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Proceedings of a Workshop to Review Conservation Principles for Atlantic Salmon in Eastern Canada

March 11 to 15, 1996
Halifax, Nova Scotia

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ABSTRACT

A workshop held during 11 to 15 March 1996 addressed a number of issues related to conservation of Atlantic salmon in Canada. The first part of the workshop dealt with the concepts of targets and thresholds for managing fish resources. It addressed questions related to the potential consequences of not meeting targets and the impact of continuing harvests on the resource in such cases. The second part of the workshop considered the advice which Science provides to management and the rationale for using different conservation criteria for the establishment of management protocols if such was the case.
In the last part of the workshop, participants dealt with the elaboration and review of the International Commission for the Exploration of the Sea (ICES) questions including justification for the conservation spawning targets for the rivers of eastern Canada.

RESUME

Des questions portant sur la conservation du saumon atlantique au Canada ont été abordées lors d'un atelier tenu le 11 au 15 mars 1996. Dans un premier temps, les participants ont discuté des aspects de cibles et seuils pour gérer les resources aquatiques. Il a été question de réfléchir aux conséquences sur la ressource de ne pas atteindre la cible de conservation et conséquemment des impacts sur la ressource de continuer d'exploiter la ressource sous de telles circonstances. En deuxième partie, les participants ont discuté des avis communiqués aux gestionnaires par les scientifiques et la justifiication pour utiliser des critères différents dans l'élaboration de protocoles de gestion, selon le cas. Enfin, les questions posées par le Conseil International pour l'Exploration de la Mer (CIEM) ont été discutées par les participants; en particulier. celle qui demandait de justifier les cibles de conservation pour les rivières de l'est du Canada.

Introduction

The status of the Atlantic salmon (*Salmo salar*) populations differs among geographical regions but there has been an overall decline in total abundance of Atlantic salmon in the northwest Atlantic since the 1970's (Anon. 1996). Extremely depressed stock levels have been observed throughout the Bay of Fundy and Atlantic Coast of Nova Scotia rivers and in Labrador. The spawning escapement to most rivers in the southern Gulf of St. Lawrence and Quebec improved two-fold or more since the closure of the Maritime commercial fisheries and adjustments to the Newfoundland and Labrador commercial fisheries which occurred in 1984. Subsequent to closure of the Newfoundland commercial fishery in 1992 and reduced seasons and effort in the Labrador fishery, returns to rivers have also noticeably increased in most regions of insular Newfoundland with the exception of some south and southwest coast rivers of the island. These management measures were undertaken in response to the assessments of stock status which indicated that the spawning escapement was below the desired spawning escapement for the resource. The desired spawning escapement for a river has been defined as the conservation level.

A workshop was held during 11 to 15 March 1996, to address a number of issues related to conservation of Atlantic salmon in Canada. The terms of reference were drafted in response to a perception that conservation was being interpreted differently across the various regions of eastern Canada. In particular, it appeared inconsistent that some fisheries were closed when anticipated escapements were below the conservation requirement while elsewhere fisheries were allowed to continue when conservation had not been achieved nor was anticipated to be met in the coming year. Was conservation clearly defined and interpreted similarly by Science personnel? Was the advice from Science to fisheries managers consistent with the conservation principles?

The terms of reference for the workshop were:

1 - to consider the effect on the Atlantic salmon resource of not meeting the conservation requirements,

2 - to consider the impact of continuing harvests of Atlantic salmon in those cases when the conservation egg depositions were not being met,

3 - to consider the rationale for using different criteria for conservation of Atlantic salmon in different Regions,

To address the terms of reference, the meeting was structured into 2 parts. The first part dealt with the concepts of targets and thresholds for managing fish resources. It addressed questions related to the potential consequences of not meeting targets and the impact of continuing harvests on the resource in such cases (terms of reference 1 and 2). The second part considered the advice which Science provided to management and the rationale for using different conservation criteria for the establishment of management protocols if such was the case (term of reference 3). This document summarizes the presentations and deliberations of these two parts of the workshop.

During a third part of the workshop, participants dealt with the elaboration and review of the International Commission for the Exploration of the Sea (ICES) questions and the submissions which would be brought forward to ICES. These discussions are summarized in part 3.

A copy of the agenda is presented in Appendix 1, the working paper titles are presented in Appendix 2, supporting documents are in Appendix 3, and a list of the participants is in Appendix 4.

Part 1: Targets and Thresholds

Conservation for Atlantic salmon: clarification of intent and application

With the Sparrow decision, the Supreme Court of Canada indicated that conservation for Atlantic salmon had priority over all human use. This decision by the courts was the driving force behind the initiative undertaken in 1991 by the Canadian Atlantic Fisheries Scientific Advisory Council (CAFSAC) to formally define conservation principles for Atlantic salmon and provide an operational translation of conservation which would guide the management of the resource.

The formal definition of conservation of Atlantic salmon was recorded in the 1991 CAFSAC Advisory Document (91/15) as:

> "That aspect of renewable resource management which ensures that utilization is sustainable and which safeguards ecological processes and genetic diversity for the maintenance of the resource concerned. Conservation ensures that the fullest sustainable advantage is derived from the resource base and that facilities are so located and conducted that the resource base is maintained."

There is no doubt that conservation means different things for different people and this confusion is not recent. In a perspectives paper, Olver et al. (1995) provide a historical overview of the two generally opposing philosophies regarding conservation. The utilitarian philosophy focused on meeting the material needs of people, with extreme utilitarian attitudes promoting the monetary valuation of resources and considering nature as a collection of entities to be manipulated at will (domesticated). The opposing philosophy, the preservationist school, argued for the intrinsic value of wilderness to fulfill the aesthetic and spiritual needs of humans. Extreme preservationists viewed ecosystems as temporally static, and therefore non-modifiable.

Each of these schools claimed exclusive rights to the meaning of the term conservation. Both philosophies suffered from the same narrow minded view that "nature" existed for the good of humans (anthropocentric view).

Wanting to recognize the species and its environment as most important, Olver et al. (1995) proposed a definition of conservation which excluded the term "use":

> "the protection, maintenance, and rehabilitation of native biota, their habitats, and life-support systems to ensure ecosystem sustainability and biodiversity".

Fisheries management should have as its primary goal the perpetuation of self-sustaining populations of indigenous aquatic species, the key being the sustainability of naturally reproducing wild stocks of native fish (Olver et al. 1995). Stocks are considered as being the repository of genetic diversity within each species. Primary conservation requirements would be met when the sustainability of individual fish stocks is secured. In order to respect these conservation requirements, the resource could not be considered in exclusion of the users, contrary to Olver et al.'s preference. Conservation for exploited populations requires that management of use be directly linked to the conservation principles for the species.

Conservation as defined for Atlantic salmon in 1991 is consistent with the definition of Olver et al. (1995) and is still a relevant concept today. The principles of sustainability as well as the safeguarding of ecological processes and genetic diversity are explicitly stated. The CAFSAC definition strongly promoted the protection of individual stocks within stock complexes as a means of ensuring the fullest production potential. It also recognizes the importance of incorporating use by people as part of the ecosystem in reference to the concept of aspiring for the fullest sustainable advantage being derived from the resource base.

Conservation as a Biological Reference Point

CAFSAC suggested an operational translation of conservation to be 2.4 eggs/m^2 of fluvial rearing habitat and in addition for insular Newfoundland, 368 eggs / hectare of lacustrine habitat (CAFSAC 1991). This operational translation for conservation is a reference level (also commonly referred to as a Biological Reference Point; BRP). In general terms, reference points can be either targets to be achieved or danger zones to be avoided. The objective for fisheries management would be to achieve the targets while avoiding the danger zones. Fisheries management strategies must consider two types of risks:

1 - the risk that yields will fall below the maximum attainable level. This is the risk of not attaining a desirable target, and

2 - the risk the stock will fall below a minimum size. This is the risk of falling below an undesirable threshold or a danger zone possibly leading to recruitment overfishing and even stock extinction.

The most important difference between the two types of BRPs is that fishing activity would be expected to fluctuate about targets while thresholds should generally not be crossed (Rosenberg et al. 1994). Overfishing concerns apply to both targets and thresholds while conditions favouring low survival are of most concern at threshold spawning levels.

What kind of biological reference point was 2.4 intended to be?

The intent of the group which formulated the operational translation of conservation was that 2.4 be synonymous with a threshold reference point. This is supported by the acknowledgment that:

"the level below which CAFSAC would strongly advise that no fishing should occur could not be defined with absolute precision, allowing the stock complex to fall to such low abundance was regarded as involving unnecessary risks of causing irreversible damage to a resource's ability to recover in a reasonable period of time." (CAFSAC 1991).

If the definitions of thresholds and targets referred to in the scientific literature are to be applied to the management of Atlantic salmon, then 2.4 can not be referred to as a target conservation requirement. This is a contradiction. Either it is a threshold with no option for maintaining a fishery on the resource when spawning escapement falls below the threshold level or it is a target which is the way management appears to have utilized it in many cases, albeit in an inconsistent manner. The confusion becomes even more important when river-specific reference levels are derived and a decision must be made as to the spawning escapement corresponding to the threshold and the target.

During this workshop, the consensus from the group was that a threshold should be the biological reference level for the species whereas the target should be the reference level for managing people. The target should clearly be well above the threshold value and the threshold value should not be as low as the point of population extinction. The threshold level should be one that is large enough to endure events of various perturbations and can do so within its own biogeographic context (CAFSAC 1991).

Derivation of river-specific reference points

The following are a few possible reference points of relevance to the conservation principles for Atlantic salmon. The only acceptable reference points are those which can be calculated objectively and directly from the fitting of stock and recruitment relationships or the modeling of processes of salmon populations. The reference points should avoid the use of terms such as optimum, minimum and relative since these are subject to individual interpretation.

Threshold reference points

1 - Recruitment overfishing

The recruitment overfishing definition applicable as a threshold reference point is the spawning stock where expected recruitment is 50% of the maximum (Mace 1994). This threshold definition has the advantage that it takes into account the degree of compensation in the stock-recruitment relationship although the estimate is frequently unreliable because of minimal spawning escapement contrast in the data and the validity of the stock-recruitment model (Rosenberg et al. 1994).

2 - Minimum effective population size

This reference point considers the genetic factors limiting the sustainability of wild stocks. Using estimates of minimum effective population sizes for individual stocks, it accounts for the importance of individual stocks (spatial, temporal or both) within a river. The quantification of the number of genetically distinct stocks within a given river and definition of minimum effective population size remain the most significant obstacles to its application.

3 - Minimum Biologically Acceptable Level (MBAL)

The point of maximum gain on a stock and recruitment curve, otherwise referred to as the point of maximum sustainable yield, has been referred to as MBAL (Anon. 1994). Regardless of the form of the stock and recruitment relationship, there is no biological or management reason to have the reference point below this value. All spawning escapements below this point on average produce inferior recruitment and inferior harvest potential. It is preferably referred to as a threshold given the steepness of the slope of the stock and recruitment relationship at that point; spawning escapements below that point can result in wide variation and rapidly declining recruitment.

Target reference points

1 - Spawning escapement for maximum recruitment

In at least the Ricker form (overcompensatory) stock and recruitment relationships, the spawning escapement that produces maximum recruitment is directly calculated from the function. Spawner stock size for maximum recruitment is never less and generally substantially larger than the spawners for maximum gain (MBAL threshold). Spawner level for maximum recruitment is undefined for the Beverton-Holt type models (compensatory) and the only appropriate value is the spawners for replacement (point where each spawner produces one recruit).

2 - Spawning escapement that reduces the risk of recruitment at the same level as obtained at the threshold reference point.

This target depends upon the amount of variation in recruitment and the degree of compensation in the stock and recruitment function (general productivity of the stock).

3 - Spawning escapement that trades off the risk of falling to the threshold levels of spawners and that of obtaining the maximum gain or maximum recruitment from the stock.

Conclusions

Atlantic salmon was the first fish species in Atlantic Canada for which conservation principles were defined (CAFSAC Adv. Doc. 91/15). During the workshop, the concept of conservation for Atlantic salmon and the interpretation of the conservation principles for the formulation of management plans were extensively discussed. The first task was to clarify the conservation definition in terms of its status as a biological reference point. Was it a target or a threshold reference point? These terms have been discussed recently in the fisheries literature. A target refers to a point to be achieved whereas a threshold is a danger zone to be avoided. Fishing activity would be expected to fluctuate about targets while thresholds would not be crossed.

After an extensive discussion, it was concluded that the operational translation of conservation was intended to be used as a threshold reference point - no fisheries induced mortality on spawners when spawning escapement was less than or equal to the conservation level.

Re-analysis of historical data sets, combined with recent data and alternate models of stock and recruitment showed that the general conservation requirement of 2.4 eggs$\bullet$m^{-2} with additional eggs for lacustrine habitat was higher than the egg deposition levels which would provide maximum yield and/or prevent recruitment overfishing (threshold definitions). This is good. The greater danger was that the conservation definition was lower than threshold values derived from empirical observations. For some rivers, specific reference points could be defined but based on the analyses presented, there was no reason for changing the default conservation level of 2.4 eggs$\bullet$m^{-2} of fluvial habitat. As a result, the following recommendations were made:

- In the absence of river specific information, the reference level of 2.4 eggs per m^2 of fluvial habitat and an additional egg requirement of 105 to 368 eggs per hectare of lacustrine habitat (depending on latitude for insular Newfoundland and Labrador) should be maintained as a threshold reference point applicable to the definition of conservation for Atlantic salmon. This implies that stock status documents should substitute "conservation egg requirements" for the term "target egg requirements" when referring to the conservation definition.

- Where river-specific reference points can be derived using stock and recruitment relationships, process-based models or other quantitative analyses, both conservation levels and targets should be defined.

- In all these analyses, the reference points should be compared to the values (recruitment and spawning escapement) derived using the general conservation reference point (2.4 eggs per m^2 of fluvial habitat and an additional egg requirement for lacustrine habitat). This will provide important insight into the appropriateness of 2.4 as a general conservation reference point for all rivers of eastern Canada.

Summary and abstracts of presentations

Two papers presented at the workshop provided examples of reference points and targets derived using stock and recruitment data. These papers also considered the consequences to recruitment and to sustainability of not achieving the conservation threshold. A review of the factors affecting population viability was provided with emphasis on the implications of genetic stochasticity. One paper addressed the problem of spawner overfishing which is the situation where spawners in one generation are insufficient to replace the parent stock. This concept is important for assessing stock rebuilding efforts. Three papers addressed marine survival trends over time and clearly illustrated that in numerous stocks, higher survivals occurred in the early 1980's than have been observed in the last five to ten years. For several stocks in Newfoundland, survivals since the Newfoundland commercial moratoria (salmon and cod) have been lower than in years prior to the closure of these fisheries. An analysis of relationships between small salmon returns in one year and large salmon returns in the subsequent year indicated that survivals to the river of both size groups were highly correlated. On two rivers, 2SW to 1SW ratios were similar with very low returns in recent years affecting both age groups.

Derivation of targets and thresholds for Atlantic salmon

(G. Chaput)

Stock and recruitment data were used to derive targets and thresholds. Two stock and recruitment models were considered: a Beverton-Holt model and a Ricker model. There are three targets which can be objectively defined from these models: 1) spawning escapement for maximum recruitment, 2) spawning escapement for replacement, and 3) spawning escapement for maximum gain. A threshold biological reference point was suggested as the spawning escapement which produces 50% of maximum recruitment (consistent with the recruitment overfishing definition used for many marine fish species). Stock and recruitment models were fitted to the following data sets: 1) Western Arm Brook (eggs to smolts), 2) Canadian eggs to smolts data set for fluvial and lacustrine rivers, and 3) Margaree River adult-to-adult data set.

Uncertainty around the average stock and recruitment relationships was described using the unconditional non-parametric bootstrap technique. The probability of recruitment overfishing, as a proportion of target met, was determined from the proportion of the total bootstrap estimates where predicted recruitment was less than or equal to half the maximum recruitment. Consequences of target overfishing (and underfishing) were expressed in terms of the gain in present harvest relative to the gain in subsequent future harvest from the management action. It was assumed that the strategy was to manage the spawning escapement at target and any harvestable surplus was calculated as the difference between predicted recruitment and the target.

Western Arm Brook: egg to smolt data set

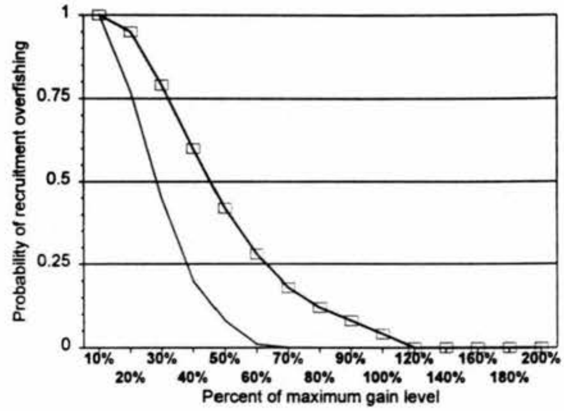
Smolt production has been less variable than egg depositions. Both Beverton-Holt and Ricker models provided reasonable descriptions of the egg to smolt relationship, explaining 38% and 31% of the total variance in smolt output, respectively. The estimated threshold egg deposition for this stock differed for the two models: 294 eggs per $100m^2$ of fluvial habitat for the Beverton-Holt model and 159 eggs per $100\ m^2$ for the Ricker model. For the Ricker model, maximum recruitment would be expected at egg depositions of 690 per $100\ m^2$ of fluvial habitat. The conservation egg deposition for this river is currently 314 eggs per $100\ m^2$ of fluvial habitat (0.91 million eggs and $290{,}000\ m^2$ of fluvial habitat) which is within the 90% confidence interval for maximum recruitment from the Ricker model but also within the very wide confidence interval of the threshold based on the Beverton-Holt model.

Generalized egg to smolt data set converted to adults

This approach considered modeling the egg-to-egg relationship in two steps: 1) model the egg-to-smolt relationship using a Beverton-Holt model by combining data from different rivers but adjusting for the presence of lacustrine habitat, and 2) use the observed biological characteristics of the recruiting adults to translate smolts into recruiting eggs. This two step process which converts the stock and recruitment axes to similar units allows the calculation of reference points for maximum gain and replacement. Two example rivers, Western Arm Brook for lacustrine type river and rivière Bec-Scie as a fluvial river, were presented.

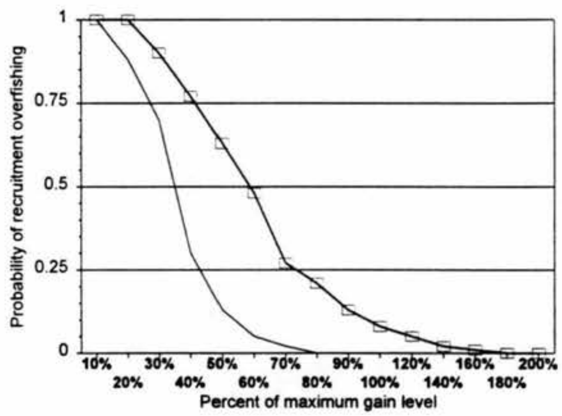
Western Arm Brook

The threshold egg deposition for Western Arm Brook was 47 eggs per 100 m^2 while egg deposition for maximum gain was about 100 per 100 m^2. The probability of recruitment overfishing was greater than 0.75 at escapement levels of less than 30% of the maximum gain level but less than 0.10 at 90% of the maximum gain point (open squares). If the survival rates are doubled (assuming 50% exploitation rate in the commercial fisheries, solid line in figure), then the probability of recruitment overfishing is less than 0.10 when escapement falls to 50% of the maximum gain level. The present conservation level of 314 eggs per 100m^2 of fluvial habitat exceeds the 90% C.I. range of the maximum gain level.



Rivière Bec-Scie

Egg depositions for maximum gain were about 75 per 100 m^2. The probability of recruitment overfishing was high (0.75) at escapement levels of less than 40% of the maximum gain level but low (0.10) at the maximum gain level (open squares in figure). At twice the recently observed sea survival rates (solid line), the probability of recruitment overfishing was low (0.10) at an escapement of 60% of the maximum gain level and there was no chance of recruitment overfishing at escapements of 80% or more of maximum gain. Under the scenario of a doubled sea survival, the maximum gain level was 125 eggs per 100 m^2. The conservation level of 240 eggs per 100 m^2 is 92% higher than the maximum gain level at the doubled sea survival rate but within the 90% C.I. of the estimated spawning escapement level for maximum gain.



Margaree River adult-to-adult

The Margaree River adult-to-adult data set for the years 1947 to 1995 (Marshall et al. 1996) was analyzed. The replacement spawning stock for the Margaree River was estimated to be about 4000 fish. Spawning escapement for maximum gain was higher for the Ricker model, 1376 spawners compared to 1045 spawners for the Beverton-Holt model. The threshold reference point was similar under both models, 441 based on Beverton-Holt compared to 478 spawners from the Ricker model. The current conservation point for the Margaree River is 1036 MSW spawners, more than twice the threshold reference point but similar to the spawning level for maximum gain under the assumptions of the Beverton-Holt model.

Expected average recruitment was greater than half maximum recruitment for spawning escapement levels as low as 40% of the maximum gain level from the Ricker model. The probability of recruitment overfishing is 1.0 when only 32% of the maximum gain level is achieved but drops to 0% (no chance) when 38% of the spawning level for maximum gain has been achieved. Under Beverton-Holt model assumptions, the risk of recruitment overfishing is 0.30 when 50% of the maximum gain level is attained and the risk is 1.0 of recruitment overfishing at escapements of 20% or less of the maximum gain level. The only completely safe range of escapement for avoiding recruitment overfishing was at 80% or greater of the maximum gain level.

Overfishing and underfishing the maximum gain level results in a deficit, the absolute loss being small at escapements ranging between 70% and 120% of maximum gain level.

Conclusions

Targets and especially thresholds should never be less than the spawning escapement which produces maximum gain because any lower spawning escapement results in reduced recruitment and inferior harvest levels. Based on the egg-to-smolt data sets, the probability of recruitment overfishing was about 0.25 when spawning escapement was 70% of maximum gain level. At high production rates, a 0.25 level of risk of recruitment overfishing occurred at a spawning escapement 50% of maximum gain. For the Margaree River adult-to-adult data analysis, the probability of recruitment overfishing was greater than 0.25 when the spawning escapement was 50% or less of the maximum gain level. In terms of the level of maximum gain which is synonymous with the recruitment overfishing threshold reference point, 50% would be the lowest value and 70% would be a very low risk point. All these analyses assume that forecasts of recruitment are perfect, that harvests can be perfectly regulated and that harvesting and spawning occurs in balance with the substock components of the populations. For Atlantic salmon, full production from the resource will only occur when all the substocks are at optimal levels (CAFSAC 1991). In reality, this can never be assured. The surest strategy is to manage for greater than 100% of the maximum gain reference at all times. The conservation reference level based on 2.4 eggs per m^2 is appropriate for managing the Atlantic salmon stocks of eastern Canada. This egg deposition level is within the 90% C.I. of the estimated spawning escapements for maximum gain of the rivers examined and well above the spawning escapement which produces recruitment overfishing.

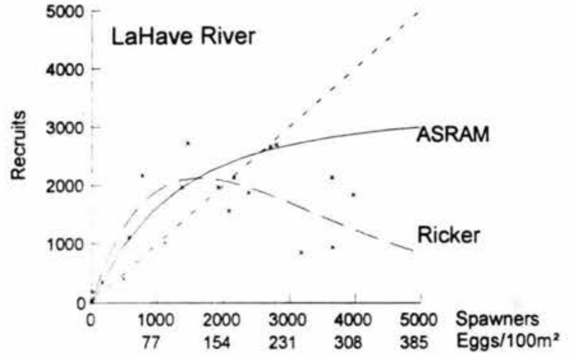
Evaluation of target egg depositions for Atlantic salmon using a simulation framework which considers conservation, yield, and habitat

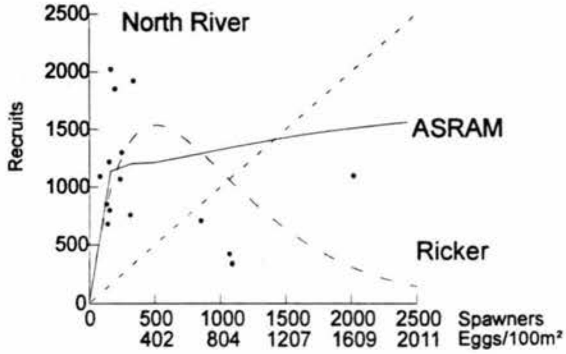
(J. Korman and P. Amiro)

Target egg depositions of Atlantic salmon were evaluated using a simulation framework. Yields were calculated based on 500 trials of 50 year simulations of empirically derived stock-recruitment relationships for two rivers, LaHave River (upstream of Morgan Falls, Lunenburg County, Nova Scotia) and North River (Victoria County, Nova Scotia). A processed-based approach (Atlantic Salmon Regional Acidification Model, ASRAM) and empirically derived stock-recruitment models are used dynamically in a Monte Carlo framework to determine the expected yield and probabilities of failing to meet a conservation limit for a wide range of egg deposition policies. Egg deposition maximizing the difference between yield and probability of failing to meet the conservation limit was proposed as the optimal egg deposition. The influences of environmental variability, errors in managing the fishery (estimating the population and the harvests) and habitat degradation (declining pH) on the selection of 'optimal' egg depositions were examined.

A population size conservation limit based on minimum genetic-risk population levels of 100 fish for each third order and higher tributary was proposed. Conservation limits were 1,400 fish for the LaHave River and 100 fish for the North River.

Egg deposition which maximized yield on a sustained basis (E_{msy}) for the LaHave River, occurred at 110 eggs•100 m^{-2} based on the ASRAM function, and 80 eggs•100 m^{-2} based on the Ricker function. For the North River stock, the E_{msy} values were 175 eggs•100 m^{-2} from ASRAM and 325 eggs•100 m^{-2} from the Ricker model.

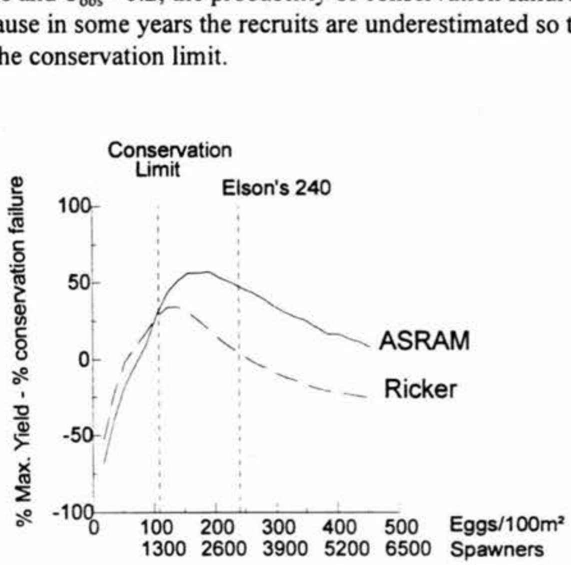




As target depositions increased past the E_{msy} point, the decline in yield was greater based on the Ricker function due to the descending limb of the stock-recruitment curve at higher stock sizes. Yield curves with and without management error (σ_{obs}) were similar for each model although yield declined less at higher egg depositions when management error was simulated. Hilborn (1985) indicated that when σ_{obs} is increased, recruitment is on average over-estimated, resulting in over-harvesting and therefore less of a reduction in yield at higher egg depositions. Management error infers that it takes higher egg depositions to reach the same probability of conservation failure as under perfect management.

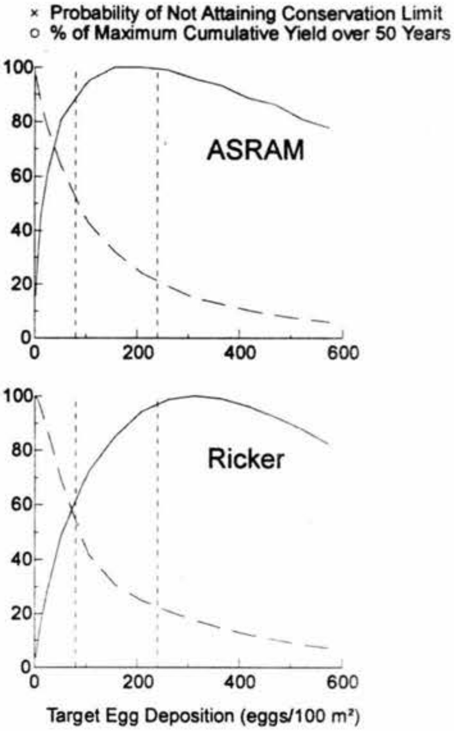
For the LaHave River, when $\sigma_{obs} = 0$, an egg deposition rate of 150 eggs•100 m^{-2} resulted in a conservation failure rate of 25% and a yield which was 90% of Maximum Sustainable Yield (MSY). However, to achieve the same risk of conservation limit failure when $\sigma_{obs} = 0.2$ required an egg deposition of 200 eggs•100 m^{-2} which resulted in 80% of MSY. At low egg deposition rates and $\sigma_{obs} = 0.2$, the probability of conservation failure is actually lower than at high egg deposition rates because in some years the recruits are underestimated so that little or no harvest is taken resulting in escapements above the conservation limit.

The maximum difference between conservation limit and yield occurred at about 200 eggs•100 m^{-2} for the ASRAM projections resulting in 85% MSY and a 25% probability of conservation failure. The optimal egg deposition based on the Ricker model occured at 125 eggs•100 m^{-2}, resulting in 87% of MSY and a probability of conservation failure of 55%.

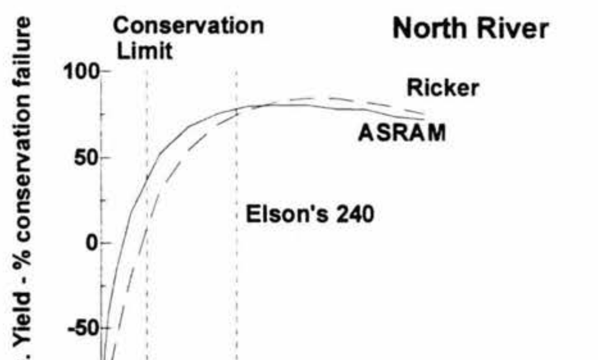


For the North River stock, when $\sigma_{obs} = 0.2$ management error was used these egg depositions resulted in 20% and 30% probabilities of conservation failure for the ASRAM and Ricker models, respectively.

While the projected E_{msy} points were quite different between the two models, the probability of conservation failure curves (dashed lines) were similar, as were the shapes of the yield curves (solid lines). Consequently, the yield-conservation optimal curves were similar between the models.



Egg deposition which maximized the difference between the loss in yield and the probability of conservation failure for the North River was 300 eggs•100 m^{-2} based on ASRAM and at 400 eggs•100 m^{-2} based on the Ricker model.



Two important differences are noted between the LaHave and North River projections. First, E_{msy}, when expressed per unit area, is considerably higher for the North River stock compared to the LaHave River because the North River stock has a much higher replacement stock size (per unit area) than the LaHave. This is the result of better habitat quality in the North River in terms of both pH and gradient compared to the LaHave. Second, the ratio of the S_{msy} levels (e.g. Ricker LaHave - 1300, North - 373) to the conservation limit (LaHave - 1400, North - 100) is much lower for the LaHave River (0.9) than for the North River (3.7) stock. Consequently, the probability of conservation failure at S_{msy} is much lower for the North River (Ricker - 20%) compared to the LaHave (65%) and thus there is less to be gained in terms of conservation by increasing egg depositions beyond E_{msy} in the North River.

Projections were more sensitive to the conservation limit for the LaHave than the North river because of the higher production / intrinsic rate of growth for the North River relative to the LaHave River. Projections were also sensitive to high process error (environmental stochasticity). Average recruitment at any spawner level increases by $\sigma_{env}^2/2$ so the optimal escapement increases with σ_{env}. The decline in yield at higher target deposition decreases with increasing σ_{env}. The higher the process error, the less recruits will be influenced by stock size so the less of an effect stock size will have on yield. In terms of conservation, as σ_{env} increases so does the probability of failing to meet the conservation limit at a given target deposition. The combined effect of process error on the optimal yield/conservation target deposition applied to the LaHave River is to decrease the target at lower error levels (125 eggs•100 m^{-2} at $\sigma_{env} = 0.3$) and increase the target at higher levels (240 eggs•100 m^{-2} at $\sigma_{env} = 0.9$).

Reducing pH changed the characteristics of the stock-recruitment relation by lowering both stock productivity and the replacement stock size. An increase in E_{msy} with declining stock productivity is cancelled out by a decrease in E_{msy} with declining replacement stock size (e.g. $S_{msy} = \beta[0.5 - 0.07\alpha]$ for Ricker) with the end result that there was little change in the E_{msy} across the 3 pH targets examined (7.0, 5.25, and 5.1). When pH is reduced, the number of recruits generated from a specific stock size was also substantially reduced. Since the conservation limit as defined is invariant to pH, the probability of conservation limit failure increased with decreasing pH. For example, to attain a conservation failure rate of < 20% required a target egg deposition of 180 eggs•100 m^{-2} at pH = 7, 250 eggs•100 m^{-2} at pH = 5.25, and could never be achieved at pH = 5.1. The optimal deposition targets based on the combined yield-conservation rule were consistent across pH values (ca. 200 eggs•100 m^{-2}). This simplistic rule may not be appropriate for the pH = 5.1 example as application of this optimal target results in over a 60% chance of not achieving the conservation limit. On the other hand, there is minimal reduction in the probability of conservation failure beyond this target.

The extreme sensitivity of the probability of conservation failure to pH is driven in part by the way pH was systematically changed. Low pH events which kill fish are generally quite episodic in nature in Nova Scotia rivers, however these simulations changed pH to a constant amount for the entire year. This resulted in large differences in mortality due to small changes in pH (5.25 to 5.10). These results demonstrate that habitat quality must be considered in setting optimal targets.

Constraints on minimum viable population size

(J. Hutchings)

The viability of small populations is affected by four sources of uncertainty:

- demographic stochasticity: resulting from chance influences on age-specific survival and reproductive success,
- environmental stochasticity: resulting from temporal variation in habitat, competition, predators, parasites, and transmission of diseases, and
- natural catastrophes: the result of events such as fires, floods, droughts, etc. which occur at random through time.
- genetic stochasticity: resulting from changes in gene frequencies due to founder effects, genetic drift and inbreeding.

The dynamics of small populations are governed largely by the misfortunes of each of its individuals. Large populations are generally not susceptible to such **demographic stochasticity**. Demographic stochasticity is modeled by describing the inverse relationship between realized per capita growth rate (r) and population size (N). In the case of demographic stochasticity, the variance of r (V_1/N where V_1 is the variance in individual fitness per unit time) is also inversely proportional to N. Effective population size from a demographic perspective has been defined as the size of an ideal population with an even sex ratio and a stable age distribution that has the same net change in numbers per year as the population of interest. Small populations will therefore be more susceptible to extinction but for large populations, environmental stochasticity probably poses a greater threat.

Environmental stochasticity arises from a nearly continuous series of small or moderate perturbations that similarly affect the age-specific rates of survival and fecundity of all individuals within a population. In contrast to demographic stochasticity, the variation in the per capita growth rate of a population is independent of the size of the population. The realized per capita growth rate fluctuates with temporal changes in the environment. Environmental stochasticity is thought to pose a greater threat to population viability than either demographic or genetic stochasticity. Small populations are at greater risk if there is a threshold density below which a population cannot recover. The biological basis of this effect has been termed the "Allee" effect.

Natural catastrophes arising at random can have large influence on extinction time irrespective of population size. The average persistence time appears to scale as a power function of carrying capacity. If the long-run realized per capita growth rate is positive, a population of modest size may persist for a long time even in the presence of relatively frequent random catastrophes. No general statement can be made with respect to the relative importance of environmental stochasticity and catastrophes to persistence times for natural populations. Their relative importance depends primarily on carrying capacity, the mean and variance of the long-run per capita growth rate, and on the magnitude and frequency of catastrophes.

The major **genetic** consequence of small population size is an increase in the rate of loss of genetic variability per generation; the two major causes being genetic drift and inbreeding. Genetic drift describes stochastic changes in gene frequencies. The smaller the population, the greater the effect of random changes in gene frequencies. The probability of inbreeding (mating of closely related individuals) increases as population size declines. Over many generations, inbreeding can lead to loss of mean fitness among individuals resulting from the fixation of deleterious alleles (inbreeding depression). A population must be held at very low numbers for several generations before an extinction vortex is generated between the size of a population and the average fitness of individuals within that population.

Given that a population's ability to respond evolutionarily to environmental change increases with its genetic variability, the size of a population is a critical determinant of its probability of long-term survival. In a closed population, genetic variation increases with population size (greater total number of mutations) but the rate of loss of genetic variation due to selection and to drift increases as *effective population size* declines. Effective population size (N_e) is defined as the size of the ideal population that would undergo the same amount of random genetic drift as the actual population. N_e depends primarily on factors related to the mean and variance of individual reproductive success, sex ratio and mating systems. The effective population size per average generation of animals with overlapping generations can be approximated as :

$$N_e = 4\ (T/N_{em}T_m + T/N_{ef}T_f)^{-1}$$

where N_{em} and N_{ef} refer to the effective number of males and females respectively

T_m, T_f and T refer respectively to the generation time for males, females and averaged for the sexes combined.

A migration (straying) of relatively few individuals per generation can be sufficient to outweigh any losses of genetic variability resulting from genetic drift. The results of simulations indicate that the effective population size for a given number of censused females is affected by both straying rate and sex ratio bias:

- at a fixed censused female level, the effective population size increases as straying rate increases,
- increased female bias in sex ratio of anadromous adults results in a decrease in the effective population size,
- at a fixed sex ratio of anadromous adults, the number of females required to maintain an effective population size decreases as migration rate increases.

It is generally felt that modeling genetics is not likely to be as important when assessing the threat of extinction as modeling demographic and ecological processes. Thus, the minimum size of a population that can withstand serious losses in genetic variability may be considerably less than the minimum number of individuals able to withstand "normal" fluctuations in the environment. The main threat to which small populations are exposed is probably extinction resulting from environmental stochasticity (including catastrophes). Populations that are extremely small may be further threatened by genetic factors and demographic stochasticity but these are likely to be less important to Atlantic salmon because of moderate migration rates among rivers (e.g., 5% per annum). Although useful as a means of population identification, methods used to quantify genetic variability are unlikely to provide reliable assessments of population viability. Furthermore, it is impossible to specify "safe" levels of genetic variability with any degree of certainty and alternative techniques for quantifying different sorts of genetic variation often yield conflicting results.

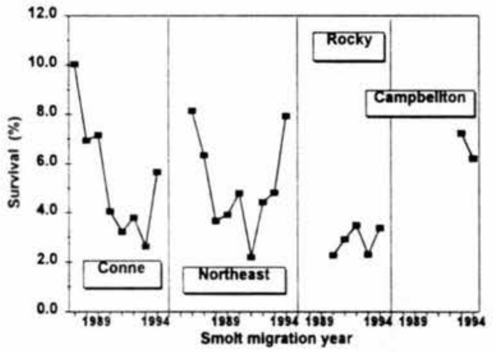
Sea survival trends - implications on the estimation of salmon production

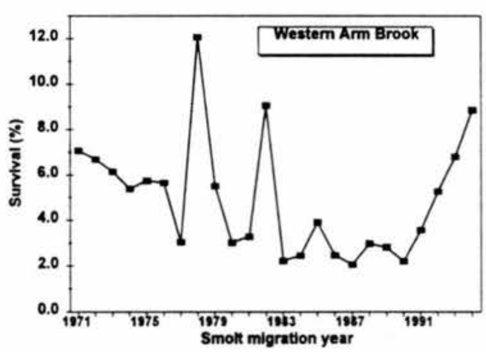
An examination of sea survival trends for wild and hatchery stocks throughout eastern Canada indicated that sea survivals in recent years are substantially below the sea survivals observed in the previous decade and a half. Reduced sea survivals to the river have been observed in spite of the extensive closures of marine fisheries which suggests that the productive capacity of the marine environment is different now. Such changes in production, which may be oscillatory, have an impact on the estimation of targets and thresholds which are based on maximizing a component of the production for Atlantic salmon. Variability in sea survival is part of the environmental stochasticity which determines the abundance of salmon populations.

Sea survival of Atlantic salmon: Newfoundland Region synthesis

(B. Dempson, M. O'Connell, D. Reddin, C. Mullins, C. Bourgeois)

Examination of trends in sea survival provides insight into effects of management measures designed to reduce marine exploitation, or alternatively, in the absence of fisheries, allow estimates of natural survival to be calculated. These data are also required in developing estimates of spawning requirements using the characteristics of recruiting adults. Sea survival from smolt to one-sea-winter (1SW) salmon was examined for five rivers of Newfoundland.





The following points were noted (Dempson and Furey, 1996; O'Connell et al. 1996):

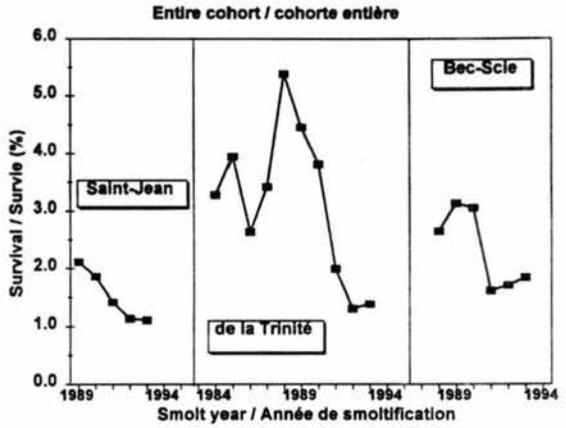
- sea survival is variable both among rivers, and among years within rivers
- in general, sea survival is well below prior expectations given the large scale reductions in marine exploitation coincident with the commercial salmon fishery moratorium

- at three rivers (Conne, Northeast Brook, Western Arm Brook), the highest sea survivals have occurred in pre-moratorium years (i.e. prior to 1992) while the lowest survivals at Conne River and Northeast Brook have occurred during the moratorium
- at two South Coast rivers (Conne and Northeast Brook), mean sea survival in the pre-moratorium years was greater than that recorded to date during the moratorium period.

Sea survival trends in three wild salmon populations of Québec

(F. Caron)

Estimates of adult returns, egg depositions and smolt production are available for three rivers of Québec: rivière St-Jean (Gaspé peninsula), rivière de la Trinité (Québec north shore) and rivière Bec-scie (Anticosti Island). The proportion of 1SW salmon in the returns is lower in rivière St-Jean (average of 25% of total returns) compared to the other two rivers (average of 50%). Sea survival of the cohort has varied between 1.11% and 5.38% with the highest sea survivals observed for the two rivers with the higher 1SW proportion in the returns. Sea survivals for all three stocks declined in 1991 relative to previous years and have remained low since. This decline in sea survivals was observed in both the 1SW and MSW components and this in spite of the dramatic reductions in marine fisheries since 1992.



Sea survival and indices of marine habitat for Atlantic salmon

(C. Harvie, P. Amiro)

Trends in survival rates of three hatchery stocks (Saint John River, LaHave River and Liscomb River) were compared to trends in marine habitat area to assess the importance of environment and management plan regimes on survival rates at sea. No significant temporal correlations were found between rivers for smolt-to-grilse or smolt-to-salmon sea survivals. Survivals of grilse and salmon within a cohort were significantly correlated for the Saint John River and the Liscomb River but not for the LaHave River. There was a significant correlation between marine habitat area (January-to-April habitat area in the Northwest Atlantic; Anon. 1995) and time (years).

For the Saint John River there were significant negative correlations between sea survival rates and time. Consequently, sea survival rates and habitat area (January-to-April habitat area in the Northwest Atlantic; Anon. 1995) were also positively correlated. After adjusting for the significant linear trend in sea survivals over time, it was found that the average sea survivals for the Saint John River hatchery smolts returning as grilse or as multi-sea-winter salmon did not differ between the pre-1984 management plan years and the management plan years (1984 to the present).

For the LaHave River, there was a weak linear relationship of hatchery smolt-to-salmon survival rates on year. As with the Saint John stock, the marine habitat index for the year of return was positively correlated with the hatchery grilse survival rate. The relationship between multi-sea-winter salmon survival and marine habitat area was weaker (p-value = 0.06). For the LaHave River hatchery smolts, survivals to the grilse stage were higher during the pre-1984 management plan years but survival rates to the salmon stage did not differ between the two management plan periods.

The opposite situation was observed for the Liscomb River. Survivals from smolt-to-grilse were similar before and after the 1984 management plan but smolt-to-salmon survival rates were significantly higher prior to 1984.

There was a significant trend in marine survival over time. Both grilse and multi-sea-winter salmon survival rates were postitively correlated with the January marine habitat in the year of return.

Small salmon to large salmon relationships for predicting large salmon returns

(F. Caron)

Analysis of time series of small salmon and large salmon returns to eight rivers in the Gaspé peninsula provided insight into the relative rates of sea survival of the age classes within the same cohort. Significant linear relationships between small salmon returns in year "I" and large salmon returns in the subsequent year "I+1" were found for six of the eight rivers. The significant relationships suggest that changes in sea survival have been similar for both small and large salmon and that the relative proportions by age have not changed during the 1984 to 1995 time period. In the rivers examined, returns of small salmon in 1995 were among the lowest observed in the time series. Expected returns of large salmon in 1996 are also expected to be low.

Spawner overfishing

(D. Reddin and P. Rago)

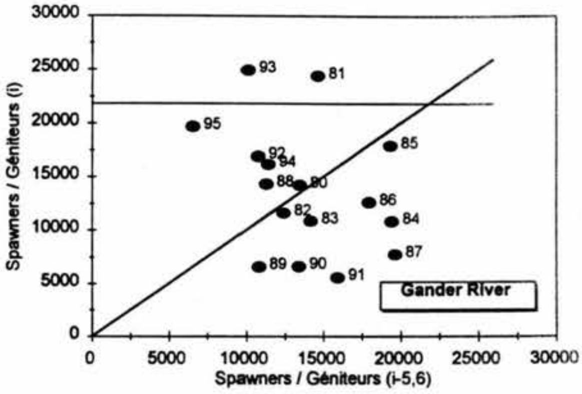
Spawner to spawner analyses can be used to detect changes in populations over time and to examine the efficacy of management plans designed to increase the level of spawners in a river.

The first definition of spawner overfishing is a level of fishing mortality that reduces the ability of a population to persist, more specifically, the failure of a cohort of spawners to replace itself. If returning spawners are not replacing the spawners that produced them and if this situation continues over a series of years then the total population will decline. The second definition of spawner overfishing relates to the biological target in terms of an egg deposition requirement. Thus, spawner overfishing would occur when in the presence of fishing the reference level of spawners for a river in a given year is not achieved.

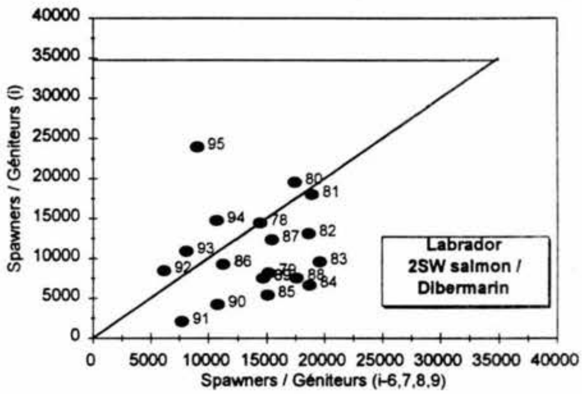
One way to evaluate salmon stocks for spawner overfishing is through the examination of spawner-to-spawner relationships. Data sets were examined to see if the numbers of spawners, which were made up of a range of chronological ages, were sufficient to replace the weighted sum of spawning parents of the same sea age. The appropriate weighting for historical spawners was determined from the average smolt-age distribution for that system. By using the appropriate weighting factors the same technique can be used to examine spawner to spawner relationships summed over several stocks. Alternately, for those salmon stocks consisting of high proportions of both small (mainly grilse) and large (mainly MSW salmon) salmon, the spawner to spawner relationships can be calculated individually for small and large components and then summed.

When the spawner to spawner relationships are plotted there are two relevant lines that can be used to assess whether or not spawner overfishing has occurred. The first is the 1:1 spawner to spawner replacement line (diagonal). Spawners have been replacing themselves if the points fall above the replacement line. The second line is the reference spawner line (horizontal) which defines the spawner reference level. A healthy and well-managed salmon stock would have points which are distributed around the intersection of the spawner replacement line and the spawner reference line.

The 1SW spawners of the Gander River salmon population consists mostly of river age 3 and 4 salmon. Examination of the spawner:spawner plots for Gander River indicate that approximately half the points are above the 1:1 replacement line although the spawner reference line has only been achieved or exceeded in two out of 16 years. Examination for annual trends in the spawner:spawner ratio indicates that for recent years the ratio has exceeded 1:1. If the trend in lower than 1:1 ratios experienced in the mid to late 80s had continued, the stock could have declined below acceptable levels.



The spawner:spawner plot for Labrador 2SW salmon presents a stock aggregate situation where neither the target spawners nor appropriate number of years above the 1:1 replacement line have been achieved. Recent management plans for the commercial fishery have included reductions in fishing effort through license buy-outs and season changes designed to increase the escapement of spawners to freshwater. These changes first began with the 1992 fishing season and have been successful in raising the spawner:spawner ratio above the spawner replacement line but escapement remains below the conservation spawner level.



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Part 2: Science Advice and Management Protocols

A presentation was provided by Newfoundland and Maritimes regions that described the advice which Science has provided in response to requests from Fisheries Management Branch. The advice forthcoming from both regions has been consistent: when spawning escapements are expected to be less than the conservation level, there should be no fishing induced mortality on the stock. Fisheries Management has not always accepted Science's advice on the minimum stock size below which no fisheries should occur and have subsequently requested advice on harvest options which would also incorporate a stock rebuilding strategy. In Newfoundland this advice has suggested that if stocks are at least 75% of the conservation level, then they should be able to grow to over 100% of the conservation level by the next generation. Hence for rivers in which fisheries are permitted when escapements are below 100% of the conservation level the total recovery of the stocks to full production may be delayed by at least one generation. The advice on the rate of growth of stocks was based on observations from monitored stocks, which indicated that the numbers of recruits produced per spawner would be at least 1.3 to 6. In recent years there has been between 2 and 3 recruits produced per spawner. There was no information available to the Workshop to determine the impact of using this strategy for rebuilding stocks.

Quebec assessment scientists also provide advice that there should be no fishing induced mortality when stocks are below the conservation level. Regional biologists have negotiated with user groups on the level of exploitation which would be allowed on the stocks relative to the conservation level.

Regarding the advice from Science to Fisheries Management, it was concluded that Science advice has been consistent in all the regions of Atlantic Canada. Frequently, Fisheries Management has not heeded the Science advice and has asked what would be the consequences to stock status and stock rebuilding of not meeting the conservation egg depositions. Although Science has responded to such requests, the response does not support managing stocks below the conservation level.

Requests for advice also relate to the opening and closing of angling fisheries as a result of warm and frequently low water conditions. Generally in the absence of angling warm water is not necessarily a threat to conservation for Atlantic salmon. The stresses on salmon in freshwater during warm and low water episodes stem from the reduced ability of salmon to cope with agitation, injury and exhaustion associated with hook and release fisheries. During low water conditions, salmon are more susceptible to injury from foul hooking practices (intentional and accidental) and these could trigger and accelerate the onset of disease. Under such conditions, the closure of fisheries could be justified under conservation principles. A presentation was made summarizing the recent studies of physiological stress and recovery associated with hook and release fisheries under different temperature regimes. Water temperature profiles from several rivers in New Brunswick and the impact of using different temperature criteria in terms of the amount (days) and frequency of closures of the angling fisheries were summarized. Standards for obtaining temperature measurements in terms of the sampling location, time of day and descriptor (minimum, maximum, mean, range, etc.) should be derived.

Managing surpluses is required in several stocks of eastern Canada. An analysis using simple probability theory illustrated how even under perfect management of recruitment and perfectly defined biological characteristics of the recruiting adults, that the probability of not achieving the desired egg deposition level was 50%. When stock complexes within large river systems are considered, more fish must be released from the fisheries than defined by the conservation reference if a high probability of achieving the conservation egg deposition is desired.

Protocols used in Newfoundland for determining if a river will be closed for salmon angling

(T.R. Porter)

Fisheries Management in Newfoundland Region has developed a systematic decision making process for determining when a river would be closed to salmon angling based on the anticipated spawning stock size and on environmental conditions. These management protocols were developed with input from assessment scientists and put into use after extensive consultation with the angling industry. Protocols were presented which were related to retention fisheries, hook and release fisheries, and closures related to adverse environmental conditions.

The protocols for retention and for hook and release fisheries take into account projections of stock size derived prior to the opening of the season and again during an in-season review. The underlying management principle is to provide for growth in the production of salmon stocks by increasing the spawning stock. The protocols were designed to allow sufficient spawners such that the production of recruits in one generation, would exceed the spawner conservation levels. Subsequent generations would be managed to harvest salmon only if population size is above the conservation level.

The Newfoundland protocols have three management objectives:

1. To ensure that spawning populations remain equal to or above the conservation target levels in rivers that, in recent years had attained this target. (The conservation target level, as developed by CAFSAC, is the number of spawners that would produce 240 eggs•$100m^{-2}$ in fluvial habitat and 368 eggs per hectare for lacustrine habitat.)
2. To increase the spawning stock to 75% of the conservation target number of spawners in rivers that, in recent years, have had less than 75% of the conservation target. Thus, in the subsequent generation (life cycle 5-7 yrs) escapements to the rivers would be expected to be in excess of the spawning targets.
3. To permit an angling fishery in as many rivers as possible and improve production in rivers with less than optimum production levels.

The growth in the population is assumed to be at least 1.5 fish per spawner and has been between 2 and 3 fish per spawner in recent years. The protocols do allow for retention and hook and release angling fisheries, under some situations when the spawning stock is below established conservation levels with the anticipation that the stock size will be above the conservation spawning requirements in the next generation (1997 or 1998).

The protocols for determining if a river should be closed for salmon angling are:

- A river will **not** be open to angling at the beginning of the normal season if:

  1. It has attained its conservation target number of spawners for the past 3 years and the anticipated returns for the coming year are less than the conservation target.

  Rationale: Once the conservation egg depositions have been achieved, this egg deposition level becomes the threshold below which no fisheries will be permitted.

  2. It has not received its conservation target number of spawners in recent years and the anticipated spawning escapement in the coming year will be less than 50% of the conservation target.

  Rationale: The 50% level was chosen because of the uncertainty in forecasting the number of recruits prior to the beginning of the angling season. If the spawning stock is below 50% of requirements then there is a high risk that the stock will not increase in production, in the next generation, to the extent that it will have an available harvest above conservation levels. Also, if the stock is allowed to remain at below 50% of spawning requirements, the stock may never recover to historical production levels, particularly if natural mortality remains high.

- In-season closure of the angling fishery

    1. Rivers which in the past three years have received more than 100% of the conservation spawner levels will be closed to retention fisheries if the in-season evaluation indicates that the total number of spawners will be less than 100% of the conservation requirement.

    2. Rivers for which the spawning escapement in recent years has been less than the target will be closed to retention fisheries if the in-season evaluation indicates that the total spawning escapement will be less than 75% of the conservation requirement.

    Note: salmon runs in rivers that are closed to angling at the beginning of the season would not be evaluated in-season unless the river has a monitoring facility.

- Hook and release fisheries

    Hook and release fishing would be permitted only if the projected spawning escapement in either the pre-season or in-season forecast will provide greater than 50% of the established conservation egg deposition and under appropriate environmental conditions.

Protocols related to environmental conditions

The Newfoundland Region, for at least the past 25 years, has been closing rivers to angling when water levels have been low and water temperatures relatively high. There was no specific criterion established as to what temperature the rivers would be closed. Closures were subjective and inconsistent across the Province. In 1988, Fisheries Management requested advice from assessment scientists on a criterion for closing rivers. The following protocol was recommended after a review of the literature on the temperature tolerance of Atlantic salmon:

A river should be closed to angling when the water temperature is equal to or greater than 22° C on two consecutive days, measured in mid-afternoon when water temperatures are normally at the daily maximum.

Consideration was given to the fact that salmon are not as easily caught at temperatures greater than 20° C. However, it was felt that the angling activity itself would cause extra stress on the salmon and could result in mortalities. Also, fish that are stressed are more susceptible to infection from disease organisms which could cause mortality. The Protocol has been used inconsistently among Management Areas. The 1995 Salmon Management Plan explicitly identified the protocols for closing rivers due to high water temperature.

A discussion document on the implications of hook-and-release angling, with particular reference to water temperature-related river closures

(A. Bielak)

In Atlantic Canada mandatory hook-and-release of multi-sea-winter fish has been in place as a general, keystone Atlantic salmon management measure since 1984. In 1991, following controversy over a proposed extension of the angling season on the Miramichi River in New Brunswick, and in light of an almost complete lack of good scientific data on the effects of catch-and-release angling on Atlantic salmon, a comprehensive suite of studies was initiated. The goal of the research was to establish a broad scientific data base on the issue and achieve the maximum enhancement benefits from this conservation practice. As a result of the initial results of the research, several management-related opportunities and questions have arisen, including the dilemma of when rivers should be closed to angling. Additionally, with recent developments, such as court decisions related to Native fisheries, there are increasing demands for ever-greater precision of estimates of spawning escapement of Atlantic salmon.

The paper briefly reviewed the catch and release research, made some educated assumptions about the effects of catch and release fishing, modelled temperature-driven fisheries closures and raised some issues both in terms of future salmon management options as well as research needs. Responding to a broad, favourable consensus it concluded with the desirability of formulating a clear, easily-understood and communicated, policy for closing, and subsequently reopening, rivers for temperature-related reasons. It also argued that a number of inputs should be sought, and various factors carefully considered, prior to the formulation of such a policy.

It is desirable to have full and reliable temperature records available for several, strategically-chosen, locations within a given river system. As well, a standard measure (e.g. daily mean, degree days of temperature event duration etc.) of temperature must be used. This is particularly important because of the differences in temperature regime along a river system and daily variation (maximum/minimum) among river systems. An added benefit of such monitoring would be collection of data which might be useful in the context of global climate change.

With the growing role of watershed groups in fisheries management, such data collection could easily be organised by the private sector. More sophisticated arrangements could provide for maximum efficiency by using real time data downloaded to a central facility and/or the use of forecasting techniques by which air temperatures one day are used to predict water temperatures the next (Caissie, 1995, and pers. comm.). It is also fundamental to undertake a comprehensive, general baseline analysis of the risks and potential biological and socioeconomic losses that might result from keeping angling fisheries open for catch and release (or perhaps even catch and kill) fishing at certain temperatures, and/or in specific locations, or closing them.

Because of the complex factors involved, to be effective such analysis should include input from hydrologists, biologists, fisheries managers, resource users and conservation and protection staff. Once compiled this information will provide the basis for more specific in-season decisions related to particular situations. Despite the inherent challenges, the ultimate goal should be to produce a formal policy for river closure and subsequent re-opening. It would be important for any such a policy to be consistent for individual watersheds, and possibly within or across the Atlantic provinces. The product should be a clearly articulated document laying out relevant considerations, responsibilities and mechanisms.

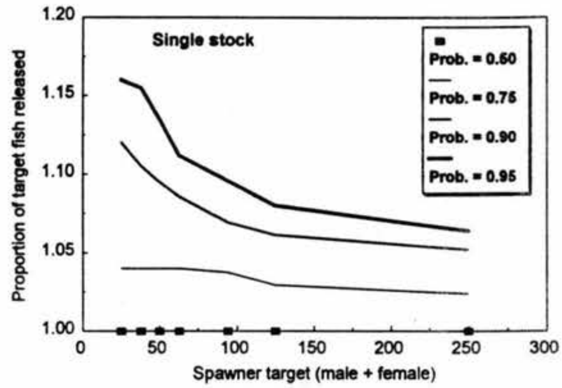
Recommendation:

If temperature criteria are to be established for determining the closing/opening of fisheries, then formalization of locations, equipment and index of temperature (mean, min, max) are required. This would require a review of factors related to heat stress of salmon including incipient lethal temperatures, physiological stresses by temperature, etc. The temperature criterion should be standardized across Atlantic Canada. It could vary regionally depending upon the acclimation temperature of the fish, daily variation in temperatures, etc.

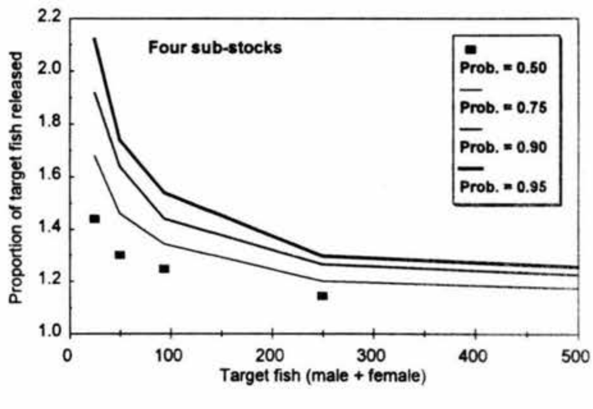
Management of surpluses: probabilities of achieving conservation requirements by releasing spawners from fisheries

Conservation egg depositions are initially established for rivers and these are translated to the number of salmon required to achieve that egg deposition using the average biological characteristics of the stock. Managing surpluses to requirements involves considering the probability of obtaining at least the required number of female fish with variable escapements from fisheries.

Simulations using probability theory revealed that releasing from fisheries the number of salmon equal to the number of females required divided by the proportion female results in a 0.50 probability of obtaining at least the minimum number of females. As stock size increases, the relative increase in additional escapement to achieve the same level of risk of respecting conservation objectives minimum spawning escapement decreases. As an example, for the Margaree River, releasing 1036 fish (conservation spawner requirement) from the fisheries results in a 0.50 probability of attaining the required number of females. Increasing the releases from the fishery to 1080 fish, a 4% increase relative to the conservation requirement, provides almost 100% probability of achieving the minimum female escapement.



When we partition the river into subcomponents which may describe genetically distinct stocks or simply production areas within a large river, then the number of fish which must be released from the fisheries to ensure that all the subcomponents receive at least the minimum required number of females also increases. The number of fish required to achieve the same level of certainty of meeting female spawning requirements increases as the stock complexity increases. As with the single stock example, the proportional increase relative to conservation decreases as the overall size of the stock increases.



Acknowledging that conservation can only be achieved when production is occurring in all the available habitat (or by all the sub-stocks in the river), consideration should be given to the complexity of the river system and the number of distinct production areas which must be seeded. As the number of these areas increases, the required number of fish which should be released from the fisheries must also increase to reduce the risk of violating the conservation objectives.

Framework for developing management plans in Newfoundland

(B. Slade)

- Convene meeting of federal-provincial working group
  - includes province, Science, DFO C&P, DFO management
  - Science had a direct input into the development of the management plan
    - indicated trouble spots with conservation concerns
- Convene meeting of NF-LAB recreational advisory group
  - includes user group representation, first nations
  - convene a meeting of area specific group, ie Bay St. George working group chaired by user group interest
    - Science prepared overview
    - Bay St. George group recommended taking required management measures to rebuild the stocks.
- Public consultations conducted by Science - review of stock abundance and stock status
- In November, Working Group meets again and science advised on management options, management plan for next year.
- In January, Minister approved management plan.
- March - Science provided final advice
  - management plan adjusted to accommodate new advice related to conservation issues.
  - developed multi-year management plan which included provisions for annual adjustments for conservation reasons.

Part 3 - Discussion of ICES Questions

Rationale and justification for the 2SW spawning targets for Canada

The group considered the request to table and justify the data and calculations used to estimate the 2SW spawning target requirement for Canada. A review of habitat areas and conservation egg requirements (or production levels as a surrogate to habitat for Labrador and Ungava Bay) by regions was presented. The conversion of the egg requirement to spawners for each region was based on the underlying conservation principle that all mature age groups should contribute to the spawning escapement in rivers. There is a recognition that the returns to rivers in eastern Canada are comprised of different proportions of each age group and that the proportions observed in river have in the past been modified by size-selective fisheries in the marine environment. Only in the last three years as a result of the minimal exploitation in marine fisheries (commercial fishing moratorium in insular Newfoundland, reduced quotas in Labrador and and quota buyouts in Greenland commercial fisheries) were the relative proportions in the returns to rivers expected to have been a truer representation of the age and size distributions of the potential spawning stock. Still, the proportions observed may have been modified from decades of exploitation in the selective fisheries. It was also recognized that not all salmon of a given age provide equivalent numbers of eggs back to the river. For the majority of Maritime and Quebec rivers, MSW salmon contribute the largest proportion of the eggs because the high female proportion in these fish relative to the one-sea-winter salmon (1SW) which have a low female proportion (generally in the order of 10% female). In numerous Maritime stocks, a single multi-sea-winter (MSW) salmon may contribute as many eggs to the river as 10 to 25 1SW salmon. It was also recognizied that the high seas fishery in Greenland was exploiting almost exclusively a single age group (2SW salmon) in exclusivity of the maturing 1SW salmon. This approach was considered to provide the balance between the biological requirements of the species and the exploitation requirements of the people.

Estimates of returns and spawning escapements of 1SW and 2SW salmon to Canada

The methods for estimating the returns and escapements of 1SW and 2SW salmon to each Salmon Fishing Area (SFA) and fishing zone in Québec (Q) of eastern Canada were reviewed and standardized where possible. The returns and escapements for both sea age groups were derived using a variety of methods and data available for individual river systems and management areas. These values are carried forward to the ICES Working Group on North Atlantic Salmon and are used to estimate the prefishery abundance of 1SW non-maturing Atlantic salmon in the northwest Atlantic. In the past, the values were brought forward to the ICES meeting without being discussed or vetted within the Canadian scientific forum. The exercise was also intended to ensure that the methods used were transparent and acceptable.

Special ICES questions in reference to changes in natural mortality

Predator-prey issues: seals

Six species of seals are in the NFLD region.

- Bearded seals only eat crustaceans.
- Ringed seals, apparently no info.
- Hooded seals are from offshore areas (no salmonids observed to date).
- Harp seals: In 1100 stomach samples mostly from the winter, no salmonid tissue recovered. There are harp seal estimates of abundance.

- Harbor seal (est. 12000 in Atlantic Canada in late 70s). Found in isolated pockets in Newfoundland. Harbor seals were observed eating salmon (D. Reddin pers. comm.) but are not sure if the fish were removed from commercial gear or captured free-swimming. In BC, harbour seals do take salmon.
- Grey seals: no estimates of population size, no stomach samples. Grey seal migrates through the Newfoundland area during March to June.

Would need indications of changes in population sizes as well as evidence of salmon in stomachs.

Avian consumption of juvenile Atlantic salmon in the Maritime Provinces of Canada

(David Cairns)

The major potential avian predators of salmon in Maritime rivers and estuaries are double-crested cormorants and common and red-breasted mergansers, whose Maritime populations are estimated as 27876, 1200 and 950 breeding pairs, respectively. Double-crested cormorants feed largely in coastal and estuarine waters, but they may also feed in rivers, especially during runs of diadromous fishes. An energetics model estimates that Maritime double-crested cormorants eat about 18000 tons of fish annually. If diet composition is 3% salmon during the smolt run, cormorants breeding near major rivers take about 424000 smolts annually. Smolt predation is potentially greatest in the Restigouche, Saint John, St. Mary's, and Liscomb rivers, where significant colonies are located near river mouths. Common merganser diet from numerous collections includes a mean salmon component of 34%, but this value may be upwardly biased by preferential sampling in salmon rivers. If salmon are assigned a more modest 5% of common merganser diet, the model estimates that these birds consume about 6 million juvenile salmon annually. However, this estimate has very wide confidence limits because of uncertainties in total population and other factors. Red-breasted mergansers are generally coastal breeders, but some also feed in fresh water. Assuming a diet that includes 5% salmon during the smolt run and 1% at other times, this species consumes about 5 tons or 350000 juvenile salmon annually. Although all of these estimates of salmon harvest have very wide confidence limits, they nevertheless suggest that birds remove substantial numbers of salmon from Maritime rivers. However, bird control would not necessarily increase salmon production by the amount of predation avoided because of complex and poorly-understood interactions in aquatic food chains.

Appendix 1. Workshop Agenda and Schedule.

Monday, March 11, 1996

13:00 to 13:30 Review agenda, tabling of working documents, review of workshop outputs

13:30 to 14:00 Definition of conservation as a biological reference point

Conservation targets and maximum recruitment defined from stock and recruitment data

14:00 to 17:00 Production potential of Atlantic salmon

Tuesday, March 12, 1996

8:30 to 10:00 Completion of production potential for Atlantic salmon

10:00 to 17:00 Defining thresholds and minimum viable population size

Wednesday, March 13, 1996

8:30 to 10:00 Review of Newfoundland Science advice protocols

10:30 to 12:00 Review of Maritimes Science advice protocols

13:00 to 14:00 Review of Québec management protocols

14:00 to 14:30 Closure/openings due to warm water temperatures

14:30 to 16:30 Round table input Science and Fisheries Management

16:30 to 17:00 Management of surpluses, incorporating risk

Thursday, March 14, 1996

8:30 to 12:00 Spawning targets for Canada (definition of target egg depositions, calculation of required spawners)

13:00 to 17:00 2SW spawner and return estimates

Friday, March 15, 1996

8:30 to 16:00 Review of other ICES questions (predator-prey considerations)

Appendix 2. Working Papers and Presentations

A. Bielak. A discussion document on the implications of catch-and-release angling, with particular reference to water temperature-related river closures.

D. Cairns. Avian consumption of juvenile Atlantic salmon in the Maritime provinces.

F. Caron. Régression entre les madeleineaux et les grands saumons et leur utilité pour prévoir les retours de grands saumons en 1996.

F. Caron. Sea survival trends in three natural salmon populations.

G. Chaput. Conservation for Atlantic salmon: clarification of intent and application.

G. Chaput. Estimation of targets and thresholds for the management of Atlantic salmon.

G. Chaput. Operational translation of conservation in the context of current data.

G. Chaput. Management of surpluses: probabilities of achieving conservation spawning escapements by releasing spawners from fisheries.

J.B. Dempson, M.F. O'Connell, C. Mullins, and C. Bourgeois. Sea survival of Atlantic salmon: Newfoundland Region synthesis.

C.J. Harvie and P.G. Amiro. Can indices of marine habitat for Atlantic salmon (*Salmo salar*) improve pre-season forecasts of returns?

J. Korman and P. Amiro. Evaluation of target egg depositions for Atlantic salmon using a simulation framework which considers conservation, yield, and habitat.

M.F. O'Connell, F. Caron, T.L. Marshall, and C.C. Mullins. Canadian 2SW spawner requirements.

T.R. Porter and B. Slade. Protocols for Newfoundland.

D. Reddin, F. Caron, A. Locke, T.L. Marshall, C. Mullins, M.F. O'Connell. Estimation of Atlantic salmon returns and escapements to Canada, 1971 to 1995.

D.G. Reddin and P.J. Rago. Recruitment (spawner??) overfishing in Atlantic salmon populations: definitions and examples.

Appendix 3. Supporting Documents to Workshop Report.

Bielak, A. 1996. A discussion document on the implications of catch-and-release angling for Atlantic salmon, with particular reference to water temperature-related river closures. DFO Atlantic Fisheries Res. Doc. 96/117.

Cairns, D. 1997. Avian consumption of juvenile Atlantic salmon in the Maritime provinces. DFO CSAS Res. Doc. 97/##.

Chaput. G. 1997. Review of the conservation definition for Atlantic salmon in the context of current data. DFO CSAS Res. Doc. 97/##.

Chaput G. 1997. Estimation of targets and thresholds for the management of Atlantic salmon. DFO CSAS Res. Doc. 97/##.

Harvie, C.J. and P.G. Amiro. 1997. Can indices of marine habitat for Atlantic salmon (*Salmo salar*) improve pre-season forecasts of returns? DFO CSAS Res. Doc. 97/##.

O'Connell, M., et al. 1996. Atlantic salmon spawner targets for eastern Canada. DFO Atlantic Fisheries Res. Doc. 96/##.

Reddin, D.G. et al. 1996. Estimated returns and escapements of small and large salmon to eastern Canada, 1971 to 1995. DFO Atlantic Fisheries Res. Doc. 96/##.

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