White Paper No. 3[1]

Global Climate Change and its Effects on the Columbia River Basin

1 Introduction

The purpose of this white paper is to describe possible impacts of climate change on the anadromous fish populations of the Columbia River Basin and to discuss the implications these changes may have on hatchery facilities used to produce fish for both conservation and harvest purposes. The primary concern in the Pacific Northwest regarding climate change is the increase in ambient temperature, i.e., global warming.

Global warming is accepted by the majority of the scientific community as a fact, though the pace and severity cannot be predicted with certainty[2]. Global warming is expected to cause sea levels to rise, alter marine productivity, change precipitation levels and timing, and increase the severity and frequency of extreme weather events such as flooding[3]. The productivity of both natural and hatchery salmon is highly dependent upon the freshwater and marine environments. Any perturbation or degradation of water quality and/or quantity has the potential to negatively impact anadromous fish.

If the pace of global change is slow enough (over decades rather than years), salmon populations may be able to adjust to changes in their environment. The larger the change and the faster the pace, the less likely wild salmonid populations will be able to adapt. Hatcheries, with their ability to tightly control at least the freshwater component of the salmon life cycle, could play a positive role in conserving salmon populations if the pace of warming is rapid.

The information presented in this paper is not an exhaustive review of the pertinent scientific literature on the topic of global warming, but is rather an overview aimed at educating the layperson as to the effects on wild and hatchery salmon populations and the implications for hatchery production and operations in the Columbia River Basin.

Several documents formed the basis for this report, including:

- Climate Change 2007- Synthesis Report. A Report of the Intergovernmental Panel on Climate Change (IPCC 2007)
- Potential impacts of global warming on salmon production in the Fraser River watershed. Canadian Technical Report of Fisheries and Aquatic Sciences (Levy 1992).

[1] White papers were prepared by the HSRG to address topics relevant to hatchery reform. They are intended to stimulate discussion and provide background, documentation and explanations not included in the body of the HSRG's report.
[2] (http://www.ipcc.ch/)
[3] (http://archive.greenpeace.org/climate/arctic99/reports/salmon.html),

- Natural Climate Insurance for Pacific Northwest Salmon and Salmon Fisheries: Finding Our Way through the Entangled Bank (Mantua and Francis 2004)
- Climate Change Impacts on Columbia River Basin Fish and Wildlife (ISAB 2007)
- On the decline of Pacific salmon and speculative links to salmon farming in British Columbia (Noakes et al. 2000)
- Projected impacts of climate change on salmon habitat restoration (Battin et al. 2007)

2 Problem Statement and Concerns

Climate records show that the Pacific Northwest has warmed about 1.0 ºC since 1900 which is about, 50% more than the global average warming over the same period. The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1-0.6° C/decade. Projected precipitation changes for the region are relatively modest and unlikely to be distinguishable from natural variability until late in the 21st century. Most models project long-term increases in winter precipitation and decreases in summer precipitation. Salmon are expected to be affected by changes in the freshwater, terrestrial, and marine environments. These impacts include: increased rainfall, decreased snowfall, increases in peak river flows, increases in stream temperatures, indirect effects from increases in terrestrial temperatures on riparian and terrestrial communities, and warmer ocean temperatures.

2.1 Warmer temperatures should result in more precipitation falling as rain rather than snow

In the Pacific Northwest, rain-dominated streams exhibit the highest stream flows in the fall, compared to the spring and early summer for snowmelt-dominated streams. The change in peak flow timing from spring to fall may affect the species of salmonids and the runs present in each stream. For example, spring Chinook run timing has evolved to coincide with spring freshets resulting from snow-melt in the mountains. The large amount of cool water present at this time allows spring Chinook to migrate long distances to spawning grounds where they hold in large deep pools until spawning in the late summer and early fall. As spring-time flows decrease due to global warming, spring Chinook may not be able to access spawning grounds and, if they do, water temperatures may be too high, causing increased mortality and reduced productivity. If the change in flow and stream temperature is too severe, spring Chinook runs may disappear from affected streams.

2.2 Snow pack should diminish and stream flow timing should be altered

Juvenile salmon of multiple species migrate to the ocean during the spring and early summer. As was the case with spring Chinook adults, juveniles take advantage of the snow-melt-freshet to migrate hundreds of miles in a relatively short time. The coldwater and turbidity associated with systems dominated by snowmelt reduces the ability of natural predators to find and consume juvenile migrants. A decrease in snow-pack decreases the magnitude and duration of the spring freshet which will likely increase predator success and change the run-timing of the juveniles migrating from the system.

For the Columbia River, reduced snow pack may lead to a reduction in the amount of stored water available to fish managers for increasing spring and summer flows during key salmon migration periods. Lower flow and higher stream temperatures may lower juvenile migration survival rates through the system due to migrational delay, increased predation, and disease incidence.

2.3 Peak river flows should increase

Fall precipitation levels will likely increase due to global warming. The result will likely be increased flood frequency and magnitude. This is especially true for streams substantially located in the snow zone. These systems are highly susceptible to rain-on-snow events where rainfall rapidly melts the early winter snow pack, resulting in large-scale flooding in the months of November and December. Flooding causes scouring of the streambed where salmon lay their eggs, effectively destroying that year's salmon production. Salmon populations are usually able to withstand these flood events because portions of the run spawn at different times and because large flood events occur infrequently. More frequent and larger floods will negatively impact salmon survival.

2.4 Stream temperatures should continue to rise

All phases of the salmon life cycle are impacted by water temperature. For example, fry emergence timing is based on the daily stream temperature, to which eggs are exposed, with higher temperatures stimulating fry to emerge after a shorter incubation period. A change in emergence timing may expose fish to unfavorable environmental conditions (such as flooding) that reduce survival. Higher summer stream temperatures may stress rearing juveniles and increase their susceptibility to disease. This same effect could occur for adult salmonids as well. Additionally, increased stream temperatures may favor the production of other native or non-native species that prey on juvenile salmon, again reducing juvenile salmon survival.

Bull trout are particularly at risk if stream temperatures rise. This species requires cold (less than 10.0 ºC) headwater streams for spawning. An analysis of the effects of temperature increases associated with climate change predicts a substantial loss of current bull trout habitat in the Columbia River Basin.

2.5 Warmer temperatures may affect riparian and terrestrial communities

Several habitat types and vegetative communities in the Columbia River Basin are likely to decrease greatly in area or disappear regionally as a result of global warming. These types are: alpine habitats, subalpine spruce-fir forests, aspen communities, and sagebrush communities. Resulting shifts in vegetation type may alter nutrient inputs to the stream and reduce the amount of riparian habitat that shades and cools streams.

2.6 Global warming will also alter marine water temperatures and sea levels

Global warming will also affect the marine environment where salmon spend a considerable amount of their life history. New research suggests that ocean temperature and associated sea level increases between 1961 and 2003 were 50 percent larger for the upper 700 meters of oceans than estimated in the 2007 IPCC report (Domingues et al.

2008). Changing ocean temperatures may alter the behavior, distribution, and migration patterns and distances that salmon have to travel from their home streams to ocean feeding areas and back. Energy demands are increased at warmer temperatures, requiring increased consumption of prey to maintain a given growth rate. Ocean temperature also influences the distribution and abundance of species that prey on salmon. Impacts from predators may be positive or negative depending on which species are most susceptible to ocean temperature changes.

Sea level rise from melting ice pack, in conjunction with higher winter river flows, could cause the degradation of estuary habitats due to increased wave damage during storms. This in turn could reduce food production in the estuary environment where salmon spend critical portions of their life history. In addition to increases in ocean temperature and rises in sea levels, other physical changes in the ocean associated with warming include increased stratification of water column, acidification, and changes in the intensity and timing of coastal upwelling. Such changes can affect the ocean food web, resulting in reduced coastal productivity and salmon survival.

3 Implications for Hatchery Management

Hatcheries require abundant sources of cold-water to rear quality juvenile salmonids. Groundwater is a key source of water for many of the hatcheries in the Columbia River Basin. A reduction in snow pack may reduce the amount of cold water entering the water table. This, in turn, could decrease the amount of water available for hatchery use. Hatcheries may have to reduce production or use expensive mechanical water chilling devices to produce high quality juveniles. Additionally, because water temperature affects the growth rate of cultured fish, any change in temperature alters the ability of managers to produce fish of sufficient size to meet size-at-release targets that have been shown to increase hatchery fish survival.

Hatcheries which rely on river water may also experience similar problems. Both the quality and quantity of water used by hatcheries for culture purposes may be seriously altered as stream flows change. Higher fall flood flows may increase the amount of sediment entering the hatchery facility or damage hatchery intake structures. Decreased summer flows mean that the proportion of a stream's water used to rear fish increases which will negatively impact the natural environment and salmon survival in stream reaches downstream of the intake.

Many common microbial diseases of cultured fish are exacerbated as temperatures in the rearing environment increase. Both the frequency and severity of these diseases may increase as temperatures in the hatchery and the natural environment increase. Infections of salmon by the parasite, *Ceratomyxa shasta*, are also likely to increase in areas such as the Cowlitz River where this organism is present.

4 HSRG Conclusions and Recommendations

Global warming is expected to result in substantial, and possibly rapid, changes to salmon habitat and population response. How fish populations will respond to this environmental change is currently unknown. Salmon life histories that were successful in the past at maintaining healthy populations may no longer be viable under a warming climate. New life histories may be expressed that have not been previously seen in each watershed. In addition, some races of salmon may disappear from the watershed and be replaced by other native or non-native species.

The scientific literature indicates that salmon are able to adapt to environmental changes if those changes are not too extreme or occur too rapidly. A good example of this is the Clearwater fall Chinook population which has responded to the decrease in stream temperatures associated with coldwater releases from Dworshak Dam by switching from a sub-yearling to a yearling life history that over-winters in mainstem Columbia and Snake River pools.

The ability of salmon to adapt to changes in the natural environment reinforces the HSRG conclusion that hatcheries should be operated so that the natural, rather than the hatchery, environment drives adaptation. This can be achieved by keeping the proportion of natural spawners (pNOS) and proportion of natural-origin fish used as hatchery broodstock (pNOB) high and the proportion of hatchery-origin fish on the spawning grounds (pHOS) low. Managers are encouraged to maintain a proportion of natural influence (PNI) for integrated hatchery programs larger than 0.67 and a pHOS of less than 0.05 for segregated programs.

Hatchery managers need to be aware that natural population life histories may change with the changing climate and respond accordingly. For example, the timing of juvenile releases from the hatchery may need to be altered to reflect different river run-off patterns and temperatures as the climate warms. Observing and monitoring the success of wild populations will help better direct hatchery programs in the future. Additionally, the size or number of fish released may need to be reduced if data collected in key areas, e.g., the Columbia River estuary, indicates substantial decreases in food production. This can be accomplished by tying hatchery production levels to wild fish abundance in the receiving watershed and the Columbia River Basin.

Because of climate change and continued degradation of habitat from human population growth, some salmon populations may not survive in the face of global climate change because their habitat is also being degraded by human population growth. Hatchery programs may be able to play a maintenance role in preserving these populations by operating as well-run integrated programs with high PNI values. The focus of these hatcheries may need to shift from emphasizing harvest to an emphasis on conservation.

5 References

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