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HC 441: Columbia River Ecology
Clark Honors College
November 23, 2005

Water Temperature and Salmon Smotlification in the Columbia River

The Columbia River basin is home to many species of salmon, including Chinook, Coho and Chum. These and other species of salmon depend on homeostatic environments to develop and reproduce properly. There are many different factors that contribute to a homeostatic environment, one of them being water temperature. When water temperatures exceed a fish's temperature threshold, that fish is susceptible to numerous dangers. What causes water temperatures in the Columbia River basin to increase, and how are salmon populations affected by those temperature changes? In addition, what has been done to keep water temperatures down and what can be done in the future to maintain healthy temperatures for salmon? These questions are pivotal in examining the health of salmon in the Columbia River basin.

Temperature change in an aquatic ecosystem can be detrimental for many reasons: "Stream temperatures are often seen as primarily directed at fish -- but in reality are a surrogate to overall stream health" (Oregon 16). So, "because water temperature affects the health of individual fish, it also affects entire populations and species assemblages" (Kolmes and Richter 23). Individual fish can, because of temperature changes in their aquatic environments, have trouble maintaining weight, fighting disease, and combating numerous stressors at a time (Kolmes and Richter 23). Thus, the whole population is affected: "Fish populations need strong individuals to maintain itself through perturbations and environmental stresses…and have the ability to continue life history functions through time and space" (Oregon* 24).

The Columbia River waters can, at times, surpass temperature thresholds for some fish, putting those populations in jeopardy. Water temperatures can be affected by natural, environmental forces, including regional and seasonal climates, precipitation, stream flow, radiation from the sun, and other environmental factors (Oregon 11). However, water temperatures are also affected by human activities. When humans develop the land around a body of water, they are directly affecting the surrounding aquatic ecosystem in numerous ways, especially "by simplifying the physical structure of aquatic systems, thereby eliminating natural thermal buffers and insulators" (Kolmes and Richter 24). Human influences include, but are not limited to, "loss of riparian vegetation, the elimination of beaver populations, removal of large woody debris, channel simplification, reduced groundwater discharge due to changes in upland vegetation or urbanization, [and] water withdrawals" (Kolmes and Richter 24). In addition, damming, irrigation, livestock grazing, draining wetlands and channeling are all activities that can affect water temperatures in the Columbia River (Oregon 93).

How do these activities change water temperature? The removal of riparian vegetation, damming and urbanization are all good example of how human activities can change water temperature. Riparian vegetation is very important to stream health and "indirectly affect[s] stream temperature by influencing microclimate, affecting channel morphology, affecting stream flow, influencing wind speed…and influencing thermal radiation" (Oregon* 28). When riparian vegetation is removed from a stream or river bank, the water is exposed to more solar radiation. Because solar radiation is "the primary source of energy responsible for the warming of water in streams and the air in riparian areas," the removal of riparian vegetation exposes water to more heat and, thus, increases its temperature (IMST 86).

Damming can increase water temperature in many different ways. However, water temperatures often rise in damming when the waters are held back during summer months. When dams release that water during the fall months, the discharge is often "warmer than natural flows…This can have profound effects on the development of the biotic community, including salmonids downstream" (IMST 74).

Urbanization increases water temperatures because "urbanization result[s] in greater surface flow to streams and less infiltration into the ground" (IMST 78). In addition, the water that does flow into the Columbia River from urbanization "spends more of its time in contact with solar radiated surfaces such as pavement, roofs, and other developed areas and gains heat energy" (IMST 78). These examples provide proof of how human activities can adversely affect water temperatures in the streams and the main body of the Columbia River, thus adversely affecting salmon populations.

Increased water temperatures, from environmental and human influences can affect salmon throughout their life and at all levels of development, from incubation to adulthood, because increased temperatures mean less dissolved oxygen in the water: "Water temperature and dissolved oxygen concentrations are inversely related…This situation stresses cold-water fishes" (IMST 34).

Most importantly, however, is how the increasing temperatures of the Columbia River specifically affects salmon smoltification. Smoltification is a developmental process that prepares salmon for the migration from freshwater to a marine environment and “involves changes in appearance, behavior, osmoregulatory and ion regulatory functions, and metabolism” (Biga, Congleton, and Peterson 57). It is undeniable that smoltification is an important part of salmon development. A salmon that does not mature properly cannot reproduce, weakening salmon populations.

Thus, the smoltification process can be severely hindered by high water temperatures. In actuality, high temperatures can “result in outright lethality, premature smolting, blockage of seaward migration, desmoltification, shifts in emigration timing resulting in decreased survival in the marine environment, and other stresses detrimental to fitness” (Kolmes and Richter 24). In addition, high temperatures can “inhibit the activity of gillATPase,” which is an enzyme that is a catalyst for smoltification (Kolmes and Richter 27). A fish that is unable to complete smoltification, or experiences an unhealthy transformation into a smolt, is unprepared for migration to the ocean and is thus susceptible to health problems, stressors, and predators.

Even small changes in water temperature can adversely affect salmon smoltification. Thus, the temperature threshold for many species of salmon is very small. An article from *Reviews in Fisheries Science,* entitled “Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest,” explores how rising water temperatures have adversely affected three different species salmon (Chinook, Coho and Chum) at all different life stages, including smoltification. The article cites that any temperatures above a range of 12 degrees C to 15 degrees C can hinder proper smoltification (Kolmes and Richter 27). However, the temperature threshold for healthy smoltification is different for each species. For instance, Chinook salmon have a temperature threshold that is 12 degrees Celsius for spring Chinook and 17 degrees Celsius for fall Chinook, and for Coho salmon, the temperature threshold is 15 degrees Celsius. The mean temperature, in this study, for an ideal, healthy smoltification among salmon is 15 degrees Celsius.

Being that smoltification is a physical development that prepares salmon for migration, temperature changes in the Columbia River not only hinder the smoltification process, but have, in some instances, changed migration patterns and adaptability of certain salmon species. For instance, the migration patterns of fall and spring Chinook salmon have changed over time due to the change in water temperature: While spring Chinook have maintained their migration patterns despite changes in water temperature, fall Chinook salmon have not. Fall Chinook salmon "may reflect a phylogenetic adaptation to summer emigration;" however, "phylogenetically determined temperature adaptations and responses to thermal stress may not protect fall Chinook salmon from the recent higher summer water temperatures, altered annual thermal regimes, and degraded cold water refugia" (Crawshaw, Maule, and Sauter 295). Thus, regardless of their adaptation to migrate during the summer, fall Chinook salmon can be affected by increased water temperatures of the Columbia River and "the long-term survival of fall chinook salmon will likely require restoration of normal annual thermographs and rigorous changes in land use practices" (Crawshaw, Maule, and Sauter 295).

As mentioned above, some fish species have adapted to warmer water temperatures in the Columbia River (which does not necessarily mean that the fish are safe from other stressors). How are fish surviving in temperatures that are inadequate for their needs? In this respect, salmon are very much like humans, because humans can survive extreme temperatures for a certain period of time: "Similarly, salmonids can persist for extended periods of time in warm streams, but are extremely vulnerable to other threats" (Oregon 16). In addition, some fish have found ways to avoid warmer waters, such as cool water pockets called thermal refugia. However, "these areas must be abundant and easily accessible to benefit the fish throughout all life history stages," which they are not (Oregon 61). There need to be more long term solutions.

The temperature of the Columbia River, and its effect on biota, has been an area of research for some time and "has become a political and emotional set of issues in Oregon," despite the fact that "the most important part of Oregon's water quality management is what happens on the ground -- the many actions of citizens that influence the environment and water temperature" (Oregon* 10, Oregon 14). The rising water temperatures of the Columbia River are actively being examined by governmental and non-governmental bodies in order to find both reasons for the problem and solutions. The Independent Multidisciplinary Science Team (IMST), "a scientific review panel charged with advising the State of Oregon on matters of science related to the Oregon Plan for Salmon and Watersheds" is a great example of a group that is actively exploring why the temperature of the Columbia River has increased and how it can be remedied (Oregon 1).

Standards for water temperature in Oregon were first instituted in 1967, around the same time that Dr. J.R. Brett "established lethal tolerance ranges for most species of Pacific salmon, documented effects of temperature on physiological performance and conducted field experiments" (Oregon 34). After a review in 1979, the standards were not changed until the mid-1990s. At that time, the Department of Environmental Quality made recommendations about the standards for temperature and they were revised in

1996. Most recently, at the urging of the Environmental Protection Act, the DEQ, once again, revised the standards for water temperature in the Columbia River (Oregon 30). The following are the temperature standards that relate to salmon and salmon development:

- 16.0 degrees Celsius for core cold water habitat use
- 18 degrees Celsius for salmon and trout rearing and migration
- 20 degrees Celsius for migration corridor use
- 13 degrees Celsius for salmonid spawning, egg incubation, and fry emergence (Oregon 15).

These temperatures are modified for each stage of the salmon life cycle and reflect the necessity of certain environments during certain developmental stages.

How do governmental agencies determine the Oregon temperature standards? Government agencies use the total maximum daily load (TMDL) to "calculate the maximum amount of a pollutant that could be added to a lake or stream without causing harm to aquatic life" (Oregon 14). Heat is considered a pollutant by the state of Oregon, and the TMDL is considered scientifically sound by the IMST.

Beyond the temperature standards, what else is being done to maintain acceptable temperatures for salmon in the Columbia River? In Oregon, each river has a Water Quality Management Plan developed by the DEQ. The Water Quality Management Plan is a guideline for restoration projects and land management, and there have been programs designed specifically to combat temperature increases (Oregon 30).

Although much has been done to combat warmer temperatures in the Columbia River (as mentioned above), there is still a lot that is unknown about the effects of warm water on salmon and about how the situation can be remedied. The Independent Multidisciplinary Science Team agrees on many issues pertaining to water temperature and its effect on salmon, including, but not limited to: The effect of, or lack thereof, riparian vegetation on water temperature, the effects of channeling on water temperature, the fact that streams heat in the downstream direction, and land use development leads to warmer stream temperatures (Oregon* 21). However, they also agree that there are many things that are unknown about the correlation between environmental factors, human influence, water temperature and salmon health. For instance, there is little data on where healthy salmon populations live, there is more data on water temperature than there is on how it affects salmon, and there is little data on just how much riparian vegetation is needed to change stream temperature (Oregon* 22, 26). These inaccuracies are proof that more needs to be done in order to better protect salmon populations from unhealthily-high water temperatures.

The IMST and EPA both have many recommendations for the future of salmon health in correlation with water temperature. The IMST has numerous recommendations, which include, but are not limited to: An "information distribution system for citizens, watershed councils, and special interest groups," a consistent guideline for assessing current stream conditions by the Oregon Watershed Enhancement Board (OWEB), a "classification system for determining riparian reference conditions," and a collaboration between OWEB and DEQ to monitor restoration programs pertaining to water temperature (Oregon 121).

The EPA believe that the "challenge of having anything beyond remnant runs of wild salmonids present at the turn of the next century is complex, societal, and involves a wide array of concerns beyond the narrow temperature considerations" (Kolmes and Richter 40). However, they also feel that exploring the effects of temperature on salmon is a "necessary (if far from sufficient) component of salmon recovery planning" (Kolmes and Richter 40).

The EPA suggests that "realistic recovery planning needs to acknowledge and address difficult truths and distinguish science, ethics, and predictable future scenarios if we are to make progress" (Kolmes and Richter 41). In addition, the EPA believe that "careful design of long-term monitoring regimes are necessary in the analysis of coupled human-environment systems for sustainability planning" (Kolmes and Richter 41).

The IMST's recommendations are extensive (there are eight total) and a great example of thought that should be going into Columbia River water temperature. Their recommendations cover not only programs that are directed at water temperature, but at programs that involve the Oregon government, water protection, fish protection, wetland protection and riparian vegetation conservation. By looking at the big picture, the IMST recognizes that the Columbia River watershed is an interconnected system where plants, animals, humans and aquatic life live together and, thus, need to be considered as a community.

Water temperature is an important issue in the health of the Columbia River. When water temperatures get too high, aquatic life is at risk. In the Columbia River, salmon populations are very much at risk when temperatures increase: They are susceptible to early smoltification, disease, predators and other health conditions that are detrimental to salmon development and reproduction.

In order to protect Pacific Northwest salmon populations, people need to be made aware that water temperatures, not just pollution and damming, are detrimental to salmon development. By taking actions that can help keep Columbia River water temperatures at a healthy level for salmon, we are taking one more step toward improving the state of the Columbia River watershed.

Bibliography

Biga, P.R., J.L. Congleton and B.C. Peterson. "Plasma Insulin-like Growth Factor-I Concentrations in Yearling Chinook Salmon (*Oncorhynchus tshawytscha*) Migrating from the Snake River Basin, USA." Fish Physiology and Biochemistry. (2003) 29: 57-66.

Crawshaw, Larry, Alec Maule, and Sally Sauter. "Behavioral Thermoregulation by Juvenile Spring and Fall Chinook Salmon, *Oncorhynchus tshawytscha*, During Smoltification." Environmental Biology of Fishes. 61 (2001): 295–304.

Kolmes, Steven and Ann Richter. "Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest." Reviews in Fisheries Science. 13 (2005): 23-49.

Oregon. Independent Multidisciplinary Science Team. Oregon's Water Temperature Standard and its Application: Causes, Consequences, and Controversies Associated with Stream Temperature. Salem: IMST [2004].

*Oregon. Independent Multidisciplinary Science Team. Influences of Human Activity on Stream Temperatures and Existence of Cold-Water Fish in Streams with Elevated Temperature: Report of a Workshop. Salem: IMST [2000].

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