Climate Change, Adaptation, and ‘Endangered’ Salmon in Canada

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Abstract: The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has designated four Canadian salmon populations as Endangered: (1) Atlantic salmon (*Salmo salar*) from the inner Bay of Fundy; (2) coho salmon (*Oncorhynchus kisutch*) from the interior Fraser River watershed; (3) sockeye salmon (*O. nerka*) from Sakinaw Lake; and (4) sockeye salmon from Cultus Lake. Each population experienced significant declines after about 1989. Climate-related changes to marine conditions played a role in the decline of Atlantic and coho salmon, and probably the two sockeye salmon populations. Regional differences in marine survival patterns of other salmon are evident, however. For example, coho survival in southern British Columbia declined during the same time period that they increased in northern British Columbia. Physical effects of climate change are projected to result in reduced survival for each of the four COSEWIC-listed populations. Climate effects are anticipated to negatively affect inner Bay of Fundy Atlantic salmon and interior Fraser River coho because of their relatively local and southern marine distributions. The marine distribution of the two sockeye populations is unknown, but since these populations are near the southern extent of their natural distribution, they will also likely suffer. Major effects anticipated for each population include reduced marine survival because of food chain effects, increased competition and predation due to northward shifts in the distribution of various marine warm water species, reduced survival and growth in summer because of poorer feeding conditions resulting from increased summer temperatures and reduced flows, possible adult migration delays due to reduced flows and increased temperatures, and decreased spawning success because of increased sedimentation and scouring. Scientists and managers need to adapt fisheries and habitat management practices to ensure the sustainability of salmon populations, a particularly challenging task during climate change. Various regulatory adaptations that have already been made to reduce the likelihood of extirpation of salmon populations include fishery closures, the use of increasingly selective gear, and shifts in the location and timing of fisheries; nevertheless, more changes need to be made, including additional involvement of stakeholders.

Key Words: climate change, adaptation, endangered species, salmon, inner Bay of Fundy Atlantic salmon, *Salmo salar,* interior Fraser River coho salmon, *Oncorhynchus kisutch,* Sakinaw Lake sockeye salmon, Cultus Lake sockeye salmon, *Oncorhynchus nerka,* global warming, Canada

Introduction

The primary objectives of this paper are to

- provide an overview of four Canadian populations of endangered (i.e., at imminent risk of extinction) salmon;
- review the role of climate change on declines of these populations; and
- discuss possible adaptations to mitigate climate effects.

Endangered Salmon and the Role of Climate Change

The four Canadian populations of endangered salmon are

1. inner Bay of Fundy Atlantic salmon (*Salmo salar*) (designated by the Committee on the Status of Endangered Wildlife in Canada [COSEWIC] in 2001; legally listed by the Species at Risk Act [SARA] in 2003)
2. interior Fraser River coho salmon (*Oncorhynchus kisutch*) (designated by COSEWIC in 2002; not legally listed at this time)
3. Sakinaw Lake sockeye salmon (*O. nerka*) (designated by COSEWIC in 2003; not legally listed)
4. Cultus Lake sockeye salmon (designated by COSEWIC in 2003; not legally listed)

The inner Bay of Fundy (iBoF) Atlantic salmon are genetically and geographically distinct from other Atlantic salmon. They usually spend two years in freshwater and one year at sea, and have a high incidence of repeat spawners (~50% of the population contributes ~75% of eggs). These salmon have a local marine distribution, and rarely leave the Bay of Fundy and the Gulf of Maine because the infusion of cold marine water creates suitable year-round habitat (Amiro 2003).

The primary reason given for recent declines of the inner Bay of Fundy Atlantic salmon (Fig. 1a) is reduced marine survival. The mechanisms behind the decline are not clear but may include ecological changes in the Bay of Fundy and interactions between commercial salmon farming and survival of wild iBoF salmon (Amiro 2003).

Climate effects will be most evident in coastal areas where inner Bay of Fundy Atlantic salmon live. Probable physical effects of climate change that are relevant to these salmon (Mountain 2002; Milewski 2002) include

- increased marine temperatures of 2–3ºC in winter and 3–4ºC in summer;
- increased marine stratification in summer;
- increased precipitation and increased size of the Labrador Current (which may counteract warming caused by atmospheric heating); and
- altered (reduced) river flow patterns and estuarine conditions, and increased stream temperatures.

In turn, these physical changes are likely to

- reduce marine survival via food chain effects by altering species and sizes of phytoplankton, which could affect iBoF Atlantic salmon prey such as sand lance and euphausids;
- lead to increased competition and predation due to a northward shift in the distribution of marine warm water species;
- reduce freshwater survival (e.g., due to possible adult migration delays and decreased spawning success) because of increased stream temperatures and reduced flows; and
- benefit aquaculture with a concomitant negative effect on wild iBoF Atlantic salmon.

Interior Fraser River coho salmon are reproductively isolated from other coho salmon. They usually spend one year in freshwater and 18 months at sea, and have a local marine distribution (Irvine 2002). Sakinaw Lake and Cultus Lake sockeye salmon are reproductively isolated from other sockeye. They usually spend one year in freshwater and two years at sea, and are lakeshore spawners. Their marine distributions are unknown (COSEWIC 2003a, 2003b). Sakinaw Lake sockeye rear in an unusual (meromictic) and small (6.9 km^2) nursery lake, and have an early (summer) and protracted return run timing as well as a protracted lake residency before spawning (COSEWIC 2003a). Cultus Lake sockeye also rear in a small (6.3 km^2) nursery lake, but adults return to freshwater later in the year (fall) than Sakinaw Lake sockeye, and delays off the mouth of the Fraser River are common (COSEWIC 2003a).

The primary cause given for recent declines of these populations of Pacific salmon (Figs. 1b, c, d) is overfishing (COSEWIC 2002, 2003a, 2003b). Habitat perturbations (generally freshwater) are usually regarded as being secondary to fishing effects. For coho, overexploitations during periods of reduced marine survival were accompanied by shifts in marine distributions. For Cultus Lake sockeye, overexploitation impacts have been exacerbated since 1995 by very high pre-spawn mortality associated with unusually early migration into freshwater, and with *Parvicapsula* infestation (Cooke et al. 2004).

Probable physical effects of climate change that are relevant to Pacific salmon include

- reduced peak and summer flows in the Fraser River and earlier-timed freshets;
- increased winter flows, scouring, and sedimentation;
- increased stream temperatures (1.9ºC in summer); and
- salinity, temperature, and wind changes within the Fraser River estuary, Strait of Georgia, Johnstone Strait, and Strait of Juan de Fuca (Levy 1992; Beamish and Noakes 2002; Morrison et al. 2002).

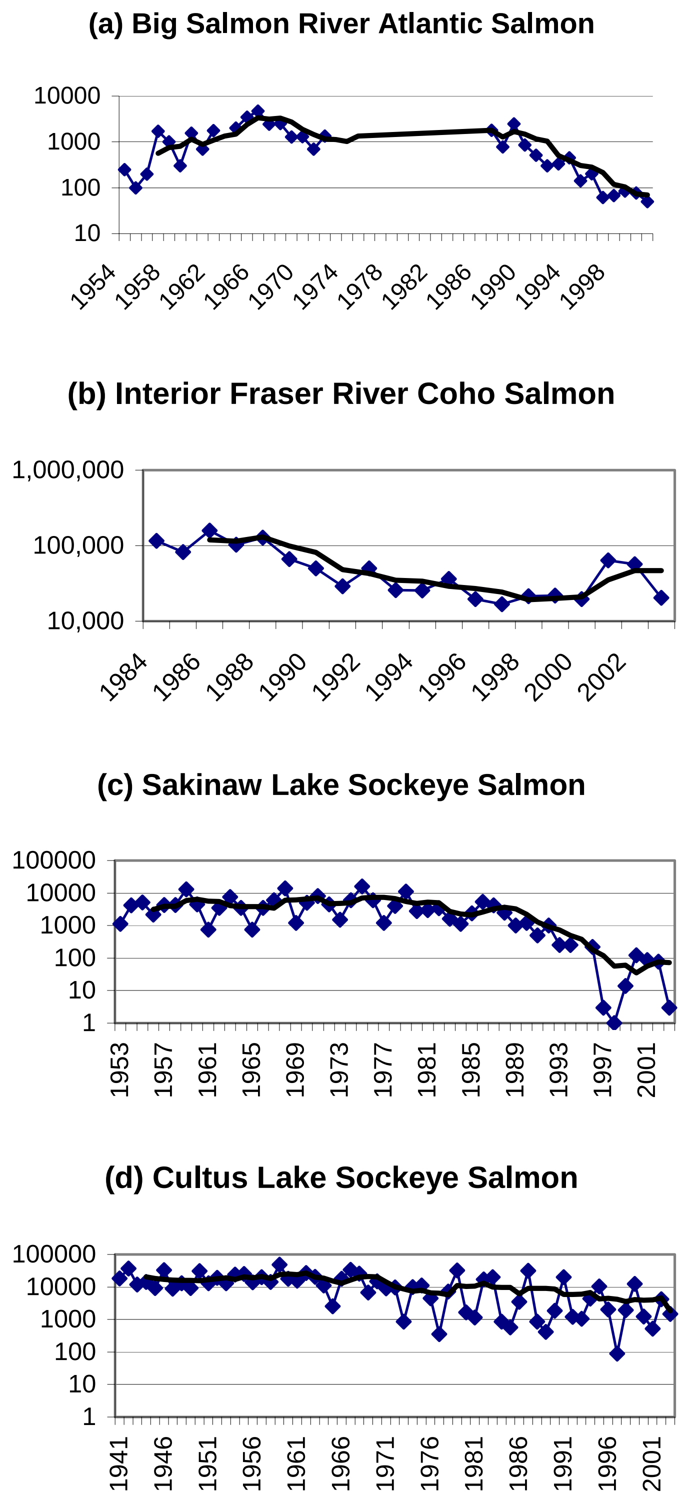

Figure 1. Spawner numbers for (a) inner Bay of Fundy Atlantic salmon in the Big Salmon River (no estimates for 1973–1986), (b) interior Fraser River coho salmon, (c) Sakinaw Lake sockeye salmon, and (d) Cultus Lake sockeye salmon. Note vertical logarithmic axes.

It is anticipated that ecological effects of climate change relevant to Pacific salmon will include

- reduced marine survival via food chain effects;
- increased competition and predation due to northward shifts in the distribution of various marine warm water species;
- poorer freshwater summer feeding conditions due to increased summer temperatures and reduced flows;
- possible adult migration delays due to reduced flows;
- reduced spawning success due to increased sedimentation and scouring; and
- more rapid declines for populations spawning and rearing in freshwater areas with serious habitat concerns (Levy 1992; Bradford and Irvine 2000; Beamish and Noakes 2002; Morrison et al. 2002).

The generally warmer sea surface temperatures experienced from the mid-1970s to the 1990s were a kind of ‘natural’ experiment on the effects of climate change. The four endangered salmon populations declined during this period, as did many other salmon populations at the southern end of their distribution. Coho have shown some recent signs of recovery, but Sakinaw and Cultus Lake sockeye and iBoF Atlantic salmon populations remain in poor shape. Regional differences exist, however. For example, southern coho survival declined during recent years while northern coho survival increased.

In conclusion, with climate change, we expect that

- salmon survival and abundance will be more variable;
- there will be regional differences in how populations respond (north/south and east/west);
- southern salmon populations, including the four endangered populations, will be vulnerable to climate variability and change; and
- effects on survival and abundance will be generally negative.

Adaptations

Climate change is occurring, and as fish populations react to the changing climate, society also needs to adapt. Scientists and managers need to adjust fisheries and habitat management practices to ensure the sustainability of salmon populations and fisheries, a particularly challenging task during climate change. Various adaptations that have already been made to reduce the likelihood of extirpation of salmon populations include

- increasingly selective fisheries;
- regulations to reduce fisheries mortalities of nontarget species and populations;
- elimination of salmon harvesting in the inner Bay of Fundy in 1985 for commercial fisheries and in 1990 for recreational fisheries;

- adoption of abundance-based management in the Pacific Salmon Treaty. For example, as long as the coho population remains low, the U.S. is limited to a maximum of 10% exploitation of Thompson (interior Fraser River) coho (maximum for Canadian fishers in 2003 was ~3%);
- reduced exploitation of late run Fraser River watershed sockeye to protect co-migrating Cultus Lake sockeye; and
- delays in fishery openings in Johnstone Strait to protect Sakinaw Lake sockeye.

More changes are needed, however, to avoid future listings. In particular, we need increased involvement of stakeholders who can provide new perspectives on how to operate fisheries while ensuring conservation values are maintained. One possibility is to develop science-based processes that allow salmon fisheries to adapt to climate change (Fig. 2). Using this approach, the vulnerability of fisheries to climate change would be assessed, in part, by reviewing previous experiences with adaptations to change, and by examining the ability of industry and management to cope with, and adapt to, future changes. At multidisciplinary workshops, stakeholders would be provided with overviews of likely effects of climate change on fish (Step 3, Fig. 2). At Step 5 in the process, stakeholders would be reassembled, the findings in preliminary reports would be presented, reviewed, and revised as appropriate, and plausible future adaptation strategies would be identified.

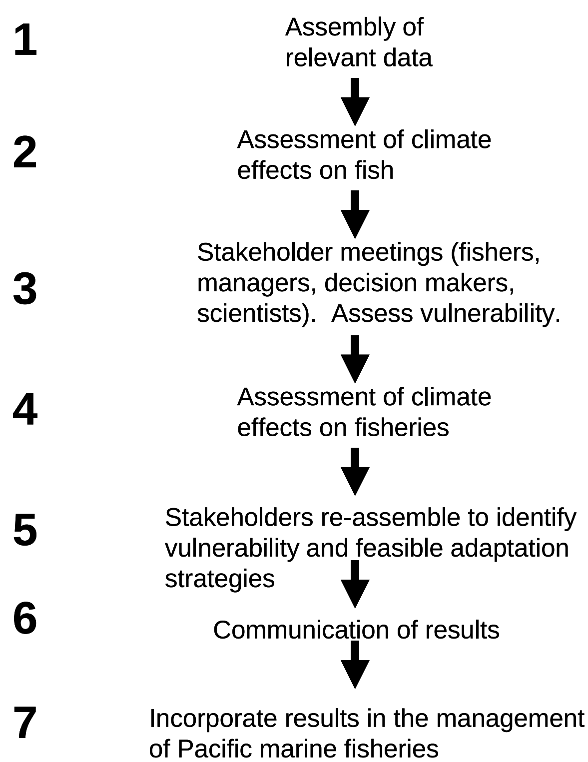

Figure 2. Multidisciplinary approach proposed to allow input from stakeholders to better adapt fisheries to climate change.

Fisheries should benefit by incorporating an improved understanding of climate impacts and adaptation responses into the development of management advice. Done properly, planned adaptations should enable us to minimize negative impacts of climate change on marine fish populations, and may allow us to benefit from new marine fisheries opportunities.

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