Atlantic salmon status review

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Executive summary

The goal of the technical review was to ensure that the *Status Review for Atlantic salmon in the United States* is factually supported and that the methodology and conclusions are based on the best available scientific information. The conclusion of the Status Review that the Atlantic salmon of the Gulf of Maine (GOM) Distinct Population Segment (DPS) meets both the discreteness and the significance criteria under the DPS Policy is well founded. Moreover, the scientific data present clearly indicates that the population abundance is extremely low and the risk of extinction significant. The threats to the GOM DPS are comprehensively presented and examined, leading to the well-founded conclusion that the five listing factors are linked to the present low abundance of salmon in the GOM DPS. While the present technical review raises some issues about interpretation of the scientific information and missing information, it does not bring into question the major conclusions of the Status Review as mentioned above.

Introduction

On 1 May 2006, the *Status Review for Atlantic Salmon (*Salmo salar*) in the United States* was received from Center for Independent Experts (CIE) for review. The purpose of the technical review is to ensure that the scientific information presented and analyzed in the *Status Review for Atlantic salmon in the United States* is the best available scientific data. It is also to ensure that the contents of the Status Review can be factually supported and that the methodology and conclusions are scientifically valid.

The specific terms of reference for the CIE review were as follows:

a. Is the species delineation supported by the information presented?
b. Does the Status Review include and cite the best scientific and commercial information available on the species and threats to it and to its habitat?
c. Are the scientific conclusions sound and derived logically from the results?
d. Where available, are opposing scientific studies or theories acknowledged and discussed?

The report was to be submitted no later than 15 May 2006.

a. Species Delineation and Discreteness

The Status Review concludes that the GOM DPS of Atlantic salmon is discrete. That is, it is markedly separated from other populations of the taxon as a consequence of physical,

physiological, ecological or behavioral factors. This is well supported based largely on molecular genetic differences.

Analysis of DPS structure of Atlantic salmon within the United States indicates that geologic and climate features shaped population structure historically. Using the concept of Ecological Drainage Units (i.e. watersheds of similar zoogeographic history, physiographic conditions, climatic characteristics, and basin geography), groundwater structure and nearshore marine community structure, the Status Review concluded that three Distinct Population Segments of anadromous Atlantic salmon likely existed historically in the US. The arguments for this are well supported based on existing evidence, though definitive determination cannot be made because of the absence of genetic and other biological information from each DPS. Only one of the three DPSs have Atlantic salmon not been extirpated, i.e. the Gulf of Maine (GOM) DPS.

The southern limit of the GOM DPS coincides largely with the terminus of the Laurentian Mixed Forest Province. This delineation reflects scientific evidence of significant environmental differences relative to areas to the south, resulting from basin geography, climate, groundwater temperatures, hydrography and zoogeography. The delineation of the northern boundary of the Denys watershed, however, does not match with the terminus of an Ecological Drainage Unit, which includes the lower St. John and lower St. Croix Rivers. In this case, the second criteria of the DPS policy for discreteness can be invoked, i.e. delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist. This is appropriate given the international boundary and differences in management. However, the Status Review argues that this second criterion is not necessary and that there is sufficient evidence to argue for discreteness based on genetic information to support the first criterion.

It is argued that the life history characteristics, smolt age and age at spawning, are important in explaining population structure both within and among DPSs. The evidence of large differences in smolt age between the GOM and outer Bay of Fundy populations in Canada is not strong, with both having a large preponderance of age-2 smolts (Hutchings and Jones 1998). Moreover, smolt age is known to have a strong environmental component to its determination (Metcalfe and Thorpe 1990). Age at spawning, however, does show a level of distinctness for GOM Atlantic salmon, with the vast majority of salmon returning after two sea winters. This is a pattern not seen to the same extent in the neighboring outer Bay of Fundy populations (Hutchings and Jones 1998). Sea age at first maturity is also known to have a significant genetic component (Gjerde 1984, Ritter et al. 1986) and this would be worth mentioning. Therefore, the evidence for discreteness based on life history characteristics is suggestive, but not overly compelling.

The most compelling scientific data for discreteness comes from genetics. There are clear continental and intra-continental differences, as supported by the cited references. Three additional references should also be considered for citation (Cordes et al. 2005, Verspoor 2005, Verspoor et al. 2005). The scientific evidence (including Cordes et al. 2005, Verspoor et al. 2005) indicates that Atlantic salmon of the GOM show levels of genetic variability and differentiation within and among populations which is comparable to native populations from other parts of the species range of similar geographic size. The evidence is compelling that the history of artificial stocking in the GOM DPS has not homogenized the remnant populations.

There are also indications of differentiation between the GOM and outer Bay of Fundy (oBoF) populations (Spidle et al. 2003, Cordes et al. 2005, Verspoor et al. 2005). The latter, while not definitive, supports the contention of discreteness of the DPS from Canadian populations to the north. As such, the best science available would indicate that the GOM populations are discrete and constitute a DPS. The implementation of criteria 2 of discreteness (i.e. international governmental boundary) provides further compelling justification for the designation of the DPS.

The inclusion of the Penobscot (Kenduskeag stream) and lower Kennebec (Bond Brook and Togus Stream) populations in the DPS is supported by the best available scientific information as available in Spidle et al. (2003) and Cordes et al. (2005). These populations show similarities to each other and to nearby populations within the GOM, which are greater than that shown to Canadian populations. The contemporary Penobscot population may either reflect the genetic character of its historical population or that of historical populations in the Narraguagus and Machias Rivers. In either case, logical, scientifically founded justification is provided for considering it to be a biologically significant component of the GOM DPS.

One issue that is not resolved in the Status Review is whether the hatchery populations should be considered part of the DPS. As identified by Hey et al. (2005), "shared phylogenetic history is a necessary starting point for many questions, but important biological processes can be overlooked if it is used to the exclusion of other aspects of the evolutionary process. A strict phylogenetic or taxonomic approach overlooks the fact that even within a single generation, hatchery and wild fish differ because of their responses to dissimilar environments. This response is partly physiological and developmental, but it is also genetic, because the two environments create different selective regimes. It is important that ESUs be considered not just from the perspective of shared phylogenetic history, but also in terms of ecological exchangeability and the short term evolutionary forces."

> … there are biological differences between hatchery and wild fish that arise because of the differences between artificial and natural environments. These differences could be used to justify the exclusion of hatchery fish from an ESU even when they are phylogenetically related to wild fish and even when the hatchery fish are progeny of wild fish that belong to an ESU. This exclusion need not preclude the use of hatcheries as a conservation tool and the justification for exclusion is clearest for hatchery fish that are not required for conservation and recovery of the ESU. In those cases where hatchery origin fish are deemed of critical importance for the conservation of the wild populations, the hatchery fish need protection as well. While recognizing that ESUs can, on biological grounds, be identified as including only wild populations, the maintenance of those hatcheries that are deemed necessary for the preservation of an ESU is also important (Hey et al., 2005).

Consideration and discussion should be given to the question of whether hatchery fish should be included in the DPS. Opposing scientific ideas on the issue should be acknowledged and discussed.

b. Inclusion of Best Scientific and Commercial Information

The Status Review is thorough and includes much of the best scientific and commercial information available. Not surprisingly, however, there is additional information worthy of inclusion and I have attempted to note this below in both my general and specific comments (also see Species Delineation and Discreteness above for suggestions specific to that aspect).

The scientific information presented provides a thorough basis upon which to assess the biological and ecological significance of the GOM Atlantic salmon. The section on Biological Information, however, was weak in its description of Life History, particularly in terms of reproduction. There are a number of important aspects overlooked which have direct bearing on how natural and sexual selection shape the dynamics and genetics of salmon populations. Only passing mention is given to reproduction in comparison to the considerable attention given to survival. This is despite both being central to fitness and thus the action of selection.

Information presented on historic and current distribution and abundance, as well as artificial propagation is thorough. The compilation of listing factors (threats) is comprehensive and the matrix of factors and stressors affecting the GOM DPS (Appendix 8) an effective means of presentation. There was overlap and repetition in the presentation of factors and stressors; however, this seemed reasonable given the subheading structure of this section (i.e. the 5 listing factors). It is the most comprehensive listing of threats and stressors to salmon (Pacific or Atlantic) that I am aware of, and is based on a thorough consideration of both empirical and theoretical knowledge. The review does an excellent job of considering ecosystem level effects and the subsequent repercussions for Atlantic salmon.

Specific Comments

Pg 9, 3rd para, 1st sent – this is an over simplified description of run timing. There are important differences (likely genetically based) in running among salmon populations of the Gulf of Maine (GOM) as described by Baum (1997). This is important in the management of the populations (i.e. river-specific).

Figure 3.1 — “gravel nests called redds” – this is incorrect; nests are not equivalent to redds - females deposit their eggs sequentially in a series of nests within the gravel (a nest or egg pocket is constructed for each spawning event). The contiguous area of gravel containing the nests (i.e. 1 or more egg pockets) is referred to as a “redd” (White 1942, Crisp and Carling 1989, Fleming 1996).

Pg 11, 2nd par – would be useful to compare the degree of iteroparity (3%) for salmon in GOM with that of other Atlantic salmon populations – this appears to be on the low end (Fleming 1998).

Pg 11, 3rd par – “optimal water temperature” for what?

Pg 11, 3rd par – a redd is an area of disturbed gravel containing one or more nests. It is not equivalent to a nest. The description of redd size referred to later in the paragraph reflects the

area of disturbed gravel that may contain one or more nests. It would also be useful to provide some idea of the number of nests a female makes and that this number increases with female size (Fleming 1996, de Gaudemar et al. 2000).

Pg 11, 3rd par – the data on eggs per kg are not general for Atlantic salmon, but are likely specific for the GOM – e.g., 1,200-2,500 (Randall 1989, O'Connell et al. 1997, Klemetsen et al. 2003). Moreover, an important point that is missed is that eggs/kg decrease with increasing female size. Related to this, is the increase in egg size with female size (e.g., Jonsson et al. 1996). It should also be noted that artificial culture (e.g. hatchery rearing) can alter this relationship in salmonids, which thus has implications for the fitness of cultured fish in the wild.

Pg 12, 3rd par – A single sentence over 283 pp. devoted to mature male (precocious) parr is not sufficient. This alternative reproductive strategy is central to the mating system of Atlantic salmon and has important implication for the genetically effective size of populations (e.g. Martinez et al. 2000, Jones and Hutchings 2002) and gene flow (genetic introgression; Garant et al. 2003, Weir et al. 2005)

Pg 19, 4th par – excellent point made about the important contribution other diadromous species likely would have made to nutrient cycling in Maine's Atlantic salmon rivers. However, if the contribution of Atlantic salmon are to be included in this, then some detail on post-spawning mortality rates should be provided (survival to depart rivers after spawning ranges from 9-89%; Fleming 1996)

Pg 90, 5th par – It would be useful to have some idea of rates of tag detection (or detection failure rate) to give some perspective to the percentages given.

Pg 121, 1st par – there is recent evidence that mortality during the early postsmolt stages may not be as high as previously presumed (LaCroix et al. 2004, LaCroix and McCurdy 2005, LaCroix and Knox 2005; see also Welch et al. 2006 for steelhead)

Pg 122, 2nd par – Should be stated that post-release mortality (delayed mortality) because of handling was not assessed.

Pg 122-123 – It should be stated that all mortality estimates are <u>minimum</u> estimates.

Pg 140, 3rd par – Viability of brown trout crosses with Atlantic salmon depend on the direction of the cross (i.e. whether the mother is a trout or salmon)

Pg 165, 1st par – There is no discussion of how attempts are being made to reduce concerns about domestication in "hatchery dependent populations" of the GOM DPS. Such an addition would be appropriate.

Pg 166, 1st par (also 2nd) – Farm salmon also spawn prior to wild salmon in some regions – it is incorrect to state that they "generally spawn later in the season than wild salmon" (see Webb et al. 1991, Fleming et al. 1996).

Pg 167, 1st par – should clarify that percentages of farm fish in the North Atlantic refer only to the Norwegian Sea north of the Faroes and for the mid-1990's.

Pg 167, 1st par, last sent – during what period were these numbers derived? The reference seems rather dated – 1994.

c. Logical Basis and Soundness of Scientific Conclusions

The comments below are structured around the key elements of the DPS policy and the conclusions drawn by the Status Review (except for Species Delineation and Discreteness which was discussed under that heading above). More specific comments are provided at the end of this section. Overall, I felt that the conclusions drawn with regards to the key elements of the DPS policy to be logically founded and sound.

Biological and Ecological Significance

The scientific information presented on the GOM Atlantic salmon provides a thorough basis for the conclusion of biological and ecological significance. These salmon represent the southern-most remnant populations in North America, and as such, occupy a distinct ecological setting (i.e. the Laurentain Mixed Forest) and exhibit characteristics special to the environment (e.g., long oceanic migration, two sea winters prior to maturity). The conclusion that the loss of the GOM DPS would result in a significant constriction in the range of the taxon and loss of distinctive life history and genetic characteristics that may well not be easily replaced is well founded.

Conservation Status and Likelihood of Extinction

The size of the populations and their corresponding growth rates (low survival), even without population viability analysis (PVA), are indicative of a DPS faced with a high risk of extinction. The PVA presented is effective in quantitatively providing extinction probabilities. The approach of considering the dataset in two parts, 1980-2004 and 1991-2004 (following a "regime shift"), is justified. While the forecast is dismal when considering the 1980-2004 period, it is even worse for the 1991-2004 period. The authors of the Status Review do an effective jog of pointing out the important caveats of such an analysis (e.g., assume environmental factors remain unchanged, based on data from a single population [Penobscot], which includes hatchery supplementation).

Listing Factors

The conclusion of the Status Review that dams have played a central role in the destruction, modification and curtailment of habitat, connectivity and range of Atlantic salmon in the GOM is logically founded. The scientific information presented is more comprehensive than that presented in NRC (2004), which reached a similar conclusion.

Specific Comments

Pg 19, 1st par – can only be considered a supplemental foraging resource for juvenile Atlantic salmon if the other diadromous species overlap with them temporally and spatially. Details are not provided however, and this remains speculative.

Pg 21-22 – the discussion of the importance of metapopulation structure and connectivity is well described. It provides strong justification for the conservation of complexity of Atlantic salmon populations in the GOM and why they should be thought of as a Distinct Population Segment (DPS).

Pg 105, 3rd par – it seems highly speculative to suggest that "anadromous fish provided substantial nutrient subsidies to many rivers." Need to clearly separate conclusions based on empirical evidence from those of a more speculative nature.

Pg 115, 2nd par – the discussion of hook and release fishing needs to consider non-lethal effects (e.g., on spawning performance).

Pg 116, 2nd par – It appears contradictory to be suggesting that a catch and release fishery might have little effect (i.e. few mortalities) and in the next paragraph, discussing how "even low levels of poaching will adversely affect Atlantic salmon populations." There would appear to be no justification for a catch and release fishery of any sort based on the scientific information presented elsewhere in the Status Review on the precarious state of GOM Atlantic salmon. That is, there appears to be no logical, scientific grounds for allowing a catch and release fishery. The discussion here needs to be reconsidered.

Pg 120, 2nd par – what evidence is there that parr mortality due to sampling is compensatory? Compensation would seem to be expected primarily at higher densities than currently experienced by GOM populations. It is thus speculative and there is insufficient evidence provided to support such a conclusion.

Pg 120, 3rd par – Again, it is speculative to conclude that mortality is compensatory and not additive at such low population densities as experienced by Atlantic salmon of the GOM.

Pg 122, 2nd par – Any discussion of mortality due to research and assessment should be presented in terms of the benefits versus costs. This has not been done and needs to be considered.

Pg 122, 3rd par – Again, no justification is presented to suggest that mortalities will be compensatory. To the contrary, theory would suggest that given the population densities mortality is unlikely to be compensatory to a significant degree.

Pg 123 – It should also be stated that all mortality is likely to be additive (i.e. not compensatory). The key is whether the benefit from such sampling outweighs the cost in terms of fish mortality. Arguments should be provided to this end.

Pg 125, 2nd par – Whether mortality is likely to be compensatory will depend on population density and at what life stage the population is likely to be density limited/constrained, if at all. This needs to be clarified.

Pg 140, 2nd par – Superimposition will only be a problem if brown trout spawning overlaps or follows that of Atlantic salmon. Existing evidence from Europe, however, indicates that brown trout typically spawn before Atlantic salmon.

Pg 141, 2nd par, last 2 sent – not all spawning habitat is equal and little is known about how females actually chose locations. Moreover, even at low densities redd superimposition occurs (reviewed in Fleming 1996)

Pg 163, 1st par – It is unclear how marking aquaculture fish will aid in the protection of wild fish. It is like "closing the barn door after the cow has gotten out." Escapes need to be stopped before they happen.

d. Acknowledgement and Discussion of Opposing Scientific Studies and Theories

The Status Review a commendable job in recognizing and discussing opposing scientific studies and ideas.

In the section on Historic Distribution and Abundance, however, it would be useful to have a discussion of opposing thoughts on the precolonization abundance of Atlantic salmon in the GOM. While this is mentioned elsewhere in the document, it would seem appropriate to present the views in a synthesized manner here.

With regards to Species Delineation and Discreteness, opposing ideas are acknowledged and logical arguments presented for the conclusions arrived at. In cases where the cause of genetic structuring is uncertain (e.g. the Penobscot R.), it is clearly identified and opposing hypotheses presented. Similarly, the issue of the distinctness of GOM populations from the Canadian populations to the north is discussed openly and logical arguments presented.

Analysis of conservation status and likelihood of extinction recognizes associated caveats, including temporal effects (i.e. analyses are performed incorporating different temporal scales). This allows the reader to better assess the conclusions drawn.

As mentioned previously, the discussion of Listing Factors is comprehensive and inclusive.

e. Minor Comments

Pg 5, 2nd para – clarify what proportion of the fewer than 1,500 adults derive from wild versus hatchery sources.

Pg 11, 4th par, 4th sent – wording

Pg 49, 2nd par – Lage (2005) is missing from References.

Pg 78, 2nd par, last sent & 4th par, last sent – these are identical; one should be deleted.

Pg 120, 3rd par – please provide some detail about “operational changes” that have resulted in decreased electrofishing mortalities.

Table 8.2.6.2a – difficult to interpret because of lack of explanation of the various acronyms used in the table legend and column headings.

Pg 159, 5th par, 2nd sent – “greater” than what?

Pg 199 – journal reference missing for McCormick et al. 2002

References

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APPENDIX 1: Materials provided by the Center of Independent Experts

Fay, C., M.Bartron, S.Craig, A Hecht, J Pruden, R.Saunders, T.Sheehan, and J. Trial (2006) Status Review for Anadromous Atlantic Salmon (***Salmo salar***) in the United States. Report to the National Marine Fisheries Service and US Fish and Wildlife Service. 283pp.

Selected references from Fay et al. (2006).

APPENDIX 2: Statement of Work

Consulting agreement between the University of Miami and Dr. Ian Fleming

April 24, 2006

Atlantic salmon status review

Background

The purpose of this technical review is to ensure that the scientific information presented and analyzed in the Status Review for Atlantic salmon in the United States is the best available scientific data.

On November 17, 2000, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (the Services) issued a final rule to list the Gulf of Maine Distinct Population Segment of Atlantic Salmon (GOM DPS) as endangered under the Endangered Species Act (ESA). The GOM DPS was defined as all naturally reproducing wild populations of Atlantic salmon, having historical river-specific characteristics found north of and including tributaries of the lower Kennebec River to, but not including the mouth of the St. Croix River at the United States-Canada border and the Penobscot River above the site of the former Bangor Dam. Populations which met these criteria were identified as being in the following rivers: Dennys, East Machias, Machias, Pleasant, Narraguagus, Sheepscot, Ducktrap, and Cove Brook.

In the final rule listing the GOM DPS, the Services deferred the determination of inclusion of fish that inhabit the main stem and tributaries of the Penobscot River above the site of the former Bangor Dam. The deferred decision reflected the need for further analysis of scientific information, including a detailed genetic characterization of the Penobscot population. In addition, the Services were committed to reviewing data regarding the appropriateness of including the upper Kennebec and other rivers as part of the DPS. In late 2003, the Services assembled a Biological Review Team (BRT) comprised of biologists from the Maine Atlantic Salmon Commission, Penobscot Indian Nation, NMFS, and USFWS. The BRT was charged with reviewing and evaluating all relevant scientific information necessary to evaluate the current DPS delineations and determining the conservation status of the populations that were deferred in 2000 and their relationship to the currently listed GOM DPS.

NOAA Fisheries is required to use the best available scientific and commercial data in making determinations and decisions under the ESA. The first question that must be addressed is what the appropriate species delineation is for consideration of conservation status. The ESA defines an endangered species as “any species which is in danger of extinction throughout all or a significant portion of its range,” and a threatened species as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” A species may be determined to be threatened or endangered due to any one of the following factors:

(1) the present or threatened destruction, modification, or curtailment of its habitat or range;
(2) overutilization for commercial, recreational, scientific or educational purpose;
(3) disease or predation;
(4) the inadequacy of existing regulatory mechanisms; and
(5) other natural or manmade factors affecting its continued existence.

The scientific and commercial information contained in the Status Review will likely contain essential factual elements upon which the agency could base its ESA determination. Accordingly, it is critical that the Status Review contain the best available information on the species and the threats, that all relevant information is identified and included, and that all scientific findings be both reasonable, and supported by valid information contained in the document.

Objectives of the CIE Review

As stated above, the Status Review has been prepared by the BRT. The Center for Independent Experts (CIE) shall review the Status Review Report to ensure that its contents can be factually supported and that the methodology and conclusions are scientifically valid.

There are several primary issues related to this species that must be addressed, and, therefore, reviewers with the following expertise are required to ensure the best available information has been utilized:

1. Life history and population dynamics of Atlantic salmon;
2. Atlantic salmon genetic, physiological, behavioral, and/or morphological variation throughout the species' range;
3. Habitat requirements;
4. Predation and disease;
5. Regulatory mechanisms for managing the species;
6. Other natural or manmade impacts affecting Atlantic salmon;
7. Aquaculture; and
8. Conservation actions including restoration efforts and recovery activities (including the conservation hatchery program).

Familiarity with ESA is also highly desirable. Each reviewer will be supplied with the Status Review Report prepared by the BRT. Any of the reports and papers cited in the Status Review Report will be made available to the reviewers upon their request.

Specific terms of reference for the CIE review:

e. Is the species delineation supported by the information presented?
f. Does the Status Review include and cite the best scientific and commercial information available on the species and threats to it and to its habitat?
g. Are the scientific conclusions sound and derived logically from the results?

h. Where available, are opposing scientific studies or theories acknowledged and discussed?

Specific Activities and Responsibilities

The CIE shall provide four reviewers to conduct a letter review of the Status Review Report. Each reviewer's duties shall not exceed a maximum of five work days. Each reviewer shall analyze the Status Review Report and develop their report in response to the above terms of reference. The reviewers shall conduct their analyses and writing duties from their primary locations. Each written report is to be based on the individual reviewer's findings, and no consensus report shall be accepted. See Annex I for additional details on the report outline.

No later than May 15, 2006, each reviewer's report shall be submitted to the CIE for review[1]. The reports shall be sent to Dr. David Sampson, via email at david.sampson@oregonstate.edu, and to Mr. Manoj Shivlani, via email at mshivlani@rsmas.miami.edu.

[1] Each written report will undergo an internal CIE review before it is considered final.