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Techniques for the Provision of Advice in Information-Poor Situations

Techniques pour la prestation d'un avis dans les cas où il y a peu de renseignements

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TABLE OF CONTENTS

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ABSTRACT

A workshop was held among the regions of Fisheries and Oceans Canada to develop approaches to stock assessment in data limited situations. Methods and approaches from international organizations such as NOAA and CSIRO and universities were provided as keynote presentations. Case studies from each of the regions for groundfish, marine mammals, pelagic fishes, freshwater and anadromous fishes and marine invertebrates were presented. Each case study was analyzed within smaller groups to determine suitable options for developing stock assessments. As well, a table of assessment methods, with reference to richness and type of data required to develop the analysis, was created.

RÉSUMÉ

Un atelier a été organisé pour les régions de Pêches et Océans Canada afin de mettre au point les approches pour l'évaluation des stocks dans les cas où l'on dispose de peu de données. Lors des présentations, on a indiqué les méthodes et les approches adoptées par des organisations internationales comme la NOAA et la CSIRO et par les universités. On a présenté des études de cas provenant de chacune des régions qui concernaient les poissons de fond, les mammifères marins, les poissons pélagiques, les poissons d'eau douce et les poissons anadromes, ainsi que les invertébrés marins. Chaque étude de cas a été analysée au sein de plus petits groupes afin de déterminer les options appropriées en vue de préparer des évaluations des stocks. On a également créé un tableau des méthodes d'évaluation, avec des indications sur l'abondance et le type de données nécessaires en vue de réaliser l'analyse.

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INTRODUCTION

The problem of stock assessment in data limited or data poor situations is universal to organizations involved in resource management. Within the mandate of Fisheries and Oceans Canada (DFO), new fisheries have recently been developed, sometimes for previously unexploited species where data is scant. As well, for many existing fisheries where the dynamics of the stock has changed or overarching environmental influences, such as climate warming, come into play, long time series of data may tell us that parameters assuming to be stationary are changing with time and render using past performance to make predictions moot.

At the initial Training in Expertise in Stock Assessment (TESA) workshop held in Vancouver in January 2009, all regions of DFO identified data-poor or data-limited situations as problematic for the provision of scientific advice to manage fisheries. It was proposed that all regions come together with representative case studies of data-limited or data-poor cases to have a workshop on stock assessment in these situations.

KEYNOTE PRESENTATIONS

AUSTRALIAN APPROACHES TO DATA POOR SPECIES ASSESSMENT AND MANAGEMENT

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Methods and approaches to managing exploited marine species in Australia have been driven by fisheries and environmental legislation and by oceans policy and harvest strategy policy. In particular, there has been a need to assess the status of many hundreds of by-catch species, resulting in the need for data poor assessment methods. These methods include ecological risk assessment for the effects of fishing (ERAEF), described in Hobday et al. 2011. ERAEF comprises a suite of methods moving from qualitative to fully quantitative, depending on the availability and quality of data, and includes the Sustainability Assessment for Fishing Effects (SAFE) method for rapid assessment of by-catch species (Zhou and Griffiths, 2008). To implement harvest strategies in data poor situations, a set of Tier rules was developed (Smith et al. 2008) that also uses a range of data-poor assessment methods. It is important that the performance of such harvest strategies be tested using approaches such as management strategy evaluation. A "cost-catch-risk" framework was discussed, which identifies tradeoffs between levels of exploitation, costs of acquiring information, and levels of risk to sustainability.

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EVALUATING STOCK ASSESSMENT METHODS FOR DATA-LIMITED FISHERIES

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Defining "data-limited" in fisheries is difficult because practically all fisheries are managed based on inadequate information. Even where long time-series of catch, effort, and age-composition are available, such data may not be informative about important management parameters, such as the optimal exploitation rate, optimal escapement, or the maximum sustainable yield. Furthermore, a large degree of uncertainty in management parameters typically leads to biased and imprecise estimates of stock biomass and subsequent chronic periods of over- or under-fishing. Predicting the consequences of complex, non-linear interactions among data quantity and quality, stock assessment model choices, decision-rule parameterization, and fish stock dynamics is therefore necessary when designing fisheries management systems, regardless of how "limited" the data may seem. Failure to take such interactions into account ignores substantial uncertainty about the potential outcomes of stock assessment and management choices. Unfortunately, most stock assessments focus narrowly on statistical uncertainties associated with one particular model fitted to one particular data set. We argue that such "best assessment" approaches are by no means precautionary as required under the Precautionary Approach, the Johannesburg Agreement, the U.N. Fish Stocks Agreement, ecosystem-based management, and certain eco-certification programs.

In the most fundamental data-limited situation, so-called traffic-light approaches are sometimes advocated where harvest regulations are adjusted in response to categorical changes in raw or smoother indicators, such as fishery or survey CPUE. As far as we know, these approaches have never been rigorously evaluated for their ability to meet precautionary harvest strategy requirements. It seems almost inconceivable how such a simple indicator-based approach could be precautionary, except in very unlikely circumstances in which a fishery system is linear. In this paper, we use closed-loop simulations to demonstrate how simple traffic-light approaches would easily fail to recognize an impending stock collapse for a relatively long-lived, low productivity species like Big Skate (*Raja binoculata*). Similarly, we also show that even some apparently good stock assessment models can fail in a situation where reliable stock assessment is most critical; that is, when a stock is strongly depleted and in need of fishing mortality rate reductions. In particular, even the more advanced statistical catch-age models can be unreliable if the age-composition data are allowed to dominate biomass trend information. We conclude that basic indicator-based approaches provide a false sense of security, even for cases with 20+ years of catch and effort data. Longer time-series, as well as adding age-composition data, is not a panacea to assessment problems, especially when stocks are heavily depleted and in need of rebuilding. Our experience applying closed-loop fishery assessment and management simulations to hypothetical examples, as well as to B.C. sablefish, indicates that the "safest" assessment methods typically under-estimate stock biomass and therefore sacrifice varying amounts of yield to achieve long-term conservation and yield stability goals. We recommend a broader systems approach to designing assessment and management systems for Canadian fisheries. This view is especially important, for example, for developing fisheries where biomass assessments for quota-based fisheries are impractical. A systems perspective would consider altering the regulatory framework such that a reliable monitoring-assessment-decision system could be developed.

DATA-POOR STOCK ASSESSMENT, AND SOME NEW CATCH-BASED APPROACHES: DCAC AND DB-SRA

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Data-poor stock assessment

Data-poor stock assessment requires a fundamental change in attitude. Whereas in "data-rich thinking" we tend to respond to uncertainty by seeking more data, in "data-poor thinking" we are forced to accept whatever data we have and just do the best we can. Very often, the results cannot be summarized in a precise single point estimate, but rather must be expressed as probability distributions. However, it is only fair to say that most data-rich assessments incorporate fixed parameter values (e.g., natural mortality rate, M), and consequently misrepresent their precision. Some principles of data poor assessment include:

- Find a way to use the data you have.
- Prudently borrow information you do not have (e.g., Bayesian priors). Fishing effort is borrow-able, but borrowing abundance trends from other stocks is not recommended.
- Thoroughly explore the possibilities, with alternative model specifications and Monte Carlo exploration of parameter uncertainty.
- Test the model against data-rich assessments and/or simulated data.

Catch-based methods

What can we do if we only know historical catches (even only approximately)? Restrepo et al. (1999) suggested using percentage reductions in recent average catch, but this approach does not reflect information about the stock. MacCall (2009) developed an approach called Depletion-Corrected Average Catch (DCAC), which makes a quantitative correction in average catch depending on whether abundance increased or decreased during the time period. Dick and MacCall (In prep.) developed a more informative analysis called Depletion-Based Stock Reduction Analysis (DB-SRA) that can be used in cases where the time series of known catches extends back to the beginning of fishing.

Depletion-Corrected Average Catch (DCAC): This approach treats the catches as consisting of two sources, one being sustainable, and the other being a one-time "windfall" derived from fishing down the stock abundance. The "windfall" is expressed as being equivalent to a number of years of sustainable catches. Data requirements for DCAC are aggregated catch data (ΣC, where the sum is over n years), and approximate probability distributions describing the uncertainty about parameters governing stock productivity and status. These distributions include natural mortality rate (M), the ratio of F_{msy} to M (F_{msy}/M), the location of peak net productivity expressed as a fraction of unfished biomass ($B_{peak}=B_{msy}/B_{unfished}$), and the change in biomass during the time period, expressed in units of unfished biomass ($\Delta=(B_1-B_2)/B_{unfished}$). We generate 10,000 random draws from each of the four input distributions and calculate

$$DCAC = \frac{\Sigma C_t}{n + \Delta \cdot \left[B_{peak}\left(\frac{F_{MSY}}{M}\right)M\right]^{-1}}$$

The resulting DCAC values are expressed as a probability distribution, and tend to be somewhat smaller than MSY values.

Depletion-Based Stock Reduction Analysis (DB-SRA): The analysis uses the same inputs as DCAC and can also be used to describe a production function P(*B*). That production function in turn can be used in a stock reduction analysis by sequential use of the simple equation

$$\mathbf{B_t = B_{t-1} + P(B_{t-a}) - C_{t-1}}$$

where *a* is age at knife-edged maturity. If abundance at the beginning of the catch series is at unfished biomass, and it is at a given fraction of that level at the end of the series, the unfished biomass can be determined. Again, Monte Carlo exploration provides a probability distribution of the results. Useful outputs include the time trajectory of biomass, the current catch at *Fmsy*, and the probability that fishing pressure has exceeded *Fmsy*.

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SOLUTIONS TO THE PROBLEMS OF DATA POOR FISHERIES FROM AN ATLANTIC COAST POINT OF VIEW

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Fish stocks without age data and with severely limited biological and fishery information are encountered all too frequently due to limited resources to collect data. However, it is still possible to derive management advice by exploring the general trends in abundance and fishing mortality, which can be deduced using only a time series of catch and a survey index. One such approach the model AIM (An Index Method) which is readily available on the NOAA Fisheries Toolbox website (http://nft.nefsc.noaa.gov). In this model, the relative fishing mortality rate is calculated as the ratio of catch to survey index and is related to changes in a population index termed the replacement ratio. The replacement ratio is an analytic, although heuristic, tool for examining the historical behavior of a population and any potential influences of removals due to fishing activities. The model allows for explicit hypothesis testing that the fishery removals are related to changes in the population. Results from this simple method have been compared to results from more complex assessments of the same stock and the comparisons have demonstrated that AIM can capture major features of complex assessments in a data rich environment. In general, AIM correctly tracked the population trend and identified relative impacts due to fishing, which supports the inference that AIM can be used in many data poor situations. However, manifestations of problems in complex assessments, such as nonstationarity, can also arise in AIM results, demonstrating that simple models are not immune to the pathology of misspecification.

ESTIMATING REFERENCE POINTS IN MIXED-STOCK SALMONID FISHERIES
Steven J.D. Martell and Carl J. Walters

With the wild salmon policy and potential for SARA listing of overfished populations, it has become critical to provide estimates of sustainable harvest rates for salmonid stocks that are taken primarily in mixed stock fisheries., We typically base these parameter estimates on analyses of stock-recruitment data, to provide an assessment for each stock of the mean relationship between spawners and resulting recruits. The steepness of that relationship at low stock sizes determines the maximum sustainable exploitation rate, and its height at high stock sizes determines the maximum potential to contribute to fisheries and other values related to total abundance (e.g., contributions to ecosystem function). Many years of data are needed to assess mean stock-recruitment relationships; short time series lead to severely biased estimates of maximum productivity and stock size. We cannot estimate long term recruitments directly for most stocks as catch plus escapement because (?); there are no direct measurements of stock-specific catches. Stock composition sampling, fence counts, Coded Wire Tagging programs, etc. provide such estimates for some stocks, but typically for only really large and-or ”indicator” stock units and only for recent years. Here, we develop a method for jointly estimating stock recruitment for several stocks in a mixed stock fishery, which then can be used to estimate stock specific reference points. The method requires information on stock specific escapement and the cumulative catch from all stocks or an estimate of average fishing mortality rates. Estimates of average exploitation rates (U) across stocks is the total catch of all stocks divided by the sum of total catch plus escapement over all stocks. This can be translated into a fishing mortality rate (F) as F=-ln(1-U). Given estimates of the average fishing mortality rate, recruitment for each stock can be approximated by $R_i = S_i \exp(F\text{-}d_i)$, where i is an index for stock, and d_i is a stock specific deviation in fishing mortality rates. Given the initial observed escapements S_{it} for the first generation (t=1,..4), estimates of stock specific escapements can then be updated using a time series model where the log of escapement X_{it+k}=ln(S_{it}):

$$X_{it+k} = X_{it} + a_i - F_t - b_i \exp(X_{it}) + \rho\, w_t + (1\text{-}\rho)\ v_{it} \qquad (1)$$

Given the observed and predicted estimates of escapement, we then use maximum likelihood methods (assuming log-normal observation errors) to jointly estimate the stock recruitment parameters (a_i, b_i), a vector of shared environmental effects (w_t) and a matrix of process errors (v_{it}), conditional on the estimated average fishing mortality rates (F_t), and a parameter that defines the proportion of the shared environmental effects (ρ).

Simulation studies with high contrast in fishing mortality rates and high correlations in shared environmental variation (ρ=0.75).were conducted to determine if the method actually works when all of the model assumptions are met. The simulations also assessed how robust the parameter estimates were if there were large variations in stock specific fishing mortality rates from the actual mean fishing mortality rate. Estimates of stock specific reference points are relatively unbiased and precisely estimated, even in cases where there are large variations in stock specific fishing mortality rates (assuming that these deviations are independent and identically distributed). Additional simulations were conducted with low contrast in fishing mortality rates. These simulation results indicated a slight downward bias in estimates of optimal escapement, but little or no bias in estimates of stock specific exploitation rates.

Simulations with low environmental variation (ρ=0.25) and low contrast in average F over time were also conducted. These experiments found a slight downward bias in estimates of optimal spawning escapement and a slight upward bias in optimal exploitation rates for highly productive stocks. These slight biases in parameter estimates were insensitive to the level of observation error, but the precision of stock specific parameter estimates decreases with increasing error.

The method was applied to 29 Skeena River Sockeye salmon stocks to estimate parameters and stock recruitment curves (Figure 1). Based on the estimated parameters, parameter uncertainty and a long-term equilibrium view of equation 1, estimates of long-term equilibrium yields summed over all stocks occur with an exploitation rate of approximately 0.6. At this exploitation rate, nearly half of the stocks would be overfished and 5 of those stocks are likely to be fished to extinction.

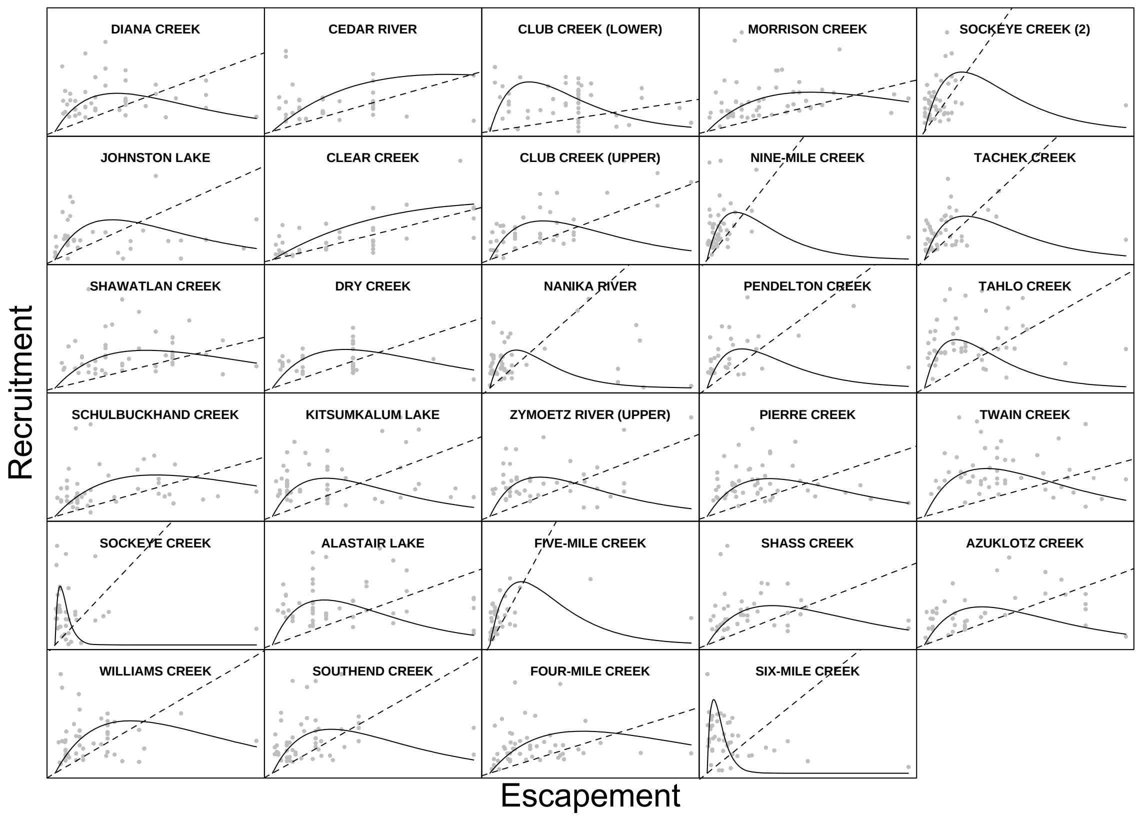

Figure 1. Reconstructed stock-recruitment data sets for Skeena River Sockeye and corresponding Ricker curves. The dashed line is the replacement line; one recruit per spawner (escapement).

PRESENTATIONS BY REGIONS

Each region was asked to present three to four case studies that might represent some of the problems for data poor stocks. The presenters were to use the following questions as a guide for their discourse:

1. What advice is being requested for decision making?
2. What is the particular assessment problem represented by the case study given the advice request?

The presentations were divided according to taxonomic groupings into groundfish, pelagics, marine mammals, freshwater and anadromous fishes, and invertebrates.

GROUNDFISH

Rick Stanley and Murdoch McAllister – Pacific Rockfish (Pacific Region)

The Bocaccio, *Sebastes paucispinis* is a member of the Sebastidae (rockfish) family. Other common names for this species include Salmon Grouper, Grouper, Tom Cod (juveniles), and Slimy Rockfish. Within Canadian waters, biomass estimates declined severely from 1980-2000. The decline was evident in both an U.S. triennial survey (1980-2001) and a DFO shrimp survey. Stanley et al. (2004) reported that Bocaccio was still in a threaten state. A number of analyses (Stanley and Starr 2004, Stanley et al. 2009, DFO 2009) have subsequently confirmed the dire state of Bocaccio stocks. The species has been assessed by COSEWIC as Threatened.

The assessments were limited due to poor data on catch, a fishery independent survey, and limited understanding of the life history. A variety of fleets harvest Bocaccio (Table 1)

Table 1.

Gear	Commercial Sector	Years	Fixed or Estimated
Trawl	US domestic	1935-2006	Fixed
Trawl	CDN domestic	1950-2006	Fixed
Trawl	Soviet and Japanese	1965-1977	Fixed
Handline and Setline (HL)	Rockfish	1940-2006	Fixed
Setline	**Halibut**	**1935-2006**	**Estimated**
Troll	**Salmon troll**	**1935-2006**	**Estimated**

Natural mortality is low, with estimates of M at around 0.075. Age-at-maturity is roughly 6 to 7 years.

Data from each of these sources is limited for conventional assessments. Our approach to assessment has been to use Bayesian models.

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Daniel Duplisea – Redfish (Quebec)

Gulf of St Lawrence and southern Newfoundland (Units 1 & 2) redfish (*Sebastes spp.*)

There Acadian Redfish (*Sebastes fasciatus*) and Deepwater Redfish (*Sebastes mentella*) are the main species of redfish in eastern Canada:.The range of *S fasciatus* extends further to the south while *S. mentella* ranges further to the north. However, both species co-occur in a large are that, includes the Gulf of St Lawrence and off southern Newfoundland. These species look almost identical and the only relatively quick and reliable morphological test to distinguish them is by counting the anal fin rays. This difficulty in distinguishing species has had large repercussions for how commercial catch data and fishery independent data have been interpreted for the stock. In addition to the difficulty in distinguishing the species, strong sub-population structure exists in most *Sebastes* species. These species are long-lived mouth brooders with low fecundity and old age at maturity. All of these characteristics make the east coast *Sebastes* a difficult complex to assess. Even when data are available it is often flawed or difficult to interpret in a manner that would aid the provision of assessment advice.

One of the peculiar characteristics of Gulf of St Lawrence (unit 1) redfish is that strong year classes can appear for several consecutive years as pre-recruits and then completely disappear from the survey, never to appear again (Figure 2). It is not clear what is happening; it is unlikely to be a survey catchability issue and more likely that at some point the cohorts move to an area outside what was considered the original stock area. For this reason, at present, the stock definitions have changed from one species in two areas to two species in one area.

Two assessments are therefore still required, but the nature of the assessments is qualitatively different than before and the analysis is in many ways more difficult because it requires integration of data over two or more DFO regions. Because regions often use different survey sampling gears and have different protocols for collecting commercial data, we are now more likely to run into issues related to combining data that are not completely compatible in order to properly assess the whole stock.

Another major issue with the east coast redfish complex is that commercial data have not distinguished catches based on the two species but have reported a combined catch. It is therefore very difficult to divide the data retrospectively to determine which species was caught. In some cases, this division may be possible by simply using the geographic locations of catch landings, but in much of units 1 and 2 this would be very uncertain and would require considerable amounts of work. Survey proportions of species can be used to divide up catches, but this raises issues of independence between surveys and catch data that could bias the assessment results. In some cases, surveys have not distinguished the two species in their catches, which further complicates the issue of providing management advice.

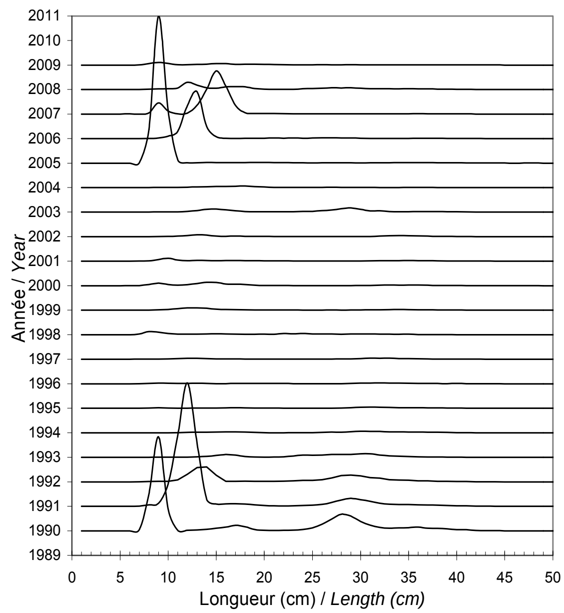

Figure 2. Cohorts of unit 1 redfish show large peaks in abundance in some year classes which persist in the survey for two or three year but then disappear before recruitment to the fishery. Disappearing cohorts like this are common for unit 1 redfish and may suggest migration and/or misidentification of the stock area.

East coast redfish used to exist in very high abundance but they are currently at only a fraction of their biomass levels from the 1980s. Consequently, east coast redfish have been labelled threatened and endangered by COSEWIC. DFO has now been tasked with determining a recovery potential assessment for these species. This is problematic because of the issues discussed above. An RPA requires that we have a definition of recovered, therefore it demands that we develop a precautionary approach with reference points and a legitimate assessment. Furthermore, the RPA demands projections under various fishing and natural mortality scenarios, thus a harvest control rule needs to be developed. The RPA is demanding in one pass what the redfish assessment apparatus in three regions has not accomplished in about 30 years of work. Results will be produced by this process, but they will inherently contain many of the issues related to the discussion above.

Doug Swain – Witch Flounder (Gulf)

Witch Flounder in the Gulf of St. Lawrence (NAFO Divisions 4RST)

Witch Flounder, *Glyptocephalus cynoglossus*, is widely distributed in the Gulf of St. Lawrence. Seasonally, Witch Flounder juveniles of less than 30 cm live in the deep channels year round while adults move up onto the shelves in the summer and overwinter in the deep channels. Landings averaged 3700 t in 1960-1980 but dropped to only 765 t in recent years (1991-2009).

There are two fishery independent research vessel surveys, one in September for the southern Gulf (NAFO area 4T) and one in August in the northern Gulf (NAFO areas 4RS). Assessment is confounded by several changes in vessel, gear type and sampling protocol. Some adjustments for changes in fishing efficiency were made based on comparative fishing experiments and the present standardization is based on night tows from the vessel ‘Lady Hammond’ using a ‘Western IIA’ trawl.

Changes in fishing mortality do not appear to explain changes in biomass throughout the time series. Even with the lower catch in recent years, fishing mortality appears to be increasing. The abundance of large fish declined sharply in the early 1990s and has not recovered despite relatively high abundances of small fish. This suggests that mortality is high. Changes in productivity have occurred throughout the southern Gulf demersal fish community, with decreased mortality for small fish and increased mortality for large fish.

A surplus production model produced a good fit with the research survey index. The model suggested that catch at MSY is 1000 t and that biomass in 2006 was about 30-50% of K. However, it does not explain how catches of 3500 t were sustained throughout the 1960s and 1970s.

The main questions are related to the stock decline in the early 1990s and the failure of the stock to rebuild despite strong recruitment. Management wants to know if a catch of 1000 t is sustainable at the stock's current level of productivity.

From the participants at this workshop, it was noted that seal populations have increased dramatically in recent years and the question was raised of whether seal population and seal diet data can be used as a prior or a variable in a Witch Flounder population model to try to explain increased mortality? In fact, there are two large seal populations in the Gulf, but seal diet analysis is inconclusive in determining their effect on the Witch Flounder population. Seal diets and foraging behaviours are different for the two species, however, and the seal distribution is not homogeneous in the zone. Discussions of these issues are still ongoing.

A number of additional approaches were suggested: two-state production models incorporating a change in productivity, Leslie life table analysis, spawner per recruit and yield per recruit analyses, and constructing abundance indices by comparing survey catch rates between Witch Flounder and species with analytical assessments. The life-history data required for some of these approaches (e.g., life table analysis) are not available, but may be forthcoming from on-going ageing studies.

Margaret Treble – Turbot (Central and Arctic)

Case Study: Greenland Halibut

Background

The Greenland Halibut, *Reinhardtius hippoglossoides*, stock in SA0+1(offshore) is managed as a discrete stock shared with Greenland. The fishery began in 0B and 1CD in the 1970s and expanded into 0A and 1A in late 1990s. The fishery deploys multiple gear types, although trawls are the most common. A fishery independent annual research survey has been conducted by Greenland in NAFO area 1CD since 1997. A biennial Canadian survey has been conducted in southern 0A since 1999. A small area in 0A has been closed to fishing to protect sensitive benthic habitat.

Data and Assessment

Data available includes commercial landings and fishery data (CPUE, Length Frequency). There is limited biological sampling from fixed gear fleets. Surveys provide partial coverage and 0A surveys only occur biennially. There are also trawl selectivity issues - the analysis produces an index of population size, not an absolute value. The abundance of age 1 individuals in Greenland waters provides a recruitment index. There is no accepted ageing method and no accepted analytical model for the fishery. Yield-per-recruit, XSA, and Aspic surplus production model analysis have been tried with satisfactory results. At this point the assessment is descriptive.

Survey Issues

Buffered random depth stratified bottom trawl survey (population indices). Larger fish can escape the trawl (i.e. mature fish, particularly females, are not caught in the survey).
Only a portion of the stock area is included in the surveys in any given year. Greenland Halibut are highly migratory, moving within and between stock areas. The current survey design may not be sufficient to detect changes in stock status.

Unanswered Management Questions

Advice on TAC is derived from available data using expert judgment.
Fishing mortality cannot be calculated; even relative mortality indexes (catch/survey biomass) are questionable due to poor survey coverage and trawl selectivity.
Spawning stock biomass cannot be determined.
Recruitment estimates are weak (only from a portion of the stock area and based on the Petersen method).
Precautionary approach reference points have not been identified for this stock.
Harvest control rules have not been developed.

Carolyn Miri –Wolffish of the Northwest Atlantic (Newfoundland)

All three species of Wolffish in the Northwest Atlantic are listed on Schedule-1 of Canada's Species-At-Risk-Act (SARA): Northern Wolffish and Spotted Wolffish are "threatened", and Atlantic Wolffish is of "special concern". These species are the subject of long-term monitoring and periodic reassessment according to SARA requirements, and present three special challenges for assessments. (1) the SARA ecological unit is the Designatable Unit" (DU) The Wolffish DU encompasses all Northwest Atlantic waters within Canada's 200-mile limit. This Wolffish DU requires the analysis of research vessel survey data from four DFO Regions (Central & Arctic, Newfoundland & Labrador, Nova Scotia-Bay of Fundy, Gulf of St. Lawrence); thereby involving a myriad of gears, ships, seasons (etc.) that have not been standardized across Regions. (2) COSEWIC (Committee On the Status of Endangered Wildlife In Canada) requires population decline rates to be analyzed over three generations, thus population projections should be modeled for three generations. (3) no quantitative assessment or predictive model exists for Wolffish populations.

In addition, other challenges should be addressed while assessing Wolffish with respect to COSEWIC criteria: 1) there have been no "directed" fisheries for any of the three Wolffish species in Canada's Exclusive Economic Zone (EEZ), except for a small fishery in the Gulf of St. Lawrence; and 2) all by-catch of Wolffish species in commercial fisheries are combined and reported as "catfish" by Canadian fishers operating within Canada's EEZ (DFO-NL Zonal Interchange Format landings database; 1985-present) and NAFO member countries fishing mainly outside Canada's 200-mile limit (Northwest Atlantic Fisheries Organization's STATLANT-21A database; 1960-present). An exception to aggregated commercial data is the Canadian Fisheries Observer database (1978-present), in which observers always report Wolffish catches and discards at the species level on a set-by-set basis while at sea aboard commercial fishing vessels. However, annual average observer coverage is only 5-8% for fisheries occurring in Canadian Atlantic waters.

Furthermore, other uncertainties concerning fisheries data exist with respect to the following: [i] All commercial fishing gears catch adult Wolffish, but not young-of-the-year (YOY), except for shrimp trawls, which catch YOY but do not retain adults due to internal Nordmore grates or other groundfish excluders. [ii] Commercial discarding and live release of Wolffish usually occurs unreported. [iii] Survival rates of Wolffish after release from fishing gear remain unknown.

Meeting attendees recommended that observer-reported catches could be summed each year by fishery/ species/ NAFO Area (etc.); then a ratio could be applied to aggregated (unspeciated) commercial data to estimate the amount of by-catch of each Wolffish species in specific fisheries. A caution was raised for the observer data regarding covariance between the different Wolffish species in commercial catches. Investigation of effort was also suggested for each fishery reporting Wolffish by-catch; but in the context of determine whether effort for a "directed" species represents that of a "by-catch" species, such as Wolffish. It was also recommended that a Bayesian Surplus Production model be applied to research survey indices for each Wolffish species by DFO Region. The results of the regional analysis would be summed over the whole DU. Finally, it was suggested that Wolffish otoliths collected since 2001 during DFO-NL research surveys be aged to allow subsequent age-based assessments.

Lei Harris – Cusk (Maritimes)

Cusk (*Brosme brosme*) is a groundfish landed along the Atlantic coast. There is no directed fishery for Cusk but it is caught as by-catch in several fisheries. Cusk is principally caught in fisheries for other groundfish, especially Cod and Haddock longline fisheries. Georeferenced landings from groundfish fisheries are recorded in Maritimes region databases. This data source provides the longest time series for the species. Based on trends in longline CPUE, Cusk abundance appears to have declined since the 1980s. CPUE may have been stable or declining slightly in recent years. It is not known how changes in management have affected catch rates. Cusk are also caught in invertebrate traps (mainly lobster pot fisheries). Finfish, including Cusk, were landed legally in the lobster fishery until 1999 but now must be discarded. These discards are generally not reported.

Anecdotal information suggests that Cusk by-catch in the lobster fishery may be high. A special sampling program to quantify this by-catch was undertaken between 2005-2007. Sampling focused on Lobster Fishing Areas (LFAs) 34 and 41, which includes the geographic areas with the highest Cusk landings from the longline fleet. The results of the lobster sampling program estimated by-catch by number and then converted the count to mt based on the average length in the sampling area and a length weight relationship. There were some issues in these estimates: 1) Only part of LFA 41 was sampled; some effort in LFA 34 was not assigned to a grid, therefore it was not used (~5%); mortality rates do not include Cusk used as bait or Cusk mortality after being returned to the water. There are no estimates from other LFAs and no estimates for other fisheries, such as crab fisheries.

Other various sources of data provide a partial picture of the status of Cusk. Industry based longline surveys have suggested that Cusk may still be widespread and common. Although these surveys provide valuable information, they were initiated after the decline was observed in the commercial CPUE. The halibut longline survey began in 1998. This survey includes the hard bottom, deeper waters, and geographic areas preferred by Cusk. CPUE in this survey from 1998 to the present appears to have fluctuated without trend, although there may be a slight decline over the time series. It should be noted that the highest CPUE in the time series occurred in 2009. The 4VsW sentinel survey is a longline survey on the Eastern Scotian Shelf that has been conducted from 1995 to the present. Recently, the number of stations was drastically reduced, making this survey less useful for future monitoring of trends. Other sentinel surveys, such as the area 5Z fixed gear, Monkfish, skate, ITQ, are too limited in time span or area, or use a gear type that is inappropriate for providing any information on Cusk. DFO research surveys do not sample Cusk well and therefore are inconclusive.

Cusk and SARA
COSEWIC assessed Cusk as Threatened in May 2003 with the following rationale:
"The main population … has been in decline since 1970. Over three generations, the decline rate is over 90%, and the fish occurs in fewer and fewer survey trawls over time. Fishing, unrestricted until 1999, is now capped but remains a source of mortality. "

In April 2006, the Governor in Council referred the assessment back to COSEWIC for further information and consideration since all available information was not used in the assessment. In December 2006, COSEWIC reaffirmed the original assessment without reassessing the species, citing an absence of new information that would lead to a change in the status of this species.

DFO has various requests for advice, including a socio-economic analysis, development of management scenarios for SE analyses, and recovery planning. There are many challenges to meeting these requests: 1) earlier data from fisheries are less reliable; 2) there is unreported fishing mortality; 3) there have been changes in management for quota species and for by-catch species; 4) there is no dedicated survey (no fisheries independent data source that covers the period of higher abundance); 5) there is no age determination for this species; 6) there are some indicators of status but there is no estimate of abundance, the magnitude of decline is not known and current trends in abundance are not known.

Fisheries and Resource Assessment for Hagfish in the Maritimes
Sherrylynn Rowe

Sherrylynn Rowe provided an overview of fisheries and resource assessment for Atlantic Hagfish (*Myxine glutinosa*) in the Maritimes Region. Atlantic Hagfish is distributed in the North Atlantic from Florida to Davis Strait, around southern Greenland and Icelandic waters, and from the Mediterranean Sea to Murmansk, including the North Sea and the waters around the UK. They are found in depths <1200 m, in temperatures <14 ºC, in salinities >32 ppt, and seem to prefer areas with soft substrates and low current velocities.

There has been a directed fishery for hagfish off Nova Scotia since the late 1980s. At present, there are seven fishers authorized to harvest hagfish in the Scotia-Fundy portion of Nova Scotia. Of these fishers, two were granted permanent commercial access in 1997, four remain at the exploratory stage, and the remaining one received experimental access in 2005. The hagfish fishery is conducted using baited traps which are modified plastic barrels (no larger than 38" high and 24" in diameter) punctured with four funnels from Korean style hagfish traps and containing a minimum of 24 escape holes. Management measures presently employed in the hagfish fishery in the Maritimes Region include: trap limits, minimum escape hole size (≥1/2" diameter at present, ≥9/16" until 2009), 100% hail-out and hail-in, at-sea observers (one observed trip per NAFO area per year since 2009), 100% VMS, completion of a standard monitoring document, and 100% dockside verification of catch (monitoring rate was approximately 20% prior to 2009).

Landings increased during the early years of the fishery to reach 1757 t in 2004, after which they declined to 1228 t by 2007, before reaching a peak of approximately 2066 t in 2009. During the early years of the fishery, landings were derived almost exclusively from NAFO Division 4X. Since 2000, the fishery has expanded eastward and NAFO Division 4W has also become an important source of hagfish landings. Landings were also reported from NAFO Division 5Z for the first time during 2008. The hagfish fishery is primarily an emerging fishery in the Maritimes Region and like many emerging fisheries, there are a number of assessment challenges.

Because hagfish primarily live within soft sediments, they are seldom detected by visual surveys and have a low frequency of occurrence in trawl surveys thus limiting the potential for fishery independent metrics of abundance (e.g., population and biomass estimates). With respect to fishery data, industry has indicated that reported landings information may not be reliable, particularly prior to 2009, as the level of dockside monitoring was low during the early years of the fishery, there was no sequentially numbered monitoring document, and the conversion weights used to estimate landings may not have been applied consistently. Fishing effort has also been poorly captured to date, limiting our ability to assess the degree to which catch-per-unit-effort might be a suitable abundance index. In addition, sampling of commercial catch has been minimal.

Life history and reproductive ecology of hagfish are poorly understood. There is no known method to determine hagfish age or practical method for tagging. Females strongly outnumber males in the commercial catch but it is unknown whether this reflects sex differences in catchability or skewed sex ratios in the population. Reproductive rate is suspected to be low, with mature females producing 12-20 large eggs over a protracted development period. Eggs may be deposited in burrows although there is much uncertainty given that only three embryos of Atlantic Hagfish have ever been collected. All available information suggests that these are slow-growing, long-lived animals with limited reproductive potential. In the short term, activities pertaining to hagfish in the Maritimes Region are anticipated to focus on: (1) improved monitoring of catch and effort, and (2) investigation of trap selectivity, as well as spatial variation in size/sex composition and life history.

MARINE MAMMALS

Walrus (*Odobenus rosmarus rosmarus*) stock assessment. R.E.A. Stewart (Central and Arctic)

Walrus are a large amphibious marine mammal represented by two subspecies: the Atlantic walrus, *Odobenus rosmarus rosmarus,* and the Pacific walrus, *O. r. divergens*. Only Atlantic walrus occurs in Canada, currently grouped into 7 stocks.

The simplest questions in stock assessment are: What are the stocks?; How many are there?; and What are the removals and additions? For walrus in Canada we have estimates of the minimum number alive, based on surveys at haulout sites, for some stocks and no information at all for others. There are general estimates of reproductive rate but no current stock-specific estimates. Catch statistics are approximations and we know nothing about natural mortality. With these limited data, is there an assessment method to determine if the current reported removals are sustainable?

Potential Biological Removal (PBR) is the name given to a Catch-limit algorithm / Limit Reference Point developed for marine mammals in the United States in response to the legislated requirements under the Marine Mammal Protection Act (MMPA). Its formulation

$$PBR = N_{min}*0.5* R_{max}*F_R$$

requires minimal data. Detailed modelling has shown that if the estimate of minimum population size (N_{min}) is the 20th percentile (~lower 60% log-normal confidence limit) of the abundance estimate, the simulated populations of marine mammals maintained or exceeded their Maximum Net Productivity Level (MNPL) for 100 simulated years. Populations starting at 30% of carrying capacity (K) also recovered to at least MNPL after 100 years. The MMPA and DFO's National Marine Mammal Peer Review Committee accept haulout counts of pinnipeds as N_{min}. The only empirical derivation of the maximum net productivity rate (R_{max}) is for a rapidly expanding population of Pacific walrus (R_{max} = 0.07). Theoretical values for pinnipeds (0.12), which generally pup annually, are thought to be too high for walrus, which calve about every 3 years, similar to comparably-sized odontocetes (R_{max} = 0.04). The Recovery Factor (F_R) ranges from 0.1 to 1.0 with 0.5 used in the absence of more detailed information because 0.5 allowed nearly all modelled populations to recover when used with N_{min} = 20th percentile.

Examples of the use of PBR span a range of data-deficiencies for walrus. The spatially limited West Jones Sound stock has been surveyed for several years and has a recent estimate of N_{min} (haulout count). Using R_{max} = 0.04 or 0.07 and F_R = 0.5 (possibly depleted) or 1.0, estimated PBR exceeds current reported harvest levels.

In Foxe Basin, there are no stock-specific data and only a rough population estimate from the late 1980s (5500, 95% CI 2700-11200). Using the lower 95% as a conservative N_{min} = 2700 and the previous ranges of R_{max} and F_R, PBR = 27 to 95. Current removals are thought to be about 150, exceeding this lower limit, but the survey is out of date and unreliable for this analysis.

Walrus are spread more or less continuously from the NW corner of Hudson Bay to West Greenland. This is the North Hudson Bay-Davis Strait stock which is extreme in its lack of data. Further clinal stock subdivisions are expected; survey coverage in Canada is limited to one small area on SE Baffin Island. Catch statistics are poor in Canada and imperfect in Greenland, where there has been a noticeable decline however. Calculating a stock-wide PBR is not feasible.

While PBR has provided some information on the sustainability of current harvests, walrus remain seriously data-deficient. Surveys should be adjusted for survey-availability but hauling behaviour can be synchronized by recent storms, which also tend to synchronize survey effort. The risk of applying average hauling out estimates to such behaviour has the potential to seriously over-inflate the direct counts. Direct estimates of R_{max} will be difficult to ascertain with current removal rates.

PELAGICS

Tom Therriault – Eulachon (Pacific)

British Columbia Eulachon *Thaleichthys pacificus*

Eulachon is one of seven smelt species endemic to the NE Pacific and is distributed from California to Alaska. Eulachon are semelparous and return to rivers to spawn at age-3. In British Columbia, spawning generally occurs in March or April but Fraser River eulachon spawn during May. Eggs and larvae are flushed from the river into the estuary where they reside for an unknown amount of time before migrating to offshore waters. Eulachon are found offshore at age-1+ and age-2+. The major eulachon producing rivers in B.C. are the Nass River, Skeena River, Kitimat River, Kemano River, Bella Coola River, Owikeno River, Kingcome Inlet, Klinaklini River and Fraser River but Eulachon have been reported sporadically from a number of other mainland systems.

Eulachon are an important food, social, and ceremonial species for all BC First Nations (high cultural significance). Beyond the Fraser River, Eulachon are primarily used to make eulachon grease; a commodity that is highly prized and traded. The species collapsed coastwide in the mid 1990s and although formal assessments began on the Fraser River in 1995, none of the other stocks are assessed. Eulachon have essentially disappeared from many Central Coast rivers, with limited/no fish reported in over a decade. The Fraser River stock, which is the largest run in BC, remains at a precariously low level. Eulachon are caught as by-catch in trawl fisheries, especially shrimp trawls. The species is under consideration for potential SARA listing and will be reviewed by COSEWIC in April 2011.

Science Advice
What are the harvest opportunities on the Fraser River? FAM request for commercial/FSC fisheries.
What is the status of Eulachon beyond the Fraser River? COSEWIC review of BC Eulachon.
What would recovery targets look like for BC Eulachon? RPAs are required under SARA. Targets provided to recovery teams.

Existing Scientific Data
There are three potential indicators of stock status: 1) egg and larval survey in the Fraser River that provides a SSB estimate; 2) Eulachon index from an offshore multi-species trawl survey; and 3) catch data from the Columbia River (largest Eulachon run in the world). The 4th was a management test fishery that was discontinued in 2005. None of the indicators provide forecasts of abundance(?)..

The egg and larval survey assesses SSB by estimating the total number of eggs produced (must count eggs/larvae). The assessment uses egg/larval density, Fraser River discharge and eggs per female to estimate SSB. The Fraser River SSB, estimated from the egg and larval survey, was 10 tonnes in 2008 and 14 tonnes in 2009. The offshore Eulachon Index comes from data collected in an annual multi-species trawl survey off the West Coast of Vancouver Island and in Queen Charlotte Sound. This provides an index for Eulachon dating to the 1970s, making it the longest dataset available. However, based on DNA results, the offshore index represents mixed stocks. The Fraser/Columbia River have been fished for 100s of years. Initially, these were First Nations fisheries but commercial fisheries have operated since the 1930s-40s on the major eulachon rivers, notably the Fraser and Columbia. Prior to recent management interventions, Eulachon catches likely provided a reasonable proxy for Eulachon abundance, especially on the Columbia River where the run is substantially larger. In 2005 the Fraser River was closed to commercial fishing.

Fraser Test Fishery
- Conducted from 1995-2005 by FAM. Has not been conducted since.
- Designed to allow commercial openings once Eulachon action levels had been reached. Could provide data on run timing and independent measure of abundance.
- Test fishing site at New Westminster was fished daily for 15 min to enumerate abundance. Method was standardized for gear (gillnet) and tide.

Fraser River Assessment
- A stoplight approach was developed based on four indicators to allow/stop commercial fishing for Fraser River eulachon.
- A 2005 review concluded the egg and larval survey was the best available indicator for SSB (the offshore index and Columbia catch have been included for consistency).
- Fraser River Eulachon remain below current action levels with no signs of SSB returning to historic levels.

Major Gaps
- No assessment of BC Eulachon stocks pre-collapse. Thus, no baseline to contrast changes against.
- Currently, only the Fraser River Eulachon stock is assessed. No qualitative or quantitative analysis of other Eulachon runs. Science advice still required for management.

- Offshore stock structure not well understood. Age determination not possible, several key baseline rivers not sampled for genetic analyses.
- Recent genetic analyses are providing some information on the amount of spatial and temporal offshore mixing. This is not currently used for management.
- Apparent discrepancy between in-river SSB estimates and the offshore Eulachon index. Multiple modeling attempts have failed to reconcile this issue.
- Catch records not overly informative.
- Limited TEK information. Data often not shared with DFO and difficult to relate to current indices.

Eulachon Summary

- FAM will need harvest advice.
  - ongoing for Fraser River
  - needs development for other rivers
- SARA will need recovery advice.
  - targets for each listed unit

Jake Schweigert and Jaclyn Cleary – Pacific Herring (Pacific)

Pacific Herring are short-lived, generally less than 10 years, maturing at age 3. They spawn in the inter-tidal and shallow sub-tidal zones, are an important commercial and forage species and are prized by First Nations. There are 5 major and 2 minor stock areas that are monitored annually on the British Columbia coast as well as a number of other areas that support spawn on kelp fisheries but are surveyed intermittently.

Herring spawning and the release of milt turns the water white and the area of egg deposition is surveyed annually as an indicator of population abundance. Monitoring these spawning locations is a fundamental component of assessment and resource management of eastern Pacific Herring stocks. Spawn surveys are conducted from the surface or using SCUBA. Data is collected on time, location and extent of each spawning event.

Pacific Herring in the main assessment regions is managed using a risk adverse policy that has been in place since 1983. The harvest policy has aimed for a harvest rate (HR) of 20% of forecast mature biomass. Beginning in 1986, a fishing threshold or "cutoff" was implemented which was set at 25% of the estimated unfished mature biomass, effectively ensuring a spawning reserve. The fishery is focused on the major migratory stocks. If the forecast is above the Cutoff, HR is 20%. If the forecast is near the Cutoff, then the HR = Forecast – Cutoff. If the Forecast is less than the Cutoff, there is a recommendation for no Harvest. Modified Harvest Control Rules are applied to the minor stocks with a 10% HR of forecast biomass but no Cutoff level. Since the other stocks are not monitored regularly and are data limited, there are no fixed HR rules in these areas.

In particular, Statistical Areas 10 and 12 have an iintermittent time series of spawn survey data and limited catch data prior to 1980. Both areas currently support a SOK fishery but there is no basis for evaluating whether the fishery is sustainable or if it can support the current level of removals. SOK licenses are not relocatable and as such there is a need to develop rules for closing the fishery in the absence of a Cutoff in these areas, and subsequently a basis for determining if and when a fishery could be resumed.

Francois Gregoire – Atlantic Herring (Quebec)

Quebec North Shore (NAFO Division 4S) herring stocks

Context:
There are two stocks of Atlantic Herring (*Clupea harengus harengus*) in the Quebec North Shore waters. Spring herring generally spawn in April and May, and fall herring in August and September. Even though the geographic size of the Quebec North Shore territory is significant, most herring landings are concentrated in only three NAFO unit areas, namely 4Sz in Division 4S WEST and 4Sv and 4Sw in Division 4S EAST (Figure 3). Spring herring are usually fished in 4Sz with gillnet and fall herring in 4Sv and 4Sw are fished with traps.

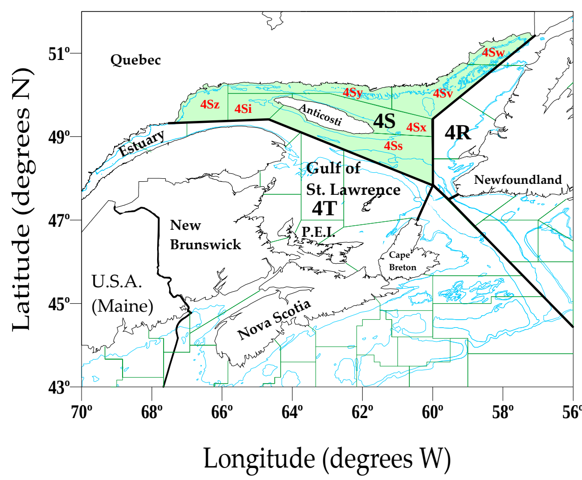

Figure 3. Map of unit areas of NAFO Division 4S (Quebec North Shore). Division 4S is identified by the coloured area.

Herring landings on the Quebec North Shore saw rapid expansion through the 1970s. From less than 80 t per year during the 1960-1970 period, landings have reached an average of 595 t since 1979 (Figure 4). Over the years, herring landings on the Quebec North Shore have also shown significant annual variations due to fluctuating markets; the most significant one being bait.

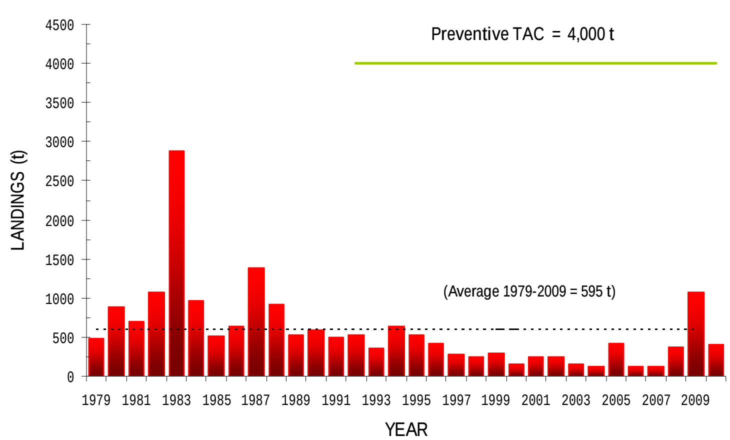

Figure 4. Herring landings and TAC (t) for NAFO Division 4S between 1979 and 2010 (average landings for the years 1979-2009 are indicated by the horizontal dotted line).

There has been an extensive effort over the past five years to develop the Quebec North Shore herring fishery because cod is not coming back. Despite increased interest by some fish harvesters, annual landings have remained low as has the amount of biological samples.

For now, there is no SPA type (Sequential Population Analysis) analytical assessment conducted on the two Quebec North Shore herring spawning stocks. Consequently, it is impossible to calculate their respective abundances, fishing mortalities and minimum reference points, which could help establish, according to the Precautionary Approach, a strategic framework for the fishery and a Total Allowable Catch (TAC). Since 1992, the Quebec North Shore herring stocks are managed using a preventive TAC of 4,000 t.

The Fisheries and Aquaculture Management Branch of DFO has requested scientific advice on these stocks for the 2011 and 2012 fishing seasons. This is a challenge as these stocks represent good cases as data-poor fisheries.

Objective:
The main objective of this presentation to TESA members was to collect their ideas and suggestions concerning the possibility of developing some kind of harvest strategy for these two stocks.

Results:
Different possible solutions were discussed at the TESA meeting. Among them, the Depletion-Corrected Average Catch (DCAC) method presented by Dr. A. MacCall seems the most promising.

John Wheeler – Atlantic Herring (Newfoundland)

Newfoundland East and South Coast Herring
“Qualitatively Rich / Quantitatively Poor”

Based on tagging experiments, this stock consists of five coastal stock complexes. There are two spawning components: spring and autumn spawners. Until recently, spring spawners dominated in most areas. The various populations are most discrete during the spring spawning season. Spawning occurs in coastal waters, in <10 m water depth with a high degree of homing: > 75% of herring return to the same area to spawn in successive years. During summer, herring undertake northward feeding migrations where there will be substantial intermixing of local populations within the bays through the summer and early fall. In the fall, the herring return southward to overwintering areas. There are multiple spawning populations within each stock complex; complexes are defined for fisheries management.

Table 2. shows the data sources available for assessment.

Table 2.

Spring research gill net catch rates	**1982 - present**	**Catch rates**
Fall research gill net catch rates	1980 - 1991	Catch rates
Acoustic survey biomass estimates	1983 - 2000	Absolute
Gill net logbook catch rates	1996 - present	Catch rates
Gill net fisher abundance index (from logbooks)	1997 - present	Observational
Gill net fisher abundance index (from telephone surveys)	2006 - present	Observational
Purse seine fisher abundance index (from telephone questionnaires)	1996 - present	Observational

The fall research survey protocol is as follows: Five standardized gill nets -Panels : 50.8, 57.2, 65.5. 69.9, 76.2 mm, Fished for 45 days at approximately the same time each year. Fished from a fixed location that is consistent among years. Nets hauled once per day, weather permitting. Daily record of catch numbers recorded by net size. In addition, 12 samples (2 per week) of 50 fish per sample, 10 chosen randomly per net, are taken for processing.

Concerns

- Sample sizes per stock area are small (4 to 9 fishers per area).
- Spring research gill net program is designed to catch spring spawning herring at a time when stock mixing (spring and autumn spawners) is minimal.
- Within the last 3 to 6 years, the percentage of autumn spawners has increased substantially in research gill net and commercial fishery catches.

Annual catch rates from harvesters suggest a temporal shift in the fishery.

Several models or analyses have been attempted to assess stock status over the years. These include: Biomass estimates from acoustic surveys (1985 – 1993); Extended survivors analysis (XSA) (1994,1995); Research gill net catchability analysis (1996); Integrated catch at age (ICA) (1998, 2000); Performance Reports (2002, 2004, 2006, 2008, 2009); ADAPT (2008, 2009); SURBA (2009).

Current Background and Methodology

The above models were used to summarize the current status and prospects for each stock. They do not provide biomass estimates or biological reference points. A traffic light method (Caddy 1998) has been proposed to assess the fishery. Five series of abundance indicators are evaluated:1)Research gill net catch rates; 2) Gill net logbook catch rates; 3) Gill net fisher observations (from logbooks); 4) Gill net fisher observations (from telephone surveys); 5) Purse seine fisher observations (from telephone surveys). Additionally, there is an evaluation of biological characteristics, including research gill net age composition and year class sizes.

Sources of Uncertainty

- The inability to estimate current stock sizes and exploitation rates, and to place these estimates within an historical context. Models that depend on catch at age are difficult to calibrate due to low catch levels in some areas and years. Such models are further complicated due to uncertainties in catch at age. Estimates of dead discards in the purse seine fishery and estimates of herring caught for use as bait were added to the catch at age matrix this year (2010). However, population sizes still could not be accurately estimated using ADAP.

- Evaluations of trends within abundance indices are dependent, among other things, upon the uncertainties associated with each index. Due to the limited fishery and research data, sample sizes for most indices are generally small, resulting in higher uncertainties. This becomes particularly evident in their resulting residual patterns in ADAPT calibrations.
- The inability to estimate population sizes has precluded (to date) the calculation of stock status zones and reference points. This severely limits the implementation of the precautionary approach in fisheries management decisions.

Management Concerns

- The lack of biomass estimates upon which to establish TACs.
- The lack of limit and upper stock reference points to allow the implementation of the precautionary approach in a decision making framework.

FRESHWATER AND ANADROMOUS FISHES

Ross Tallman – Arctic Charr (Central and Arctic)

Charr biology

Arctic Charr, *Salvelinus alpinus*, has a unique life history compared to other anadromous taxa. Intra-specific variation both within and between stocks in life history traits important to production is considered the highest of freshwater fishes. There are three main forms of charr; anadromous, resident and land-locked. The anadromous form migrates to sea for summer feeding but must return to freshwater to over-winter. The resident form spend its life in freshwater but has access to the sea. The land-locked form cannot access the sea due to physical barriers. The anadromous form is thought to return to its natal system to spawn but may not return to the same river to over-winter. There is no northern limit to the distribution of charr

Arctic Charr are extremely important to the economies of northern communities, both for subsistence and commercial purposes. All communities in Nunavut utilize Arctic Charr. Management and the supporting science are complicated by the legal requirements of working within settled aboriginal land claim areas and all operations must proceed within a prescribed co-management framework.

There are conflicting goals between DFO resource management and agencies such as the Nunavut Wildlife Management Board. For example, DFO wishes to manage using limit reference points on commercial fisheries while the Nunavut Wildlife Management Board is legally required to set a total allowable harvest (commercial and subsistence) for each fishery. Further complicating the picture is the Government of Nunavut's aim to eco-certify charr fisheries. Thus, there are high expectations for science advise for a large number of stocks spread over a vast area.

DFO and the co-management boards manage 195 commercial charr stocks in Nunavut and the NWT. Few of these stocks has been sampled more than once or twice. Effort information is generally nonexistent and catch information is available for commercial licenses but generally not for the subsistence catch.. Many important stocks are harvested both for subsistence needs of the community and commercially. Demographic parameters vary widely among charr stocks making it difficult borrow parameters estimates from other stocks. Many fisheries involve mixed stock harvests, with the proportions of each stock likely varying from year to year.

There are additional sources of uncertainty. The understanding of the marine portion of the life cycle is limited. The ,makeup of stocks running charr rivers is unknown in most rivers.. Spawning areas and overwintering feeding areas are only vaguely defined in most cases. Spawning adults may spawn once every 2 to 10 years. In the intervening times they may over-winter in other systems. Finally, climate conditions are rapidly changing, therefore the limited data available may not represent future stock characteristics. Assessments are also under considerable pressure to formally integrate traditional ecological knowledge into the final advice.

Technical problems
A standard harvest rate is uncertain. Currently, a cautious rate of 5% of the presumed stock size is being used, but given the variability in charr populations it is likely inaccurate for all stocks. In the one documented case of significant over-harvesting in the Sylvia Grinnell River, the stock has taken decades to show signs of recovery (Gallagher and Dick 2010). Little is known about limiting habitats in freshwater – whether spawning or over-wintering or both are key factors for total production.

Current data includes some catch records but log books to record effort have not been successfully implemented due to language and cultural barriers. There is some biological data from 95 stocks. Recently, there has been a concerted effort to acquire fishery independent data from emerging stocks within Cumberland Sound, Baffin Island.

Rod Bradford – Striped Bass (Maritimes)
Bay of Fundy Striped Bass: Monitoring and Assessment

Striped Bass (*Morone saxatilis*) are anadromous perch that reach lengths of greater than 1 m. They are long lived, frequently reaching 30 years in age. Adult females are highly fecund, producing 10^5-10^6 eggs per female. Striped Bass are widespread along the Atlantic seaboard. Spawning populations are generally considered to be discrete and extend into Canada. Three spawning populations were known from the Canadian portion of the Bay of Fundy, one is healthy (Shubenacadie River), another may persist as a remnant population (Saint John River), and the third (Annapolis River) was extirpated a few decades ago.

Several drivers have generated a need for DFO Science Advice concerning the status of Bay of Fundy Striped Bass. First, they have been designated as threatened (COSEWIC 2004). Depending upon the outcome of a pending update status assessment, which will re-visit the status of these populations as a single Designatable Unit, a Recovery Potential Assessment may be required for one or more of the populations. Second, critical habitat must be designated for this species. Third, fisheries management requires advice on directed and non-directed fisheries for Striped Bass. Finally, in-stream tidal power management will require a thorough understanding of Striped Bass biology.

Bay of Fundy Striped Bass are fished for aboriginal food, social and ceremonial uses and recreational angling purposes. There are no specified communal allocations for First Nations. An estimated 8,000 anglers participate in the recreational fishery. A daily bag limit of 1 Striped Bass >68 cm TL is in effect from mid-June – October, catch and release is permitted during the May-June spawning season. There are no directed commercial fisheries and sale of by-catch was prohibited in 1996. There is an authorized retention of 1 Striped Bass >68 cm TL per day in some Gaspereau/shad and herring fisheries.

There is no data from the aboriginal fisheries. By-catch in commercial fisheries is obtained from returned logbooks but is not considered reliable. In the recreational fishery there is no reporting requirement. DFO has experimented with voluntary logbooks in recent years but the return rate was generally low (<25 percent).

Fishery independent data collection for the adult component of the Shubenacadie population does not have consistent funding to undertake annual monitoring, but consists of gathering data using a research trapnet fished in May 1999-2002 and 2008-2009. The data acquired gave information on daily catch, run-timing, some data relevant to mortality and recruitment, and basic biological data on adults and sub-adults. A beach seining program has been run to gather data on young of the year (YOY) since 1999, except for 2008. There have been fewer sets annually with time but the data provides information on distribution, abundance and growth.

Issues/Concerns

• Saint John River population

- Recent data indicates that the Saint John River population is probably extant and susceptible to directed capture and by-catch. Biological, ecological, and abundance information is non-existent.

- PSA (potential)

•Shubenacadie River population

- With assumption that means will be found to continue YOY surveys there is potential to assess spawner success and recruitment potential.
- Deficient in measures of:
    - –Adult status
    - –Removals/angler success (and associated effects on productivity)

INVERTEBRATES

Development of the Pacific Sea Cucumber Fishery: Phase 0 to Phase 2, 1995 to 2008. Nicholas Duprey and Claudia Hand (Pacific)

The Original Problem

Commercial exploitation of Pacific Sea Cucumber, *Parastichopus californicus,* began in BC in 1971. An experimental fishery occurred in southern waters in the early 1980s, which allowed markets to be established. There was rapid escalation in effort during the 1980s that led to conservation concerns and the implementation of various management actions. Initially, there was no useful time-series of fishery-dependent data or estimates of biomass for any portion of coastal BC. Biological information was insufficient and the age of Sea Cucumbers could not be determined. Area closures and arbitrary quotas were introduced in 1986 to limit effort, however, the number of licences continued to increase, quotas were often exceeded and CPUE declined in some areas. This led to quota reductions in 1989, licence limitation in 1991, further quota reductions in 1993 and area closures in 1994. An individual quota system was put in place in 1995.

The Approach Taken

The fishery was identified as a “developing and data-limited fishery” in 1995 and the Phased Approach to development was instituted (Perry et al. 1999). The phases are as follows: Phase 0, review of the species biology and fisheries in BC and elsewhere (Phillips and Boutillier 1998); knowledge gaps identified and recommendations for a Phase 1 fishery ‘fishing for information’ (Boutillier et al. 1998); analysis and evaluation of data collected during Phase 1 and recommendations for a Phase 2 fishery 'fishing for commerce' (Hand et al. 2008). The commercial fishery was maintained along 25% of the coast in static areas, which allowed the collection of time-series fishery data, and quotas were based on precautionary estimates of density, mean weight and a risk-averse harvest rate, all borrowed from neighbouring American jurisdictions.

During Phase 1, surveys of select commercially-open PFMA Subareas were conducted every three years to obtain estimates of the density of *P. californicus* and examine trends in density and the size-frequency distribution. Biological samples were collected for mean weight estimation. Density data from approximately 2,290 transects was collected in twelve survey areas along the British Columbia coast. Estimates from these surveys have shown that most survey areas have densities higher than the initial conservative assumption of 2.5 Sea Cucumbers per metre of shoreline. In 2008, all survey data were reviewed and new baseline density estimates for un-surveyed Subareas were calculated, by Region. This resulted in baseline densities of 6.0, 6.0, 4.1, and 1.9 Sea Cucumbers per metre shoreline for the North Coast, Central Coast, East Coast Vancouver Island, and West Coast Vancouver Island, respectively.

A key activity during the Phase 1 fishery was experimental fishing. In 1997, four Experimental Fishing Areas (EFAs) were established to compare population responses to different harvest rates over a range of habitat types. Four sites at each EFA were harvested annually at different rates and density surveys were conducted in the four sites and at a control site at 2 and 4 year intervals. The 10–year time series of EFA data was used as an input to a production model to estimate the rate at which Sea Cucumber populations were able to recover from a range of depletion-levels. The results of the analysis produced estimates of maximum sustainable harvest rates. The results indicated that the harvest rate of 4.2% used during the Phase 1 fishery was very conservative, being lower than the one percentile estimate for three of the four EFAs. A harvest rate of 6.7% was recommended for all areas of coastal BC except areas that are expected to have slow recovery, which would include areas similar one of the four EFAs (Hand et al. 2008).

A Limit Reference Point (LRP) was also established for the Sea Cucumber fishery using these model results. A LRP of 50% pre-fishery biomass was recommended and considered to be highly precautionary.

Ongoing Research

The long-term goal of the Department is to develop an ecologically-based management regime for a sustainable fishery through a better understanding of stock dynamics of the resource.

Three EFA research sites are still active and the collected data will be used to re-visit the model and update our advice on harvest rates and recovery rates in the future.

Newly-opened areas are surveyed before opening and their quotas are based on biomass estimates derived from the surveyed densities. No-take zones are also being established along the coast as new areas are opened to commercial harvesting. These areas will provide an opportunity to monitor natural trends in populations for comparisons to neighbouring harvested areas. Deep water populations (50-250 m) have been surveyed using remotely operated vehicles to compare near shore densities to deep water densities. These deep water populations act as pseudo-reserves, remaining in depths unattainable by commercial divers.

A study is underway to better understand the early stages of juvenile Sea Cucumber growth in a natural setting. A study is also underway to determine the speed at which Sea Cucumbers resettle in an area after it has been harvested and to better understand whether Sea Cucumbers migrate vertically or horizontally into depleted areas

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Fisheries and Resource Assessment for Sea Cucumber in the Maritimes

Sherrylynn Rowe and Jim Simon (Maritimes)

Sherrylynn Rowe and Jim Simon presented an overview of Sea Cucumber (*Cucumaria frondosa*) fisheries and resource assessment in the Maritimes Region. Interest in harvesting Sea Cucumber in the Maritimes began in 1989. During 1990, an experimental project was undertaken to assess the feasibility of a Sea Cucumber fishery in St. Mary's Bay, Nova Scotia but development of the fishery stalled due to a lack of market potential as this species is thin-walled relative to other Sea Cucumber species that are fished internationally. One experimental fishing licence was issued in 1996, although again, the small catches of small thin-walled animals were not marketable. In 1999, there was renewed interest in harvesting Sea Cucumber and six experimental/exploratory licences exist in the Scotia-Fundy area at present, covering portions of both the inshore and offshore, as well as the eastern and western Scotian Shelf. While most Sea Cucumber fisheries throughout the world are undertaken by divers, *Cucumaria frondosa* is harvested using variations of modified scallop/urchin gear. Average prices to fish harvesters have increased to approximately $0.40/kg in recent years. Management measures presently employed in Sea Cucumber fisheries in the Maritimes Region include: at-sea observers (primarily in the form of Industry technicians although there are occasional trips involving DFO certified at-sea observers to ground truth this information), 100% VMS, total allowable catch levels for each fishing zone, time limits (i.e., season and/or number of fishing days), 100% hail-out and hail-in, completion of standard monitoring documents and scientific logbooks during all trips, and dockside monitoring of catch ranging from 20-100% depending on the area. The Sea Cucumber fishery is an emerging fishery in the Maritimes Region, and like many emerging fisheries, there is little biological information to assess fishery sustainability. Small scale surveys have been conducted in some areas both before and after Sea Cucumber fishing activity. However, changes in factors such as survey area, survey design, vessel, and gear have made it difficult to compare survey catch rates over time. In addition to survey information, assessment of Sea Cucumber fishing activities currently includes an examination of landings, catch rates, size frequency data, and by-catch. Landings in the Maritimes Region have been increasing, with approximately 2765 t reported in 2009. Landings have been derived primarily from an inshore area of southwestern New Brunswick, although since 2006, an area in offshore NAFO Division 4W has also become an important source of Sea Cucumber landings. Trends in catch rates have been consistent with those that might be expected for an emerging fishery. Sea Cucumber size composition is monitored in the fishery through daily sampling of the catch. Variables measured have included: contracted length, contracted wet weight, circumference, body wall thickness, and meat weight. Standard measuring procedures have been employed but because Sea Cucumbers are comprised of 80-90% water and are able to swell and contract, there has been considerable variability in the data and investigation of improved size measurement techniques is warranted. Key information gaps pertaining to the assessment of Sea Cucumber fisheries in Maritimes Region include reliable metrics of Sea Cucumber abundance (e.g., biomass estimates), life history data required to determine Sea Cucumber productivity (e.g., age/size at maturity, growth, fecundity), and an understanding of the impacts of Sea Cucumber fishing gear on the benthic habitat.

Toad Crab fishery in Quebec (Jean-Paul Dallaire)

The toad crab fishery in Quebec targets 2 different species. The Toad Crab or Great Spider Crab is *Hyas araneus* and the Lyre Crab or Lesser Toad Crab is *Hyas coarctatus*. Both are distinguishable since *Hyas coarctatus* has a prominent winglike carapace extension posterior to the eyes. These crabs have not yet revealed all of their biological secrets, but we do know that they belong to the superfamily Majoidea (Oregoniidae family), as does the Snow Crab, and thus undergo a terminal moult to maturity. A mature female crab may mate with one or more mature male crabs and males may then copulate with more females if they are present in sufficient numbers. The terminal moult puts a limit on the number of years that males will be available to the fishery and this should be taken into account when implementing a harvesting strategy. Males can reach a size of 90 mm in carapace width while females reach their maximum at 60 mm. Their range distribution includes both sides of the Atlantic. On the east side of North America, they are found from Greenland to Cape Hatteras. In the Magdalen Islands, these crabs are usually fished at depths between 30 and 50 m, whereas *Hyas coarctatus* in Newfoundland and Labrador are mostly found at 60 to 140 m. The Toad Crab diet includes amphipods, polychaetes, bivalves, ophiuroids, gastropods, chitons, sea urchins and small crabs. They will also scavenge on dying or dead fish. Predation on Toad Crab larvae is done by other plankton and surface feeding fish, while the benthic phase is mostly preyed upon by ground fish species.

Since 2000, a toad crab fishery has been going on in Quebec, mostly around the Magdalen Islands in LFA 12A. The fishery management plan was at first implemented using an arbitrary individual quota (IQ), a 60 mm minimum size limit, fishing effort restrictions (maximum 65 traps of a volume not exceeding 2.1 m^3, a minimum 40 mm mesh size or a minimum of 4 - 65 mm circular escape vents, a closed fishing season), a prohibition on landing females, and a minimum participation clause of 10 days of fishing per year (1 day in LFA 12 counts for two days in LFA 12A) to avoid back pocket permits . Previous analyses of data taken from Snow Crab fishery surveys between 1992 and 2002 enabled us to extract a minimum carapace width based on morphological maturity in males . The 60 mm length ensures that more than 50 % of all mature males are protected.

<u>Magdalen Islands</u>
The last IQ was fixed at 29 500 kg, of which a maximum of 25 000 kg can be fished in LFA 12A and the remainder must come from LFA 12. The global TAC represents 265 000 kg for 9 fishers. Landings have always been less than 200 000 kg and the TAC has never been

reached, partly because fishers do not exploit adjacent LFA 12 where part of their quota comes from . Because this is a young fishery, data for stock assessments are scarce but come from mandatory logbooks, sales slips, and at-sea and at-port sampling. Historically, *Hyas coarctatus* constituted the majority of all toad crab landings in LFA 12A, but in recent years, there seems to be an increasing contribution of *Hyas araneus*.

For this fishery, managers usually want to know what next year's total TAC should be, if the existing fishing licences can become permanent and, since crab meat prices are higher in the spring, if an earlier spring fishing season can be implemented.

Data analysis indicates that CPUE from the landings has been in an upward trend in the last 6 years and the sustainability of the stock does not seem to be compromised by fishing activities . On the other hand, at sea sampling of commercial crab shows that the average carapace width of *Hyas coarctatus* has dropped since 2005, from 76.2 mm to 71.5 mm. At the same time, the carapace width of *Hyas araneus* remained more stable until 2007 (with an average of 72.9 mm) and then increased up to 75.0 mm in 2009. This could either be a sign of over exploitation, or simply due to the fact that both species do not have synchronous population dynamics, or even that *Hyas araneus* was favoured by some change in the environmental conditions. The size frequency distributions show no knife-edge effect at the legal size limit of 60 mm, suggesting this is not a recruitment fishery where most of the landings depend on newly entered recruits, as is often observed in North American Lobster fisheries.

Quebec North Shore

Another region, the North Shore of Quebec, also issues fishing licences, but landings have not been as stable as for the Magdalen Islands. Toad crabs are smaller than and not always as appealing to customers as Snow Crabs are. This limits the market to a meat industry where profits are dictated by Snow Crab prices. When the price falls, the remoteness of these sites from their markets curtails the development of this fishery. Scientific advice for these regions is further hampered because no at-sea or at-wharf sampling has yet been done.

For all regions, the landing history is small and fishing effort is limited to only a small area. This is a coastal activity, so there is a risk of catching specimens from other coastal species. We still lack certain biological information, such as moult periods for each species, growth rates, life histories, natural population cycles, sex ratios, the extent of suitable habitats and the environment's carrying capacity. What is missing most of all, because it would give us a predictive index for the short, middle and long term, is a fishery-independent survey; either a post-season trap survey conducted by the fishers, or a scientific trawl survey.

One participant noted that this is a data-poor case because of the low number of years for which information is available, but it could be considered a data-rich case because information has been gathered from the very beginning of the fishery.

From the participants at this workshop, it was proposed to also use data coming from other sources, such as that compiled from the Magdalen Island scallop scientific survey, during which scallop dragging covers most of the area of interest here. Another suggestion was to see whether the data from the Snow Crab scientific survey from LFA 12 could help, even though the survey does not always go near enough to the Magdalen Island shores. Some of the stations in that survey should be located on the *Hyas* fishing grounds, although species differentiation for *Hyas* was only done during 2 summers.

In the near future, further efforts will be made to better understand certain biological aspects and population dynamics of these two species. We will also explore different analytical tools, such as AIM, CASA, Depletion estimates, MPA, MULTIFAN (although the terminal moult might be a problem), as was suggested by the workshop group.

BREAKOUT GROUPS

We employed breakout groups to assess the case studies presented and comsider possible approaches to developing a precautionary advice for each. Table A shows the composition of the breakout groups.

Table A. Breakout groups to assess case studies.

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Participants	Bradford	Cox	Brulotte	Hedges	Bourdages
	Cass	Harris	Cadigan	McCall	Dallaire
	Duplisea	Healey	Duplisea	Rowe	Legault
	Gregoire	Howland	Martell	Simon	Miri
	Smith	Shelton	Stewart	Swain	Schweigert
	Tallman	Treble	Therrialt	Trzcinski	Wade
	Zhu	Wheeler			

The breakout groups provided recommendations for each stock (Tables B1, B2, B3, B4, B5)

RECOMMENDATIONS

Table B1. Group 1

Case studies considered: Striped Bass, Arctic Charr, Northern Gulf Herring, Redfish

Case Study	Data Category	Method	Data required	Questions addressed	Method Reference	Comments
Arctic Charr	1	MPA / Demographic protection method	Monitor unexploited river runs	Baseline and impact of fishing on exploited populations relative to baseline, test if the 5% exploitation rate target is sustainable		Need to find unexploited streams and choose exploited stocks
Arctic Charr	1	Habitat/Potential carrying capacity methods	Available habitat maps, production per unit of habitat area	Potential productivity	Atlantic Salmon escapement work	Need habitat maps
Striped Bass (St John)/ Arctic Charr	1	PSA (Smith, CSIRO)	life history			Borrow data from neighbouring populations
Striped Bass (St John)	1	PVA (Multiple packages in development)	life history			Borrow data from neighbouring populations
Redfish	1	Bayesian SPM (Multiple implementations; Meyer & Millar)	CPUE, catch	MSY, ref pts	Meyer & Millar	Need to put priors on species split proportion
Striped Bass	2	MSS (Mixed stock salmonids, Martell)	Recruitment index, catch data	Escapement target, F on population	Martell	Need Catch curve analysis to get exploitation rate, iteroparous animals
Redfish	2	Multifan□CL David Fournier (Otter research)	Length, use mix dist to determine age at length	SPA standard outputs	Fournier	Need to look at Cape hake assessment, similar issues
Arctic Charr	1	Morphoedaphic index (Ryder)		Abundance estimate		Need lake surface area, mean depth, total dissolved solids or conductivity
Striped Bass/Arctic Charr	1	Traffic light	Whatever you have. For Striped Bass: R index, yoy size, environment	Stop, yield, go	Caddy	
Striped Bass/Herring	1	Catch curve with variable R (Bravington, CSIRO)				Need population age distribution over time
4S Herring	2	SVPA	Catch at age, CPUE tuning series not needed	Standard SPA outputs		External method for M evaluation would be useful
4S Herring	1	RSPR (MacCall)				

Table B2. Group 2
Case studies considered: Greenland Halibut, Newfoundland Herring, Cusk

Case Study	Data Category	Method	Data Required	Questions addressed	Method Reference (Literature)	Comments
0+1 Greenland Halibut				TAC advice and PA reference points		
0+1 Greenland Halibut	1	Area Swept as a proxy for F	Commercial logbook	Potential to comment on sustainability of recent TACs	Cox	
0+1 Greenland Halibut	2	AIM	Surveys, CPUE, catch	Potential to comment on sustainability of recent TACs	Rago / NFT toolbox	
0+1 Greenland Halibut	1	PSA	Life history, fishery footprint		Smith, CSIRO	
0+1 Greenland Halibut	1	Habitat / Potential carrying capacity methods		? Unsure - need expert advice		
0+1 Greenland Halibut		SAFE?				
0+1 Greenland Halibut	1	DCAC	Assumptions + catch			
Herring - NL	1	PSA	Life history, fishery footprint	TAC advice and PA Reference points		
Herring - NL	3	SCAA / VPA	Catch at age, surveys at age			
Herring - NL	2	SPM - ASPIC/Bayesian	Catch, biomass index			
Herring - NL	2	SURBA	Survey indices			
Herring - NL	2	AIM	Survey indices + catch			
Herring - NL	2	FLICA	Catch at age			
Herring - NL						
Cusk - Maritimes	2	Depletion models	Catch + index	SARA-type advice		
Cusk - Maritimes	2	Stock-reduction models	Catch			
Cusk - Maritimes	1	DB-SRA	Catch			
Cusk - Maritimes	1	PSA	Life history, fishery footprint			
Cusk - Maritimes	1	DCAC				

Table B3. Group 3
Case studies considered: Eulachon, Walrus

Case Study	Data Category	Method	Data required	Questions addressed	Method Reference (Literature)	Comments
Eulachon	1	SRA	C & I	Harvest/PA/RPA		Data available: indices/catch
Eulachon	1	Egg survey	??	None		Advice required:Fraser harvest level/RPA
Eulachon	1	Hierarchial SRA	C&I	Harvest/PA/RPA		
Eulachon	1	PSA	Life history	Vulnerability		
Eulachon	1	PVA	Age-based abundance??	Extinction risk		
Eulachon	2	AIM	C&I			
Eulachon	2	ASPIC	C & I	Harvest/PA/RPA		
Eulachon	2	Bayesian SPM	C & I	Harvest/PA/RPA		
Walrus						Partial abundance estimates/some idea of reproductive rates/spotty catch records
Walrus	1	DCAC	Catch	Harvest		Advice required: total allowable harvest
Walrus	1	DB-SRA	C&I	Harvest		
Walrus	1	PSA	Life history	Vunerability/relative risk		
Walrus	1	PBR				

Table B4. Group 4
Case studies considered: Sea Cucumber, Hagfish, Witch Flounder

Case Study	**Data Category**	**Method**	**Data required**	**Questions Addressed**	**Method Reference**	Comments
Hagfish, Cucumber	1	MPA based mgmt	Occasional surveys of fished and unfished areas	Relative exploitation status. Adaptive management policy.	Mcgilliard et al CJFAS in press	
Hagfish, Cucumber	1	Potential yield	Habitat mapping. Local density. M guess	Yield	Textbook	
Hagfish, Cucumber	1	Deplection analysis phase 1	Experimental depletion	Local abundance. Q	Textbook	
Hagfish, Cucumber	1	Deplection analysis phase 2	Apply phase 1 to mgmt	Abundance trends (cpue * Q); abundance in new areas.		
Hagfish, Cucumber	1	Transitional SPR	Time series of length (hagfish) or weight (cucumber) distributions of catch. Guesses at growth parameters and M. Additional data to collect: Area-specific life history (size at maturity, fecundity) - would be helpful for other methods also.	Reduction in spawning potential; MSY proxy	Mace et al.	Conservative proxy SPR should be precautionary e.g. 50%. Works better with low M and data near start of fishery.
Offshore Cucumber	1	AIM	Biomass index and catch series	PGY		
Cucumber	1	Regional PSAs	Distribution and general life history info relative to fishery levels	Regional risk		
Witch Flounder	2	2-state production model (non-Schaefer)	Catch and biomass index	Change in productivity		
Witch Flounder	2	Leslie life table	Life history data: mortality and growth rates	Change in natural mortality		
Witch Flounder	2	SPR/YPR	Life history data: mortality and growth rates	Alternative models: change in life history vs unreported catch		
Witch Flounder, Cucumbers	2	Catch ratio to assessed stocks	Survey catch rates for witch and assessed species	Longterm abundance index by reference to assessed stocks	Publication opportunity for Kurtis	
Hagfish, Cucumber				Finer-scaled habitat-based data: 1. Area-specific life history (size at maturity, fecundity); 2. Additional survey stratification based on bottom type		
Witch Flounder				New ageing and maturity data imminent		

Table B5. Group 5
Case studies considered: Pacific Rockfish, Wolffish, Pacific Herring, Toad Crab

Case Study	**Data Category**	**Method**	**Data required**	**Questions Addressed**	**Method Reference**	Comments
Wolffish	1	MPA based mgmt	Occasional surveys of fished and unfished areas	Relative exploitation status. Adaptive management policy.	Mcgilliard et al CJFAS in press	
Wolffish	1	Potential yield	Habitat mapping. Local density. M guess	Yield	Textbook	
Wolfish, Crab	1	Deplection analysis phase 1	Experimental depletion	Local abundance. Q	Textbook	
Wolffish, Crab	1	Deplection analysis phase 2	Apply phase 1 to mgmt	Abundance trends (cpue * Q); abundance in new areas.		
Wolffish, Crab	1	Transitional SPR	Time series of length (hagfish) or weight (cucumber) distributions of catch. Guesses at growth parameters and M. Additional data to collect: Area-specific life history (size at maturity, fecundity) - would be helpful for other methods also.	Reduction in spawning potential; MSY proxy	Mace et al.	Conservative proxy SPR should be precautionary e.g. 50%. Works better with low M and data near start of fishery.
Crab	2	AIM	Biomass index and catch series	PGY		
Wolffish	1	Regional PSAs	Distribution and general life history info relative to fishery levels	Regional risk		
Rockfish	1	Bayesian SPM (Multiple implementations; Meyer & Millar)	CPUE, catch	MSY, ref pts	Meyer & Millar	Need to put priors on species split proportion
Redfish	1	Multifan□CL David Fournier (Otter research)	Length, use mix dist to determine age at length	SPA standard outputs	Fournier	
Herring – Pac	1	PSA	Life history, fishery footprint	TAC advice and PA Reference points		
Herring – Pac	3	SCAA / VPA	Catch at age, surveys at age			
Herring – Pac	2	SPM - ASPIC/Bayesian	Catch, biomass index			
Herring – Pac	2	SURBA	Survey indices			
Herring – Pac	2	AIM	Survey indices + catch			
Herring – Pac	2	FLICA	Catch at age			

LIST OF ASSESSMENT MODELS AND APPLICATIONS

At the latter part of the third day, the working groups provided input into developing a list of assessment models and their level of data requirements. The purpose of developing this list was to point stock assessors to models that they could explore for assessment in their respective stocks. There was no attempt to describe methodology. Table C1 shows the list of models and a qualitative assessment to classify models as to whether the method is appropriate for data-poor, data-moderate or data-rich circumstances. Table C2 shows the full name of the method, its purpose and typical data needed to perform an assessment.

Table C1. List of assessment models and applications

	Classification with respect to data requirements
1	Data-poor
2	Data-moderate
3	Data-rich
4	Proxies/indirect methods
0	In development

Data requirement	List of methods
0	MPA / demographic protection method
0	Non-linear forecasting
1	DB-SRA (MacCall NOAA)
1	DCAC (MacCall NOAA)
1	ECOPATH/ECOSIM
1	Egg surveys / etc.
1	ERAEF (Smith, CSIRO)
1	Habitat/potential carrying capacity methods
1	Hierarchical Bayes stock reduction analysis (McAllister)
1	Leslie matrix models (Poptools)
1	MARK (Tagging - many other methods)
1	Nutrient/phytoplankton/zooplankton - bottom-up approach
1	PBR
1	PSA (Smith, CSIRO)
1	PVA (Multiple packages in development)
1	SAFE (Zhou, CSIRO)
1	SESSF (Smith, CSIRO)
2	AIM (Rago Replacement Ratio)
2	ASPIC Michael Prager (Southeast Fisheries Science Center, NMFS)
2	Bayesian SPM (Multiple implementations; Meyer & Millar)
2	CASAL Alastair Dunn (NIWA, New Zealand)
2	CSA Benoit Mesnil (IFREMER, Nantes) / NFT Toolbox
2	Depletion models
2	FLR (Suite of methods www.flr-project.org)
2	ICA Ken Patterson (EC, Brussels)
2	ISVPA (if only C@A available)
2	MSS (Mixed stock salmonids, Martell)
2	Potential yield
2	SEINE (NFT Toolbox; Gedamke)
2	SPR (Spawning Potential Ratio)
2	SR fitting
2	SS III Rick Methot
2	SURBA Coby Needle (MSS, Aberdeen) / Noel Cadigan (DFO, St John's)
2	YPR / YPRLEN

3	ADAPT Stratis Gavaris; NFT Toolbox
3	AMAK (Ianelli?)
3	AMCI (?ICES list of methods)
3	ASAP
3	A□SCALA Mark Maunder (IATTC, La Jolla)
3	B□ADAPT Chris Darby (CEFAS, Lowestoft)
3	Bayesian catch□at□age model Carmen Fernández (IEO, Vigo)
3	Coleraine Ray Hilborn
3	Gadget Daniel Howell (IMR, Bergen)
3	Genetic mixed stock analysis
3	mseR (Cox, SFU)
3	Multifan□CL David Fournier (Otter Research)
3	SAM Anders Nielsen (DTU□Aqua, Copenhagen)
3	SCAA/SCAL (NFT)
3	SMS Morten Vinther (DTU□Aqua, Copenhagen)
3	SXSA Dankert Skagen (IMR, Bergen)
3	TISVPA Vasilyev (Murmansk)
3	TSA Rob Fryer (MSS, Aberdeen)
3	VPA2Box (NFT Toolbox)
3	XSA Chris Darby (CEFAS, Lowestoft)
4	Morphoedaphic Index (Ryder)

Table C2. Modeling methods with information to learn more (source/reference), the purpose of the model, typical data required and if the method works for data poor situations.

Method	Full Name	Source/Refererence	Purpose	Typical Data	Classification
DB-SRA	Depletion-Based Stock Reduction Analysis	Alex MacCall (NOAA)	Determine harvest levels with buffers for uncertainty	Time series of catches from the onset fishing	Data poor
DCAC*	Depletion-Corrected Average Catch	Alex MacCall (NOAA)	Determine harvest levels with buffers for uncertainty	Time series of catches for a period	Data poor
ERAEF*	Ecological Risk Assessment for the Effects of Fishing	Alistair Hobday and Tony Smith (CSIRO)	Risk assessment of fisheries	Conceptual (no data) to full assessment s	Data poor-rich
EwE*	Ecopath with Ecosim	University of British Columbia's Fishery Centre	Ecological/ecosyste m modeling software	Indices, catches, etc	Data rich
SRA*	Stock Reduction Analysis	Carl Walters, Steve Martell, Murdoch. McAllister, et al.	Estimate stock size and fishing mrotality	Time series of catch, with effort or abundance indices	Data moderate
PopTools*		Greg Hood, CSIRO	Analysis of matrix population models and simulation of stochastic processes	Birth and death rates	Data moderate
MARK*		Gary White, Colorado State	Estimates of population size and capture probabilities	Encounter history of marked animals	Data moderate-rich
PSA*	Productivity and Susceptibility Analysis	Alistair Hobday and Tony Smith (CSIRO).	Semi-quantitative risk assessment of fisheries	Basis population attributes	Data poor
PVA*	Population Viability Analysis	Multiple	Method of risk assessment, often used for extinction risks		Data poor
SAFE*	Sustainability Assessment for Fishing Effects	Shijie Zhou et al. (CSIRO)	Quantify the effects of fishing on sustainability for large numbers of species with limited data.	Spatial over-lap of fisheries and species	Data poor
AIM*	An Index Method	Dr. Paul Rago, (NOAA)	Estimate relative fishing mortality at which the population is likely to be stable.	Time series of abundance index and total catch	Data moderate
ASPIC*	A Stock Production Model Incorporating Covariates	Dr. Michael Prager	Estimate stock size and fishing mortality rates	Time series of abundance index and total catch	Data moderate
Bayesian	Bayesian	R. Meyer and R. Millar	Estimate stock size	Time series	Data moderate

SPM*	Surplus Production Models	(Univ Auckland), and others	and fishing mortality rates	of abundance index and total catch	
CASAL*	C++ Algorithmic Stock Assessment Laboratory	Alistair Dunn et al (NIWA)	Generalised age- or length-structured fish stock assessment model to estimate stock size and fishing mortality rates	Time series of catch-at-age or -size data; survey or other biomass indices, or survey catch-at-age or -size data	Data moderate-rich.
CSA*	Collie-Sissenwine Analysis	Various (J Collie, R Conser, B Mesnil)	Estimates abundance and mortality rates	Time series of indices of recruits and post-recruits, and total catch	Data moderate
	DeLury Depletion models	M. McAllister, M. Robert, et al.	Estimates abundance and mortality rates	Time series of abundance index and total catch	Data moderate
ICA*	Integrated Catch at Age	K R Patterson	Estimates abundance and mortality rates	Time series of catch-at-age; survey or other biomass indices, or survey catch-at-age	Data moderate-rich.
ISVPA*	Instantaneous Separable Virtual Population Analysis	Z.I. Kizner, and D.Vasilyev	Estimates abundance and mortality rates	Time series of catch-at-age; surveys optional.	Data moderate-rich.
SEINE*	Survival Estimates In Non-Equilibrium situations	Gedamke and Hoenig	Estimates mortality rates	Time series of mean lengths ; growth curve	Data poor-moderate
SS3*	Stock Synthesis Version 3	R Method (NOAA)	Estimates abundance and mortality rates	A diversity of fishery and survey data	Data moderate-rich.
SURBA*	SURvey Based Assessment	C Needle (Marine Scotland), N Cadigan (DFO)	Estimates relative abundance and mortality rates	Time series of age-based abundance indices	Data moderate
ADAPT*	ADAPTive framework for stock assessment	S Gavaris; NOAA toolbox	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
VPA-2BOX*	Dual Zone	Clay Porch	Estimates	Time series	Data rich

	VPA Model		abundance and mortality rates for two mixed stocks	of catch-at-age and survey catch-at-age; tagging information	
AMAK*	Assessment Method for AlasKa	J Ianelli (NOAA)	Estimates abundance and mortality rates	Time series (possibly sparse) of catch-at-age and survey catch-at-age	Data rich
AMCI*	Assessment Model Combining Information from various sources	D Skagen	Estimates abundance and mortality rates	A diversity of fishery, survey, and tagging data	Data rich
ASAP*	Age Structured Assessment Program	C Legault (NOAA) and V. Restrepo	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
A-SCALA	A statistical catch-at-length analysis	M. Maunder	Estimates abundance and mortality rates	Time series of catch-at-length; abundance indices, age-length keys	Data rich
B-ADAPT*	ADAPT when some landings are biased	C. Darby	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
	Bayesian catch at age model*	C Fernandez	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
Coleraine*	A fine NZ wine	R Hilborn	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
GADGET*	Globally applicable Area Disaggregated General Ecosystem Toolbox	Bjarte Bogstad	Single and multispecies models, as well as single-species and mixed fisheries. Estimates abundance and mortality rates	A diversity of fishery and survey data	Data rich.
MULTIFAN-CL*		J. Hampton, F, Bouyé (SPC), P. Kleiber (NMFS), D. Fournier.	A statistical, length-based, age-structured model	Length-frequency sampling data	Data moderate-rich.
SSAM*	State Space Assessment	Anders Nielsen (DTU)	Estimates abundance and	Time series of catch-at-	Data rich

	Model		mortality rates, with good assessment of uncertainty	age and survey catch-at-age	
STATCAM*	Statistical Catch at Age Model	Jon Brodziak (NOAA)	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
SCALE*	Statistical Catch At LEngth model	P Nitschke and C. Legault (NOAA)	Estimates abundance and mortality rates	Total catch, survey indices of adults and recruits, length compositions	Data rich
SMS*	Stochastic MultiSpecies model	Morten Vinther (DTU)	Multi-species estimates of abundance and mortality rates	Multi-species time series of catch-at-age and survey catch-at-age	Data rich
TASACS*	A Toolbox for Age-structured Stock Assessment using Catch and Survey data	Dankert Skagen and Åsmund Skålevik	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
TISVPA*	Triple Instantaneous Separable VPA	D.A.Vasilyev	Estimates abundance and mortality rates	Time series of catch-at-age; surveys optional.	Data moderate-rich.
TSA	Time Series Analysis	Rob Fryer (Marine Scotland)	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich
XSA*	EXtended Survivor Analysis	C. Darby (CEFAS)	Estimates abundance and mortality rates	Time series of catch-at-age and survey catch-at-age	Data rich

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Two useful websites are:
http://www.ncfaculty.net/dogle/fishR/packages/packages.html
http://nft.nefsc.noaa.gov/

Other useful methods

Method	Classification
MPA / demographic protection method	
Non-linear forecasting	
Egg surveys	Data poor
Habitat/potential carrying capacity methods	Data poor
Nutrient/phytoplankton/zooplankton - bottom-up approach	Data poor
PBR – Potential biological removals	Data poor
SPR – Spawning potential ratio	Data moderate
YPR – Yield per recruit	Data moderate
YPR – Length-based yield per recruit	Data moderate
Genetic mixed stock analysis	Data rich
MSE	Data rich
Morphoedaphic index (Ryder)	Proxies/indirect methods

CONCLUSIONS

To facilitate the integration of the ecosystem and precautionary approach into fisheries assessment in Canada, the Department of Fisheries and Oceans (DFO) has developed the Sustainable Fisheries Framework (SFF) and Fisheries Renewal scheme (Figure 1). The SFF summarizes DFO's approach to EBFM which considers the system of stock and fishery as the center and analyzes the impacts of fishing on ecosystem components as well as the impacts of the state of the ecosystem on fisheries through its approach to integrated ocean management (Figure 1). The SFF serves to develop and articulate a series of policies to consider the effects of fisheries on sensitive benthic areas, forage fish and bycatch species (i.e. ecosystem impacts) as well as the precautionary approach policy for management of harvest rate.

While the new policy is more comprehensive it will undoubtedly increase the number of situations where stock assessment is required for data limited fisheries, such as by-catch or forage fish fisheries.

As noted in the body of this report, while there are many problems with data limited stocks and these problems will increase, there are a number of alternative approaches that may be employed for data limited situations.

These alternative approaches are difficult to initiate within a regional management structure. Regional organizations tend to develop standard approaches for their most data rich stocks and do not apply significant resources to small scale, non-industrial or new fisheries. Therefore, meetings such as this one, which are conducted outside of a regional structure and focus on the problem of data limited assessment, allow for cross connections of species/species problems and methods.

We recommend that there be additional inter-regional exercises in developing approaches for data limited assessments.