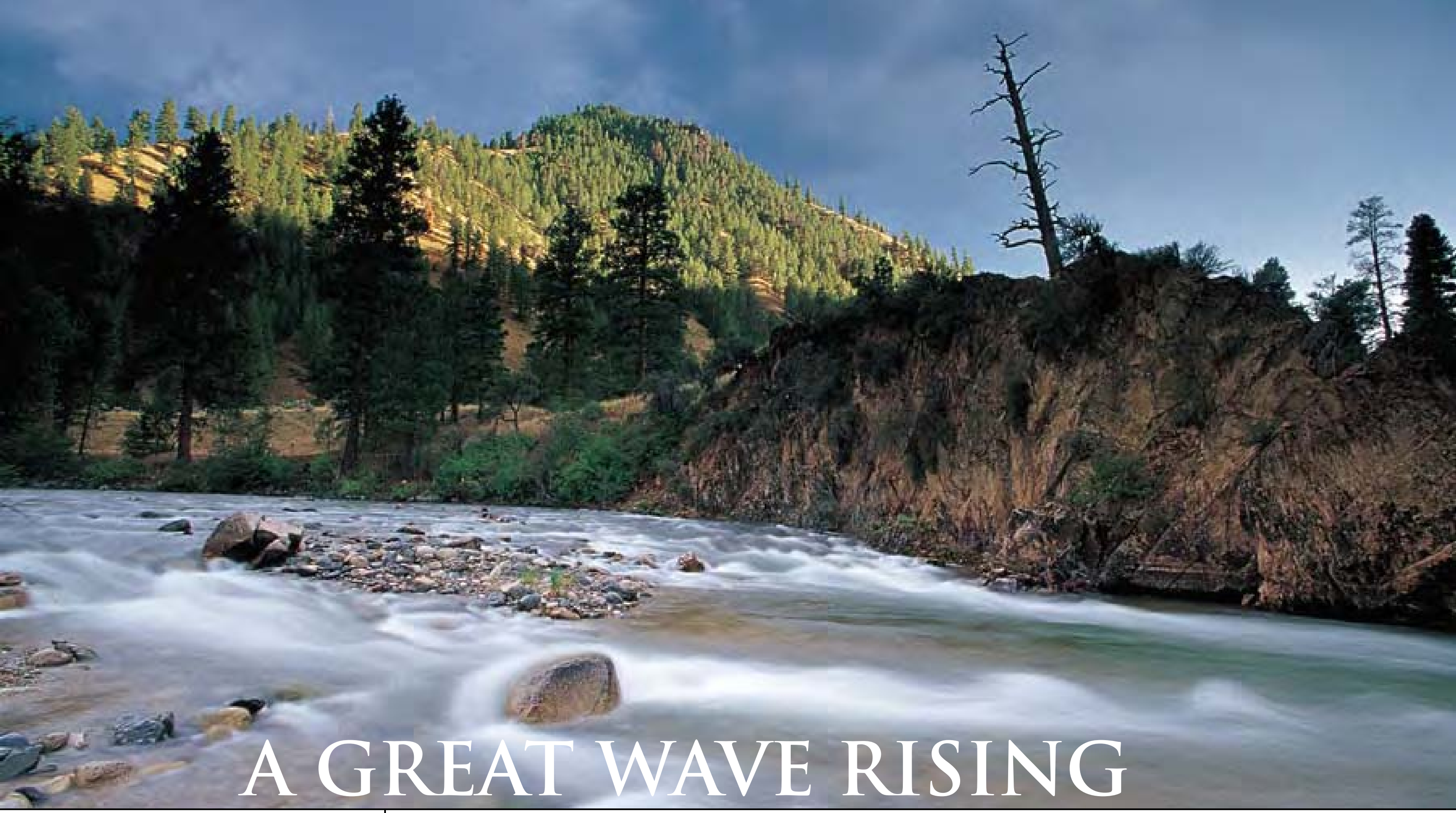


# A GREAT WAVE RISING

Solutions for Columbia and Snake River Salmon
in the Age of Global Warming

Jim Martin & Patricia Glick

LIGHT in the RIVER

Photo by Matt Leidecker

# LIGHT IN THE RIVER

**About *Light in the River* Reports:**

*Light in the River* is a new collaborative project that seeks Northwest solutions to global warming that will serve as models for the nation.

*Light in the River*'s report series, and the conversation we hope it engenders, offers and explores solutions that will counter global warming; preserve healthy waters, fish, farms and communities; and advance initiatives to achieve these goals.

These reports are factual and forward-looking. They start from today's realities but focus on tomorrow's imperatives. Each report will express its authors' informed views, rather than hew to any project sponsor's party line. Given the tough challenge posed by global warming, each paper will tackle tough questions but do so with determination to find and implement solutions.

*This report is made possible by a grant from the William and Flora Hewlett Foundation.*

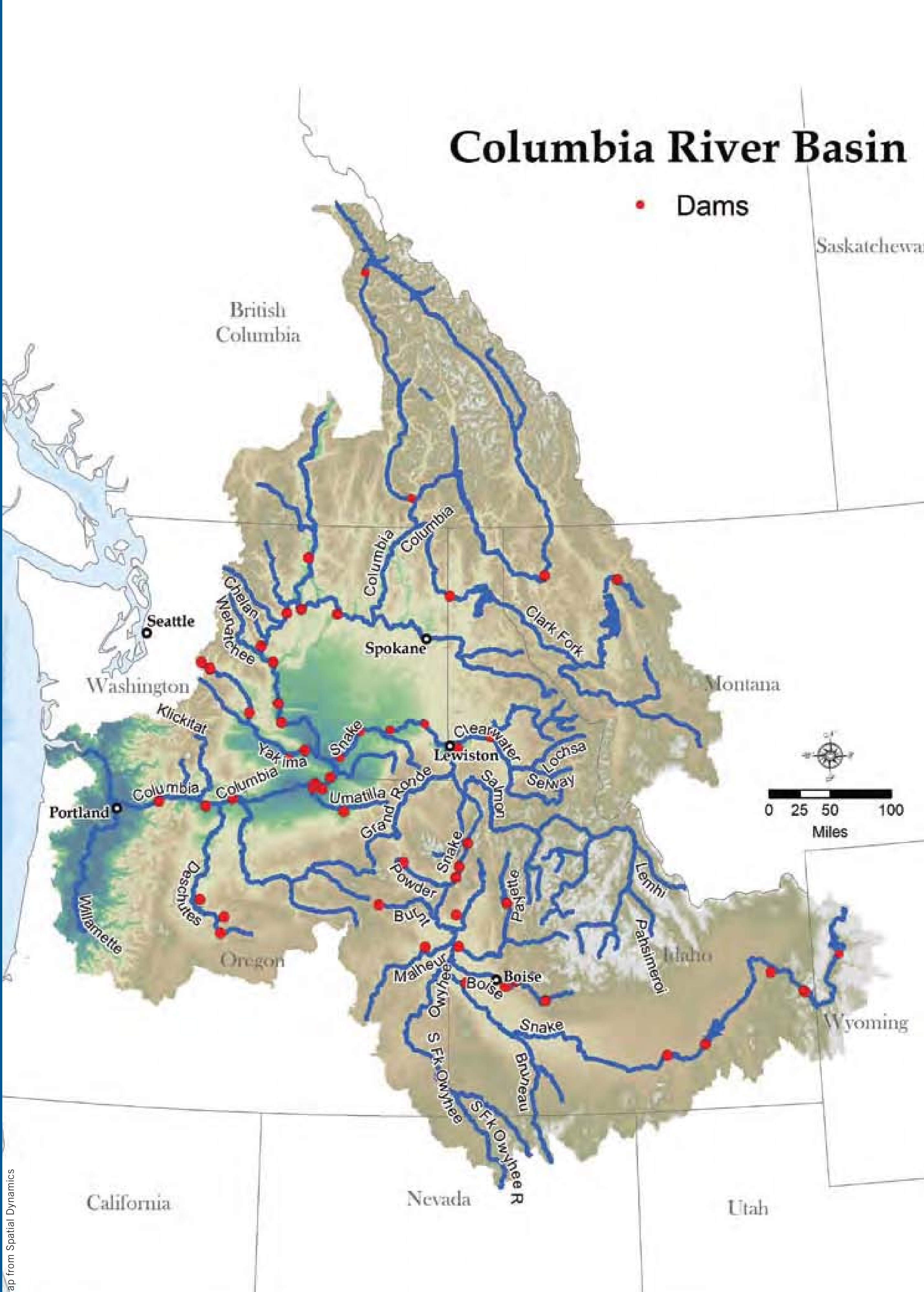
Cover photo by Matt Leidecker

**About *Light in the River*:**

This project owes its name to Don Sampson, a leader of the Confederated Tribes of the Umatilla Reservation. Some years ago, in a talk near the Columbia River, Mr. Sampson acknowledged the light from the river: electricity from the river's dams illuminating the room in which he spoke. He then asked equal regard for the light **in** the river: the salmon whose illuminations reach deep and far. Writer David James Duncan found the same image independently when, in *My Story as Told by Water*, he called salmon "a fire in water – an impossible watery flame."

For these leaders, and for others, the light is in the salmon, in the waters bearing them, and in all that both nourish.

The *Light in the River* project offers hope by seeking practical steps to counter global warming while protecting our waters and wild salmon that give us health, food, livelihoods and endless inspiration. **www.LightInTheRiver.org**




Map from Spatial Dynamics

# EXECUTIVE SUMMARY

Global warming is changing the waters of the Columbia and Snake rivers, with worse change to come. Like a great wave rising, global warming has emerged as a new over-arching threat to salmon as well as people, which cannot be ignored by federal agencies charged with salmon recovery.

This report offers a detailed review of the effects of global warming on Columbia and Snake River salmon. And it offers solutions that we believe should be implemented immediately to help counter or compensate for those effects.

Our findings, based on a thorough review of available science, show that changes already underway due to global warming will further harm already-endangered salmon and steelhead populations in both rivers. Hotter waters, changes in rain and snow patterns, and altered ocean and estuary conditions will harm salmon at each stage of their life-cycle, and will interact negatively with other stresses such as the development impacts associated with increased human population.

Human-caused warming is now a fundamental component – like dams, development, hatcheries and harvests – of present and future conditions affecting Columbia and Snake River salmon and steelhead. Federal agencies are now making a fifth attempt to develop a lawful plan to restore endangered Columbia and Snake River salmon, with a plan to be released in May 2008. The previous plan, which was ruled illegal, offered no action steps regarding global warming. The new plan needs both a strategy and specific actions to counter and help salmon populations adapt to the changes caused by warming. This report offers such a strategic response, missing in federal efforts to date.

Ample scientific analysis exists on which to build this strategy. Its first priority should be immediate actions to reduce warming impacts or buffer salmon against them, based on three principles: (a) reconnecting salmon to headwater habitats, (b) protecting headwater flows and temperatures, and
(c) reducing mainstem Columbia and Snake River mortalities to adult and especially juvenile salmon.
In particular, the large, well-connected, high-elevation and publicly owned salmon habitats of eastern Oregon, southeastern Washington and central Idaho should serve as an anchor for salmon survival and recovery in the era of global warming. This report proposes eight action steps based on these principles.

A strategy and actions based on these principles can directly counter or temper specific impacts of global warming on salmon and steelhead habitats. More importantly, it can preserve and expand the productivity and spatial and genetic diversity that underlies salmon resilience, thus giving salmon populations the maximum opportunity to self-adapt to habitat changes wrought by global warming.

Salmon recovery in the Columbia and Snake Basin is still possible but it depends on immediate and strong actions to counter the threats to their survival, which now include global warming.

> Whether salmon recover in the Columbia and Snake Basin depends primarily on federal policy. Will it keep backing into the future with eyes on the past? Or will it turn forward, scout the changes coming fast, and act strategically?
>
> \- Jim Martin

# INTRODUCTION

For thousands of years, the Columbia and Snake rivers supported the most diverse and abundant salmon and steelhead populations on Earth.[1] Salmon are fundamental to Pacific Northwest ecology, culture, economy, food, art and religion.[2] Fishing for Columbia and Snake River salmon still supports dozens of communities and thousands of jobs from California to Alaska. Salmon are the heart of diverse Indian cultures and at the legal heart of 19th-century treaties between those Tribes and the United States. This history has made people and salmon partners in the Columbia and Snake River Basin.

But that partnership is foundering. In less than a century, human actions have led to sharp decline in populations of Columbia Basin salmon and outright extinction of many. Today, 13 evolutionarily specific groups of salmon populations in the Basin are legally endangered or threatened with extinction. Whether they continue into extinction or climb back to abundance is a primary challenge facing the Western salmon states and our national government. The challenge is directly before us; our immediate choices will determine the outcome.

At this time of choice, a new over-arching threat to people and salmon has emerged. Global warming, like a great wave rising, is changing the waters of the Columbia and Snake River Basin. Hotter waters, changes in rain and snow, and snowpack declines have begun and are likely to continue in the Pacific Northwest.[3] The effect on already-beleaguered salmon is likely to be large and negative.[4] The impacts of global warming will also combine, in ways likely to be adverse for salmon, with the near doubling of human population expected in the Columbia Basin by midcentury.[5]

In 2008 the federal government is making its fifth attempt to develop a lawful plan to restore endangered Columbia and Snake River salmon and steelhead.[6] Three of the last four tries have been ruled illegal in federal court. The government must use the "best available science" in this plan, and there is now ample science documenting the present and probable impacts of global warming on these endangered salmon.[7] We intend this report to assist in the urgent task of acting on that science to restore salmon as required by law. We also hope it further stimulates practical discussions on global warming and salmon now occurring among fishermen, managers, scientists, and others dedicated to ensuring that Columbia and Snake River salmon survive today and thrive tomorrow.

We begin with an overview of the compelling scientific evidence of global warming and its effects on Pacific Northwest climate. We then examine likely impacts of global warming on Columbia and Snake River salmon and describe the current federal response. Finally, we propose a strategy and recommended actions to help Columbia and Snake River salmon survive. We understand that as the science of global warming improves, statements and suggestions we have made in this report will need to reflect those changes. However, we believe that salmon can survive global warming if we act now to help them and that we know enough now to begin that work.

## FOOTNOTES

[1] National Research Council, 2004. Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival (Washington, D.C.: National Research Council of the National Academies).

[2] Glick, P., 2005. Fish Out of Water: A Guide to Global Warming and Pacific Northwest Rivers (Seattle, WA: National Wildlife Federation).

[3] Barnett, T.P., et al., 2008. "Human-Induced Changes in the Hydrology of the Western United States," http://www.sciencexpress.org (accessed 2/12/2008).

[4] Miles, E., et al., 2007. HB 1303 Interim Report: A Comprehensive Assessment of the Impacts of Climate Change on the State of Washington (Seattle, WA: University of Washington JISAO CSES Climate Impacts Group).

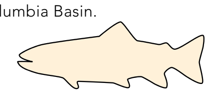
[5] Lackey, R.T., 2003. "Pacific Northwest Salmon: Forecasting their Status in 2100," Reviews in Fisheries Science 11: 35-88; Martin, James T., "Climate and Development: Salmon Caught in the Squeeze," pp. 411-424 in Robert Lackey, Sally Duncan, and Denise Latch, eds., Salmon 2100: The Future of Wild Pacific Salmon, American Fisheries Society, September 2006.

[6] National Marine Fisheries Service (NMFS), 2007*a*. Biological Opinion – Remand Draft: Consultation on Remand for Operation of the Federal Columbia River Power System (Seattle, WA: NOAA National Marine Fisheries Service Northwest Region); NMFS, 2007b. Draft Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Consultation: Upper Snake River Basin (Seattle, WA: NOAA National Marine Fisheries Service Northwest Region); and NMFS, 2007c. Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and Other Tributary Actions (Seattle, WA: NOAA National Marine Fisheries Service Northwest Region).

[7] Independent Scientific Advisory Board (ISAB), 2007. Climate Change Impacts on Columbia River Basin Fish and Wildlife (Portland, OR: Northwest Power and Conservation Council).

## SPRING/SUMMER CHINOOK SALMON

spawn primarily at higher elevations in the Columbia Basin. Their life histories expose them to freshwater habitats for lengthy periods.



# GLOBAL WARMING

The world's scientists and scientific bodies agree overwhelmingly that global warming is occurring, is altering earth's climate and affecting natural systems, and that human activities – particularly burning of fossil fuels and destruction of forests – are largely responsible. In February 2007, the Intergovernmental Panel on Climate Change (IPCC) released its fourth assessment since 1990 of the body of science about global warming. The IPCC found global warming to be "unequivocal" and "very likely due to the observed increase in anthropogenic [human-produced] greenhouse gas concentrations."[8]

As reported in this important assessment, the earth's average surface temperature has increased more than 1.3° Fahrenheit (F) since the early 20th century, and the IPCC projects it will rise another 2-11.5° F before the end of this century.[9] By comparison, the average global temperature difference between the peak of the last ice age 20,000 years ago and today's climate is 9° F.[10] Global warming is thus expected to change earth's temperature in a similar range, but in a matter of decades. This change means far more than hotter weather. As the atmosphere heats up, it is disrupting earth's entire climate system. Precipitation patterns are changing; extreme weather events such as droughts, floods, storms, and heat waves are becoming more frequent and severe; and average temperatures are rising, including those in lakes, rivers, and oceans.[11]

In addition, global warming is causing sea levels to rise due to both thermal expansion of the oceans and rapid melting of glaciers and polar ice sheets. The global average sea level has risen about 6.7 inches over the past century, which is about 10 times faster than over the previous 3,000 years.[12] The most recent IPCC estimates project a further 7- to 23-inch rise in global average sea level before the end of this century.[13] And many scientists are increasingly concerned that the rate of rise could be considerably greater – perhaps reaching 4 feet or more – as several new studies have indicated that ice sheets in Antarctica and Greenland are melting much more rapidly than previously thought.[14]

## FOOTNOTES

[8] IPCC, 2007a. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S.D. Solomon, et al., eds.] (Cambridge, UK: Cambridge University Press).

[9] Ibid.

[10] Ibid.

[11] Ibid.

[12] Ibid.

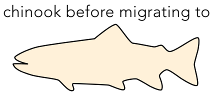
[13] Ibid.

[14] Rahmstorf, S., 2007. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise," Science 315: 368-370; Rignot, E. and P. Kanagaratnam, 2006. "Changes in the Velocity Structure of the Greenland Ice Sheet." Science 311: 986-990; and Otto-Bliesner, B.L., et al., 2006. "Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation." Science 311: 1751-1753.

Mount Rainier in Washington

## FALL CHINOOK SALMON

spawn at lower elevations where waters will warm more, but are exposed to freshwater fluctuations for less time than other chinook before migrating to the ocean. Estuary changes due to global warming will affect fall chinook significantly.



# GLOBAL WARMING IN THE PACIFIC NORTHWEST

The Pacific Northwest is feeling the effects of global warming. According to the Climate Impacts Group (CIG) at the University of Washington, average regional temperature has increased about 1.5° F over the last century, slightly above the global average rate.[15] From 1950 to 2006 Northwest snowpack declined significantly, especially at lower elevations. Some parts of the Cascades, for example, experienced a 30-60% decline in spring snow water equivalent (the amount of water contained within snowpack) between 1945 and 2006.[16] In addition, the onset of snowmelt and peak streamflows in many snow-fed rivers has moved about one to a few weeks earlier in the year.[17]

CIG projects that many of these trends will continue across the Northwest in coming decades, given expected increases in greenhouse gas concentrations in the atmosphere.[18] Annual regional temperatures are projected to rise another 1.1-3.4° F by the 2020s, and 1.6-5.2° F by the 2040s, with a greater relative increase in summer temperatures.[19] These higher air temperatures are likely to translate to higher water temperatures across the region, including in the Columbia and Snake River Basin.

The region's winters are projected to become wetter on average, but higher temperatures should lead to more rain and less snow in high to mid-elevation watersheds, resulting in reduced spring snowpack and earlier snowmelt. Average snowpack throughout the region is projected to decline significantly in coming decades. The Cascade Mountains of Oregon and Washington, for example, are projected to suffer a 44% decline in average April 1 snowpack by 2025-2034, and an 88% decline by the 2090s.[20] These changes will contribute to increased winter streamflows, reduced summer streamflows, and earlier peak runoff in rivers, including those in the Columbia and Snake Basin. In addition, the average sea surface temperature of Washington's coastal waters is projected to rise by about 2.7° F by the 2040s, and average sea levels in the central and southern coast of Washington are projected to rise 1-18 inches by 2050 and 2-43 inches by 2100.[21]

## FOOTNOTES

[15] Climate Impacts Group, 2004. Overview of Climate Impacts in the U.S. Pacific Northwest (Seattle, WA: University of Washington).

[16] Mote, P.W., A.F. Hamlet, and E.P. Salathé, 2007. "Has Spring Snowpack Declined in the Washington Cascades?" Hydrology and Earth System Sciences Discussions 4: 2073-2110.

[17] Stewart, I.T., D. R. Cayan, and M.D. Dettinger, 2005. "Changes Toward Earlier Streamflow Timing Across Western North America." Journal of Climate 18: 1136-1155.

[18] Mote, P.W., E.P. Salathé, and E. Jump, 2007. Scenarios of Future Climate for the Pacific Northwest (Seattle, WA: University of Washington JISAO CSES Climate Impacts Group).

[19] Miles, et al., 2007

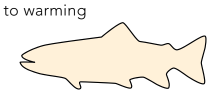
[20] McCabe, G.J. and D.M. Wolock, 1999. "General Circulation Model Simulations of Future Snowpack in the Western United States." Journal of the American Water Resources Association 35: 1473-1484.

[21] Mote, P., et al., 2008. Sea Level Rise in the Coastal Waters of Washington State (Seattle, WA: University of Washington Climate Impacts Group and the Washington Department of Ecology).

Photo by Natalie Fobes

## SOCKEYE SALMON

in the Columbia Basin spawn in rivers and lakes at relatively high elevations. They are likely to be very sensitive to warming ocean temperatures.



# IMPACTS OF GLOBAL WARMING ON COLUMBIA AND SNAKE RIVER SALMON

Higher water temperatures, shifts in streamflows, and altered estuary and ocean conditions due to global warming will profoundly affect endangered Columbia and Snake River salmon and steelhead. Salmon use and thus depend on both freshwater and marine habitats. They need clean, cold water, well-connected rivers, and reliable streamflows for spawning, rearing, and migration. They need healthy estuaries where juveniles can acclimate to ocean conditions and adults can rest before migrating upstream to spawn. They need productive ocean conditions, with plentiful food sources and optimal temperature regimes. Global warming will affect every phase of this complex life cycle:

- Higher stream temperatures will make conditions increasingly inhospitable to salmon and steelhead in all of their freshwater life stages.
- Reduced summer flows will exacerbate warmer temperatures and make it more difficult for migrating salmon to pass both physical and thermal obstacles.
- Heavier rainfall and increased flooding in fall and winter will scour salmon nests.
- Earlier spring runoff will disrupt migration timing for juvenile salmon.
- Rising sea level, warmer water temperatures, and changes in freshwater flows will cause dramatic changes in estuary habitats.
- Higher average ocean temperatures will alter the marine food web and reduce survivability of salmon.

To its "Four H's" of Columbia and Snake River salmon recovery, the federal government must now add a fifth: Habitat, Hydro, Harvest, Hatcheries – and Heat.

- Patty Glick

The habitat needs and behaviors of Columbia and Snake River salmon populations are fundamental to their historic resilience, and their vulnerability to global warming. Wild salmon have developed remarkable physiological and behavioral traits that have enabled them to thrive for millennia. They are born in freshwater streams and rivers. They travel downstream toward the ocean and spend from a few hours to a few months in the estuary, acclimating to salty waters. They then range in the ocean for one to four years, as far south as mid-California and as far north as Alaska. Salmon then return to freshwater, spawn a new generation, and die,[22] in the same rivers or streams where they were born.

As different salmon and steelhead species, and populations within species, evolved over time, they acquired diverse spawning and migratory behaviors to take advantage of almost-countless variations in temperatures, streamflow, ocean conditions, and other habitat features. One example among hundreds: Snake River spring/summer chinook salmon (also called "stream-type") remain in freshwater habitats a year or more after hatching before migrating to the sea. The adults then return in spring and summer, often taking several months to migrate upstream to high-elevation headwater streams to spawn.[23] For these populations, freshwater conditions are particularly important for both juvenile survival and spawning success. In contrast, Columbia and Snake River fall ("ocean-type") chinook out-migrate just a few months after hatching, spend much time acclimating in estuary waters before their ocean life cycle, and the adults return to spawn in summer and fall in the mainstem river and the lower reaches of tributaries.[24]

The behavioral and spatial diversity among different populations produced by these many variations historically provided wild salmon a buffer against natural extreme events, such as El Niño-Southern Oscillation (ENSO) ocean cycles, volcanic eruptions, floods, and droughts.[25] If one population were devastated by an extreme event, behavioral and spatial diversity ensured other populations would be less at risk.

Historic salmon abundance also helped, making recovery from short-term damage more likely. Further, diverse natural habitats offer physical features, such as deep pools, well-connected tributaries, and cooling riparian vegetation, that help salmon survive periodic heat waves and other extremes. These few examples among many show why protecting the fine-grained "evolutionarily significant units" within each salmon species, and why protecting or restoring good conditions across a wide range of spawning, rearing and migratory habitats, are so important as salmon confront and respond to stressful conditions.

Human activities in the past century have greatly reduced healthy and varied habitats, and thus salmon productivity and variety. Today less than 2% of historic wild salmon and steelhead numbers in the Columbia Basin remain.[26] Many populations have gone extinct, and 13 of the Basin's remaining unique population groups, including all in the Snake Basin, are listed as endangered or threatened with extinction under the Endangered Species Act. Habitat conditions that once fostered abundant and diverse populations and buffered against oscillations and catastrophes have been degraded or destroyed.[27] With human numbers in the Basin expected to nearly double by mid-century, development will intensify the challenge to secure and restore diverse salmon habitats, and thus secure and restore the characteristics of salmon resilience – abundance, productivity, and spatial and genetic diversity – they need now and will need even more to survive global warming.

Photo by Jerome Charaoui

## FOOTNOTES

[22] Unlike salmon, steelhead do not necessarily die after they spawn. Some repeat the cycle more than once.

[23] Healey, M.C., 1991. "Life History of Chinook Salmon (O. tshawytscha)," in C. Groot and L. Margolis, eds, Pacific Salmon Life Histories (Vancouver, British Columbia: University of British Columbia Press): 311-394.

[24] Ibid.

[25] Mantua, N.J. and R.C. Francis, (In review), "Climate and the Pacific Northwest Salmon Crisis: A Case of Discordant Harmony," Chapter 7 in A.K. Snover, E.L. Miles, and the Climate Impacts Group, Rhythms of Change: An Integrated Assessment of Climate Impacts on the Pacific Northwest (Cambridge, MA: MIT Press).

[26] National Research Council, 1996. Upstream: Salmon and Society in the Pacific Northwest (Washington, D.C.: National Academy of Sciences)

[27] U.S. EPA, 2001. Technical Synthesis: Scientific Issues Relating to Temperature Criteria for Salmon, Trout, and Char Native to the Pacific Northwest (Seattle, WA: U.S. EPA Region 10).

# Impacts on Freshwater Life Stages

**Warmer Rivers.** Water temperatures fundamentally affect the health and distribution of salmon and steelhead. Although varying by species, life stage, and season, the optimal range for juvenile and adult salmon in this region is 55-64° F.[28] Stream temperatures of 70° F and above are extremely stressful for most species. An increase of even a few degrees above optimum range can change migration timing, reduce growth rates, reduce available oxygen, and increase susceptibility to toxins, parasites, predators, and disease.[29]

Human activities have contributed to higher-than-normal river temperatures in many parts of the Columbia and Snake Basin. Construction and operation of hydroelectric dams have had a major impact on water temperatures.[30] For example, surface waters in reservoirs behind dams can get too warm when air temperatures rise, particularly when water volumes are low. Deposition of sediments from logging, agricultural activities, and development has made many rivers wider and shallower, leading them to heat up more easily. Warm wastewater discharges from industrial sources along rivers have increased temperatures downstream. In addition, clearing of vegetation from riparian areas has eliminated shade that helps keep stream temperatures cooler.[31] As a result, scientists already have identified human-caused warming of river temperatures as a key factor in the decline of salmon populations in the Columbia and Snake River Basin.[32]

Recent summer water temperatures in the Columbia River have averaged 68-70° F, which straddles the thermal limit for salmon.[33] Given the strong correlation between air and water temperatures, higher air temperatures due to global warming are likely to exacerbate this trend. Research suggests that 20% of the Columbia Basin, compared to a small percentage today, will see average August air temperatures exceed 70° F by the 2040s.[34] Increased stream temperatures are likely to follow. For example, CIG recently looked at a number of water quality monitoring stations in Washington. From 2001-2006, 15% of the stations studied registered a weekly maximum average temperature greater than 70° F. Under a global warming scenario of 5° F, nearly half of those stations are projected to exceed this 70° F threshold, including all stations in the Columbia Basin.[35]

Photo by Matt Leidecker

## FOOTNOTES

[28] McCullough, D.A., 1999. "A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, With Special Reference to Chinook Salmon." Region 10 Water Resources Assessment Report No. 910-R-99-010 (Seattle, WA: U.S. EPA Region 10).

[29] Poole, G., et al., 2001. Technical Synthesis: Scientific Issues Relating to Temperature Criteria for Salmon, Trout, and Char Native to the Pacific Northwest (Seattle, WA: U.S. EPA Region 10).

[30] U.S. EPA, 2001. Problem Assessment for the Columbia/Snake River Temperature TMDL: Preliminary Draft (Seattle, WA: U.S. EPA Region 10).

[31] Ibid.

[32] ISAB, 2007.

[33] Goniea, T.M., et al., 2006. "Behavioral Thermoregulation and Slowed Migration by Adult Fall Chinook Salmon in Response to High Columbia River Water Temperatures." Transactions of the American Fisheries Society 135: 408-419.

[34] Mantua, N. and Nordheim, R., 2005. Climate Impacts Group, University of Washington.

[35] Miles, E., et al., 2007. HB 1303 Interim Report: A Comprehensive Assessment of the Impacts of Climate Change on the State of Washington (Seattle, WA: University of Washington JISAO CSES Climate Impacts Group).

# Freshwater Life Stages continued

**Altered Streamflows.** Streamflow changes due to global warming will have large effects on salmon, especially coupled with warmer temperatures. Reduced summer flows exacerbate warmer temperatures and make it more difficult for adult salmon to pass obstacles in their struggle to reach their natal spawning grounds.[36] In extreme cases, low flows will stop fish short of their spawning grounds. Streamflow changes can also hinder the ability of juvenile fish to migrate to the ocean due to shifts in peak runoff timing and volume. Excessively high flows in winter, due to rapid melting or increased rainfall, can cause "scouring" events that wash away the gravel beds salmon use as nesting sites.[37] This is likely to be a particular problem in transient snowmelt/rainfall basins in western Washington and Oregon that experience increased fall/winter flooding.[38] And once spawning occurs, reduced flows can dewater nests, exposing eggs to the elements.

Groundwater withdrawals and water diversions for irrigation, urban consumption, and hydropower have already altered natural streamflows in the Columbia and Snake Basin. Further change due to global warming will make it more difficult to manage water for competing needs, including salmon flows. A recent review of strategies to mitigate climate change effects on Columbia Basin water resources concluded that higher winter and lower summer streamflows due to global warming will increase conflicts between maintaining reservoirs for hydropower demands and meeting flow needs for salmon.[39]

Recent studies have shown that warmer water temperatures and altered streamflows are likely to accelerate the decline of threatened and endangered Columbia and Snake River salmon, though with much variation among populations. Scientists have assessed potential impacts of warming-induced changes in water temperatures and streamflows on four populations of Snake River spring/summer chinook.[40] They found the populations are likely to decline significantly as summer stream temperatures increase and summer-fall flows decrease. For example, a projected 22% decline in mean October streamflow and a 5.5° F increase in average June temperature (compared to the base period) led to a 37-50% decline in mean population size for all populations.

Photo by Matt Leidecker

## FOOTNOTES

36 Spence, B.C., et al., 1996. An Ecosystem Approach to Salmonid Conservation, TR 4501-96-6057 (Corvallis, OR: ManTech Environmental Research Services Corp.).

37 Ibid.

38 Battin, J., et al., 2007."Projected Impacts of Climate Change on Salmon Habitat Restoration." Proceedings of the National Academy of Sciences 104: 6720-6725.

39 Payne, J.T., et al., 2004. "Mitigating the Effects of Climate Change on the Water Resources of the Columbia River Basin." Climate Change 62: 233-256.

40 Crozier, L.G., R.W. Zabel, and A.F. Hamlet, 2007. "Predicting Differential Effects of Climate Change at the Population Level with Life-cycle Models of Spring Chinook Salmon." Global Change Biology 14: 1-14.

# Impacts on Marine Life Stages

**Altered Estuarine Habitats.** Rising sea level, warmer water, and changes in freshwater flows due to global warming are likely to cause dramatic changes in estuary habitats in the Northwest.[41] Nearshore ecosystems play critical roles for salmon and steelhead, many of which use coastal marshes for feeding and refuge as they transition from freshwater to the ocean.[42] Scientists believe that historical loss of nearshore marine and estuary habitats regionwide has already contributed to the decline in salmon populations.[43] Additional loss and/or changes in coastal marsh composition and higher estuarine water temperatures due to global warming will cause further harm.[44] Juvenile chum and fall chinook salmon, considered to be the most estuary-dependent species, are at special risk. For example, a recent analysis in the Skagit Delta of Puget Sound estimates that the rearing capacity in marshes for threatened juvenile chinook salmon would decline by 211,000 and 530,000 fish, respectively, for an 18- and 32-inch sea-level rise.[45]

A number of studies have identified the loss of wetlands in the lower Columbia River estuary due to reduced freshwater flows, diking, and other problems as limiting factors in recovery of Columbia and Snake River Basin salmon.[46] A recent report by the Northwest Power and Conservation Council's Independent Scientific Advisory Board (ISAB) suggests that the Columbia River estuary's importance, especially to fall chinook, warrants conservation actions to ameliorate the impacts of climate change.[47]

**Altered Ocean Conditions.** Salmon are highly vulnerable to global warming-enhanced changes in ocean conditions. Scientists have shown how sensitive salmon are to climate by studying how ocean cycles have affected them in the past.[48] El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) cycles influence salmon in many ways, notably via their role in determining North Pacific ocean temperatures and food availability. During El Niño and/or warm-phase PDO, higher ocean temperatures and changes in wind patterns can diminish nutrient upwelling from the deep ocean, reducing food sources for salmon. They can change the timing and distribution of salmon predators such as Pacific mackerel, which are drawn to the region's coastal waters by warmer sea surface temperatures.[49] Both factors alter the marine food web and can much reduce the ocean survival rates of salmon. Accordingly, the El Niño and warm-phase PDO are generally considered to be "unfavorable" ocean conditions for salmon.

Pacific Ocean near Astoria, Oregon

## FOOTNOTES

[41] Glick, P., 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest (Seattle, WA: National Wildlife Federation).

[42] Bottom, D.L., C.A. Simenstad, J. Burke, A.M. Baptista, D.A. Jay, K.K. Jones, E. Casillas, and M.H. Schiewe, 2005. Salmon at river's end: the role of the estuary in the decline and recovery of Columbia River salmon. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-68.

[43] Williams, G.D. and R.M. Thom, 2001. Marine and Estuarine Shoreline Modification Issues (Sequim, WA: Battelle Marine Sciences Laboratory/Pacific Northwest National Laboratory).

[44] Mote, P. et al., 1999. Impacts of Climate Variability and Change, Pacific Northwest (Seattle, WA: National Atmospheric and Oceanic Administration, Office of Global Programs, and JISAO/SMA Climate Impacts Group).

[45] Hood, W.G., 2005. "Sea-level Rise in the Skagit Delta." Skagit River Tidings. (Mount Vernon, WA: Skagit Watershed Council).

[46] Fresh, K.L., et al., 2005. Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead: An Evaluation of Limiting Factors (Seattle, WA: NOAA National Marine Fisheries Service Northwest Fisheries Science Center).

[47] ISAB, 2007.

[48] Mote, P.W., et al., 2003. "Preparing for Climate Change: The Water, Salmon, and Forests of the Pacific Northwest." Climatic Change 61: 45-88.

[49] Pearcy, W.G., 1992. Ocean Ecology of North Pacific Salmonids (Seattle, WA: University of Washington Press).

# Marine Life Stages continued

Although it is unclear how global warming will affect regional ocean conditions in the coming decades, some scientists believe the long-term warming trend in the North Pacific Ocean will begin to dominate natural variations in the next 30-50 years.[50] For example, one study projects a 2.7° F increase in the average sea surface temperatures for the region by the 2040s compared to the late 20th century average, a change that is much larger than the range of natural variability.[51] There is also growing concern among scientists that extremely high levels of atmospheric $CO_2$ are being absorbed by the oceans, causing "ocean acidification."[52] Higher acidity erodes the basic mineral building blocks for the shells and skeletons of invertebrates (such as a type of sea snail called pteropods) that are at the beginning of the marine food chain.[53] While the potential impacts of these changes on Columbia and Snake River salmon remain uncertain, existing analysis suggests a precautionary assumption of harmful impact is warranted. Since our ability to influence ocean conditions, and thus reduce harmful ocean impacts directly if they occur, will be very limited, precaution will lead to stronger protection actions in estuary and especially freshwater habitats. This is where our opportunities to reduce and buffer global warming impacts on Columbia and Snake River salmon are the greatest.[54]

Columbia Basin salmon are caught in ocean fisheries from California to Alaska.

## FOOTNOTES

[50] Overland, J.E. and M. Wang, 2007, "Future Climate of the North Pacific Ocean." Eos 88:178-182.

[51] Miles, E., et al., 2007. HB 1303 Interim Report: A Comprehensive Assessment of the Impacts of Climate Change on the State of Washington (Seattle, WA: University of Washington JISAO CSES Climate Impacts Group).

[52] IPCC, 2007a.

[53] Orr, J.C., et al., 2005. "Anthropogenic Ocean Acidification Over the Twenty-First Century and its Impact on Calcifying Organisms," Nature 437: 681-686.

[54] Williams, R.N., et al., 2005. "Return to the River: Strategies for Salmon Restoration in the Columbia River Basin," Chapter 13 in R.N. Williams, ed., Return to the River: Restoring Salmon to the Columbia River (Burlington: Elsevier Academic Press): 629-666.

Recent studies provide directions and models for helping Columbia and Snake salmon deal with global warming. For example, a 2006 study found populations of Snake River spring/summer chinook inhabiting wider, warmer streams were more vulnerable to higher temperatures, and those inhabiting narrower, cooler streams were more vulnerable to altered streamflows – reinforcing the strategy of securing diversity across and within populations.[55] A more recent study made the same point by suggesting considerable variation in the likely response of four separate Snake River spring/summer chinook populations to global warming-induced changes. That study also concluded that, since "[g]lobal warming will likely reduce potential habitat at lower elevations in the Pacific Northwest and at the southern edge of the range in California," preserving high-elevation populations in the Snake Basin and elsewhere is a "top conservation priority."[56]

Other studies investigated the responses of Columbia River fall chinook salmon and summer steelhead to high river temperatures.[57] Both species generally initiate their migration upstream to spawn in the summer, making them vulnerable to high temperatures and low flows. After studying more than 2,000 upriver bright Columbia River fall chinook salmon over 6 years (1998, 2000-2004), scientists found that in most cases average migration rates slowed when water temperatures reached about 68° F, as the fish harbored in cooler tributaries until temperatures moderated.[58] Another study followed 2,900 adult steelhead in 1996, 1997, and 2000, and determined that an average of 61% that normally spawn above The Dalles temporarily staged in downstream tributaries when Columbia River temperatures were higher than normal.[59] These studies underscore the importance of maintaining thermal refuges in lower reaches of the Columbia Basin.[60]

In addition, a recent study of habitat restoration for threatened chinook salmon in the Snohomish Basin provides a direct example of identifying stronger recovery actions given the added stresses of global warming. The study found that, after accounting for warmer temperatures and altered flows due to global warming, the land-use changes proposed in the current Snohomish River Basin Salmon Conservation Plan are likely to be much less effective in recovering depleted populations than originally thought.[61] The study suggested added actions to help overcome these warming impacts – e.g., restoring juvenile rearing habitat to boost low-elevation sub-populations of chinook salmon in compensation for potential declines at higher and steeper elevations.


Photo by U. of Washington/Thomas Quinn

## FOOTNOTES

[55] Crozier, L.G., and R.W. Zabel, 2006. "Climate Impacts at Multiple Scales: Evidence for Differential Responses in Juvenile Chinook Salmon." Journal of Animal Ecology 75: 1100-1109.

[56] Crozier, Zabel, and Hamlet, 2007.

[57] Goniea, et al. (2006); and High, B., C.A. Peery, and D.H. Bennett, 2006. "Temporary Straying of Columbia River Summer Steelhead into Coolwater Areas and its Effects on Migration Rates." Transactions of the American Fisheries Society 135: 519-538.

[58] Goniea, et al.,2006.

[59] High, Peery, and Bennett, 2006.

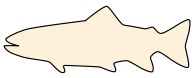
[60] Mantua and Francis (in review).

[61] Battin, et al., 2007.


HEALTHY
HABITAT
HEALTHY
ECONOMY
I'M PRO
SALMON
AND I VOTE
www.wildsalmon.

## COHO SALMON

spawn in small tributary and headwater streams more frequently than other salmon. Coho have been sensitive to ocean conditions, with severe declines associated with warm ocean phases.



# GLOBAL WARMING AND COLUMBIA AND SNAKE RIVER SALMON: RESPONSE AND ACTIONS

As noted above, federal agencies are again developing a plan, in two linked "Biological Opinions" on operations of federal dams and reservoirs, to restore endangered and threatened Columbia and Snake River salmon and steelhead. A draft of this plan was issued in October 2007.[62] The draft acknowledges global warming with some five pages of discussion. The draft's sole action in response is a planning assumption: to use a base period of 1980-2001 for the plan's quantitative analyses, which are then used to estimate the results of its proposed actions upon the listed populations. According to the draft plan, 1980-2001 was a period "of generally unfavorable inland and ocean conditions for salmon," and thus its use as a base period is a "conservative approach, assuring that survival within each brood year [i.e., the future survival assumed before estimating the effect of the plan's actions] will be significantly less than the historical average."[63]

This is not an effective response. Global warming is an over-arching new threat to endangered Columbia and Snake River salmon and steelhead, affecting every stage in their life-cycle, progressively worsening as warming intensifies, and likely exacerbating existing impacts that are already leading the species toward extinction. It requires a strategic response, not just a change in one assumption. The plan's discussion of global warming relies on historical trends and qualitative factors, rather than incorporating ample available quantitative analyses, some of which are cited above. The assumption that conditions for salmon in the next 10 years will not be worse than in a recent 20-year period is not "conservative" when weighed against the threat. While this period featured somewhat unfavorable river and ocean conditions, these conditions are not representative of the likely changes projected to occur within a few decades due to global warming. Finally, one planning assumption cannot substitute for specific actions that counter or compensate for the impacts of warming on salmon habitats and habitat conditions.

### FOOTNOTES

[62] NMFS (2007a, 2007b, and 2007c).

[63] Ibid.

# The Outline of a Strategic Response

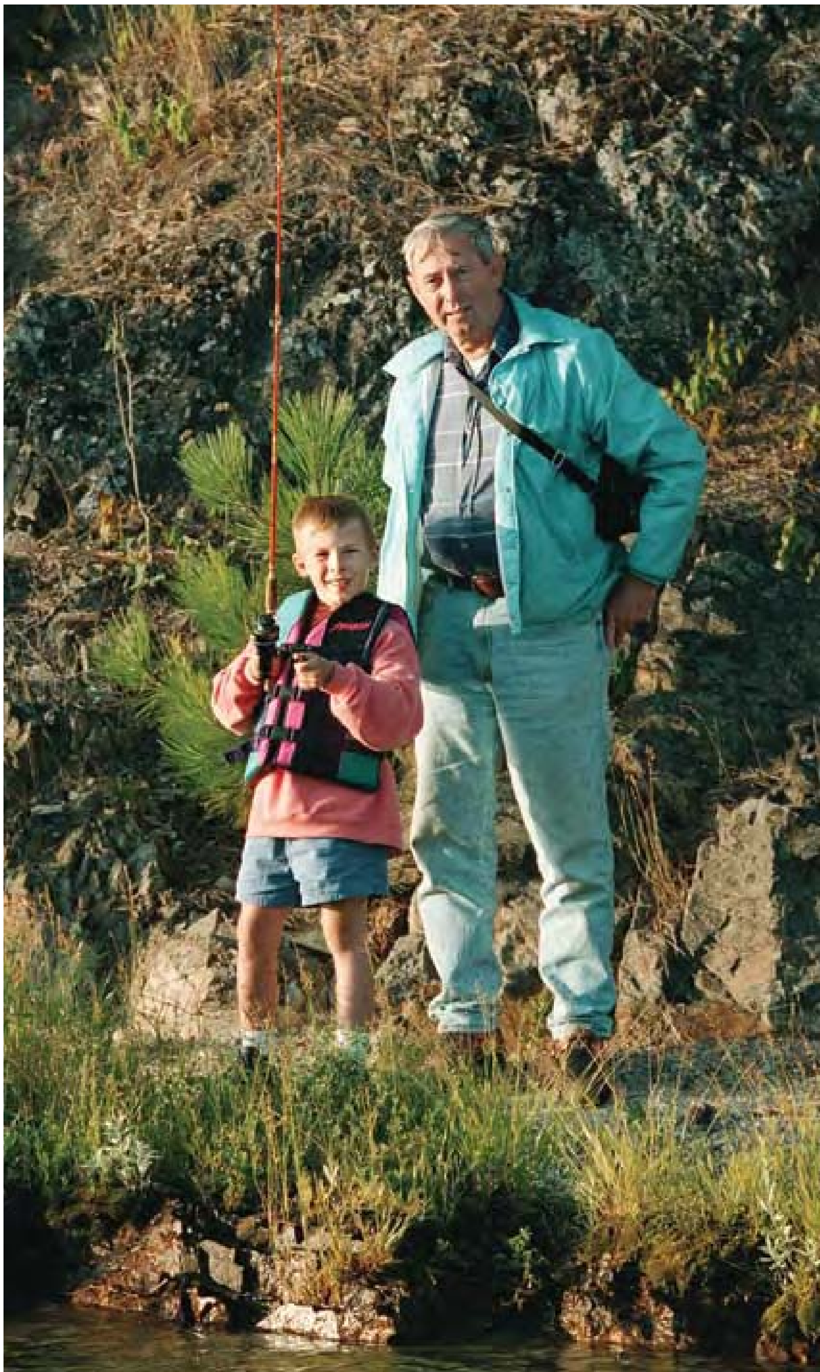
Global warming will harm every habitat and life-stage of Columbia and Snake River salmon and steelhead. The harm will be sustained through coming decades, and most likely grow steadily worse over that period. Its negative synergies with existing stresses to salmon are likely to be profound. We propose that a restoration strategy for endangered Columbia and Snake River salmon that seeks to respond to such serious, sustained harm should have four primary features:

- **Immediate actions** to reduce those impacts or buffer salmon against them, with priority focus on (a) reconnecting salmon to headwater habitats, (b) protecting headwater flows and temperatures, and (c) reducing mainstem Columbia and Snake River mortalities to adult and especially juvenile salmon;
- **Population-specific analyses and actions** as precise as possible to the status, life histories, and warming effects on each species and evolutionarily significant unit;
- **Assured feedback** so that research and evaluation of effects on species of both chosen actions and warming impacts loop back quickly and certainly to modify and add actions, on an annual or at most biennial basis; and,
- **Assured commitment to the precautionary principle** under the Endangered Species Act – which, simply stated, requires human actions, not salmon, to bear more of the risks from global warming uncertainties and unknowns.

Any initial plan to respond to global warming's effects on salmon will be imperfect on all four counts. But it is possible now to develop a plan with tangible, scientifically sound content in each. We focus here on the first feature – **immediate actions** – because it best illustrates what we mean by a strategic response, and because taking stronger actions now to help salmon survive global warming will be the hardest of the four to implement.

Actions that reconnect salmon to headwater habitats, protect headwater flows and temperatures, and reduce mainstem Columbia and Snake River salmon mortalities should be top priorities in response to global warming for several overlapping reasons, beginning with the salmon themselves. The exceptional resilience, flexibility, and diversity that characterize salmon are fundamental to their wide distribution, historic abundance, and value to ecosystems and people. They will need all that diversity and resilience to survive global warming.[64] Therefore we must protect and recreate habitat conditions and linkages that promote these characteristics of healthy salmon populations.

The places salmon are born and rear – spawning and rearing habitats – are the foundation of their diversity and resilience.[65] Most though not all of these habitats are in headwaters. The responses of salmon to the countless small and large differences among headwater habitats build and constantly renew the diversity of species and populations. For various reasons, these headwater habitats are generally (though not universally) in healthier condition than lower-elevation downstream habitats. Many Columbia and Snake River Basin headwaters still retain high-to-good connectivity within and across sub-watersheds. Many headwater habitats are in public or Tribal ownership and thus less developed than downstream areas. The best example is in the Snake Basin in central Idaho and eastern Oregon, where several thousand stream-miles of habitat across millions of acres are near-pristine and protected from development as "Wilderness" and "Wild and Scenic Rivers."



Headwater habitats in the Columbia and Snake River Basins will warm due to global warming, but since they are at the highest elevation in a watershed, they will generally remain cooler than low-elevation habitats in the same watershed. Their greater degree of current health and connectivity gives them further comparative advantage over lower-elevation habitats in a warming period. In short: these habitats are vital because they are where the majority of Columbia and Snake River salmon and steelhead are born and first grow; their generally better current condition, plus their elevation, makes them more robust to both development and global warming; and their ownerships and associated protections make them less vulnerable to development as human population grows.[66] Therefore, protecting high-quality headwater habitats, restoring healthy function and connections in damaged headwater areas, and re-connecting more salmon to headwater areas where downstream connections have been degraded are strategic priorities for endangered Columbia and Snake River salmon and steelhead in the age of warming.

A sound strategy must also account for two further facts about headwater habitats. First, global warming *will* damage them, and our actions can reduce but not prevent that. There will be less snow and more rain, higher water temperatures and altered streamflows. This means salmon survival in their spawning and rearing streams will very likely decline. Second, even where their headwater habitats are now in very good or even pristine condition, many Columbia River and all Snake River wild salmon are still sliding towards extinction under current recovery efforts.[67] Indeed, this is the case even for wild populations that have little or no hatchery influence and little human harvest. Their human-inflicted mortalities are largely caused by a series of dams and reservoirs on the Snake and Columbia rivers, which affect adult and especially juvenile salmon and steelhead of all species that use this long migration path.

This downstream mortality must be reduced so productive upstream headwater habitats can realize their potential to anchor salmon and steelhead recovery.[68] This is now even more urgent, as global warming hits salmon and downstream development continues. Reducing salmon mortalities in the mainstem Columbia and Snake rivers will help buffer Columbia and Snake salmon against the certain damage global warming will do to their headwater and ocean habitats. All populations of salmon and steelhead will benefit, since so many mix in the mainstems of these rivers. Reducing mainstem mortalities will connect more salmon to healthier headwater areas, and thus take maximum advantage of the healthiest, best-connected, and highest-elevation salmon spawning habitat left in the 48 states, that in central Idaho and eastern Oregon. And, in contrast to some effects of global warming, reducing these downstream mortalities *is* within our control.

This priority to headwater habitats and mainstem mortalities does not imply giving up on low-elevation salmon and habitats. Indeed, reducing mainstem mortalities will aid many low-elevation spawning populations as well. But low-elevation habitats, already the most altered by human development, will generally be damaged most by the added stresses of global warming and continuing development.[69] We propose that the best general strategy for low-elevation Columbia Basin salmon streams is to manage them for the best possible water quality, to integrate stream and water quality protection much better with land use and development planning by localities and states, and to protect or restore low-elevation stream channels to function optimally as migratory paths to and from the headwaters.[70]


Photo by Cristina Watson

## FOOTNOTES

[64] Mantua, N.J., and R.C. Francis, 2004. "Natural Climate Insurance for Pacific Northwest Salmon and Salmon Fisheries: Finding Our Way Through the Entangled Bank." In E.E.Knudsen and D. MacDonald, eds. Sustainable Management of North American Fisheries. American Fisheries Society Symposium 43: 127-140.

[65] Lee, D., et al., 1997. Broadscale Assessment of Aquatic Species and Habitats. An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins. Volume 3, Chapter 4. U.S. Forest Service General Technical Report PNW-GTR-405.

[66] McCullough, 1999.

[67] McClure, M., et al., 2003. "A Large-scale, Multi-species Status Assessment: Salmonids in the Columbia River Basin." Ecological Applications 13: 964-989.

[68] Marmorek, D.R., C.N. Peters, and I. Parnell, 1998. Plan for Analyzing and Testing Hypothesis (PATH): Final Report for Fiscal Year 1998 (Vancouver, B.C.: ESSA Technologies, Ltd.).

[69] Casola, J.H., et al., 2005, Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture. A Report Prepared for King County (Washington) by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle).

[70] There will be exceptions, but in general the authors of this report believe the approach laid out herein will protect and support the majority of salmon and steelhead in the Columbia and Snake River Basin.

# A Strategic Response continued

Based on this strategy, here is a partial list of actions that should be undertaken now to reduce the damage of global warming to endangered and threatened Columbia and Snake River salmon, and to buffer salmon against the damage that cannot be prevented.

1. *Remove unneeded or marginal barriers that block salmon from headwater habitats.* This ranges from removing low-value dams, to acquiring water to restore de-watered streams and protect thermal refugia, to accelerating culvert replacements.

2. *Assure migratory passage through, and better water quality in, low-elevation rivers and streams.* For instance:

• Require water pollution hot spots, such as the Potlatch pulp mill at Lewiston, to remediate their chemical and thermal pollution on accelerated timetables;

• Provide more federal support for state and local Willamette River clean-up;

• Re-invigorate the Environmental Protection Agency's Clean Water Act enforcement and incentives in the Columbia and Snake rivers, and their low-elevation tributaries, to reduce adverse and illegal water temperatures.

3. *Accelerate efforts to re-establish self-sustaining populations of salmon and steelhead above dams that now block fish passage but are unlikely to be removed.* Such efforts often focus on trapping and hauling adult salmon around dams, and trapping or screening juvenile salmon at the head of reservoirs for transport below dams. Prioritize such efforts based on production and habitat potential above the dam(s), re-establishment probability, and contribution to salmon diversity. Measures can include:

• Require experimental fish passage (dam modification, capture technologies, or both) in federal license renewals for relevant private dams. An example is the pending renewal for Idaho Power Company's Hells Canyon Complex; Oregon and Indian Tribes have proposed passage requirements in the new license.[71]

• Apply lessons from current re-establishments to other dams that block access to productive headwater habitats. An example is Portland General Electric's project on the Clackamas River, where juvenile salmon are trapped in North Fork Reservoir, piped past the Faraday and River Mill projects, and returned to the Clackamas below River Mill Dam for downstream migration.[72]

4. *Identify river stretches with highest potential for thermal blockages (areas of warm-to-hot waters that delay or prevent salmon migration) and reduce them.* Blockages are most likely at low-elevation; Ice Harbor reservoir on the lower Snake River is an example, where summer temperatures already routinely exceed 70° F. Measures can include:

• Acquire water to increase summer flows;

• Identify cold-water storage sources for application at critical periods;

• Remove dams or obstructions that slow water and thus warm it further;

• Reduce or eliminate thermal water pollution from human sources;

• Reconfigure hydro-system rule curves and operations to include the objective of ameliorating thermal blockages to fish migration;

• Investigate local potentials for limited groundwater pumping to augment flows in critical summer periods of greatest danger to salmon.

5. *Develop and implement watershed-specific headwater flow and temperature protection plans.* Measures can include:

• Acquire water to restore de-watered and enhance diminished river reaches;

• Protect healthy stream habitats from removal or reduction of shade, cover, and vegetation or channel complexity;

• Restore damaged headwater stream habitats via site-specific actions;

• Pre-plan rapid response to catastrophic disturbances, to both protect and restore streams and stream habitats;

• Investigate local potentials for limited groundwater pumping into small streams at critical high temperature/low flow periods, to bridge salmon through them during spawning and rearing.

6. *Remove the lower Snake River dams.* Scientists have already identified this measure as the surest and perhaps only way to restore endangered Snake River salmon and steelhead.[73] It is more urgent with global warming. Extensive headwaters above these dams in the Salmon, Clearwater, Grand Ronde and Imnaha watersheds are in excellent condition, with low development risk due to public ownership and Wilderness/Wild and Scenic River designations. And, as the highest-elevation salmon spawning and rearing habitats in the 48 states, they are likely to warm the least over coming decades. For these reasons, Snake River salmon and steelhead must be managed as anchors for salmon survival through global warming, rather than remain among the closest to extinction of the ESA-listed populations due to downstream mortalities. Removal of these dams will sharply reduce juvenile and adult Snake River salmon and steelhead mortality,[74] and reduce thermal barriers in the lower Snake.[75] It will also re-create 140 miles of low-elevation spawning and rearing habitats for Snake River fall chinook salmon.

7. *Reduce mainstem Columbia River salmon mortalities.* Though the Columbia River dams will remain in place, a range of measures can reduce their toll on salmon and steelhead populations in the Columbia and Snake River Basin. Measures can include:

• Modify flood control operations to help ameliorate low flows and thermal blockages. This is most possible and most critical in low water years, when flood control needs are diminished and stored water can significantly boost spring and summer flows for out-migrating juveniles. Augmented flows in such years are especially important to prevent major setbacks to rebuilding.

• Modify power operations to provide more system flexibility for populations critically affected by warming waters (e.g., summer-migrating salmon);

• Implement spill regimes at each dam during salmon migration at levels that salmon managers and the Fish Passage Center[76] find necessary.

• Acquire additional water to augment flows at critical periods for migrating salmon, such as in summer.

• Adopt adult salmon passage protocols at each Columbia River dam as recommended by the Fish Passage Center.

• Evaluate hydroelectric operations annually for how global warming effects are altering the impacts of those operations, singly and cumulatively, on migrating salmon. Then implement actions as needed to restore the status quo ante.

8. *Curb global warming.* If global warming continues unabated, salmon and other cold-water fish near the warmer boundaries of their range will eventually be reduced to tatters if not die out altogether. Any success helping salmon bridge near-term moderate warming would eventually be swamped by more intense warming. Immediate actions to stop and then reverse rising greenhouse gas emissions are thus salmon survival measures – and of course much more than that.

Greenhouse gases in the atmosphere must remain below about 450 parts per million of $CO_2$ to keep warming below 3.6° F of warming in the coming century.[77] To achieve this, growth in global greenhouse gas emissions must be halted within the next ten years, and overall emissions cut 50-85% below current levels within 50 years. We recommend enactment of federal laws that set these goals and then attain them by a mix of regulations and incentives that include tax and fiscal policies. Actions by states, cities, businesses and citizens are also urgent, but the goals will not be achieved without federal legislation.

## FOOTNOTES

[71] State of Oregon Comments to the Federal Energy Relicensing Commission on the Final Environmental Impact Statement, Hells Canyon Hydroelectric Project, February 28, 2008; see also, e.g., Nez Perce Tribe's comments to FERC, January 26, 2006.

[72] Martin, 2006

[73] Budy, P., et al., 2002, "Evidence Linking Delayed Mortality of Snake River Salmon to their Earlier Hydrosystem Experience," North American Journal of Fisheries Management 22: 35-51; Peters, C.N., D.R. Marmorek, and R.B. Deriso, 2001. "Application of Decision Analysis to Evaluate Recovery Actions for Threatened Snake River Fall Chinook Salmon (Oncorhynchus tshawytscha)." Canadian Journal of Fisheries and Aquatic Sciences 58: 2447-2458; and Nemeth, D.J. and R.B. Kiefer, 1999. "Snake River Spring and Summer Chinook Salmon – the Choice for Recovery," Fisheries 24: 16-23.

[74] See, e.g., NOAA Fisheries, 2000 FCRPS Biological Opinion, Appendix A: Analysis of Effects of Proposed Action and Reasonable and Prudent Alternative on Species-Level Biological Requirements of Listed Species, December 2000.

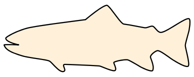
[75] Independent Scientific Group, 1996, Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem (Portland, OR: Northwest Power Planning Council).

[76] The Fish Passage Center (FPC) provides technical services to the fish agencies and tribes impacted by the operation of the FCRPS. Those agencies' and tribes' recommendations for river management are based on FPC analysis and summary of current and historical fish passage data.

[77] IPCC, 2007b. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, et al., eds.] (Cambridge, U.K.: Cambridge University Press).

## STEELHEAD TROUT

spawn in a wide variety of rivers, and go to sea after one to two years in freshwater. Steelhead will be at high risk from warming river temperatures when returning from the sea as adults.



# CONCLUSION

The inclination to "wait for more information" before taking action to respond to global warming is neither prudent nor thoughtful. If followed for endangered Columbia and Snake River salmon, this will accelerate their already-critical slide toward extinction. Indeed, ample information exists upon which to act now.

The history of efforts to restore salmon and steelhead contains few if any examples where we "overdid" it by providing endangered salmon too much protection or restoration. Rather, there are all too many examples – notably, every federal plan to restore Columbia Basin salmon since 1994 – where recovery targets were undershot, needed actions avoided, promised actions under-implemented, and extinction trends not reversed. Salmon science always lags behind real-world impacts to salmon, and salmon management lags even further.

Human-caused warming is now a fundamental component – like dams, hatcheries and harvests – of the present and future condition of Columbia and Snake River salmon and steelhead. The federal government's next Columbia/Snake salmon plan must respond to the effects of global warming on salmon. It is not proper to pass that responsibility to the next plan or next group of policymakers. We hope this report contributes positively to immediate, scientifically-founded actions by the federal government, with its state, Tribal and citizen partners, to help the Columbia Basin's iconic and valuable wild salmon and steelhead survive the era of global warming.

Salmon habitat at 7000 feet in Idaho's Sawtooth Valley

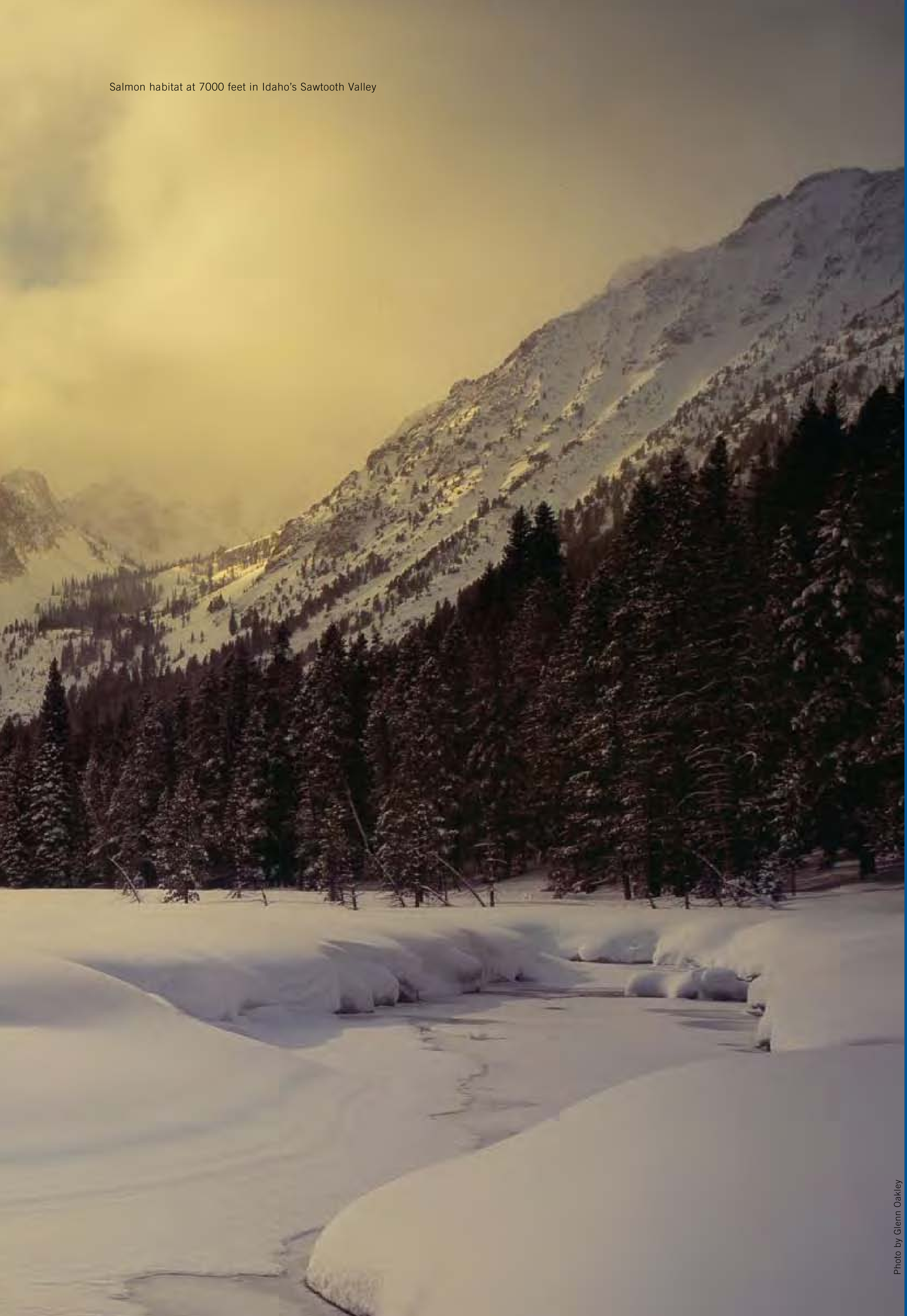


Photo by Glenn Oakley

**Jim Martin**, who served a 30-year career with the Oregon Department of Fish and Wildlife, was Oregon's Chief of Fisheries for six years and served for three years as Salmon Advisor to Governor John Kitzhaber. Martin led the team that developed the Oregon Plan for Salmon and Watersheds, a state conservation plan to address endangered species and clean water issues in Oregon.

Martin now works as Conservation Director for the Berkley Conservation Institute, a branch of Pure Fishing, one of the world's largest fishing tackle companies and an industry leader in conservation advocacy. Martin has a Bachelors Degree in Wildlife and Masters Degree in Fisheries from Oregon State University.

He also is a board member for the Theodore Roosevelt Conservation Partnership, and a science advisor for the Doris Duke Foundation and the Northwest Sportfishing Industry Association. In 2005, Martin was inducted into the National Freshwater Fishing Hall of Fame in Hayward, Wisconsin.

**Patricia Glick** is Senior Global Warming Specialist with the National Wildlife Federation (NWF).

An economist and global warming expert, Patty has been dedicated to the issue of climate change for more than 16 years, the last ten for the National Wildlife Federation where she develops policy solutions.

Prior to joining NWF, Glick served two years as a Senior Fellow for the Sierra Club in Washington, D.C., where she worked with the Club's Global Warming and Energy Program to study the economic and social costs of climate change around the world. She has also conducted policy-related analysis of U.S. energy markets for The Alliance to Save Energy and worked as a transportation and energy economist for the Montana Department of Natural Resources and Conservation. Glick received an M.S. degree in economics from the University of North Carolina in Chapel Hill and a B.A. from Sweet Briar College in Virginia.

LIGHT in the RIVER

NW Energy Coalition

SIERRA CLUB

Save Our wild Salmon

www.LightInTheRiver.org