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Canadian Stock Assessment
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Évaluation des stocks canadiens
Séries des comptes rendus 99/41

Science Strategic Project on the

Precautionary Approach in Canada

Proceedings of the Second Workshop

1- 5 November 1999

Pacific Biological Station
Nanaimo, BC

Laura J. Richards and Jon T. Schnute
Co-Chairs

Rowan Haigh and Charline Sinclair
Editors

Fisheries and Oceans Canada
Science Branch, Pacific Region

Pacific Biological Station
Nanaimo, BC V9R 5K6

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Abstract (Rivard)

A workshop, sponsored by the national science strategic project on the precautionary approach, was held on November 1-5, 1999, at the Pacific Biological Station in Nanaimo. This workshop represents the culmination of the three-year research project aiming at developing concepts and tools for the implementation of the precautionary approach for Canadian fisheries. Although it is recognized that the precautionary approach raises issues much broader than the science context, the project focused primarily on biological and scientific aspects. In particular, the specific role of scientists is to assist in developing a conceptual framework, to provide advice on biological limits and to assist in establishing targets and identifying risks associated with a given set of management objectives. In order to establish the grounds for further exchanges in this area, fishery management was represented at the workshop by a few selected individuals, in anticipation of their future role in the implementation of the precautionary approach.

When the project was initiated, case studies were identified as the mechanism for gaining insight into the precautionary approach. Near final reports are included in the workshop report for seven case studies, including Atlantic cod in 3Ps and 4TVn, Atlantic spring spawning herring in 4R, snow crab in the southern Gulf of St. Lawrence, Eastern Hudson Bay beluga, Fraser River sockeye, and Pacific Ocean perch. Most of these case studies focused on exploring conceptual frameworks and on identifying the risks associated with different potential management strategies.

Over the past few years, the international community has progressed in the implementation of the precautionary approach. The participants reviewed reports from ICES and NAFO, as well as progress in the USA and each region of Canada. Most regions have held meetings among science, management and industry on the precautionary approach.

Canada is now a signatory to the United Nations Fishery Agreement (UNFA) that explicitly acknowledges the precautionary approach. This workshop served to formulate a general framework on the precautionary approach in Canada, consistent with UNFA. This framework characterizes the relationship between removal rate and an index of the stock by four zones. In zone 1, the stock index is above the stock reference level, the removal rate is lower than the removal reference level; this is the desirable state and, in this situation, the status quo with respect to the harvest strategy is acceptable. In zone 2, the stock is above the stock reference level but the removal rate is above the removal reference level; consequently, measures should be taken to reduce the removal rate to a level that is below the pre-agreed reference. In zone 3, the stock is below the stock reference level and removals should be restricted to allow a high probability of moving to zone 1, the desirable state. In zone 4, the stock is below the minimum acceptable level and removals should be kept as low as possible.

The discussions on the precautionary approach in various fora suggest that harvest strategies, which are sometimes implemented by controlling removals, should be accompanied with complementary management or technical measures aiming at conservation. Also, the state of the resource does not need to be evaluated solely in terms of removal rate and stock size; a number of metrics could be used to describe the status of the

resource and to characterize the exploitation level. Various schemes have been referred to during the workshop and others are still under active investigation.

The impact of these new requirements could be significant. Both in domestic and international fora, the implementation of the precautionary approach is expected to continue to be front-and-centre in discussions on conservation. The demand for advice on conservation measures under a precautionary framework will likely generate new challenges for scientists and create new opportunities for research.

Résumé (Rivard)

Un atelier organisé par l'équipe du projet national sur l'approche préventive a eu lieu du 1er au 5 novembre 1999 à la Station de biologie du Pacifique, à Nanaimo. Cet atelier constituait le point culminant du projet de recherche de trois ans, lequel visait l'élaboration de concepts et d'outils pour la mise en œuvre de l'approche préventive dans les pêches canadiennes. Même s'il est reconnu que l'approche préventive soulève des questions qui vont bien au-delà du domaine scientifique, le projet a essentiellement porté sur divers aspects biologiques et scientifiques. Le rôle spécifique des scientifiques est de participer à l'élaboration d'un cadre conceptuel, de donner des avis sur les limites biologiques et de participer à l'établissement des cibles et à la définition des risques associés à un ensemble donné d'objectifs de gestion. Quelques gestionnaires des pêches ont assisté à l'atelier en raison du rôle qu'ils seront appelés à jouer dans la mise en œuvre de l'approche préventive; cet atelier a ainsi servi à établir des liens utiles pour des échanges futurs dans ce domaine.

Au début du projet, il a été décidé d'avoir recours à des études de cas pour évaluer les effets de l'approche préventive. Le rapport de l'atelier inclut les rapports presque finaux de sept études de cas portant notamment sur la morue de l'Atlantique de 3Ps et 4Vn, le hareng de 4R qui se reproduit au printemps, le crabe des neiges du sud du golfe du Saint-Laurent, le béluga de l'est de la baie d'Hudson, le saumon rouge du Fraser et le sébaste du Pacifique. La plupart de ces études ont porté sur l'évaluation de cadres conceptuels et sur la définition des risques associés à différentes stratégies de gestion.

Au cours des dernières années, la communauté internationale a fait des progrès dans la mise en œuvre de l'approche préventive. Les participants ont examiné des rapports du CIEM et de l'OPANO et se sont intéressés aux progrès qui ont été réalisés aux É.-U. et dans les différentes régions du Canada. Des réunions auxquelles ont participé des scientifiques, des gestionnaires et des membres de l'industrie ont eu lieu dans la plupart des régions sur l'approche préventive.

Le Canada a signé l'Accord des Nations Unies sur la pêche (ANUP) qui reconnaît explicitement l'approche préventive. L'atelier a permis de formuler un cadre général sur l'approche préventive au Canada, lequel est conforme à l'ANUP. Ce cadre définit la relation qui existe entre le taux de prélèvement et l'indice d'abondance du stock en fonction de quatre catégories. Dans la première catégorie, l'indice d'abondance est supérieur au niveau de référence du stock et le taux de prélèvement est inférieur au niveau de prélèvement de référence; dans cette situation, qui correspond à la situation idéale, le statu quo est acceptable et la stratégie de récolte n'a pas à être modifiée. Dans la deuxième catégorie, la taille du stock est supérieure au niveau de référence du stock mais le taux de prélèvement est

supérieur au niveau de prélèvement de référence; par conséquent, des mesures devraient être prises pour réduire le taux de prélèvement à un niveau qui se situe en deçà du niveau de référence. Dans la troisième catégorie, la taille du stock est en dessous du niveau de référence du stock et les prélèvements devraient être limités pour que le stock ait plus de chances d'atteindre l'état souhaité (catégorie 1). Dans la quatrième catégorie, la taille du stock est inférieure au niveau minimum acceptable et les prélèvements devraient être maintenus au niveau le plus bas possible.

Les discussions sur l'approche préventive qui ont eu lieu en divers endroits montrent que les stratégies de récolte, qui consistent parfois à contrôler les prélèvements, devraient également s'accompagner de mesures de gestion ou de mesures techniques destinées à assurer la conservation. Par ailleurs, l'état de la ressource n'a pas besoin d'être évalué uniquement en fonction du taux de prélèvement et de la taille du stock; d'autres données pourraient en effet être utilisées pour décrire l'état de la ressource et définir le niveau d'exploitation. Diverses approches ont été proposées lors de l'atelier; d'autres approches sont toujours à l'étude.

Ces nouvelles exigences pourraient avoir un impact important. Sur la scène nationale et la scène internationale, la mise en œuvre de l'approche préventive devrait continuer d'être au centre des discussions sur la conservation. La demande pour des avis sur les mesures de conservation dans un contexte de prévention se traduira par de nouveaux défis pour les scientifiques et créera de nouvelles possibilités pour la recherché

1. Introduction

This report summarizes the proceedings from a workshop held November 1-5, 1999, at the Pacific Biological Station in Nanaimo. The workshop was sponsored by the national science strategic project on the precautionary approach, initiated in 1997. An interim workshop on the project was held at the Pacific Biological Station in 1998 (Rice et al. 1999). The 1999 workshop represents the culmination of the three-year project.

When the project was initiated, case studies were identified as the mechanism for gaining insight into the precautionary approach. Over the last three years, team members from each region developed the case studies following the framework discussed in the 1998 report. The 1999 meeting focussed on developing the precautionary approach in the context of each of the case studies and identifying common elements. Reports on these case studies form the bulk of these proceedings. The workshop was also tasked with developing a communication plan for the results of the study.

The authors identified in the header for each section prepared the contents of this report. Rapporteurs recorded the discussion for each case study and other major topics. These reports were not reviewed in plenary and, with a few exceptions as noted, should not be interpreted as consensus statements.

The meeting agenda is given in Appendix A, with the list of participants in Appendix B. Many acronyms have become common usage in the context of the precautionary approach and these are explained in Appendix C. Some of the participants tabled working papers for discussion, and these are listed in 0.

1.1. Project Review (Schnute)

Our project began with a proposal from the Pacific Region in November 1996. Last year's report (Rice et al. 1999) describes its remarkable inception. We received official funding on March 20, 1997, when Scott Parsons, the Assistant Deputy Minister of Science, approved a collection of projects to be financed with Strategic Science Funds in FY 1997/1998. The entire package totalled $13.5 M, of which $4.5 M was directed to High Priority Strategic Research. Our project was not listed in the printed memo; apparently, it had not made the final cut. Nevertheless, when Scott added his signature, he amended the memo with exactly one hand-written note:

> "Approved with amendment of High Priority to add $50 K for Precautionary Approach – the money for a national network of researchers. This is to be managed by Bill Doubleday . . ."

As I said last year, I like to think of this note as evidence that the pen is mightier than the word processor. It also shows interest at a high level in the subject we're addressing at this, our second and final, workshop.

Table 1.1.1 presents a chronology of various project highlights. After an initial planning meeting in Dartmouth NS, the project was launched by a memo from Bill Doubleday on September 26, 1997. Case studies would be used to investigate application of the precautionary approach in Canada. Eight studies were proposed initially, but the number has varied during the project's history, as listed in Table 1.1.2. Distinguished visitors to our workshops have extended the list beyond those originally contemplated. For example, in 1998 Scoresby Shephard discussed precautionary management of Australian abalone (Rice et al. 1999, p. 38–39). This year, Ian McQuinn added 4R herring to the Canadian list.

Table 1.1.1. Brief chronology of the High Priority Project for the Precautionary Approach

Date	**Event**
November 1996	Initial Pacific proposal
March 20, 1997	Approval by Scott Parsons, Bill Doubleday to head national project
June 8, 1997	Initial planning meeting, Dartmouth, NS
September 26, 1997	Official project launch Case studies: 8 → 10 → 6 → 7
November, 1997	Pacific Web site started
December, 1997	National proposal for 1998–2000
August 14, 1998	½ funding for 1998/99 and 1999/2000
October 5–9, 1998	First Nanaimo Workshop
January, 1999	1998 Progress Report
May, 1999	1998 Workshop Proceedings published
November 1–5, 1999	Second Nanaimo Workshop

Table 1.1.2. List of case studies, with years of presentation at Nanaimo workshops

Case Study	**1998**	**1999**
St. Pierre Bank cod (3PS)	✕	✕
Northern cod (2J3KL)	✕	
Capelin (NAFO SA 2 + 3KL)	✕	
Herring (E & SE)	✕	
Herring (4R)		✕
Gulf of St. Lawrence cod (4T)	✕	✕
Gulf of St. Lawrence snow crab (4T)	✕	✕
Hudson Bay Beluga	✕	✕
Pacific ocean perch	✕	✕
Fraser River sockeye salmon	✕	✕
Australian abalone	✕	

Beyond the two workshops, this project has become a focal point for scientific exchange and collaborative research among assessment scientists from all regions of Canada. In late 1997, the Pacific Region developed a web site that now serves as a focal point of communication for all team members. The site includes data and technical documents related to the case studies, as well as position papers, reference lists, links to other sites, and discussions of computer software. In Nanaimo, we have been privileged to host several ad hoc seminars and dialogues with visitors from across the country. These conversations have produced new syntheses of stock assessment methods, in which diverse approaches give deeper insights into the techniques currently in use. We have spent many days discussing state space models, appropriate software implementations, and risk assessments.

For example, our risk analyses typically begin with such fundamental questions as

1. How many fish are out there?
2. How many can safely be caught?

In precautionary practice, these often translate to setting a lower limit $S_{\lim}$ for stock size S and an upper limit $F_{\lim}$ for fishing mortality F. If failure is defined as exceeding one of these limits, then the general idea is to keep the failure probability

$$a = P(F > F_{\lim}, S < S_{\lim})$$

as small as possible.

The project has succeeded in developing a national community of assessment scientists with important common understandings and goals. In my view, this qualifies as a major Canadian achievement, given the diversity of approaches with which we began. Although all team members are keenly aware of broad interest in implementing the precautionary approach, we have not attempted to produce a definitive Canadian manual for that purpose. The case studies illustrate clearly that a precautionary approach spans many sectors and requires collaboration with stakeholders outside the community of assessment scientists. Nevertheless, the process must begin with solid scientific methods that honestly admit the limits of science. We hope that products from the project, such as this report and the assembled team, will advance precautionary fishery management in Canada.

2. Update on Precautionary Approach Frameworks

2.1. Update on Implementation of PA at NAFO (Rivard & Steinbock)

In 1999, the Northwest Atlantic Fisheries Organization (NAFO) held a meeting of the Joint Fisheries Commission-Scientific Council Working Group on the Implementation of the Precautionary Approach from May 3 to May 5, 1999, in San Sebastian, Spain. That meeting was preceded by a workshop of the NAFO Scientific Council, from April 27 to May 1, 1999. The most important event for 1999 was the adoption by the Fisheries Commission, at its Annual meeting (September 1999) of a resolution to guide the implementation of the Precautionary Approach within NAFO. That resolution specifies that the Fisheries Commission resolves to apply a precautionary approach widely for stocks under NAFO purview and, to achieve this goal, agrees:

1. To determine precautionary reference points for stocks where sufficient data exists.
2. For all other stocks, to determine provisional precautionary reference points, wherever possible, and a precautionary approach otherwise.
3. To provide mechanisms to fill in data gaps.
4. To implement precautionary management strategies (harvest control rules) consistent with 1 and 2 above.
5. To consider additional supportive management measures to complement the application of the precautionary approach.
6. To define and adopt precautionary strategies for the re-opening of fisheries and for new and developing fisheries.
7. To harmonize terminology and concepts for the application of the precautionary approach within relevant fisheries organizations.

Using the simulations and analyses, the Scientific Council recommended reference points for 3 model stocks: cod in Div. 3NO, yellowtail flounder in Div. 3LNO, and shrimp on the Flemish Cap (3M). Using these results, the Joint FC-SC Working Group identified elements/options for management strategies applicable for these 3 stocks.

For cod on the southern Grand Banks (NAFO Div. 3NO), the Joint working Group identified the following elements of a precautionary approach:

1. Restore and maintain stock at level that can support sustainable fisheries.
2. Rebuild SSB to level that will increase probability of good recruitment.
3. Keep directed fisheries closed in short term.
4. Determine SSB at which fishery will re-open.
5. Develop additional criteria to guide potential fishery re-openings.
6. Identify and evaluate options for B_{lim} (60,000 t for high productivity; 35,000 t for low productivity) and, in doing so, use the following performance measures in risk analyses.
7. Evaluate yield potential at re-opening
8. Evaluate time to reach B_{lim} at various probability levels.
9. Evaluate risks of stocks being below B_{lim}.
10. Full review of options for B_{lim} using appropriate risk analysis.

At the June meeting of the scientific council, simulations were carried out to determine the time to reach B_{lim} and ½ B_{lim} under various assumptions. The scientific Council indicated that the current best estimate of B_{lim} is 60,000 t and that it will review in detail the reference points when the SSB has reached half the current estimate of B_{lim}.

For yellowtail flounder on the Grand Banks (NAFO Div. 3LNO), the Joint working Group identified the following elements of a precautionary approach:

1. Maintain harvest levels that will continue to rebuild and maintain the stock biomass above the rebuilt biomass level.
2. Continue comprehensive suite of management measures.
3. Ensure that the conduct of the fishery will occur in a manner that will not jeopardize the recovery of other stocks still under moratoria (e.g., 3NO cod, 3LNO American plaice).
4. Performance measures could be expressed in terms of biomass and its trajectory and where it is with respect to reference level and catch levels.
5. Production models do not permit determination of all reference points. Ensure data are available to move to age-structured modelling.
6. There is a need to develop “target” biomass levels that could be higher than the biomass limits so as to take into account management objectives.
7. Endorse the work of the Scientific Council in its attempts to develop a better understanding of the stock-recruit relationship.

F_{buf} was determined to be 0.13, corresponding to an exploitation rate of about 11%. This level of exploitation was used by the Scientific Council to provide TAC advice for 2000. The Scientific Council noted that this gave the same yield as that obtained from a production model using ? F_{MSY} (but a production model was not used as the basis for the

June assessment). The Scientific Council was unable to derive any biomass-based reference point at its June 1999 meeting but noted the progress made on tagging and its relevance to age determination, a prerequisite to age-structure analyses.

For shrimp on the Flemish Cap (3M), the Joint Working Group noted the following in the context of precautionary approach:

1. The traffic light approach is appropriate to assist managers in making short-term decisions but is currently not appropriate for the determination of management strategies.
2. Further development of the traffic-light approach would require interaction between managers and scientists (still need to incorporate managers' views on certain elements of the approach).
3. In the formulation of a traffic light approach, there is a need to separate the measures of uncertainty in data and assessment and the measures of stock performance.
4. In order to improve our ability to assess this stock, data must be improved, including comprehensive surveys on the resource.
5. Decrease exploitation on males so that sufficient numbers have the opportunity to change sex and spawn at least once.
6. Ensure a suite of conservation and enforcement measures is maintained to adequately monitor fishery.
7. Continue with the mandatory use of sorting grates, and closely monitor by-catches in the fishery.

<u>Management measures as part of a comprehensive application of PA</u>

The Canadian delegation presented a list of management measures complementing harvest control rules and reference points. The implementation of the precautionary approach should not be seen solely as an exercise to determine reference points but must also include a suite of technical and management measures consistent with conservation. This is echoed in a recent paper published by the FAO (Technical Paper 379, 1998):

> "One fundamental aspect here that is left out of much of the technical documentation on RPs is that in both the Code and UN Agreement, and also emphasized in the guidelines for applying the precautionary approach (FAO, 1995c), it is understood that reference points are only relevant if placed in their management context as part of a Fisheries Control Law that must include industry and management to be effective and must take into account risk at all levels of implementation of a Control Law. "

Measures proposed to illustrate the use of other management measures to complement the application of the precautionary approach included:

TAC/Moratorium	By-catch closures
Limited entry	Observers
Vessel replacement restrictions	Dockside monitoring
Effort Control	Vessel monitoring systems
Conservation harvesting plans	Air patrols
By-catch protection provisions	Ship patrols

Minimum fish size	On-board inspections
Spawning closures	Basic and comprehensive scientific surveys
Juvenile closures	
In-season management:	Fishing gear restrictions:
Small-fish protocols	Minimum mesh size
By-catch protocols	Separator grids

General

During these discussions, a few participants expressed concern with certain elements of the UN Fisheries Agreement (UNFA). The principal difficulties lie with the need to have "pre-determined" or "pre-agreed" management actions under the precautionary approach, and the reference to F_{msy} as a target reference point. What measures do we take when the biomass limit is reached (e.g., closure, moratorium vs. continued fishing)? What is the shape or form of the "harvest control rules"? In the discussion of the Joint Working Group, it was pointed out that the groundfish stocks of the Northwest Atlantic have been less resilient to over-exploitation than those in NE Atlantic and may thus require a different precautionary framework.

Another meeting of the Joint NAFO Working Group on the Precautionary Approach is planned for February 2000. The agenda for that meeting includes a discussion of the following:

- Harmonization of concepts and terminology;
- Ways to make the precautionary approach operational by developing a Management Plan for the Three Model Stocks;
- Implementation Plan the other NAFO stocks;
- Changes required to the Fisheries Commission request for advice;
- Criteria for re-opening a fishery in light of the precautionary approach;
- Management measures to complement the application of the PA.

Discussion (Sinclair)

It has been difficult for the NAFO Fisheries Commission (FC) to establish management objectives in isolation from specific cases. However, in joint meetings of the FC and Scientific Council (SC), and in reviewing the 3 specific case studies, some specific stock-by-stock objectives emerged. In the case of 3NO cod, for example, the primary objective was to promote stock recovery.

The participants expressed concern that provisional reference points, which are required when data are lacking, could result in management decisions that are "risk prone". When data are poor, there is a general tendency to use point estimates instead of probability distributions of estimates. This tendency is due, in part, to the difficulties associated with the estimation probability distributions when assessment models are non-standard (due to the nature or availability of data). While this is not a problem unique to NAFO, such situations merit investigation with the aim of identifying provisional reference points and management strategies that are risk averse.

There was some discussion about the recovery probabilities with some fishing vs. no fishing. While it is expected that recovery will be faster with no fishing, the information to monitor stock size may be more limited than if there was some limited fishing. The simulation work undertaken at NAFO did not attempt to simulate the assessment process. While this is a difficult undertaking, it may provide some insight on the value of maintaining some limited fishing activity when stock sizes are below a limit reference point.

In the yellowtail example, it was noted that a stock production framework wouldn't estimate spawner biomass directly, but rather a fishable biomass. Apparently, NAFO interpreted UNFA biomass limits reference points as being based on spawning biomass. It was pointed out that spawning biomass is not referred to specifically in UNFA.

NAFO has used the so-called stoplight approach to look at short-term measures vs. management strategies. It was suggested that it is difficult to link the management measures to one of the stoplight criteria. For example, it is difficult to determine if a certain catch (TAC) results in a change in stock distribution or condition. When multiple criteria are used in a stoplight approach, how are the different criteria weighted in making the final decision? NAFO recognized this as a point that requires more study.

NAFO noted that NE Atlantic stocks seem to be much more resilient to exploitation than stocks in the NW Atlantic. This was based on the stocks being able to withstand higher F. It was pointed out that during the late 1980s in eastern Canada, when fishing mortalities were well above $F_{0.1}$ targets, it was thought that all cod stocks were resilient to such levels of exploitation. Unfortunately, the stocks crashed soon thereafter.

Canada has been actively involved in various international fora such as NAFO, ICES, NASCO, ICCAT, PICES, in the development of frameworks related to the precautionary approach. The experience gained in this involvement will no doubt influence the Canadian Precautionary Approach framework but the Canadian implementation needs to be crafted so as to address the peculiarities of domestic stocks and the domestic management system.

2.2. Development of Precautionary Approach Experiences in Other Areas

2.2.1. ICES Update (Sinclair)

ICES appears to have completed its work in defining a PA with the publication of the PA Working Group report in February 1998 and the various assessment working groups providing ACFM with estimates of the suggested reference points. It was noted that ICES has opted for limit reference points designed primarily to prevent stock collapse and have abandoned reference points designed to promote optimal yield, at least until some progress is made in reducing fishing mortality. It was noted that the Comprehensive Fisheries Evaluation Working Group, where a considerable amount of modelling work was done on the PA theme, has been disbanded and replaced by a Fisheries Systems Working Group. The terms of reference for the working group are being drafted.

2.2.2. NASCO (Calcutt)

In 1998 at its annual meeting, NASCO's contracting parties reached agreement on adoption of the Precautionary Approach. In 1999, NASCO agreed to an "action plan for application of the Precautionary Approach." It recognized that implementation of the precautionary approach is likely to be an evolving process over a number of years.

The action plan identifies action items in a number of areas including management of North Atlantic Salmon fisheries, socio-economic issues, unreported catches, scientific advice and research requirements, stock rebuilding programs, and habitat issues among others.

The NASCO Standing Committee/Working Group will meet intersessionally in February 2000, to further activities related to the Plan.

Discussion (Sinclair)

What are the parallel items between NASCO and NAFO? Now that NASCO has identified what needs to be done (9 elements) the challenge is to come up with management actions. In Canada the fisheries are largely river sport fisheries, and aboriginal fisheries. In Europe there are extensive salt-water fisheries. Some Canadian stocks migrate to the Greenland coast thus becoming vulnerable to a fishery in Greenland coastal waters prosecuted by Greenlanders. There is some mixing of NE and NW Atlantic stocks off Greenland.

The scope of management for Canadian river fisheries is to determine on what rivers there should be no fishing, catch and release, bag limits, etc.

NASCO has an action plan and a timetable to address application of the Precautionary Approach. In the context of reference points, salmon management in Atlantic Canada has been based on achieving a "target" egg deposition of 2.4 eggs/m^2 of fluvial habitat.

2.2.3. ICCAT (Gavaris)

The Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Tunas (ICCAT) created an ad hoc Working Group to develop a discussion document of what the "precautionary approach" means in the context of ICCAT stocks. This group has prepared a document, which was reviewed by SCRS in October 1999. Of the 17 ICCAT stocks, none were considered information-rich, 8 were considered information-moderate and the remainder were considered information-poor. It was also noted that the ICCAT Convention specifies F_{MSY} as a reference target while the Precautionary Approach refers to F_{MSY} as a reference limit. The SCRS concluded that they required additional evaluations before final determination of precautionary limits.

2.2.4. FRCC (Rivard)

The draft document of the Fisheries Resource Conservation Council on the precautionary approach was discussed at a workshop held by the Council in December 9-10, 1998, in Halifax, Nova Scotia, Canada. The document has been updated since to take into account the comments received during the workshop and is now nearly completed. A second workshop, planned for January 1999, will focus on the application of the precautionary approach to domestic stocks of redfish in eastern Canada. Participation will include representatives of the fishing industry, DFO managers and scientists, and members of the Council. The purpose of the workshop is to test the applicability of the approach, and in particular that of the “report card” or “performance report”, on specific case studies.

2.2.5. Other National and International Marine Mammal PAs (Richard)

Two PA approaches for marine mammals are in use at present. The International Whaling Commission has developed its Revised Management Procedure for commercial whaling. This is a highly conservative method of calculating a TAC based on robustness trials. The method is more conservative for stocks whose status is unknown or which has not been assessed in recent years. Despite the fact that it is not yet adopted by IWC, it is presently being used by Norway to regulate its own commercial whaling.

The US NMFS has developed the Potential Biological Removal (PBR) approach for incidental mortality of marine mammals. This approach involves determining a threshold level of mortality, based on conservative assumptions of stock rate of increase and population size, that is further defined by a factor termed “recovery” that ensures the recovery of the stock if (i) the stock is deemed to be endangered, (ii) the status is known to be below optimum sustainable yield, or (iii) the status is unknown.

2.2.6. USA (Gavaris)

National Standard 1 of the Magnuson-Stevens Fishery Management Act requires conservation and management measures to prevent over-fishing while achieving, on a continuing basis, the optimum yield. National Standard Guidelines to assist in the development of fishery management plans consistent with the Act were published and refer to the precautionary approach. Of note, the guidelines refer to MSY reference points as limits. National Marine Fisheries Service prepared technical guidance on the use of the precautionary approach to implementing National Standard 1. Data-rich, data-moderate and data-poor situations were identified. Recommended default targets were identified for these situations. Where MSY reference points can be obtained, the recommended target fishing mortality is 0.75 F_{MSY} for biomass greater than 0.75 B_{MSY} while for biomass less than 0.75 B_{MSY} the target fishing mortality decreases proportionately from 0.75 F_{MSY} to zero. For over-fished resources, there are legislated requirements to rebuild within specified time frames. Non-equilibrium surplus production models have been applied liberally to estimate MSY reference points. Consideration is given to comparing these results with age based production model results. A complication, which has arisen in the northeast USA, is the requirement to evaluate the conservation equivalency of alternative management measures, e.g., area closure versus effort regulation.

2.2.7. USA Finfish (James)

There is one US initiative that appears contrary to the Precautionary Approach. Legislation currently being considered in the US to implement the 1999 Canada-US agreement under the Pacific Salmon Treaty with a tag-on that, if approved, would exempt Alaska from its Endangered Species Act (ESA) requirements on salmon.

2.2.8. NGOs (Fréchet)

Non-governmental organisations (NGOs) are also referring to the precautionary approach. Issues raised recently relate to the impact of trawling activities and ultraviolet radiation effects on fish resources.

2.3. Development of PA in Canada / Regional PA Updates

2.3.1. Laurentian (Fréchet)

The precautionary approach was discussed at a meeting shortly after the first workshop in Nanaimo in October 1998. In attendance were managers, fisheries scientists and communications officers. A few articles aiming to popularize the precautionary approach were written in fisheries magazines and circulars of the Maurice Lamontagne Institute.

The Northern Gulf cod stock has been used as a case study in the FRCC's approach to the precautionary approach. A workshop was struck to involve scientists, managers and stakeholders to the framework developed by the FRCC. The Gulf redfish stock will be yet another case study that will be examined shortly by the FRCC.

The most recent assessment of the West Coast of Newfoundland herring stock (NAFO Division 4R) incorporated key elements of the precautionary approach (SSR B4-01, 1999). Provisional values of target reference points around spawning stock biomass and fishing mortalities were derived. These reference points, as well as a « traffic light » Report Card[1] were presented to the 4R Herring Co-management Group. The Gulf shrimp assessment also had some elements of precautionary approach through the « traffic light » approach. In the case of Gulf shrimp, the stakeholders were informed about these innovations and generally understood and appreciated them. For 4R herring, these concepts were somewhat new to the Co-management members, and will require further discussions and negotiations before they will be accepted. In both cases, the harvest control laws still have to be agreed upon.

2.3.2. Maritimes (Gavaris)

The Fisheries Management System Working Group, a component of the Maritimes Regional Advisory Process was tasked with producing a discussion paper on implementing the precautionary approach. The purpose of this discussion paper is to describe what a Precautionary Approach to management of harvest fisheries entails and to clarify issues surrounding its application to Maritimes Region fisheries. It is hoped that the paper will foster dialogue about the Precautionary Approach and contribute to its speedy introduction as a central tenet of Regional fishery management.

[1] Appendix I

The discussion paper examines how fisheries management planning is impacted by the principles advocated in the precautionary approach. Three aspects of fisheries management planning are considered objectives, strategies and the decision process. For each, the implications of the precautionary approach are considered and recommendations for implementation in the Maritimes Region context are proposed.

2.3.3. Newfoundland (Shelton)

Only one of the case studies initially considered has continued to term – 3Ps cod. In the most recent assessment of this stock (October 1999) Quasi-likelihood Sequential Population Analysis (QLSPA) was used to estimate current stock size. Profile quasi-likelihood methods were then used to determine risk relative to a number of biological reference points in a short-term projection. Alternative methods for estimating population size and associated uncertainty, evaluating risk and developing reference points were considered in the October 1999 assessment by inviting outside experts to carry out alternative assessments. QLSPA has been developed further since the last project meeting (November 1998) by employing a more flexible approach for modelling the variance and for allowing the data to determine more of the structure of the partial recruitment vector. Further work has been done on developing reference points. In particular, limit reference points were given special attention. These are biologically determined. Two candidates are being emphasised: (i) a fishing mortality limit corresponding to expected recruitment and the lowest observed spawner biomass (F_{loss}) and (ii) the spawner biomass corresponding to 50% of the estimated asymptotic recruitment. Uncertainty in reference points is not currently being taken into account. In addition to short-term risk, medium-term risk analysis is being evaluated, restricted to a time horizon short enough that the estimates are not overly influenced by guesses about future recruitment (2-3 years).

Roundtable Discussion with Regional Fisheries Managers

In order to improve understanding of the precautionary approach from different perspectives, a two-day workshop was held with regional fisheries managers in September 1999, as recommended in the November 1998 meeting of the project.

The discussion was structured around brief presentations of the most recent scientific assessments for shrimp, crab, capelin, herring, flatfish, cod and seals, and presentations of the corresponding harvest plans.

The respective roles of scientists and fisheries managers with respect to the Precautionary Approach were discussed. It was decided that the role of scientists is to determine stock status in terms of biomass and mortality rates, calculate limit reference points and security margins, describe and characterize uncertainty associated with current and projected stock status, conduct risk analysis with respect to biomass and mortality reference points, and evaluate recommendations regarding comprehensive management measures that may enhance probabilities of avoiding limit reference points. The role of fisheries managers is to specify management objectives, select target reference points, specify management strategies, implement other (non-TAC) management measures to enhance probabilities of achieving objectives, develop comprehensive management plans that explicitly take the Precautionary Approach into consideration, specify time horizons for stock rebuilding and for fishing mortality adjustments to ensure stock recovery and collapse, and to specify acceptable levels of risk to be used in evaluating management actions.

A difference in emphasis was noted in that fisheries managers tend to stress the importance of management measures additional to TAC controls for achieving conservation, such as mesh size, small fish protocol, effort restrictions, seasonal distinctions, etc. Most often these measures have not been scientifically evaluated to determine the likelihood that they will have the desired effect.

Some thought was given to the impact of multispecies and ecosystem considerations with respect to determining reference points, evaluating risk, and deciding on alternative management measures within a precautionary approach. Clearly such considerations complicate application of the precautionary approach far beyond current single species considerations.

2.3.4. Central and Arctic (Richard)

In the Central and Arctic region, scientific advice is routinely presented to a co-management board with confidence limits, lower confidence limits being termed ‘low risk’ advise. In the case of bowhead whales, the NMFS’ Potential Biological Removal approach, a robust and conservative approach to marine mammal management of human-induced mortality, has been used to give advice on TAC. More formally, the region is involved with the Laurentian region since the summer of 1998 in the PA case study on Eastern Hudson Bay belugas described herein.

2.3.5. Pacific (Richards)

The Pacific Region is developing a series of policy papers that provide the context for fishery management including the precautionary approach. In October 1998, the Pacific Region released the report “A new direction for Canada’s Pacific Salmon Fisheries” which explicitly acknowledges the principle of a precautionary approach to fisheries management. The report also states that operational guidelines for implementing the precautionary approach will be developed. Other policy papers on salmon allocation and selective fishing (all species) in this series are also based on a risk-averse approach to fishery management.

The wild salmon policy (draft for consultation in preparation) attempts to define a set of principles needed for a precautionary approach to salmon fishery management. The principles begin with the need to establish the geographic extent of the stock unit to be conserved. Given these units, biological limits define the minimum stock size to ensure long-term viability, and management targets define stock sizes that optimize long-term management objectives. The policy acknowledges that short term enhancement or other measures may be required to preserve stock units at extreme low stock sizes.

The region has also adopted a policy for new and developing fisheries that sets out a phased approach (Perry et al. 1999). In Phase 0, existing information on the target or similar species is reviewed, leading to formulation of potential management strategies. In Phase 1, new information is collected from pilot fisheries or surveys, addressing the data gaps identified in Phase 0. Phase 2 consists of commercial fishing according to the management strategies identified from Phases 0 and 1. To date, this framework has been applied mostly to invertebrate species.

2.3.6. Gulf (Chouinard)

In the Gulf Region, a meeting was held with groundfish resource managers on July 15, 1999, to brief them on the precautionary approach. It was agreed that a pilot project to involve the stakeholders in the development of a precautionary approach should be pursued. The PA will be described and discussed at a special meeting of the Gulf Groundfish Advisory Committee (GGAC) in early 2000. It will be suggested that a WG should be formed to examine the implementation of the PA for cod in the Southern Gulf of St. Lawrence. It was noted that stakeholders often make reference to the precautionary approach in fishing plan discussions but that the concept is not well defined.

3. The HPPPA Case Studies

3.1. Atlantic Cod in 3Ps (Cadigan/Stansbury/Shelton)

The analytic assessment of this cod stock was based on Sequential Population Analysis (SPA). Advice for the precautionary management of this stock was formulated as a one-year stochastic projection of stock size under a variety of total allowable catch (TAC) options for the year 2000. Quota recommendations and management practises are established based on the advice of the FRCC.

Several modifications to SPA formulation and estimation (Cadigan 1988) were introduced in the recent assessment (Brattey et al. 1999) of this stock. The age-14 numbers were approximated using constraints on the fishing mortalities for the last year in which a catch was reported for a cohort. The constraints involved setting the fishing mortality equal to an unknown multiple of average fishing mortality for the three previous ages in the same year. The effect of this approach is that the SPA no longer had a “converged block”. The rationale for this approach was that the “converged block” was somewhat artificial, and that the new approach provides a more realistic model for uncertainty about historical stock abundance.

The SPA cohort parameters were estimated using the Canadian research vessel (RV) survey index and a Gillnet catch-rate index (ages 3-10 for 1995-1998) derived from the Newfoundland Region Sentinel fishery program. Some mixing strata were removed in the computation of the RV index. As a result, it no longer appears necessary to treat the Winter and Spring portions of the time-series as separate indices.

Another new feature was that inferences were based on a quadratic variance model. Such a model appears more appropriate for modelling a stock that has experienced large changes in abundance. The variance model was estimated separately for the RV and Gillnet indices. Also, the estimation-weight for the RV and Gillnet indices was based on the inverse of the variance (i.e., self-weighting). RV indices in the Spring and Winter were also self-weighted to accommodate the increased variability observed in the Spring time-series.

Science Framework for the Precautionary Approach

In the October 1999 assessment of the stock, Brattey et al. (1999) increased their attention on the development of reference points for evaluating risk. Both precautionary reference points and biological limits to overfishing were considered. Two precautionary and two limit reference points were considered to be most useful at present. The precautionary reference points that were selected are the risk of exceeding $F_{0.1}$ and the risk of spawner biomass declining. The limit reference points that were selected are the risk of exceeding F_{loss} and the risk of the spawner biomass falling below the level corresponding to 50% of asymptotic recruitment. It was considered that limit reference points should be determined only on scientific (biological) grounds. For F_{loss} the expected recruitment at the lowest observed spawner biomass was estimated using a Cauchy kernel smoother with the shape parameter estimated by cross validation. The estimates are sensitive to the method for extrapolating to the origin in spawner-recruit space. Asymptotic recruitment was estimated by fitting a Beverton-Holt model using maximum likelihood methods, assuming lognormal error.

Short-term risk, i.e., the risk associated with fishing in the year 2000 (evaluating F for year 2000 and spawner biomass for the beginning of the year 2001) was computed using profile quasi-likelihood methods. The risk of exceeding the limit F and biomass reference points is illustrated in Fig. 3.1.1.

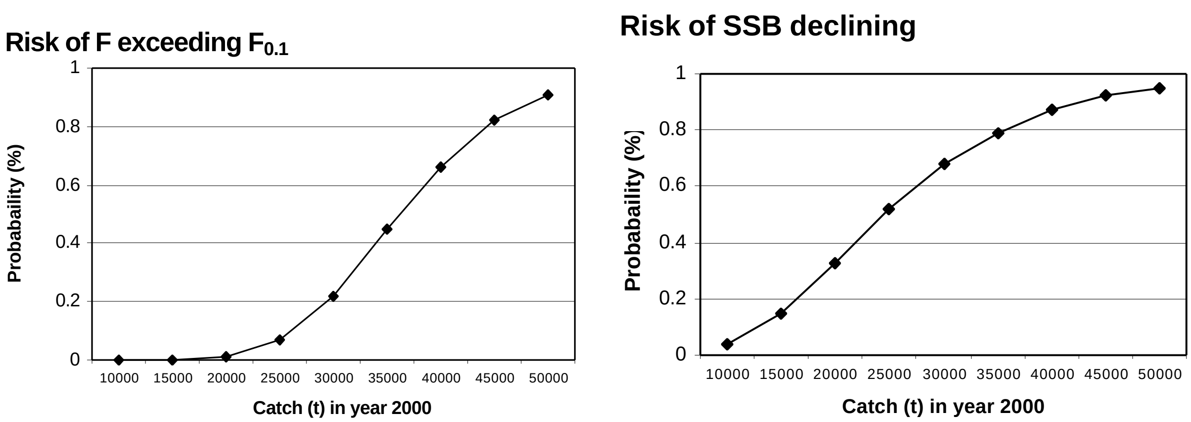


Figure 3.1.1. Risk of F exceeding $F_{0.1}$ and SSB declining

In addition to short-term risk, the computation of medium-term risk was used to explore the risk of further stock declines. It was decided that medium-term risk should be limited to a time horizon no longer than that obtained by projecting the youngest estimated age in 1999 to an age at which the proportion mature exceeded 50%, thus reducing the influence of estimating future recruitment. This limited the medium-term projection in the current assessment to the beginning of the year 2002, i.e., a two-year projection. The risk analysis involved Monte Carlo simulation with samples of numbers at age drawn from the asymptotic-normal distribution of the QLSPA parameter. Recruitment was sampled from past values with the probability determined by a fitted Cauchy PDF. Medium-term risk was evaluated for a 30,000 t TAC in both year 2000 and year 2001. Although there is a reasonably high probability of the spawner biomass declining in the medium-term, there is a relatively low probability of the spawner biomass and fishing mortality falling on the wrong side of the defined limit reference points.

These analyses are all based on an SPA with clear deficiencies. Year-effects are apparent in the RV time-series, and at present there is no sensible way of dealing with these. Different assumptions about the catchability of the RV survey can result in substantially lower estimates of stock size. In addition, the commercial fishery selectivity suggested by the SPA has concerned some scientists, and more research is required to investigate the validity of these estimates.

Other precautionary measures specified by fisheries management involve restrictions on mesh size, small fish protocols, effort restrictions, seasonal distinctions, etc. Most often these measures have not been scientifically evaluated to determine the likelihood that they will have the desired effect.

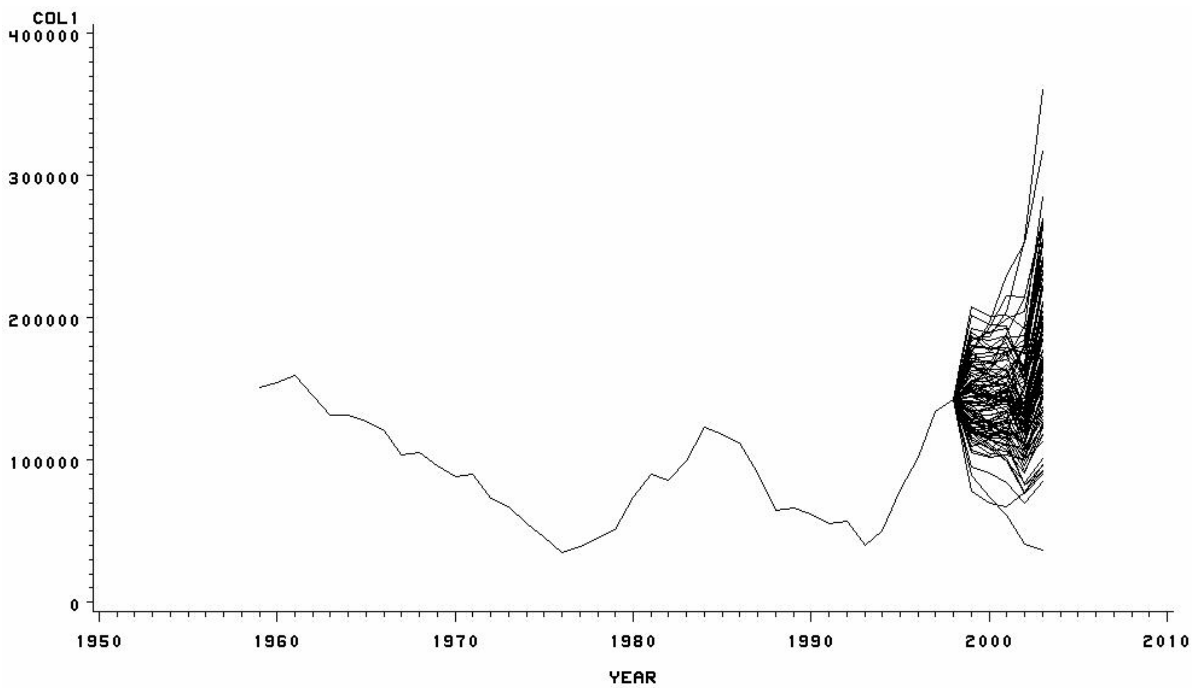


Figure 3.1.2. Medium-term spawner biomass projections of uncertainty in survivors

It must be emphasised that within the current assessment framework for 3Ps cod, Science has only a limited influence on the precautionary management of this stock. The Fisheries Resource Conservation Council formulates the advice for this stock from both Science and fishermen’s inputs. It is not clear that the Council is working within a precautionary approach framework at present or whether they are giving consideration to the computed risk relative to defined reference points in some objective manner, particularly with respect to recent cod stock assessments and their ensuing advice.

<u>Prospects for Future Developments</u>

The assessment of this stock could benefit by including data already collected by DFO. This includes using the Cameron RV survey data that precede the present RV index, and using commercial catch at age by gear type to assist in addressing the fishery selectivity problem. DFO already collects acoustic data that could assist in dealing with the “year-effects” problem outlined in the previous section. An industry survey may improve the assessment of this stock in the future. Noteworthy here is the potential of developing a more efficient design because of the single-species nature of the industry survey. In addition, the extensive cod-tagging program ongoing in this region has a significant potential of providing absolute abundance estimates, gear selectivity estimates, and estimates of natural mortality rates. This program may also, in time, provide information about annual changes in the availability of the stock to the survey, i.e., an important component of survey catchability. It is anticipated that the assessment of this stock will improve in the next several years; however, this is exasperated by poor commercial catch data.

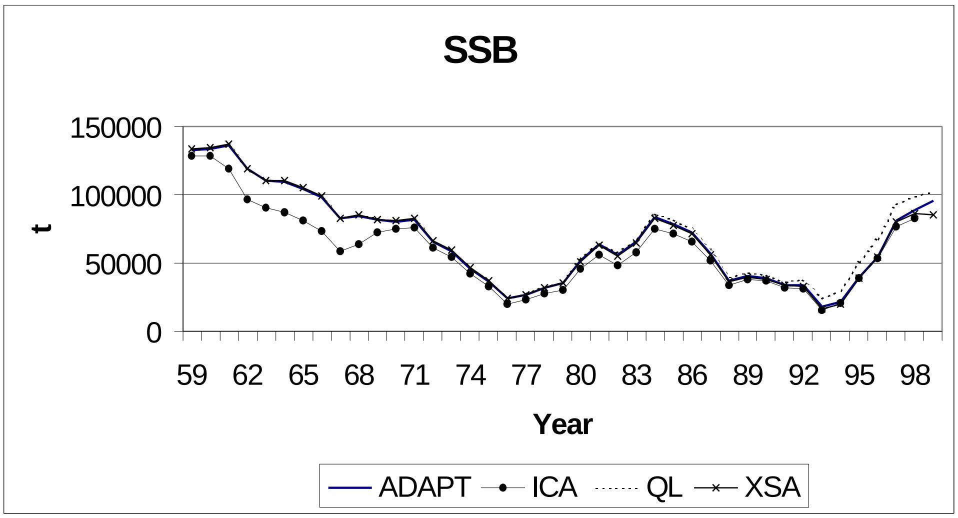


Figure 3.1.3. Estimated spawner biomass of 3Ps cod

In 1999, the October regional assessment used four different SPA software packages (each with different estimation methods) to estimate stock size (Fig. 3.1.3). All of these packages (ADAPT, ICA, QLSPA, XSA) gave similar stock size estimates when the packages used the same data for estimation in the SPA model, and when the SPA structure for each package was made as similar as possible. The conclusion from this exercise was that SPA estimation for 3PS cod is more sensitive to SPA model structure than the method of estimation. However, the SPA formulation and estimation methods presently used can still be improved substantially. Potential improvements are:

1. Investigate the utility of incorporating commercial catch-at-age by gear type (i.e., a separable component) into SPA to improve inferences about the fishery selectivity. This should also include utilising tagging estimates of gear selectivity.
2. Investigate better approximations to the distribution of the profile quasi-likelihood statistic. This will improve the risk analyses of stock size projections.
3. Include uncertainty about the fishery selectivity, stock weights, and reproductive rates in the risk analyses.
4. Investigate an “errors in variables’’ approach to SPA, where commercial catch is modelled in terms of age-distribution and total catch; that is, model separately the errors in the age distribution and the errors in the total amount of commercial catch.

5. Include a process-error model component into the SPA, and thereby produce a “real’’ risk analysis. This should include a more realistic model of our uncertainty about natural mortality, and define whether this “parameter” is constant or not.
6. Investigate more efficient statistics for summarising RV abundance indices for SPA estimation. This includes dealing with large catches.
7. Investigate the incorporation of realistic models of the RV index sampling variability into SPA inferences.
8. Develop practical influence diagnostics that measure the sensitivity of SPA inputs on key estimates and inferences. This is useful for understanding why different models produce different inferences.
9. Incorporate a recruitment model option into the SPA.
10. Investigate smooth nonparametric models for SPA index catchabilities (i.e., put in a spline smoother for q’s).

Future Plans for Case-Study Completion

As outlined in the previous section, the case study will continue to evolve and improve as time and resource permits. This will be in conjunction with annual assessments of this stock and will also consider developments within NAFO and ICES.

Discussion (Chouinard)

Three presentations were made relative to the case study for 3Ps cod. The October 1999 stock assessment review provided an opportunity to compare various methods for this stock. First, Don Stansbury presented the results of VPA calibrations using four methods: Integrated Catch Analysis (ICA), ADAPT, Extended Survivor Analysis (XSA) and Quasi-Likelihood sequential population analysis (QLSPA). The four techniques used the same model structure. Catch at age for 1959-1999 (ages 2-14) and the research vessel abundance indices (ages 2-12) for 1983-1999 (spring and winter series) with an M assumed at 0.2 were the main aspects of this structure. Except for XSA, the methods all used least-squares minimization of some objective function. In order to make the methods as comparable as possible, various options specific to the different methods (e.g., shrinkage in XSA, estimating the relationship between the variance and the mean in QLSPA, bias correction in ADAPT) were turned off. The results of the various population re-constructions were very similar. Based on the observation that the same structure employed with the various methods gave similar results, it was concluded that the method was less important than the structure that is imposed.

The second presentation by Noel Cadigan presented the details of the model that was accepted as the best population reconstruction at the assessment meeting. The QLSPA method was used with a different model structure than the one used in the previous assessment of 3Ps cod. Population estimates and catchability-at-age coefficients for the research vessel indices were also different from the previous assessment. The model estimated F-ratios for the oldest age groups in 1998 and 1999 and for several age groups in 1993 (due to zero catches for several age groups during the period of the moratorium). In addition, a constant F-ratio for age 14 for 1959-1993 was estimated. The estimation was based on a quadratic variance model. The abundance indices used for the calibration included the research vessel index (spring and winter) and a new index derived from the gillnet sentinel surveys from 1995-1998. Several questions for clarification were asked related to the structure used by the participants.

The results suggested a dome-shaped partial recruitment and a current spawning stock biomass that is near the highest levels observed in the time series with the beginnings of a decline. The variance model includes a parameter that is equivalent to self-weighting. The gillnet sentinel survey was much more variable and was given a lower weight in the calibration procedure.

The third presentation by Peter Shelton focused on the calculation of biological reference points based on the spawner-recruit trajectories from the calibration described above. The author noted that risk analysis calculations did not appear to have had much impact on the setting of quota for several cod stocks in 1999.

The eight reference points were: F_{med}, $F_{0.1}$, F_{loss}, $F_{35\%SPR}$, F_{high}, spawner biomass corresponding to 50% asymptotic recruitment, spawner biomass corresponding to F_{high} and the 90th percentile recruitment and spawner biomass corresponding to 20% of the virgin spawner biomass. It was noted that F_{loss} was unusually higher than F_{high}. In addition, the estimates of F_{loss} near the origin were sensitive to the estimation method used.

It was noted that the estimates for various levels of fully recruited F were high (e.g., $F_{0.1}$ = 0.59; F_{high} = 1.65) compared to perceived safe levels from dome-shaped partial recruitment patterns currently observed in the fishery. These fishing mortality reference points could be considerably lower if partial recruitment other than the status quo were to be used for the future fishery. It was suggested that it might not be precautionary to set high levels of F as fishing limits, even if they did occur only on one or two age classes.

It was also noted that some significant temporal trends in the stock-recruit relationship were apparent. An analysis of these trends could lead to refinement of the reference points for periods of high and low productivity. This is common to most stock-recruit data sets for groundfish and there is no agreement on the appropriate way of dealing with non-stationarity of this kind in developing limit reference points.

3.2. Eastern Hudson Bay Beluga (Richard)

This case study is focused on determining a precautionary approach for the Eastern Hudson Bay Beluga within the context of co-management. The challenges in this case study are to: (i) reach a consensus with users that a precautionary approach is conducive to successful resource conservation; (ii) make explicit to users current scientific knowledge about that stock and techniques of risk analysis using stochastic population models; (iii) to elicit user knowledge about the stock and integrate it into the analyses; (iv) to jointly (users and scientists) ‘play’ with the models and come to consensus on a precautionary approach to co-management, including rules of implementation and compliance.

<u>What can you do with existing data and analytical tools?</u>

Working framework for a precautionary approach: The framework is a marriage of risk analysis and co-management. The risk analysis is stochastic modelling using a stage-structured model of the population. The co-management approach will involve a pilot co-management workshop to evaluate the effectiveness of the risk analysis models in a co-management context (i.e., joint-analysis and interpretation, consensus-building, joint determination of a precautionary approach).

Practicality of implementation (e.g., management and compliance issues): The large territory and subsistence nature of beluga hunts and the constitutional and legal circumstances of native harvesting make the co-management approach essential to the implementation of a precautionary approach. Successful implementation is possible only with meaningful participation of hunter representatives and the wide acceptance of the precautionary approach among hunters.

Limit and target reference points: There are several candidate reference points that are being considered and should be determined during the pilot co-management workshop through modelling and consensus building.

Approach for testing Harvest Control Rule: Hunt control rules and the determination of their effectiveness will be discussed at the co-management workshop.

Other (non-TAC) conservation and technical measures: The effectiveness of seasonal closures and sex/age limitations will be explored through modelling in the workshop.

Technical difficulties: The modelling relies on assumptions because some parameters of the model cannot be estimated very well. Survival-at-age and its time variance and that of fecundity cannot be estimated exactly or at all. The model parameters are derived from logical arguments and analogies with species having similar life histories. Present population size is imprecise and may be biased. Density dependence cannot be estimated and will have to be modelled at theoretical extremes.

Analytical issues: The choice of uncertainty distributions and the choice of density-dependent versus density-independent models are in question, the latter at least when modelling small population sizes. Clearly, because of the number of assumptions used in the modelling, the models should be considered more as learning tools than as black-box risk analysis tools. Consequently, the emphasis of this case study is at the co-management workshop phase.

Software tools and implementation: The software used is Analytica™, a visual stochastic modelling software that provides graphics and tabular methods of representing the model structure and outcomes of the model.

Prospects for Future Developments

Can we realistically expect better data? Yes, for initial population size and removals (catches and losses). No for survival, fecundity, MSY and K.

Identify possible improvements in analyses, analytical or computational tools, etc. We are not far enough in the analysis to recommend on these aspects. A lot will depend on the pilot co-management workshop evaluation.

Future Plans for Completion of Case Study

The next steps are (i) continued model validation and sensitivity analyses (Nov-Dec 1999), (ii) preliminary modelling to estimate thresholds and target reference points (Dec 1999 - Jan 2000), (iii) pilot co-management workshop on the precautionary approach (Feb 1999), and (iv) preparation of project report (March 2000).

Discussion (Cass)

Despite the sparseness of assessment data for this stock, stock assessment appears quite tractable. Concepts of the precautionary approach should be easily conveyed given what is known about the birth rate, mortality and current stock size. Sufficient information at least to bound birth rate and stock size estimates is now available. Recent survey data indicates the stock may consist of about 2000 animals. The fact that the estimated range of stock size is small compared to many exploited fish stocks, implies that credible results are likely even with the limited data presently available. Uncertainties about stock delineation could bound the upper range of the stock size at 7000-8000 animals if neighbouring populations are part of that stock. These numbers represent a decline in abundance from historical levels that are thought to have been at 10,000 or more animals. The estimated median birth rate is one calf in three years but hunters who see females with neonates and yearlings have reported estimates of one calf in two years.

The use of models that have been used to demonstrate potential trajectories of stock rebuilding to co-management partners was questioned during the discussion. There was some concern about their credibility because these models have no parameter estimation component and only simulate population trajectories based on assumption about the model inputs. Assigning weights to the various assumptions might be more informative. The case study team leader noted that these models are still under development and are only used to demonstrate the relative effect of different assumptions and management choices to the hunter community.

The COSEWIC conclusion that this stock is “threatened” was mentioned during the discussion but the case study team leader discounted the usefulness of the COSEWIC approach.

Future gains in the quality of assessment data could come from surveys designed to determine uncertainty in stock abundance estimates. Recognizing that uncertainly in stock delineation is a serious issue, approaches that identify both the uncertainty in the geographic range and stock abundance should be considered. It was suggested that collection of appropriate data such as catch-at-age information could, in time, be used to apply traditional cohort analysis. It was noted that ageing estimation methods are developed and that there have been attempts to do such a thing in the Beaufort Sea but there were technical problems. The challenge is to initiate sampling programs that reliably sample the catch.

Considerable discussion focussed on the role of scientists in assessment and management of this stock. The committee acknowledged that this is a co-managed stock and that successful management depends on the cooperation and collective knowledge and skills of both the hunters and the scientists. From a science perspective, committee members felt that consistent and representative data collection programs initiated now will be extremely important for future analysis like catch-at-age modelling. The case study leader was unsure if such a program could be successfully implemented in this case because of logistic, cost and technical problems.

3.3. Snow Crab in the Southern Gulf of St. Lawrence (Wade)

Management Practices

The snow crab fishery in the Gulf of St. Lawrence has key aspects built in that are inherently precautionary (e.g., the fishery targets males larger than 95mm). Fishermen are limited by the number of traps they can use and by the timing and length of the season. In the spirit of rebuilding the commercial-sized portion of the stock, the target exploitation rate was set at a conservative level of 35 to 40% starting in 1991.

There was a transition in the late 1980s from a competitive fishery to an individual quota system. Since 1994, co-management agreements were put in place, which among other things, helped initiate an at-sea observer program to monitor the fishery. This program has been useful in monitoring and reducing the high-grade practices of the fishery. The program is also useful in measuring the occurrence of soft crab as the fishery progresses. A provision is built into the system so that when 20% of the catch in a given sector is recorded for a pre-determined amount of time, the fishery is encouraged to move to other grounds. When the occurrence of soft crab is generalized over the whole zone for an extended period of time, the fishery is closed. This measure helps protect the recruitment for next year's fishery.

Other Conservation Measures

Limited entry fishery
By-catch protection provisions (negligible by-catch)
In-season management
Soft crab (R-1) sector closures when at 20%
Fishing gear restrictions
Minimum mesh size
Escape / ghost fishing mechanisms
Dockside monitoring
Air patrols
Ship patrols
On-board inspections
Accurate catch statistics (98% compliance)
Adequate sampling

Co-Management Practices

It is important to note that DFO-Industry co-operation, agreements, and information sharing played an important role in the stock rebuilding processes and in self-monitoring measures that were put in place recently. Indeed, industry funds the annual trawl survey, port sampling and at-sea observer programs.

Lowered target exploitation rates were agreed upon by industry during the stock recuperation phase of the early 1990s. Industry was encouraged to continue this practice during periods of high recruitment, in the spirit of accumulating a reserve for the upcoming low recruitment periods of the late 1990s.

Assessment Techniques

Projections for stock biomass and recruitment are based on data from the annual post-season trawl survey. Specifically geostatistics are used to assess commercial biomass and map out the population of several key indicator categories. Logbook data and observer-based information are used to corroborate our results. (Fig. 3.3.1)

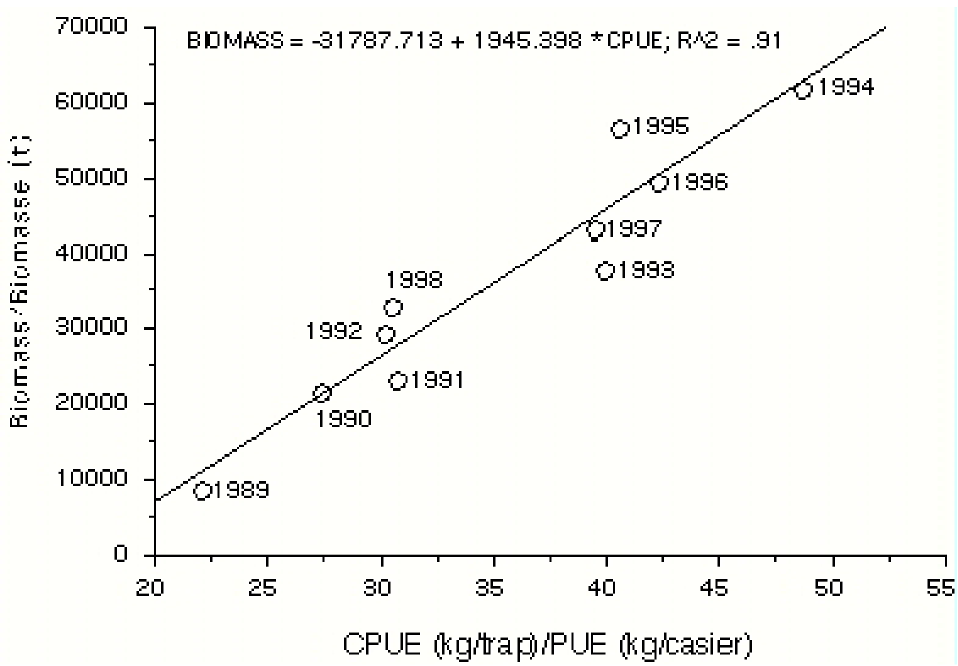


Figure 3.3.1. Projections for stock biomass and recruitment

Scientific Advice

Specifically, scientific advice consists of using a direct estimate approach from fall trawl survey data to estimate the relative biomass for the commercial sized adult male portion of the stock. Additionally, we determine the proportion of various categories of the stock that describe the ageing of the adult population (shell conditions 1 through 5) and recruitment R-1, R-2 and R-3.

Issues to be Addressed Before Setting Limit and Target Reference Points

Although year to year projections of biomass seem to follow the trends observed the following year by data from the at-sea observers and fishermen, it is important to consider some of the uncertainties inherent to the biology of the species when setting any limit and target references. As an example, the rate of maturity at differing sizes seems to vary with time. We have observed a higher incidence of maturity below legal size in recent years. Another important factor is the role the old adult males play in the replenishment of the stock. Although older males have smaller economic value, their reproductive value is thought by some to be important. What level of SSB will increase the probability of good recruitment? How does the life expectancy of adult crabs vary with environmental factors? What are the efficiency factors when surveys use different trawl sizes? These are just some of the issues that need to be addressed before giving clear guidelines on target limits.

Progress Since 1998

Since last year's meeting, the work completed includes (i) estimates for rates of maturity-at-size and proportions of skip molters, (ii) conversion and organization of information from trawl surveys, logbooks, observer and tagging data, and (iii) migration of summaries and density maps into databases or other structured formats.

Working Framework for a Precautionary Approach

Certainly the most important aspect required to further develop the approach is the continuation of the manager/scientists/client interaction. Without the industry "buying-in", without effective communication from science to managers and industry, and without respect for each other's ideas and views, an effective approach is difficult to attain. From the science perspective, the continuation of annual surveys is critical. We also need to ensure the continuation of conservation and enforcement measures to adequately monitor the fishery and develop traffic light approaches to make short-term decisions.

Practicality of Implementation

Many of the factors are already in place in the fishery, although a cautious approach will be taken in proceeding to the next level of setting limits and target levels. Consultations with our peer review committees and clients are needed to consider reasonable limits.

Threshold and Target Reference Points

The status quo on F_{TARGET}, which was set in the early 1990s, has been 35-40% (Fig. 3.3.2). This figure is thought to be somewhat too conservative, since it is believed that an abundance of old crab might result in a high natural mortality rate within this population. Others cite the possible higher reproductive value of this group. Another management strategy might be to have a sliding fishing mortality rate that would change as a function of recruitment. Much will be discussed before a strategy on this issue is agreed upon.

When the fishery was closed in 1989, the projected biomass was 7500 mt. This figure could be regarded as a precedent to be at or below B_{BUFFER}, or the level of biomass that would close the fishery. It should be pointed out that the reason for closure at that time included economic considerations and stock protection issues.

B_{TARGET}, the level of biomass that would warrant a reduction of the exploitation rate, would need to be set through consultations.

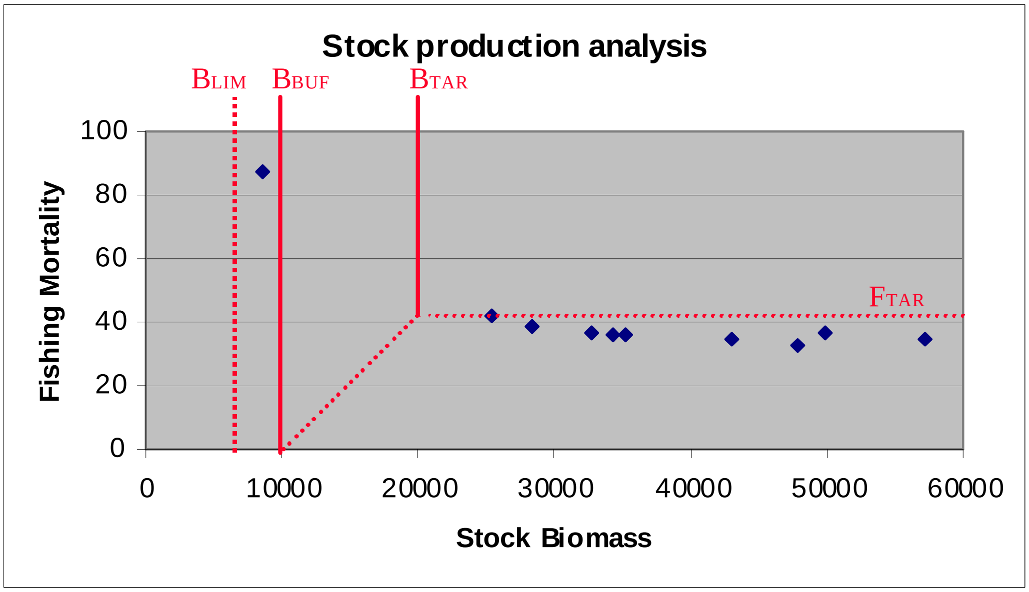


Figure 3.3.2. Past exploitation levels of snow crab

Technical Difficulties

Philosophical issues need to be worked out within a snow crab working group to set proper target reference points. There is a need to get familiar with risk analysis tools (e.g., Analytica) to help describe our uncertainties in a formal way. We also need to familiarize the snow crab community on risk analysis approaches.

Reality Check

The Alaska snow crab fishery was one of the world's largest, reaching a level of 250,000,000 lbs in recent years. That fishery, while using many of the same 'built-in' systems to protect the stock as the Gulf, has not shown any apparent recruitment for the past seven years, and is in danger of being closed next season. An understanding of the processes that might precipitate such an event is important in establishing a sound precautionary approach strategy.

Future Plans for Completion of Case Study

We will adopt risk analysis procedures on these data and discuss the practicality of implementation at the next peer review (Jan 1999).

Discussion (Schnute)

Work on the Precautionary Approach must be coordinated among assessments for Canada's three snow crab stocks (Newfoundland, Laurentian, and Gulf stocks).

Some participants expressed concern for the philosophy of fishing mortality, which might be fixed at 35% or adjusted according to the recruitment.

Precautionary snow crab management does not necessarily have to follow a finfish prototype. Attempts to find suitable values F_{lim} and B_{lim} might be like trying to fit a square peg into a round hole. Nevertheless, appropriate science must be done. For example, what are the ecosystem impacts of high harvest rates, such as those imposed on lobster stocks?

The historical closure, followed by a 35% harvest rate cap, seems consistent with practices elsewhere. Still, economic realities produce a strong incentive to allow high harvest rates. Apparently, we lack the biological knowledge needed to support higher rates. One participant remarked that it is not up to us to prove that a high rate is bad, but rather up to the industry to demonstrate that it would be safe.

The Alaskan experience of a crash in the snow crab population shows that something different needs to be examined, such as the influence of environmental variables. Also, an industry concerned with economic stability must want to avoid a major stock crash, such as the one in Alaska.

We have a five-year management plan intended to resolve disputes in the allocation process. Currently, this highly lucrative fishery goes to about 200 license holders. Many new players are eager to participate as temporary fishermen. A possible formula for sharing catch with new fishermen in years of high stock size might be implemented in the future.

The stop light approach might be applicable, at least for triggering some alarm bells. Some aspects of the biology seem well enough defined to make a few models and analyses useful.

Last year’s report dealt with relatively well-known results from surveys. The report this year addresses biological processes that are poorly understood, but necessary for estimating precautionary reference points.

Evidence seems to support the concern that the fishery on large crabs might be altering the genetic pool in favour of small crabs.

3.4. Fraser River Sockeye (Schnute/Cass)

Fraser River sockeye salmon provide the backbone of the Canadian commercial salmon fishery on the Pacific coast of Canada. More than 150 stocks have been identified by adult migratory patterns and spawning location within the watershed. Four management stock groupings or runs are recognized (Early Stuart, Early Summer, Summer and Late). Some stocks exhibit cyclic dominance, which occurs when stock abundance in one year of the four-year life cycle dominates the abundance in other years in the cycle. As a result, sockeye returns vary markedly over the four-year cycle representing different brood lines (Ricker 1950, 1987, 1997). In the first part of this analysis, we present a generalized framework for a complete Bayesian decision analysis to evaluate multistock harvest goals in the fishery on Fraser sockeye. In the second part, we compare harvest policy outcomes for two alternative stock-recruit models, with or without interactions among year classes.

<u>Analytical framework</u>

Our analytical framework (Schnute et al. 2000) offers an iterative route to policy design, where managers play an active role in formulating policy options and evaluating their consequences. We identify four key steps necessary to assess a resource production system:

1. define the system;
2. model the dynamics;
3. simulate harvest policies;
4. evaluate policy results.

Each step entails choices that can alter the perceived consequences of management decisions.

In identifying the system components (step 1), we restrict our analysis to specific data sets, stocks, cycle lines and ages. For illustration, we choose the Summer run (Late Stuart, Quesnel, Chilko and Stellako stocks) and confine our analysis to age-4 sockeye. Our analysis uses spawning escapement data from years 1949-1997 and recruitment data from years 1953-97. Step 2 models the stock dynamics. We apply a simple dynamics model (step 2) of the form $R_{i,t+4} = g(S_{it}, q_i)$ for each stock *i*, where recruitment $R_{i,t+4}$ in year $t+4$ is related to spawners S_{it} in year *t* with suitable parameters q_i. We use a variant of a family of stock-recruitment curves proposed by Schnute and Kronlund (1996) to represent these dynamics. We examine various recruitment functions g, such as the classical functions of Ricker (1954, 1958), Schaefer (1954, 1957), and Beverton-Holt (1957). We also consider a variety of residual transformations, such as normal, square root or lognormal. For illustrative purposes here, we restrict our analysis to the Ricker model

$$g(S,q) = \frac{S}{1-h^*} \exp\left[h^*\left(1 - \frac{S}{S^*}\right)\right],$$

where $q = (h^*, S^*)$. For each stock *i*, the parameters h_i^* and S_i^* represent the harvest rate and escapement at the maximum sustainable yield, respectively. We use a log-normal error structure to model the residuals $h_{it}(q_i) = \log R_{i,t+4} - \log\, g(S_{it}, q_i)$.

Uncertainty plays a major role in this analysis, in which we use Bayesian methods to evaluate risk. A Markov chain Monte Carlo (MCMC) sample from the posterior distribution captures uncertainty in the population dynamics. The Bayesian formalism then translates this uncertainty into uncertain policy outcomes. We adopt a simple prior distribution, where the prior on each parameter is uniform across an admissible range and 0 elsewhere. Each parameter h_i^* is confined only to the interval (0,1). Based on past history and informal data from the watersheds, we set an upper limit of spawning escapement E_i for each stock i. The prior for S_i^* is then restricted to (0, E_i). Figure 3.4.1 portrays 1,000 data points (h_i^*, S_i^*) systematically extracted from a sample chain of 20,000 MCMC samples from the posterior distribution for each stock. Contours in Fig. 3.4.1 correspond to 20%, 40%, 60% and 80% posterior confidence regions. These are computed directly from the posterior function, based on probability quantiles from the full MCMC sample.

In step 3, we examine a simple two-dimensional policy space (T, f) with a minimal target escapement T and a removal fraction f applied to the excess population above the target. Special cases $(T,1)$ and $(0, f)$ correspond, respectively, to setting a fixed escapement target T or fixed harvest rate f. A given policy (T, f) applies collectively to the combined run of four stocks, which occur together in the fishery. We restrict our attention to retrospective policy analysis. Thus, we examine what might have happened to sockeye stocks if management had proceeded differently during years for which data are available. We could examine much more complex policy spaces than the one proposed here, which we only apply to the dominant cycle line for the Quesnel and Late Stuart stocks.

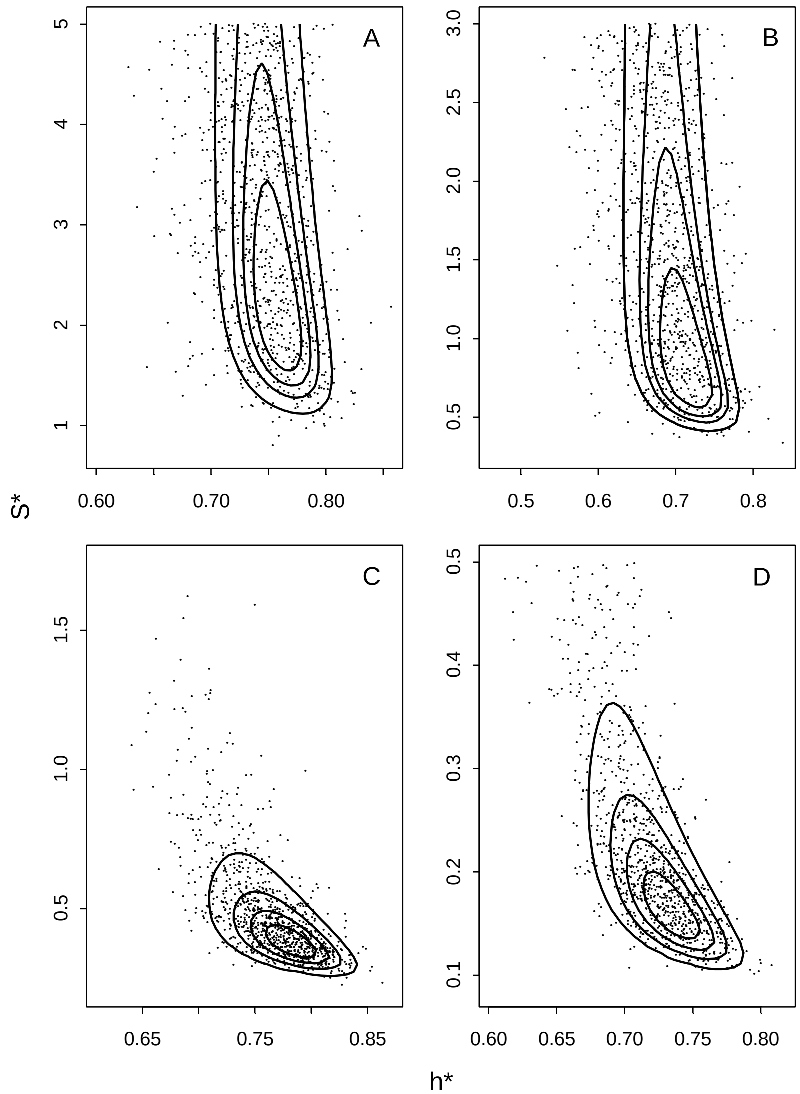


Figure 3.4.1. Scatter plot of 1,000 estimates (h^*, S^*) taken from an MCMC sample of length 20,000 for each stock in the Summer run of Fraser River sockeye (A)-(D). Analysis of stock (C) and (D) include all available data points $(S_{it}, R_{i,t+4})$ from years $t = 1,\ldots,45$ (1959-93). Data for stock (A) and (B) are restricted to cycles 1 and 2 only. Contour lines in each panel correspond to 20%, 40%, 60%, and 80% posterior confidence regions.

Each policy has an uncertain outcome associated with the unknown parameter vectors q_i. We capture this uncertainty by taking 250 sample vectors q_i' from the MCMC samples used to create Figure 3.4.1. We use a prime (′) to distinguish reconstructed values from their historical counterparts. Each simulation is initialized with the spawner abundance in each cycle equal to their numbers at the start of the historical time series. Residuals $h_{i,t-4}'$ associated with q_i' are calculated from the observed historical data and then used to predict recruits R_{it}' in the next generation. The simulation model uses the recruitment function to set a relative scale between simulated and historical spawners. The constant harvest policy (T, f) implies the harvest rate

$$h_t' = \min_i \max\left[0, f\left(1 - \frac{r_i T}{R_{it}'}\right)\right],$$

for all stocks *i* in year *t*, where $r_i = E_i / \sum_j E_j$ is the prior estimate of the proportion of stock capacity available to stock *i*. The allowable rate for a given stock i is the product of two factors, *f* and $1 - r_i T / R_{it}'$, where the second assures that the target $r_i T$ is achieved. If recruitment R_{it}' is inadequate (i.e., $R_{it}' < r_i T$), this factor is negative, and the maximum function defines a zero harvest policy. The minimum function restricts the overall harvest so that no stock i is over-harvested. The projected catch $(C_{it}' = h_t' R_{it}')$ and escapement $(S_{it}' = R_{it}' - C_{it}')$ are computed and the iteration proceeds to the next year t. In this analysis, we confine our re-constructions only to years corresponding to the dominant cycle line for the Quesnel and Late Stuart stocks. The simulation gives a complete population trajectory for every stock.

We evaluate policy results (step 4) with a formal objective function that quantifies societal values. The objective function could be tailored to favour either conservation or high exploitation of the fish stocks. We adopt a simple value function that assigns a high penalty to years with low catch. In Figure 3.4.2, contours suggest a correlated influence between T and f. A low escapement target T with a low harvest rate f on the surplus can give an average catch similar to that achieved by a high T with a high f. The figure shows a diagonal ridge with a maximum average annual catch of about 11 million fish, in comparison with the historical average catch of 5.3 million fish per year on the dominant cycle. A steep decline from the ridge in the upper left corresponds to a combined low T and high f that drives the population to extinction, thus giving a low average catch.

We consider our analysis illustrative, rather than definitive. It offers a framework for investigating the influence of model assumptions on policy design. A value function, such as the one used here, translates results from the statistics of population models into the practical realm of public policy.

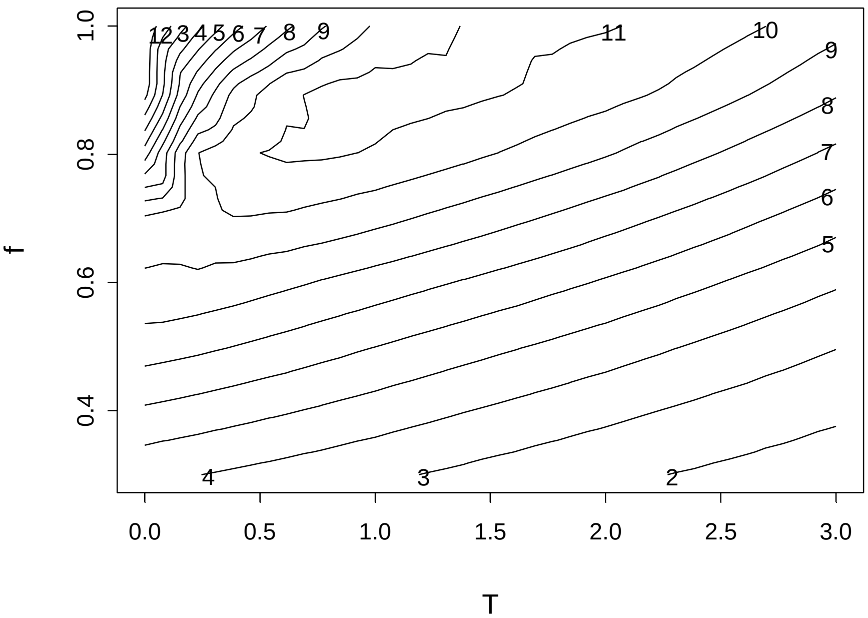


Figure 3.4.2. Mean contours of the value function in relation to policy choices (T, f), based on values corresponding to 250 parameter vectors drawn from the MCMC runs in Fig. 3.4.1.

Cycle line interaction model

We next examine the potential effects of cycle line interaction on management policies. In this case, we confine our analysis to the Late run of Fraser sockeye and to the three main stocks that co-migrate as part of the Late run (Birkenhead River, Weaver Creek and spawning channel and the Adams River/Shuswap Lake complex). We chose the Late run because the cyclic behaviour of Adams River sockeye is the most widely studied and significant interactions among cycles have previously been reported (Larkin 1971; Collie and Walters 1987; Welch and Noakes 1990; Meyers et al. 1998).

We again use a variant of the stock-recruitment curve proposed by Schnute and Kronlund (1996); however, we include extra terms to quantify cycle line interaction as considered by Larkin (1971) for the Ricker model:

$$g(S_0, S_1, S_2, S_3, q) = \frac{S_0}{1-h^*} \exp\left[h^* \left(1 - \frac{S_0}{S^*} \right) - b_1 S_1 - b_2 S_2 - b_3 S_3 \right],$$

where, $q = (h^*, S^*, b_1, b_2, b_3)$ and the earlier interpretation of (h^*, S^*) applies only if $(b_1, b_2, b_3) = (0,0,0)$. The interaction coefficients (b_1, b_2, b_3) represent the effects of spawning escapements (S_1, S_2, S_3) in years $t-1$, $t-2$, and $t-3$. Within the Late run, only the Adams/Shuswap stock complex exhibits persistent cycles. In the years of the dominant cycle-line return of Shuswap Lake sockeye (1902, 1906,…1990, 1994, 1998) the catch and spawning escapement of the late run consists predominantly of Shuswap Lake bound sockeye. Conversely, in the two off-cycle return years of Shuswap Lake sockeye the returns are mainly Birkenhead and Weaver sockeye. For the Weaver and Birkenhead stocks the interaction terms (b_1, b_2, b_3) were fixed at zero. For the highly cyclic Adams/Shuswap stock, these parameters were estimated.

In the first section of 3.4 above we focussed solely on age-4 sockeye and a single cycle line. Here we estimate the stock-recruitment parameters and reconstruct runs for age-4 and age-5 sockeye sequentially for all years that data are available. The recruitment of age-5 sockeye is negligible in most years compared to age-4 sockeye. In highly cyclic stocks, however, the abundance of age-5 returns in the year following the dominant and sub-dominant year of age-4 sockeye can contribute significantly to the catch and escapement.

As before, we generate policy outcomes for each of 250 MCMC stock-recruit parameters q' extracted from a chain of 20,000 samples of the Bayes posterior distribution. Harvest rates h_t' and trajectories of catch C_t' and escapement S_t' were generated from a value function that maximizes the sum $\sum_t \log C_t'$. Logarithmic values in this function penalize years of low catch and discount high catches in favour of low inter-annual catch variance (Deriso 1985). Here harvest rates are treated as decision variables. Optimal harvest rates are found using the Small-Scale Solver Dynamic Link Library (DLL) (software copyright © 1991-1998 Frontline Systems Inc). The optimal harvest rate trajectory is the harvest policy a manager would chose with perfect knowledge of present and future recruitment rates (omniscient manager), given a particular value function. We evaluate the effect of cycle line interaction by comparing policy outcomes of the interaction model $(b_1, b_2, b_3 \neq 0)$ with outcomes based on a non-interaction model $(b_1, b_2, b_3 = 0)$.

Figure 3.4.3 shows the distribution of spawning escapements from the 250 MCMC sub-samples, accumulated after five generations of run reconstruction (20 years), for each cycle line and stock-recruit model. The interaction model gives a much narrower range optimal escapement policies than the non-interaction model for each cycle line. For all cycle lines combined, the mean number of spawners is 0.8 million sockeye assuming interaction compared to 2.6 million spawners assuming no interaction among cycles. The variability in the distributions among cycle lines for each stock-recruitment model results from historical variability in survival patterns among cycles (i.e., the residuals), not from the particular stock-recruitment model. Simulations that use parametric log-normal residual error over many trials (not shown) indicate that the variability in the distributions of optimal escapement policy among the four cycle lines are very similar to the results of the retrospective analysis but without the variability among cycles.

Observed spawning escapements on the dominant Adams/Shuswap cycle line have exceeded the levels prescribed by the cycle-interaction model for the simply policy objective considered here. The escapement on the dominant cycle for that stock has averaged 2 million sockeye since 1949, while the other cycles have remained at low levels. The model suggests that over-escapement for the dominant cycle is not precautionary, due to high mortality on the low cycles induced by negative interactions among cycles.

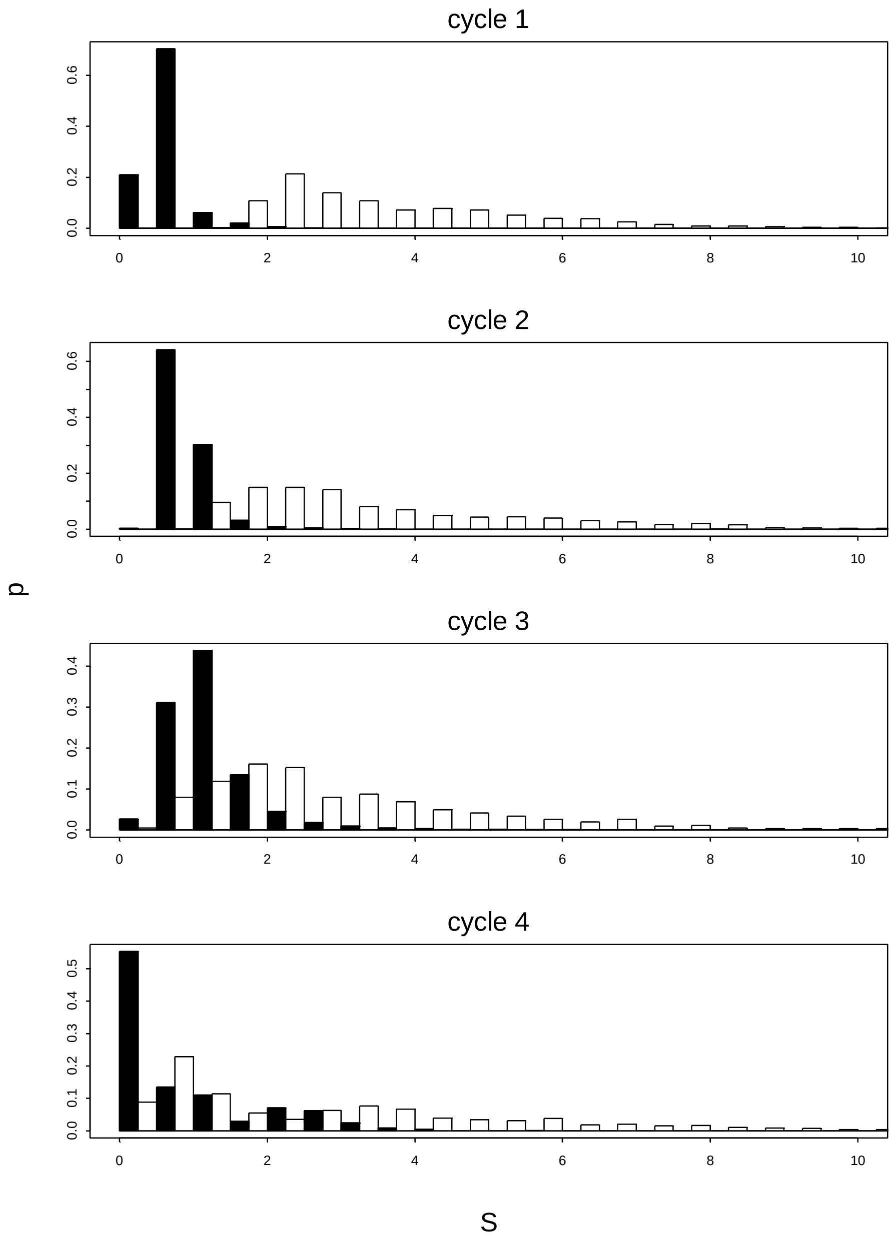


Figure 3.4.3. Distribution of spawners S (millions of fish) for Late run Fraser sockeye that maximize a logarithmic value function for a Ricker stock-recruitment model that (A) includes cycle line interaction terms (solid bars) and (B) sets interaction terms equal to zero (open bars). The distribution results from uncertain population dynamics captured in 250 sub-samples from 20,000 MCMC samples of the Bayes posterior distribution. The y-axis (p) is scaled so that the height of the bars sum to 1.

Discussion (Stocker)

Two presentations were made relative to the Fraser River sockeye case study. First, Jon Schnute presented a general framework for a Bayesian decision analysis for summer run Fraser River sockeye stocks (Quesnel, Late Stuart, Chilko, and Stellako). A functional parametric S-R model expressed the stock dynamics. Uncertainty in the S-R parameters was estimated in the analysis. Stock productivity was defined as sockeye returns resulting from spawning that took place four years ago. The two S-R parameters of the Ricker model α and β were expressed in terms of h* and S*. The productivity parameter h* is defined as the harvest rate at the MSY level. The capacity parameter S* is the spawning escapement at the level that produces h*. The results of the Bayesian analysis were portrayed using pairs plots. It was noted that the densest regions in the two-dimensional space h*, S* coincided with the peaks in the probability plots.

The second presentation by Al Cass evaluated cycle line interactions for the late run component. This analysis was done because a number of Fraser River sockeye stocks show persistent cycles in abundance.

It was noted that harvest rates in these mixed stock fisheries have been high. For example they have averaged 78% on the 1997 cycle year. It was also noted that there is a lot of uncertainty about the capacity parameter (S*). However, a feature of the approach is that other information can be introduced to establish limits on S* (e.g., habitat capacity).

It was noted that the processes that maintain population cycles are poorly understood. There is strong evidence that cycles are not merely echoes of past random catastrophic perturbations, such as the rockslide at Hell's Gate in 1913, which persist due to the simple age structure of the population.

3.5. Atlantic Cod in 4TVn (Sinclair/Chouinard)

Broad issues related to the stock assessment and PA management of this fishery were presented at the 1998 PA workshop and are summarized in its report and on the PA website. This year's presentation focused on the following; new analyses of biological factors that affect stock production, including changes in natural mortality (M), size selective mortality, and variations in recruits per spawner (the recruitment dilemma); stock production considerations in light of these changes; modelling initiatives; and PA implementation issues.

Changes in Natural Mortality

The latest assessment of this stock has included a knife edged change of M from 0.2 to 0.4 in 1985. The timing of this assumed change in M was supported by diagnostics from SPA calibration although it was recognized that such a change would more likely have occurred over a number of years and possibly over different ages. In an attempt to gain further insight into the timing of this change, the SPA analysis was divided into a number of year and age blocks. M was fixed at the traditional value of 0.2 for all ages during the years 1971 – 81, and separate values were estimated as part of the SPA calibration for the year and age blocks indicated in Table 3.5.1.

Table 3.5.1. Estimates of M for different year and age blocks for 4TVn cod.

Years	Ages	Age Specific k
1971-81	all	fixed 0.2
1982-87	all	0.32
1988-93	3-6	0.59
1988-93	7-15	0.36
1994-98	3-6	0.15
1994-98	7-15	0.57

There appears to be some information on possible changes in M in the SPA data and that M may be returning to more traditional values at least at younger ages. It is recognized, however, that the choice of blocks was arbitrary and the results may vary if different blocks were used. The results were encouraging and we hope to continue investigating alternative formulations.

It was interesting to note how a change in M would affect yield per recruit and stock production reference points (all other things remaining equal). The equilibrium yield curve and the estimated F_{msy} for an M of 0.4 were much lower than that for an M of 0.2 (Fig. 3.5.1 left panel). Yield per recruit was also lower with a higher M, but the estimated $F_{0.1}$ reference point was higher (Fig. 3.5.1 right panel). In fact, the estimated $F_{0.1}$ for an M of 0.4 would not be sustainable from a stock production perspective. The production model essentially says: ‘fish less at high M in order to ensure the stock can replace itself’. It would be ill advised to follow the yield per recruit model in a case where M increased, all other things remaining equal.

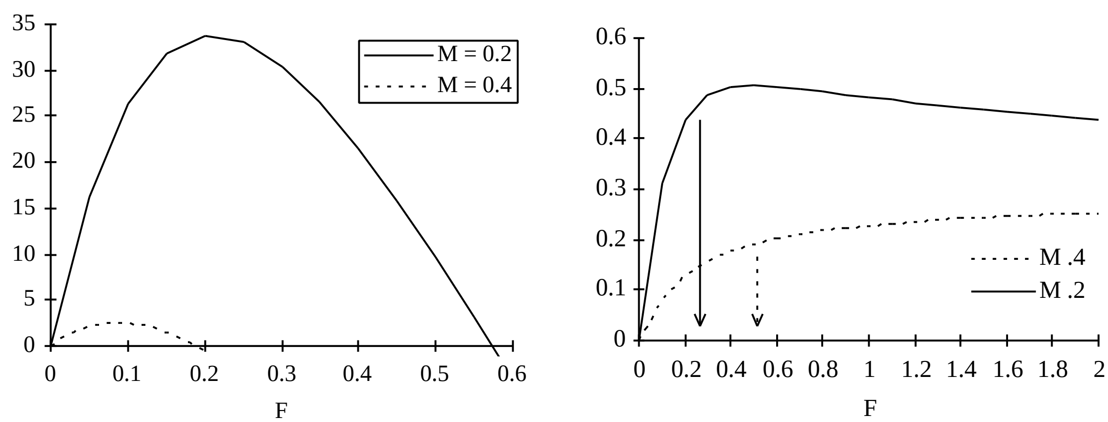


Figure 3.5.1. Equilibrium yield (left panel) and yield per recruit (right panel) curves from stock production analysis of southern Gulf of St. Lawrence cod at two levels of M, 0.2 and 0.4.[2]

[2] From Sinclair et al. (1998)

<u>Size Selective Mortality</u>

We have been investigating the possibility that size selective mortality may have been an important cause of changes in population length-at-age for this stock. The otolith collection from annual research vessel surveys from 1971 – 98 and ages 3-11 was used to establish a database of back-calculated length-at-age. During the 1980s, it was observed that within cohorts, as the fish got older, the back-calculated mean length-at-age 3 declined. This suggests that the faster growing fish were experiencing relatively higher mortality than slower growing fish. This effect has not been evident since the closure of the fishery, suggesting that fishing was the main source of this size selective mortality.

A simulation was used to demonstrate the effect that size selective mortality could have on population mean length-at-age and yield per recruit type reference points. A test population was created from the otolith back-calculation database by making a random selection from the available age 11 fish (N = 112). Individual von Bertalanffy growth curves were fit to their back-calculated lengths-at-age and the resulting predicted values were used to represent the growth variation of the test population. An age structured population was created using these 112 fish as constant recruitment, assuming a constant natural mortality of 0.2, and imposing a size selective fishing mortality at length. The latter was derived from the ratio of commercial catch-at-length divided by the research survey estimate of population abundance-at-length (Fig. 3.5.2). The F-at-length was found to be strongly dome-shaped, peaking at around 60 cm. This meant that the slowest growing fish were never exposed to the maximum rate of fishing mortality. The fastest growing fish would eventually grow through the size range vulnerable to fishing. The fish with medium growth rates would remain in this vulnerable window for most of their adult lives. The net result is that the population mean length-at-age of the fished population was depressed relative to that of the unfished population (Fig. 3.5.2).

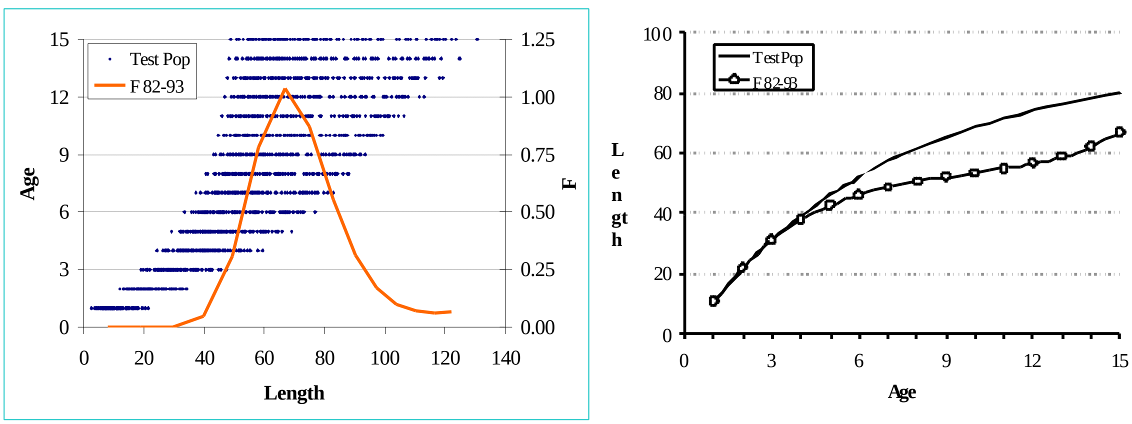


Figure 3.5.2. Simulated test population (left) lengths at age, represented as small dots, with a fishery F-at-length (solid line). The right panel presents the unfished (solid line) and the fished (circles) population mean length at age.

The same simulation was used to investigate the effect of size selective mortality on yield per recruit and spawning stock biomass per recruit. It was found that as fishing mortality increased so did the reduction in population mean length (and weight)-at-age. Thus, it may be incorrect to use a fixed mean weight-at-age vector when estimating these reference points, as has normally been done. It was found that the traditional approach would overestimate the F reference points associated with yield per recruit (e.g., $F_{0.1}$, F_{max}) and spawning stock biomass per recruit ($F_{35\%}$) (Fig. 3.5.3).

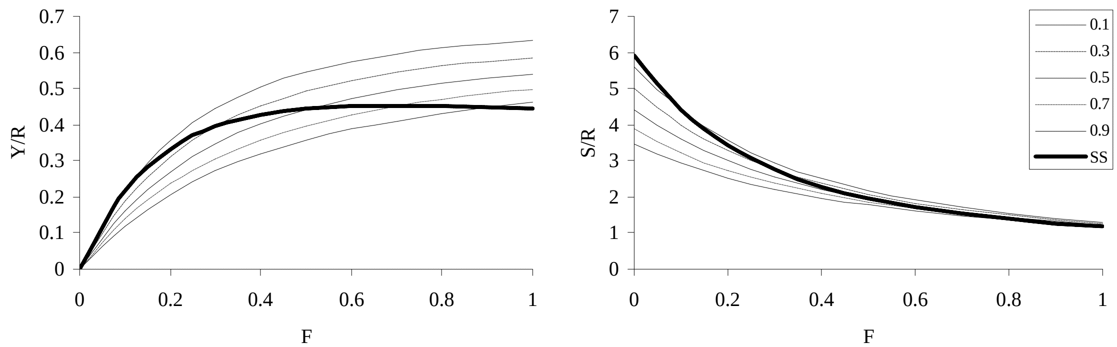


Figure 3.5.3. Yield per recruit (left) and spawning stock biomass per recruit curves calculated assuming size selective mortality (SS) and using population mean weights-at-age corresponding to different rates of fishing mortality (0.1 to 0.9).

<u>The Recruitment Dilemma</u>

Examination of the stock/recrtuitment scatterplot for this stock suggests the existence of two production regimes as shown in Figure 3.5.4. The number of recruits per spawner produced for the 1973 – 1987 year-classes were, on average, three times higher than that for the other year classes in the time series.

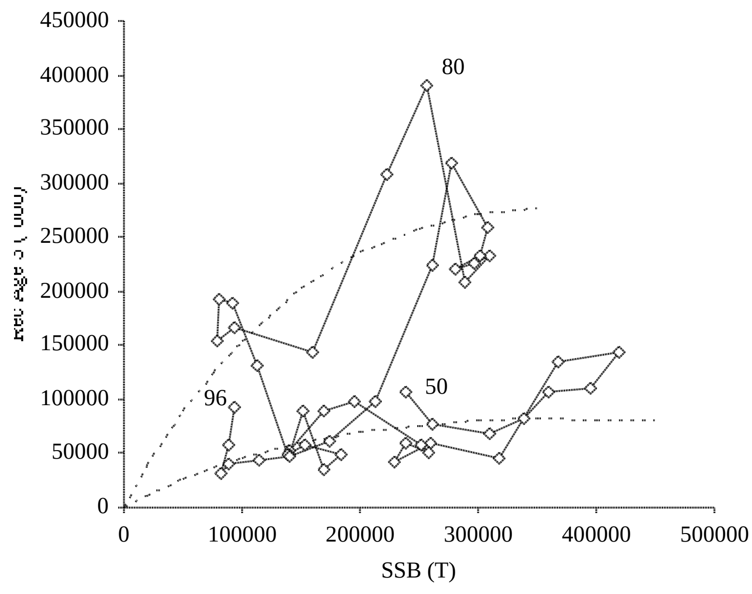


Figure 3.5.4. Stock recruitment relationship for southern Gulf of St. Lawrence cod showing two production regimes.

An analysis of factors that may be affecting cod recruits per spawner was presented to the 1999 CSAS Fisheries Oceanography Committee (Swain 1999). The analysis included physical factors such as water temperature, freshwater input (RIVSUM), atmospheric pressure, ice coverage; and biological factors such as herring biomass, mackerel biomass (two potential pelagic predators on cod eggs, larvae and juveniles), and juvenile syurvival of American plaice. Grey and Harp seal abundance was included in a subsequent analysis. Herring biomass was found to have a strong negative correlation with cod recruits per spawner. This suggests the possibility of a so-called triangular food web (B_{ax}) involving cod, seals, and herring. The FRCC recently recommended a substantial reduction of seal herds in Atlantic Canada in an effort to increase cod production. Their recommendations did not consider such a food web possibility. It is well recognized that, in the presence of such a food web, it would be very difficult to predict the outcome of such a seal cull. While a cull might reduce seal predation on cod, it could also reduce seal predation on herring. This could, in turn, increase predatory pressure of herring on cod.

<u>Production Considerations</u>

This cod stock has undergone significant changes in biological parameters that affect stock production. There have been large changes in population mean weight-at-age, recruits per spawner, and in natural mortality. This has in turn affected stock surplus production, i.e., the production over and above that needed to maintain a constant biomass, and the ratio of surplus production to biomass, i.e., the harvest rate that would maintain a constant biomass. The ratio varied between 0.1 – 0.35 from 1950 – 1970, increased to as high as 0.6 in 1977 as a result of exceptionally high recruitment, but returned to around 0.2 quickly thereafter (Fig. 3.5.5). The strong year-classes produced in the late 1970s had relatively low weights at age. The ratio then descended to below 0.1, and even to below 0 in the early 1990s, mainly as a result of a change in natural mortality.

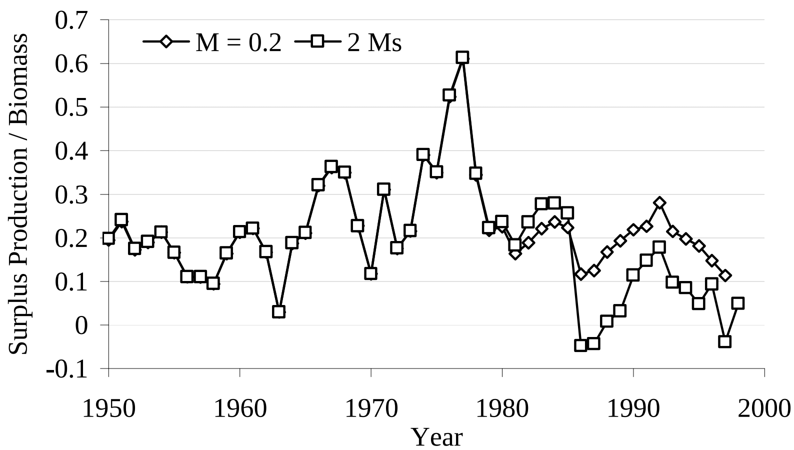


Figure 3.5.5. Trends in the ratio of surplus production to biomass for southern Gulf of St. Lawrence cod. Two series are shown, one calculated assuming a constant M of 0.2 for the whole time series and the other assuming M changed from 0.2 to 0.4 in 1985 (2 Ms).

When developing a PA framework that uses biological reference points based on stock production, it would be necessary to consider such changes in stock production. This might mean using two stock recruitment curves to represent different production regimes. It might mean using a model that accounts for size selective mortality. Consideration needs to be given to developing a management framework that would be robust to undetected changes in productivity.

Modelling

The traditional SPA for this stock has estimated population abundance parameters only for cohorts in the final year of the analysis. A constraint was used to estimate cohorts at the oldest age in the analysis, and this has been that F on the oldest age is equal to the mean F at ages 9 and 10. This rule was imposed because in initial analyses (*circa*. 1987) where all cohorts were estimated, these estimates reached unbelievable levels, several orders of magnitude higher than what would be expected based on survey results. We revisited this issue by attempting two less-constrained SPA formulations. The catch-at-age data include ages 3 to 16+. One formulation, thought to be the least constrained, estimated all cohorts up to age 16, and maintained a plus group. A second collapsed the catch-at-age and survey index to age 3 to 10, and an 11+ group. In this case, the implicit assumption was that the F on ages 11+ was the same. This is more constrained than the 16+ formulation where F was free to vary to age 16, but less constrained than the traditional assessment where many fewer cohorts were estimated.

The results indicated that the estimated population parameters became larger as the formulation became less constrained. This was evident for both the parameters in the last year and at age 10 where then lowest estimates were from the traditional formulation, followed by the 11+ and the 16+ formulations (Fig. 3.5.6). Is this an artefact of the “liberty/constraint” afforded to calibration?

Consultations

A second presentation explained the management context for southern Gulf cod and how it relates to the precautionary approach. The overcapacity of the harvesting sector and the fact that stakeholders belong to diverse groups (fleets, provinces, etc.) is likely to present some challenges to the implementation of the precautionary approach. It will be important that the precautionary approach be considered at the various steps in the fishing plan development from the assessment of the resource to the establishment of Conservation and Harvesting Plans (CHP). The Gulf Groundfish Advisory Committee (GGAC) and the Fisheries Resource Conservation Council (FRCC) are bodies where elements of a precautionary approach will need to be well understood.

A project proposal for consultations on the precautionary approach was discussed at a meeting of the Maritimes Region, Fisheries Management Studies Working Group (June 21-23, 1999). It was noted that it was considered important to include all stakeholders to discuss the entire precautionary approach from objectives to assessment and implementation. It was also important to make the point that some approaches in use are precautionary (not entirely new concept) while others need to be changed.

A meeting with groundfish fishery managers in the southern Gulf of St. Lawrence was subsequently held on July 15, 1999 where some of the background to the precautionary approach was presented and the approach to some consultations with industry was discussed. It was agreed that the elements of a precautionary approach should be presented at a GGAC special meeting to be held in early 2000. It was hoped that a working group of industry, science and managers could be formed with the intent of developing a precautionary approach along with an implementation plan.

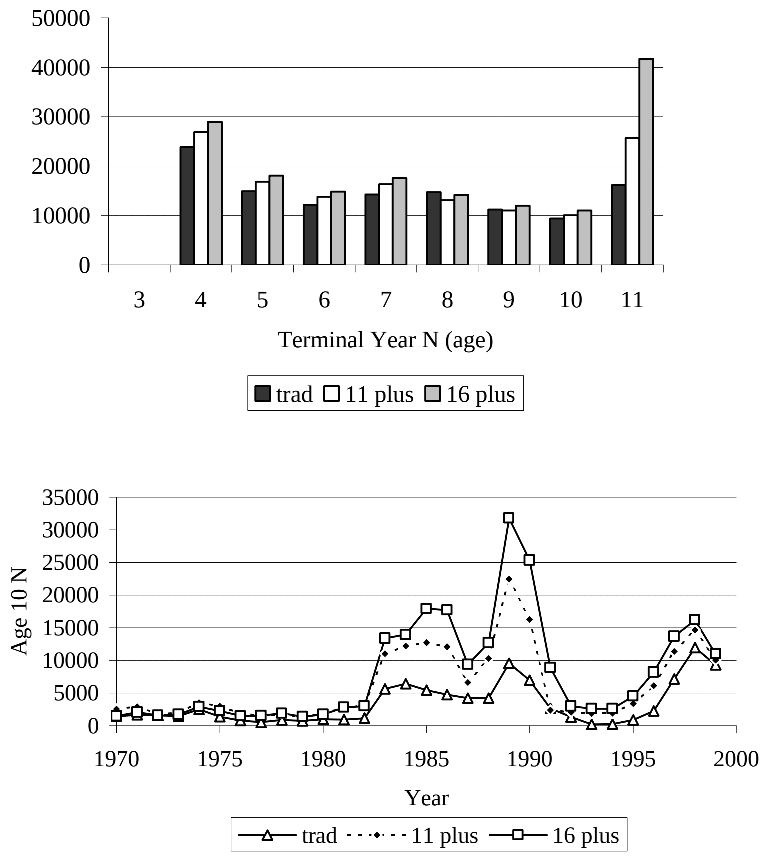


Figure 3.5.6. Population abundance parameter estimates from 3 SPA formulations described above. The upper panel gives the estimates for the last year in the SPA, the lower panel gives the estimates for the oldest age.

It was noted that a clear policy statement on the precautionary approach would be useful in discussion with industry. A challenge for groundfish in Atlantic Canada was that, given the role of the FRCC of recommending harvesting options based on their view of the resource, the base information to be used in determining reference points or targets needs to be agreed. A clearly defined precautionary approach could significantly streamline the fisheries decision process.

Discussion (Cadigan)

The first presentation involved the effect of different values of M on stock production. Higher values of M are associated with lower stock surplus production. Some confusion was noted about why production does not increase with M. It was noted that changes in M could be transitory. Time dependence is evident in the stock-recruitment relationship estimated for this stock, and it was questioned whether this was related to changes in M.

Recruit per spawner has changed substantially in 4T between the 1970s and 1990s. An investigation was presented about potential causal factors for this change. It was suggested that herring abundance was most correlated with changes in recruit per spawner. A participant asked whether such an association was evident for other cod stocks. Qualitative information from NAFO catch statistics suggests that herring were abundant on the eastern Scotian shelf in the 1960s but declined substantially in the 1970s. Herring are appearing in greater abundance around Sable Island in the 1990s. Some association between cod and seal abundance was evident, although it was noted that the association was reverse prior to the 1970s.

The final part of the first presentation dealt with a diagnostic analysis of the SPA for this stock. When the terminal abundance for each cohort is estimated separately the total population size was estimated to be substantially higher than for the "preferred" SPA in which constraints on fishing mortality are used to compute terminal abundance. In addition, the fishery selectivity and the survey catchability appeared more "domed" than in the "preferred" SPA. It was noted that such F-constraints might be related to estimates of changes in M. It was also noted that a separable SPA might provide information on the fishery selection pattern. The increasing amount of data available for SPA estimation allows the consideration of more complex models, and it was questioned whether the SPA diagnostics provided any information on whether the complex model provided a better fit.

It was noted that the two regimes exist in the stock-recruitment relationship, and that lagged depensation was a possible explanation for this. The cultivation hypothesis should be considered. Some would suggest Spawner Biomass reference points should be shifted to the right under this situation.

The second part of the presentation by Ghislain Chouinard dealt with issues involved in implementing the PA for this stock. A description of the management context, a summary of discussions with fisheries managers, and planned consultations with industry were presented.

It was noted that although risk analyses were communicated to the FRCC, they decided on high risk TACs for 3 of 4 east-coast cod stocks after industry consultations. This puts science in perspective. Can we learn from this; i.e., is the risk we calculate of only passing interest to the FRCC? It was noted that interest is minimal when industry thinks science does not have the right information. It was also noted that we are not considering the social and economic costs of being (or not being) precautionary.

3.6. Spring Spawning Herring in 4R (McQuinn)

The 4R herring stock has been included this year as the subject of a case study for the PA Workshop. The spring-spawning stock has been chosen to illustrate this case study. Although, the precautionary approach has not been formally implemented in the 4R herring Management Plan, a process of calculating the reference points has begun, and the principles have been introduced to the members of the 4R herring Co-management Committee over the past year.

Data for the west coast herring stock off Newfoundland can be considered data-rich, and we have a number of analytical tools that are available to estimate reference points and to illustrate the risk to stock status of the application of various management strategies.

Analytical Tools

Adaptive Framework

The stock status assessment was based on sequential population analyses (SPA) that were calibrated age-by-age using the adaptive framework (Gavaris, 1987). The formulation estimated beginning-of-the-year population numbers (N) at ages 5 through 11+ in 1999 and the age-specific catchability coefficients (q) by predicting the index-fisherman gillnet catch rates-at-age (in numbers) and the acoustic survey population numbers-at-age. The residual sum of squares (natural lognormal) was minimised in the objective function. The spring spawning stock analysis used commercial catch-at-age and abundance trends from both the index-fisherman catch rates (1984 to 1998) and the last 4 biennial acoustic surveys (1991 to 1997). The summary of the formulation used in the calibration is as follows:

- Estimated parameters:
  - Year-class estimates: $N_{i,t}$ (i=5-11+; t=1999)
  - Catchability coefficients: $q(IF)_i$ (i=3-11+)
$q(RV)_i$ (i=2-11+)
  - Number of parameters: 26

  where:
  IF = Index Fisherman catch rates
  RV = Research Vessel (acoustic) survey

- Model structure:
  - M=0.2
  - F for oldest age-group (11+) = F at age 10
  - Recruitment at age 2 in 1998, 1999 = average of medium recruitment level
  - Recruitment at age 2 in 1997 = average of low recruitment level
  - No intercept term included

- Input Data:
  - Catch at age: $C_{i,t}$ (i=2-11+; t=1965-98)
  - Index Fisherman catch rates-at-age: $IF_{i,t}$ (i=3-11+; t=1984-98)
  - Population estimates (N) from research vessel (acoustic) survey: $RV_{i,t}$ (i=3-11+; t=1991,1993,1995,1997)
  - Number of observations: 166

- Objective function:
  - minimize $\Sigma_{i,t}$ ([ln $IF_{i,t}$)-(ln(q(IF)i $N_{i,t}$))]^2, [ln $RV_{i,t}$)-(ln(q(RV)i $N_{i,t}$))]^2)

Diagnostics

The ADAPT framework includes a number of diagnostics which allows you to evaluate how well the model is fitting the data. The majority of the values in the correlation matrix were between –0.2 and 0.2, with a few values between –0.2 and –0.4, indicating that the parameter estimates were relatively independent. There were 6 of 126 (or 5%) of the IF standardised residuals, and 3 of 40 (7%) of the RV residuals which were above |1.5| and only 1 within the last 3 years. Of these outliers, none involved important year-classes. There were no obvious signs of age effects in the residuals, although there were some year effects with the IF index. These diagnostics indicated that in general, the model fit was adequate, although the CVs were considered high (Anon, 1995a). The analysis did not suffer from a retrospective pattern.

Risk Analysis and Reference Points

Uncertainty about year-class abundance creates uncertainty in forecasted yields. This uncertainty is expressed as the risk of not achieving various reference targets. The primary reference targets defined for this stock are (i) F_{BUF}, the long term average $F_{0.1}$ for east coast herring of 0.3 (ii) B_{BUF}, the lowest observed historical spawning-stock biomass and (iii) B_{LIM}, 20 % of the maximum observed historical spawning-stock biomass (i.e., “virgin stock size”). Catch projections were therefore estimated given various scenarios in relation to these reference points using risk projections (Gavaris et al. 1998). These uncertainty calculations do not include variations in catch-at-age, partial recruitment to the fishery, natural mortality or future recruitment. In particular, because the recruitment of age 2 fish in 1997, 1998, 1999 and 2000 is unknown, a level of recruitment must be assumed. Three levels of recruitment (poor, medium and good) were derived for the SPA and risk projections. These levels were defined as the geometric mean of the third poorest, the middle third and the third best recruiting year classes observed at age 2 during the historical time series (Schweigert et al. 1998).

For this stock, a medium recruitment was assumed for age 2 in 1998 and for the projections in 1999 and 2000. In addition, the SPA was unable to estimate the recruitment at age 2 in 1997. Since this cohort was below average in the catch-at-age, the mean of the low recruitment level was assumed in the analysis. With these assumptions, a calculated $F_{0.1}$ yield in 1999 would be approximately 2,300 t. A status quo catch of 6,500 t in 1999 (the 1998 spring-spawner catch) would result in a 100% risk of a further decrease in the spawning-stock biomass. A catch of 2,300 t would result in a 40% risk that even a 20% increase in mature biomass would not be achieved by the year 2000 (from 14,000 t to 17,000 t). The minimum SSB target of 38,000 t (B_{LIM}) cannot be achieved in 2000 even without fishing. A catch of 2,300 t therefore cannot be recommended under precautionary principles if the primary objective is to rebuild this stock.

Alternative Scenarios (Assumptions)

To examine the sensitivity of the risk analyses to the recruitment assumptions, additional analyses were conducted using alternative scenarios for the recruitment of various year-classes. If, for example, the recruitment of the 1998-2000 year classes assumed to be low, which has been the observed pattern since the 1990 year class, the calculated $F_{0.1}$ yield in 1999 would be around 1,200 t, and would result in a 70% risk of the SSB not increasing by even 10%. However, if the recruitment of the 1994 year class were assumed to be high, as was suggested by industry members, then the estimated $F_{0.1}$ yield in 1999 would be ~ 4,700 t. These scenarios illustrate the sensitivity of the projection calculations to the recruitment assumption, and the need to be prudent when determining the TAC in 1999.

Qualitative Tools

Stakeholders' Perceptions

Comments collected from written questionnaires sent to all licensed inshore herring fishermen in 4R as well as comments collected from index-fisherman logbooks are used to get a qualitative appreciation of industry's perception of the stock status. These tools indicated some improvement in the abundance of spring spawners around Port-au-Port Bay, St. George's Bay and Bay of Islands in 1996 relative to 1995, although it was felt that spawning activity had not yet improved significantly. The 1990 spring-spawner year class, which had been captured in the fall purse seine fishery since 1994, had started to spawn in these southern bays. These observations are consistent with the catch rate data from index-fishermen in these areas. However, comments were generally negative in 1997 and 1998, indicating that the improvement was short lived, and there was a widespread opinion that the herring was small. Index-fishermen logbooks stated that herring were scarce, schools were small and catches were the lowest seen for many years.

Overall Coherence of Stock Status Indicators

A summary of the various stock status indicators have been tabulated with respect to their data quality (or knowledge status) and their inference about stock status, to produce an overall view or Report Card for the stock (Appendix I). Observations have been noted for each indicator, along with an interpretation, including the uncertainties associated with them. In addition, indicators were classified into primary, secondary and auxiliary, as a first level prioritization. For this herring stock, most of the indicators are either in the "Danger" or "Collapse" category. Although the various indicators were not weighted as to their importance in determining stock status, the Report Card concept nonetheless presents a rapid and visual summary of the coherence among indicators, and an evaluation of their usefulness.

Harvest Control Rules

To date, no harvest control rules have been developed for 4R herring. Presently, there is a 3-year management plan that will be renewed in 2000. The only catch restrictions in the plan are associated with the TAC, based on a long-term average $F_{0.1}$ (estimated to be 0.3), although there are some supportive management measures including local closures (i.e., inner most portion of St. George's Bay kept closed to mobile gear), and a minimum length requirement (10% < 26.5 cm fork length). Therefore, when stock sizes are low, i.e., below reference biomass levels (B_{LIM}), there is an *ad hoc* decision-making process by the co-management group that is used to decide management strategy.

Reference Points

These northern gulf herring stocks are characterized by pulses of strong year classes followed by a number of years of below average recruitment. In the past, these strong year classes tended to dominate the fishery for a decade or more. However, in the past decade, no single year class has been dominant for more than 5–7 years before being replaced by another. This indicates that the recruitment pulses, especially for the spring spawners, are not as strong as in previous decades.

An examination of the production schedule of this stock in relation to fishing over the past 30 years shows that losses through fishing have increased from an average of 4,000 t for the period 1965–1975 to 11,000 t between 1976–1986 and 1987–1997, while surplus production (recruitment + growth – natural mortality) decreased from 12,000 t between 1965–1975 and 1976–1986, to be in fact negative (–400 t) between 1987–1997. We have therefore been through an 11-yr period of low productivity where annual surplus production has rarely been positive, and annual net production (surplus production – fishing mortality) has been consistently negative. This is principally due to reduced average recruitment in the last 10 years, brought about by either reduced survival of young herring with less favourable environmental conditions, reduced spawning due to increased fishing pressure on spawning concentrations and/or a possible increase in seal predation (although the consumption estimates are subject to large uncertainties). Regardless of the cause, the production of this stock (growth and recruitment) has not kept up with removals (catches and natural mortality) resulting in a declining spawning-stock biomass that is presently at a very low level.

As a general guideline, over the past 30 years, the annual surplus production for the spring spawners has averaged 7,700 t, indicating that the long-term sustainable harvest for this stock should be around this level. In contrast, the actual average annual harvest has been 8,700 t, or 1,000 t above the sustainable level. However, because of the overwhelming influence of incoming year classes on surplus production, there are large inter-annual and inter-decadal variations in production. Comparing the production over the past decade (1987–1997) with the previous decade (1976–1986), it is clear that surplus production was above average (12,000 t) between 1976 and 1986 mainly due to the recruitment of the 1980 and 1982 year classes, and well below average – in fact negative – since 1987. In the mean time, the catch biomass remained relatively stable at 11,000 t over these two decades, but well above the long-term sustainable level of 7,700 t.

Cultural Change

The concepts of the precautionary approach are relatively new within fisheries management and have not been sufficiently exploited in 4R herring management. There is a need to develop consensus among managers and stakeholders on how to smoothly implement the precautionary approach. The implementation needs to be functional and would include a dispute regulating mechanism. It must be remembered that the stakeholders are not a homogeneous group and this consensus will not be easy to reach. However, if these principles are to be understood, and used in practice, stakeholders will have to “buy in” to the processes. Therefore, the advantages to them must be communicated carefully.

Monitoring Requirements

At present, the principle monitoring is on the catch. There has been dockside monitoring of purse seine catches (the main gear sector) since the late 1980s. In addition, purse seine and index-fisherman logbooks, as well as extensive questionnaires, are collated and analysed for effort and fishing distribution information. Biological sampling is designed to cover all gear sectors, months and fishing areas, although a reduction in resources dedicated to sampling has had a major negative effect on the coverage in some years. Fishery independent monitoring of abundance is achieved through a biennial acoustic survey conducted in the fall of the year.

Although the fishery related variables have been monitored for more than 30 years, there is an increasing appreciation for the need to monitor ecosystem status. This has been initiated for many of the physical and chemical variables (e.g., temperature, salinity, oxygen) and an annual Status of the Gulf of St. Lawrence is now produced. However, it is obvious given evidence from several stocks, that the biological characteristics of the ecosystem (prey, predator and competitor abundance) are also influencing stock productivity and mortality rates. These shifts or trends in productivity rates of target species with changing ecosystem productivity will affect the estimation of biological reference points and, consequently, management strategy. Presently, little effort has been put into the evaluating biological elements of the ecosystem. In the case of 4R herring, the assessment of prey (zooplankton), predators (seals) and competitors (capelin and mackerel) would improve our understanding of the causes of observed regime shifts in this stock.

Discussion (Fréchet)

1. The stock recruit relationship for this stock is highly domed as the maximum recruitment occurs at intermediate values of the SSB (50,000 to 75,000 kt). Larger SSBs have not produced significant recruitment levels in the observed time period (1963–1997). The exact cause for this is not known.
2. A “traffic light” report card was produced to graphically represent stock status. These report cards summarise many key parameters independently and thus require additional interpretation (weighting). However, in the case of analytical assessments, many available statistics allow to make such inferences.
3. Concerns were expressed around the wording used in the co-management protocol for this particular stock such as “Ensure optimal utilisation of available allocations”. This is not consistent with the precautionary approach.
4. Surplus production for this stock has been negative in some years, indicating that stock biomass can decline even in the absence of fishing. The ratio of surplus production per unit of biomass over the long term has been relatively low, i.e., 6% between 1965 and 1997.
5. Can the harvest control rules derived for the eastern Newfoundland herring be applied to the west coast (see Rice et al. 1999, p. 44-45)?
6. Risk curves that have been produced by a variety of imposed recent-recruitment values will result in deterministic outcomes since there is now error distribution around the estimates.
7. Concerns were expressed about the process of advice on this stock. While the stock status report is quite clear on the precarious state of the spring component, the

outcome of the co-management meeting was to keep the *status quo*. The information sent from the region to the senior management refers only to the outcome of the co-management meeting. Such an approach does not reflect Science's position and does not show how the management plan relates to the precautionary approach.

8. The episodic recruitment observed in this stock has many consequences. Any spike in recruitment will sustain the fishery for a number of years. This means that the fishery will actually target particular year classes. Any derived partial recruitment will depend on the number of years considered. This also has implications for the calculation of $F_{0.1}$. The arbitrary value of $F_{0.1} = 0.3$ for this stock may be high in the situation where a recruitment spike does not occur over a long time period. This may be the case presently.

3.7. Pacific Ocean Perch (Schnute)

Initially, this case study dealt with a single stock of Pacific ocean perch in area 5AB on the Pacific coast. A formal catch-age analysis gave estimates of parameters and uncertainty. Forward simulations with various levels of catch then produced a risk analysis leading to yield recommendations. We defined the risk a_t of removing a constant annual catch *C* until future year *t* as

$$a_t = P(B_t < B_{\text{lim}} \mid C),$$

where B_t denotes the projected future biomass in year *t* and B_{lim} corresponds to a suitably defined limit reference biomass. For historical reasons associated with low stock abundance, we used the estimated biomass in 1977 as our measure of B_{lim}.

Both B_{lim} and B_t contain statistical error. Figure 3.7.1A illustrates these uncertainties. Model errors come from trajectories estimated with past measurement error (related to B_{lim}) and future process error (related to B_t). Thus, we do not follow the simpler scheme portrayed in Fig. 3.7.1B, where the historical trajectory (including B_{lim}) is presumed known from model estimates and only future process error enters the projection B_t. The risk a_t can be quantified in a scatter plot of points (B_{lim}, B_t) taken from sample trajectories, where a_t corresponds to the proportion of points below the line $B_t = B_{\text{lim}}$. Figure 3.7.2 illustrates this analysis for four choices of fixed annual catch *C*, given a time horizon $t = 50$ yr. Further documentation of this analysis appears in Schnute and Richards (1995), Richards et al. (1997a), Richards et al. (1997b), and Richards et al. (1998).

As the project evolved, it became clear that the above example takes place in a much wider context. The Pacific Canadian groundfish trawl fishery captures over 300 species, including more than 50 commercial fish species. Among these, seven slope rockfish species occur primarily along the sloping habitat that marks the edge of the continental shelf. Combinations of seven species within six geographic areas define 42 assessment units for slope rockfish. Only one of these combinations, Pacific ocean perch in area 5AB, receives the relatively rigorous assessment described above. The remaining 41 assessment units have almost no survey data and limited biological data with which to conduct assessments.

Starting in October 1995, a mandatory observer program for most trawl vessels became an important new data source for this fishery. Over 70,000 tows have been monitored for the biomass of each species caught, where a single tow captures an average of 11.5 species (Schnute et al. 1999a, 1999b). Furthermore, a system of individual vessel quotas (IVQs) began in April 1997. These two developments have created favourable conditions for collaborative work between science and industry. The new catch database provides detailed information on spatial and bathymetric distributions of fish species and fishing activities. Furthermore, the IVQ system directly links the capital value of a quota to the long-term prospects for a species. Consequently, fishermen and scientists find common ground in the search for a scientific approach to conservation that preserves the capital value of vessel quotas.

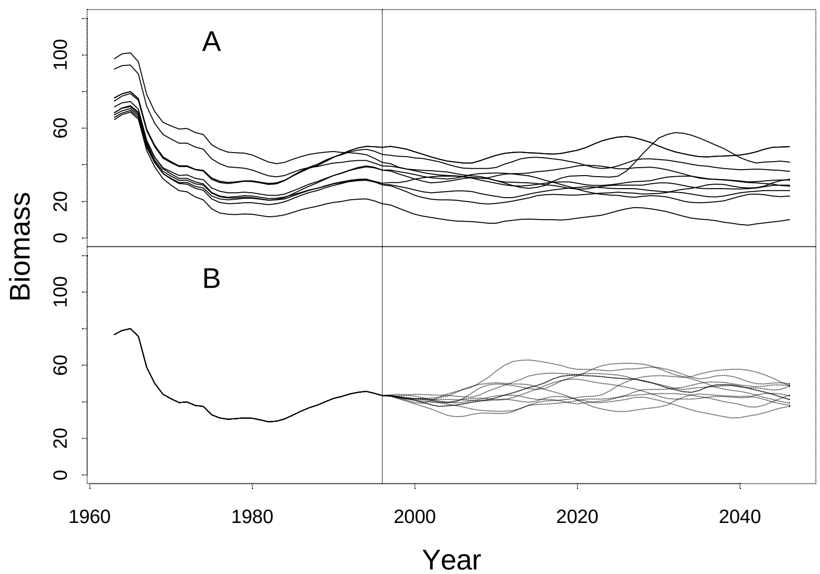


Figure 3.7.1. Ten sample trajectories of stock biomass (1000 tonnes) from model reconstructions and forward projections under a catch policy of 2,000 tonnes for (A) the full model error approach and (B) the future process error approach. A vertical line identifies the final year of historical reconstruction, based on a catch-at-age model.

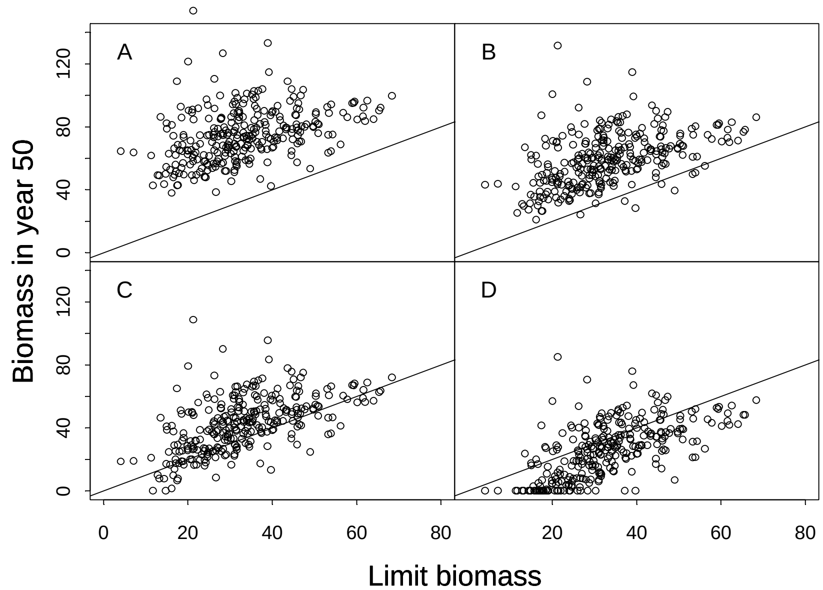


Figure 3.7.2. Projected biomass B_{50} (1000 tonnes) in relation to historical estimates of B_{lim} for the full model error approach under annual catch policies of (A) no fishing, (B) 1,000 tonnes, (C) 2,000 tonnes, and (D) 3,000 tonnes. Points correspond to 300 sample trajectories for each policy. A solid line identifies the condition $B_{50} = B_{\text{lim}}$.

Although catch per unit effort data from the fishery are not adequate for biomass estimation, they do provide a useful starting point for survey design. As part of a strategic plan to improve assessments with the use of research tows sponsored by industry, our current work (Schnute et al. 1999b) includes:

1. development of a bathymetric database and spatial analysis of the fishery;
2. compilation of trawl characteristics of the ocean floor, based on knowledge of experienced fishermen;
3. calculation of key reference points for the slope rockfish species from available biological data.

Figure 3.7.3 illustrates Canada's Pacific coastal bathymetry, where the slope rockfish species occupy marine canyons and other geological features created by glacial carving during the last ice age. Tows occur in specific locations associated with fish abundance and bottom characteristics suitable for trawling (Fig. 3.7.4).

In the future, management of slope rockfish stocks will combine (i) estimates of stock abundance from industry-sponsored surveys and (ii) the use of biologically based reference points to indicate appropriate harvest rates. Schnute et al. (1999b) present a complete mathematical framework for calculating reference point values from underlying biological parameters, and they provide initial estimates for the seven slope rockfish species. These estimates will be refined using new sample data from the fishery and an improved database of historical samples.

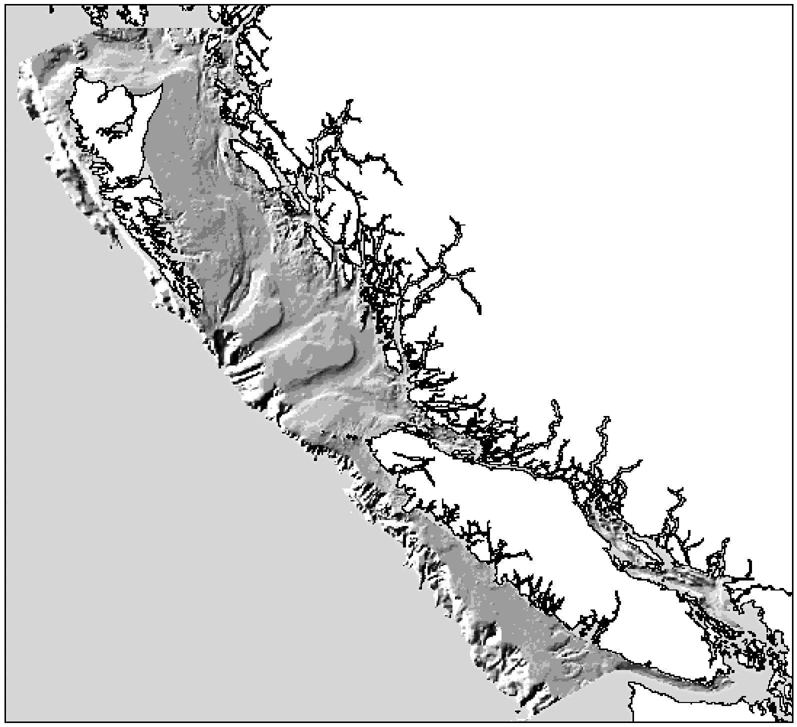
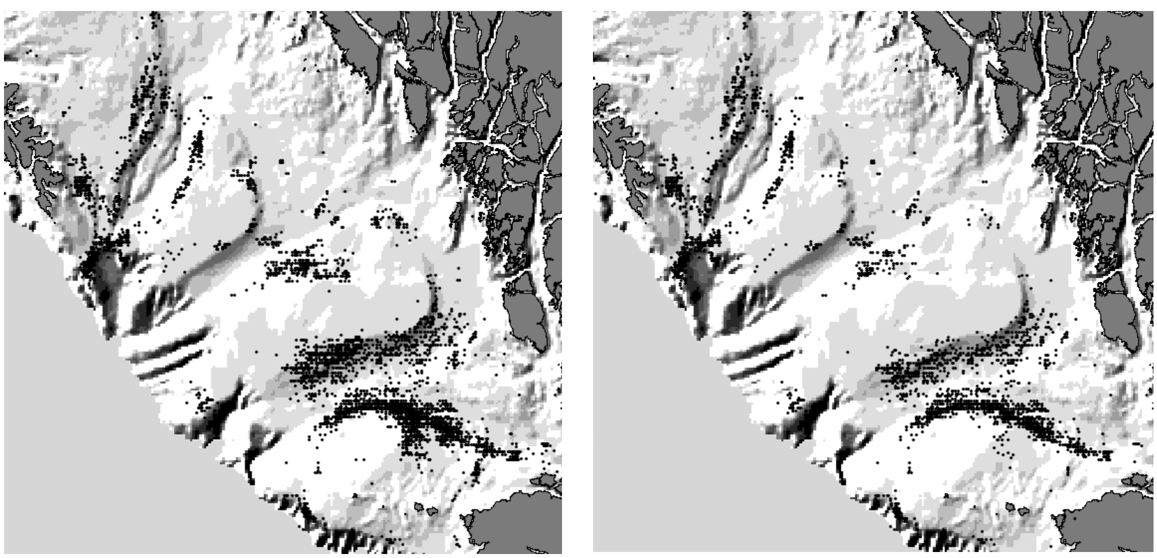


Figure 3.7.3. Hillshade view of BC coastal bathymetry down to 1700 m, showing Vancouver Island (lower right) and the Queen Charlotte Islands (upper left).



A B

Figure 3.7.4. (A) Groundfish bottom tow locations in 1998 along the central coast of British Columbia, between Vancouver Island and the Queen Charlotte Islands. (B) Subset of tow locations at which slope rockfish were caught. Three marine canyons from southeast to northwest are: Goose Island Gully, Mitchell's Gully, and Moresby Gully.

Discussion (Wade)

Some participants expressed a desire to have access to the modelling approach presented by this presentation. The method seems to be applicable to all data-rich or data-poor scenarios.

4. Report from Breakout Groups

Following the presentation of case studies, breakout groups were formed to facilitate small group discussion on implementation of the precautionary approach. Participants were challenged to consider the lessons learned from the case studies and the key questions that remain unanswered. The following sections summarize the reports from the groups, including the plenary discussions stimulated by the group reports.

4.1. Group A (McQuinn/Chair, Gavaris/Rapporteur)

Participants: Noel Cadigan, Mike Calcutt, Alan Cass, Ghislain Chouinard, Stratis Gavaris, Rowan Haigh, Ian McQuinn

Reference Points

It is the role of science to establish safe biological limits within which the stock can produce maximum sustainable yield. Managers, fishermen and other interested parties would be involved in defining targets while science's role would be to ensure that the targets are consistent with the limits. While socio-economic aspects have been considered in the definition of target reference points for some cases, socio-economic factors have entered the decision process independently in other cases and have taken precedence over conservation concerns. While some exploration of MSY reference points has been attempted, operational MSY reference points have not been implemented for any of the case studies. Further, for many of the case studies, estimation of MSY reference points has proven elusive or difficult to interpret. For all case studies, existing proxies continue to be used in the provision of fisheries management advice but these proxies have not explicitly been evaluated in relation to "safe biological limits within which the stock can produce maximum sustainable yield".

Decision Rules

Take uncertainty into account through a risk analysis on the forecast state of indicators. For some of the case studies, reference points are used to trigger pre-agreed responses; however, in others there is no understanding about what should occur when the thresholds are approached or reached. Adoption of rigid F/B harvest control rules was not considered essential in order to be consistent with the precautionary approach. It is sufficient to ensure that development and implementation of a rebuilding plan is triggered when a reference point is approached or reached. Though rigid F/B harvest control rules have been employed in some of the case studies, they are viewed as an impediment to adoption of the precautionary approach in many cases.

Regime Shifts

Reference points and/or acceptable risk levels should be adjusted to reflect shifts in productivity. The adjustments should be based on accumulated evidence and major annual changes would probably not be warranted.

Information Needs

Accurate landings (catches) are a high priority to properly implement a precautionary approach. Data accessibility problems and potential resource limitations for processing / analyzing data are hampering progress with a precautionary approach. Also, limitations of available information to evaluate regime shifts, multi-species interactions, etc. are hampering progress.

Implementation

We should consider the impact of new candidate management measures on fishing behaviour and their implications to the success of the precautionary approach (e.g., ITQs may result in increased discarding).

Security of Access

The Precautionary Approach necessarily requires a long-term perspective. Acceptance of PA principles by stakeholders is therefore linked to security of access.

Communications

We need to conduct detailed work in the background but develop succinct, clearly understood messages of the essence.

Discussion

It was noted that lack of credibility in assessment results has led to failure in considering precautionary measures and risk analysis results. This highlighted the need for an open process with the opportunity for all interested parties to contribute. It was recognized that establishing credibility and trust could be a demanding but necessary task. A very important common element among cases where credibility had been established and where consideration of PA had been received more favourably was the presence of a biologist/scientist who had worked very closely with interested parties to establish effective two-way communication and common understanding. The fisheries management planning process would flow more efficiently where all participants have well-defined roles and responsibilities.

Socio-economic pressures have varied among the case studies and played a very influential role in the acceptance of assessment results and the precautionary approach. There was some concern regarding the time it takes to detect productivity shifts so that we can make the appropriate adjustments to reference points. Some consideration should be given to designing fisheries management plans that improve knowledge over time to aid in refinement of PA implementation, recognizing the realities of conducting fisheries.

Implementation of PA involves developments of technical aspects and institutional / communication aspects, both of which have to be addressed in parallel.

4.2. Group B (James/Chair, Shelton/Rapporteur)

Participants: Din Chen, Marc Clemens, Alain Fréchet, Heather James, Pierre Richard, Kasumi Sakuramoto, Jon Schnute, Peter Shelton

Human Aspects

The group recognized that useful progress is being made on developing a scientific basis for the precautionary approach in all the case studies. It was acknowledged that in those studies where the approach was technically sophisticated, greater effort was required in making the results simple enough that they could be effectively communicated and implemented. Inconsistencies in the application of the precautionary approach could result from differences in (i) databases available, (ii) biological and fishery characteristics, and (iii) technical skills of researchers involved in the studies. Perhaps one of the most critical factors in determining whether a precautionary approach is adopted is the acceptance by stakeholders and managers.

The involvement of those who are closest to the resource when developing precautionary approach frameworks was considered a priority. The likelihood of an approach being implemented is much higher when there is a sense of having contributed to the process. It was noted that the ocean perch and beluga case studies were encouraging in this regard. It was acknowledged that, in addition to fishermen input, the involvement of non-fishermen in the process would create an environment more conducive to implementation of the precautionary approach. The selling point for the PA to fishermen should be that the long-term gain is worth the short-term pain of being precautionary. In some regions, the short-term pain may be so acute that the longer-term gain gets little weight. In this context the value of modelling future economic scenarios associated with a precautionary framework may be very valuable. It was noted that progress in this regard was being made in the ocean perch case study. The key seems to be to provide the information required so that people (fishermen and public) actually demand a precautionary approach, thereby prompting politicians to implement it.

In the beluga case study, co-management is legally binding and DFO can only take over direct management if conservation is not respected. Therefore, there is a strong motivation to manage conservatively and thereby protect the direct role in management. In the Pacific ocean perch case, the implementation of individual vessel quotas has led fishermen to view their quota as a real asset to be protected. These fishermen have a long-term perspective in resource management and viability.

There is no single correct way of determining reference points and limits. The appropriate reference points are highly dependent on the dynamics of the stock / fishery and on the quantity / quality of data. Reference points should not be constrained by an inflexible definition; they should be specific to each case.

In the context of limit reference points, fisheries managers in the group stressed the need for a phase-in of restrictions and ramping down of the TAC as one approaches the limit

– some warning before science jumps up and waves the red flag. It was noted that control rule approaches were being considered to achieve this effect in several of the case studies.

Technical Factors

The original set of technical tools considered in some of the case studies was found to be too narrow by those doing the research. It was found that realities regarding spatial aspects and issues such as multiple stocks had to be dealt with in terms of modelling the stock within the precautionary framework. Fishermen were able to contribute valuable information to the scientific assessment on the fishery and the stocks. The statement had been made in the course of the week that we could not wait until we had the perfect technical approach (model, estimation method, etc.) before developing a precautionary approach. It was noted that, under the precautionary approach, when you do not have sufficient information the fishery would/should be shut down. In some cases this means that emerging or developing fisheries would never get off the ground.

The group felt that even when we do not have any data, we might know something about the system that allows "what-if" simulation scenarios to be investigated. The group discussed the limitations of science and data versus the common sense approach and the respective roles of science and others (fisheries managers?) under these situations. It was acknowledged that within science the more we know the more we know what we don't know. Those case studies that were the most detailed raised several issues where understanding and technical approaches needed to be improved to provide a defensible precautionary approach. Some of the group argued that as scientists the only skills we had were to take samples of data and attempt to make inferences from these data to support conclusions that could be defended among our peers. Others saw this as a potential restriction on the implementation of the precautionary approach, leading to a discussion of God and our role in the universe.

4.3. Group C (Sinclair/Chair, Rivard/Rapporteur)

Participants: Bob Huson, Norm Olsen, Denis Rivard, Alan Sinclair, Don Stansbury, Max Stocker, Elmer Wade

Conceptual Framework

The NAFO framework (Fig. 4.3.1) has in essence served as the underlying framework for many of the case studies. In absence of a domestic framework, it seemed to have been taken as the starting point for many of the case studies. This points to the need for a domestic framework, with proper documentation.

At first glance, the Case Studies appear to have some common features that we should attempt to capture in a "common" framework. While a unique framework is desirable, the diversity of the Case Studies suggests that the PA implementations will likely differ among stocks. Adjustments are acceptable but must be rationalized in the context of a precautionary approach. For example, a particular implementation should avoid "full blown" fisheries when information is uncertain and provisions to that effect should be built in (e.g., harvest control rules, pre-agreed conservation measures).

The domestic implementation of the PA framework should include an explicit determination of risk (risk analyses), wherever possible.

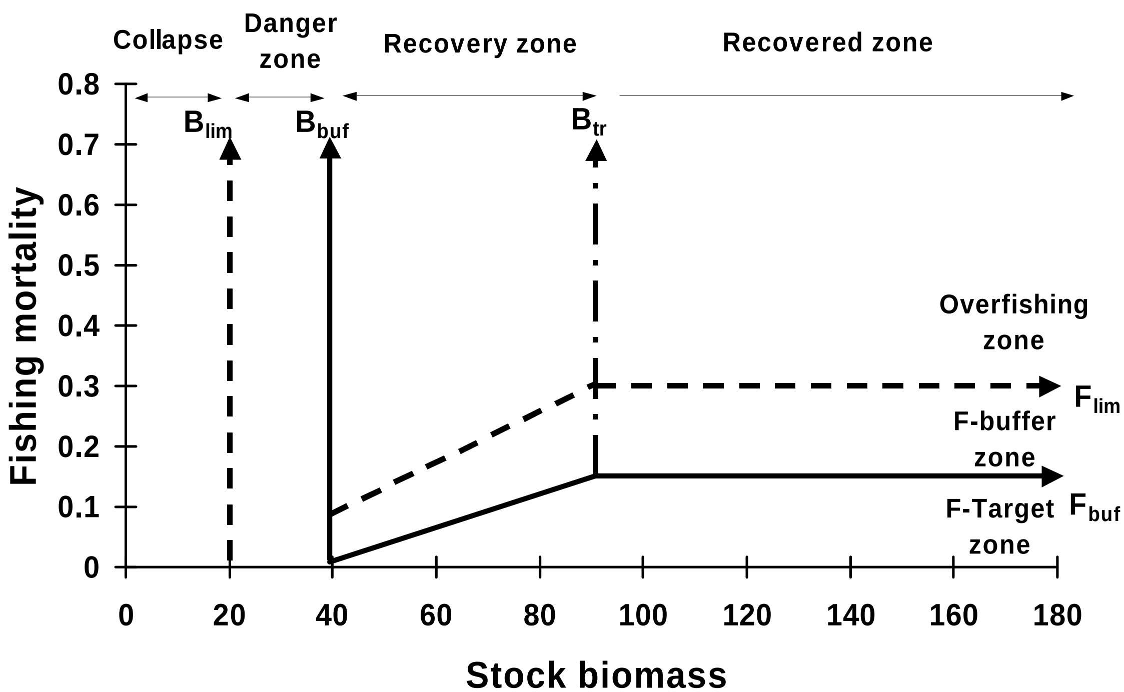


Figure 4.3.1. Harvest control rule used by NAFO in its precautionary approach.

Meta-analyses (which work across stocks for a given species group) and simple population models (such as the ones described by Dr. Jon Schnute during this meeting) should be used to gain insight into reference points when data are limited, or to confirm reference points determined through more complex models.

Data and Monitoring Requirements

The Working Group discussed the data and monitoring requirements associated with a broad implementation of the Precautionary Approach and concluded that workload implications are not to be overlooked. In particular, data acquisition and management are not trivial tasks, and new and innovative research takes time. Some of the new demands will affect the agenda of assessment meetings (RAP and ZAP) and workload. In addition, scientists will be called to take part in the consultative process. These new demands will have to be reflected and taken into consideration in the Science planning process.

Analytical Frameworks

A precautionary approach framework must recognize data availability and quality. For instance, the NAFO framework takes into account data-rich, data-moderate, and data-poor environments. The report card or performance report approach is seen as one way to bring in PA elements despite the absence of “hard” mathematical definitions. The case study on west coast Newfoundland herring provided a good example of how measures of information quality and stock status could be considered under such a framework.

The “traffic light” approach was seen as a way to illustrate the “report card” or “performance report”. Initially proposed for data-poor situations, this approach appears to be useful for data-rich situations as well. It could thus serve to bridge data-rich, data-moderate, and data-poor situations and/or to capture ecosystem considerations. In this qualitative framework, adjustments to management measures (or harvest controls) should be described as “speed bumps” and “speed limits”. Productivity indicators, or attributes, could be made “operational” by linking them to reference points.[3]

The Working Group noted the progress made in the development of approaches on how to deal with Harvest Control Rules under a traffic light framework. In particular, the work done in the Maritimes Region in this area is encouraging. The question of the relative weights to be attributed to various indicators when developing an overall measure of performance need more research, and will require input from managers and stakeholders.

Testing Control Rules

None of the Case Studies were sufficiently advanced to include an evaluation of the Harvest Control Rules (HCRs). The degree to which embedded HCRs can be made operational remains unclear. Ideally, these HCRs should remain simple while maintaining their intended role, i.e., to put “feedback control” in the population-harvest dynamics. For instance, an automatic reduction of the reference fishing mortality when the biomass is below its “productive” level would serve to reduce overall mortality and maybe reverse the decline. This feature (known in engineering as feedback control) is desirable and can be implemented in harvest systems through a progressive reduction of the exploitation rate when the biomass falls below a given limit. Such adjustment appears to be a desirable feature and has been included, for instance, in west coast Newfoundland herring. Such a feature may gain general acceptance because reducing exploitation when the stock is in trouble makes sense. If such automatic “rules” are to be invoked in practice, they should remain simple; complex rules are unlikely to meet general acceptance.

Pitfalls

There is a general concern from the discussion on case studies that regime shifts could influence drastically the determination of limits and targets, and should thus be taken into account in PA implementations. A precautionary approach framework should account for such shifts when they are believed to occur.

The case studies followed the current line of thinking and took a “single species” approach in developing their PA framework. We must start thinking in terms of multi-species systems, and the “traffic light approach” could be useful for exploring hypotheses in a PA context.

[3] see Gavaris, Section 5.1

<u>Canadian-domestic PA Framework</u>

There is general concern that new concepts are being developed independently in various fora, creating potential for inconsistent PA approaches and reference points. To avoid this and to facilitate the development of consistent approaches, the PA developers and practitioners would benefit from having a toolkit that would include:

- A conceptual framework that guides the implementation of the Precautionary Approach for domestic stocks,
- Practical guidelines for reference points under the PA, and
- Checklist(s) identifying key elements to be found in a particular implementation.

A discussion paper outlining the domestic *conceptual framework* should expand on:

- Objectives, principles, concepts
- Concepts to include:
  - biological limits, target limits
  - uncertainty (risk analysis)
- Recognize varying degree of knowledge (e.g., data-rich, moderate, poor)
- Indicators:
  - F and SSB
  - others (growth or condition, migration and distribution, etc.)

Practical guidelines for reference points under the PA should provide default biological limit reference points and default target reference points. When data are limited, the guidelines should call for provisional reference points that are at least as precautionary as intended by the defaults. For instance, as a starting point the guidelines could promote the use of current targets as the default if nothing else is available. Back-of-the-envelope calculations could serve for situations where data are limited. Workarounds should be suggested to address pitfalls: for example, workarounds are needed to deal with (i) spiked age-selection patterns that could only be the result of temporary or anomalous gear composition, and (ii) regime shifts. Limit reference points may already fall from past management decisions. For instance, the debates that accompanied the introduction of a moratorium may have centred about low biomass levels that may represent, in essence, *de facto* limit biomass reference points. The conservation debate has already taken place for these situations, and a suite of conservation measures has already been implemented. In such cases, there is no need to reinvent the wheel; we just need to cast these in terms of the underlying PA framework.

An implementation checklist was proposed as a practical tool for the PA practitioners to evaluate how their implementation meets minimum standards. For illustrative purposes, a sample checklist based on the PA elements contained in UNFA and the FAO Code of Conduct was tabled (Appendix D). While the focus of this checklist is on the legal aspects, other types of checklists could be developed (e.g., on management measures consistent with the PA) so as to cover other elements found to be important.

The Working Group proposed that these three tools be made visible in specific products (one or more documents) that could be used in the implementation of the Precautionary Approach for domestic stocks.

General Considerations

The case studies served to illustrate that communication is a key element of PA implementation. This is particularly true in the case study on beluga in eastern Hudson Bay where co-management is front-and-centre of the PA implementation. This is also true for the case study on snow crab in the southern Gulf of St. Lawrence, where stakeholders, scientists and managers are operating in partnerships. It is clear that a successful implementation of a Precautionary Approach will require an involvement from all players. Success is more likely to occur where there is good co-operation with stakeholders, and within the Department.

5. Generic Framework for a Precautionary Approach

5.1. Proposal 1 (Gavaris)

Decision Rules

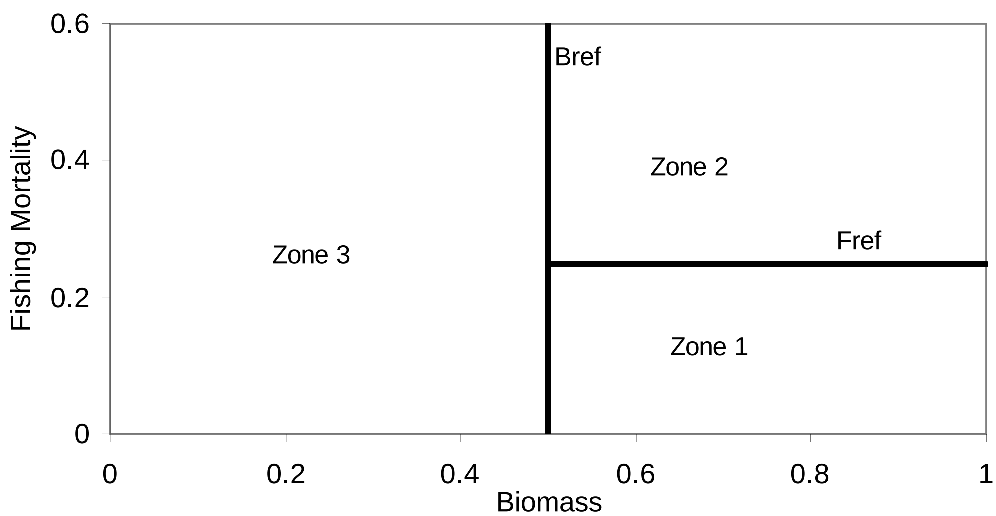


Figure 5.1.1. An exploitation rate harvest strategy option for a minimalist decision rule that is consistent with the Precautionary Approach.

Definition of Reference Points

- B_{ref}
  - Level of biomass that we desire the population to stay above
  - Where applicable, must be = B_{msy}
  - In the absence of B_{msy}, identify a suitable proxy
  - Default: must be equal to or greater than median observed biomass
- F_{ref}
  - Level of fishing mortality which we will aim for on average
  - Where applicable, must be < F_{msy}
  - Must be selected to maintain population out of Zone 3 most of the time
  - Default: must not exceed assumed natural mortality

B_{ref} and F_{ref} are defined for “normal” conditions and may be adjusted to reflect productivity shifts. Alternatively, the acceptable risks in the pre-agreed responses may be adjusted to reflect these shifts.

Pre-agreed Responses that will be Triggered

- *Zone 1 and Zone 2*
  - Management measures will be consistent with risks of
    - = 50% that F will exceed F_{ref}
    - Appreciably < 50% that B will be < B_{ref}
- *Zone 3*
  - Develop a rebuilding strategy to achieve B > B_{ref} and consistent with risks of
    - Appreciably < 50% that F will exceed F_{ref} in each year of the rebuilding period
    - Appreciably < 50% that B will decrease on average during the rebuilding period

5.2. Proposal 2 (Richard/Wade)

Framework

A generic framework for the PA is illustrated in Figure 5.2.1. It is similar to ones presented here but we attempted to be more generic and less rigid in defining a target reference limit. This is in keeping with the notion that a PA approach that is not accepted, and therefore not used, is not precautionary.

The precautionary approach is to try to move the fishery away from the limit level (biomass or number) and move towards the zone below the dark line where the population is high and productive and the fishing mortality is at a safe level.

Guidelines for a Target Reference

Target population levels may vary according to management objectives depending on the different purposes of stakeholders but they should all have the same basic characteristic, a safe distance from the biological limit.

To be safe, a target level should be a function of the capacity of the fishery (numbers of boats, fishers, gear), the strength of the recruitment rate of the stock, the degree of information available on the stock, and the degree of assessment error in evaluating status.

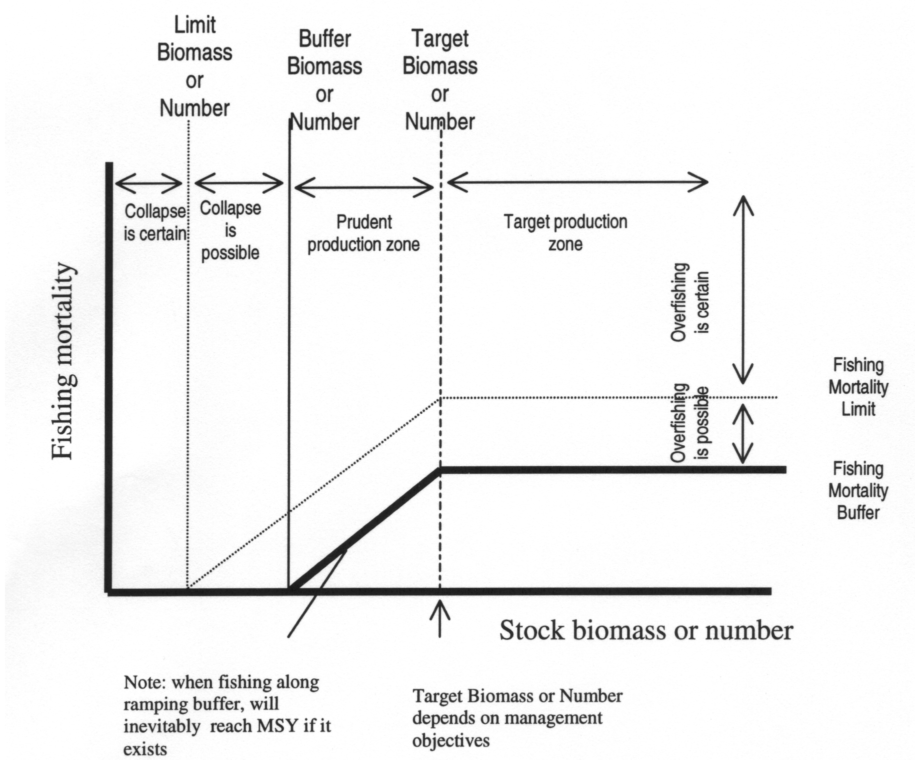


Figure 5.2.1. A generic framework for the precautionary approach.

If		**Then**		**Why?**
Capacity		Target	↗	Ease of rapid decline.
Recruitment rate	↘	Target	↗	Difficulty in detecting decline.
Information available	↘	Target	↗	Difficulty in determining biological limit and detecting decline.
Assessment error	↗	Target	↗	Undetected decline.

5.3. Workshop Consensus on the Generic Framework for a PA (Gavaris & Rivard)

The workshop recognized that the Precautionary Approach is much broader than the science context. Science can provide advice on biological limits. Science can also assist in establishing targets, given a set of objectives. Ideally, objectives should be determined through broad consultation. Figure 5.3.1 serves as a useful generic template.

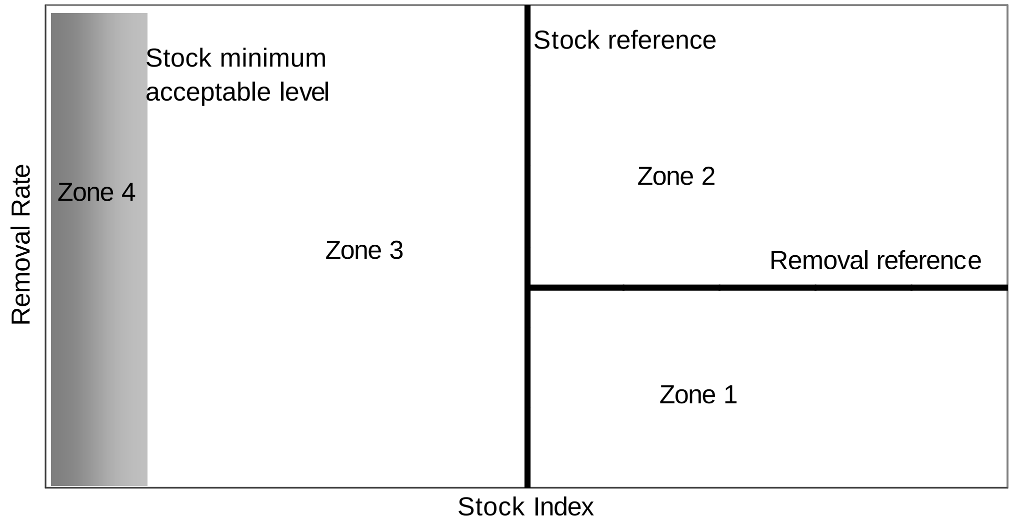


Figure 5.3.1. A consensus generic framework for the precautionary approach.

Zone 1: Stock is above the Stock reference level and removals are below the Removal reference level – status quo is acceptable.
Zone 2: Stock is above the Stock reference level but removals are above the Removal reference level – removals should be reduced to below the Removal reference level.
Zone 3: Stock is below the Stock reference level – removals should be restricted to allow a high probability of moving to Zone 1.
Zone 4: Stock is below the Stock minimum acceptable level – removals should be kept to the lowest possible level.

<u>Example Applied to the UNFA Context</u>

An exploitation rate harvest strategy option for a minimalist decision rule that is consistent with the Precautionary Approach as articulated for example in the UNFA.

<u>Definition of Reference Points</u>

- *Stock reference*
  - Stock level that we desire the population to stay above
  - Where applicable, must be equal to or greater than Stock maximum sustainable yield
  - In the absence of Stock maximum sustainable yield, identify a suitable proxy
  - Default: must be equal to or greater than median observed stock level

- *Stock minimum acceptable level*
  - Stock level where there is severe recruitment over-fishing and below which recovery potential may be compromised and the risk of extinction is significant
  - Where applicable, proxies associated with F_{loss}, etc. can be used
  - Default: lowest observed stock level in exploited populations

- *Removal reference*
  - Removal rate which we will aim for on average

- Where applicable, must be less than Removal maximum sustainable yield
- Must be selected to maintain population out of Zone 3 most of the time
- Default: must not exceed assumed natural mortality

Stock reference and Removal reference are defined for "normal" conditions and may be adjusted to reflect productivity shifts. Alternatively, the acceptable risks in the pre-agreed responses may be adjusted to reflect these shifts.

Pre-agreed Responses that will be Triggered

- *Zone 1 and Zone 2*
  - Management measures will be consistent with risks of
    - = 50% that Removal will exceed Removal reference
    - Appreciably < 50% that Stock will be < Stock reference
- *Zone 3*
  - Develop a rebuilding strategy to achieve Stock > Stock reference and consistent with risks of:
    - Appreciably < 50% that Removal will exceed Removal reference in each year of the rebuilding period
    - Appreciably < 50% that Stock will decrease on average during the rebuilding period
- *Zone 4*
  - Aggressive rebuilding strategy to achieve Stock > Stock minimum acceptable level by reducing removals to the lowest possible level

6. Next Steps

6.1. Communication Plan (Sinclair)

The target audience for a communication plan includes DFO stock assessment staff who didn't attend the workshop, DFO management, FRCC and possibly PFRCC, and the fishing industry.

A discussion paper on the PA is to be developed summarizing what has been learned from the project thus far. It will describe the common elements of the case studies, highlight issues where there are different approaches that reflect different situations of the respective fisheries, and describe next steps for the project. Denis Rivard will take the lead role, using the breakout group discussions as a starting point. The discussion paper will be circulated to members for comment, and included as an appendix to the workshop report[4].

A PowerPoint "deck" will be prepared to summarize the work to date of the project. The discussion paper will form the basis of the deck with the addition of a popularized version of a stock production theory with reference to biological reference points relevant to our interpretation of the PA. Pierre Richard and Al Cass will take the lead on preparing the deck.

[4] See Appendix E

The website will be maintained and opened to the public. It was suggested that there be a link to the site from CSAS. Working group members are encouraged to review material currently on the website to ensure it is suitable for public release. The Pacific Region will handle co-ordination of the website. The site will have to be bilingual. CSAS has a standard operation that we could follow. We should consider posting a bilingual version of the report. The website should include copies of the workshop reports, links to research documents and other publications relevant to the working group, an extended abstract of each case study, slide presentations (decks) that are useful for explaining the PA and what we did. The decks should reflect material reviewed and published in other fora or that meets with the approval of the working group.

It was suggested that popularized pamphlets describing the PA be prepared for distribution to the fishing industry and general public. The information content would be based on previously prepared material relevant to the project. The pamphlet would be a two-sided 8½" x 11" page. In addition to French and English, there may be a need to produce a version in Inuktitut. Ghislain Chouinard volunteered to help with its production.

6.2. International Symposium on the Precautionary Approach (Shelton)

Proposed venue: Québec City, Proposed date: mid-2001

A week-long international symposium devoted to the theory and application of the precautionary approach for marine finfish, shellfish and marine mammals is proposed for 2001. Sessions will consider: (i) technical issues related to estimating population size, determining reference points and evaluating both short-term and medium-term risk under alternative management approaches, (ii) case studies for stocks corresponding to the four Precautionary Zones, (iii) ecosystem considerations related to implementing a precautionary approach, (iv) social and economic considerations in developing and implementing the precautionary approach, and (v) the role of traditional knowledge and community stewardship in a precautionary approach.

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Acknowledgements

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Appendix A. Agenda

Monday, November 1, 1999

Introduction (Richards) (9:00 – 9:30 am)
Project Review (Schnute) (9:30 – 10:00 am)
Update on Precautionary Approach Frameworks (10:00 – 11:00 am)
Update on Implementation of a Precautionary Approach at NAFO (Rivard)
    Rapporteur (Sinclair)
Development of Precautionary Approach Experiences in Other Areas (11:30 – 12:30 am)
ICES Update (Sinclair)
NASCO (Calcutt)
ICAT (Gavaris)
FRCC (Rivard)
Other National & International Marine Mammals PA Approaches (Richard)
USA (Gavaris)
USA Finfish (James)
NGOs (Fréchet)
Development of Precautionary Approach in Canada
Regional Precautionary Approach Update (11:30 – 12:30 am)
    Laurentian – Fréchet
    Maritimes – Gavaris
    NFLD – Shelton
    C&A – Richard
    Pacific – Richards
    Gulf – Chouinard

<u>The HPPPA Case Studies</u>

Atlantic Cod in 3Ps (Shelton/Stansbury/Cadigan) (1:30 – 3:00 pm)
    Rapporteur (Chouinard)
Eastern Hudson Bay Beluga (Richard) (3:30 – 5:00 pm)
    Rapporteur (Cass)

Tuesday, November 2, 1999

<u>The HPPPA Case Studies</u>

Snow Crab in the Southern Gulf of St. Lawrence (Wade) (9:00 – 10:30 am)
    Rapporteur (Schnute)
Fraser River Sockeye (Schnute/Cass) (11:00 – 12:30 pm)
    Rapporteur (Stocker)
Atlantic Cod in 4TVn (Sinclair/Chouinard) (1:30 – 3:00 pm)
    Rapporteur (Cadigan)
Spring Spawning Herring in 4R (McQuinn) (3:30 – 5:00 pm)
    Rapporteur (Fréchet)

Wednesday, November 3, 1999

<u>The HPPPA Case Studies</u>

Pacific ocean perch (Schnute) (9:00 – 10:30 am)
    Rapporteur (Wade)

Wild Salmon Policy – Chris Wood (11:00 – 11:30 am)
Brainstorm on Initial Lessons Learned (11:30 – 12:30 pm)
Breakout Groups (1:30 – 3:00 pm)
    Group A (Gavaris/Rapporteur, McQuinn/Chair)
    Group B (Shelton/Rapporteur, James/Chair)
    Group C (Rivard/Rapporteur, Sinclair/Chair)
Break, Informal Meetings, Walkabout (3:00 – 5:00 pm)

Thursday November 4, 1999

Working Tools – Hands on (9:00 – 10:30 am)
Report from Breakout Groups (11:00 – 12:30 pm)
Next Step Part 1 (1:30 – 3:00 pm)
Next Step Part 2 (3:30 – 5:00 pm)

Friday, November 5, 1999

Plan Communications Strategy – Part 1 (9:00 – 10:00 am)
Plan Communications Strategy – Part 2 (10:30 – 12:30 pm)
Generic Framework (1:30 – 3:00 pm)
Approve Report and Finalize Writing (3:30 – 5:00 pm)

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Appendix C. Glossary of Acronyms and Technical Terms

Acronym	Description
ACFM	Advisory Committee of Fisheries Management
ADAPT	Name of software used for VPA tuned to abundance indices
ADMB	AD Model Builder
B	Stock Biomass
B_{BUF}	Stock Biomass, Buffer: to ensure B_{LIM} is not reached
B_{LIM}	Stock Biomass, Limit: stock should not fall below this level
B_{LOSS}	Stock Biomass, Lowest observed spawning
B_{MSY}	Stock Biomass, Maximum Sustainable Yield
B_{PA}	Stock Biomass, ICES Precautionary Points
B_{TAR}	Stock Biomass, Target: recovery level for stock
CAFSAC	Canadian Atlantic Fisheries Scientific Advisory Committee
CFD	Cumulative Frequency Distribution
CHP	Conservation Harvesting Plan
ComFiE	ICES Comprehensive Fishery Evaluation Working Group
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch per Unit Effort
CSAS	Canadian Stock Assessment Secretariat
CV	Coefficient of Variation
CW	Carapace Width
CWS	Canadian Wildlife Service
DFO	Department of Fisheries and Oceans
EB	Exploitable Biomass
ENSO	El Niño-Southern Oscillation
EOF	Empirical Orthogonal Function
EPR	Egg per Recruit
ESS	Eastern Scotian Shelf
EU	European Union
Exp Rate	Exploitation Rate
F	Fishing Mortality
FC	NAFO – Fisheries Commission
$F_{0.1}$	Fishing Mortality, Precautionary level associated with yield per recruit curve
F_{BUF}	Fishing Mortality, Buffer: mortality that ensures F_{LIM} is not reached
F_{CRASH}	Fishing Mortality, Crash: level that causes stock to collapse
F_{LIM}	Fishing Mortality, Limit: mortality that should not be exceeded
F_{MAX}	Fishing Mortality, Max: level that produces maximum yield per recruit
F_{MSY}	Fishing Mortality, Maximum Sustainable Yield
F_{PA}	Fishing Mortality, ICES Precautionary Points
F_{TAR}	Fishing Mortality, Target: $<= F_{BUF}$
FAO	Food and Agriculture Organization
FJMC	Fisheries Joint Management Committee
FMSWG	Fisheries Management Studies Working Group
FRCC	Fisheries Resource Conservation Council for Canada’s East Coast
FY	Fiscal Year
GEAC	Groundfish Economic Alliance Council

Acronym	Description
GGAC	Gulf Groundfish Advisory Committee
HCR	Harvest Control Rules
HPPPA	High Priority Project on the Precautionary Approach
ICA	Integrated Catch at Age Analysis
ICCAT	International Commission for the Conservation of Tunas
ICES	International Council for the Exploration of the Sea
IFMP	Integrated Fisheries Management Plan
ITQ	Individual Transferable Quota
LRP	Limit Reference Points
MBAL	Minimum Biologically Acceptable Level for a stock (ICES)
MCMC	Markoff Chain Monte Carlo
MPA	Marine Protected Area
MSVPA	MS Virtual Population Analysis
MSY	Maximum Sustainable Yield
NAFO	Northwest Atlantic Fisheries Organization
NASCO	North Atlantic Salmon Conservation Organization
NGO	Non Governmental Organizations
NHQ	National Headquarters
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NRC	National Research Council
OSYL	Optimum Sustainable Yield (population) Level
PA	Precautionary Approach
PDF	Probability Density Function
PFRCC	Pacific Fisheries Resource Conservation Council
PR	Partial Recruitment
QLSPA	Quasi-Likelihood Sequential Population Analysis
RAP	Resource Assessment Process
RV	Research Vessel
SC	NAFO – Scientific Council
SCRS	Standing Committee on Research and Statistics
SPA	Sequential Population Analysis
SPM	Surplus Production Model
S-R	Stock-Recruitment
SPR	Spawner per Recruit
SS	Stock Synthesis Software used for Catch-Age Analysis
SSB	Spawning Stock Biomass
SSR	Stock Status Report
SSSC	Statistics, Sampling and Surveys Committee
TAC	Total Allowable Catch
TAH	Total Allowable Harvest
UNFA	United Nations Fisheries Agreement
US	United States
VPA	Virtual Population Analysis
XSA	Extended Survivors Analysis
ZAP	Zonal Assessment Process

Appendix D. Checklist for Implementation of a PA Framework

Consistent with the provisions of UNFA (Anon 1995b) and applied here to the NAFO framework as an example.

UNFA	FAO Code of Conduct	NAFO PA Framework and precautionary measures
Provisions/general principles		
Implement improved techniques for dealing with risk and uncertainty (Article 6.3a) Take into account uncertainty (Article 6.3c)	Take into account uncertainties relating to stock size and productivity, reference points, etc. (7.5.2)	PA framework includes provision for buffer (applied to limit reference points) to take uncertainty into account. Risk analyses tools available to evaluate short-term risks. Unclear if annual risk assessments will be used to determine risks to fall below limit reference points. Work ongoing to evaluate long-term risks and management scenarios.
Apply stock-specific reference points (Article 6.3b and Annex II)		Work underway to define limit and target reference points under the PA framework for each stock in the NRA. Current request of the Fisheries Commission for advice specifies target reference points for each stock. February 2000 FC-SC Workshop to discuss changes required to request for advice to reflect PA framework.
Ensure that reference points are not exceeded when approached (Article 6.4)	When a limit reference point is approached, measures should be taken to ensure that it will not be exceeded (7.5.3)	Buffers applied to the limit reference points to define F_{buf} and B_{buf} PA framework also includes provision for harvest control rule whereby fishing mortality should be reduced when biomass falls below the target (B_{tr}).

UNFA	FAO Code of Conduct	NAFO PA Framework and precautionary measures
Concepts and terminology		
Precautionary reference points: two types (Annex II-2)		PA framework calls for conservation (or limit) and management (or target) reference points. Management reference points to be determined by managers.
Conservation or limit reference points: to constrain harvesting within safe biological limits (Annex II-2)		Limit reference points expressed in terms of fishing mortality (F) and Stock Spawning Biomass (SSB). Use of analytical models complicated by “regime shift”. Limit reference points determined from recruit-spawner data and fishing mortality trajectories.
Management or target reference points: intended to meet management objectives (Annex II-2)		Management reference points to be determined by managers. Scientists to describe and characterize uncertainty associated with current and projected stock status with respect to reference points. PA framework includes provision for SSB target.
Precautionary reference points should be stock specific to account for (Annex II-3): reproductive capacity; resilience other sources of mortality; major sources of uncertainty		PA framework calls for stock-specific reference points. Reproductive capacity accounted for in description of recruitment-SSB dynamics used in determination of limit reference points. Stocks not resilient to high exploitation; compounded by low productivity experienced in recent years. Lower resilience will likely translate into lower values for F reference points. Sources of uncertainty accounted for in the buffers applied to the limit reference points and/or in use of risk analyses. Changes in population dynamics parameters (e.g., natural mortality) reflected in recent assessments.

UNFA	FAO Code of Conduct	NAFO PA Framework and precautionary measures
Precautionary reference points shall be used to trigger pre-agreed conservation and management actions. (Annex II-4)		Pre-agreed management actions under the PA framework to be determined by managers.
Ensure that the risk of exceeding limit reference points is very low. (Annex II-5)		Ensured through implementation of buffers on the limit reference points. Managers to determine risk levels to be used in evaluating consequences of management actions; scientists to conduct risk assessments. Unclear how this will be implemented (annual risk assessments vs. buffer determination or both).
Fishery management strategies shall ensure that target reference points are not exceeded on average. (Annex II-5)		PA framework includes provision for target reference point expressed in terms of biomass (B_{tr}). Also includes provision for harvest control rule whereby fishing mortality should be reduced when biomass falls below the target (B_{tr}).
If information is poor, use provisional reference points (Annex II-6).		Many stocks under moratorium and situation unlikely to change for a number of years. Scientific studies have described stock trajectory in relation to limit reference points and identified milestones in recovery path for two stocks. Work need to be extended to other stocks. Special effort needed to determine reference points when analytical assessments not available.
The fishing mortality rate that generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. (Annex II-7)		Maximum value for F_{buf} is F_{MSY} .

UNFA	FAO Code of Conduct	NAFO PA Framework and precautionary measures
For stocks that are not over-fished, fisheries management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield and that the biomass does not fall below a pre-defined threshold. (Annex II-7)		Maximum value for F_{buf} is F_{MSY} . PA framework has provision for harvest control rule that reduces fishing mortality when biomass limits are approached.
For over-fished stocks, the biomass that would produce maximum sustainable yield can serve as a rebuilding target.		PA Framework recognizes a target Spawning Biomass Level (B_{tr}). Because many stocks are so low with respect to any conceivable biomass the limit reference point, B_{lim} and B_{buf} are in essence acting as first guideposts on the road to recovery.
Research		
	Take in to account best scientific evidence in adoption of conservation and management measures (7.4.1)	Peer review by Scientific NAFO Council. Annual advice
	Promote research in support of fishery conservation and management (7.4.2)	Regular surveys by member states. PA framework includes provision for precautionary monitoring below biomass limit reference point.
	Collect and maintain timely, complete and reliable statistics on catch and fishing effort (7.4.4)	Catch and effort statistics maintained by NAFO. C&P programs of member states used to verify reliability of data.
	Research on social and economic aspects (7.4.5)	
	Cooperation in research and data exchange on stocks (7.4.6 and 7.4.7)	Member state cooperation in research and data exchange.

UNFA	FAO Code of Conduct	NAFO PA Framework and precautionary measures
Management		
Adopt conservation and management measures on an emergency basis if adverse natural phenomenon. (Article 6.7)		Moratorium for fishing in place for many stocks in the NRA.
Need cautious conservation and management measures, including catch limits and effort limits (Article 6.6)	States should implement measures to ensure that fishing effort is commensurate with the productive capacity (6.3 and 7.1.8)	TACs determined for most stocks; Effort control scheme in place for 3M shrimp.
	Take appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species. Such measures may include technical measures related to fish size, mesh size or gear, discards, closed seasons and areas and zones reserved for selected fisheries, particular artisanal fisheries. Such measures should be applied, where appropriate to protect juveniles and spawners. (7.6.9)	NAFO by-catch provisions need to be improved to ensure that catches on non-target species are truly incidental. Minimum fish size. Adequacy of minimum mesh size debated. Need measures to protect unregulated species.
	Critical fisheries habitats (such as… nursery and spawning areas) should be protected and rehabilitated. (6.8)	Small fish protocols implemented in Canadian waters. No corresponding measure in NRA. Fishing on spawning concentrations minimized when moratoria lifted (e.g., yellowtail flounder).

UNFA	FAO Code of Conduct	NAFO PA Framework and precautionary measures
On biodiversity: Enhanced monitoring for non-target or associated or dependent species (Article 6.5) Implement data collection to assess impact on non-target species (Article 6.3d) Adopt plans to ensure the conservation of non-target and dependent species and to protect habitats of special concern (Article 6.3d)	On biodiversity: Ensure conservation of species belonging to the same ecosystem or associated with or dependent upon the target species (6.2) Absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment (6.5). Undertake research and data collection to improve knowledge of fisheries including interaction with the ecosystem. (6.4). Assess impacts of environment factors and relationship among populations in ecosystem (7.2.3). Apply and develop selective / environmentally safe fishing gear and practices (6.6).	FC-SC Workshops noted that technical measures and non-TAC conservation measures are part of implementation of a PA framework. NAFO by-catch provisions in place but need to be improved to ensure that catches on non-target species are truly incidental. Need measures to protect unregulated species; Fisheries Commission requested scientific Council to provide information on catch and status of Elasmobranch (skates and sharks). Sorting grates in place in shrimp fisheries. Environmental factors monitored by the Scientific Council through STACFEN.

Appendix E. PA Implementation for Canadian Harvest Fisheries (Rivard)

Introduction

The Precautionary Approach is emerging globally as a new framework for fishery management. This has come about through several developments but culminated, in 1995, with an agreement of the United Nations on the conservation and management of straddling fish stocks and highly migratory fish stocks (Anon. 1995). Canada has been a strong proponent of the management principles outlined in the United Nations Fisheries Agreement (UNFA) and ratified the Agreement in the fall of 1999. This agreement will be in effect when 30 countries have ratified the agreement. To date, 24 countries have done so and it is expected that more will join in the upcoming months.

The United Nations Fisheries Agreement defines the application of a precautionary approach and provides guidelines for the application of precautionary reference points. In particular, the precautionary approach requires that parties be more cautious when the information they have to support their conservation, management and exploitation decisions is uncertain, unreliable or inadequate, and when consequences of actions are likely to be difficult to reverse. The absence of adequate scientific information should not be used as a reason for postponing or failing to take cost-effective conservation and management measures.

The application of the precautionary approach has been dealt with under Article 6 of the United Nations Fisheries Agreement, which has been described as one of the most innovative provisions of the Agreement. Accordingly, many international fisheries organizations have embarked on the implementation of the precautionary approach. For instance, work on the application of the precautionary approach is underway in the International Council for the Exploration of the Seas (ICES), the Northwest Atlantic Fisheries Organization (NAFO), and the International Commission for the Conservation of Atlantic Tunas (ICCAT). Although the United Nations Fishing Agreement is not applicable to anadromous species, such as salmon, members of the North Atlantic Salmon Conservation Organization (NASCO) have also developed a framework for application of the approach.

In addition to taking a precautionary approach in decision-making, the United Nations Fisheries Agreement outlines a number of principles (there are 12 principles overall) to guide the management of marine renewable resources. For instance, coastal states and states fishing on the high seas should take measures to prevent or eliminate over-fishing and excess fishing capacity, and should ensure that levels of fishing effort do not exceed those commensurate with the sustainable use of fishery resources. They should collect and share information, promote and conduct research, as well as implement and enforce conservation and management measures through effective monitoring, control and surveillance. They should also take measures to protect biodiversity in the marine environment. They should attempt to minimize pollution, waste, discards, catch by lost or abandoned gear, catch of non-target species, and impacts on associated or dependent species, in particular endangered species.

Although the present Annex focuses on the “Precautionary Approach” concepts, it is clear that the implementation of the precautionary approach would greatly benefit from a broad implementation of the other principles of good management outlined in the United Nations Fisheries Agreement. Canada has already included a number of conservation measures in its domestic fishing plans, in addition to the implementation of conservative harvest limits. Although these conservation measures preceded the United Nations Fisheries Agreement, they were clearly made with conservation in mind and could serve to complement the approach discussed hereafter. Such measures typically include broad effort restrictions (e.g., limited entry, vessel replacement restrictions), fishing gear restrictions or limitations, in-season management protocols, season and area closures, etc. These are often coupled with provisions to ensure adequate monitoring of fishing performance and operations (e.g., dockside monitoring, observers, ship and air patrols, etc.). They could also be coupled with programs to collect catch statistics and biological information on the stocks being fished. The precautionary approach provides an opportunity to review these measures so as to ensure that the mix of measures used in a particular fishery is consistent with avoiding the identified unacceptable outcomes.

In brief, while the 12 principles outlined in the United Nations fisheries Agreement are front-and-centre in fisheries management, the primary focus of this discussion paper is on one of these principles, i.e., the Precautionary Approach. The purpose of this perspective paper is to illustrate how the use of "Precautionary Approach" concepts similar to those outlined in the UN Fisheries Agreement could assist fisheries management planning for harvest fisheries on stocks that are entirely under Canadian fisheries jurisdiction.

The Precautionary Approach

The Precautionary Approach is essentially a philosophy for management of fisheries. The Precautionary Approach requires the application of prudent foresight, the taking of uncertainties into account, greater caution when knowledge is less complete or less reliable, and management objectives that encompass not only stock conservation but also environmental and ecosystem considerations and the socio-economic performance of the fishery. It is no longer acceptable to assume that the effects of fishing on resource productivity and on the environment are negligible unless proven otherwise.

To be precautionary, plans should prescribe strategies to avoid unacceptable outcomes and should include measures to promote recovery of stocks when conditions approach or enter states defined as unacceptable. They should take into account the impact on non-target species, should avoid development of excess harvesting capacity, and should restrict the detrimental effects of fishing on the environment to acceptable levels. Unacceptable outcomes should trigger pre-agreed action. For new or exploratory fisheries, cautious conservation and management measures should be adopted until the impact of fisheries on sustainability of the resource can be assessed. When natural phenomena adversely affect productivity, measures should be adopted to ensure that fishing activity does not exacerbate the situation. The performance of management plans should be reviewed regularly and their measures should be revised in light of new information.

The Precautionary Approach does not define fisheries management objectives but requires that unacceptable outcomes be declared. Strategies to achieve the fisheries management objectives must be consistent with avoiding unacceptable outcomes. For example, the United Nations Fisheries Agreement prescribes the use of indicators which describe the state of the resource and of the fishery, and which can be used as a guide for fishery management.

There are generally two conceptual reference points for a given indicator, one defining a limit and the other a target. The Precautionary Approach is principally concerned with avoiding unacceptable outcomes and it associates Limit Reference Points of indicators with unacceptable outcomes. It recognizes that Target Reference Points are intended to meet management objectives, but these should be consistent with not exceeding Limit Reference Points. The United Nations Fisheries Agreement provides only general guidelines on what reference points can look like under a precautionary approach. As a minimum, the limits and targets should be expressed in terms of fishing mortality (F) and biomass (B). Using these, the United Nations Fisheries Agreement suggests that the fishing mortality at maximum sustainable yield (F_{MSY}) be used as a "minimum standard" for a limit reference point on fishing mortality, and that the biomass giving the maximum sustainable yield (B_{MSY}) be used as a rebuilding target for the biomass. The idea is that good management should attempt to maintain the stock within a range where its productivity can be fully realized.

Reference points under a precautionary approach are intended to delimit zones where pre-agreed conservation and management actions are triggered through a decision rule. Decision-making requires information on the consequences of adopting particular regulatory measures. The information on which fisheries management decisions are based can be classified into three elements: the range of possible alternative actions under consideration, the forecast state of an indicator under each of the alternative actions and the reference points for that indicator. The Precautionary Approach emphasizes incorporating consideration of uncertainty into the decision process. Application of the Precautionary Approach therefore implies identification of those actions for which there is an acceptably low risk that the forecast state of the indicator will exceed (or be less than, depending on meaning) the Limit Reference Point.

What is new from what was done in the past? Most significantly, exploitation rates exceeding those associated with the maximum sustainable yield (MSY) are unacceptable; therefore, targets must be below F_{MSY}. In cases where the scientific knowledge is inadequate to determine MSY, provisional reference points should aim to maintain population size (numbers or biomass) above, and exploitation rates below, the levels associated with the highest productivity. Secondly, the Precautionary Approach emphasizes the need to explicitly take uncertainty into account. This implies that where uncertainties are greater, more caution should be exercised. Finally, in the past, there was also a tendency to manage in a responsive mode whereby conservation measures were articulated one after the other in response to a particular situation or crisis. The challenge now is to evaluate the efficacy of these responses in meeting management objectives and to develop an integrated plan that will put management in an "anticipatory" mode with pre-agreed management actions triggered by declared reference points.

The implementation of a Precautionary Approach goes beyond the science context and will require cooperation from all involved. It includes identification of objectives that are consistent with avoiding declared unacceptable outcomes. Ideally, objectives should be determined through broad consultation. Strategies to achieve those objectives will have to be made operational in terms of reference points. Science can provide advice on limit reference points as these are based intrinsically on the biology of species or stock of interest. Science can also assist in establishing targets consistent with objectives and respecting biological limits, but input from other quarters is also essential at that stage. Decision rules that trigger pre-agreed conservation and management action based on the reference points must be devised. Regular reviews of performance of fisheries management must be undertaken.

Generic Framework for a Domestic Implementation of the Precautionary Approach

Declarations regarding the Precautionary Approach permit a great deal of flexibility for implementation; however, they do provide a general direction and offer some guidelines for implementation. Here, we provide a generic framework that minimally satisfies the Precautionary Approach, and specifically, the guidelines outlined in the United Nations Fisheries Agreement. Accordingly, the generic framework focuses on *reference points* and *harvest strategies* aiming at a direct regulation of removals.

Reference points

A minimal set of reference points must respect the principle that exploitation rates exceeding that associated with maximum sustainable yield are unacceptable. Further, limit reference points should take into account the reproductive capacity of the resource and, to achieve that purpose, limit reference points have often been expressed in terms of the stock spawning biomass or numbers of mature individuals.

The following could be considered a minimal set of reference points:

> *Stock reference*. This is the stock level that we desire the population to stay above. Where applicable, the *stock reference* must be equal to or greater than the stock size capable of producing maximum sustainable yield (S_{MSY}). In the absence of a direct estimate of S_{MSY}, a suitable provisional reference point should be identified. Provisional values should be consistent with the intended stock reference point (i.e., a stock size that is highly productive).
>
> *Stock minimum acceptable level*. This is the stock level where there is severe recruitment over-fishing and below which recovery potential may be compromised. The default value is to be taken as the lowest observed stock level in exploited populations from which the stock showed recovery in a reasonable timeframe. If there is evidence that the probability of good recruitment decreases below some stock size, the Stock minimum acceptable level must be above that size.
>
> *Removal reference*. This is the removal rate that will be aimed for, on average. This rate must be selected so as to maintain population above the stock reference most of the time. Where applicable, it must be less than the Removal Rate giving the maximum sustainable yield. Provisional values should be consistent with the intended removal reference point and should respect the uncertainty associated with not knowing the actual removal reference point.

The values selected for reference levels should take into account the uncertainty with not knowing the actual stock reference point.

The *Stock reference* and *Removal reference* are defined for “normal” conditions, which include specific patterns of growth, reproduction and natural mortality. If these aspects of a species' productivity change greatly, it may be necessary to reconsider the stock and removal references. The reference values may be adjusted to reflect productivity shifts or the acceptable risks in the pre-agreed responses may be adjusted to reflect these shifts. In either case, though, it is important to have clear evidence that the change in productivity has occurred *and is likely to persist* long enough to be of importance to management of the stock.

Harvest strategies.

The course of management action, or harvest strategy, that may be required at a given time, may be related to two basic questions: 1) "How big is the resource?" and 2) "How much can safely be removed?" The former is expressed in terms of the stock index, such as the total weight or number of animals in the population. The latter can be thought of as the fraction of the stock that is to be removed by exploitation, i.e., the removal rate. In various fora, harvest strategies have been described as "decision rules", "harvest control rules", "harvest control laws", or "feedback control laws". These generally refer to the mix of regulatory measures that could be applied. We will simply use the term "harvest strategies" to describe these measures. A harvest strategy could be formalized explicitly by specifying how the management measures will change in response to changes in the stock and in the fishery. Under a precautionary approach, reference points are used to delimit zones where the strategies are triggered.

A harvest strategy framework based on the reference points described above would delimit four zones as follows[5]:

Zone 1: The stock is above the Stock reference point and removals are below the Removal reference point – status quo is acceptable. This zone identifies the "desired" state in terms of exploitation and stock size.

Zone 2: The stock is above the Stock reference point but removals are above the Removal reference point – removals should be reduced to below the Removal Reference point. This zone is characterized by removal rates exceeding the reference signifying "overexploitation".

Zone 3: The stock is below the Stock reference point - removals should be restricted to allow a high probability of moving to Zone 1. In this zone, the stock is considered to be in an "overexploited" state.

Zone 4: The stock is below the Stock minimum acceptable level – removals should be kept to the lowest possible level. In this zone, the stock has been reduced to a very low level and is considered to be in an "unacceptable" state.

[5] Adapted from the workshop material in Section 5

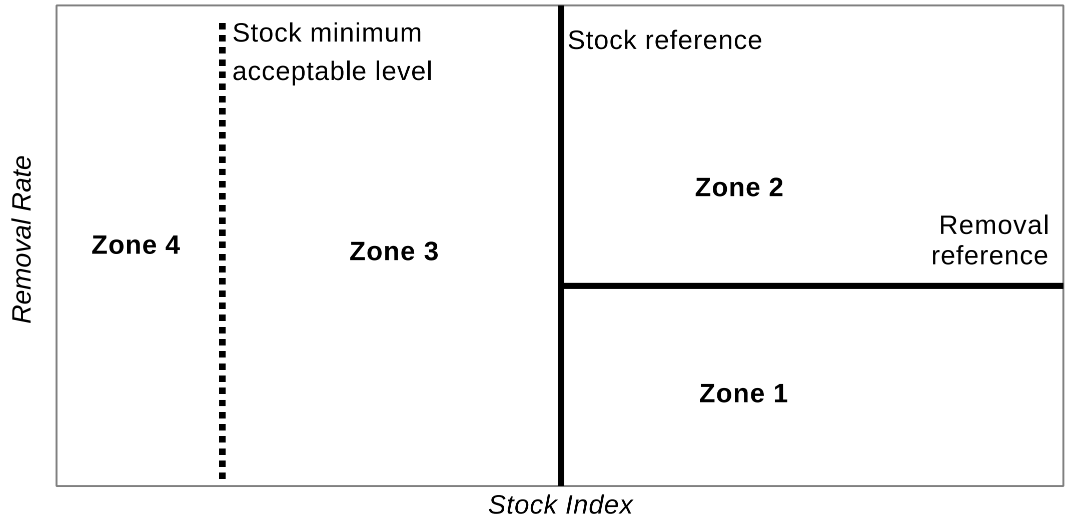


Figure E1. A minimalist harvest strategy framework. In Zone 4, the degree of "unacceptability" increases as the stock index approaches annihilation (the zero point).

These four zones (Fig. E1), and the responses associated with them, could serve as a minimal generic template for a harvest strategy consistent with the precautionary approach. Harvest strategies rely on pre-agreed responses (or management measures) that will be triggered in each of the zones. For example,

In Zones 1 and 2, management measures should ensure that the risks are

- no greater than 50% that the removal rate will exceed the *Removal reference*;
- appreciably less than 50% that the stock size will be less than the *Stock reference.*

Zone 2 signals that a reduction in the removal rate is needed; whereas *Zone 1* signals that an increase may be possible. The above-mentioned harvest strategy could be used but additional effort reduction measures could be necessary if the tendency to over-harvest persists.

In Zone 3, a rebuilding strategy should be implemented to achieve a stock size greater than the *Stock reference* and consistent with risks

- appreciably less than 50% that the removal rate will exceed the *Removal reference* in each year of the rebuilding period;
- appreciably less than 50% that the stock size will decrease, on average, during the rebuilding period.

In Zone 4, an aggressive rebuilding strategy is needed to achieve a stock size greater than the *Stock minimum acceptable level* in the shortest possible time, by reducing removals to the lowest possible level. The development and implementation of a multi-year Recovery Plan are necessary.

The harvest strategy proposed for Zones 1 and 2 is similar to the constant harvesting rate strategy used for many stocks in the past (e.g., $F_{0.1}$ strategy), with the exception that the strategy is maintained only if the stock size remains above the *Stock reference*. The harvest strategy for Zone 3 could be based on medium-term projections to characterize the rebuilding period. The approach here has some similarities to that used in the Maritimes Region for some of the groundfish stocks, with explicit determination of risk through models. The harvest strategy for Zone 4 could be thought of as a suite of measures similar to those implemented for Atlantic groundfish, considered to be severely depleted (lowest practical catch levels, measures to reduce by-catch mortality, continued monitoring of the stock in a coordinated and carefully-controlled manner). Again, medium-term projections should be considered to gain insight into stock trajectories under various scenarios.

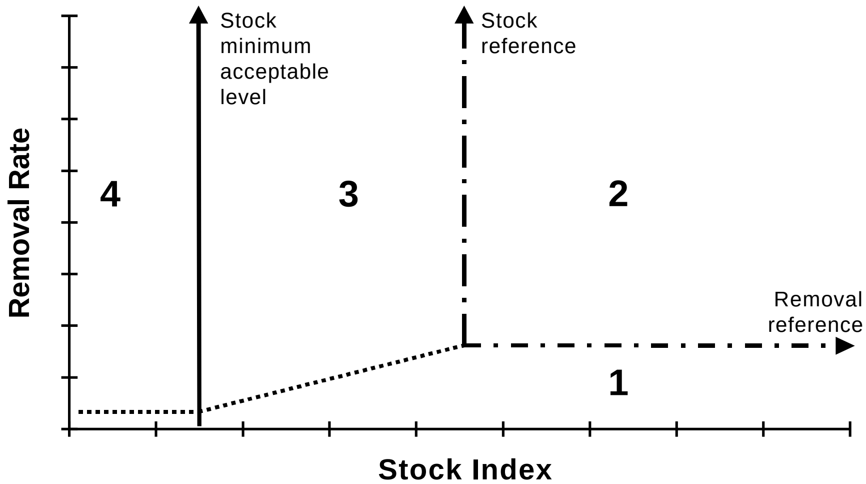


Figure E2. An extension of the harvest framework in Fig. E1.

The above minimal definition of a harvest strategy implies that the removal rate in Zone 3 must be less than the *Removal reference* but gives managers the flexibility to select a removal rate that would be consistent with rebuilding to the *Stock reference* according to some agreed schedule. Other harvest strategies consistent with a "minimalist design" can be devised. For example, in some management environments, it may be preferable to specify a progressive reduction of removal rates as a function of how far a stock may have ventured below the *Stock reference* (Fig. E2)[6]. For a stock that is recovering, such a ramping reference for the removal rate could also provide a way to rebuild exploitation as the stock recovers. When a stock is below the *Stock minimum acceptable level*, removals should be kept to the lowest possible level; the degree to which this can be accomplished in a particular case is illustrated by the dotted line in Zone 4 (Fig. E2). Variations on these themes could be envisaged.

Building from Past Experience with Reference Points

Canada has implemented a number of harvest strategies and conservation measures over time. Effort controls and technical measures limiting gear design and usage dominated the 1960s and early 1970s. Then, fixed removal rate strategies were introduced and implemented using Total Allowable Catches as the main management tactic. This approach gained popularity in the late 1970s. Monitoring and enforcement were improved in the 1980s and 1990s, through the introduction and improvement of observer programs, dockside

[6] See also the NAFO framework in Fig. 4.3.1.

monitoring programs, etc. These approaches were aimed at conservation, directly or indirectly, in response to the situation or issue of the time. The foundation for a management regime based on conservation already exists in many fisheries and, for these, the implementation of a precautionary approach may require only minor adjustments to what is already in place.

The following discussion uses past management experience to suggest defaults for the *Removal reference*, the *Stock reference* and the *Stock minimum acceptable level*.

Removal reference.

Canada opted for a fixed harvest rate management strategy for its Atlantic groundfish fisheries when coastal state jurisdiction was extended to include the 200-mile limits in 1977. The so-called $F_{0.1}$[7] harvest rate was chosen as a suitable target. While higher absolute yields might be achieved in theory by fishing at F_{MSY}, the lower $F_{0.1}$ harvest rate (or ? F_{MSY}) was adopted as the management target to better protect the spawning potential of the stocks and to make the fisheries more economically efficient (Anon. 1981). Specific harvest rates have also been used to guide the exploitation of other species groups, such as marine mammals, snow crab, shrimp and capelin.

When targets have already been established and agreed upon by managers, they can serve as the starting point for the establishment of the “Removal Reference” in the PA framework. *There are no compelling reasons to establish targets in a PA framework that are less conservative than the targets already agreed in recent management practices*. When the target removal rate in place is consistent with the full realization of stock productivity, it could be used as the default value for the “Removal Reference”.

There are at least two ways to improve the performance of past removal references, which were defined as constant over all stock sizes. Firstly, the minimalist Precautionary Approach harvest strategy prescribes a mandatory reduction of the “Removal Reference”, when stock sizes fall below the Stock reference. Such a pre-agreed response would insert “feedback control” in the management system, facilitating quicker response when a stock is in decline and faster recovery of the stock to higher level when a stock is low. Secondly, in situations where past targets can be demonstrated as being too high for the current production regime, a reduction of the Removal Reference should be considered.

Finally, it needs to be noted that in data-limited situations, proxies will need to be used to establish harvest rates that are consistent with the precautionary approach. In those cases, life-history characteristics (e.g., growth) and comparisons with closely related species could be used to determine a precautionary harvest rate.

Stock reference.

The *Stock Reference* may vary according to management objectives but it should always respect the same basic characteristic, i.e., delimit an area of stability and productivity. Ideally, this zone should also provide a safe distance from the Stock Minimum Acceptable Level. Except for escapement targets used for salmon and some small pelagic

[7] $F_{0.1}$ corresponds to the harvest rate at which an additional small increase in fishing effort will bring only 10% of the yield per unit of recruitment that the same increase in effort would bring from an unexploited population.

stocks, the consideration of a *Stock Reference* has not been common in recent Canadian fisheries policies as these were mostly stated in terms of constant harvest policies. There were explicit rebuilding targets set for some stocks at the time of extension of jurisdiction, but these targets were considered as being met in some cases by the mid-1980s.

When past strategies do not permit the identification of a *Stock reference*, then the stock size at maximum sustainable yield can be used. If that cannot be estimated, then a *Stock reference* consistent with the objective of a safe and productive population level should be used. For example, a stock size at least 50% of the maximum observed population size could be used.

Stock references could also be inferred from the constant harvest policies in place for Zones 1 and 2, so as to avoid situations leading to frequent adjustment to the removal rates. For instance, a *Stock reference* selected at a value somewhat below the average Stock index at the *Removal reference* would avoid triggering a Zone 3 response prematurely.

When very long timeframes are expected for rebuilding to the *Stock reference*, an implementation plan could nevertheless set a number of milestones along the way so that fishers/hunters can see progress within a reasonable timeframe. Also, to encourage adherence to the recovery plan, the severity of the measures allowing recovery could be proportionally diminished from one milestone to the next, as the stocks rebuilds away from the *Stock minimum acceptable level* and works its way towards the *Stock Reference*.

Stock minimum acceptable level

As defined above, this is the stock level where recruitment over-fishing may be a concern and below which recovery potential may be compromised.

In certain cases, the “minimum acceptable level” for the stock has already been defined implicitly by past management decisions. For instance, the discussions that led to severe harvest restrictions on many Atlantic cod stocks included a debate on critical levels for stock spawning size. The levels of the spawning population reached at that time were considered to be low enough to possibly compromise reproductive capacity. Certainly, any minimum acceptable level would be no lower than these stock sizes.

When the minimum acceptable stock size has already been defined implicitly by past management decisions, this level should be used as the default value for the *Stock minimum acceptable level*. When past experience does not permit the identification of a minimum acceptable level, then the default suggested above, i.e., the lowest observed stock size from which the stock showed recovery within a reasonable timeframe, can be used. In cases where there is evidence that the probability of good recruitment decreases below some stock size, the *Stock minimum acceptable level* must be above that size.

Performance Reviews

<u>Evaluation of current situation</u>

It will be necessary to conduct periodic reviews to identify the current state of a stock in relation to the reference points. The evaluation of stock status against the reference points would logically be a cornerstone of the periodic assessments done on a stock-by-stock basis, i.e., annually or according to an established schedule of regular assessments.

Risk analysis

As harvest strategies are expressed in terms of risks, assessments should include an evaluation of risks. Such analyses are already available for many stocks, although risks are likely under-estimated, as not all sources of uncertainty can be accounted for in such analyses. Where risk analyses are not available but quantitative assessments are possible, the reference points should include buffers to account for the uncertainty in assessments. “Risk evaluations” and “buffers” are ways to address a fundamental element of a precautionary approach, namely to take into account uncertainties inherent in stock assessments and management systems. Alternatively, adopting a risk-averse approach rather than actually constructing explicit buffers can achieve the “buffer” effect.

Complementary indicators

The evaluation of stock status need not limit itself to performance measures based only on removal rates and stock size. Other measures, such as indicators of growth, reproductive potential, predator/prey interactions, and environmental conditions may provide useful insight into factors that may be influencing stock productivity and stock dynamics. Changes in geographical distribution, fish migration patterns or migrations could also be indicative of changes in stock dynamics and productivity. These factors are important as they could affect the ability of a stock to respond to a given harvest strategy, i.e., to recover to the *Stock reference* or to sustain a given *Removal rate*. Such a multi-criteria approach could also be used to capture ecosystem considerations.

A typical summary of indicators would thus include qualitative and quantitative results describing productivity indicators, stock status indicators in relation to limits and targets (expressed in terms of risks), environmental indicators and ecosystem-related considerations. Such quantities may be described as system “attributes” or qualifiers. A summary of stock attributes could be useful not only for data-poor and data-moderate environments but also for data-rich situations. Approaches like this have been found to be useful for communicating the results of complex assessments. Practical applications of these approaches, such as the “traffic light” approach, are being actively researched.

In the context of a precautionary approach, the status of attributes has to be linked to pre-agreed management actions. To meet the intent of the United Nations Fisheries Agreement, the management actions should be sufficient to insert “feedback control” in the stock-fishery dynamic system. Recent research suggests that one possible way to do this is to link the status of stock “attributes” to the *Removal reference* in a manner similar to the progressive adjustments described above. In that case, the basis for the progressive adjustments of the *Removal reference* would not solely be the *Stock size* in relation to its reference limit and target, but also a function of its *attributes*.

Review of harvest strategies

Thus a framework for implementation of the precautionary approach would specify reference points and pre-agreed management actions to define a harvest strategy. To achieve a given set of objectives, ineffectual or weak harvest strategies may need to be coupled with more conservative reference points. Conversely, an effective or highly restrictive harvest strategy (i.e., a strategy that provides strong “feedback control”) may not require a precise definition for the minimum acceptable limit as the management measures in place when the limit is reached would be sufficient to ensure conservation. A holistic approach attempting to address this as a “systems design” problem is likely to be more successful than a fragmented approach, where each element is defined, debated and implemented independently, in isolation.

Whatever the approach taken to define a harvest strategy for a given stock, it will be important to evaluate the results in terms of satisfying management objectives and the principles of the Precautionary Approach (perhaps in terms of stock rebuilding, recovery, sustainability, productivity and stability). Strategic evaluations could be based on studies using the following modeling framework[8]:

Step 1: Define the system components and dynamics. The system generally consists of population dynamics models defining stock trajectories in space and time. At this stage, it is important to identify the relevant data and use exploratory data analysis to gain insight into the resource dynamics and likely response to exploitation.

Step 2: Define stochastic aspects. In particular, specify error distributions, identify parameters and the estimation model or procedure. For some estimation techniques, prior information on the distribution of parameters will also be required.

Step 3: Simulate harvest policies. First, stakeholders, managers and scientists must define policies jointly. Then, stochastic simulation models can be used to simulate trajectories under various scenarios.

Step 4: Evaluate policy results. This step requires that a “value” or “utility” function be defined, ideally in a forum involving stakeholders, managers and scientists. In absence of a uniquely defined value function, many options could be explored from inferred value functions and put forward for discussion purposes. Outputs include “trajectory values” and “distribution of outcomes” should serve as a basis for discussions on harvest policies, with the aim of identifying possible improvements.

This type of review does not need to be performed frequently. Often, only significant revisions in the knowledge of stock dynamics or a change in the basis for the stock assessment would require re-evaluations. The review of harvest strategies could provide an opportunity to review the mix of conservation measures used in a particular fishery so as to ensure that they are consistent with precautionary management. The effectiveness of various conservation measures could also be evaluated through reviews of past practices and their impact on stock performance indicators, and through simulations.

For new and developing fisheries, harvest strategy frameworks for providing scientific information for precautionary management have been proposed. For example, such an approach is outlined in Perry *et al*. (1999) who promote a phased approach to harvest while knowledge is gained on the specific resource.

[8] Illustrated in the Fraser River sockeye case study (Section 3.4).

Checklists could be used to guide the implementation of a precautionary approach for various stocks. Many types of checklists could be developed so as to cover legal aspects, monitoring and research aspects, or management and surveillance aspects. As a starting point, a checklist could simply be based on the provisions of United Nations Fisheries Agreement and FAO Code of Conduct for Responsible Fishing, as illustrated below:

Provisions and principles of a Precautionary Approach	✓
Reference Points	
Apply stock-specific reference points to constrain harvesting within safe biological limits and to account for reproductive capacity, resilience, other sources of mortality, and major sources of uncertainty.	
Apply target reference points to meet management objectives; the targets must be consistent with harvesting within safe biological limits.	
For stocks that are not over-fished, the fishing mortality rate that generates maximum sustainable yield should be regarded as a minimum standard for limit reference points.	
For over-fished stocks, the number or biomass that would produce maximum sustainable yield can serve as a rebuilding target.	
If information is poor, use provisional reference points.	
Harvest Strategies	
Reference points shall be used to trigger pre-agreed conservation and management actions.	
Ensure that target reference points are not exceeded most of the time.	
Ensure that the risk of exceeding limit reference points is very low.	
Adopt conservation and management measures on an emergency basis if adverse natural phenomenon.	
Implement measures to ensure that fishing effort is commensurate with the productive capacity.	
Take appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species.	
Protect and rehabilitate critical fisheries habitats.	
Apply and develop selective and environmentally safe fishing gear and practices.	
For new or exploratory fisheries, cautious conservation and management measures should be adopted until the impact of fisheries on sustainability of the resource can be assessed. Measures shall allow for the gradual development of the fisheries.	
Implementation and Performance Reviews	
Absence of adequate scientific information shall not be used as a reason for postponing or failing to take appropriate management and conservation measures.	
Take into account best scientific evidence in adoption of conservation and management measures.	
Implement improved techniques for dealing with risk and taking into account uncertainties relating to stock size and productivity, reference points, etc.	
Promote research in support of fishery conservation and management and on ecosystem, social and economic aspects.	
Collect and maintain timely, complete and reliable statistics on catch and fishing effort.	
Co-operate in research and data exchange on stocks.	
Enhanced monitoring for non-target or associated or dependent species and implement data collection to assess impact of fisheries on them.	
Assess impacts of environment factors and relationship among populations in ecosystem.	

As suggested in this checklist, another key part of a precautionary approach is good information and data on fisheries, the resources being exploited and their environment. There should be a co-operative effort to ensure that the best and most relevant data are used in the determination of resource status. Wherever possible, risk analyses should be used to allow management to take uncertainty into account in the context of risk.

The checklist also makes cross-references to the other principles outlined in the United Nations Fisheries Agreement, recognizing that harvest strategies should be coupled with a toolkit of management or technical measures such as the ones generally found in harvesting plans.

Process of Implementation

The frameworks and guidelines outlined above are intended to guide the discussions on how to make the "Precautionary Approach" concepts operational in various harvesting sectors. In keeping with the spirit of the precautionary approach, these discussions will have to involve stakeholders, managers and scientists. A description of respective roles and responsibilities should be developed early in the process to assist in the implementation of a precautionary approach.

Where the advisory or management functions are fostered in specific domestic organizations (e.g., Fisheries Resource Conservation Council, Pacific Fisheries Resource Conservation Council, Nunavut Wildlife Management Board), discussions on the precautionary approach are likely to occur within these organizations as well. The Fisheries Resource Conservation Council (FRCC) has recognized the need to adhere to a precautionary approach in the Groundfish Conservation Framework for Atlantic Canada. Its approach includes measures to maintain adequate spawning potential and to protect genetic diversity, the ecosystem and critical habitat. The FRCC is currently working on the development of a precautionary framework and has initiated discussions on implementation for Atlantic groundfish stocks through various workshops or exchanges.

Regional workshops are seen as a key instrument for the design and implementation of a precautionary approach. The leadership role in initiating the process of implementation naturally resides within fisheries management. These workshops could be used to develop management guidelines for the implementation of a precautionary approach. Once a conceptual framework is agreed upon and reflected in a set of reference points or guidelines, these should form the basis for the preparation of reports on resource status and for advice on conservation requirements. The strategies identified in the precautionary approach could serve to guide the development of Integrated Fisheries Management Plans.

Appendix F. List of Working Paper Documents

1. An Approach for Considering Diverse Fishery System Attributes in Fisheries Management Planning
   (Gavaris, Stratus; DFO, Marine Fish Division – Maritimes)

2. The Development of Precautionary and Biological Limit Reference Points for the 3Ps Cod Case Study
   (Shelton, Peter; DFO, Cadoids Section – NFLD)

3. Eastern Hudson Bay Beluga Case Study
   (Richard, Pierre; DFO, Science Winnipeg)

4. Models for the Precautionary Approach Case Study of EHB Belugas
   (Richard, Pierre; DFO, Science Winnipeg)

5. A Comparison of the Preliminary Assessments of the 3Ps Cod Stock using ADAPT, ICA, QL and XSA
   (Armstrong, N; Cadigan, N; Darby, C.D.; Mahe, J.C.; Stansbury, D.E.; DFO – NFLD)

6. Categories of Fishery Status Indicators to Assist in Resource Assessment: An Illustration for Discussion
   (Mohn, R; Fanning, P.; and many others; DFO – Maritimes)

7. 3PS Cod Case-Study, HPPPA Workshop
   (Cadigan, Noel; Shelton, Peter; Stansbury, Don; DFO, North Atlantic Fisheries Center – NFLD)

8. Joint Science – Fisheries Management – Policy Workshop on the Precautionary Approach
   (Shelton, Peter; Newfoundland Region)

Appendix G. Science-Related Meetings on the Precautionary Approach

Past Meetings:

July 24-August 4, 1995. United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. Held under the auspices of the United Nations.

June 6-13, 1995. Technical Consultation on the Precautionary Approach to Capture Fisheries (including Species Introductions). Lysekil, Sweden. Held under the auspices of the Food and Agriculture Organization (FAO) of the United Nations.

February 5-11, 1997. Study Group on the Precautionary Approach to Fisheries Management. Copenhagen, Denmark. Held under the auspices of the International Council for the Exploration of the Sea (ICES), Advisory Committee on Fishery Management.

June 25-July 4, 1997. Comprehensive Fishery Evaluation Working Group. Copenhagen, Denmark. Held under the auspices of the International Council for the Exploration of the Sea (ICES), Advisory Committee on Fishery Management.

January 28-30, 1998. Meeting of the Working Group on the Precautionary Approach in North Atlantic Salmon Management. Brussels, Belgium. Held by the North Atlantic Salmon Conservation Organization (NASCO).

February 3-6, 1998. Study Group on the Precautionary Approach to Fisheries Management. Copenhagen, Denmark. Held under the auspices of the International Council for the Exploration of the Sea (ICES), Advisory Committee on Fishery Management.

March 17-27, 1998. Scientific Council Workshop on the Precautionary Approach to Fisheries Management. Dartmouth, Nova Scotia, Canada. Held by the NAFO Scientific Council.

May 12-13, 1998. NAFO Working Group on the Precautionary Approach. Copenhagen, Denmark. Held under the auspices of NAFO.

October 5-9, 1998. Workshop on Implementing the Precautionary Approach in Canada, Pacific Biological station, Nanaimo, British Columbia, Canada. Workshop held under the auspices of the Science High Priority Project on the Precautionary Approach.

December 9-10, 1998. Workshop of the Fisheries Resource Conservation Council on the Precautionary Approach. Halifax, Nova Scotia, Canada. Included representatives from the fishing industry, DFO Science and Management, and the FRCC.

April 27-May 1, 1999. Scientific Council Meeting on the Precautionary Approach. San Sebastian, Spain. Held by the NAFO Scientific Council.

May 3-5, 1999. Joint Scientific Council and Fisheries Commission Working Group on Precautionary Approach. San-Sebastian, Spain. Held under the auspices of NAFO.

September 1999. Newfoundland Region Workshop on the Precautionary Approach. St. John's, Newfoundland. Involved DFO scientists and managers.

Upcoming Meetings:

November 1-5, 1999. Second Workshop on Implementing the Precautionary Approach in Canada, Pacific Biological station, Nanaimo, British Columbia, Canada. Workshop held under the auspices of the Science High Priority Project on the Precautionary Approach.

January 2000. Workshop of the Fisheries Resource Conservation Council (FRCC) on the implementation of a Precautionary Approach for redfish stocks.

February 2000. Joint Fisheries Commission -Scientific Council meeting of the Working Group on the Precautionary Approach. Brussels, Belgium. Held under the auspices of NAFO.

February 2000. FAO meeting on harmonization of terminology. Brussels, Belgium. (Proposed)

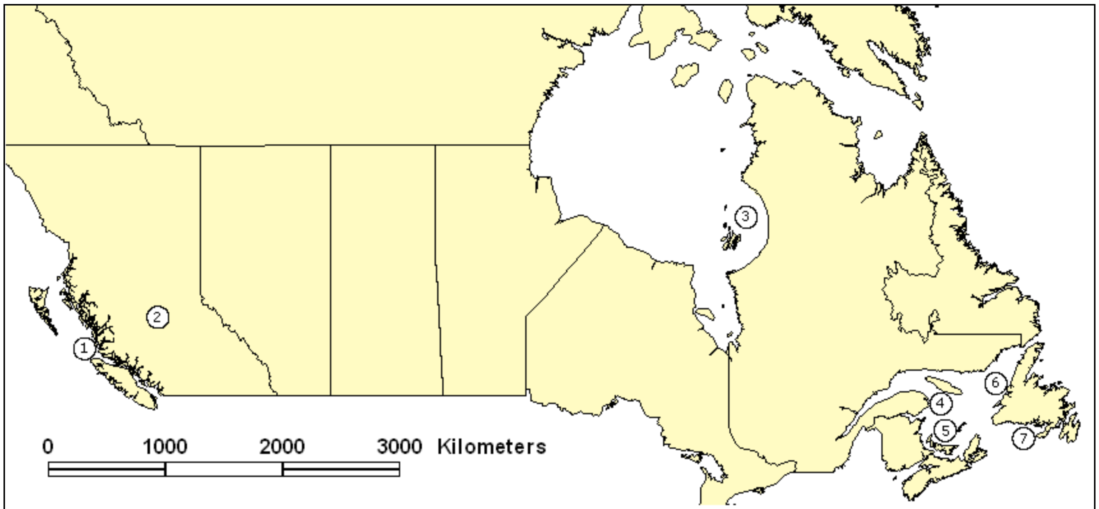
March 2000. NASCO Precautionary Approach Working Group Session on Fisheries Management. Will involve scientists and managers. Location to be determined (California, USA?).

March 2000. FAO Expert Consultation on Implications of the Precautionary Approach for Tune Fisheries. Thailand. Will focus on four scientific themes: stock assessment, data collection, biological and environmental research, and fisheries technology.

(*as of November 1, 1999*)

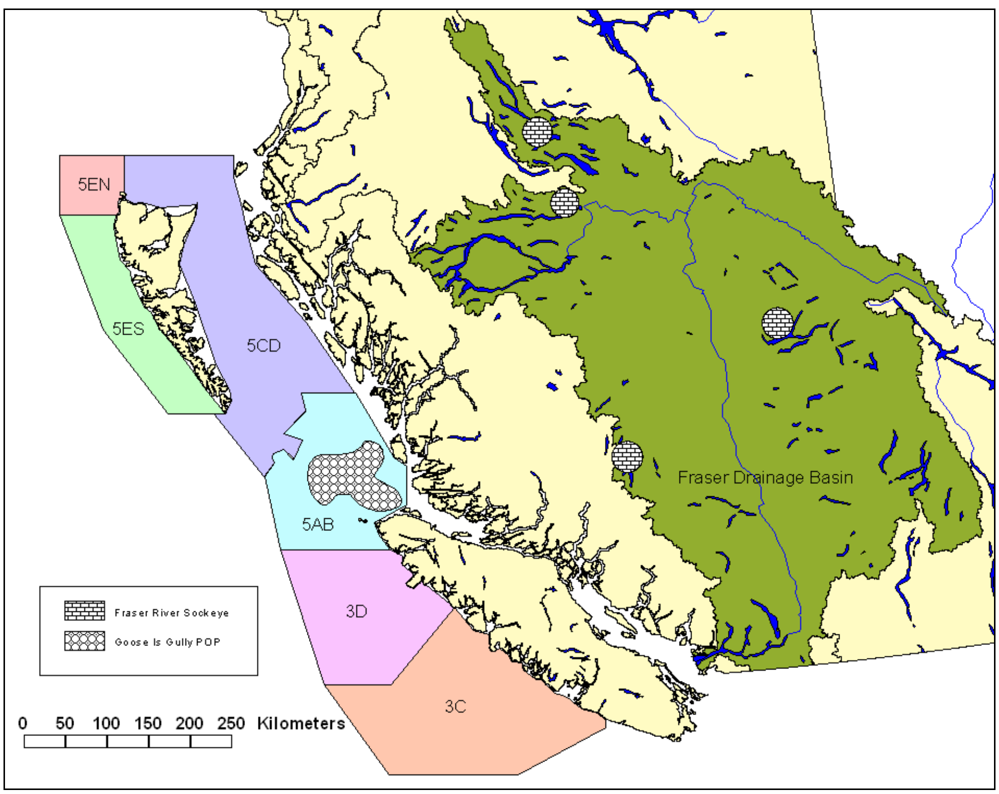
Appendix H. Case Study Maps

Case study locations across Canada

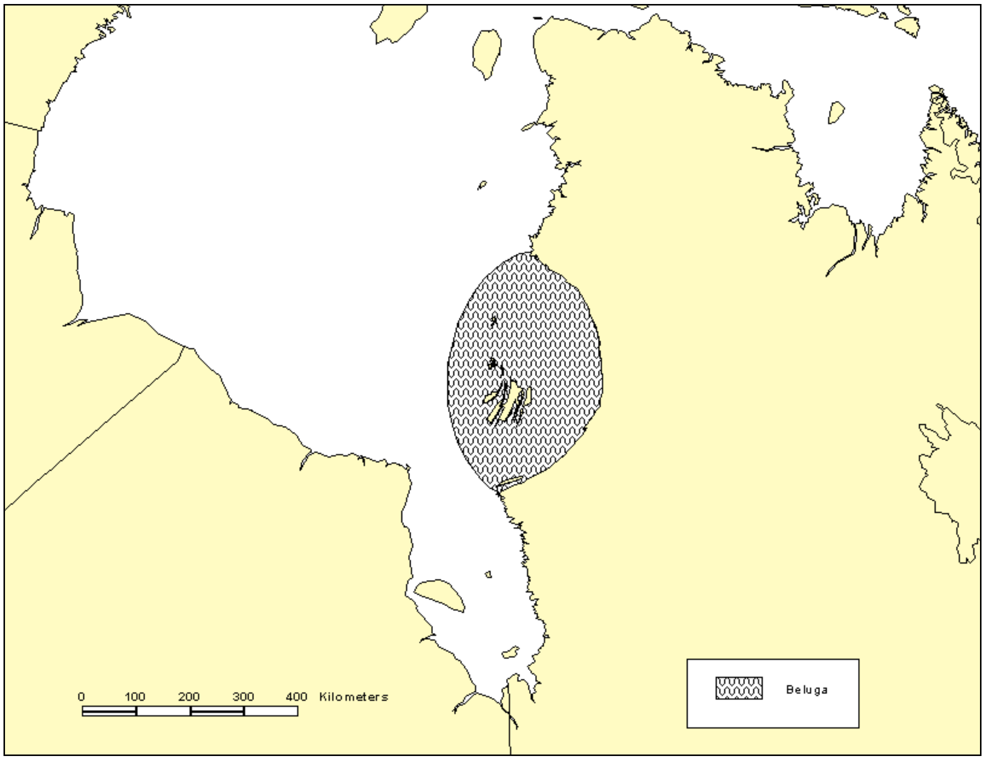


Area	Case Study	Researcher
1	Pacific ocean perch in Goose Island Gully	Jon Schnute
2	Fraser River sockeye salmon	Jon Schnute, Alan Cass
3	Eastern Hudson Bay beluga whales	Pierre Richard
4	Atlantic cod in 4TVn	Alan Sinclair, Ghislain Chouinard
5	Snow crab in southern Gulf of St. Lawrence	Elmer Wade
6	Spring spawning herring in 4R	Ian McQuinn
7	Atlantic cod in 3Ps	Noel Cadigan, Don Stansbury, Peter Shelton

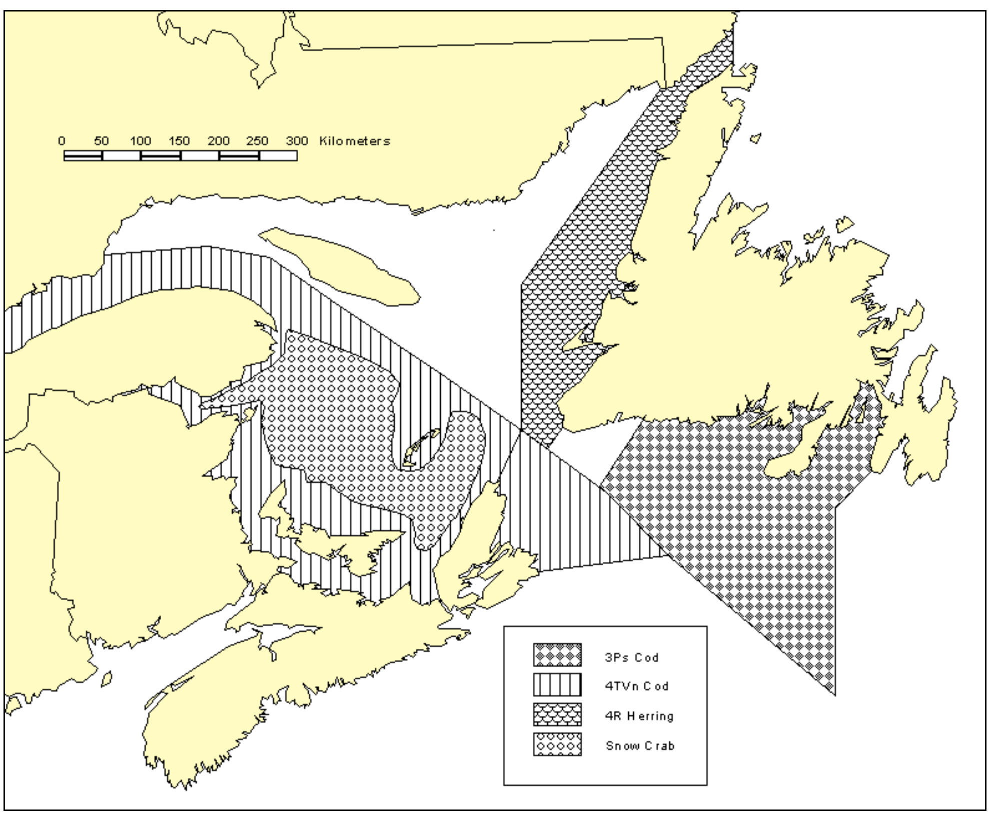
Locations of the Fraser River sockeye and Pacific ocean perch case studies



Location of the eastern Hudson Bay beluga case study



Locations of the Atlantic cod in 3Ps, snow crab in the southern Gulf of St. Lawrence, Atlantic cod in 4TVn, Atlantic spring-spawning herring in 4R case studies



Appendix I. Report Card for 4R Spring-spawning Herring

Report Card **4R Spring-Spawning Herring**

Indicators			Knowledge Status			Observation	Interpretation	Uncertainties	Stock Status			
Rating	Type	Index	Poor	Medium	High		re: Reference Levels		Collapse	Danger	Pivotal	Healthy
Primary	Population No.	VPA		yellow	green	Historical low	Population in decline since 1984	Poor 11+ residual pattern	black			
		Acoustic Survey		yellow		Historical low	1994 yearclass not strong	Sampling poor / series short		red		
		IF Catch Rates		yellow		Historical low	Decline in 1998 after rise in 1997	Model r^2 = .53		red		
	SSB	VPA		yellow	green	Historical low	Below 20% of virgin stock		black			
	Recruitment	VPA		yellow	green	Not sufficient to rebuild stock	Below medium since 1990	Not estimated from 95-97		red		
		S/R		yellow	green	Historical low	Stock-recruitment relationship unknown		black			
		Trawl Survey	red			Historical low	4R index below 4S index	Not sure what % of population is represented	black			
	Mortality	Fishing			green	Historical high	Well above $F_{0.1}$	Highly variable depending upon yearclass		red		
		Natural		yellow		Assumed to be 0.2		May have increased in 1990's		red		
	Fishery	Catches			green	Significantly reduced since 1993	Increased in 1998 after decline since 1995			red		
		Effort (t-s)		yellow		More effort towards the north	Fewer herring in the south			red		
	Industry Preception	Questionnaires		yellow		General decline in south since 1996	Decline in spawning	Possibly biased responses		red		
		IF Logbooks		yellow		Unanimous: Population in decline	Shorter spawning season	Half-dozen fishermen	black			
		Purse Seine Catch Rates	red			Increase in 1998	Lots of small fish	Fishing high densities			yellow	
Secondary	Age Structure	VPA		yellow		Reduction in old ages / decline in mean age	Young ages are assumed average	Unknown recruitment after 1994		red		
	Maturity at Age	Commercial		yellow		Tendency towards younger age at maturity	Population under stress	Highly variable data				
	Growth	Condition Factor			green	Drop in condition over past 3 years	Poor feeding conditions				yellow	
		Weight at Age			green	Drop in weight at age	Poor growth conditions				yellow	
	Spatial Distribution	Fishing Distribution		yellow	green	Shift in distribution towards the north	Fewer herring in the south			red		
		Acoustic Survey			green	Few herring in central zone	CIL influence			red		
Auxiliary	Predators	Gulf Seal Model	red	yellow		Seal consumption possibly 10,000-20,000 t / year	Possibly inhibiting production of recruits	Seal distribution and diet		red		
	Prey Abundance		red									
	Oceanography	Temperature			green	Extremely cold inshore water in fall	Upwelling of CIL			red		
Overall				yellow	green					red		

The "Knowledge Status" does not refer only to the <u>amount</u> of data available, but also the <u>reliability</u> and the <u>relevance</u> of these data.

Appendix J. Images from the Workshop

Workshop Participants

Laura Richards

Stratis Gavaris, Denis Rivard

Kazumi Sakuramoto, Pierre Richard, Rowan Haigh, Norm Olsen, Alain Fréchet, Al Cass, Max Stocker, Bob Huson, Heather James, Mike Calcutt

Presentations and Discussions

Ghislain Chouinard, Alan Sinclair

Elmer Wade, Stratis Gavaris, Denis Rivard, Marc Clemens

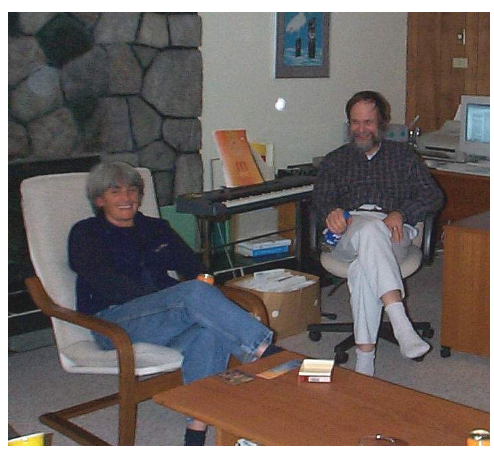
Jon Schnute, Al Cass,
Elmer Wade, Kelly Meikle

Bob Huson, Max Stocker,
Ghislain Chouinard, Don Stansbury

Ian McQuinn, Laura Richards, Kazumi Sakuramoto

Heather James, Jon Schnute

Laura Richards, Denis Rivard



Charline Sinclair, Peter Shelton