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# A Proposal for Status Indicators, Status Classifications, and Management Actions for Atlantic Salmon Populations in the Maritimes Region

# Proposition relative aux indicateurs de l'état des stocks, à la classification de l'état des stocks et aux mesures de gestion à prendre pour les populations de saumon atlantique de la Région des Maritimes

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## FOREWORD

This document is a product from a workshop that was not conducted under the Department of Fisheries Oceans (DFO) Science Advisory Process coordinated by the Canadian Science Advisory Secretariat (CSAS). However, it is being documented in the CSAS Research Document series as it presents some key scientific information related to the advisory process. It is one of a number of contributions first tabled at a DFO-SARCEP (Species at Risk Committee / *Comité sur les espèces en péril*) sponsored workshop in Dartmouth (March 2007) to begin the development of a 'Conservation Status Report' (CSR) for Atlantic salmon. When completed in 2008, the CSR could form the basis for a Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status report, recovery potential assessment and recovery strategy, and most importantly, enable DFO to implement pre-emptive management measures prior to engagement in any listing process.

## AVANT-PROPOS

Le présent document est issu d'un atelier qui ne faisait pas partie du processus consultatif scientifique du ministère des Pêches et des Océans, coordonné par le Secrétariat canadien de consultation scientifique (SCCS). Cependant, il est intégré à la collection de documents de recherche du SCCS car il présente certains renseignements scientifiques clés, liés au processus consultatif. Il fait partie des nombreuses contributions présentées au départ lors d'un atelier parrainé par le MPO-SARCEP (*Species at Risk Committee* / Comité sur les espèces en péril) et présenté à Dartmouth (mars 2007) pour commencer l'élaboration d'un rapport sur l'état de conservation du saumon atlantique. Lorsqu'il sera terminé, en 2008, ce rapport pourrait servir de base à un rapport de situation du Comité sur la situation des espèces en péril au Canada (COSEPAC), à une évaluation du potentiel de rétablissement et à un programme de rétablissement mais, avant tout, il permettra au MPO de mettre en œuvre des mesures de gestion anticipées avant même de s'engager dans un processus d'inscription.

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## ABSTRACT

In response to a diversity of information, population structures, data, and status of wild Atlantic salmon among rivers of eastern Canada, this research document proposes and evaluates a framework of indicators that may be applicable across a wide range of populations. Indicators and subsets are proposed and applied to a range of rivers and groups of rivers in areas proposed as Conservation Units (CU) that are known to be in a variety of conservation states. Indicators were standardized to a proportionate scale and assessed using proposed benchmarks suggested by historical, national, and international advisory groups that signaled a progression of proposed management actions. Salmon in a river that was listed as endangered was used to assess the performance of various combinations of indicators and benchmarks. A retrospective analysis of the endangered CU indicated for that benchmarks set at a 50% decline rate were overly cautious, while a 75% decline rate was more cautious than the historical case. Using several subsets of indicators and the proposed benchmarks, most rivers and CUs in the Maritimes Region would classify as requiring adjustment of human induced mortality, threat assessment, and management review and/or recovery actions.

## RÉSUMÉ

Face à la diversité des structures et de l’état des populations de saumon atlantique sauvage dans les rivières de l’est du Canada, et des informations et données connexes, le présent document de recherche propose et évalue un cadre d’indicateurs qui pourrait s’appliquer à un large éventail de populations. Il propose des indicateurs et des sous-ensembles de données et les applique à plusieurs rivières et groupes de rivières dans des zones proposées comme unités de conservation (UC), dont l’état de conservation varie considérablement. On a normalisé les indicateurs à une échelle proportionnée puis on les a évalués selon des points de référence suggérés au fil du temps par des groupes consultatifs nationaux et internationaux, indiquant une progression des mesures de gestion proposées. On s’est appuyé sur la population de saumon d’une rivière considérée comme étant en péril pour évaluer l’efficacité de diverses combinaisons d’indicateurs et points de référence. Une analyse rétrospective de l’UC en péril a révélé que les points de référence établis en fonction d’un taux de déclin de 50 % étaient excessivement prudents, tandis qu’un taux de déclin de 75 % était plus prudent que l’analyse historique. En utilisant plusieurs sous-ensembles d’indicateurs et les points de référence proposés, on pouvait classer la plupart des rivières et UC de la Région des Maritimes comme « nécessitant un rajustement de la mortalité anthropique, une évaluation de la menace et un examen des mesures de gestion et/ou des mesures de rétablissement ».

## INTRODUCTION

Management of Atlantic salmon in Eastern Canada started with the *Fisheries Act* in 1868. In fact, Atlantic salmon (*Salmo salar*) provided the impetus for many of the Sections and many more Variation Orders under the *Act*, e.g., Section 20 dealing with fish passage and Section 34 dealing with deleterious substances were early Sections in the *Act* principally dealing with declines in salmon populations (Dunfield 1985). While many of the encumbrances to Atlantic salmon population persistence were alleviated by these measures, populations in some areas have declined, leaving a mosaic of status. These declines and the highly migratory nature of wild Atlantic salmon have brought about a series of principles, policies, and measures designed to protect and restore populations in general. These range from closures and moratoria on interceptory commercial fishing for salmon, e.g., the 1985 and 1995 closures in the commercial salmon fisheries in coastal Canada, the 1983 non-retention of salmon bycatch in fisheries directed at other species, to reduced daily and seasonal bag limits to catch-and-release recreational fisheries for salmon larger than 63.0 cm, beginning in 1978. These domestic measures are coincident with and prescribed within international policies such as the North Atlantic Salmon Conservation Organisation (NASCO), where only terminal harvests of populations in excess of their conservation requirement is the recommended policy.

However, new legislation such as the *Species at Risk Act* (SARA) in Canada, and international compliance monitoring (NASCO's Implementation Plan) and revised domestic policy and external species status reviews (Committee on the Status of Endangered Wildlife in Canada [COSEWIC]) have placed increased demands on formally assessing, recognising, and initiating actions appropriate to the circumstances of a population. A reality of these demands is that dependence on a single indicator, such as the conservation requirement, does not completely or is not consistently available to inform these decisions. While some multiple indicator systems have been proposed (Chaput 2000), an operational suite of indicators to assess the status of Atlantic salmon has not been established. Establishing and tuning benchmarks of status indicators such that actions appropriate for a status designation are consistent across a suite of indicators has been difficult and slow to develop.

A further complication is that regulations seldom apply to a single population, river, or lake, but more often apply to a group of populations defined by a geographic area. These areas are often defined by shared attributes such as geography, geology, or biology. However, these assemblages can be consistent with groupings suggested by other legislation and review bodies such as SARA or COSEWIC. It would, therefore, be advantageous to coordinate definitions of assemblages, status rating, and prescribed actions across these jurisdictions and interests.

In response to the diversity in the status of wild Atlantic salmon in eastern Canada, and in recognition that a stock of Atlantic salmon was listed as an endangered species of COSEWIC and SARA, this research document proposes and evaluates a framework of indicators that may be applicable across a range of populations. This document proposes Conservation Units (CUs, i.e., assemblages) and benchmarks to assess indicators for a listed Designatable Unit (DU) under SARA, the inner Bay of Fundy (iBoF) Atlantic salmon, a listed endangered DU, as well as for four other proposed units and seven rivers, with different suites of available indicators. Combinations of indicators and variations of indicators are applied to the iBoF case, in order to assess the functionality of the indicators to a historical example.

## POPULATION ASSEMBLAGES AND DESIGNATED CONSERVATION UNITS

Managing for diversity has been recognised as a sound ecological principle (Koljonen 2001). Biological diversity not only means species diversity, but also intra-species diversity. Intra-species diversity can be documented through genetic description, where non-adaptive marker genes are used as an indicator of phylo-genetic divergence. These divergences are also noted for differences in behaviour, physiology, demographic, and descriptive traits that reflect local adaptations. The fact that these traits are associated with phylo-genetic divergence is testament to their lineage and value, with respect to diverse and variable environments. Genetic differentiation has been recognised in Atlantic salmon (Ståhl 1987); however, due to the extent of the last Wisconsin glaciations, the movement of Atlantic salmon populations and incomplete sampling and genetic description, not all significant divergence has been documented (O'Reilly 2006). However, within jurisdictions, genetic proof is not always required to designate units under legislation. Within various acts and jurisdictions, the weight of history, local knowledge, and recognised differences are valid indicators of Designatable Units (DUs). In Atlantic salmon, science and historical recognition of some of these units has been persistent, and was later borne out by genetic research, e.g., inner Bay of Fundy salmon, which was recognised as early as 1852, and was eventually shown to be genetically different from adjacent populations (Verspoor et al. 2002). Therefore, in the precautionary sense, while the commercial and recreational status of Atlantic salmon populations decline and become more regionally variable, DUs were proposed for Atlantic salmon populations in the Maritimes Region, and classified into groups herein called Conservation Units (CUs), using both quantitative and qualitative criteria (DFO-MNRF 2008). CUs for the Maritimes Region were extracted from the report, and are described in Appendix 1.

## INDICATORS OF STOCK STATUS AND RATIONALE FOR INCLUSION

1. Cohort recruit per spawning salmon (R/S) over 1 generation.

Age specific recruit per spawning fish (Ricker 1954, Beverton and Holt 1957, Cushing 1988, Hilborn and Walters 1992) is a data intensive parameter; however, it is also a core functional model that when collected over time and over a range of values can be used to summarise population dynamics and derive management parameters. Regardless of the model structure, generational R/S values less than 1 are not expected, when spawning stocks are below the maximum or the management assigned target recruitment point. Unless populations are in excess of the maximum recruitment or the conservation target, recruits are expected on average to be greater than the number of spawners, especially if accumulated over a generational period. Populations that have a R/S ratio of less than 1 over a generation are by definition declining and, therefore, of interest relative to conservation status. Successive generations below replacement are of acute interest to conservation.

Various forms of R/S relationships are used to derive management parameters for populations, and can contain all individuals recruited back to the local area, including all removals, to estimate un-fished equilibriums, or only those recruited to a spawning escapement. In this case, because we are using these data to assess decision points concerning conservationk, it is preferable to use the escapement data. Furthermore, because recruitment resultant of supportive rearing or enhancement is indistinguishable from natural reared parents (without extensive genetic analysis), all spawning salmon are used in the analysis.

2. Synthetic R/S over 1 generation.

Often the numbers of returns to a river and the spawning escapements are estimated rather well, but the age structure is less well known. However, these data can be used to construct a Backward Replacement Ratio (Rago 2001), termed a synthetic R/S here, by estimating the adults that contributed to the recruitment or spawning stock based on the recruitment time series at sea age and the mean proportions of smolts ages.

The formulae to estimate the number of spawning salmon (*Spawners*) that contributed to the recruits in a year ($_i$) was:

$$Spawers_{i,t} = \sum_{SmoltAge=1}^{x} \mathrm{Re}\,cruits_{i-(t-1)} * Smolts_i$$

where *Recruits* were counts or estimates of adult salmon at sea age (*t*) and *Smolts* were the proportion of smolts produced at age 1 to *x*, the oldest smolt age.

Averaged over 1 generation, values that vary about 1 indicate a stable population, and values that deviate to below 1 indicate a population in decline. The degree of this decline could be used to indicate the level of management actions.

3. Average annual "λ" (lambda, $N_t/N_{t-1}$) without age information over 3 generations.

In cases where the determination of smolt age is unknown or highly variable, lambda or the annual proportion population size relative to last year is a simple relative change indicator. Averaged over a long enough time period, this number would be expected to approximate 1. If over 3 generations' λ is substantially less than 1, then the population is likely declining or highly erratic. In either case, there is a signal of a possible population declination and rate. Values consistently greater than 1 indicate a general population increase.

4. Geometric mean of generation smoothed "λ" (Geometric mean of $N_t/N_{t-1}$)

Often high annual variation in λ and the fact that stability is not expected over short time periods can blur a possible signal of population increase or decline. High variation can be dampened by calculating a moving average of λ for the generation time of the animal. Lambda then becomes an indicator of generational replacement with all of the same features of annual λ. In this case, λ was estimated for the generation and estimated by a geometric mean, an appropriate harmonic mean for rates data.

5. Proportion of the conservation requirement attained over the last 3 generations

Conservation requirements for Atlantic salmon are generally obtained from an average egg deposition rate, including unknown removals, that was observed to maximise the number of smolts in a range of tested streams and rivers (Chaput 1997). In addition to this rate for fluvial habitat, additional eggs are required for lacustrine (lake or pond) habitat, principally in Newfoundland and Labrador. In Quebec, hierarchical Bayesian methods were used to determine maximum rates based on suitable habitat area indices and the posterior distribution of combined stock and recruitment functions (a hyper-prior distribution or probable deposition rates for habitat weighted areas). Regardless of methods, these rates are used to estimate a conservation requirement and to assess the degree to which a population is at its maximum reproductive potential. When eggs are converted to adult salmon at mean biological characteristics, this value is meant to provide a drainage specific population reference point.

Salmon management has been and continues to be adjusted or altered with respect to the attainment of this point. Based on past management history in the Maritimes Region, the 25th percentile value was used herein to indicate that "recovery actions are recommended", and the 100th percentile value was used to indicate a Category 2 (see Categories, page 8) or "adjust human induced mortality, assess threats, and review management", a condition similar to the "healthy" zone of DFO (2005b). Values in excess of the 100th percentile point were used to indicate a Category 3 or "objectives met" condition, the implications of which are discussed in DFO (2005b) and in the discussion that follows.

6. The proportion of smolt to adult survival of the reciprocal of smolts per adult spawner for 1 generation (Marine Survival/(1/Freshwater Production)).

This measure is similar to an R/S equilibrium model in that the number of smolts produced by an adult is a measure of the freshwater survival and recruitment, and the number of adults produced per smolt is a measure of marine survival. If these values are not balanced over time, then a population will increase or decline. This may be a valuable indicator when smolt production is measured for 1 generation but a complete stock and recruitment time series is not available. This indicator may also be a dynamic dependant, i.e., expected to decline at high spawning escapements and to increase for low escapements. However, as for R/S relationships, in the case of assessing the conservation status, we are more interested in populations with decline trends due to low population size, where compensation dynamics are less of a concern. The number of smolts per spawning salmon may be cohort adjusted, or simply the average of annual observation over 1 generation. Again, the possibility that higher escapement dynamics could effect freshwater production needs to be examined and considered.

Marine survival = adult recruits/smolt

Freshwater production = smolts/adult spawner

Required marine survival = 1/(smolts/adult spawner)

Production replacement = observed survival/required survival

7. Total migratory return in the last year compared to a 3 generation average.

This is the basic population indicator used by most jurisdictions. However, the duration, rate of decline, and tolerance to low population that is acceptable varies by jurisdiction. Often the acceptance of indicator limits or decision points are mediated by ancillary information. E.g., in COSEWIC, the minimum decline rate changes depending on whether there is a known cause.

8. Latest total parr density as a proportion of the 3 generation average.

Often the only quantitative information that is available for a salmon population are juvenile salmon density estimates. While there is much uncertainty over the interpretation of juvenile salmon data, particularly with respect to carrying capacity and transportability of productivity, relative change in juvenile density has been shown to indicate a change in population size (Rago 2001, Gibson and Amiro 2003).

9. Projected population in 3 generations as proportion of current generation or population.

Population prognosis is the essential question underlying conservation and management actions. Therefore, casting the current population and productivity state ahead is an essential signal of the possible time available to research and treat identified causes. The worst case, or near the worst case, would be expected if the population continued at recent observed declines. To estimate the worst case scenario, the expected population in 3 generations based on λ was used to estimate the proportion the projected population could be of the current population. The projection formula used was:

$$FP = P * \lambda^T$$

where: FP = future population
P = present population
λ = geometric mean 3 generation λ
T = time to 3 generations (12 or 15 in the cases shown here)

10. Proportion of rivers in a DU, or CU as used here, that salmon occupy relative to a 5 generation history.

Scaling from Index Rivers to a DU is problematic. One signal of particular interest would be the number of populations within the DU that have been lost. This is a surrogate for range reduction and to a certain extent population fragmentation, 2 indicators used in other jurisdictions. Again, this variable can be obtained from adult or juvenile census data.

11. Projected population of the DU, or CU as used here, in 3 generations as a proportion of the current population.

This indicator can be developed from historic estimates of returns, harvests, and spawners, much as is done for the North American Run Reconstruction Model used by International Commission for the Exploration of the Sea, (ICES), Working Group on North Atlantic Salmon (WGNAS). It may be of particular value to DUs where index rivers are small relative to the DU.

## CATEGORIES

Three status classification categories were assigned:

1. Recovery Actions Recommended
2. Adjust Human Induced Mortality, Assess Threats, and Review Management
3. Objectives Met

Classifications for individual indicators were assigned according to the benchmark breakpoints provided in Table 1.

## BENCHMARK BREAKPOINTS

All indicators were proportions and evaluated on a scale from 0 to 1 (Table 1). Population replacement indicators (1, 2, 3, 4, and 6) were evaluated against 2 benchmarks; a high breakpoint, where objectives were met, was set at a value of 1.0, and the low breakpoint was 0.94. The low breakpoint was chosen to reflect the population replacement value, where a population would be reduced by 50% in 3 generations; similar to other jurisdictions where some form of classification, other than of no concern, would be indicated, and actions would be required if a cause for the decline was not known.

Indicator 5, "proportion of the conservation requirement", which is the only fisheries management reference point indicator used herein, was evaluated using a high breakpoint of 1.0 and a low breakpoint of 0.25. These points reflect the objective of the conservation requirement as a limit reference point and past management practices, particularly within the Maritimes Region, of closing all directed access to Atlantic salmon in rivers below this proportion of the conservation requirement, e.g., closures of Aboriginal and recreational fisheries in 58 of 65 rivers on the Southern Upland of Nova Scotia since 1994.

All historical population comparisons, indicators 7, 8, 9, 10, and 11, were evaluated against a low breakpoint of 0.25, similar to the reference point indicator, but the high point was halfway to the long term mean for the indicator (0.625).

Assessment of individual indicators can result in a variation of states across indicators. In order to derive an integrated assessment across indicators for rivers or CUs, 4 combinations of indicators were examined: 1) all indicators available, 2) the 4 highest indicators, 3) the 4 lowest indicators, and 4) a standard set of 4 indicators (4, 5, 7, and 9). Average breakpoints for rivers and CUs were derived: 1) for the set of all indicators, all breakpoints in a classification category were averaged. This pair of breakpoints (0.56, 0.83) was used to evaluate the average of all indicators, a selection of the high 4 values, the low 4 values, and 2) to assess the set of the same 4 standard indicators, the average of breakpoints of 0.42 and 0.81 for indicators (4, 5, 7, and 9) for rivers and average breakpoints of 0.39 and 0.78 for 5 indicators (4, 5, 7, 9, and 10) for CUs was used.

## ACTIONS

The point of having breakpoints is to signal a change in management actions. These actions depend on the status and objectives of management. However, breakpoints also depend on the management objectives, actions, and status of the population, i.e., breakpoints and actions are interdependent. In order to propose and test a framework, breakpoints and actions needed to be hypothesised. Therefore, a decision structure and prescriptive management action plan (Appendix 2) was proposed that was comparable to other jurisdictions and similar to the history of DFO actions in the specific cases presented. These actions have similarities with other jurisdictions in that management actions are prescribed for specific categories and include reduction in exploitation, increased protection for increased survival, improved fish passage, management consultation, recovery planning, review, and intensive conservation actions.

## CASE STUDIES

Seven rivers were evaluated in the Maritimes Region; Nashwaak River, Saint John River (hatchery and wild) in the outer Bay of Fundy (oBoF), Stewiacke River in the inner Bay of Fundy (iBoF), LaHave River and St. Mary's River on the Southern Upland of Nova Scotia (SUNS), Grand River in the Cape Breton Eastern Lowlands (CBEL), and Middle River in Cape Breton Eastern Highlands (CBEH). The Stewiacke River in iBoF was a key river in the COSEWIC designation of iBoF salmon as endangered in 2001, and was considered an anchor point for this analysis. For this purpose, Stewiacke River data prior to 2001 was used to assess status. All data were derived from files used to produce DFO science advice for these rivers (Amiro et al. 2006, DFO 2008).

Where available from existing summaries that are provided annually to the ICES Working Group on North Atlantic Salmon (WGNAS) for area assemblages that equate to a proposed CU, estimates of spawners and returns were used to estimate projections for a CU. The above rivers were assumed to be an index of the status of stock within a CU. When more than 1 index river was available, the average of index rivers was used to represent the CU.

## RESULTS

Only the Stewiacke River was clearly a Category 1 by all indicators (Table 2). The Stewiacke and Grand rivers scored as Category 1 by any of the 4 combinations of indicators (Table 3).

When indicators were evaluated independently (Table 2), the St. Mary's River and the Saint John River resulted in a mixture of categories with a high frequency of Category 1 valuations. The Nashwaak River was the most extreme with a mixture of the 2 high and 4 low category scores. The LaHave River scored 1 high, 3 medium, and 5 low category scores. The Middle River scored the highest with an even mixture of Category 2 and 3 scores.

Average scores resulted in 2 rivers, Stewiacke and Grand rivers solidly scoring in Category 1 (Table 3, Figure 1). Two rivers, the St. Mary's River and the Saint John River (by either inclusion or exclusion of hatchery returns) were predominately Category 1. The LaHave River scored predominately as Category 2, and only the Middle River scored predominately as Category 3.

Only the Southern Upland and outer Bay of Fundy were derived from averages of 2 index rivers, the remaining CUs were indexed from only 1 river in each area. The proportion of rivers in a CU that were occupied by salmon compared to 3 generations ago was not available for the outer Bay of Fundy CU at this time, and was assigned an assumed value of 0.90. Projected population for a CU was only available for the Southern Upland and for the outer Bay of Fundy, as these are similar to the areas, for which annual summations of returns and spawners are provided to ICES.

When indicators were evaluated independently by CU (Table 4), no CU was uniform in its category. In the iBoF CU indicator 11, the proportion of the CU occupied by salmon, was a Category 2, compared to all other indicators in the CU, which scored at Category 1. While the indicators across CUs were varied, there was a predominance of Category 1 in all but the Cape Breton East Highlands CU.

When the average of all indicators in a CU were evaluated against the average break points (Table 5, Figure 2), the iBoF was a Category 1, the SUNS, CBEL were split between Category 1 and Category 2, and oBoF was predominately a Category 1 but scored in all categories. The highest category score 3 was the average of the highest scores and was 0.84, against the breakpoint of 0.83. The CBEH scored Category 3 by all average scores.

Using the high 4 scores, elevated the SU and CBEL to a Category 2 and the oBoF to a Category 3. Using the low 5 scores, demoted the SUNS, CBEL, and oBoF to Category 1. If a standard set of 5 categories were used, the iBoF was a Category 1, the SU, CBEL, and oBoF were Category 2, and CBEH was a Category 3.

A test of the tuning of benchmarks was evaluated by applying the indicators and subsets of the indicators to the iBoF and Stewiacke River, a previously evaluated distinct population segment under COSEWIC and listed as endangered under the *Species at Risk Act*. Low catches and assumed returns to the Stewiacke River was a concern for management since 1987. Population assessments began in 1984 for juvenile salmon and expanded to adult salmon by 1992. The river was closed to angling in 1991, and after consultation with affected governments and stakeholders, a pre-emptive proactive supportive rearing program was initiated in 1998. The iBoF was declared endangered by COSEWIC in 2001.

Retrospective analysis of the Stewiacke River data indicated that smoothing lambda yielded a more stable signal, which was consistent with historical conservation actions for this example river (Figure 3). In order to assess the signal against the history of conservation actions, the benchmarks for lambda were set to a lower risk prone (risk averse) level of 0.89, and contrasted with a more risk adverse level of 0.94 as proposed in the framework. These values translate into 75% and 50% declines in a population over 12 years, or 3 generations.

Evaluations of category assignments for lambda estimated from population estimates provided by Gibson and Amiro (2003) for the Stewiacke River, using a smoothed geometric mean "G" or by annual averaging "A", indicated that the annual method was unstable and the smoothed method, in either the prone or adverse set up, was preferable, i.e., indicated a true conservation risk (Figure 4). The analysis also indicated that the geometric mean of generation smoothed lambda was a more stable indicator of population trend. However, because the indicator was below 0.94, beginning in 1989 well before actions were taken in 1998, a benchmark of 0.94 is perhaps over cautious with respect to the management history. If the more risk adverse value of 0.89 was used, recovery actions would have been indicated in 1994.

## DISCUSSION

The results provided by the indicators, benchmark breakpoints, and averaging methods used here generally provided outcomes in agreement with historical decisions and with current management dilemmas. Adjusting breakpoints provides a mechanism to tune to historic and current actions; however, in most instances, the breakpoints used accurately reflected current concerns and historical actions. The iBoF resulted in a solid case for "Recommended Recovery Actions", and is a listed endangered species under SARA. Both the oBoF and SUNS resulted in frequent low scores and areas of concern, and have undergone surveys, reviews, and evolution from enhancement actions to population maintenance and recovery actions and research over the past 4 years.

The oBoF, SUNS, and Cape Breton East Lowlands and Highlands has areas of population improvements and deteriorations over the period examined here (3 generations). Unlike the iBoF, these areas have not benefited from national exposure of their status and prognosis, but have been regarded as in jeopardy within annual stock status reports (DFO 2003). Separation by highland and lowland rivers in Cape Breton East somewhat grouped rivers by jeopardy differences but not completely. The possibility exists that in each of these areas there are river populations that are in relatively better status and rivers that are more threatened. Regardless, this analysis indicates that relative to 3 and 5 generations ago, the status of CBEL and CBEH is poor to fair depending on the area or river examined.

The suite of indicators trialed here was derived from knowledge of the data available, the criteria used in other jurisdictions, and the desire to keep to simple indicators. The lambda generation trend method is common to this type of analysis, and generation averaging has been suggested in previous analyses (DFO 2005a). Other forms of forecasting the population size in 3 generations (exponential versus linear decline) could be used and would result in different end populations. However, unless a higher weighting is applied to this indicator, forecasting will not carry a decision.

Indicator weighting has been suggested and applied in other multiple indicator systems. Weighting can have value if there is evidence that a decision system is strongly influenced by 1 or more indicators. The spreadsheet used for this analysis has a weights matrix for the indicators; however, for this analysis, all weights were set uniformly to values of 1.0.

The standard 4 indicators, (4, 5, 7, and 9) are somewhat independent measures of population trends, recent performance compared to a standard or to past performance, and the possible status in 3 generations if the conditions that led to the decline remain. A fifth standard for CUs incorporates the spatial and temporal population distribution for the CU. These indicators were selected because they consider the range of questions posed by other agencies or jurisdictions engaged in similar processes and because they proved to be widely available for the index rivers and CUs.

The informed practitioner will recognise that many of the data and parameters necessary to derive a population viability analysis (PVA) that could be used to derive profile likelihoods for population extirpation, over a range of time projections, could have been estimated using the same or similar data. However, when reviewing the criteria used by other jurisdictions and the record of PVAs to accurately indicate future states, simpler models were used. Unlike PVAs, the models presented here are non-informative for assessing risk of extirpation and are non-informative for lambda or R/S parameter values greater than 1, but they do give an equal and relative framework to assess population trends for the immediate future based on the immediate past. This is the core of other jurisdictions' evaluations.

A quartile decision structure was chosen because it translates well to frequently used risk assessment and management profiles, and somewhat represents the history of management of Atlantic salmon in the Maritimes Region, with respect to conservation requirements for Atlantic salmon. Some managers have been reluctant to allocate fisheries below a 0.75 chance of achieving conservation requirements, and have moved to further restrict or eliminate fisheries below a 0.25 chance of attaining conservation requirements. If one assumes this profile for trends in populations, then a coherent (similar across rivers, CUs, and regions) decision structure can be developed. The benchmark values could be changed to reflect a more or less risk prone management. However, selecting a subset of indicators could perform the same result. Sampling from the distribution of indicator scores or sets of indicator scores could be used to address the uncertainty of the assessments in risk analysis decision structure.

As in all multiple indicator systems, the selection by proponents, of weights and the assignment of benchmarks for indicators are areas of much uncertainty and variance. This is both because there are seldom mathematically distinct (local minima or maxima) reference points or clear agreement among proponents and managers on qualitative reference points. This proposal allows for consultative agreement on benchmark reference points for category thresholds and for the selection of subsets of indicators. Much like a fuzzy control system (Zadeh 1976), the proposal here is to reduce the entire suite of indicators to subset of 4 or less indicators that are just as likely to result in a correct conclusion. The framework of indicators spreadsheet used to derive this result is set up to allow the user to adjust or vary the benchmarks and weights. When 1 or more anchor points are known, adjusting or varying the benchmarks and weights could provide the user with a sense of confidence and robustness for the framework. It is unlikely that a type II error, falsely accepting the null hypothesis that there is no conservation concern, would be committed by using this framework, when evaluated against a known or historically accepted outcome. The framework does not inform about the efficacy of reallocation or recovery actions.

The issue of resolving appropriate benchmarks and sets of indicators could be informed in this case by comparing output with historic management actions. In the case of the iBoF, the indicators correctly assigned the appropriate category except for the proportion of rivers occupied by salmon. This could be because the benchmark is too low, or some iBoF rivers were stocked, or the dynamic effects of low escapements and juvenile survival. However, this may be a worst case scenario and not informative to cases on the fringe of a category. While this retrospective analysis may be informative it cannot resolve the debate over the appropriate timing of recovery actions from a single case analysis or indicator.

On the SUNS, salmon populations have been declining since 1986, despite management measures to recover the populations. After review, analysis, and consultation, recovery actions were initiated in 2002 that include Category 1 actions. In 2006, these actions were increased due to low population estimates from several sources. This may inform a decision concerning appropriate benchmarks. The assignment of higher benchmarks would give rise to lower scores, and would result in lower classification categories. The set proposed here seems to indicate that our general perception of status in these rivers and CUs has been correct.

To-date, historic assessment and management and research actions undertaken in these CUs are consistent, or more risk prone, than the category classifications suggested here. Actions initiated in the past 30 years were similar to actions prescribed by COSEWIC and SARA for species undergoing declines. Management plans and actions for populations below the proposed full production recovery target have been in place for a long time, similar to the prescribed actions for populations that are assessed as better than “endangered” but less than “not of concern”.

## CONCLUSIONS

- Indicators were used for: generational replacement, limit reference points, and historical comparisons.
- Benchmark breakpoints for 3 management classifications were drawn from similar jurisdiction benchmarks and historical management practice.
- Using the assumed benchmarks, most rivers and CUs in the Maritimes Region would classify as Category 2 or 1, requiring adjustment of human induced mortality, threat assessment, and management review and/or recovery actions.
- The results obtained agreed with historical actions taken in some proposed CUs for the Maritime Region.
- Retrospective analysis of the Stewiacke River, a designated river, indicated that the 50% decline value was overly cautious, and the more risk prone benchmark of 75% was more cautious than the case history.
- Application of the framework to more known outcome cases, including populations perceived to be in better conservation conditions, would be beneficial.

## ACKNOWLEDGEMENTS

This Research Document would not have progressed without the encouragement of Drs. Larry Marshall and Jamie Gibson. This proposal for multiple indicators linked to management actions benefited from reviews by Drs. Ross Claytor and Jamie Gibson and Shane O'Neil, and latterly by Dr. Kurtis Trzcinski. They are all well appreciated and it is hoped this document will encourage the development of further risk-based multiple indicator systems for management of Atlantic salmon.

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Table 1. Breakpoint values of status indicators, classification level and associated actions for Atlantic salmon rivers or Conservation Unit populations with rationales and comments. Grey cells apply to groups of rivers.

| Indicators | Recovery Actions Recommended -1- | Adjust Human Induced Mortality, Assess Threats and Review Management -2- | Objectives Met -4- |
|---|---|---|---|
| **1. Cohort R/S over 1 generation (e.g.,over 5 years)** | <0.94 | <1 | >=1 |
| **2. Synthetic R/S over 1 generation (e.g., over 5 years)** | <0.94 | <1 | >=1 |
| **3. Average annual "λ" (lamda, no cohort account) over 3 generations** | <0.94 | <1 | >=1 |
| **4. Geomean of 3 generation smoothed "λ"** | <0.94 | <1 | >=1 |
| **5. Proportion of Conservation requirement over 1 generation** | <0.25 | <1 | >=1 |
| **6. Smolt to Adult Survival / (Smolt/Adult) for 1 generation** | <0.94 | <1 | >=1 |
| **7. Total migratory return in last year compared to 3 generation average** | <0.25 | <0.625 | >=0.625 |
| **8. Last total parr density of 3 generation average** | <0.25 | <0.625 | >=0.625 |
| **9. Projected population in 3 generations as proportion of current generation or population** | <0.25 | <0.625 | >=0.625 |
| **10. Proportion of rivers in a CU that salmon occupy relative to a 5 generation history** | <0.25 | <0.625 | >=0.625 |
| **11. Projected population of the CU in 3 generations as a proportion of the current population** | <0.25 | <0.625 | >=0.625 |

Table 2. Indicators and category scores for 7 rivers of the Maritimes Region with mean, median, and modal summation of scores. Results are coloured red for estimates below the lower break point, yellow for estimates below upper break point, and green for values above the population replacement or stability breakpoint.

| | LaHave | | St. Mary's | | Stewiacke[1] | | Middle (Vic. Co.) | | Grand (Rich Co.) | | Nashwaak | | Saint John (H&W) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | Estimate | Category | Estimate | Category | Estimate | Category | Estimate | Category | Estimate | Category | Estimate | Category | Estimate | Category |
| 1) Cohort (R/S) over 3 generations | 0.43 | 1 | | | | | | | | | | | | |
| 2) Synthetic R/S over 3 generations | 0.60 | 1 | | | | | 0.94 | 2 | | | 0.62 | 1 | 0.55 | 1 |
| 3) Average annual "λ"(lamda, no cohort account) over 3 generations | 0.74 | 1 | 0.29 | 1 | 0.04 | 1 | 1.38 | 3 | 0.97 | 2 | 1.10 | 3 | 0.90 | 1 |
| 4) Geomean of three generation smoothed "λ" | 0.89 | 1 | 0.86 | 1 | 0.70 | 1 | 0.98 | 2 | 0.83 | 1 | 0.90 | 1 | 0.88 | 1 |
| 5) Proportion of Conservation requirement over 1 generation | 0.85 | 2 | 0.29 | 2 | 0.08 | 1 | 0.65 | 2 | 0.14 | 1 | 0.15 | 1 | 0.23 | 1 |
| 6) Survival / (Smolt/Adult) for 1 generation | 0.36 | 1 | | | | | | | | | | | | |
| 7) Total migratory return in last generation to 3 generation average | 0.59 | 2 | 0.41 | 2 | 0.04 | 1 | 1.03 | 3 | 0.23 | 1 | 0.61 | 2 | 0.38 | 2 |
| 8) Last total parr density of 3 generation average | 0.65 | 3 | 1.15 | 3 | 0.06 | 1 | | | | | | | | |
| 9) Projected population in 3 generations proportion of current generation & population | 0.35 | 2 | 0.05 | 1 | 0.02 | 1 | 0.78 | 3 | 0.06 | 1 | 0.22 | 1 | 0.15 | 1 |
| Count | 9.00 | | 6.00 | | 6.00 | | 6.00 | | 5.00 | | 6.00 | | 6.00 | |
| Mean category score | | 1.6 | | 1.7 | | 1.0 | | 2.5 | | 1.2 | | 1.5 | | 1.2 |
| Median category score | | 1.0 | | 1.5 | | 1.0 | | 2.5 | | 1.0 | | 1.0 | | 1.0 |
| Modal cateory score | | 1.0 | | 1.0 | | 1.0 | | 2.0 | | 1.0 | | 1.0 | | 1.0 |

[1] Stewiacke prior to listing in 2001, i.e. as of 2000

Table 3. Combined indicator estimates and ranks evaluated using average break points for 7 Atlantic salmon rivers of the Maritime Region. Results are coloured red for estimates below the lower break point, yellow for estimates below the upper breakpoint, and green for values above the upper breakpoint, i.e., population replacement or stability breakpoint.

| | LaHave | | St. Mary's | | Stewiacke[1] | | Middle (Vic. Co.) | | Grand (Rich Co.) | | Nashwaak | | Saint John (H&W) | | Saint John (Wild) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | Estimate | Rank | Estimate | Rank | Estimate | Rank | Estimate | Rank | Estimate | Rank | Estimate | Rank | Estimate | Rank | Estimate | Rank |
| 1) Cohort (R/S) over 3 generations | 0.43 | 7 | | | | | | | | | | | | | | |
| 2) Synthetic R/S over 3 generations | 0.60 | 5 | | | | | 0.94 | 4 | | | 0.62 | 3 | 0.55 | 3 | 0.43 | 3 |
| 3) Average annual "λ"(lamda, no cohort acct) over 3 generations | 0.74 | 3 | 0.29 | 4 | 0.04 | 4 | 1.38 | 1 | 0.97 | 1 | 1.10 | 1 | 0.90 | 1 | 0.96 | 1 |
| 4) Geomean of three generation smoothed "λ" | 0.89 | 1 | 0.86 | 2 | 0.70 | 1 | 0.98 | 3 | 0.83 | 2 | 0.90 | 2 | 0.88 | 2 | 0.85 | 2 |
| 5) Proportion of Conservation requirement over 1 generation | 0.85 | 2 | 0.29 | 5 | 0.08 | 2 | 0.65 | 6 | 0.14 | 4 | 0.15 | 6 | 0.23 | 5 | 0.11 | 5 |
| 6) Survival / (Smolt/Adult) for 1 generation | 0.36 | 8 | | | | | | | | | | | | | | |
| 7) Total migratory return in last generation to 3 generation average | 0.59 | 6 | 0.41 | 3 | 0.04 | 5 | 1.03 | 2 | 0.23 | 3 | 0.61 | 4 | 0.38 | 4 | 0.31 | 4 |
| 8) Last total parr density of 3 generation average | 0.65 | 4 | 1.15 | 1 | 0.06 | 3 | | | | | | | | | | |
| 9) Projected population in 3 generations proportion of current generation and population | 0.35 | 9 | 0.05 | 6 | 0.02 | 6 | 0.78 | 5 | 0.06 | 5 | 0.22 | 5 | 0.15 | 6 | 0.08 | 6 |
| Totals | 5.45 | | 3.04 | | 0.95 | | 5.75 | | 2.24 | | 3.59 | | 3.10 | | 2.73 | |
| | | | | | | | | | | | | | | | | |
| Average all | 0.61 | | 0.51 | | 0.16 | | 0.96 | | 0.45 | | 0.60 | | 0.52 | | 0.46 | |
| Average high 4 | 0.78 | | 0.68 | | 0.22 | | 1.08 | | 0.54 | | 0.81 | | 0.68 | | 0.64 | |
| Average low 4 | 0.43 | | 0.26 | | 0.04 | | 0.84 | | 0.32 | | 0.40 | | 0.33 | | 0.23 | |
| Average same 4 (4, 5 , 7, 9) | 0.67 | | 0.40 | | 0.21 | | 0.86 | | 0.32 | | 0.47 | | 0.41 | | 0.34 | |
| | | | | | | | | | | | | | | | | |
| Score all | 2 | | 1 | | 1 | | 3 | | 1 | | 2 | | 1 | | 1 | |
| High 4 score | 2 | | 2 | | 1 | | 3 | | 1 | | 2 | | 2 | | 2 | |
| Low 4 score | 1 | | 1 | | 1 | | 3 | | 1 | | 1 | | 1 | | 1 | |
| Same 4 score | 2 | | 1 | | 1 | | 3 | | 1 | | 2 | | 1 | | 1 | |

[1] Stewiacke prior to listing in 2001, i.e. as of 2000

Table 4. Indicators and category scores for 5 Conservation Units of the Maritimes Region with mean, median and modal summation of scores. Results are coloured red for estimates below the lower break point, yellow for estimates below the upper break point, and green for values above the population replacement or stability breakpoint.

| | Southern upland | | CB East H Highlands | | CB East L Lowlands | | inner Bay of Fundy[1] | | outer Bay of Fundy (wild) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Indicators for index rivers and for the CU** | Estimate | Category | Estimate | Category | Estimate | Category | Estimate | Category | Estimate | Category |
| 1) Cohort (R/S) over 3 generations | 0.43 | 1 | | | | | | | | |
| 2) Synthetic R/S over 3 generations | 0.60 | 1 | 0.94 | 2 | | | | | 0.53 | 1 |
| 3) Average annual "λ" (lamda, no cohort account) over 3 generations | 0.52 | 1 | 1.38 | 3 | 0.97 | 2 | 0.04 | 1 | 1.03 | 3 |
| 4) Geomean of 3 generation smoothed "λ" | 0.87 | 1 | 0.98 | 2 | 0.83 | 1 | 0.70 | 1 | 0.87 | 1 |
| 5) Proportion of Conservation requirement over 1 generation | 0.57 | 2 | 0.65 | 2 | 0.14 | 1 | 0.08 | 1 | 0.13 | 1 |
| 6) Survival / (Smolt/Adult) for 1 generation | 0.36 | 1 | | | | | | | | |
| 7) Total migratory return in last generation compared to 3 generation average | 0.50 | 2 | 1.03 | 3 | 0.23 | 1 | 0.04 | 1 | 0.46 | 2 |
| 8) Last total parr density of 3 generation average | 0.90 | 3 | | | | | 0.06 | 1 | | |
| 9) Projected population in 3 generation as a proportion of current generation and population | 0.20 | 1 | 0.78 | 3 | 0.06 | 1 | 0.02 | 1 | 0.15 | 1 |
| 10. Proportion of rivers in a CU that salmon occupy relative to a 5 generation history | 0.73 | 3 | 1.0 | 3 | 1.0 | 3 | 0.5 | 2 | 0.90 | 3 |
| 11. Projected population of the CU in 3 generations as a proportion of current population | 0.15 | 1 | | | | | | | 0.21 | 1 |
| Mean score | | 1.4 | | 2.5 | | 1.2 | | 1.0 | | 1.5 |
| Median score | | 1.0 | | 3.0 | | 1.0 | | 1.0 | | 1.0 |
| Modal score | | 1.0 | | 2.0 | | 1.0 | | 1.0 | | 1.0 |

Table 5. Combined indicator values and category scores evaluated using average break points for 5 Conservation Units for Atlantic salmon areas of the Maritime Region. Results are coloured red for estimates below the lower break point, yellow for estimates below the upper break point, and green for values above the population replacement or stability breakpoint.

| | Southern upland | | CB East H Highlands | | CB East L Lowlands | | inner Bay of Fundy | | outer Bay of Fundy | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | Score | Rank | Score | Rank | Score | Rank | Score | Rank | Score | Rank |
| 1) Cohort (R/S) over 3 generations | 0.43 | 8 | | | | | | | | |
| 2) Synthetic R/S over 3 generations | 0.60 | 4 | 0.94 | 5 | | | | | 0.53 | 4 |
| 3) Average annual "λ" (lamda, no cohort account) over 3 generations | 0.52 | 6 | 1.38 | 1 | 0.97 | 2 | 0.04 | 5 | 1.03 | 1 |
| 4) Geomean of 3 generation smoothed "λ" | 0.87 | 2 | 0.98 | 4 | 0.83 | 3 | 0.70 | 1 | 0.87 | 3 |
| 5) Proportion of Conservation requirement over 1 generation | 0.57 | 5 | 0.65 | 7 | 0.14 | 5 | 0.08 | 3 | 0.13 | 8 |
| 6) Survival / (Smolt/Adult) for 1 generation | 0.36 | 9 | | | | | | | | |
| 7) Total migratory return in last generation compared to 3 generation average | 0.50 | 7 | 1.03 | 2 | 0.23 | 4 | 0.04 | 6 | 0.46 | 5 |
| 8) Last total parr density of 3 generation average | 0.90 | 1 | | | | | 0.06 | 4 | | |
| 9) Projected population in 3 generation as a proportion of current generation and population | 0.20 | 10 | 0.78 | 6 | 0.06 | 6 | 0.02 | 7 | 0.15 | 7 |
| 10. Proportion of rivers in a CU that salmon occupy relative to a 5 generation history | 0.73 | 3 | 1.00 | 3 | 1.00 | 1 | 0.50 | 2 | 0.90 | 2 |
| 11. Projected population of the CU in 3 generations as a proportion of current population | 0.15 | 11 | | | | | | | 0.21 | 6 |
| Totals | 5.82 | | 6.75 | | 3.24 | | 1.45 | | 4.28 | |
| Average all | 0.53 | | 0.96 | | 0.54 | | 0.21 | | 0.53 | |
| Average high 4 | 0.77 | | 1.10 | | 0.76 | | 0.34 | | 0.83 | |
| Average low 4 | 0.29 | | 0.84 | | 0.32 | | 0.04 | | 0.24 | |
| Average same 5 (4, 5, 7, 9, 10) | 0.57 | | 0.89 | | 0.45 | | 0.27 | | 0.50 | |
| Score all | 1 | | 3 | | 1 | | 1 | | 1 | |
| High 4 score | 2 | | 3 | | 2 | | 1 | | 3 | |
| Low 4 score | 1 | | 3 | | 1 | | 1 | | 1 | |
| Average same 5 score | 2 | | 3 | | 2 | | 1 | | 2 | |

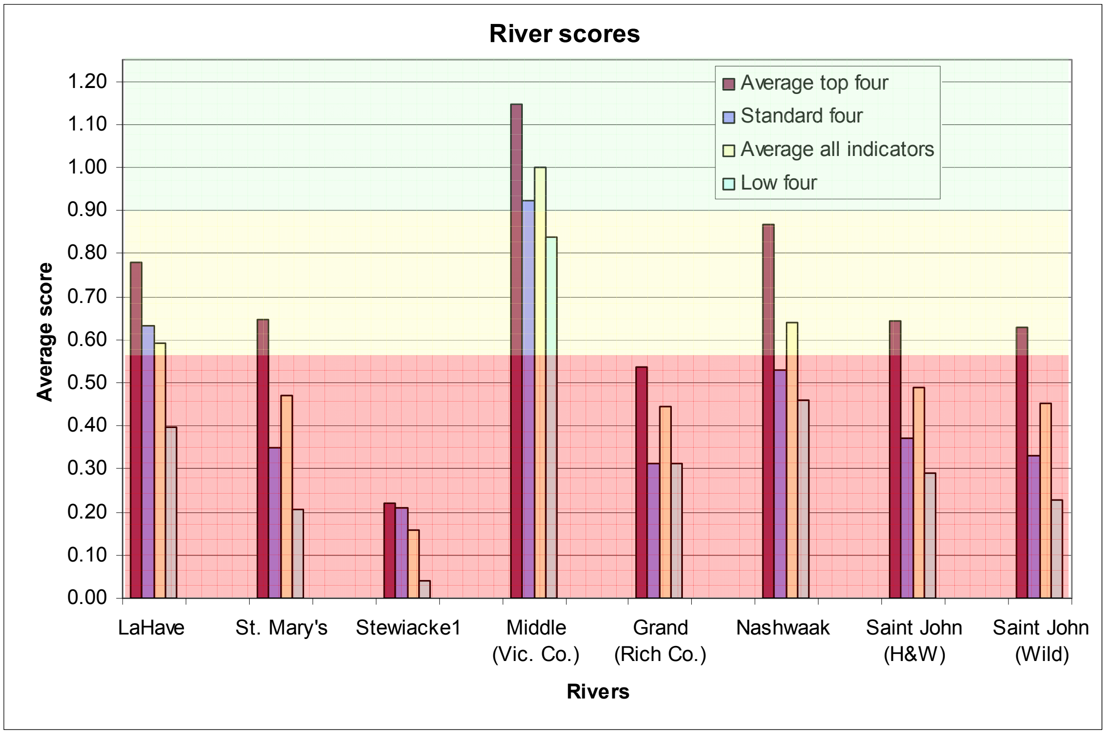


Figure 1. Average indicator scores on a background of average breakpoint values (approximate colour zones for status categories) for all, high 4, low 4, and standard 4 indicators in 7 rivers of the Maritimes Region.

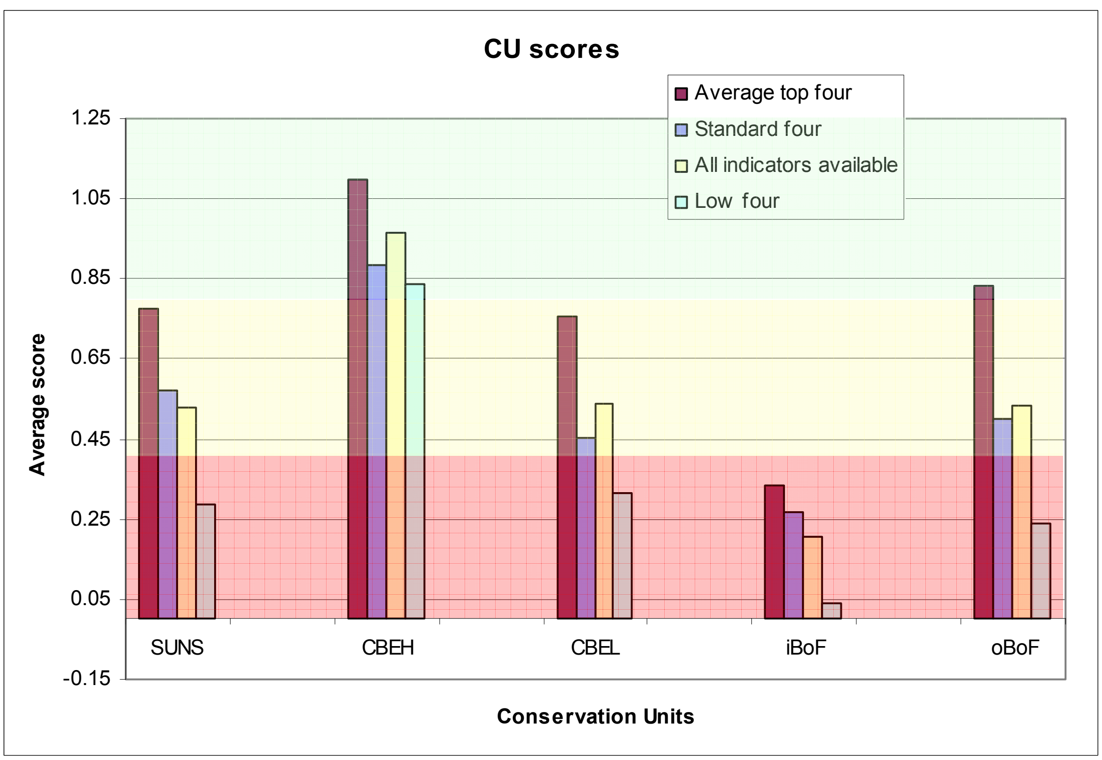


Figure 2. Average indicator score for all, high 4, and standard 4 indicators in 5 proposed Conservation Units of the Maritimes Region.

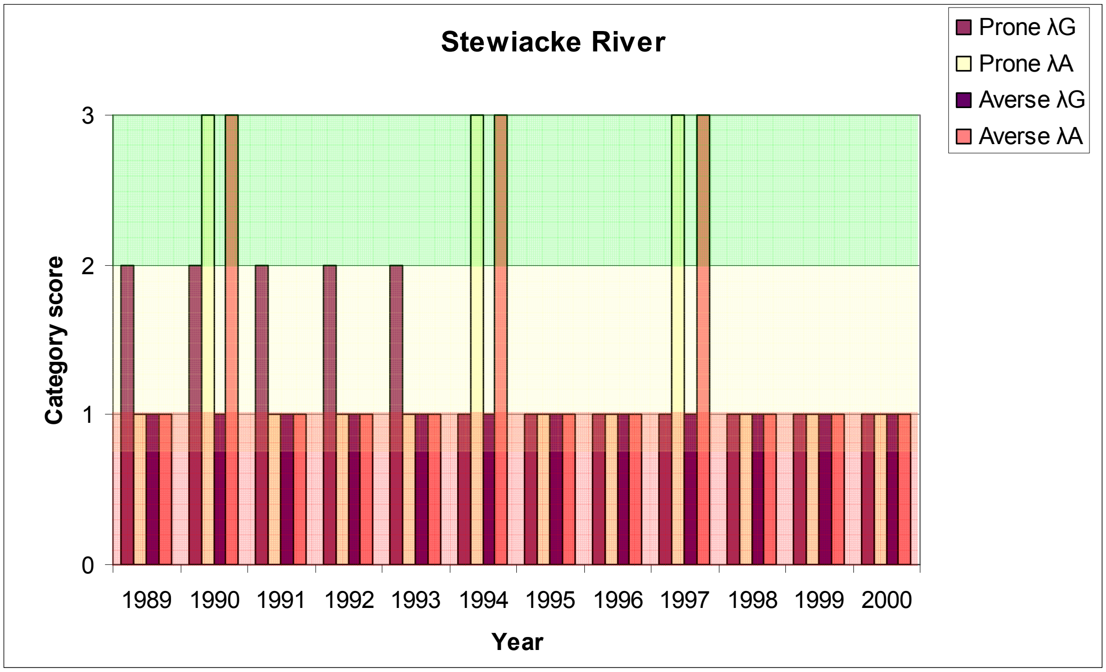


Figure 3. Retrospective analysis of the time series of generational replacement (λ lambda) estimated over 3 generations (12 years) by geometric mean of the generations or by averaging annual lambda over 3 generations evaluated against a risk prone breakpoint of 0.89 (75% decline) and risk averse breakpoint of 0.94 (50% decline) for the Stewiacke River from 1977 to 2000.

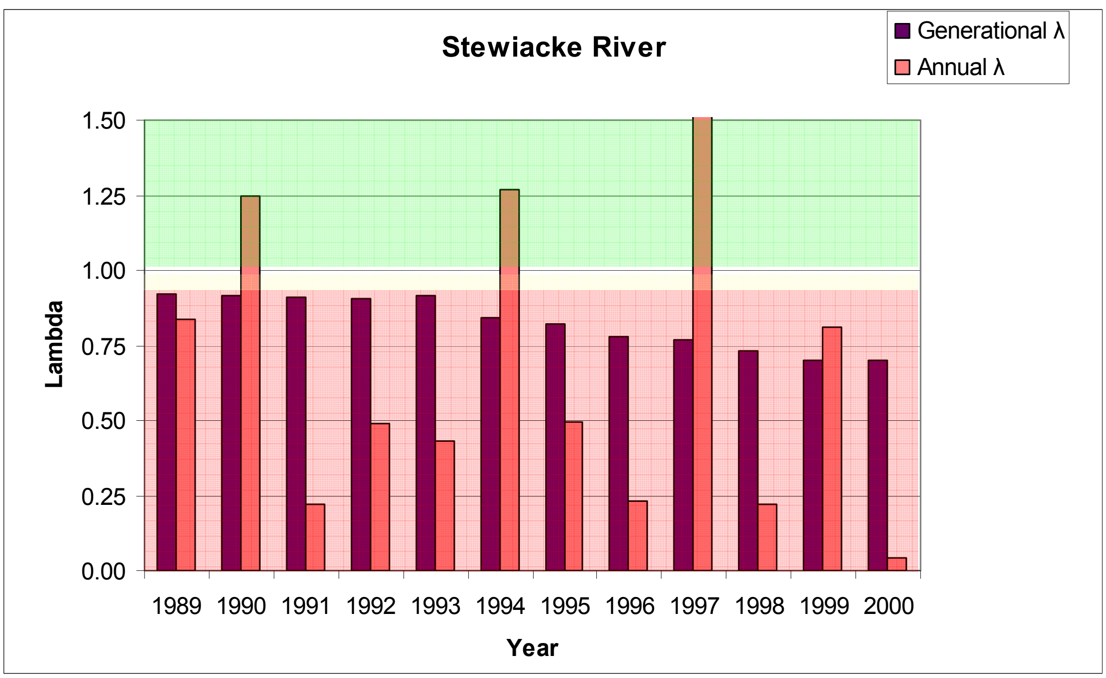


Figure 4. Retrospective derivations of generational replacement (λ lambda) estimated over 3 generations (12 years) by geometric mean of the generations or by averaging annual lambda over 3 generations and results evaluated against a risk averse breakpoint of 0.94 (50% decline in 3 generations) for the Stewiacke River from 1977 to 2000.

Appendix 1. Proposed Conservation Units (CUs) and supporting evidence from Conservation Status Report: Atlantic salmon in Canada and Québec (DFO-MNRF 2008).

| | | | **Evidence for CU designation** | | | |
|---|---|---|---|---|---|---|
| **Proposed CU** | **Nearby candidate CU** | **Presence of unique lineage(s)[1]** | **Evidence of distinctiveness (phenotypic information[2] and movement[3])** | **Genetic structure[4]** | **Ecologic information[5]** | **Geographic information[6]** |
| 13 Cape Breton E. Highlands NS (CBEH) | 6,12,14 | N/A[1] | -N/A[2]<br>-N/A[3] | -absence of a mitochondrial haplotype observed in SU populations (Verspoor et al. 2005, Verspoor, pers. comm.) | -CBEH rivers typically of higher gradient than SC or CBEL rivers | 1) separated by 10's of kms from SC or CBEH rivers, 100's of kilometres from SCNL rivers<br>2) no disjunction<br>3) separated from SCNL by Cabot Strait |
| 14 Cape Breton E. Lowlands NS (CBEL) | 6,13,15 | N/A[1] | -N/A[2]<br>-N/A[3] | -N/A[4] | -CBEL rivers typically of lower gradient than CBEH rivers | 1) separated by 10's of kms from SU and CBEH rivers, 100's of kilometres from SCNL rivers<br>2) possible disjunction between CBEL and SU (SU populations geographically close then large break to nearest CBEL salmon bearing river); no disjunction between CBEL and CBEH rivers<br>3) CBEL and SU separated by Strait of Canso and Chedabucto Bay; CBEL and CBEH separated by Bras D'Or lakes; CBEL and SCNL separated by Cabot Strait |

| | | | Evidence for CU designation | | | |
|---|---|---|---|---|---|---|
| **Proposed CU** | **Nearby candidate CU** | **Presence of unique lineage(s)[1]** | **Evidence of distinctiveness (phenotypic information[2] and movement[3])** | **Genetic structure[4]** | **Ecologic information[5]** | **Geographic information[6]** |
| 15 Southern Upland NS (SUNS) | 14,16,17 | -mtDNA haplotype not observed in adjacent populations but do not know if globally endemic (Verspoor et al. 2005, Verspoor, pers. comm.) | -N/A[2]<br>-N/A[3] | -mtDNA haplotypes observed in SU but not iBoF and vice versa; mtDNA haplotypes seen in SU salmon not in CBEL, oBoF, or other southern or northern populations (Verspoor et al. 2005, pers. comm.)<br>-SU salmon cluster separately from iBoF, CBEL and oBoF salmon at allozyme loci and identified by authors as a distinct grouping (Verspoor 2005)<br>-SU populations largely group separately from iBoF and oBoF populations at microsatellite loci surveyed (O'Reilly, unpublished data); limited microsatellite information available for SU-CBEL comparisons | -high incidence of acidified rivers within the SU relative to the iBoF, oBoF and CBEL | 1) 10's of kms from iBoF, oBoF and CBEL rivers<br>2) possible disjunction between SU and iBoF (few salmon bearing streams on SE shore of B of F, between Cornwallis and Annapolis Rivers), possible disjunction between SU and CBEL (SU populations geographically close then large break to nearest CBEL salmon bearing river)<br>3) iBoF deep inside BoF and largely internal to Cape Split and very high tides; SU and CBEL separated by Chedabucto Bay and Strait of Canso, SU and oBoF separated by Bay of Fundy |

| | | | Evidence for CU designation | | | |
|---|---|---|---|---|---|---|
| **Proposed CU** | **Nearby candidate CU** | **Presence of unique lineage(s)[1]** | **Evidence of distinctiveness (phenotypic information[2] and movement[3])** | **Genetic structure[4]** | **Ecologic information[5]** | **Geographic information[6]** |
| 16 Inner Bay of Fundy NS (iBoF) | 15,17 | -unique mtDNA haplotype 1 mutation from a common NA variant suggestive of possible refugium for iBoF salmon (Verspoor et al. 2002) | -higher incidence of maturation after 1 sea-winter in iBoF relative to oBoF and SU salmon (Amiro et al. 2003)<br>- distribution of tags returns from marine environment differs between iBoF and oBoF (Amiro et al. 2003)<br>-evidence of prolonged residency within the Bay of Fundy (Lacroix et al. 2005) | -mtDNA lineage at high frequency in iBoF not observed elsewhere in global distribution of the species, including oBoF and SU (Verspoor et al. 2002)<br>- iBoF salmon group separately from oBoF and other populations at multiple allozyme loci and considered a distinct regional grouping by authors (Verspoor 2005)<br>-oBoF and nearby Chignecto Bay iBoF populations very similar microsatellite allele frequencies (O'Reilly, unpublished data)<br>-iBoF populations largely group separately from SU populations at microsatellite loci surveyed (O'Reilly, unpublished data) | -at least part of the marine phase of their life cycle spent in high tide, high energy environment of the Bay of Fundy<br>-tendency for lower stream gradients in Bay of Fundy compared to Gaspé and Newfoundland-Labrador rivers (Claytor et al. 1991) | 1) <10 of kms from oBoF and SU rivers<br>2) no obvious disjunction between iBoF and oBoF rivers; possible disjunction between iBoF and SU salmon (few salmon bearing streams on SE shore of B of F, between Cornwallis and Annapolis Rivers)<br>3) iBoF deeper within the Bay of Fundy relative to the nearest oBoF and SU rivers and is internal to Cape Split and very high tides |

| | | | Evidence for CU designation | | | |
|---|---|---|---|---|---|---|
| **Proposed CU** | **Nearby candidate CU** | **Presence of unique lineage(s)[1]** | **Evidence of distinctiveness (phenotypic information[2] and movement[3])** | **Genetic structure[4]** | **Ecologic information[5]** | **Geographic information[6]** |
| 17 Outer Bay of Fundy NS (oBoF) | 16 | N/A[1] | -lower incidence of maturation after 1 sea-winter than in iBoF (Amiro et al. 2003)<br><br>- distribution of tags returns from marine environment differs between iBoF and oBoF (Amiro et al. 2003)<br><br>-unique but small component of oBoF, serpentine stock, enter freshwater months earlier (early winter) than majority of returns<br>-one tributary within CU have a significant fall migration of pre-smolts (Jones et al. 2003) | -oBoF and iBoF salmon exhibit very different mtDNA haplotype frequencies (see iBoF-oBoF for more details) (Verspoor et al. 2002)<br>-oBoF salmon group separately from iBoF and most other populations at multiple allozyme loci and are considered a distinct regional grouping by the authors (Verspoor 2005)<br>-oBoF and nearby Chignecto Bay iBoF populations very similar microsatellite allele frequencies (O'Reilly, unpublished data) | -at least part of the marine phase of their life cycle spent in high tide, high energy environment of the Bay of Fundy<br><br>-tendency for lower stream gradients in Bay of Fundy compared to Gaspé and Newfoundland-Labrador rivers (Claytor et al. 1991) | 1) <10 of kms from iBoF<br>2) no obvious disjunction between iBoF and oBoF rivers<br>3) oBoF at the entrance of the Bay of Fundy, iBoF deeper within the Bay of Fundy |

Footnotes:

[1] Information indicating the presence of unique or distinct lineages within the proposed CU, including evidence of distinct refugial (glacial) origins, reciprocal monophyly at mtDNA, etc.).
[2]Presence of observable differences including morphological, meristic, life history (egg size, age at smoltification, sea age, etc.) for which there is evidence that the character(s) in question are adaptive (are genetically based and confer a fitness advantage). Note: include information on the strength of evidence for adaptiveness of the trait(s).
[3]Movement information includes tagging, telemetry, or other data pertaining to movement that could indicate distinctiveness.
[4]Information from: 1) presumably neutral molecular genetic markers such as microsatellites, mtDNA, AFLPs, allozymes., etc., that indicate the presence of largely reproductively isolated groups of organisms, and 2) frequency or fixed differences at MHC and other coding loci that may be adaptive.
[5]Ecological differences between environments occupied by proposed units that may have led to the development of adaptive differences, including stream gradient, river sizes, temperature regimes, general water quality differences (pH), bedrock types, prey types, predators, etc., for which local adaptation could occur that would lead to distinctiveness.
[6]Includes: 1) geographic distance between proposed units, 2) geographic range disjunction (yes/no, see accompanying text for details), and 3) presence of physical barriers

N/A-Not Available (should not necessarily be considered as negative evidence)
CBEL-Cape Breton East Lowlands
CBEH-Cape Breton East Highlands
SUNS-Southern Upland
iBoF-Inner Bay of Fundy
oBoF-Outer Bay of Fundy
mtDNA-mitochondrial DNA

Appendix 2. Actions associated with status categories.

Objectives Met:
Category 3

- Continue management plan
- Re-allocate harvestable surplus

Adjust Human Induced Mortality, Assess Threats, and Review Management:
Category 2

- Reduce interceptory fishing mortality
- Reduce bycatch fishing mortality
- Reduce directed fishing mortality to harvest only the surplus population
- Increase fish passage efficiency where feasible
- Decrease environmentally induced mortality
- Assign team lead, assemble an assessment team, review and assign tasks and schedule a conservation unit review
- Assemble indicator data for the river, index or conservation unit
- Estimate population parameters and indicators and compare to standards, and to local and distant populations
- Identify limiting chemical, physical or biological factors and, if possible, parameterise affects
- Associate and, if possible, rate by population impact the identified limiting factors
- Review and assess existing management plans for actions that if taken could naturally recover populations
- Conduct a social and economic impact analysis for identified potential management and recovery actions
- Recommend actions that are likely to lead to population stabilisation and increase the potential for recovery
- Produce an assessment and management options report

Recovery Actions Required:
Category 1

- Assess and improve fish passage to the extent feasible
- Assess and improve damaged habitat, particularly for any identified population parameter limited by habitat
- Increase protection of pre-spawning fish and migrating post-spawned fish
- Increase protection of migrating juvenile fish, parr, pre-smolts and smolts against human induced mortality
- Increase natural survival through integrated water, forestry, fisheries and wildlife management
- Conduct stakeholder consultations concerning recovery action plans, cooperation and participation
- Conduct recovery feasibility assessment including
- Supportive rearing
- Live gene banking
- Cryogenic preservation of gametes
- Translocation of population