrophic events. Salmon populations in eastern Canada generally have at least two year classes or more in river and anywhere from two to five year classes at sea. Stocks with both 1SW and MSW spawners are expected to be more resilient than those which are predominantly 1SW spawners. Additional resilience is provided by the presence of repeat spawners in the population. A green traffic light could only be defined if information on run size and age structures in both the juvenile and adult components are available.

Annual run size	**Cohorts in freshwater**	**Cohorts at sea**	**Repeat spawners (% of annual run)**	**Resilience score**
< 100 *(Red)*				No directed fisheries
> 100 *(Red)*	< 3 *(Red)*	1 *(Red)*	< 10%	Low *(Red)*
			> 10%	Medium *(Yellow)*
		2 or more *(Yellow)*	< 10%	Medium *(Yellow)*
			> 10%	High *(Green)*
	3 or more *(Yellow)*	1 *(Yellow)*	< 10%	Medium *(Yellow)*
			> 10%	Medium *(Yellow)*
		2 or more *(Green)*	< 10%	High (Green)
			> 10%	High (Green)

There are several environmental factors which impact on the salmon survival and production rates in freshwater. These constraints should be identified and their impacts on the viability of the stock or the level of exploitation which could be sustained should be articulated. Examples of environmental constraints to be considered are described below.

1. Discharge/temperature constraints: Low water conditions delay the migration of salmon into the river and may restrict the subsequent use of the headwater spawning areas. For juveniles, feeding is reduced or ceases and basal metabolic rate increases at high temperatures resulting in depletion of energy reserves (which are required for overwintering) and declines in condition.

2. Atlantic salmon are susceptible to a range of bacterial and viral diseases and many have spread around the Maritimes in recent years. The detection of new diseases show raise a caution flag until such time as the extent of mortality resulting from the disease can be determined.

3. Freshwater carrying capacity and productivity has been severely reduced by acid deposition in many rivers of the Southern Uplands of Nova Scotia. In some areas of the

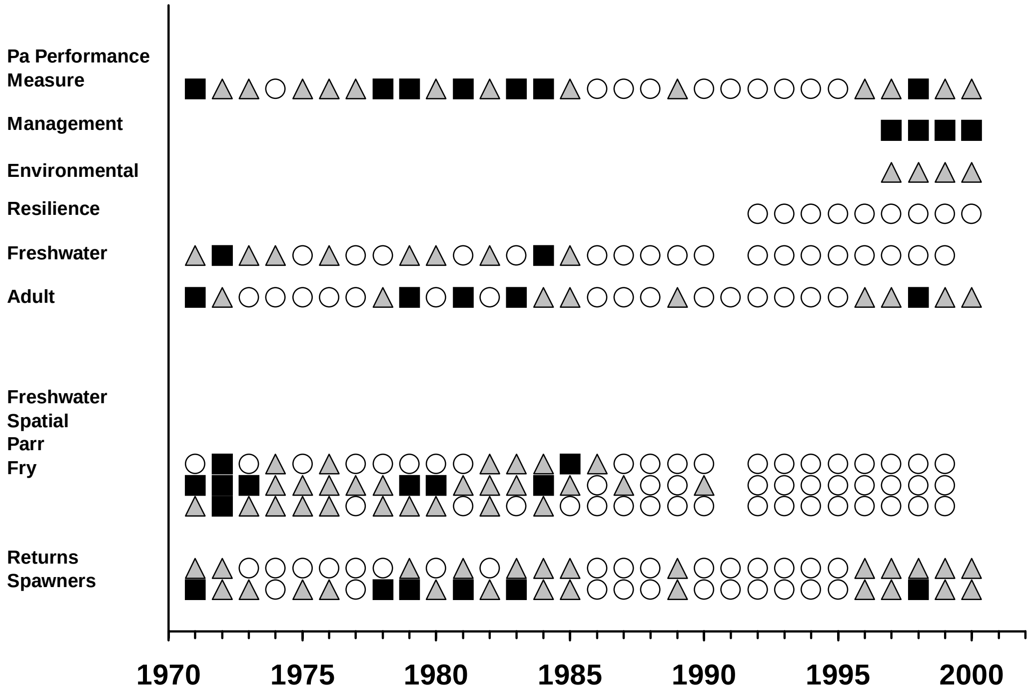
Maritimes, human activity resulting from land use practices including forestry, agriculture and urbanization have reduced the productive capacity of the rivers.

4. Barriers to migration such as hydroelectric and water storage dams, and road culverts as well as natural obstructions such beaver dams and log jams can reduce fish passage efficiency and limit access of adult salmon to spawning areas. These may also affect smolt migrations and survival directly (such as mortality through turbines or over spillways) and indirectly (by increasing predation in headponds or at the bottom of dams.

There are several management attributes to be considered including the type of resource use which occurs, whether management can make use of forecasts, both preseason and inseason, and whether supplementation of the wild population is available.

1. Directed fisheries:
   - Can the harvest rates and total harvests be controlled?
   - Are the harvest levels known (harvest statistics)?
   - Can selective fishing gears be used?
   - Is there mortality associated with the non-target animals in the selective fishing practices?
2. Bycatch in other fisheries
   - bycatch and associated mortalities from the bycatch known?
3. Preseason and Inseason forecast capabilities
   - Are preseason models available? What has been their performance in recent years? Are they used by fisheries management?
   - Are there inseason assessment capabilities? Are they used by management?
4. Is there artificial supplementation in the river
   - What is the objective of the hatchery program (preservation of a wild resource in decline, providing access to users, …?
   - Can hatchery origin fish be distinguished from the wild fish?

Example of Traffic Light Assessment for the Miramichi River Atlantic salmon stock.



Adult abundance improved through the late 1980s and early 1990s but in the last five years has declined to near reference point levels. Juvenile abundance and overall freshwater production has improved and remained high but the management regime is not capable of responding to variations in stock status. The PA performance measure symbols represent the status zones of the stock relative to the two reference points limits defined, i.e. relative to conservation requirements for spawners and relative to the egg losses from the fisheries (see Fig. 2). The performance measure relates most closely to the adult characteristic.

Outstanding issues in Traffic Light Characterization

- There is no description of the temporal trend in the characteristics and it is up to the reader to interpret the trend.
- There is no final indicator for the stock which incorporates all the characteristics.
- The boundary points should be defined specifically for the relative productive capacity of the individual stocks

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Annex 4.

MULTICRITERIA DECISION MAKING: An Overview of Techniques Relevant to Fishery Management Planning and Some Comments on Traffic Light Approach

by
Dr. Esra Köktener Karasakal

1. What is Multicriteria Decision Making?

Multicriteria Decision Making (MCDM) is the most well known branch of decision making. It is a branch of a general class of Operations Research models which deal with decision problems under the presence of a number of decision criteria. A multicriteria decision problem generally involves choosing one of a number of alternatives based on how well those alternatives rate against a chosen set of criteria.

2. Some MCDM Terminology

Alternatives: Alternatives represent the different choices of action available to the decision maker. Usually, the set of alternatives is assumed to be finite, ranging from several to hundreds. They are supposed to be screened, prioritized and eventually ranked.

Goal: Goal is the overall objective of the problem to be satisfied. It must be clearly defined.

Criteria: Each MCDM problem is associated with multiple criteria. Criteria represent the different dimensions from which the alternatives can be viewed. Some MCDM methods may explicitly consider a hierarchical structure in the criteria of a problem.

Decision weights: Most of the MCDM methods require that the criteria be assigned weights of importance. Usually, these weights are normalized to add up to one.

3. Classification of MCDM Techniques

I classify MCDM techniques into three groups according to the timing of obtaining preference information from the Decision Maker (DM).

1. *A Priori Articulation of Preferences:* These approaches require all the input from the DM at the start of the solution process.
2. *Progressive Articulation of Preferences:* The DM is required to give some preference information based on the solutions generated at each iteration. The process continues until either the DM is satisfied with the best solution found so far.
3. *A Posteriori Articulation of Preferences:* These approaches generate all possible solutions and then the DM chooses among them.

4. A Priori Articulation of Preferences

I will make short presentations of MCDM methods that can be useful for the development of the Traffic Light Approach, namely Analytic Hierarchy Process, Analytic Network Process, outranking methods, methods based on Multiattribute Utility Theory and Stochastic Multicriteria Acceptability Analysis.

Analytic Hierarchy Process (AHP) (Saaty, 1980)

AHP is based on a principle of pair-wise evaluation of alternatives, according to a built-in scale valued from 1 to 9. So, for every pair of alternatives and every used criterion, the user has to indicate his preference of an alternative on every other. AHP can combine quantitative and qualitative data under a single goal.

Analytic Network Process (ANP) (Saaty, 1996)

ANP can be applied to very sophisticated decisions involving a variety of interactions and dependencies. It can be mostly used in the complex corporate or public-sector decisions requiring a large amount of information, interaction, and feedback with a high degree of complexity.

AHP can be applied to MCDM problems that have a hierarchical structure (see Figure 1) whereas ANP can be applied to MCDM problems that have a network structure (see Figure 2).

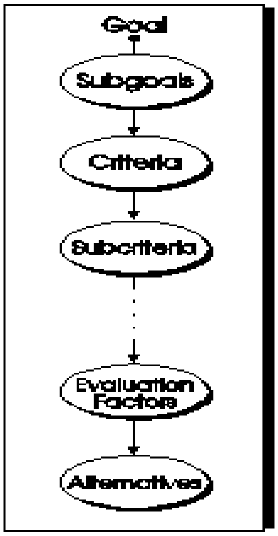

Figure 1. A general hierarchy

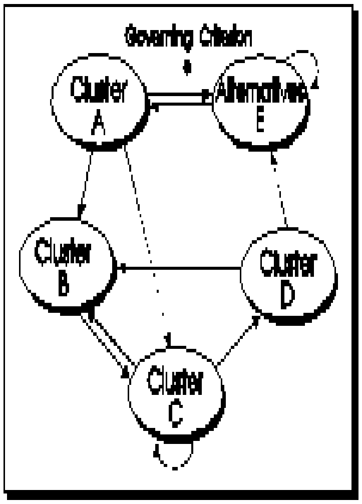

Figure 2. A network

Outranking Methods

Outranking methods are based on *outranking relation*. Outranking relation is a binary relation defined in a set of alternatives such that *a outranks b* if given what is known about the decision maker's preferences and given the quality of the valuations of the alternatives and the nature of the problem, there are enough arguments to decide that *a* is at least as good as *b*.

(a) *ELECTRE I* (Roy, 1968): This method is applicable for multicriteria choice problems. Its aim is to be able to obtain a subset of alternatives such that any alternative which is not in this subset is outranked by at least one alternative from the subset.

(b) *ELECTRE II* (Roy and Betrier, 1971): It aims to rank the alternatives from best to worst (ranking problem).

(c) *ELECTRE III* (Roy, 1978): This method takes explicitly into account indifference and preference thresholds. It is based upon a valued outranking relation, which is less sensitive to variations of the data and involved parameters. As in ELECTRE II, we are concerned with a ranking problem.

(d) *ELECTRE IV* (Roy and Hugonnard, 1982): It aims to rank the alternatives, but without introducing any weighting of the criteria.

(e) *PROMETHEE* (Brans and Vincke, 1985): This method consists in building a valued outranking relation, but this time trying to involve concepts and parameters which do have some physical (or economic) interpretation easily understandable by the decision-maker.

Multiattribute Utility Theory

In Multiattribute Utility Theory, it is presumed that the decision-maker is guided by an underlying construct that represents his/her preferences by a real-valued utility function. The utility function is then used to determine the preference order for the alternatives.

Keeney and Raiffa (1976) have developed the most commonly applied procedure for assessing multiattribute utility functions. Using their procedure the multiattribute alternative is first decomposed into its constituent attributes. A conditional utility function is then determined for each attribute. These functions are conditional in the sense that all other attributes are assumed to be fixed at know levels. Finally, the conditional utility functions are combined into a composite utility function. In order to make the assessments that are required to combine the attribute utilities, the form of the composite utility function must be known.

Stochastic Multicriteria Acceptability Analysis (SMAA) (Lahdelma and Salminen, forthcoming)

This method has been developed for multicriteria problems, where criteria data is uncertain or inaccurate and where for some reason it is impossible to obtain accurate or any weight information from the DMs. It applies assumed partial utility functions and stochastic criteria.

5. Comments on Traffic Light Approach

Following issues need to be considered for the development of the Traffic Light Approach.

- Scientific approach for solving an MCDM problem
- Group consensus building
- Hierarchical nature of criteria
- Weighting of criteria
- Boundary points

5.1 Scientific Approach for Solving An MCDM Problem

One way of summarizing the usual phases of an MCDM study is the following:

1. Determine the goal, relevant criteria and alternatives.
2. Attach numerical measures to the relative importance of the criteria and to the impacts of the alternatives on these criteria.
3. Process the numerical values to determine a ranking of each alternative.

5.2 Group Consensus Building

Delphi Method is one of the group consensus building techniques. The objective of Delphi application is the reliable and creative exploration of ideas or the production of suitable information for decision making. In this method, each member independently and anonymously writes down comments and suggestions about ways to deal with a problem of issue. Ideas are compiled, reproduced, and distributed to members for observation and reaction. Each member provides feedback to the entire group concerning each of the comments and proposed solutions. The members reach consensus on which solution is most acceptable to the group as a whole.

5.3 Hierarchical Nature of Criteria

The system should be studied in detail with a view to identifying the goal, the alternatives and the criteria/sub-criteria for comparison of alternatives. The information should be organized into a hierarchic structure. In the hierarchy shown in Figure 3, first the ultimate objective of the exercise is stated. At the first level, relationships between the goal and the criteria for comparison of alternatives are specified. With respect to each criterion, we may have several sub-criteria. Thus the criteria/sub-criteria relationships are linked at level 2. For each sub-criterion there may be further subcriteria. The relationships between sub-criteria and sub-subcriteria are represented at subsequent levels in the hierarchic structure. This is continued until all possible criteria or sub-criteria relevant to the decision making problem have been specified.

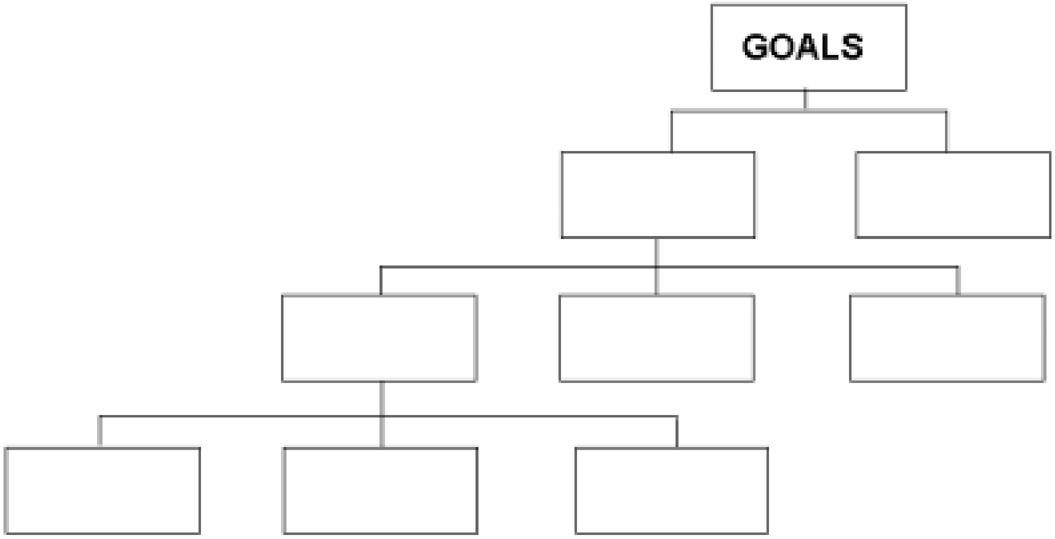

Figure 3. A Hierarchical Structure

5.4 Weighting of Criteria

Pairwise comparison method can be used to calculate the weights of criteria. In a multilevel hierarchy, the pairwise comparisons are done with respect to the criteria at the preceding level, i.e., the alternatives are pairwise compared with respect to the sub-criteria, the sub-criteria are pairwise compared with respect to their contribution towards the criteria and the criteria are compared with respect to their importance towards the ultimate objective. The qualitative information is converted into quantitative values using the following table.

Option	Numerical Index
Equal	1
Mildly Strong	3
Strong	5
Very Strong	7
Extremely Strong	9

The pairwise comparisons of various criteria generated are organized into a square matrix. The diagonal elements of this matrix are 1 (indicating that each criterion is equally important compared to itself) and the other elements are pairwise comparisons of the other criteria. The criterion in i^{th} row is better than the criterion in the j^{th} column in case the value of the element (i,j) is more than one; otherwise the criterion in j^{th} column is better than the criterion in i^{th} row. The $(i,j)^{th}$ element will be reciprocal of the $(j,i)^{th}$ element. The size of the matrix corresponds to the number of criteria. We do similar exercise at other levels in the hierarchy thereby generating matrices with respect to each criterion or sub-criterion.

The principal eigenvector of a matrix gives the relative importance of various criteria/sub-criteria/alternatives being compared in the matrix. The elements of the normalized eigenvector are termed as weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives. (Saaty, 1980).

5.5 Control Charts

Boundaries in the traffic light approach can be determined as in statistical process control. Control charts consist of a set of measurements, where these measurements of quality or quantity should be plotted as a time series graph and three horizontal lines:

The center line - which is drawn at an appropriate target value. This target value may be set at mean of past data or it may be related to the specification limits.

The upper and lower action lines - which are placed three standard deviations above and below the center line.

Moreover, Statistical Process Control (Q-charts, P-charts) can be employed to analyze the system and to diagnose the problems.

5.6 Forecasting

Forecasting is concerned with what the future *will* look like, while planning is concerned with what it *should* look like. Time series analysis and regression analysis can be used to predict the values of indicators/criteria in the future.

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Annex 5.

A Comparison of Methods for Creating Traffic Light Indicators and Integrating them into Characteristics

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Introduction

The purpose of the study was to compare 4 methods of display and integration:

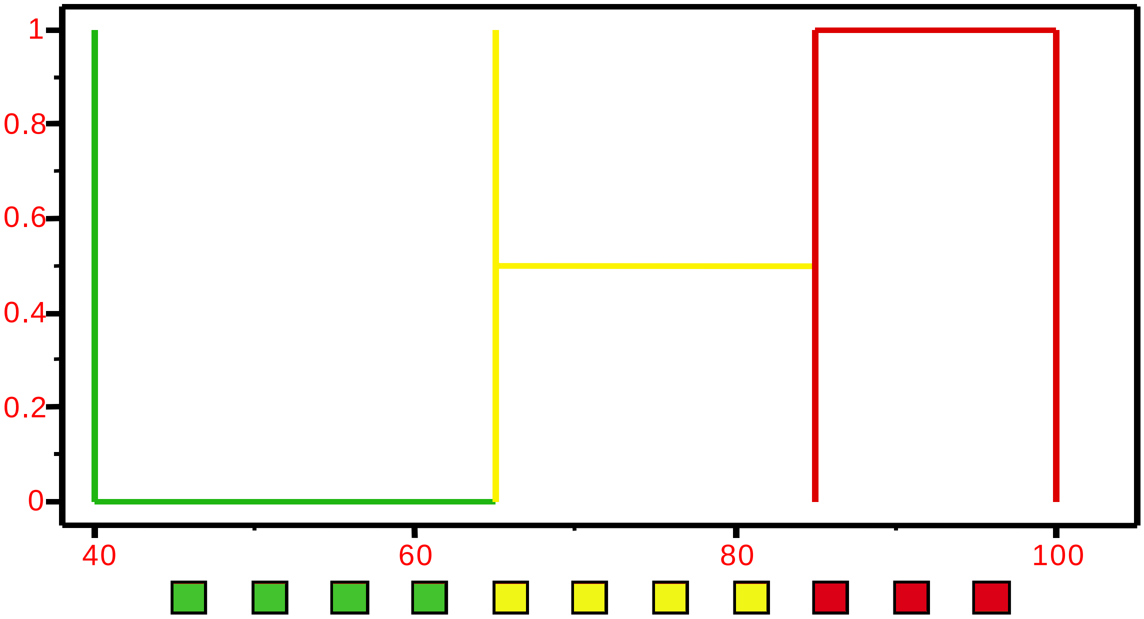
1) Strict traffic Lights – 3 colours only and abrupt transitions
2) Ramp Traffic Lights – smooth transitions between adjacent colours
3) Fuzzy Logic
4) Continuous Scaling

These methods were presented and discussed at the January 2001 meeting and more details of each can be found in the Minutes (CSAS Proc. Ser. 2001/08). A brief description of each is presented below. The integrations will be compared using simulated data.

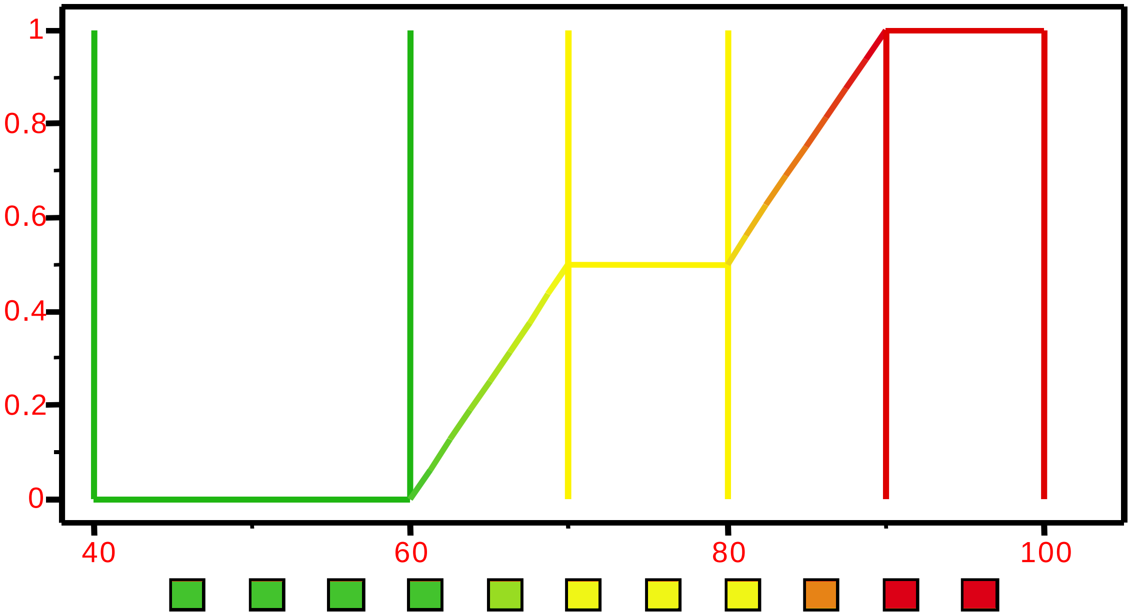
Transition from Data into Indicators – Scaling and Colouring

All 4 methods under review have the same two basic steps, scaling and then colouring. Each times series of data is scaled (or normalised) onto the range 0-1 using user-specified limits. In present examples the scaling is linear, but in general it need not be. After scaling, colours are assigned and this is the main distinction among the methods of integration. In the present examples more of the quantity is construed as bad, say a predator biomass.

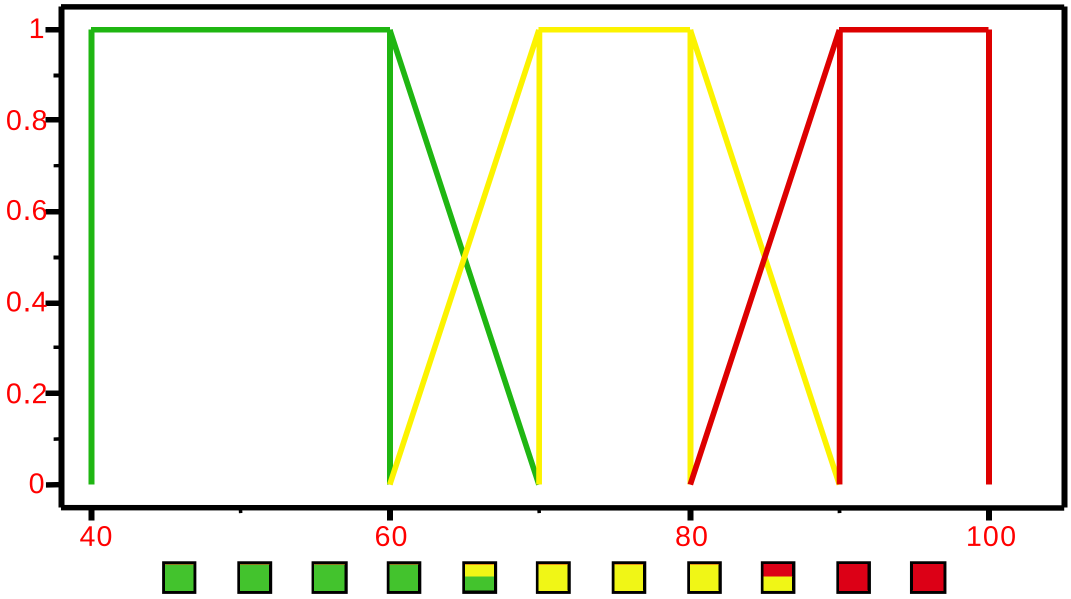
The following figure shows a schematic for Strict Traffic Lights. In this, and the following introductory schematics, the X-axis represents biomass and the scaling limits are set at 40 and 100. The green-yellow and yellow-red limits are 65 and 85 respectively. Input data are shown at the bottom and are a series from 45 to 95 in steps of 5. They are first scaled to values of 0, .5 and 1 which correspond to the colours green, yellow and red. The traffic lights are shown as coloured squares instead of circles as in previous works.



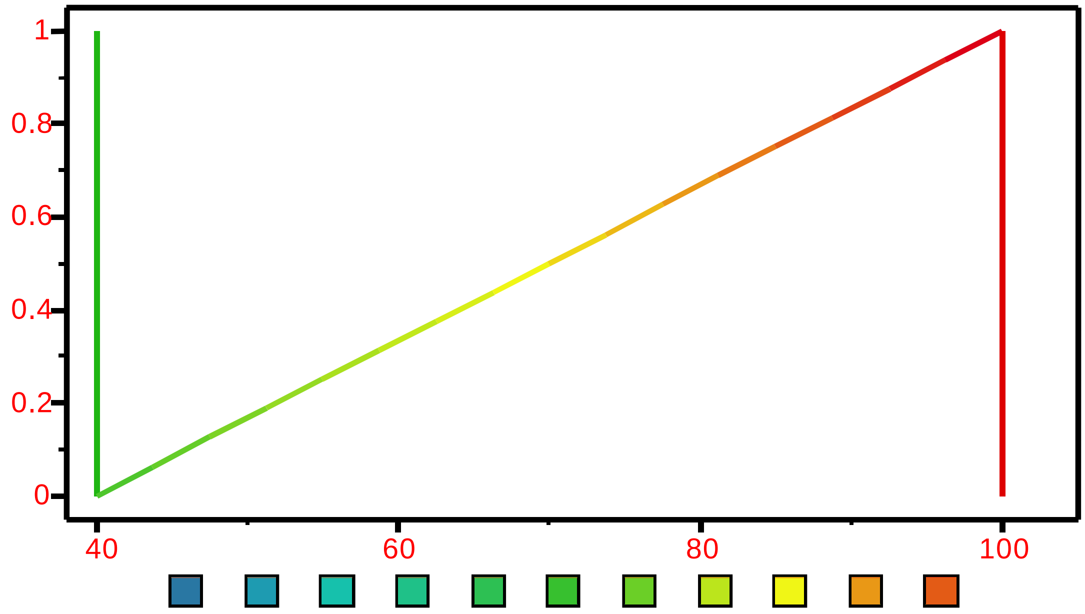
The Ramp Traffic Lights have transition zones between colours that for simplicity are shown as linear ramps. The same endpoints (40,100) are used as in the Strict Traffic Lights, but in this example the abrupt change from green to yellow at 65 has been broadened from 60 to 70. Similarly the yellow-red transition has been extended from 80 to 90. For this scheme, as well as the two end points, 4 decision points are needed: from left to right, end of green, start of yellow, end of yellow and start of red. In the transition zones the colours are shaded between the end colours, equivalently they could be shown as mixtures as in the next example, Fuzzy Logic. Although the displays may be equivalent for the Ramp and Fuzzy indicators, their integrations differ as will be shown later.



The Fuzzy Logic system (below) uses the same 4 decision points as the Ramp Traffic Lights. The distinction is that the transitions are mixtures of the neighbouring colours. That is, mid way between yellow and red is half of each colour, whereas it was shown as orange in the Ramp system. This is shown in the schematic as the green ramping down while the yellow ramps up in the transition zone.



Unlike the previous three, the Continuous Scaling system has no flat areas in the scaling and an infinite number of colours would be required. For convenience in this implementation, 30 colours from violet to red were chosen. (The figure is in error: it should have the sloping line range over all colours, starting at violet instead of green on the left.) Although the display has 30 colours, in the test program the internal storage of the indicator is essentially not limited (except by the limits of floating point arithmetic in the computer).



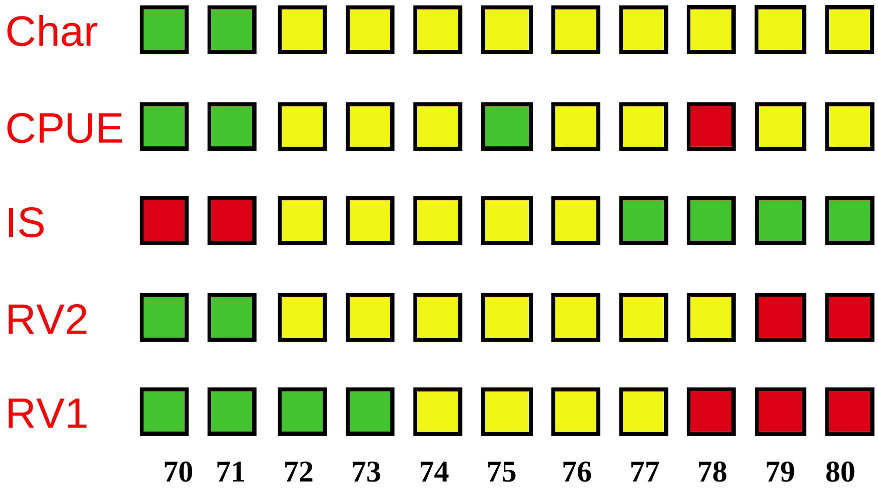
Integration of Indicators into Characteristic

In the following 4 examples, 4 indicators of abundance are to be integrated into a characteristic. The data are shown in the following table. As above, more of the quantity is coded as an undesirable state. The names RV1, RV2, IS and CPUE are given to the four indicators and Char stands for the integrated characteristic.

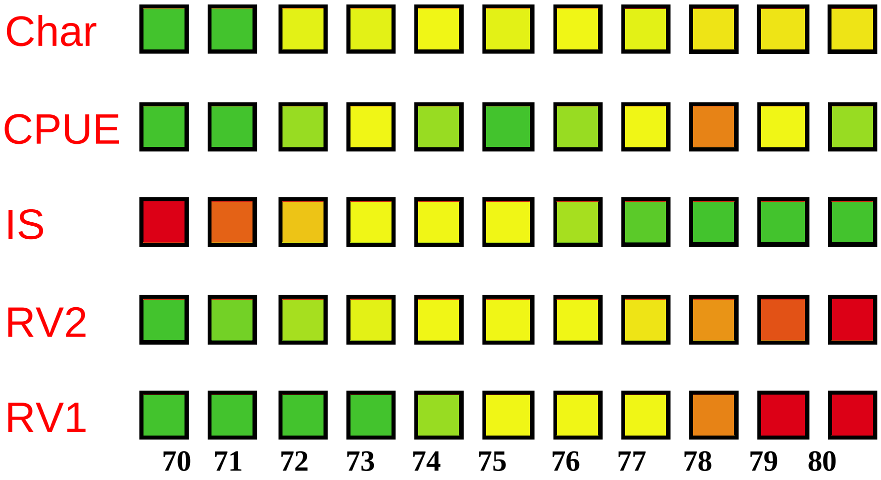
						Year					
	1970	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**
CPUE	45	55	65	75	65	55	65	75	85	75	65
IS	90	86	82	78	74	70	66	62	58	54	50
RV2	60	63	66	69	72	75	78	81	84	87	90
RV1	45	50	55	60	65	70	75	80	85	90	95

The decision points were used as above with the outer limits set at 40 and 100, the Strict limits at 65 and 85, and Ramp and Fuzzy limits at 60, 70, 80 and 90. The four indicators and resultant characteristic are shown for each system.

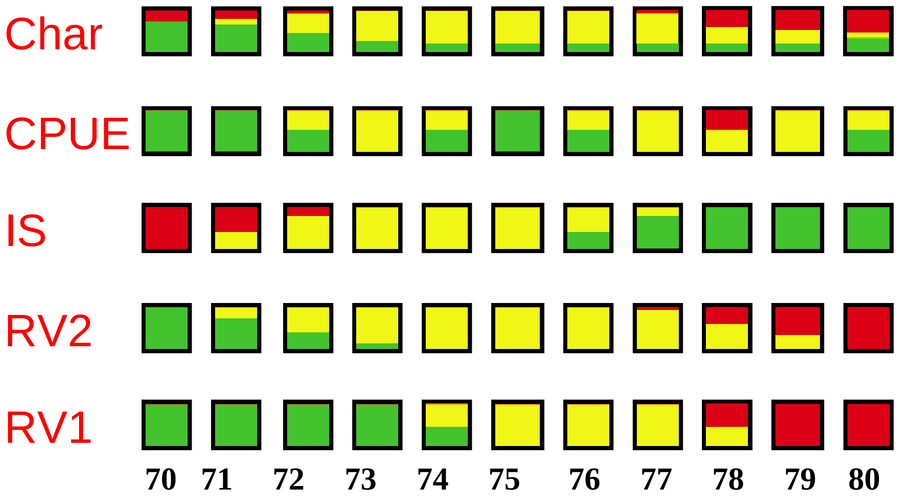
Recall that the Strict Traffic Light assigned a value of 0, .5 and 1 to green yellow and red respectively. The integration in this system is by averaging the number values for each colour. If the average is less than .33 green is assigned, if in the range .33-.67 yellow is assigned and if above .67 red is assigned. These limits are chosen only as an illustration and are not meant as recommendations. In this example most of the time the characteristic is yellow.



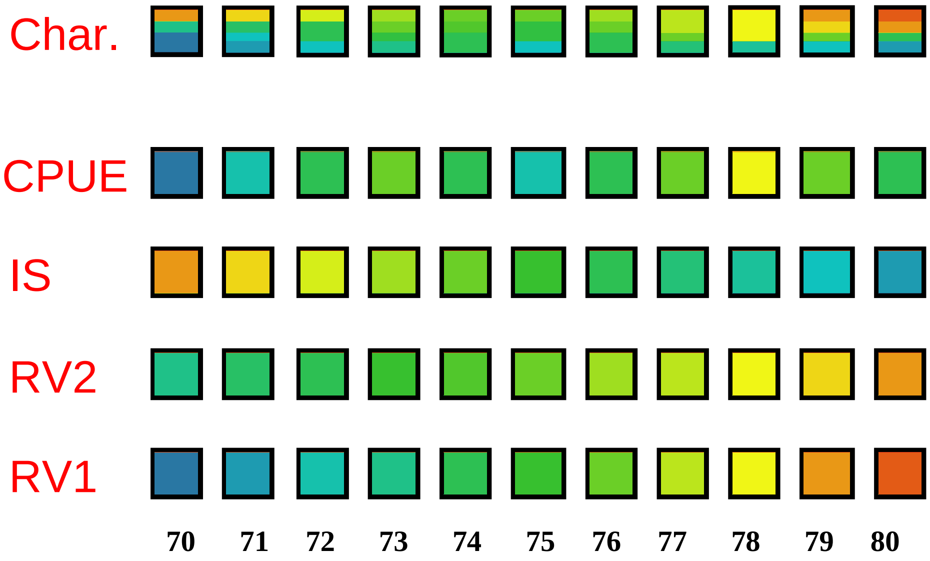
Integrating in the Ramp Traffic Light system requires the definition of transition zones for the characteristic as well as for the indicators. Again the indicators are simply averaged and then compared to a set of 4 decision levels. In the following example the green-yellow transition for the characteristic is from .28 to .38 and for yellow-red .62 to .72. As above yellow dominates but shades can be seen, especially in the most recent years.



The Fuzzy Logic example simply adds up the individual indicators and no decision levels are required. For example the 1970 data had 3 indicators which were green and one which was red. The characteristic is thus 75% green and 25% red. Very little of the information is lost in the Fuzzy characteristic as all constituent colours are kept. For example, in the first two methods (above) 2 yellows or a red and a green would both give a yellow summation whereas in the Fuzzy System the two situations are distinguishable. However some information is lost. For example, a Fuzzy characteristic which was half yellow and half green could be the result of either two yellow and two green indicators or four half yellow and half green indicators.



The Continuous integration is similar to the Fuzzy approach except that there are more than three colours. Arbitrarily, a resolution of 0.0001 was used to aggregate the indicators. That is if two Continuous indicators were closer that 0.0001 they were considered to be the same 'colour'. After aggregation, this fine scale of resolution was rounded to the 30 steps of colours used for display. It is reiterated that the 10000 steps are for integration and the scale could be made finer if it were felt to be a limitation. The 30 steps are for display only.



Discussion

The conversion of data into indicators has two steps, normalisation and colouring. In these examples the normalisation was from 0 to 1 for all four schemes but the colours were different for each. The Ramp and Fuzzy Logic approaches used the same decision points but assigned colours differently. In these two examples the indicators from either system (Ramp or Fuzzy) are completely interchangeable. However, the characteristic from each is not, as the Fuzzy

Logic characteristic does not lose as much information in the integration[1]. There is no information loss in the conversion to a Continuous indicator. However, something is always lost in integrations, but this need not be serious. The indicators are still available for decision rules that might require more information than is contained in the characteristics.

Because the fundamentals of conversion from data to indicator are similar, the program written for this example does all four at once. All four are saved for any further analysis. Thus there is no necessity to pick one system over another. Simplicity and communicability may be served if a consistent analysis were used, but there is no need to throw away any useful attributes on technical grounds.

Although not implemented here, the width of each of the square lights could be used to indicate its weight (see Annex 5). The problem with such a display is that in many applications an indicator may not have a unique weight, but rather has one for each characteristic in which it appears as well as one for an overall summary (Called Direct Summary in earlier reports).

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[1] Fuzzy Logic is described here only in the context of these limited examples and the comments are not meant as a review of Fuzzy Logic or its applications.

Annex 6.

Integration, Characteristics and Decision Rules with Traffic Lights

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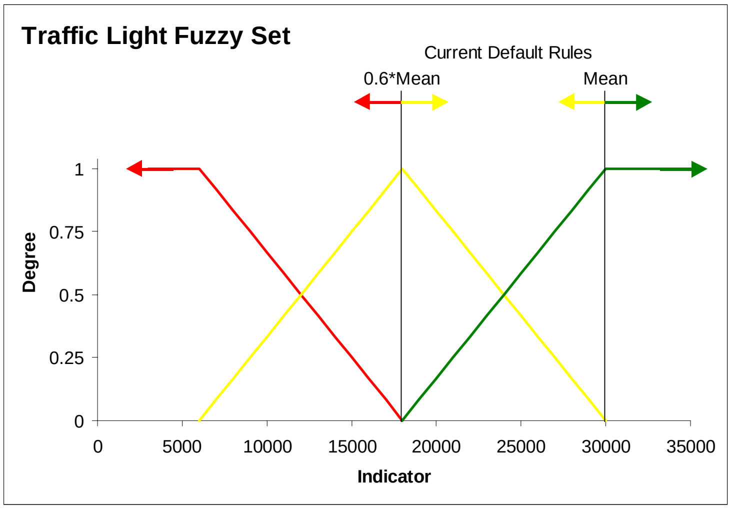
The traffic light approach, as developed so far for application in fisheries management, requires three levels of decision-making. In the first instance, there is a need to determine the boundaries between red and yellow and yellow and green. The second level of decision-making determines how different indicators are integrated into a single result, a characteristic. The final level of decision-making is the determination of the appropriate fisheries management measures as a result of the stock status. Most of the development on the traffic light approach taken so far has been directed to the first and second levels of decision-making. In spite of this, there remains considerable controversy about appropriate techniques for both boundary determination and integration.

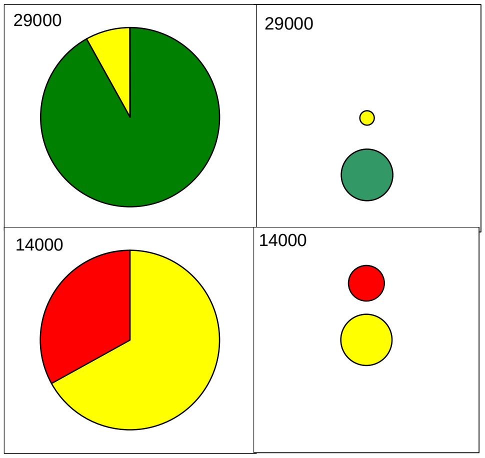
A Traffic Light as a Fuzzy Set

At the most fundamental level, fuzzy sets differ from classical sets in a single property. Fuzzy sets are not mutually exclusive with their negation. A classical set disallows the intersection of sets A and not-A i.e. $A \cap {\sim}A = \varnothing$ (empty set). In fuzzy sets this is not so, sets A and not-A, can co-occur to some degree. Operations of logic on classical sets leads to classical logic, that is Aristotlean bivalent logic. Bivalent reasoning leads to black and white answers, a thing is either A or not-A and there is no middle ground (the law of the Excluded Middle). An alternative to classical sets did not exist from the time of Aristotle until the early 20th century when it was identified but not pursued by Bertrand Russell and Alfred North Whitehead in their Principia Mathematica as vague sets. Several others published on the idea of vague sets and their consequent multivalent logic but it was only pursued intensively by Lotfi Zadeh in the mid-1960's under his new name Fuzzy Sets and Fuzzy Logic. The name notwithstanding, both the sets and the logic are mathematically rigorous.

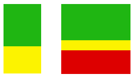
The determination of boundaries between the different colour levels is really a process of discretising a continuous indicator into a simple three-state variable i.e. defining three sets. The current default practice, in cases where there are no external boundaries, has been to set the long-term mean as the green/yellow boundary and 60 percent of this as the yellow/red boundary. The following discussion is in terms of these default boundaries but is applicable regardless how the boundaries are determined.



In reality, there are no sharp boundaries between levels of red and yellow or yellow and green. When we do choose a sharp boundary it results in the situation where a very small change in the level of the continuous indicator can result in a changing state of the traffic light indicator. A much better representation of the boundaries between the different colours of traffic lights is to treat them as a fuzzy set. In this case, the indicator represents a degree of red, yellow or green and any given level will include all three colour to some degree, possibly zero. Consider a well studied indicator such a survey abundance. We are reasonably confident that values above the mean, say 30,000, can be considered in a green state. However it is not clear that a value very slightly less than the mean, say 29,000, has changed enough to indicate that a yellow or cautious condition exists. In fact, the overall condition is still essentially green, however a small degree of yellow is now warranted. In fuzzy logic terms, the indicator belongs to the set green to a large degree and the set yellow to a small degree (and the set red to 0 degree). An additive rule in fuzzy sets requires that for any given value, the degrees of membership in the fuzzy sets sum to one. That is, although a given value can belong to more than one set, in sum it must belong wholly to the domain (set of sets). Representation of the fuzzy membership functions as piece-wise linear (triangles or trapezoids) is a simplification that is rarely optimal when sufficient data exist to determine an optimal shape. In spite of that it is an extremely useful representation and performs as well as most alternatives in data poor situations (such as fisheries). The triangles can be translated to adjust the boundaries or they can be asymmetric indicating that there is greater uncertainty in one boundary than the other. Trapezoids (shown at the extremes in these examples) can also be used in central sections where ranges of non-fuzzy indicators exist. This last is not likely in our applications. Although there is no mathematical restriction on the number of fuzzy sets co-occurring at a given point the traffic light sets will be restricted to a maximum of two co-occurring colours. This restriction simply states that red and green cannot overlap in the ordered sets of red/yellow/green defined for the traffic light method.



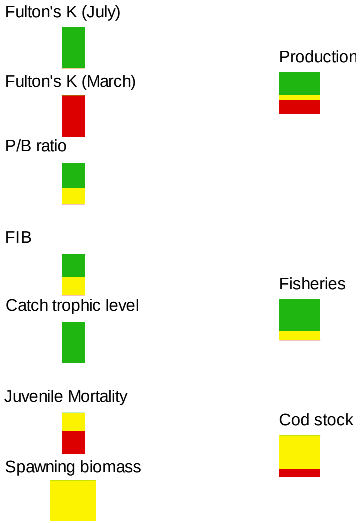
Graphical representation of fuzzy traffic light sets is a bit more complicated than in the sharp case. We need to include more than one colour in a given indicator. Two possibilities are to structure the indicator as a pie chart or as a bubble chart (the latter option gives the appearance of a traffic light). In these examples the values of 29000 and 14000 are taken from the fuzzy indicator above. In the first instance the value is slightly below the mean, i.e. the green/yellow boundary. In the case of a crisp set with sharp boundaries, the indicator would be yellow. In the fuzzy case, crossing the boundary has resulted in a small degree of yellow being reported. The second example is a value below the lower yellow/red boundary. In this instance the indicator includes mostly yellow but with a large fraction of red as well. In the extremes (>30000 or <6000) there is no uncertainty and hence no fuzz, the indicator is all green or all red, respectively. Differing weights may be assigned to different indicators and the weights given can be represented by differing sizes of pie or bubble charts. However, differences in size are not as readily visible in the bubble chart case.



A third alternative, (W. Silvert, pers. comm.) represents the traffic lights as stacked bar charts, i.e. rectangular 'lights'. In this case the relative weights of different traffic light sets can be easily seen. The examples here show a two-fold difference in weights and a two-light versus three-light set. Although indicators are restricted to two colours at a time, the results of integrating multiple indicators will often show all three colours (see discussion of characteristics below). This rectangular light display will be used for this discussion.

Fuzzy Characteristics

Characteristics, in the Traffic Light Method are integrations of one or more indicators which reflect the status of a single factor or process related to the productive capacity of a stock (within the stock assessment framework). This concept is easily extended to characteristics of additional aspects of the fish/ecosystem/fishery system. A characteristic needs to preserve all the colour information of the relevant input indicators. As a result a characteristic traffic light set can and often will require all three colours at once. Because the indicators within a characteristic are all believed to be reflections of the same thing they can be integrated by a simple weighted integration of the colours. In this instance a simple summation of the total area of each colour, renormalised to sum to 1.0, will preserve both the amount of each colour present in the indicators and the relative weights assigned them. Independent weighting can be applied to multiple characteristics in subsequent uses.



In the adjacent example there are three characteristics, production, fisheries (impact on the ecosystem) and cod stock, integrated from three, two and two indicators respectively. Amongst the characteristics, each is given equal relative weight, however the spawning biomass indicator has twice the weight of the rest of the indicators. This is reflected in the fact that the cod stock characteristic shows over ¾ yellow (from SSB) and less than ¼ red (from juvenile mortality). The production characteristic reflects inputs from three indicators and the disparity between the March and July Fulton's K is reflected in the presence of both red and green in the production characteristic. Because the characteristics are results of fuzzy set integration, they are already fuzzy and there is no requirement to specify the shape and values of the fuzzy set definitions. A complete set of fuzzy characteristics (as opposed to the incomplete and contrived example presented here) would be the basis of a stock assessment, integrating all data-based indicators and model-based results into a single framework of information.

Decision Rules

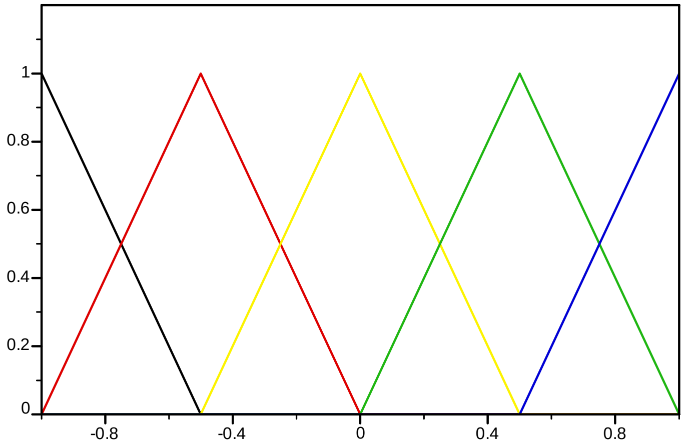
For the past 30 years, a 'quantitative' or 'analytical' stock assessment has typically described the current (and usually past) state of the fish stock in terms of one or two model outputs. A single model-derived objective ($F_{0.1}$) has been evaluated and formed the basis of management action. In the traffic light method the conventional model outputs are embedded in a framework with many other indicators and represented by the three-colour characteristics as outputs. As a necessary result of successfully incorporating additional sources of both information and uncertainty, the potential decision-making framework is more complex. This corresponds well with the increased complexity being demanded by initiatives such as Objectives-Based Fisheries Management and Integrated Oceans Management. These evolving approaches will demand that multiple objectives be reflected, monitored and managed towards in all aspects of management. The traffic light method will dovetail into these new approaches as a methodological framework whereby decision rules relating the state of the stock (or fishery, or ecosystem) characteristics to specific objectives will specify the appropriate management response.

The application presented here implements a sample of feasible fuzzy control decision rules based on the three characteristics and controlling a single output variable. The output variable is implemented as an increment (positive or negative) of the current total allowable catch (TAC). In cases where the current or recent catches are significantly different from the TAC the increment could or should be applied to the actual catches. The operating assumption in the example is that the current state reflects the effects of the recent catches (and other factors) and the near future (next year) will be similar to this year in most ways, i.e. the best predictor of tomorrows weather is today's weather. There are obviously many ways to improve the implicit projections within this framework however they are not pursued here.

In fuzzy control systems each rule in the system is evaluated on each iteration and its' contribution (fuzzy implication) to the final output determined. Fuzzy rules are all of the form ‘IF x THEN DO y’, similar to a conventional IF statement in logic. The fuzzy form is perhaps better read as ‘TO THE DEGREE THAT x IS true, INCLUDE y IN THE OUTPUT’. Thus every rule is included but in some cases it may have 0 contribution to the output, i.e. x is not true to any degree. The rule system used in the example includes the following nine rules:

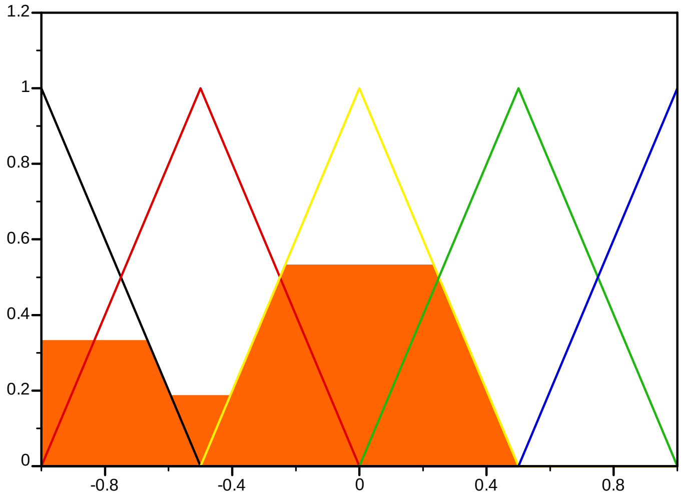
IF fisheries= green AND production= green AND stock= green THEN tac_increment is large positive
IF production= green AND stock= green THEN tac_increment is small positive
IF production= green AND stock=yellow THEN tac_increment is no change
IF production=green AND stock=red THEN tac_increment is small negative
IF production=yellow AND stock=green THEN tac_increment is no change
IF production=yellow AND stock=yellow THEN tac_increment is small negative
IF production=yellow AND stock=red THEN tac_increment is large negative
IF production=red AND stock=green THEN tac_increment is small negative
IF production=red AND stock ≠ green THEN tac_increment is large negative

The output given by this system of rules is in the form of degrees of membership (≡ truth) of the TAC increment in five fuzzy sets. The sets cover the range [-1,1] and are called ‘large negative’ (black), ‘small negative’ (red), ‘no change’ (yellow), ‘small positive’ (green) and ‘large positive’ (blue) in order over the range. An increment of –1.0 would imply reducing the catch (or TAC) to 0 while 1.0 would imply doubling. The sets are fuzzy because there is a range of values which could be considered, for example, a small positive increment. Here, a small positive increment (represented by the green set) covers any positive value to some degree, peaking at 50% increase. These sets are used in the next step of ‘defuzzifying’ the result to determine the actual control action to take.

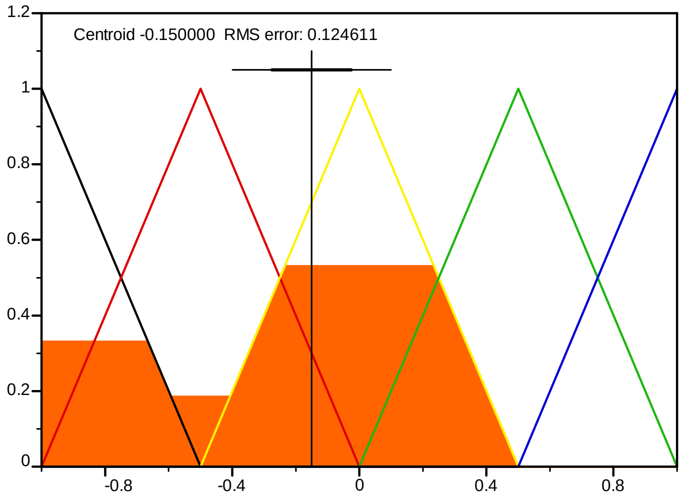


Control Action

Evaluating the nine rule system and the fuzzy characteristics given above, results in the adjacent output sets. The degree of membership for the sets 'small positive' and 'large positive' are both 0 simply because the rule system (rules 1 and 2) requires that both stock size and production be green to produce a positive increment. In the example, the cod stock size is yellow and red and so no positive increments are indicated. In spite of that there is still a component of the output on the positive side of the axis since the set 'no change' includes all values between –0.5 and +0.5 to varying degrees. Given that more than one rule may imply a value for a given set, the combined result is the maximum value for the set. In this example, the set 'large negative' has a value of 0.34, 'small negative' is 0.18 and 'no change' is 0.55. In all cases where sets overlap, the greater value is used. For example, the 'no change' set is triggered as a result of two rules (3rd and 5th) in the preceding rule set. Rule 3 triggers the set 'no change' to the degree that the production characteristic is green and the stock characteristic is yellow. In this example, production is green is true to 0.55 degree while stock is yellow is 0.7 degree. Thus they are both true to the lesser degree, i.e. 0.55 which become the degree to which this rule triggers the 'no change' set. The fifth rule reverses the two colours with respect to the characteristics. In this instance, production is yellow to about 0.1 degree and stock is green to about 0.17 degree which triggers the 'no change' set to 0.1. Combining the effects of the two rules the set is triggered to the greater of the two values, i.e. 0.55, which is represented by the height of the shading inside the triangle defining the set.



Once all the decision rules have been evaluated a fuzzy set of outputs has been defined. The fuzzy set now needs to be transformed into a specific, i.e. crisp, output response through a process of defuzzifying. There are a variety of options for this process although only one, the centroid method, is used here. The centroid is the centre of mass of the output sets, i.e. the point on the abscissa to either side of which the included area in all sets is equal. The indicated result is that the TAC



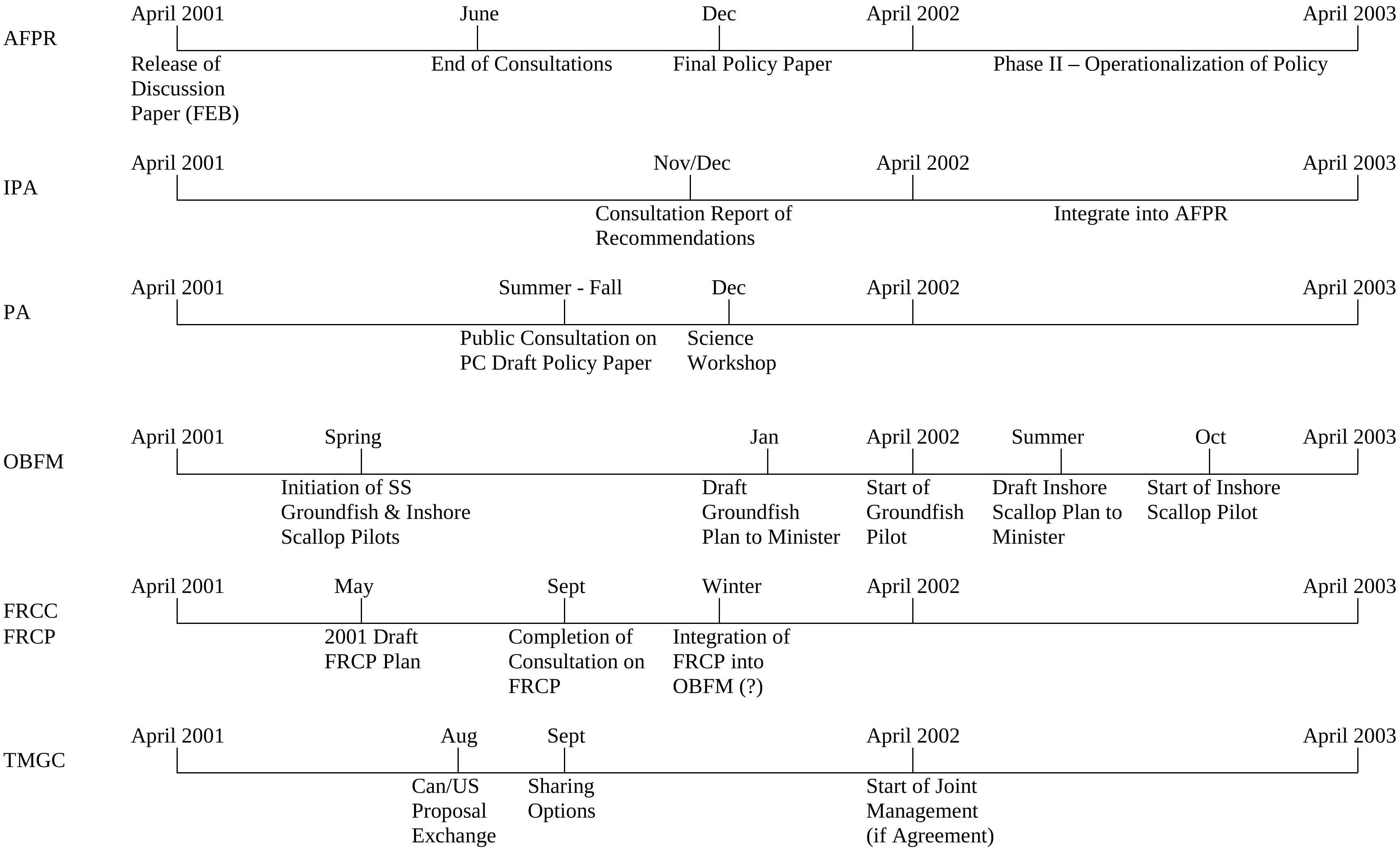
increment should be –15%. A fuzzy controller such as this is not statistical and does not routinely use estimates of uncertainty in the output value. Because we are considering a system to provide input to a further control system (fisheries management) there is considerable value in being able to characterise the precision of the control output. To assess the uncertainty associated with that value, the root mean squared (RMS) error is provided as an analogue of a standard deviation. The graph lines indicate ±1 (thick line) and ±2 (thin line) RMS errors.

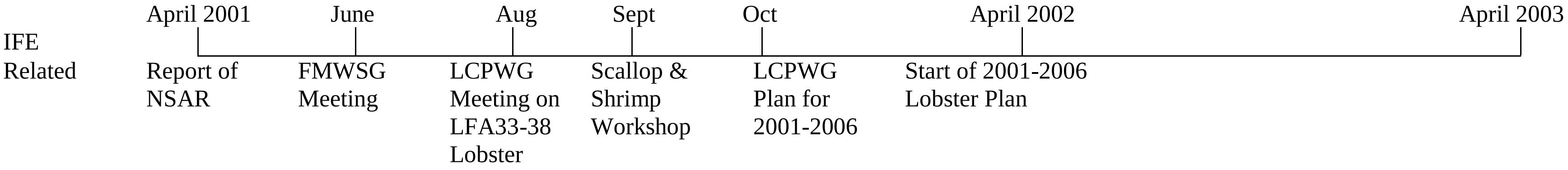
Summary

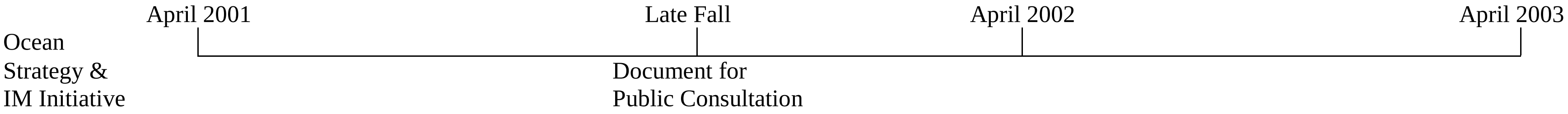
Representation of the traffic lights leads in a very simple way to the use of fuzzy logic and fuzzy control theory as a means of generating management actions towards specified objectives. This approach is fully compatible with the emerging approaches to fisheries management such as objectives-based management and in fact is dependent on such an approach being used to define the particular control objectives. Within the still obscure framework of Intensive Fisheries Evaluations, the fuzzy control system of traffic lights provides a means by which to relate indicators to objectives and decision rules, based on the indicators (or integrated products). The decision rules would be the formalisms describing the pre-agreed decision rules that fisheries managers and resource users are required to formulate under the precautionary approach.

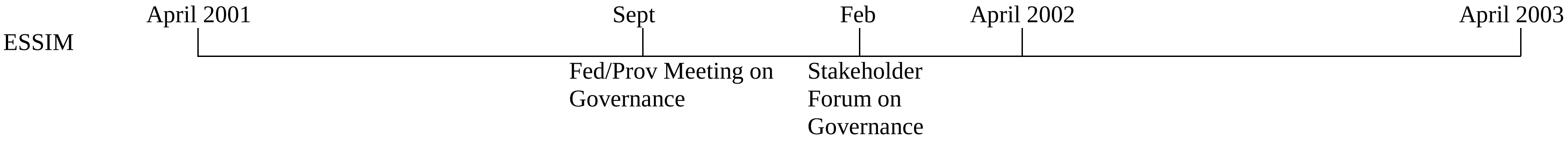
Annex 7.

Summary of Policy and Planning Initiatives









AFPR -- Atlantic Fisheries Policy Review
EBM -- Ecosystem-Based Management
ESSIM -- Eastern Scotian Shelf Integrated Management
FRCC -- Fisheries Resource Conservation Council
FRCP -- Fisheries resource Conservation Plan for Cod and Haddock in 4X and 5Y
IFE -- Intensive Fishery Evaluation
IPA -- Independent Panel on Access
LCPWG -- Lobster Conservation Plan Working Group
NSAR -- National Stock Assessment Review
OBFM -- Objectives-Based Fisheries Management
PA -- Precautionary Approach
TMGC -- Canada/US Transboundary Management Guidance Team
WGEO -- Working Group on Ecosystem Objectives