SALMON AND CLIMATE CHANGE

Fish in hot water

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Summary

- Salmon have a long historical association with human society and make a large contribution to economies. They also have important ecological roles.

- Some salmon populations have declined significantly in recent decades. While human activities are largely responsible, climate change could now exacerbate or even supersede these threats, particularly in the southern part of their natural range.

- Physical changes to freshwater ecosystems resulting from climate change will degrade and diminish available habitat, reduce reproductive success and jeopardise migration.

- Although not well understood, impacts on salmon's marine habitat could lead to temporal and spatial shifts in both their prey and predators. Possible changes to the timing of migration represents an important new threat.

- These species highlight the effects of rising temperatures on both freshwater and marine ecosystems, and illustrate how climate change impacts on wild species can have a direct effect on economies.

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Salmon have a long historical association with human society and represent one of the most valuable wild capture fisheries in the world. In a recent assessment in 2007, the salmon fishing industry contributed more than $2 billion to economies in Russia, Japan, the US and Canada and directly employed more than 35,000 people. Salmon are also harvested on a smaller scale, both for recreational and subsistence purposes, and many individuals, communities and small businesses are dependent on salmon for their livelihoods.

Salmon have important cultural and ceremonial associations. Such associations range from those of Native American tribes, who have held salmon with great reverence and believed that their annual returns were a 'self-sacrifice' to feed the people, to the many people who derive pleasure from viewing their captivating migrations.

Salmon play an extremely important role in the functioning of their ecosystems. They provide food for a suite of predators and scavengers, including seals, whales, otters, bears, birds and countless invertebrates. Salmon also transport essential nutrients from the marine environment to freshwater and terrestrial habitats. This occurs through the excretion of waste and the decay of carcasses, including those discarded by terrestrial predators.

What do we know about salmon?

Salmon belong to the family Salmonidae, which includes other well known fish such as trout, grayling and char. The salmon species covered here include Chinook, sockeye, pink, coho, cherry and chum (collectively belonging to the 'Pacific salmon'), as well as Atlantic salmon, all of which perform their renowned migrations from freshwater to marine habitats and back again. This behaviour is called 'anadromy'.

Pacific salmon live in coastal and river waters from Alaska and Russia in the north, to Japan and Mexico in the south, while Atlantic salmon inhabit areas in the North Atlantic Ocean and Baltic Sea, including associated river ways in USA, Canada, Iceland, Norway, Finland, Sweden and the United Kingdom.

One of the most intriguing aspects of salmon is their extraordinary life cycle. Salmon eggs are laid in small pits (called 'redds') that are excavated in gravel-based freshwater streams by egg-bearing females. These nesting sites are selected because of their specific temperature, currents and oxygen levels.

Salmon eggs hatch after about three months, although juveniles remain dependent on the yolk-sac for several weeks after hatching. Eventually the juveniles begin their downstream migration1 during which time they develop a tolerance to saline waters. Young salmon may remain in fresh water for up to four years, before entering the ocean. It is during this period that juveniles are thought to be most vulnerable to predation.

Entry into the ocean coincides with planktonic blooms, upon which the juveniles feed. Older individuals may feed upon small invertebrates, squid and a diversity of marine fishes.

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Depending on the species, salmon may spend between one and seven years at sea, where they continue to grow. Once sexually mature, the salmon migrate back to their original hatching grounds to reproduce. Such migrations (which can be extremely long) use a combination of chemical, magnetic and celestial cues for navigation. For most species this landward migration occurs throughout the summer and autumn months, with a few species, such as Chinook, coho and chum salmon, continuing to migrate through the winter months.

Salmons' spawning migration is both risky and energetically costly. Salmon must travel continually against the current and overcome numerous threats and barriers including predators, disease and waterfalls. As a result, many salmon die during the migration, and those that survive are often bruised and battered. Upon arrival at the nesting site a salmon will typically spawn several times before dying, although some species (notably Atlantic salmon) can survive and may even repeat spawn.

How is climate change affecting salmon?

Freshwater habitats:

As water temperatures increase, a number of negative effects on salmon may arise. Direct biological impacts on salmon include physiological stress, increased depletion of energy reserves, increased susceptibility and exposure to disease and disruptions to breeding efforts.

Such direct impacts on the biology of salmon may potentially lead on to further, less direct impacts. For example, as the developmental rate of salmon is directly related to water temperature, it is possible that increasing temperatures could cause the more rapidly developing juveniles to enter the ocean before their planktonic food source has reached sufficiently high levels.

Additional indirect effects to salmon, associated with increasing air and water temperatures, relate to negative changes to their habitat. It has been noted that areas of particularly warm freshwater can present a thermal barrier to migrating salmon that requires additional energy to navigate around. Such barriers can also delay or even prevent spawning.

As the air temperatures warm, much of the snow that feeds the river systems is expected to melt earlier. In many cases snow is predicted to be replaced by rain. This will lead to a reduction in the summer flows of many rivers, coupled with an increase in freshwater inputs during the winter.

A reduction in summer flow levels will serve to increase water temperatures further and is likely to reduce the overall habitat available to salmon. Increased winter flows are likely to scour the river beds, disturbing nests and causing physical damage to both salmon eggs and juveniles.

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Coupled with an increase in freshwater inputs, is an increase in the sedimentation of river and stream beds. Such sedimentation is likely to reduce the amount of gravel substrate available for spawning, and to smother both eggs and juveniles.

Marine habitats:

Predicting the specific effects of climate change on salmon in their marine environment is extremely difficult. This is due to our limited knowledge of the marine habits of salmon, combined with uncertainties about how marine habitats will be affected by climate change.

It has been suggested that many of the food webs of which salmon are a part will be disrupted by climate change. For example, the timing of the planktonic 'blooms' required by the young is governed by climatic factors. Changes in the timing of these blooms could cause a scarcity of food at a critical stage of the salmon's life cycle.

Warmer ocean temperatures have been shown, in certain areas, to reduce the abundance of other smaller fish into these newly warmed areas. These two factors, when coupled together, could cause a significant rise in predation pressure on salmon.

Can salmon adapt to climate change?

Not all salmon populations will be affected by climate change in the same way, and some populations at higher latitudes may actually benefit from warmer temperatures through increased production. It is possible that a warmer climate could make new spawning habitats available, and this has been observed in parts of Alaska. Such changes are likely to lead to unexpected consequences and shifts in ecosystems and fisheries, and humans will need to be prepared to adapt to these new conditions.

It is important to note that a multitude of other threats to salmon currently exist. These include:

- Overexploitation by the fishing industry.
- Habitat destruction and degradation (particularly through activities such as mining, forestry, agriculture and/or urbanisation).
- Pollution and sedimentation of river waters
- Obstruction of migratory routes, (especially by dams and hydropower stations).
- Interbreeding and ecological interactions with artificially propagated salmon (originating from either farms or hatcheries).

This suite of threats will all serve to jeopardise salmon's chances of adapting to the new threats arising from climate change.

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"Continued research on how salmon will cope with climate change is important and should be emphasised. But we also need to support efforts to control greenhouse gases, do everything we can to help wild salmon adapt to a new, changing environment, and work on adapting to a new way of doing business through proactive, precautionary management and actively promoting wild salmon conservation."

- Pete Rand, IUCN SSC Salmonid Specialist Group

Salmon geographical range – © IUCN Red List

For more information please visit: www.iucnredlist.org

Salmon

(2007) 'This year's harvest was the 4th largest since statehood'. ADF&G (Alaska Department of Fish and Game) Press release: no. 07-27, November 7, http://www.adfg.state.ak.us/news/2007/11-7-07_nr.php

(2009) Water Quality in Salmon Spawning Gravels. Technical document. Fisheries Research Services, Freshwater Laboratory, Pitlochry, Perthshire, UK, http://www.marlab.ac.uk/FRS.Web/Uploads/Documents/FW17Gravels.pdf

Anderson, D.M., and Scott, M.J. (1993) Valuing the salmon resource: Columbia River stocks under climate change and fishery enhancement. In *27th Annual Pacific Northwest Regional Economic Conference*, 83-88, http://economic-analysis.pnl.gov/pubs/proceedings/ValuSalmonResource.pdf

Augerot, X. *et al.* (2005) *Atlas of Pacific salmon: the first map-based status assessment of salmon in the north Pacific*. University of California Press

Babaluk, J.A. *et al.* (2000) First records of sockeye (*Oncorhynchus nerka*) and pink salmon (*O. gorbuscha*) from Banks Island and other records of Pacific salmon in Northwest Territories, Canada. *Arctic* 53, 161-164

Battin, J. *et al.* (2007) Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences* 104, 6720

Beacham, T.D., and Murray, C.B. (1990) Temperature, Egg Size, and Development of Embryos and Alevins of Five Species of Pacific Salmon: A Comparative Analysis. *Transactions of the American Fisheries Society* 119, 927-945

Ben-David, M. *et al.* (1998) Fertilization of terrestrial vegetation by spawning Pacific salmon: the role of flooding and predator activity. *Oikos* 83, 47-55

Bradford, M.J., and Irvine, J.R. (2000) Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. *Canadian Journal of Fisheries and Aquatic Sciences* 57, 13-16

Cederholm, C.J. *et al.* (2001) Pacific Salmon and Wildlife-Ecological Contexts, Relationships, and Implications for Management (Special Edition Technical Report). In *Wildlife-Habitat Relationships in Oregon and Washington*, Washington Dept. Fish and Wildlife, Olympia, WA, 138 pp

Crozier, L.G. *et al.* (2008) Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications* 1, 252-270

Crozier, L.G. *et al.* (2008) Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. *Global Change Biology* 14, 236-249

Groot, C., and Margolis, L. (1991) *Pacific salmon life histories*. University of British Columbia Press, Vancouver

Irvine, J.R. (2004) Climate Change, Adaptation, and 'Endangered' Salmon in Canada. In *Species at Risk 2004 Pathways to Recovery Conference* (Hooper, T.D., ed), Pathways to Recovery Conference Organizing Committee, Victoria, B.C.

Irvine, J.R. *et al.* (in press) Salmon in the Arctic and how they avoid lethal low temperatures. *NPAFC Bulletin* 5

Lisle, T.E. (1989) Sediment transport and resulting deposition in spawning gravels, north coastal California. *Water Resources Research* 25, 1303-1319

Mantua, N. *et al.* (2009) Impacts of climate change on key aspects of freshwater salmon habitat in Washington State. Washington. In *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*, Climate Impacts Group, University of Washington, Seattle, Washington

Mantua, N.J. (2005) Impacts of Climate Change on Washington Resources. 23, Climate Impacts Group, Center for Science in the Earth System Joint Institute for the Study of the Atmosphere and Oceans. University of Washington.

Marine, K.R., and Cech Jr, J.J. (2004) Effects of High Water Temperature on Growth, Smoltification, and Predator Avoidance in Juvenile Sacramento RiverChinook Salmon. *North American Journal of Fisheries Management* 24, 198-210

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. 279, USEPA

Mote, P.W. *et al.* (2003) Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. *Climatic Change* 61, 45-88

Patz, J.A. *et al.* (2000) The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment. *Environmental Health Perspectives* 108, 367

Rand, P.S. *et al.* (2006) Effects of river discharge, temperature, and future climates on energetics and mortality of adult migrating Fraser River sockeye salmon. *Transactions of the American Fisheries Society* 135, 655-667

WWF (2001) The status of wild Atlantic salmon: a river by river assessment. World Wildlife Fund – European Freshwater Programme, Copenhagen, Denmark