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Assessing recovery potential: Long-term projections and their implications for socio-economic analysis

Évaluation du potentiel de rétablissement : projections à long terme et répercussions sur l'analyse socio-économique

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ABSTRACT

Recovery Potential Assessment (RPA) and associated socio-economic analysis are required to inform the decision on whether or not to list a species under the *Species at Risk Act* (SARA). RPA should also provide the basis for the Recovery Team to develop a Recovery Strategy and Action Plan after listing. While DFO has considerable experience in providing short-term scientific advice in support of fisheries management, approaches constituting best scientific practice and standards for long-term advice in support of listing decisions and recovery planning are still developing. Biological processes are best captured in a life-history model. This model needs to deal with both observation error and process error. Uncertainty associated with process error expands rapidly in projections beyond three years and methods have to take this into account. Bayesian state-space approaches provide a way of incorporating both observation and process error in the analysis. In most cases management strategy evaluation (MSE) of performance relative to a simulation of the biological process, assessment process and management process (operating model) may have the greatest potential given difficulties associated with making long-term quantitative projections. This approach could be expanded to include socio-economic aspects. Scientific analysis can be completed as a first step and the results then passed to Policy and Economics to undertake socio-economic analysis. This two-step approach is considered to be less attractive than a fully integrated approach in which scientific and socio-economic analyses are undertaken and peer reviewed in a joint assessment. The current review was unable to fully develop the best-practice standard without further work. In order to make progress it is recommended that DFO management chose an upcoming high-profile RPA as a national case study to establish a best-practice standard for the preferred fully integrated biological/socio-economic approach that is described. The case study should include establishing independent socio-economic and scientific peer review, and public communication of expert advice on recovery potential and cost-benefit of alternative recovery options, independent of the political process of determining SARA listing.

RÉSUMÉ

Une évaluation du potentiel de rétablissement (EPR) et une analyse socio-économique connexe sont nécessaires pour éclairer la décision d’inscrire ou non une espèce sur la liste de la *Loi sur les espèces en péril* (LEP). Une EPR devrait aussi servir de base à l’élaboration, par l’équipe de rétablissement, d’un programme de rétablissement et d’un plan d’action après l’inscription. Bien que le MPO dispose d’une expérience considérable de la formulation de conseils scientifiques à court terme à l’appui de la gestion des pêches, les méthodes qui constituent les pratiques scientifiques optimales et normes pour la formulation de conseils à long terme à l’appui des décisions d’inscription et de la planification du rétablissement sont encore en développement. Le meilleur moyen pour définir les processus biologiques est le modèle du cycle biologique. Ce modèle doit tenir compte à la fois de l’erreur d’observation et de l’erreur de traitement. L’incertitude associée à l’erreur de traitement se répand rapidement dans les projections de plus de trois ans et les méthodes utilisées doivent en tenir compte. Les approches bayésiennes de l’espace d’états offrent un moyen d’intégrer les erreurs d’observation et de traitement à l’analyse. Dans la plupart des cas, l’évaluation du rendement de la stratégie de gestion par rapport à une simulation du processus biologique, du processus d’évaluation et du processus de gestion (modèle opératoire) pourrait offrir le plus grand potentiel, compte tenu des difficultés associées à des projections quantitatives à long terme. Cette démarche pourrait être étendue de manière à inclure les aspects socio-économiques. L’analyse scientifique peut être réalisée en premier lieu et les résultats transmis au groupe des Politiques et de l’économie qui entreprendra l’analyse socio-économique. Cette démarche en deux volets est jugée moins intéressante qu’une approche entièrement intégrée dans le cadre de laquelle les analyses scientifiques et socio-économiques sont effectuées et soumises à des pairs au cours d’une évaluation conjointe. Pour arriver, pendant le présent examen, à élaborer l’ensemble des normes de pratiques optimales, il aurait fallu entreprendre des travaux supplémentaires. Afin de faire des progrès, il est recommandé que la direction du MPO choisisse une des prochaines EPR à haut profil pour en faire une étude de cas nationale de l’établissement de normes des pratiques optimales pour l’approche privilégiée biologique/socio-économique entièrement intégrée qui est décrite. L’étude de cas devrait inclure l’établissement d’un processus d’examen socio-économique et scientifique par des pairs indépendants, ainsi que de communication publique de conseils d’experts au sujet du potentiel de rétablissement et de la rentabilité des différentes solutions de rétablissement, indépendant du processus politique décisionnel d’inscription sur la liste de la LEP.

INTRODUCTION

Background (Jake Rice)

A National Workshop on Further Developments to the National Framework on Recovery Potential Assessments (RPAs) for species at risk: Part 1 - Long term Population Projections, was held March 19 2007 in Ottawa at the Lord Elgin Hotel (see APPENDIX for the terms of reference). This multi-authored research document outlines the main ideas communicated in the presentations related to long term projections for recovery potential assessment and a brief summary plenary discussion of the topic.

Provisions of the Species at Risk Act require jurisdictions to prepare Recovery Strategies and Action Plans for each listed species. These Strategies and Plans must include a description of critical habitat and recovery targets for range and abundance of a listed species. Provisions of the Plan must include measures to protect individuals of protected species from mortality, harm or harassing by human activities, or destruction of their habitats or, when appropriate, residences. Plans may allow such harm or mortality only when it can be shown that the activities do not jeopardize survival or recovery.

Prior to listing decisions by Governor in Council, the responsible jurisdiction must consult with Canadians on the social and economic consequences of the recovery plans.
For these consultations to be informed, scenarios often have to be explored analytically, to investigate the likelihood of recovery under different assumptions about the levels and nature of various human activities. Both the direct provisions of SARA and the information needed for modeling social and economic impact scenarios require significant input from Science Sector. An initial framework for these Recovery Potential Assessments was developed in a series of CSAS workshops in 2004-2006. Science support required for assessing recovery potential and social and economic effects of listing was discussed further, gaps were identified, and priorities assigned at a workshop between Science Sector and the SARA Secretariat, with participation from all DFO Sectors, in September 2006. Following that Workshop, Science Sector appointed a Recovery Potential Assessment study group to commence work to address the gaps and build national and regional capacity to conduct recovery potential assessments.

The study group identified two areas for immediate action - long term population projections and quantifying the amount of critical habitat. With respect to long term projections, the objectives were to:

i) review the state of knowledge and provide guidance on best practices for long term population projections required as part of social and economic scenario exploration;

ii) review the results of the Science Sector – SARA Secretariat workshop, and develop a workplan for addressing other gaps and priorities.

The proposed approach was to:

i) Prepare and review working papers on the state of knowledge of methods for long term population projections, considering:

   a) requirements for pre-listing socio-economic analyses and post-listing recovery planning;

b) appropriateness of alternative methods for marine and freshwater fish species with differing life histories and data availability;

c) how risks and uncertainties should be accounted for in analyses and provision of advice.

ii) With the information available, provide guidance on the best practices (and possibly on unacceptable practices) for long term projections, considering the factors in (i), and identify any further work that would be needed in order to improve the best practices.

The *Species at Risk Act* (SARA) (Jake Rice)

The key relevant sections of SARA with respect to long term population projection are:

Preamble:

…community knowledge and interests, including socio-economic interests, should be considered in developing and implementing recovery measures,

39. (1) To the extent possible, the recovery strategy must be prepared in cooperation with…

(e) any other person or organization that the competent minister considers appropriate.

39 (3) To the extent possible, the recovery strategy must be prepared in consultation with any landowners and other persons whom the competent minister considers to be directly affected by the strategy, including the government of any other country in which the species is found.

41. (1) If the competent minister determines that the recovery of the listed wildlife species is feasible, the recovery strategy must address the threats to the survival of the species identified by COSEWIC, including any loss of habitat, and must include …

(b) an identification of the threats to the survival of the species and threats to its habitat that is consistent with information provided by COSEWIC and a description of the broad strategy to be taken to address those threats;…

(d) a statement of the population and distribution objectives that will assist the recovery and survival of the species, and a general description of the research and management activities needed to meet those objectives;

49(1) …(e) an evaluation of the socio-economic costs of the action plan and the benefits to be derived from its implementation; and

These provisions have been interpreted by DFO as requiring both an analysis of the potential social and economic impacts of the mandatory prohibitions that would follow from listing a species, and of the costs of measures necessary to achieve recovery. They have also been interpreted as requiring that DFO undertake wide consultation on the acceptability to stakeholders of those social and economic costs.

Consultation process (Jake Rice)

To meet the terms of the Act, DFO conducts a formal consultation process for species assessed by COSEWIC as TH (threatened) or EN (endangered), varying in detail depending on the species under consideration. The consultations are a key part of the information used by the Minister of Fisheries and Oceans to decide on a recommendation to the Minister of Environment and Governor in Council, with regard to listing the species under the Act. The consultations also contribute to the information made available to recovery teams, in cases when the decision is made to list a species, or otherwise to undertake measures intended to recover the species, even if it is not listed under the Act. These consultations are usually coordinated by Fisheries and Aquaculture Management, but may be supported by information from all sectors of DFO. Science has a supporting role for the consultations through the Recovery Potential Assessments (RPAs), which provide the best possible science advice, given the information available, on:

- biologically appropriate recovery targets in terms of population size and range;
- present status of the species;
- expected productivity of the species given its status;
- current sources and levels of mortality;
- reduction in total mortality necessary to achieve the recovery targets in biologically appropriate time frames.

In some cases the RPA also provides advice on options for achieving the necessary reductions in at least some of the sources of human-induced mortality, depending on the scale and nature of participation in the RPA by other DFO Sectors. Where there is a possibility that the measures necessary to ensure survival and recovery of a species would have more than minor social or economic impacts, Economics Branch also provides supporting information to the consultations, as well as directly to the Minister. This support often consists of model-based exploration of alternative scenarios for recovery strategies and action plans. In addition to a status quo baseline simulation of no change in management, alternative scenarios include assumptions of how mortality caused by one or more human activities impacting the species would be reduced through some management measure, or how productivity of the species would be enhanced through positive interventions in, say, habitat quality. Costs and benefits of the measures are also estimated, including both implementation costs and social and economic costs of lost opportunity to obtain goods or services provided by the species during the recovery period. To obtain these costs and benefits the scenarios must simulate how the species would respond to the management actions, such that the duration and annual size of the costs and benefits for implementation and lost opportunity can be calculated. This creates a need for long-term projections of population trajectories, under specified assumptions about productivity and mortality schedules.

DFO Science has a history of treating long-term projections of the trajectory of exploited populations with caution. Even the five-year resource projections which formed the basis for economic planning within DFO and the Atlantic groundfish industry (Munro 1980, Munro and MacCorquedale 1981, Parsons 1993) were widely criticized inside the sector as speculative and unreliable (Rice 2006). When industry and FAM expressed interest in multi-year TACs in the late 1990s and early 2000s, the groundfish RAPs and NAPs agreed not to undertake yield projections that depended substantially on contributions of yield from cohorts not already estimated empirically within the Sequential Populations Analyses, and/or supported by commercial and/or research survey time-series of data.

Although DFO Science has been cautious in provision of advice on estimates of stock-specific yield from long-term projections, it – and the fisheries science community more broadly - also have a long history of using equilibrium solutions in evaluating the consequences of alternative management strategies. For example, both B_{msy} (and its many variants) and $F_{0.1}$ were the results of analytical steady-state solutions to population dynamics problems (Ricker 1975, DFO 1981). More recently testing the family of spawner per recruit reference points such as $B_{35\%}$ and its variants relied heavily on long-term simulations to assess the robustness and sustainability of various reference points (Mace 1994). Long-term simulations also play a core role in the growing interest in Management Strategy Evaluations (ICES 2006; Proceedings of Galway Symposium – ICES Journal of Marine Science, Volume 64, Number 4, May 2007).

The requirements of Economics Branch for long-term simulations of population responses to alternative recovery strategies have more similarities with the well-established use of long-term projections in evaluating fisheries management strategies than they do with the less-accepted use of them in estimating specific expected yields. The objective of the simulations within the SARA consultations framework is to assess the consequences of alternative provisions in recovery strategies, and not forecast the precise trajectory of a recovering species. The goal is to assess what suites of measures could be included in a SARA-compliant recovery strategy, which, as the name states, is a strategic document, not a tactical one. The users want insight into the general scale of measures needed to achieve targets, and general time courses required, but not specific figures for budgeting. The more specific figures only become necessary at the time of developing Action Plans, which, under SARA, are restricted to at most five years before re-evaluation.

Although the use of long-term projections as a tool in evaluating the social and economic costs of alternative (or any) recovery strategies may be consistent with other sound practices in fisheries science, the long term projections still must be done using the best practices for the discipline. Long-term projections require assumptions about how all four components of a stock's productivity (recruits per spawner, growth, maturation, and natural mortality) will vary over time, in addition to the scenario-specific assumptions about level and nature of human-induced mortality. Appropriate assumptions about population productivity may vary with the species life history, for example possibly differing among a capelin or herring-like species, a Sebastes-like species, a stream minnow, and a large shark (Charnov 1993, Jennings *et al*. 1998, Denney *et al*. 2002, Goodwin *et al*. 2006). Moreover, the fact that in a species-at-risk context these projections must start at very low population sizes, means that additional risks and uncertainties may be associated with assumptions about population productivity at low population size (Myers *et al*. 1995, Liermann and Hilborn 2001, Shelton and Healey 1999).

This research document attempts to outline current "best practices" that should be followed when making long-term projections in species-at-risk contexts within DFO. These guidelines and further work in the future needs to address issues of particular concern to DFO Science, including life-history differences among species, inclusion and expression of uncertainty, and accommodation of ancillary concerns such as climate change, compliance, and multiple sources of mortality, as long as the guidelines are clear, practical, and explicit.

APPROACH

Current approach to RPAs (Saba Khwaja)

The current approach to RPAs involves two phases. Under Phase I current species status is assessed:

1. Evaluate present species status for abundance and range;
2. Evaluate recent species trajectory for abundance and range;
3. Estimate amount of critical habitat currently available (using critical habitat descriptions defined in pre-COSEWIC Advisory Process and considering information in COSEWIC status report;
4. Evaluate expected population and distribution targets for recovery according to DFO guidelines;
5. Evaluate expected generation time for recovery to target assuming only natural mortality, and estimate how time to recovery targets would increase at various levels of human-induced mortality
6. Evaluate residence requirements if any.

Under Phase II scope for human induced mortality is evaluated:

7. Evaluate maximum human induced mortality which the species can sustain without jeopardizing survival or achievement of recovery targets for the species;
8. Quantify to the extent possible the magnitude of each major potential source of mortality/harm identified in the pre-COSEWIC Advisory Process and considering information in the COSEWIC status report;
9. Aggregate total mortality / harm attributable to all human causes and contrast with that determined in 5 and 7;
10. Evaluate to the extent possible the likelihood that critical habitat is limiting;
11. Compile an inventory to the extent possible of the threats to critical habitat.

SARA and Socio-Economic Analysis – requirements from science
(Barb Best and Saba Khwaja)

The explicit incorporation of socio-economics in SARA acknowledges stakeholder concerns over the potential social and economic costs of measures to individuals, communities and industries. It also acknowledges the need to develop an understanding of the potential benefits arising from the development and implementation of such measures in so far as they contribute to the recovery of species at risk. In its preamble, SARA recognizes that wildlife species have value in and of them selves, and are valued by Canadians for aesthetic, cultural, spiritual, recreational, educational, historical, economic, medical, ecological and scientific reasons. The key sections of SARA regarding socio-economic analysis are as follows:

- The preamble to SARA specifies that socio-economic interests should be considered in developing and implementing recovery measures.

- Section 38 of SARA states that for recovery strategies, action plans and management plans that if there are threats of serious or irreversible damage to the listed wildlife species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty.
- Section 49(1)(e) of SARA requires that an action plan must include an evaluation of the socio-economic costs of the action plan and the benefits to be derived from its implementation.
- Section 55 of SARA requires that the competent minister monitor the implementation of the action plan and the progress towards its objectives, as well as assess and report on its implementation, including ecological and socio-economic impacts five years after the plan comes into effect.

The addition (or removal) of a species from the SARA Schedule 1 list is treated as a regulatory amendment (actually an order), and as such, Federal Regulatory Policy guides the listing process. This entails all of the requirements of the federal regulatory process (triggered by s. 27 of SARA), including that:

- the benefits outweigh the costs to Canadian governments, businesses, and individuals;
- Canadians have been consulted;
- government intervention is justified, and that regulation is the best alternative;
- regulatory activity impedes as little as possible Canada's competitiveness;
- regulatory burden has been minimized through co-operation with other governments;
- systems are in place and resources sufficient to manage regulatory programs effectively.

Socioeconomic analysis under SARA must be considered in the context of analyzing potential recovery measures, whether it is in support of listing decisions, for recovery planning (strategies and action plans) or in the development of management plans.

There are three forms of economic analysis that are useful for integrated SARA decision-making:

1) Cost-effectiveness analysis
2) Benefit-cost analysis
3) Economic Impact Analysis

These analyses are not mutually exclusive and may often be used together to complement one another in an overall socio-economic assessment.

Cost-effectiveness analysis is generally employed in situations where a goal is taken as given, and strategies are evaluated so as to achieve that goal at lowest cost. Although biological goals needn't be monetized in this type of analysis, cost-effectiveness analysis may be most useful when it is employed within the context of a benefit-cost analysis (below). For example, one might use cost-effectiveness analysis to minimize the costs of achieving a stated goal, but then employ benefit-cost analysis to determine if that goal is indeed a net benefit to society. If not, the goal may be modified appropriately in a sort of "pseudo-optimization" procedure. For example, it may be pragmatic to revise a goal to allow a longer time to achieve some recovery target, thus reducing immediate cost burdens.

Benefit-cost analysis is the analysis required by law for any new government regulations or regulatory amendments (such as listing a species in this case). Treasury Board guidelines are the standard for this form of analysis, which seeks to ensure that the benefits of government interventions outweigh the costs. Ideally, all benefits and costs are monetized to produce a single value - the Net Economic Value - which is a measure of changes in consumer plus producer surplus arising from a given government action.

Economic impact analysis is different than cost benefit analysis, in that it focuses on changes in the flow of resources which might arise under a proposed action. Typically, an impact analysis will examine effects on employment, incomes, revenue to businesses, and net changes in the flow of money into and out of a region. Decision makers are often particularly interested in the kind of estimates produced in impact analyses.

For any comprehensive economic analysis, benefits and costs are projected over some time horizon (often 20 to 50 years), and the values are discounted back to the present using some discount rate that represents the social rate of time preference. In most instances, costs are accrued immediately, while benefits are not realized until some time in the (perhaps distant) future. If there is any hope of giving due respect to the benefits of species protection, the long term projection of populations is essential.

As discussed elsewhere in this document, forecasting actual population numbers (and for some species commercial yields) in the distant future is an uncomfortable and largely speculative undertaking. However, projections are more acceptable if it is established that the analysis is hypothetical and relative. In such a case, the same inevitably erroneous assumptions about the future state of the world will be applied to the status quo projection as will be applied to any intervention scenarios. The exercise is justified in that it is likely to provide some information that is at least slightly better than no information, and with reasonable diligence, possibly even good information.

Policy sector has developed a framework for socio-economic analysis under SARA, a key feature of which is flexibility. After initial scoping of the potential impacts, the depth of the analysis is adjusted accordingly. This tiered approach is intended to promote efficient utilization of capacity, in order to best meet the demands of the decision-making process. The approach is supported within the Treasury Board guidelines, and one important consequence is that the demands from economists for population projections and other science information will also vary.

This framework is a strong argument for early collaboration between Science and Policy, and where commercial species are impacted, Resource Management. The earlier in the process that an integrated approach is adopted, the more likely that the level of analysis required can be agreed upon, and that plausible and cost-effective scenarios can be developed, reviewed, and refined with input from all relevant expertise.

Biological Information Requirements of the Socioeconomic Analysis

There are two key components of the socio-economic analysis that rely upon information from Science and Resource Managers:

1. Directly and plausibly linking costs to projected benefits via specific actions.
2. Monetizing benefits.

Specific Actions. Good socio-economic analysis can only be done if specific actions can be linked to specific outcomes. From the economic analyst's point of view, it is not sufficient to say that (e.g.) reducing juvenile mortality by 20% will increase annual biomass growth by 25%. To link benefits to costs, it is necessary to specify particular actions that can reduce juvenile mortality by 20% (e.g. close fishing area A from March to May each year; or, remove barriers on 10 of 50 inhabited streams).

The next step in the link is the actual population projection which arises from the specific scenario. Whether economists are provided the population model itself or the time series (and some measure of uncertainty) it produces under each scenario, the projections are the cornerstone of the benefit-cost analysis. This process obviously begs for a rarely-attained level of demographic knowledge about future states of a natural system - an important problem driving the discussion of this workshop. It also argues for close collaboration between scientists and economists, to develop a consensus bio-economic model that is both comprehensive and pragmatic.

Monetizing Benefits. The path to monetizing benefits is littered with obstacles, but there is no chance of carrying out this task in a defensible manner if the beneficial outcomes are not first identified and quantified in their natural units (e.g. biomass, population size, population trajectory). Furthermore, some units are more amenable to monetization than others. Canadians may indeed place some value on knowing that a species' population is increasing, however, that may not be the best definition of the "good" for which they are willing to pay. The key to quantifying non-market benefits is developing an appropriate proxy good - whether it be a market-based good that reveals willingness to pay for the non-market good (e.g. travel costs) or a hypothetical good with clearly defined and exclusive attributes that can be used to elicit willingness to pay in stated preference surveys. In general, a measure of abundance will be much more easily monetized than a population trajectory. This is particularly true in the context of commercial benefits, which are more easily quantified than non-market benefits. If a harvest scenario can be devised, the commercial benefits under that scenario can be estimated, albeit with uncertainty.

If there are important indirect biological effects (either costs or benefits), economists may also depend upon Science and Resource Management for quantitative knowledge of those outcomes. For instance, actions that protect one species often protect several, and occasionally harm others. Where these effects are prominent, they should be included in the analysis. There is a risk of multiple counting of costs and benefits when there are several overlapping SARA processes ongoing, but this is another technical matter to be worked out in the context of ecosystem considerations under SARA.

When examining Canadian regulatory or policy change, both the costs and benefits of change should be considered. From an economic perspective, that means that changes in both producer and consumer surplus should be tallied (i.e., the costs to producers should be compared to the benefits derived by Canadian citizens). Benefits of conservation to society as a whole may include option values and non-use values, the value – reflected by willingness to pay – that Canadians hold for preserving species for current and future generations. While generally recognized in the current Order, quantitative estimates of consumer surplus were not available for cod and porbeagle shark at the time the socio-economic reports were prepared.

Standards for long-term analyses (Peter Shelton)

Single species stock assessments frequently make use of short-term projections in order to provide scientific advice on TAC options. There is currently no DFO national standard for these projections and consequently they differ from one assessment to another and from regional laboratory to regional laboratory. Generally however, they include some means of estimating the current numbers at age (survivors) in a population (e.g. ADAPT) and then projecting these numbers forward for a period of usually three years based on recent average (usually past three years) weights at age, with TAC options quantified in terms of fishing mortality at age by applying recent average partial recruitment at age based on fishing mortality estimates. Geometric mean recruitment over the past three years is usually applied in the projection, but for most stocks has limited effect on the evaluation of short-term TAC options, depending on the age at first maturation and the fishery partial recruitment vector.

While some short-term projections are deterministic, others are stochastic. In most cases stochastic projections only take into account the uncertainty in the model estimates of survivors. This uncertainty, normally expressed in terms of standard errors (SE) of the estimates, reflects the goodness of the model fit to the data. In the case of ADAPT, the data are indices of population size, usually age-disaggregated, from research vessel surveys and other sources. It is common practice to draw independent random samples of survivors for each age by assuming a distribution around the estimate described by the SE. Less commonly, covariance in the survivor-at-age estimates are also taken into account. This is a parametric bootstrap approach. An alternative approach is the non-parametric bootstrap. In this case the model is fit many times to pseudo-data to get a distribution of survivors at each age. Pseudo-data are generated by taking the original model fit, computing the residuals for each index-at-age value, and then randomly drawing residuals with replacement to add to each model predicted index-at-age value to create a pseudo data point. This is consistent with the assumption of independent, identically distributed (iid) residuals. Since non-linear models such as ADAPT lead to biased estimates of the parameters (Gavaris 1999), analytical or bootstrap bias correction may be taken into account in projections.

Short-term projections are therefore quite complicated and no DFO scientific best-practices standard currently exists. Long-term projections are likely to be much more complicated and difficult to standardize. Not only must the propagation of uncertainty in survivors over time be taken into account, uncertainty in future year-class strengths is also very important. Observation error dominates short-term projections whereas process error will tend to dominate long-term projections. For example, uncertainty in the stock-recruit relationship and variability in year to year recruitment values around any relationship will be very important, as will any changes in productivity regimes over time such as systematic changes in natural mortality, age at maturation and body growth. These latter factors tend to co-vary as a consequence of life-history tradeoffs, further complicating such analyses.

In general, long-term projections should incorporate as much of the uncertainty in the population modeling as is possible. Observational (measurement), process, model and implementation uncertainties should all be considered to the fullest extent possible. Analyses should particularly consider the impact of changes in biological factors (e.g. change in *M*, body growth rate, etc.) with respect to a variety of management actions.

Given that it is difficult to provide useful bounds on uncertainty with regard to future states, alternative approaches may be more appropriate, such as Management Strategy Evaluation (see below). In this approach relative performance measures of alternative management strategies can be evaluated conditional on the uncertainty, but absolute performance measures are not computed. This approach may not be consistent with current socio-economic approaches described in the preceding section.

Population viability analysis (Jamie Gibson)

Long term projections in RPAs are analogous to the population projections used in population viability analysis (PVA). PVAs are used extensively in conservation biology to predict both the risk of extinction for populations and species and to evaluate management strategies to recover at-risk populations. In a PVA, a population dynamics model is used to determine how the probability of persistence is affected by current conditions and future perturbations (Beissinger and McCullough 2002). The goals of a PVA are to 1) determine the current viability of a population, 2) identify threats to persistence, and 3) provide a defensible structure for management and legal action.

Several authors have cautioned against the use of PVAs because the predictions, typically time to extinction, are almost always quite uncertain (e.g. Taylor 1995; McCarthy *et al*. 1996; Ludwig 1999). While the absolute predictions of PVA's (time to extinction) are highly questionable, many authors believe that PVAs can be used to assess relative risk (e.g. Akçakaya and Raphael 1998; Beissinger and Westphal 1998; McCarthy *et al*. 2001) This relative risk provides a basis for evaluating specific management strategies based on the probability that a population will increase or decrease in response to the strategy (e.g. Akçakaya and Raphael 1998, Gibson and Campana 2005), or for choosing the most effect management strategy given a set of possibilities (e.g. Lindenmayer and Possingham 1996). Reed *et al*. (2002) argue that these relative evaluations are the most appropriate use of PVAs. Using a simulation study, McCarthy *et al*. (2003) found they were able to identify the better of two management strategies 67–74% of the time using 10 years of data, and 92–93% of the time with 100 years of data, leading to the conclusion that, despite considerable uncertainty in the predicted risks of decline, PVAs may reliably contribute to the management of species-at-risk. This type of application, rather than estimation of time to extinction, is the basis for RPA, and is not dissimilar to the approaches used to provide advice for fisheries management (see the section "Management Strategy Evaluation").

PVAs consist of a population dynamics model that uses model parameters to project the population forward through time. The estimation of model parameters is well developed in the fisheries literature. The linkage between fisheries assessment models, in which model parameters are estimated, and PVAs, which then use these estimates, is developed by Maunder (2005). Advances in fisheries modeling that can be applied to PVAs include: (1) integrated analysis, which allows the use of all information on a particular population, (2) Bayesian analysis, which allows for the inclusion of prior information (3) hierarchical modeling, which allow information to be shared among parameter estimates, (4) non-parametric representation of parameters which allows for a more flexible relationship among the parameters, and (5) robust likelihood functions which automate the reduction of the influence of outliers. These approaches help to ensure that all model assumptions and parameter are consistent throughout the analysis, that uncertainty is appropriately represented, that uncertainty is propagated throughout the analysis and that the correlation among parameters is preserved, and methods for separating process error from estimation error. Although not all methods discussed by Maunder (2005) are applicable for all species and questions, they do represent a current standard for population projections.

Choosing a metric for evaluating PVA output can be problematic, because projections from PVAs can be quite nonlinear. Lui *et al*. (1995) found that a sparrow population was expected to decline sharply prior to a slow rebuilding. Gibson and Campana (2005) predicted that porbeagle total abundance would continue to decline for a few years, even if all fisheries were closed, prior to the onset of rebuilding because of the limited number of mature individuals in the population. In these cases, evaluation of the predicted trajectories can be more important than examination of the endpoint of the simulation. Given uncertainty in model inputs and their effect on the ability to estimate reference points for many populations, Taylor *et al*. (2000) concluded that analyses of trends could be more appropriate for analyzing management plans than status relative to a biomass based reference point such as carrying capacity.

Several reviews of PVAs are available in the literature. Beissinger and Westphal (1998) review the use of demographic models in species at risk management, including analytical, deterministic single population, stochastic single population, meta-population and spatially explicit models. They stress that predictions from these models are unreliable due to issues such as difficulties in estimating variances for demographic rates, lack of information on dispersal, uncertainty in the timing and nature of density dependence, and uncertainty about environmental trends and flucuations. They suggest that PVAs are most useful for evaluating relative rather than absolute rates of extinction, that short-term projections should be emphasized (although long-term can be used as extensions of short-term projections for strategy evaluation), that models can be cautiously used to diagnose cause of decline and pathways to recovery, and to examine recovery scenarios. They also stress the importance of field tests of model assumptions and field validation of model predictions. In a review of emerging issues with PVA's, Reed *et al*. (2002) draw similar conclusions and caution that as software programs for PVA become available, there is a greater potential for the unintentional misuse of PVAs. They suggest that model structure, inputs and results should be viewed as hypotheses to be tested and stress the importance of independent external review of the model construction and results.

Management strategy evaluation (Alan Sinclair, Daniel Duplisea)

In Management Strategy Evaluation (MSE) there is no attempt at absolute estimates of forecasts. Instead, the focus is on the comparison of the relative performance of alternative management strategies, including recovery strategies, applied to an operating model which simulates the true state of nature (e.g. Kell *et al*. 2007; Fig. 1). Stating how long it will take to get to a particular state is equivalent to making a prediction. This is avoided in the MSE approach. What science can legitimately state is that given one realization of the real world (the operating model), one strategy would require, say, twice as long to reach a particular state (for example an agreed to 'recovered' reference point) than an alternative strategy. There is information in this statement, but it avoids trying to forecast absolute future recruitment, environmental patterns, survival conditions, etc. Science can be useful but its limits should be recognized. Under an MSE approach, socio-economic analyses carried out to inform the listing process should recognize the limitations regarding predictions of absolute population dynamics and instead frame evaluations in comparative terms.

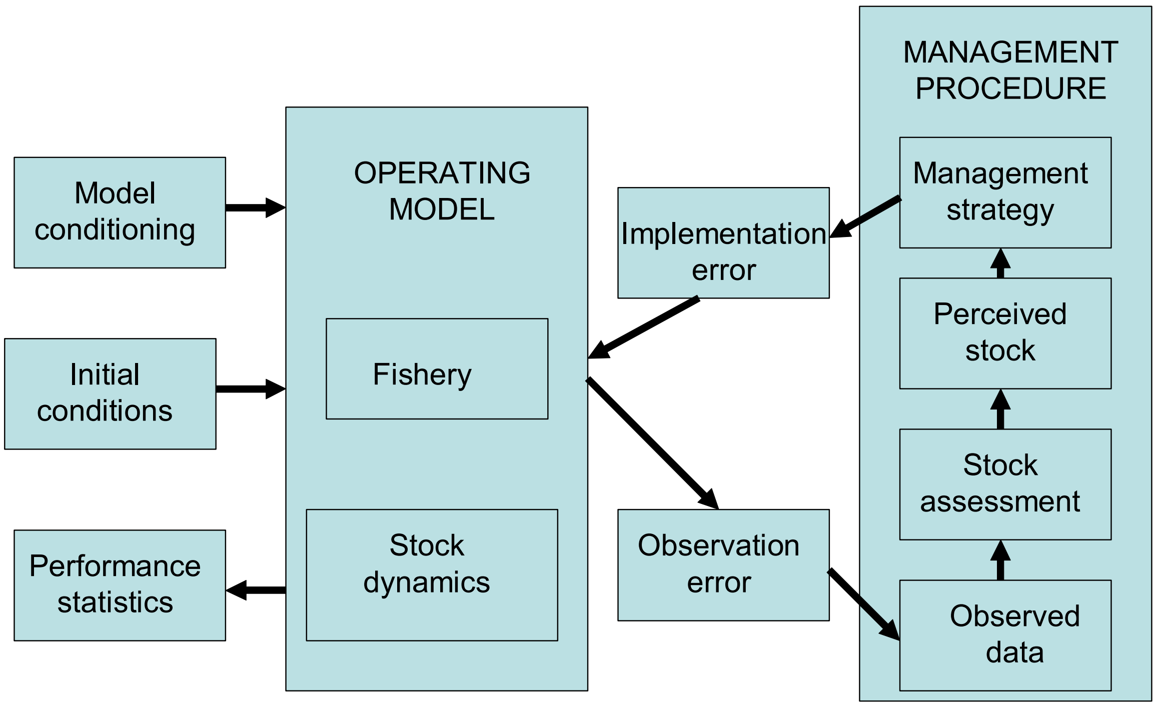

Fig. 1. Conceptual framework for management strategy evaluation (adapted from Kell *et al*. 2007)

For the evaluation of recovery strategies, issues such as Allee effects or predator induced depensation could be more important than in MSEs applied to non-depleted populations. The advantage of the MSE approach is that if phenomena like Allee effects can be operationalised in a model, the robustness of a recovery plan to the particular phenomenon can be assessed. Likewise any process that can be operationalised, even in a rudimentary fashion, can become part of the underlying operating model used to assess its potential influence on recovery.

MSE takes into account various sources of uncertainty in fish stock assessment and management: Process error – natural variability, in both time and space, in dynamic processes of the populations (e.g. recruitment, predation, growth and migration) and of the fisheries; Observation error – related to collecting in-situ observations, such as total catch, catch composition, biological data (e.g. length, size, maturity), research survey, effort; Estimation error – when estimating parameters of the various models used in the assessment procedure, such as growth models, stock-recruitment models, virtual population analyses, statistical models; Model error –related to the ability of the model structure to capture the core of the system dynamics; and Implementation error – management actions are never implemented perfectly and may result in realised total catch, catch composition and effort that differ from those intended (Kell *et al*. 2007 and references therein).

Most practitioners of MSE are programming the routines themselves for specific applications and therefore, until recently, there have not been general tools that can be applied in many different areas. Fisheries Library in R (FLR, http://flr-project.org) is one of the few standard tools for MSE being developed and maintained at the present time. Usage to date is primarily within the EU-ICES community but wider interest is growing as a result of training workshops in North America and elsewhere. Descriptions of tools available that could aid in the development of MSE has been outlined by the ICES Study Group on Management Strategies (ICES 2006, Chapter 8).

Bayesian state-space models (Doug Swain)

One approach to dealing with uncertainty in population size and projections is to use Bayesian state-space models in order to simultaneously allow for both process and observation error (Swain *et al*. 2006; Fig. 2). Although these two sources of error can be accounted for in MSE simulations, there are few practical alternatives to Bayesian state-space models for incorporating them both into estimation models. State-space models comprise two coupled components, a state process model and an observation model. The first model represents the unobservable stochastic processes governing the population's dynamics. The second model describes the observation errors. A Bayesian approach facilitates incorporating prior information on population dynamics and the observation process into the model. Models can be developed for both data-rich and data-poor species. Examples of the latter are the stage-structured models applied to winter skate in the southern Gulf of St. Lawrence and on the eastern Scotian Shelf (DFO 2005c and DFO 2005d). However, a caveat is that even these types of models do not fully incorporate all sources of uncertainty. For example, in the application that is given on winter skate, the analysis does not account for uncertainty in model structure, nor does it fully account for uncertainty in parameters estimated outside of the model and given as informative priors in the model (e.g., stage-dependent catchability in the winter skate models). The latter can be partly examined through analysis of the sensitivity of the posterior to alternative assumptions about the prior.

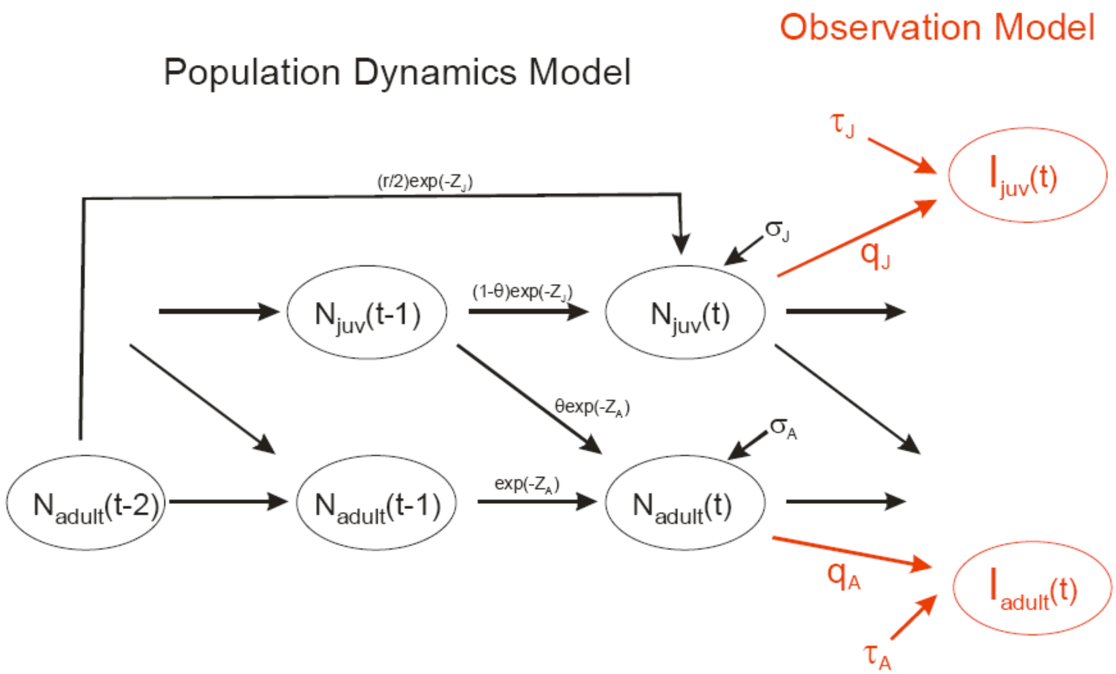

Fig. 2. The basic stage-structured state-space model used for winter skate population modeling from Swain *et al*. (2006). *Z* is a mortality rate, *r* is recruitment rate, θ is the transition probability between stages, *q* is catchability, *N* is abundance, *I* is a survey index of abundance, *σ* is process error, *τ* is observation error, and *t* indexes time.

A demographic approach (Luis A. Vélez-Espino and Marten A. Koops)

We discuss herein the main characteristics of a quantitative approach to assessing allowable harm, recovery efforts, and recovery timeframes within a demographic framework (Fig. 3). This methodology is intended to be feasible and applicable to all species at risk (or populations) for which basic life history information can be obtained or inferred. The approach relies on demographic modeling, widely applied in conservation biology (e.g., Crouse *et al*. 1987; Cortés 2002; Wilson 2003; Vélez-Espino 2005), resource management (e.g., Getz and Haight 1989; Hayes 2000) and pest control (Rockwell *et al*. 1997; Shea and Kelly 1998; Neubert and Caswell 2000). Within this framework, population growth rate (either deterministic or stochastic) is considered the best indicator of population fitness (Metz *et al*. 1992; Caswell 2001). Perturbation analysis, a demographic prospective technique that depends on the construction of projection matrices, assesses the sensitivity of population growth rate (λ) to changes in the vital rates (survival, growth, fecundity) and is used to project the effects of management interventions (Caswell 2000). From this perspective, harm and recovery efforts are considered as negative and positive perturbations, respectively, that can target one or more vital rates and life cycle stages simultaneously. More specifically, allowable harm will be a function of (a) the vital rates impacted by human actions, (b) the sensitivity of population growth rate to perturbations of impacted vital rates (i.e. elasticities), (c) the population growth rate before allowing harm, and (d) the minimum population growth rate that will not jeopardize the survival and future recovery of the population. Similarly, recovery efforts will be a function of (a) the vital rates most sensitive to management actions, (b) the elasticities of impacted vital rates, (c) population status before recovery actions, and (d) the minimum population growth rate expected to improve the probability of survival and future recovery. Additional characteristics of this approach

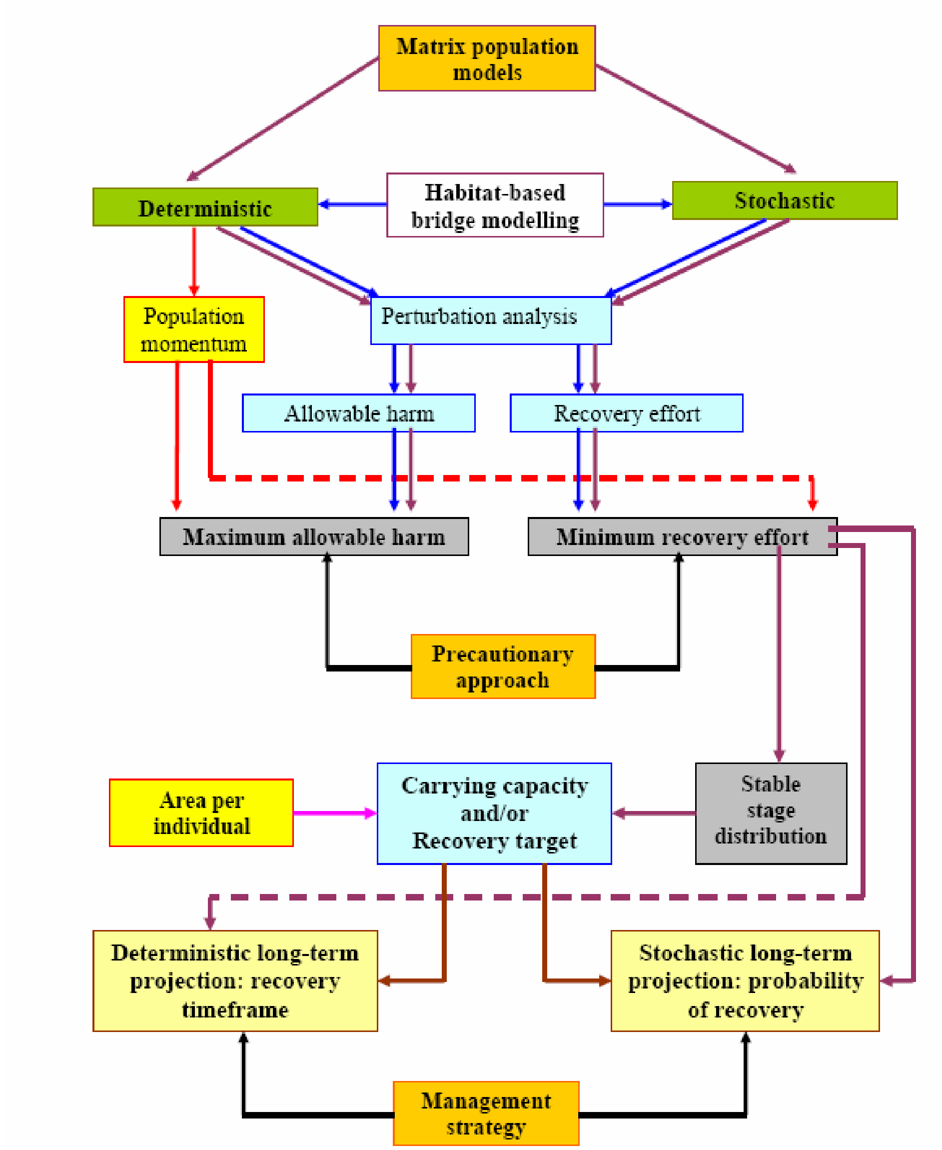

Figure 3. Demographic modelling framework for the assessment of allowable harm, recovery efforts, targets and timelines (adapted from Vélez-Espino and Koops *in prep a*).

are that it requires minimal data whilst using all available data, has the capability to link population dynamics with habitat-based information, is flexible enough to assess complex life histories, and follows a precautionary approach.

Maximum allowable harm and minimum recovery efforts are computed separately from elasticities using a deterministic approach that uses only mean values of lower level parameters and a stochastic approach that uses the observed variation. Computer simulations and resampling techniques are used to incorporate environmental stochasticity and to estimate confidence intervals for elasticity values and population responses. In addition, the effects of large human-induced changes in vital rates are also assessed by means of directly perturbing the projection matrices, thus relaxing the requirement for small changes in the application of analytical solutions when non-linearity is exhibited between vital rates and population growth (see Mills *et al*. 1999; de Kroon *et al*. 2000). Density dependence, demographic stochasticity, and depensation can be readily incorporated in the projection matrices when required and justified by a population's status, life history, and dynamics (e.g., Burgman *et al*. 1993; Ratner *et al*. 1997; Gaona *et al*. 1998; Vélez-Espino *et al*. *submitted*). This approach also accounts for the inertial effect of population structure on future population size through the computation of population momentum (Keyfitz 1971).

Finding a quantitative, scientifically robust approach to assessing allowable harm and determining recovery targets that is applicable to populations with poor data and flexible enough to accommodate the differences in life histories found in aquatic species is considered a pressing need (DFO 2004, 2005a) but has remained a challenge. This demographic approach (Vélez-Espino and Koops *in prep a, in prep b*) represents a modelling effort in that direction but also introduces a first attempt to unify the three essential elements of a recovery potential assessment (allowable harm, critical habitat, and recovery targets; DFO 2005b, 2005c), within a unique modelling framework. This approach also responds to the need to integrate scientific advice on allowable harm and components of recovery plans, which has been identified as crucial to increasing the likelihood of achieving recovery targets within reasonable timeframes (DFO 2004). The unifying factor in this approach is the use of population growth rates as the main ecological currency to evaluate both allowable harm and recovery efforts. The ecological basis not only facilitates the integration of results but also provides a common working framework to enhance the effectiveness of management decisions within SARA and the communication of goals, strategies, and results.

Information on area requirements per individual for critical stages, obtainable from allometric relationships between territory size and body size (e.g., Grant and Kramer 1990), can be combined with stable stage distributions from projection matrices to determine carrying capacity and recovery targets in terms of threshold densities. Recovery efforts can be combined with recovery targets to project recovery timeframe in a deterministic fashion using exponential, ceiling, logistic, compensatory, overcompensatory or other projections of population growth, or to project the probability of recovery in a stochastic fashion using Monte Carlo simulations and a diffusion approximation for structured populations (Lande and Orzack 1988). This flexibility allows the long-term projection of management scenarios targeting combinations of vital rates and also facilitates cost-benefit analyses. For a deterministic scenario, a cost-benefit analysis can consist of a relationship between the economic cost of management strategies and the time to reach a recovery target. In the case of the stochastic approach, time to recovery is uncertain and a better measure of success could be the probability of reaching a population threshold, previously identified as a population target, in a time period scaled to the generation length.

Data-poor projections (Kent Smedbol and Jamie Gibson)

A variety of techniques exist for projecting population size under data-poor situations. For data poor populations, abundance estimates cannot be obtained from quantitative age-based models. Alternative methods depend on what limited data are available and what is known about the life history of the species in question. Information on population size may come from count data (indices or raw counts), mark-recapture, sightings, or commercial catch or bycatch rates. These data can be used to derive estimates of abundance using aggregate or multiple count methods (e.g. Morris and Doak 2002), line transect distance methods (e.g. density surface estimation; Buckland *et al*. 2001), mark-recapture models, and age- or stage-based matrix models. Where information exists about the species, but limited population-specific data is available, a range of possible parameter values may be proposed to be used in the projections. This approach was adopted for Atlantic salmon in Maine, which used an expert panel to select the possible parameter values (Legault 2005).

Meta-analyses of life history parameters are available that can aid in the development of projection models for data poor populations. Myers *et al*. (1999) analyze over 700 spawner-recruit time series and provide a summary of the maximum reproductive rate of any species and higher level taxa, while Myers *et al*. (2002) present a meta-analysis of the maximum reproductive rates using ecologically-similar species. Meta-analyses of carrying capacity, which can aid in the development of recovery targets, are also available for some species (e.g. cod: Myers *et al*. (2001); alewife: Gibson and Myers (2003); coho salmon: Barrowman *et al*. (2003); Atlantic salmon: Gibson (2006)), although in each of these examples, carrying capacity was found to be highly variable among populations. Natural mortality remains one of the most difficult parameters to estimate, however some empirical derivations exist based on relationships between natural mortality and other life history parameters such as longevity (Hoenig 1983), growth parameters (Pauly 1980) or the age at which a cohort reaches its greatest biomass (Alverson and Carney 1975). These approaches, and others, are summarized by Quinn and Deriso (1999). Although meta- and empirical analyses are available and can be used to parameterize models in data poor situations, caution is warranted when using their results because, if a population is at risk of extinction, values derived from populations that are not at-risk may not be representative for the at-risk population, particularly when the cause of the decline is unknown.

A series of abundance estimates may allow fitting some form of simple model that can be extrapolated into the future for a range of assumptions. When only a single estimate of abundance exists, life history information on vital rates for conspecific populations or closely related species may be useful in the development of simple models. In the absence of data on birth rates, maturation rates and survival rates, but given some information on minimum current population size and the maximum rate of population increase, heuristic methods such as Potential Biological Removal (PBR) developed for cetaceans and pinnipeds (Wade 1998) can be considered. PBR is calculated as the minimum current population size times one half of maximum net growth rate (default of ½ of 4% for cetaceans) times a recovery factor. The recovery factor reflects that status of the stock and the perceived quality of the data. A recovery factor of 0.1 is used for stocks classified as endangered or threatened under the US Endangered Species Act. For other stocks, the recovery factor reflects uncertainty; the more uncertain the information about the stock, the smaller the recovery factor. PBR is aimed at maintaining the population at or above the maximum sustainable yield (MSY) level.

Under data-poor conditions, projections should be considered in terms of providing alternative scenarios under alternative parameter values or other assumptions. The value is in the comparison of the different scenario simulations, rather than in the evaluation of individual projections directly against some desired end point (such as the time needed to reach a recovery target). Note that this is similar to the approach advocated above in the section on Management Strategy Evaluation, but involves analysis of species that are not data-rich.

Problems specific to modeling populations near extinction (Jamie Gibson)

Although the approaches to modeling populations are similar, modeling population dynamics at low population sizes presents some issues that are more important than when population size is larger. These include the potential for depensation, the increasing importance of demographic stochasticity and year to year autocorrelation in environmental variability as population size decreases, and potential changes in vital rates as the result of changes in the genetic composition resulting from causes such as genetic drift, inbreeding depression or outbreeding depression. While these considerations are most important at low population size, they are also important in any population projections in which there is the potential for the projected population to reach a low size.

Most spawner-recruit (SR) models used in fishery assessments are compensatory. Implicit in their use is the assumption that per capita survival from the egg to the age of recruitment is a decreasing monotonic function of the number of eggs (or spawner biomass or abundance), and that the maximum reproductive rate occurs at the origin. If there exists a spawner abundance threshold, below which survival is an increasing function of the number of eggs, a phenomenon known as depensation (Clark 1976), these models would overestimate the potential for population growth at low abundance. The presence of a depensatory region in the SR relationship does not necessarily mean that the population with become extinct if it goes into that region. Population replacement may or may not be possible in this region, although if the SR curve does dip below the replacement line (into a region where population replacement does not occur), the population size would be expected to decline to zero.

Depensation within fish populations is an area of controversy. Myers *et al*. (1995) did not find evidence of depensation in 125 of 128 spawner-recruit time series they examined. Liermann and Hilborn (1997) conducted a similar analysis to Myers *et al*. (1995) with a different depensatory model and concluded that depensation may be more common that suggested by Myers et at. (1995). Also, Shelton and Healey (1999) showed that the arbitrary choice of the form of depensatory model used in the Myers *et al.* (1995) power analysis exaggerated the power of detecting depensation and that an alternative analysis suggested that in most cases depensation would be difficult to detect in actual spawner-recruit data. Populations that undergo large declines often do not rapidly recover (Hutchings 2000, Hutchings 2001), possibly indicating that depensatory population dynamics may be quite common. If so, the use of purely compensory models, such as are used in most recovery studies, would be inappropriate and would provide an overly optimistic assessment of the impacts of human activities on recovery. When attempting to detect depensation, model selection can affect the outcome of the analysis. Chen *et al*. (2002), proposed an SR model which includes an offset such that recruitment can be zero at a spawner abundance greater than zero. As well as being useful for detecting depensation, this model includes an extinction threshold greater than zero, and therefore may have application for addressing issues of population projections at low population size (see below). Finally, although depensation is an important consideration in model development, selection of a compensatory model (e.g. Ricker, Beverton-Holt, hockey-stick) will also effect population growth rates at low abundance, and thus has the potential to alter conclusions about recovery potential. Sensitivity analyses are recommended when the form of the SR relationship is not clear.

Predator pits are one way in which depensatory relationships can arise, and are more likely to be a factor for populations with a strong abundance-occupancy relationship. If a population contracts its occupied range as the total population size decreases, it may still be locally abundant thus available for searching predators or fisheries even at low population sizes (Ellis and Wang 2007). This is analogous to a hyper-stability in a CPUE-abundance relationships in which catch rates in fisheries may remain high even though abundance is decreasing (Harley *et al*. 2001). If either depensation or predator pits are potentially at play for the population they should be considered in the recovery strategy evaluation and the potential for non-recovery owing to these processes clearly articulated in the recovery plan.

The preceding paragraphs about selection of SR models have to do with the deterministic (predictable) component of a population's dynamics, but these dynamics also have a stochastic (unpredictable) component as well. The stochastic component can be further subdivided into demographic stochasticity, which refers to change events operating at the level of the individual, and environmental stochasticity, which operates at the level of the population affecting the mortality and/or reproductive rate of all individuals simultaneously (Engen *et al*. 1998, Lande *et al*. 2003). Because variability operating at the individual level tend to cancel out as populations increase in size, demographic stochasticity is most important at low population size, whereas environmental stochasticity is important at all population sizes. Demographic stochasticity is not well studied in fish populations, but has been studied in birds (e.g. Engen *et al*. (2001), Saether *et al*. (1998a, 2000a, 2000b, 2002) and brown bears (Saether *et al*. 1998b). Together, these studies, which analyze the variability in individual reproductive success, suggest that the demographic variance can be from about 1 to more than 10 times greater than the environmental variance. Whether these relationships are applicable to fish populations is not known. Additionally, when complex life history models are used for population projections, demographic stochasticity may enter the model at more than one place in the life cycle. Lande *et al*. (2003) suggests that the effects of demographic stochasticity can be ignored when the population size is more than 10 times greater than the ratio of the demographic variance to the environmental variance.

Given uncertainties in the dynamics of populations at low population size, the most common approach to addressing these issues is to establish a quasi-extinction threshold, where if the population drops below that threshold in a simulation, it is considered extinct. This boundary may be set at a level that is high enough that demographic stochasticity and Allee effects may be ignored (Lande *et al*. 2003). This approach was used in a population viability analysis for chinook salmon (Zabel *et al*. 2006), and the SR model of Chen *et al*. (2002), if used for projections, has this threshold as a model parameter. Quasi-extinction thresholds are closely tied to the concept of minimum viable population size (Soulé 1987). Presently, no process is available for estimating a viable population number (VPN) with any degree of certainty (Hallerman 2003). A 50/500 rule is at times cited in the conservation biology literature (Hallerman 2003), in which a minimum effective population size (N_e) of 50 individuals is recommended for short term conservation and 500 individuals is used for longer term planning. The actual VPN is determined using the ratio of effective population size to census population size (N_c). Trzcinski *et al*. (2004) reviewed Ne/Nc ratios for Atlantic salmon, and concluded that a ratio in the range of 0.26 to 0.88 would be a course approximation for this species. Based on these ratios, and a minimum N_e of 500, they concluded a VPN for Altantic salmon would be in the range of 568 – 1,923 individuals per population. While these kinds of methods may be appropriate for some fish species, it seems intuitive that these methods would provide unrealistically low estimates of a VPN for marine fish. Establishing quasi-extinction thresholds for most marine species remains a topic for future research.

Metapopulation structure can increase regional persistence, particularly when immigration 'rescues' a local population from extinction (Hanski 1999). Hill *et al*. (2002) contrast single population dynamics with dynamics of two populations that exhibit dispersal and show that small rates of dispersal can substantially increase time to extinction. Although low rates of dispersal may not be an important consideration at higher abundance, it is potentially an important consideration if population simulations are indicating a high probability of extinction.

National Experience with Recovery Potential Assessments (Bob O'Boyle, Al Cass, Charley. Cyr, Kathleen Martin, Kent Smedbol and Nadine Wells)

Since proclamation of the 2003 Species at Risk Act (SARA), DFO Science has undertaken a number of analyses related to the harm that a species listed under the Act can sustain. A national workshop was convened during 8 – 10 March 2004 in Moncton to define the requirements of science advice under s.33 and s.34 of SARA (permitting of allowable harm) and concluded that the following (herein termed the Moncton framework: appendix 6 of Rice 2004) were necessary in any harm assessment:

- Current status and abundance trends
- Recovery potential, targets and time to recovery
- Sources and scope for harm
- Alternatives and mitigation of harm

This framework was used as a general guide to the analysis presented below.

At the 25-29 Oct 2004 Allowable Harm National Peer Review meeting (Rice 2004), the scope of allowable harm for the species considered (two designatable units of cod, cusk and boccacio) was limited to the permitting period, generally one year. By the time of the National RAP Coordinators' meeting in February 2005, these reviews had been termed Recovery Potential Assessments (RPAs) and were not limited to the permitting period. A national workshop was held during August 2005 in Ottawa to define recovery targets but did not reach consensus (DFO 2005a).

The current analysis documents recovery potential assessments undertaken since 2003 using the Moncton framework. Some analyses (e.g. cusk) were not included as their scope, under an Allowable Harm Assessment (AHA) framework, was restricted to the permitting period. Some AHA analyses were included (e.g. inner Bay of Fundy salmon and Leatherback Turtle) because the scope of the analysis was consistent with the Moncton framework. Thirty four Designable Units (DU) were considered (Table 1). Of these, 15 have been listed under SARA, six have been considered for listing and have not been and the rest (pending) are in the process of being considered for listing. The information content in support of the RPAs varies markedly – from high (cod) to very low (white shark) based upon a qualitative examination of the relevant Science Advisory

Reports[1]. Overall, the information content was considered at the low end of that generally available for most commercially exploited species.

Regarding the determination of current status and trends, most DUs did not have enough information to allow synthesis through modeling, with most RPAs relying on interpretation of limited historical abundance and distribution data (Table 2). Where modeling was employed, it varied in complexity from mark/recapture (bottlenose) through demographic (right whale) to integrated assessment/PVA models using both Bayesian state-space (winter skate) and likelihood-based (porbeagle) methods.

Regarding the determination of recovery potential and targets, a variety of models have been used (Table 3), but these are often not the same as what were used to determine the current status and historical trends. As well, there is a wide variety of targets and directions (e.g. increasing trend in abundance over three generations for Right Whale) in evidence. This may be related to the lack of consensus on recovery targets at the August 2005 national meeting. As well, given information gaps, some of these targets are based on recent information while others benefited from longer time series. Thus, these targets may suffer from Pauly's 'shifting baseline' syndrome (Pauly 1995). It was noted that there is often limited monitoring capacity to judge whether or not the target has been reached.

Table 1. Designatable units considered, sorted qualitatively from high (cod) to low (white shark) information content.

Designation	No. DUs	Sara Listed	Species
EN,TH	2	No	Cod
EN	1	Yes	Right Whale
EN	1	No	Porbeagle
TH	1	Yes	Abalone
EN	1	Pending	Winter Skate/4T
TH	1	Pending	Winter Skate/4VW
TH	1	Yes	Sea otter
TH	1	Pending	Bocchacio
EN	6	Yes	White Sturgeon
Various	4	Pending	Beluga
EN	2	No	Bowhead
EN	1	Yes	IBoF Salmon
EN	1	No	Fraser coho
EN	1	Yes	Bottlenose/SS
TH	1	Yes	Northern Wolffish
TH	1	Yes	Spotted Wolffish
TH	1	Pending	Striped Bass/4T
TH	1	Pending	Striped Bass/BoF
EN	1	Yes	Leatherback
TH	1	Pending	Copper Redhorse
EN	1	Yes	Atl. Whitefish
Not Designated	1	Pending	Fur Seal
TH	1	Pending	Shortfin Mako
EN	1	Pending	White Shark

[1] These Science Advisory Reports are not provided in the Reference Section of this document but can be obtained from the CSAS website.

Table 2. Determination of current status and trends in RPAs considered.

Species	Current Status & Trends	
	Data-derived	Model-derived
Cod	Survey	ADAPT
Right Whale	NA	Demographic
Porbeagle	CPUE	Integrated assessment /PVA
Abalone	Survey	None
Winter Skate/4T	NA	State-Space
Winter Skate/4VW	NA	State-Space
Sea otter	Survey sightings	None
Bocchacio	Survey	None
White Sturgeon	Various Pop monitoring incl radio-telem	Mark/Recapture
Beluga	Survey sightings	Pella - Tom SPM
Bowhead	Survey sightings	None
IBoF Salmon	Survey index	Integrated assessment /PVA
Fraser coho	Escapement monitoring	None
Bottlenose/SS	NA	Mark/Recapture
Northern Wolffish	Survey Index	None
Spotted Wolffish	Survey Index	None
Striped Bass/4T	Tag returns	None
Striped Bass/BoF	Bycatch studies	None
Leatherback	Counts of females or nests	None
Copper Redhorse	Tag returns	None
Atl. Whitefish	Area of Distribution	None
Fur Seal	Pup counts	None
Shortfin Mako	CPUE	None
White Shark	Encounters	None

Table 3. Recovery models, targets and time to recovery for RPAs considered; UTA = Unable to Assess.

Species	Recovery Model	Recovery Target	Time to Recovery
Cod	None	None	UTA
Right Whale	Demographic	increasing trend over 3 generations	60 years
Porbeagle	PVA	SSN20%, SSNmsy	Over 10 years
Abalone	Simulation	Mortality, Density of N & SSN, SSB patch size	Decades
Winter Skate/4T	State-Space	7-14 x RV CPUE	Conditional on M
Winter Skate/4VW	State-Space	3 - 6 x RV CPUE	Conditional on M
Sea otter	Logistic/PBR	80% Carrying	Downlisted?
Bocchacio	None	Halt decline	UTA
White Sturgeon	Age - based Simulation	No loss of reproductive potent, 1000 SSN	50 years
Beluga	Pella - Tom SPM	70% historical N	Discussed
Bowhead	Logistic growth	70% historical N	100 years
IBoF Salmon	PVA	Pre 1990 N & distribution	UTA
Fraser coho	2/3 yr Simulation	Min SSN escapement	UTA
Bottlenose/SS	Logistic	Approx current N	UTA
Northern Wolffish	None	Mean survey index	15 years (2 gen)
Spotted Wolffish	None	Mean survey index	15 years (2 gen)
Striped Bass/4T	None	Exceed N target 5 of 6 years	10 years
Striped Bass/BoF	None	Distribution	UTA
Leatherback	Matrix	Increase N of nesting females	Decades
Copper Redhorse	None	Increase N, 3% spn ratio, min SSN	UTA
Atl. Whitefish	None	Increase area of distribution	UTA
Fur Seal	None	Halt decline	UTA
Shortfin Mako	None	UTA	UTA
White Shark	None	UTA	UTA

For example, for porbeagle (Gibson and Campana 2005), the main indicator of abundance had been commercial catch rates from a fishery which is now very much reduced in size. Recovery times are reported for several scenarios involving different assumptions about population growth rates as well as differing reductions in fishing mortality. Although recovery targets were not established, recovery was assessed relative to SSB_{msy}, and $SSB_{20\%}$, two commonly used fishery reference points. Given the uncertainty with long-term projections, recovery times were presented in very general terms (e.g. decades). The use of short term and long term targets for projections is a feature worthy of broader consideration.

The scope for harm, the sources of harm and mitigation were generally qualitative in nature (Table 4). Scope for harm was often referenced in relation to the current level of harm. Virtually no RPAs undertook an assessment of alternatives, although Trzcinski *et al*. (2004), in a preliminary step towards the indentification of critical habitat, did examine the effectiveness of recovery actions focused on different life stages for inner Bay of Fundy salmon. These effects would most likely apply to freshwater and diadromous DUs (e.g. mussels). In addition, most RPAs, undertook only descriptive examinations of the main sources of harm and their mitigation.

Table 4. Scope for harm, its main sources, alternatives and mitigation for the RPAs considered

Species	Scope for Harm	Main Source of Harm	Alternatives identified?	Mitigation identified?
Cod	None	Fishery	No	No
Right Whale	None	Strikes & entanglement	No	Yes
Porbeagle	Current	Fishery	No	Yes
Abalone	Below current	Fishery & natural (otter)	No	Yes
Winter Skate/4T	None	Natural	No	No
Winter Skate/4VW	None	Fishery & natural	No	No
Sea otter	PBR of 150/yr	Entanglement	No	No
Bocchacio	Current	Fishing	No	Yes
White Sturgeon	Current	Fishing & Habitat Alteration	No	Yes
Beluga	Current	Hunt	No	Yes
Bowhead	Above current	Hunt	No	No
IBoF Salmon	None	Marine & Habitat Alteration	No	Yes
Fraser coho	Current	Fishing & Habitat Alteration	No	Yes
Bottlenose/SS	PBR of 0.3 N per yr	Fishery	No	No
Northern Wolffish	Current	Fishery	No	Yes
Spotted Wolffish	UTA	Fishery	No	Yes
Striped Bass/4T	Current	Habitat Alteration	No	Yes
Striped Bass/BoF	Current	Habitat Alteration	No	Yes
Leatherback	1% Mortality	Fishery	No	Yes
Copper Redhorse	UTA	Habitat Alteration	Some	Yes
Atl. Whitefish	Current	Habitat Alteration	Yes	Yes
Fur Seal	None but…	Small hunt; mostly natural	No	No
Shortfin Mako	Current	Fishery	No	Yes
White Shark	None	Fishery	No	Yes

Over 23 freshwater species (over 30 DUs) await RPAs in DFO's Central and Arctic Region (Table 5). Most have limited historical and current data and are at the limit of their distributional range. There are recovery plans for some of these with which the results of the RPAs may ultimately conflict. Regarding sources of harm and mitigation, for these DUs, habitat is the main issue (critical habitat, historical changes e.g. damming, water quality / quantity e.g. agriculture). Close collaboration with the habitat managers will be essential to resolve these. There were very few harvest issues and some competitive issues with invasive or stocked species.

Overall, the RPAs for the data poor DUs in particular employed different approaches for current status and trends (predominantly data derived) and recovery potential (model derived using simulation). In these cases, which is characteristic of the majority of SARA related species so far, historical time series were not available to allow life history parameter investigation through more sophisticated state-space or related modeling which was the case in the relatively data rich RPAs. Guidance for both data poor and data rich situations is required. It may be possible and indeed preferable to undertake a common modeling approach, perhaps state-space, for the historical and future recovery period. As well, guidance on the recovery targets is required. This is related to the issues raised in the August 2005 national workshop. The concept of using short and long-term targets might be useful to consider.

Table 5. Main sources of harm to DUs in the Central and Arctic Region; RD = restricted distribution.

Designation	# Dus	Species	Main Source of Harm
EN(5)TH(1)	8	lake sturgeon	Fishing & Habitat (dams) & Anthropogenic
TH	1	black redhorse	Anthropogenic (habitat , dams)
TH	1	carmine shiner	Anthropogenic (habitat, flow) RD
TH	1	channel darter	Anthropogenic (habitat)
TH	1	eastern sand darter	
TH	1	eastslope sculpin	Anthropogenic (habitat) RD
TH	1	lake chubsucker	Anthropogenic (habitat) RD
EN	1	northern madtom	Anthropogenic (AIS, habitat) RD
EN	1	pugnose shiner	Anthropogenic (AIS, habitat) RD
EN (EX?)	1	shortnose cisco	overfishing, competition
TH	1	spotted gar	Anthropogenic (habitat) RD
TH	1	western silvery minnow	(habitat) RD
TH (1)	2	westslope cutthroat trout	Overfishing, competition, Anthropogenic (habitat)
EN	1	rayed bean	Anthropogenic (habitat)
EN	1	round hickorynut	Anthropogenic (habitat) + host
EN	1	kidneyshell	Anthropogenic (habitat)
EN	1	wavy-rayed lampmussel	Anthropogenic (habitat)
EN/TH	2	mapleleaf	limited distribution
EN	1	mudpuppy mussel	Anthropogenic (habitat) + host
EN	1	rainbow	Anthropogenic (AIS, habitat)
EN	1	round pigtoe	Anthropogenic (habitat)
EN	1	northern riffleshell	Anthropogenic (habitat)
EN	1	snuffbox	Anthropogenic (habitat)

On a final note, the porbeagle RPA occurred over three meetings while that for the two winter skate DUs required close collaboration over an extended period between scientists at the Gulf Fisheries Centre and Dalhousie University. The leatherback turtle meeting was dominated by non – DFO scientists. Often, RPAs will have to engage expertise outside DFO. As well, close collaboration will be required with fisheries and habitat managers as well as provincial representatives to better define mitigation options in future RPAs.

DISCUSSION

RPA Process

The RPA should provide the basis for the Recovery Team to develop a recovery strategy and action plan. The RPA is needed in the fall of the same year as COSEWIC comes out with its spring determination. Planning for the RPA process should commence before the spring COSEWIC meeting given the time limitations. By mid-January, designations will be recommended by the species specialist subcommittees of COSEWIC, although these may be subsequently revised by COSEWIC. If sophisticated analyses such as Monte Carlo simulation, Bayesian state-space modeling or recovery strategy evaluation using simulation models are to be carried out, then having adequate time and expertise for the analysis is essential. A “triage” system is proposed in order to give most attention to those designations that are likely to have a high impact on society should the fisheries be restricted. To some extent, the SARCEP Committee is already doing a first-pass triage approach.

A Recovery Strategy is required only if the species is listed as threatened, endangered, or extirpated on Schedule 1 of SARA. A Management Plan is required if the species is listed as special concern on Schedule 2 of SARA. Although recovery strategies are typically developed by recovery teams, DFO remains accountable for them. The expectation is that five years after the action plan has commenced, DFO will assess the state of the species relative to the expectations in the recovery strategy. There are no national standards for management plans at present.

Once data have been compiled for the RPA, the preferred approach would be to develop a life history-based analytical model which would allow the quantitative evaluation of threats. Threats may be natural, reflected in increased natural mortality, or induced by human activities including fishing. Thus modeling is needed, both to estimate the overall mortality rate and to quantify separately the human-induced and natural components. Work on this issue could commence within the pre-COSEWIC National Advisory Process meetings (NAPs) that DFO conducts to support development of COSEWIC Status Report. At the present time the ToRs for NAPs do not require the determination and quantification of threats, but this could be changed. Recovery is considered feasible unless it can be proven otherwise, in which case it would be useful to have the results of such analyses early in the RPA process. Early analysis of threats in the RPA could also improve DFO’s pre-COSEWIC assessment advice, leading to more comprehensive status reports by COSEWIC. It is recognized that in some cases there will be multiple threats. For example, climate change, bycatch and habitat quality might all jeopardize recovery; the latter two threats still have to be managed unless it can be demonstrated that environmental change itself makes recovery infeasible.

It seems clear that RPA, listing decisions and recovery planning could benefit from more teamwork among scientists, economists and fisheries managers. In the current approach Science ceases to be involved once the RPA is completed and passes on to Policy and FAM, except for its subsequent participation in the recovery team. In a fully integrated approach, economic analyses to inform the listing process would be undertaken at the same time as biological modeling, within the purview of the RPA, rather than as a separate process. However it is recognized that a fully integrated approach would require considerable expertise and effort. Socio-economic factors such as transfer payments, discount rates, non-use value, biodiversity value, etc. may be hard to model and review in the same way as strictly biological factors. In a partially integrated approach, the peer-reviewed results from the biological models would be made available early in the process as input into socio-economic analysis. Once the biology is fairly well understood, including the sources and magnitudes of threats, and the degree to which they must be reduced to achieve recovery has been estimated, Fisheries Management, Habitat and Policy groups could meet and jointly decide which scenarios to consider in the socio-economic analysis. If this two-stage partially integrated approach is adopted instead of a fully integrated approach, the biological experts for the species and some subset of the RPA team should form part of the socio-economic analysis team. As the socio-economic analysis proceeds, there could be a request for further Science input which could be recognized and initiated by the biological experts on the socio-economic team. Of concern to Science is that this would not fully comply with SAGE (Scientific Advice for Government Effectiveness) criteria unless the whole process were subject to open peer review.

Each of these proposed approaches has advantages and disadvantages. If the economics and biology are done together, they will be subject to the same level of peer review, which would be good. However, there may be a disadvantage in blending policy and science early on in the process in that politically unpalatable but biologically effective options may not be put on the table. If the science is done first and then handed over to Policy and Economics, the scenarios are decided on separately from the scientific process. If, for example, the decision is made to reduce aggregate human mortality by some factor, it would be useful to have science involvement to evaluate alternative ways of achieving a mortality reduction and what the impact will be within the population model.

Under current procedures, if Government decides not to list a species under Schedule 1 of the Species at Risk Act, a Recovery Plan and an Action Plan are not required. In these situations government may put in place a Conservation Strategy. While recovery plans followed by action plans may take a number of years to be developed and implemented, conservation strategies are more rapid but less rigorous. Although conservation strategies are considered by Government to be already in place for Sakinaw Lake sockeye, Cultus Lake sockeye, and interior Fraser River coho salmon, and for Atlantic cod stocks, there is no scientific analysis to demonstrate that these are likely to be effective in terms of recovery of the species.

Recovery targets

Guidelines to establish recovery targets for species at risk have yet to be agreed on by DFO. Above the boundary between the Critical/Cautious zones and above the boundary between the Cautious/Healthy zones have both been considered. These zones are described in DFO (2006). In some cases recovery teams have adopted an increasing population trajectory or increasing area of distribution as sufficient. SARA. Section 41 states that a recovery strategy must include:

> (d) a statement of the population and distribution objectives that will assist the recovery and survival of the species, and a general description of the research and management activities needed to meet those objectives;

One possible approach to resolving the different views regarding recovery target is to consider above the boundary between Critical/Cautious zones as the short term target and above the boundary between the Cautious/Healthy zones as the long-term target.

It should be noted that the socio-economic analyses do not evaluate social or economic objectives *per se*. Instead, they involve evaluating the social and economic implications of biological objectives. SARA requires objectives for population size and distribution range targets to be set by science on biological grounds. Society needs to be consulted regarding how best to meet these objectives and appropriate time frames. Recognizing the predictive limitations of fisheries science, a comparative approach may be most appropriate in this regard. In this approach, the relative probability of attaining the objective in a specified period of time is compared across management options. The economic and social implications of the alternative strategies can then be compared to the probability of meeting the objectives. It is recognized that there must be a high accountability for moving in the direction of the target even if it takes a lengthy period of time to reach. Although it may not be possible to make quantitative predictions regarding the future states of the population with any accuracy, it should be possible to rank alternative actions in terms of the timing and extent of the benefits relative to the cost of taking the actions.

Discount rate and non-use value

There is concern regarding the appropriate choice of discount rate in socio-economic analyses involving evaluation of the costs and benefits of listing and management for recovery of species at risk of extinction. The higher the discount rate considered to be appropriate, the smaller the emphasis likely to be placed by Government on the benefits of rebuilding populations-at-risk to a recovered state. Currently, DFO tends to carry out analyses at 3, 5 and 10% to inform the listing process. Use of discount rate >1% per annum can render long-term lack of recovery of negligible importance now, implying no need to take action. A lower discount rate should be considered in addition to the higher values currently in use to provide a wider perspective to the decision process. The discount rate that is used needs to be compatible with sustainability objectives and in some cases, this may be a value of zero or may even be negative. Although it is difficult to monetize the potential benefits to society of recovery, it is considered that persistence values, non-use values, utility from biodiversity and non-market values must be considered when deciding whether or not to list in future evaluations carried out by DFO in the context of SARA. Alternative units for evaluating the trade-offs besides the dollar value exist. For example there are other methods for measuring societal value. Whether or not dollar value is used, there needs to be a common currency to evaluate the trade-offs.

Modeling approaches

Minimally, modeling approaches for RPAs have to consider two scenarios in order to be informative for socio-economic analyses: status quo with regard to human-induced mortality and no human-induced mortality. A third scenario that is considered useful is to evaluate the maximum human-induced mortality the species can withstand and still recover. Models for RPAs need to be able to evaluate threats and alternative approaches for mitigating the threats. A number of different modeling approaches have been used (see above). Important factors include the available data and the life history of the species. Meta-analysis and life history invariants might be useful in constructing models for RPA in cases where empirical data for the population are limited, although if a population is at risk of extinction, values derived from populations that are not at-risk may not be representative particularly when the cause of the decline is unknown.

Short-term Science advice for Canadian fisheries is typically provided in the form of the statements of risk of specific outcomes under different policy options without dictating the option. For example, the risk of the population not growing over the next three years is estimated as X under policy Y. One possibility for RPA is to extend these short term models by providing risk computations for longer term predictions, however this is not considered to be the best way to proceed. Long term Monte Carlo simulations have to account for process error (e.g. uncertainty in recruitment, growth and mortality) in addition to observation error, and are likely to rapidly become uninformative regarding the probability of future states as one projects further into the future. Uncertainty may be better handled using state-space models and Bayesian techniques. These models treat observation and process error separately and the covariance structure is maintained by sampling from the posterior distributions of key parameters. Some examples of this approach already exist with regard to Canadian RPAs (e.g. winter skate).

Scientific best practice may dictate that analyses be restricted to more general evaluations of the expected time frame for recovery and the maximum human-induced mortality that can be sustained so as not to jeopardize recovery, rather than providing specific predictions regarding future states. It is not clear that Science can adequately consider uncertainty under various recovery options when providing advice on long-term prospects for recovery. On the other hand, there is concern that if Science does not attempt to provide this advice, that Policy and FAM will proceed with scenarios that lack a scientific basis.

The management strategy evaluation (MSE) approach, tailored to recovery strategy evaluation (RSE) appears to provide the best way forward from a scientific point of view. In this approach, the performance of alternative recovery strategies are evaluated against an operating model which attempts to simulate the biological process, the assessment processes and the management processes. This could be expanded to include modeling the social and economic processes and associated uncertainty. This would provide an integrated environment for RPAs. However, few MSE applications currently exist with regard to the assessment and management of Canadian fish stocks and it is recognized that such analyses require a considerable amount of effort and expertise. DFO is currently engaged in reducing expertise in the area of stock assessment in a move towards an indicator based ecosystem approach and greater emphasis on industry involvement in management decisions through a policy of shared stewardship. Without diminishing stock assessment expertise, RSE approaches may be beyond the time-scale of most RPAs. Efficiencies may be possible through the application of a triage approach and the development of standardized and streamlined RSE methodology that can be applied within RPAs despite a limited availability of experts.

It is recognized that modeling populations at low population size poses some extra challenges. The possibility of depensation caused by Allee effects and predator phenomena needs to be considered. Also, random processes including demographic variability, year to year autocorrelation in environmental variability, and genetic drift, have an increasingly greater influence on population viability as population size decreases. These are problems that are not routinely considered in stock assessment for populations at higher levels of abundance supporting directed commercial fisheries. Expertise in these areas needs to be developed within DFO.

Review process

It is recognized that all aspects of the RPA process, including the socio-economic analysis, require peer review and documentation in a transparent, publicly accessible form. The DFO CSAS structure could be expanded to include socio-economic analysis applying the same peer review standards currently used for DFO science. If the RPA and socio-economic analysis are done in an integrated way, either through an MSE approach or by some other means, then joint review of all the analyses could be carried out simultaneously. This is the preferred approach but would require considerable commitment of resources. It is recognized that there are only four research economists in DFO. Also, quantitative scientific staff with experience in fisheries statistics and models are being reduced through attrition and redirection to ecosystem approaches. Remaining expertise is stretched between regular stock assessments, Precautionary Approach implementation, pre-COSEWIC assessments and other activities. Since it is the same core group of quantitative professional staff involved, it is clearly important for Science management to establish and clearly communicate priorities. Given limited numbers of quantitative socio-economic and biological experts in DFO, some RPAs may need to be carried out at a national level in order to gain critical mass for peer review.

RPA and socio-economic cost-benefit analysis is complex and methodology is still evolving. The current review was unable to fully develop the best-practice standard without further work. In order to make progress it is recommended that DFO management chose an upcoming high-profile RPA as a national case study to establish a best-practice standard for the preferred fully integrated biological/socio-economic approach described above. This should include establishing independent socio-economic and scientific peer review, and for public communication of expert advice on recovery potential and cost-benefit of alternative recovery options, independent of the political process of determining SARA listing.

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APPENDIX

Terms of Reference
National Workshop

Further developments to the national framework on Recovery Potential Assessments (RPAs) for species at risk

Part 1, March 19, 2007 - Long term population projections
Part 2, March 23, 2007 – Critical Habitat

Lord Elgin Hotel, Ottawa

Chairperson: Jake Rice

Background and Context:

Provisions of the Species at Risk Act require jurisdictions to prepare Recovery Strategies and Action Plans for each listed species. These Strategies and Plans must include a description of critical habitat and recovery targets for range and abundance of a listed species. Provisions of the Plan must include measures to protect individuals of protected species from mortality, harm or harassing by human activities, or destruction of their habitats or, when appropriate, residences. Plans may allow such harm or mortality only when it can be shown that the activities do not jeopardize survival or recovery.

Prior to listing decisions by Government in Council, the responsible jurisdiction must consult with Canadians on the social and economic consequences of the recovery plans. For these consultations to be informed, scenarios often have to be explored analytically, to investigate the likelihood of recovery under different assumptions about the levels and nature of various human activities.

Both the direct provisions of SARA and the information needed for modeling social and economic impact scenarios require significant input from Science Sector. An initial framework for these Recovery Potential Assessments was developed in a series of CSAS workshops in 2004-2006. At a workshop between Science Sector and the SARA Secretariat, with participation from all DFO Sectors, in September 2006, the types of science support required for assessing recovery potential and social and economic effects of listing was discussed further, gaps were identified, and priorities assigned. Following that Workshop, Science Sector appointed a Recovery Potential Assessment “SWAT Team” to commence work to address the gaps and build national and regional capacity to conduct recovery potential assessments. That SWAT team identified two areas for immediate action, and commenced activities to have working papers ready to review at a Workshop in March 2007.

Objectives:

1) To review the state of knowledge and provide guidance on best practices for:
    a) Long term population projections done as part of social and economic scenario exploration
    b) quantifying the amount of critical habitat
2) Review the results of the Science Sector – SARA Secretariat workshop, and develop a workplan for addressing other gaps and priorities.

Proposed approach and Working Papers:

1) Review working papers on the state of knowledge of methods for long term population projections, considering:
   a) the requirements for pre-listing socio-economic analyses and post-listing recovery planning
   b) the appropriateness of alternative methods for marine and freshwater fish species with differing life histories and data availability
   c) how risks and uncertainties should be accounted for in analyses and provision of advice.
2) With the information available, provide guidance on the best practices (and possibly on unacceptable practices) for long term projections, considering the factors in 1, and identify any further work that would be needed in order to improve the best practices.
3) Review working papers on published methods on the quantity and quality of critical habitat, or habitat of aquatic organisms in general, considering:
   a) the appropriateness of different quantification methods for aquatic habitats with different types of properties;
   b) the appropriateness of different quantification methods for aquatic species with different types of habitat affinities;
   c) the appropriateness of different methods for different quantities and qualities of data;
   d) risks and uncertainties that should be communicated about the results of any methods.
4) Provide guidance on best practices for quantifying critical habitat, considering the factors in 3.

Output:

A Science Advisory Report, a Proceeding, and at least two Research Documents (on the themes of 1 and 3).

Participation:

DFO scientists who were identified as part of the Recovery Potential Assessment “SWAT team” are expected to participate in one or both parts of this workshop, depending on their field of expertise. Participation may also be influenced by a concurrent SARA-related workshop, held March 20-22 in Ottawa. Participants from other DFO sectors are also expected.