Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2006/021

Document de recherche 2006/021

Not to be cited without permission of the authors *

Ne pas citer sans autorisation des auteurs *

Definition and application of conservation requirements for the management of Atlantic salmon (*Salmo salar*) fisheries in eastern Canada

Niveaux de référence et impératifs de conservation pour la gestion de pêcheries du saumon atlantique (*Salmo salar*) dans l'est du Canada

G. Chaput

Science Branch
Fisheries and Oceans Canada
P.O. Box 5030
Moncton, New Brunswick E1C 9B6

ISSN 1499-3848 (Printed / Imprimé)

Canada

Foreword

This document is a product from a workshop that was not conducted under the Department of Fisheries and 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 Moncton (February 2006) to begin the development of a ‘Conservation Status Report’ (CSR) for Atlantic salmon. When completed in 2007, 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) à Moncton (février 2006) en vue de commencer l’élaboration d’un rapport sur la situation de la conservation du saumon atlantique. Lorsqu’il sera terminé, en 2007, 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.

Abstract

The following document provides a review of the concepts of reference points and how these relate and have been applied to the management of Atlantic salmon. Atlantic salmon are managed using conservation limits defined as an egg deposition rate. Conservation egg requirements have been defined for rivers and management zones of insular Newfoundland, the Maritime provinces, and Québec; the exceptions being Labrador and some acid rain impacted rivers on the eastern shore of Nova Scotia. There are some variations in the rate used and the life stage being optimized among the management regions of eastern Canada. A fixed escapement strategy has been chosen for the management of Atlantic salmon fisheries. The conservation limits presently used in eastern Canada are based on data which date several decades. Survivals in both fresh water and at sea today are likely lower in most of the range of Atlantic salmon than during the time period when the data used to develop the reference points were collected. The risk is therefore not that the advice would be to allow fisheries on stocks that are below their conservation limits but rather that the expectations for recovery will be overly optimistic.

Résumé

Le document qui suit passe en revue les notions de points de référence, ainsi que leur pertinence pour la gestion du saumon atlantique et la façon dont ils y sont appliqués. Le saumon atlantique est géré à l'aide de limites de conservation définies comme le taux de ponte. Des impératifs de ponte ont été établis pour les cours d'eau et les zones de gestion de l'île de Terre-Neuve, des provinces Maritimes et du Québec; les exceptions sont le Labrador et certains cours d'eau détériorés par les pluies acides sur la côte est de la Nouvelle-Écosse. On note certaines variations du taux utilisé et du stade biologique optimisé selon les régions de gestion de l'est du Canada. Une stratégie d'échappée fixe a été sélectionnée pour la gestion des pêches du saumon atlantique. Les limites de conservation actuellement utilisées dans l'est du Canada sont basées sur des données qui remontent à plusieurs décennies. Le taux de survie en eau douce et en mer aujourd'hui est vraisemblablement plus bas dans une grande partie de l'aire de répartition du saumon atlantique que pendant la période au cours de laquelle ont été recueillies les données utilisées pour établir les points de référence. Le risque n'est donc pas que les conseils autorisent l'exploitation de stocks qui ont atteint un niveau inférieur à leur limite de conservation, mais plutôt que les attentes de rétablissement soit exagérément optimistes.

INTRODUCTION

Biological reference points (BRPs) are used to provide advice for the management of Atlantic salmon in eastern Canada. This advice has consistently and almost exclusively involved biomass or spawning escapement reference points, in contrast to marine fisheries management for which reference levels based on fishing rates essentially formed the basis for the provision of advice. The use of spawner reference levels against which to assess stock status has a long established history for Atlantic salmon (Potter 2001). The association between future recruitment and parental stock is for the most part uncontested in Atlantic salmon (Chadwick 1985; Chaput and Prévost 2001). What remains uncertain is the type of density dependent survival which occurs and the role the environment plays in modifying recruitment (Walters and Korman 2001).

The following document provides a review of the concepts of reference points and how these relate to the management of Atlantic salmon. A history of the application of reference levels is provided which shows how the reference points have been refined through time. The impediments to the definition of reference levels in some areas are summarized. Finally, future directions that will lead to reference levels best suited to the evolving challenges for Atlantic salmon management, for both fisheries and population management, are reviewed.

BIOLOGICAL REFERENCE POINTS: LIMITS VS TARGETS

A BRP is essentially a signpost, a marker against which the abundance of a resource, the outcome of an activity, and the performance of a management plan can be measured. BRPs are usually defined in terms of removal rates and spawner biomass or escapement levels. So far for Atlantic salmon in eastern Canada, only escapement reference points have been defined (CAFSAC 1991a, 1991b; Caron et al. 1999). The value of establishing reference points, both fishing rates and spawner levels, and managing accordingly, depends upon the consequences to the resource of variations in spawning stock abundance. The choice to be made is whether to manage a resource assuming recruitment depends on spawning stock or is independent of spawning stock size. Prudent action to minimize the risk of overfishing and stock depletion is achieved by managing on the assumption of a relationship between spawning stock and recruitment. ICES (1997) stated that under the precautionary approach, unless it can be scientifically demonstrated otherwise, a relationship between stock and recruitment should be assumed to exist.

BRPs are generally referred to as target and limit reference points. Limit reference points (LRP) are often referred to as thresholds and are intended to minimize the risk of the stock falling below a minimum size (Mace 1994). Target reference points (TRP) are levels to aim for and are intended to meet management objectives (Mace 1994). The most important difference between the two types of BRPs is that anthropogenic activities which cause mortality of the fish would be expected to fluctuate about target levels of impact while thresholds should generally not be crossed (Rosenberg et al. 1994). LRPs should be defined relative to biological principles which are consistent for the species regardless of variations in the economic or social value. In contrast, TRPs would be defined to optimise the sustainable benefits of the stocks based on human social and economic values that may vary among stocks (Potter 2001). The objective for fisheries management would be to achieve the targets while avoiding the limits, or danger zones.

TOWARDS A CONSERVATION DEFINITION FOR ATLANTIC SALMON

The concept of regulating fisheries to manage for spawning escapement pre dates by decades the formal 1991 definition of a limit reference point. Indeed, the concern about maintaining sufficient numbers of spawners so as not to deplete the resource stems from the centuries of interest to fish salmon and ultimately to do so in a way as not to deplete the resource for future generations. The wide recognition of the importance of spawners to recruitment also stems from the ease with which salmon can be cultured in hatcheries, had been cultured for centuries, and the broad evidence from these practices that large numbers of juveniles could be produced from a small number of spawners.

It is instructive to review the history of the management of Atlantic salmon in eastern Canada as it relates to the development of reference points. Potter (2001) provides a very good review of the development and use of reference points in eastern North America and for the northeast Atlantic and he notes that fishery management actions were required well before reference points were clearly articulated and derived. This need to do something before being clear on definitions and approaches has resulted in confusion at all levels. Over the last 15 years, we have used the terms targets, limits, thresholds, optimum spawning escapements, conservation requirements, frequently in reference to the same values, but as frequently in reference to different values and objectives. The following brief history describes the process leading to the definition of conservation and its use.

Huntsman (1931), in his review of the catches and some aspects of the biology of Atlantic salmon in the Maritime provinces, interprets the fluctuations in catches and severe declines in some areas as resulting from overexploitation and habitat destruction. His extensive descriptions of cycles of abundance and dominance lines and their changes or disappearance speaks volumes of his conviction that poor spawning escapement lead to poor recruitment.

In 1957, Elson published a brief article to address the issue of whether the abundance of salmon in the Maritime rivers could be increased by increasing the abundance of juveniles through more spawning escapement or through the intervention of hatcheries. Elson (1957) concluded that plantings of hatchery underyearlings in the Pollett River (New Brunswick) at a rate of about 35 per 100 yd^2 would result in a density of 10 large parr (> 10 cm total length) which would produce the maximum production of 5 to 6 two-year old smolts per 100 yd^2 of stream bottom. Following on this and based on three years of natural spawning data, Elson suggested that to get the 10 large parr for maximum smolt production required an egg deposition rate of about 200 eggs per 100 yd^2 at the average survival rate from egg to parr of 5%. This was considered to be the general rate for the stream as a whole, not just for nursery areas or spawning beds. Elson concluded:

> “..the best figure for the number of adult salmon required to maintain stocks can be set at between 40 and 50 pounds of adult females per mile of stream 10 yards wide.” (Elson 1957; p. 23).

This value refers to a level of egg deposition which would produce maximum smolt production.

Elson (1975) revisited the Pollett River data and presented additional analyses for the Miramichi River (Canada) and River Foyle (Northern Ireland). In the analysis of the Canadian data, it is clear that the objective was to achieve maximum smolt production. Elson felt that a production rate of between five and six smolts per 100 yd^2 was the most to be expected from a "rather good stream". In the natural spawning experiment, Elson indicated that optimum spawning (i.e. spawning for maximum smolt production) would be at 200 to 250 eggs per 100 yd^2. Based on the analysis of egg to fry abundance data from the Northwest Miramichi River Elson concluded:

> "The index of 140 for virtual egg deposition is not out of line with the earlier suggestion of an index of 200 for potential egg deposition, when it is recalled that the figure for potential egg deposition assumed a loss of as much as 25% of adults before spawning. The underyearling production from such spawning (index 140) appears ample for producing the normal limit of 5 or 6 smolts / 100 yd^2, even when allowing the additional year of mortality associated with many 3-year smolts in the Miramichi compared to mostly 2-year smolts in the Pollett (Elson 1962b)." (Elson 1975: p. 111).

> "An average overall rate of smolt production should probably not be expected to exceed a rate of about 5 smolt/100 yd^2 in streams which are icebound in winter. To achieve such production, spawning intensity should be at an average overall rate of about 140 eggs/100 yd^2. Heavier spawning may result not only in waste of fish which could be used in other ways, but in inter-yearclass competition among juveniles which will actually reduce smolt production." (Elson 1975).

This last statement suggests that the egg to smolt function may be over-compensatory and that there is possibly a penalty in terms of reduced recruitment to high spawning escapement.

In 1977, the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) Subcommittee used the term optimum and minimum in reference to spawning requirements.

> "The ban on commercial fishing with some angling cutbacks was instituted in 1972 after it had been shown that spawning stocks in two of the three major New Brunswick rivers, the Saint John and Miramichi, just prior to 1972 had declined to less than 25 percent of the estimated optimum spawning escapement." (Anon. 1977; p. 1)

> "Management of Atlantic salmon is based on maximum stock recruitment resultant of an identified minimum number of adult spawners." (Anon. 1977; p. 3).

> "For all three river systems, a similar method has been employed to estimate the minimum number of required spawners. The basic assumption is that for maximum smolt production, about 44 lb of female salmon are required per mile of stream 10-yd wide (Elson 1957) (20 kg/ 14,700 m^2). With female large salmon carrying approximately 800 eggs per pound (360/kg) *[mistake in text, conversion should be 1760/kg]*, egg deposition is then at the general rate of 200 eggs per 100 yd^2 (240/100m^2). The number of female large salmon is determined using a 12-lb (5.44 kg) average for Restigouche fish and a 10-lb (4.5 kg) average for both the Miramichi and Saint John. Total required escapement of large salmon and grilse is then calculated using the sex ratios to assure that a "normal" proportion of males accompanies females to the spawning grounds. The estimates for each river system were increased to compensate for natural mortality, poaching, and a possible underestimation of salmon producing areas." (Anon. 1977; p. 4).

Important features of this subcommittee report are:

- the basis for management is clearly articulated and archived,
- the conclusions on the optimum spawning escapement are based on the interpretations of Elson (1957),
- the optimum spawning requirement is an egg deposition rate that would maximize smolt production (freshwater model), and
- the general rate derived from the Pollett River, tributary to the Petitcodiac River (Bay of Fundy) was applied to three rivers of New Brunswick (transport of reference level to other rivers).

In 1978, an Atlantic Salmon Task Force was established to develop a resource management and development plan to maximize economic and social benefits of the salmon resource (Anon. 1978). The group considered the production potential of rivers of eastern Canada. Egg deposition rates to achieve smolt production potentials in the Maritimes, Québec, and Newfoundland were defined. For the Maritimes, an egg deposition rate of 240 eggs per 100 m^2, (168 eggs per 100 m^2 for two areas with poorer habitat quality), was considered sufficient to achieve potential smolt production levels of 1 to 3 smolts per 100 m^2 , these levels corresponding to production from poor to good habitat. For rivers in Québec, the smolt production potential was assumed to be 1.5 smolts per 100 m^2 because it was more northern than the Maritimes and generally had steeper gradients but an egg requirement of 240 eggs per 100 m^2 was chosen. For Newfoundland, smolt production potential was considered to vary between 2 and 3.5 smolts per 100 m^2 with corresponding egg deposition rates of 150 to 225 eggs per 100 m^2.

Symons (1979) constructed a juvenile life history model and derived egg to smolt (stock and recruitment) curves based on published or assumed inter-stage survival rates. The two most relevant conclusions from this paper are:

- maximum smolt production was attained asymptotically, and
- maximum smolt production rates and corresponding optimal egg deposition rates decreased with increasing smolt age.

Maximum smolt production levels of 5 per 100 m^2 for two year old smolts, 2 per 100 m^2 for 3 year old smolts and 1 per 100 m^2 for 4 year old smolts would be achieved at egg deposition rates of 220, 165 to 220, and 80 per 100 m^2, respectively (Symons 1979).

In October 1980, a workshop was convened to address the assessment capabilities for Atlantic salmon and what research was required to improve the assessments (Anon. 1981). The workshop attendees concluded that the existing database was insufficient for providing detailed and accurate advice on management measures to optimize production on a river-by-river basis. It was concluded that: "achieving potential egg depositions of 200 per 100 sq. metres of salmon rearing habitat or, where possible, at spawning levels associated historically with high levels of recruitment is adequate to conserve stocks and to retain future options." (Anon. 1981).

Following on the 1978-1980 task force (Anon. 1978, 1981), a discussion paper was published outlining the federal government policy and the course for salmon management in the future (DFO 1982). The first priority was to satisfy resource conservation requirements to achieve optimum sustainable yield which was defined as "the annual harvest in weight which can be taken from the stock year after year while maintaining stock size and allowing the greatest socio-economic benefit" (DFO 1982). The discussion paper also described the conservation objective.

> "Spawning requirements to achieve optimum sustainable yield to the fisheries and, insofar as possible, fullest production of the largest fish within the capabilities of the different rivers and their stocks, are assigned priority over allocations to the various user groups. The ultimate goal is to define spawning requirements by river system and tributary and according to individual stock and stock component. These requirements are defined on the basis of biological and physical inventory information. Priority will be given to upgrading this basic information to ensure stock conservation and facilitate achievement of resource allocation objectives. In preparation of annual fishing plans, utmost consideration will be given to resource conservation requirements since reduced spawning escapements would drastically affect future production and therefore stability in the fisheries." (DFO 1982).

Through the early 1980s, there was a substantial amount of activity associated with defining spawning requirements. At that time, the reference levels were described as target spawning requirements. In 1983, target spawning requirements were established for 16 individual rivers as well as for the combined Salmon Fishing Area 13 in southwest Newfoundland based on 240 eggs per 100 m^2 of juvenile rearing area (Porter and Chadwick 1983). Target spawning requirements were also established for the Miramichi River (Randall 1985), the Restigouche River (Randall 1984), the Nepisiguit River and the Saint John River (Marshall and Penney 1983), all using a rate of 240 eggs per 100 m^2. In 1984, target spawning requirements were established for the LaHave River, Margaree River, St. Mary's River, and the Stewiacke River, also based on the default egg deposition rate. For the Stewiacke river, habitat is weighted using a gradient variable which modifies potential parr production (Amiro and McNeill 1986)

In 1985, the members of the 1978-1980 task group produced a table summarizing spawning requirements by salmon and grilse for 25 zones of Atlantic Canada (excluding Québec) (Anon. 1985). In 1986, a spawning requirement was established for Conne River (Newfoundland) based on an assumed recruit to spawner ratio of 4.5:1. The spawner requirement was calculated from the estimated stock size for 1981 to 1985 based on assumed exploitation rates in the angling and commercial fisheries.

In 1990, there was a proposal for a method to define spawning requirements for Newfoundland rivers to account for production of smolts from lacustrine areas (see O'Connell et al. 2006). The method is fully described in O'Connell and Dempson (1995).

Definition of Conservation

In 1990, the Supreme Court of Canada rendered a decision in the case of Regina vs Sparrow which recognizes that native food fisheries have first right of access to natural renewable harvestable resources, once conservation was assured. However, the court did not define conservation nor provide any guidance on how to determine when conservation needs were met. In 1991, CAFSAC borrowed a definition from the United Nations Environment Program which defined conservation 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." (CAFSAC 1991a).

The subcommittee of CAFSAC then considered the operational translation of conservation for Atlantic salmon and it is in this regard that confusion arises as to whether the conservation level would be a limit or a target. They state:

> "CAFSAC then considered translating the definition as the spawning escapement below which CAFSAC would strongly advise that no fishing should occur. However, because this level cannot be defined with absolute precision, allowing the stock complex to fall to such a 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 1991a).

The subcommittee of CAFSAC then provided a reference level which in the current environment would be synonymous with a precautionary reference level.

> "CAFSAC, therefore, suggests as an operational translation of conservation the current target egg deposition rate of 2.4 eggs/m^2 of fluvial rearing habitat, and in addition for insular Newfoundland, 368 eggs/hectare of lacustrine habitat." (CAFSAC 1991a).
>
> "The 2.4 eggs/m^2 reference level is assumed to provide a modest margin of safety for some instream adult losses between the time salmon enter into a river and subsequent spawning, as well as for disproportionate adult exploitation and unequal rate of recruitment of the multiple stocks comprising a river stock complex. CAFSAC considers that the further the spawning escapement is below the biological reference level, and the longer this situation occurs even at rates only slightly below that level, the greater the possibility exists of incurring the following risks, some of which may cause irreversible damage to the stock:
>
> - accentuation of annual fluctuations in run size and reduction in the long-term capability of the stock to sustain native food fisheries, recreational fisheries, or commercial fisheries;
> - increased susceptibility to extinction from genetic, demographic, or environmental catastrophes and consequent decreases in productivity;
> - permanent changes in demographic characteristics of the spawning population;
> - replacement in the ecosystem by other competing fish species of potentially less social and economic value." (CAFSAC 1991a).

Subsequent to the definition of conservation, conservation requirements were confirmed or defined for 34 rivers in Atlantic Canada (CAFSAC 1991b). Spawning requirements were defined for several Newfoundland rivers based on an additional requirement for lacustrine production of 368 eggs per hectare of lacustrine habitat, an additional 105 eggs per hectare of lacustrine habitat for rivers of the northern peninsula of insular Newfoundland and Labrador (O'Connell and

Dempson 1991a, b). Conservation requirements remained undefined in rivers impacted by acid precipitation.

In 1992, the Anadromous Catadromous Freshwater Fish (ACFF) Subcommittee of CAFSAC met to review progress on refinement of Atlantic salmon spawning requirements (Anon. 1992). Stock and recruitment (SR) data were presented for Saint John River (above Mactaquac), LaHave River (at Morgans Falls), Margaree River, and Western Arm Brook. As well, preliminary life history modeling (ASRAM) was examined for several rivers in Nova Scotia (Korman et al. 1994). The results of the SR analyses were generally within +/- 20% to 30% of the interim value of 2.4 and no change to the general interim value was proposed. This is the first review of the conservation spawning requirements which considered the stock and recruitment dynamics of the entire life cycle of salmon rather than limiting itself to the fresh water phase.

In 1996, a workshop was convened to address a number of issues related to conservation of Atlantic salmon. There was a perception that conservation as a reference point was being interpreted differently within eastern Canada (Chaput 1997). The workshop participants concluded that the operational translation of conservation was intended to be a limit reference point. Reanalysis of historical data sets and more recent data and alternate models indicated that generally, the defined conservation requirement based on 2.4 eggs per m^2 with additional eggs for lacustrine habitat was higher than the egg deposition levels which would provide maximum gain and / or prevent recruitment overfishing (Chaput 1997). Some river specific reference points could be defined but there was insufficient information presented to support a change in the general egg deposition rate of 2.4 eggs per m^2 of fluvial habitat. A terminology issue was resolved and from then on, stock status documents were advised to use the term conservation egg requirement and not target egg requirement when referring to the conservation definition. During the same workshop, conservation requirements for all areas of eastern Canada were reviewed. O'Connell et al. (1997) provide the details on the methods used to define the conservation requirements and table requirements in terms of eggs or fish for individual rivers or zones. Conservation egg requirements have been defined for 55 rivers and all Salmon Fishing Areas of insular Newfoundland and Labrador. In the Maritime provinces, conservation requirements have been defined for more than 150 rivers. Similarly, in Québec, conservation requirements have been defined for 110 rivers.

Refinements to the conservation definition.

In an attempt to refine the river-specific spawning requirements for eastern Canada, Chaput et al. (1998) modeled egg to smolt data from 10 rivers in eastern Canada and tested for the effect of lacustrine habitat or mean age of smolts as factors modifying smolt production rates. They concluded that the presence or absence of lacustrine habitat was an important feature defining the freshwater carrying capacity and that variations in adult characteristics including sea survivals should be used to calculate river-specific reference points. Although unclearly stated, it seems that they proposed the egg deposition which resulted in maximum gain of eggs as the conservation definition, consistent with the ICES definition of the minimum biologically acceptable level (MBAL) (ICES 1993). A higher egg deposition rate which resulted in 90% of maximum gain of eggs could be an appropriate management target (Chaput et al. 1998). This approach has not been used to refine any conservation definitions in eastern Canada.

The most recent progress in derivation of river-specific spawner requirements was completed by the province of Québec in 1999. The revisions consisted of two components (Caron et al. 1999):

1) egg to egg stock and recruitment data were reconstructed for six rivers, and

2) units of production in terms of m^2 of habitat were defined based on a weighting of habitat characterized by habitat type, substrate and width of stream, and degree days and relative juvenile densities within each of the habitat characteristics.

The egg deposition rate was defined from a stock and recruitment analysis based on the Ricker model with the optimum spawning escapement (S_{opt}) defined as the level of egg deposition which produced the maximum gain in eggs (Caron et al. 1999; Prévost et al. 2001). In terms of the revised habitat characterization, the 75th percentile of the distribution of S_{opt} was chosen as the reference level, equal to 1.67 eggs per UP (unit of production). This value was transported to all 110 rivers of Québec (Caron et al. 1999). This represents the most significant change in defining conservation in eastern Canada.

Conclusion

In reviewing the history of the spawning escapement reference levels, it is clear that the conservation requirement is considered to be a limit reference point that could be used to justify the closure of all fisheries. The egg deposition rate that corresponds to conservation is expected to maximize smolt production. The refinements introduced by the province of Québec differ from this approach in that the reference level, termed Sopt, refers to the spawning level which would produce maximum gain, also known as MSY (Maximum Sustainable Yield) and not maximum recruitment as is the case in other regions of eastern Canada.

AREAS WHERE CONSERVATION HAS NOT BEEN DEFINED

Other than the revisions for the rivers of Québec, there has been with but one exception neither change in the approaches nor river-specific definitions of conservation in eastern Canada since the 1991 exercise. Exception to this is for Conne River for which the conservation definition now corresponds to the combined fluvial and lacustrine habitat egg deposition rates values used for insular Newfoundland rivers rather than the value derived in 1986 which is now termed a management target. O'Connell et al. (1997) provide details on habitat areas, egg requirements and spawner requirements for the rivers of eastern Canada which are still relevant today (with the exception of the rivers of Québec).

Two regions of eastern Canada do not have conservation definitions appropriate to their situations. For Labrador and the Ungava Bay region of northern Québec, an absence of fluvial and lacustrine habitat area estimates have precluded the definition of conservation requirements using procedures used in other regions of eastern Canada. The conservation requirements for Labrador in terms of 2SW maiden salmon, used in the provision of management advice for the West Greenland fishery, are based on the objective of achieving an escapement of 30% of the total returns to the rivers of Labrador based on the abundance estimated in 1974 to 1978 (O'Connell et al. 1997).

Naturally reproducing salmon are no longer present in many of the 65 rivers in the southern Uplands region of Nova Scotia (SFA 21) due to low pH associated with acid precipitation (DFO 2000). Conservation requirements have been defined for rivers in this region which are not as impacted by acid precipitaton. An age-structured life history model which incorporated pH-dependent mortality was developed to assess the impacts of acidification, and provide insight into recovery potential of the impacted rivers, and changes in stock and recruitment dynamics with habitat capacity (Korman et al. 1994). To date, the model has not been applied to define river-specific conservation requirements for southern Uplands rivers. The majority of the populations are threatened with extirpation and conservation reference points are not currently relevant.

USE OF REFERENCE LEVELS IN FISHERIES MANAGEMENT

The statutory responsibility for managing Atlantic salmon in Canada lies with the national (federal) government. The only exception is the province of Québec which in 1922 was delegated the responsibility for managing the salmon resource. Provincial governments have legislative authority which can impact on salmon management through licensing of recreational fisheries and the uses of freshwater within their jurisdiction. Through a number of management-oriented exercises in the early 1980s, some principles of salmon management were established and remain in effect (Anon. 1986). The long-term management framework emphasized the need for a zonal or river system basis for all aspects of management with a reduction in mixed-stock fisheries. Conservation was also attributed priority over all uses of the resource.

Management of homewater fisheries

In 1991, CAFSAC (1991a) formally defined conservation for Atlantic salmon as a level of egg deposition in individual rivers and in a subsequent advisory document provided preliminary estimates of surplus to conservation requirements for a number of rivers in eastern Canada (CAFSAC 1991b). These two documents established the reference points for subsequent fisheries management based on a fixed escapement policy with all fish in excess of this requirement considered surplus and available for harvest.

The management of homewater fisheries in eastern Canada now occurs on a river specific basis (see Jones et al. 2006). In the Maritime provinces , large areas are closed to exploitation by all users because of low abundance, other rivers are open to modest Aboriginal fisheries and catch and release fishing, while most of the rivers of the Gulf Region are open to retention of small salmon in recreational fisheries, small and large salmon harvests in Aboriginal fisheries. In the province of Québec, there is a broad range of management in place, from closures to all fisheries of small rivers with returns of less than 100 salmon, retention of small salmon only, to retention of small and large salmon supported by inseason assessments. In Newfoundland and Labrador, river-specific management plans have been developed with exploitation based on the size and status of rivers relative to achieving conservation.

In conclusion, Canada has adopted a fixed escapement strategy for the management of Atlantic salmon fisheries on a river-specific basis.

Management of high seas mixed-stock fisheries

Canada is a member of the North Atlantic Salmon Conservation Organisation (NASCO) whose main objective is to contribute to the conservation, restoration, enhancement and management of Atlantic salmon. Through the NASCO Convention, parties agreed to cooperate in the management of fisheries which exploit Atlantic salmon originating in rivers of other parties, the two principal fisheries being in the West Greenland and Faeroes Islands (Potter 2001). NASCO fulfils its responsibility for management of distant water fisheries through management measures derived from catch advice commissioned from the International Council for the Exploration of the Sea (ICES). ICES has advised that the fisheries should be managed according to a fixed escapement policy with the objective of protecting spawning escapement in the several hundred salmon stocks subject to the mixed stock fisheries (Crozier et al. 2004). Since the adoption of the Convention for the Conservation of Salmon in the North Atlantic Ocean, the distant water fisheries at West Greenland and Faroes have been regulated by internationally negotiated quotas, which have been greatly reduced and in some recent years have not been fished, due to locally negotiated arrangements with interested parties.

The definition of safe biological limits originally developed by ICES with respect to Atlantic salmon and adopted by NASCO, is the level of stock that will achieve long-term maximum sustainable yield (MSY) to fisheries (S_{MSY} or S_{opt}) (ICES 1993). Accordingly, the spawning stock at the MSY point on an adult-to-adult Atlantic salmon SR relationship was adopted as the conservation limit (CL). In 1993, the ICES Study Group on North American salmon fisheries provided a composite estimate of 2SW spawner requirements for rivers of North America for the provision of management advice for the West Greenland salmon fishery. The study group indicated that “optimal” numbers of smolts or returns would be ensured if there was an adequate supply of eggs to “saturate the fluvial habitat” (ICES 1993). Since the West Greenland fishery exploited primarily non-maturing 1SW salmon destined to return to homewaters to spawn as 2SW salmon, a composite spawner requirement for eastern North America, in terms of 2SW fish, was obtained by summing the 2SW requirement from the 37 salmon fishing areas and zones (ICES 1993; Table 6.1.2.1).

The mixed stock nature of the North Atlantic salmon fishery poses significant problems. The aim of management is to regulate catches while achieving overall spawning escapement defined by conservation limits in the large number of generally small North American and European rivers. These differ in biological characteristics (especially size and fecundity), in status, and in productivity (Prévost et al., 2003). Low productivity stocks are particularly vulnerable in mixed stock fishery situations (Chaput 2004). Acknowledging that conservation can only be achieved when production is occurring in all the available habitat (or by all the spawning components in the river), the formulation of fisheries management advice needs to take account of the complexity of the mixed stock fishery being managed and the number of distinct production areas which must be seeded. As the number of these areas increases, the required number of fish that should be released from the fisheries must also increase (Chaput 2004). These considerations clearly become critical when considering mixed stock fisheries that exploit stocks that are already well below conservation limit and especially if those stocks are of low productivity.

IMPROVEMENTS TO DERIVATION AND USE OF REFERENCE LEVELS FOR FISHERIES AND POPULATION MANAGEMENT

Moving away from management based on limits

An alternative to managing fisheries relative to a conservation limit is to set a management target. The target would be set to a level at which the probability of recruitment being less than the conservation limit would be very low. Management targets have not been developed for Atlantic salmon stocks in eastern Canada with the exception of a few rivers in Québec, the spawner objective in those rivers was set at a point between Sopt and S replacement, relative to the goals of the organisations managing the economic benefits of the fisheries (F. Caron, Ministère des Ressources Naturelles et de la Faune du Québec, 830 chemin Ste.-Foy, Québec (Qc)). As yet, neither ICES, NASCO, nor any DFO sectors, has proposed methods for setting management targets for Atlantic salmon fisheries. In some regions of eastern Canada, the setting of management targets is not relevant as the stocks are substantially below the conservation limits.

Non-stationarity in recruitment dynamic

The conservation limits presently used in eastern Canada are based on data which date several decades. We therefore put substantial faith that the population dynamics which generated the spawner and recruitment observations are still relevant for the salmon stocks being managed today. But this may not necessarily be the case. There are more likely to have been temporal changes in survival at various stages of the life cycle resulting from a number of factors including shifts in the environment and habitat degradation (Beamish et al. 1999, DFO 2000). These changes in survivals through time generate annual and mean recruitments at spawning escapements which differ from the past, a phenomenon known as non-stationarity (Walters and Korman 2001; Chaput et al. 2005). These changes will affect not only the reference points corresponding to those conditions but also the expectations of responses of populations to management interventions.

The conservation limit presently used in most of eastern Canada, except for Québec, was derived from a fresh water stock and recruitment model. It assumed that survival at sea was not density dependent. If sea survival has declined independent of density, then the freshwater derived reference points are unaffected, but the performance of the stock relative to achieving the conservation limits will likely be disappointing. A model which would account for differences in sea survival among rivers or among time periods would produce reference points which are lower under the reduced marine survival conditions (Chaput et al. 1998). If fresh water survival had declined, then the reference points derived from the historical data would be higher than what could be achieved under the current versus historical conditions.

The important consideration is whether the survivals of Atlantic salmon in both the fresh water and marine conditions are higher now than during the years contributing to the reference point derivation. I suggest that the survivals in both fresh water and marine today are not higher, in some cases may be similar but more likely lower in most of the range of Atlantic salmon (O’Connell et al. 2006). As such, the risk is not that there will be fisheries on stocks that are below their conservation limits, it is more that the expectations for recovery will be overly optimistic. Since management is based on an escapement reference point rather than a fishing rate, spawning escapement should be protected when stocks are low.

REFERENCES

Amiro, P.G. and A.J. McNeill. 1986. Status of juvenile Atlantic salmon stocks of the Stewiacke River in 1984 and 1985 and forecasts of recruits to fisheries in 1986 and 1987. CAFSAC Res. Doc. 86/32. 40 p.

Anon. 1977. Anadromous, Catadromous, and Freshwater Subcommittee New Brunswick salmon assessment - stock forecasts for the 1977-1980 period. CAFSAC Subcommittee Report 77/1.

Anon. 1978. Biological Conservation Subcommittee Report. Atlantic Salmon Review Task Force.

Anon. 1981. Anadromous, Catadromous, and Freshwater Fishes Subcommittee, February 2-6, 1981. CAFSAC Subcommittee Report 81/3.

Anon. 1985. Anadromous, Catadromous, and Freshwater Fisheries Subcommittee Meeting, Halifax, NS, January 22-23, 1985. CAFSAC Subcommittee Report 85/2.

Anon. 1986. Strategies for the Long-Term Management of Atlantic Salmon. Report of the Special Federal/Provincial Atlantic Salmon Working Group. 35 p.

Anon. 1992. Anadromous Catadromous and Freshwater Fisheries Subcommittee Report, Halifax, St. John's, Newfoundland, November 24-27, 1992. CAFSAC Subcommittee Report 92/16.

Beamish, R. J., D. J. Noakes, G. A. McFarlane, L. Klyashtorin, V. V. Ivanov, and V. Kurashov. 1999. The regime concept and natural trends in the production of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 56: 516-526.

CAFSAC. 1991a. Definition of conservation for Atlantic salmon. CAFSAC Adv. Doc. 91/15.

CAFSAC. 1991b. Quantification of conservation for Atlantic salmon. CAFSAC Adv. Doc. 91/16.

Caron, F., P.M. Fontaine, et S.E. Picard. 1999. Seuil de conservation et cible de gestion pour les rivières à saumon (*Salmo salar*) du Québec. Faune et Parcs Québec, Direction de la faune et des habitats. 48 p.

Chadwick, E.M.P. 1985. The influence of spawning stock on production and yield of Atlantic salmon, *Salmo salar* L., in Canadian rivers. Aquaculture and Fisheries Management 1985 1: 111-119.

Chaput, G.J. (Editor). 1997. Proceedings of a workshop to review conservation principles for Atlantic salmon in eastern Canada. DFO Atlantic Fisheries Proceed. Ser. 97/15.

Chaput, G. 2004. Considerations for using spawner reference levels for managing single- and mixed-stock fisheries. ICES Journal of Marine Science 61: 1379-1388.

Chaput G., J. Allard, F. Caron, J. B. Dempson, C. C. Mullins, and M. F. O'Connell. 1998. River-specific target spawning requirements for Atlantic salmon (*Salmo salar*) based on a generalized smolt production model. Canadian Journal of Fisheries and Aquatic Sciences 55: 246-261.

Chaput, G., C. M. Legault, D. G. Reddin, F. Caron, and P. G. Amiro. 2005. Provision of catch advice taking account of non-stationarity in productivity of Atlantic salmon (*Salmo salar* L.) in the northwest Atlantic. ICES Journal of Marine Science 62: 131-143.

Chaput, G. and E. Prévost. 2001. Reference points to improve Atlantic salmon management. p. 17-24. In: E. Prévost and G. Chaput [Editors]. Stock, recruitment and reference points: assessment and management of Atlantic salmon. INRA Editions. 223 p.

Crozier, W. W., P-J. Schön, G. Chaput, E. C. E. Potter, N. Ó Maoiléidigh, and J. MacLean. 2004. Managing Atlantic salmon in the mixed stock environment: Challenges and considerations. ICES Journal of Marine Science 61: 1344-1358.

DFO 1982. Management of Atlantic Salmon in the 1980s. A discussion paper. 21 p.

DFO 1993. 1993 Atlantic Salmon Management Plan: Guiding Principles and Major Elements. 49 p.

DFO 2000. The Effects of Acid Rain on the Atlantic Salmon of the Southern Upland of Nova Scotia. DFO Maritimes Regional Habitat Status Report 2000/2E.

Elson, P. F. 1957. Number of salmon needed to maintain stocks. Canadian Fish Culturist No. 21: 19-23.

Elson, P.F. 1975. Atlantic salmon rivers smolt production and optimal spawning: an overview of natural production. International Atlantic Salmon Foundation Special Publication Ser. 6: 96-119.

Huntsman, A. G. 1931. The Maritime Salmon of Canada. Biological Board of Canada Bulletin No. XXI. 99 p.

ICES 1993. Report of the Working Group on Methods of Fish Stock Assessment. International Council for the Exploration of the Sea C.M. 1993/Assess:12.

ICES. 1993. Report of the North Atlantic salmon working group, Copenhagen, 5-12 March 1993. International Council for the Exploration of the Sea CM 1993/Assess: 10.

ICES 1997. Report of the Study Group on the precautionary approach to fisheries management. International Council for the Exploration of the Sea 1997/Assess:7.

Jones, R., F. Caron, and J.B. Dempson. 2006. Atlantic salmon (*Salmo salar*) fisheries and fisheries management in eastern Canada. DFO Can. Sci. Adv. Sec. Res. Doc. 2006/020 (In prep.).

Korman, J., D. R. Marmorek, G. L. Lacroix, P. G. Amiro, J. A. Ritter, W. D. Watt, R. E. Cutting, and D. C. E. Robinson. 1994. Development and evaluation of a biological model to assess regional-scale effects of acidification on Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 51: 662-680.

Mace, P. M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Canadian Journal of Fisheries and Aquatic Sciences 51: 110-122.

Marshall, T. L. and G. H. Penny. 1983. Spawning and river escapement requirements for the Saint John River, New Brunswick. CAFSAC Res. Doc. 83/66.

O’Connell, M. F. and J. B. Dempson. 1991a. Atlantic salmon (*Salmo salar* L.) target spawning requirements for selected rivers in Salmon Fishing Area 5 (Bonavista Bay), Newfoundland. CAFSAC Res. Doc. 91/17.

O’Connell, M. F. and J. B. Dempson. 1991b. Atlantic salmon (*Salmo salar* L.) target spawning requirements for rivers in Notre Dame Bay (SFA 4), St. Mary’s Bay (SFA 9), and Placentia Bay (SFA 10), Newfoundland. CAFSAC Res. Doc. 91/18.

O’Connell, M. F. and J. B. Dempson. 1995. Target spawning requirements for Atlantic salmon, *Salmo salar* L., in Newfoundland rivers. Fisheries Management and Ecology 2: 161-170.

O’Connell, M. F., J. B. Dempson, C. C. Mullins, D. G. Reddin, N. M. Cochrane, and D. Caines. 1997. Status of Atlantic salmon (*Salmo salar* L.) stocks of the Newfoundland region, 1996. DFO Atlantic Fisheries Res. Doc. 97/42.

O’Connell, M. F., J. B. Dempson, and G. Chaput. 2006. Aspects of the life history, biology and population dynamics of Atlantic salmon (*Salmo salar* L.) in Eastern Canada. DFO Can. Sci. Adv. Sec. Res. Doc. 2006/014.

O’Connell, M. F., D. G. Reddin, P. G. Amiro, F. Caron, T. L. Marshall, G. Chaput, C. C. Mullins, A. Locke, S. F. O’Neil, and D. K. Cairns. 1997. Estimates of conservation spawner requirements for Atlantic salmon (*Salmo salar* L.) for Canada. DFO Atlantic Fisheries Res. Doc. 97/100.

Porter, T. R. and E. M. P. Chadwick. 1983. Assessment of Atlantic salmon stocks in statistical areas K and L, western Newfoundland, 1982. CAFSAC Res. Doc. 83/87.

Potter, T. 2001. Past and present use of reference points for Atlantic salmon. p. 195-223. In: E. Prévost and G. Chaput [Editors]. Stock, recruitment and reference points: assessment and management of Atlantic salmon. INRA Editions. 223 p.

Prévost, E., G. Chaput, and E.M.P. Chadwick. 2001. Transport of stock-recruitment reference points for Atlantic salmon. p. 95-135. In: E. Prévost and G. Chaput [Editors]. Stock, recruitment and reference points: assessment and management of Atlantic salmon. INRA Editions. 223 p.

Prévost, E., E. Parent, W. Crozier, I. Davidson, J. Dumas, G. Gudbergsson, K. Hindar, P. McGinnity, J. MacLean, and L. M. Sættem. 2003. Setting biological reference points for Atlantic salmon stocks: transfer of information from data-rich to sparse-data situations by Bayesian hierarchical modelling. ICES Journal of Marine Science 60: 1177-1194.

Randall, R.G. 1984. Number of salmon required for spawning in the Restigouche River, N.B. CAFSAC Res. Doc. 84/16.

Randall, R.G. 1985. Spawning potential and spawning requirements of Atlantic salmon in the Miramichi River, New Brunswick. CAFSAC Res. Doc. 85/68.

Rosenberg, A., P. Mace, G. Thompson, G. Darcy, W. Clark, J. Collie, W. Gabriel, A. MacCall, R. Methot, J. Powers, V. Restrepo, T. Wainwright, L. Botsford, J. Hoenig, and K. Stokes. 1994. Scientific Review of Definitions of Overfishing in U.S. Fishery Management Plan. NOAA Tech. Memor. NMFS-F/SPO-17. 45 p.

Symons, P. 1979. Estimated escapement of Atlantic salmon (*Salmo salar*) for maximum smolt production in rivers of different productivity. Journal of the Fisheries Research Board of Canada 36:132-140.

Walters, C. and J. Korman. 2001. Analysis of stock and recruitment data for deriving escapement reference points, p. 67-94. In: E. Prévost and G. Chaput [Editors]. Stock, recruitment and reference points: assessment and management of Atlantic salmon. INRA Editions. 223 p.