Global Warming and the Columbia River Basin

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HC 441: Columbia River Ecology
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November 23, 2005

The Columbia River Basin was created out of the most powerful geologic and climatic processes on earth. The bedrock of the Basin rose up from the ocean floor and came from half a world away, enormous lava flows lay down basalt thousands of meters thick, wind blew in sediment over the course of millennia, and the main channel of Columbia River was scoured out repeatedly by floods to which there is no modern equivalent. What resulted is a river 1232 miles long, which drains an area of 258,000 square miles spread between British Columbia, Oregon, Washington, Idaho, Nevada, Utah, Montana, and Wyoming. The Columbia River Basin is host to many thousands of plant and animal species, many of which are endogenous, and spans temperate, arid, and moist environments from sea level to the top of the Canadian Rockies.

In order to disrupt the natural processes occurring in this system massive changes must be instituted, but those changes do not always start in an obvious way. Today more than 400 reservoirs and dams are in place along the Columbia River and its tributaries. Cities and industries have come and gone in the last 150 years, leaving their mark on the landscape, environment, and river. It is easy to point at the dams, smelters, and cities in the Columbia River Basin and the environmental problems they create. They are the most obvious and recognizable violators and will have long term effects on the Basin. These are truly visible signs of human interference in need of correction, but can be seen as secondary problems that only compound the threat of climate change that the Basin is facing at the start of the 21st century.

Since the late 19th century the global mean temperature has risen ~ 0.5°C (~1°F). This phenomenon responsible for this is anthropogenic global warming and is facilitated by the release of greenhouse gases from industry, transportation, and other activities. Although CO_2 is the gas mentioned most in relation to anthropogenic global warming, nitrogen oxides (NO_x), methane, and hydrofluorocarbons are greenhouse gases of varying effect that are release mostly through combustion and industry. When present in the atmosphere, greenhouse gases share the common trait of expanding its heat storage capacity. This increased storage capacity allows the atmosphere to retain more incoming solar radiation and other energy that would normally be reflected or radiated back into space. This added energy warms the atmosphere and with the buildup of gases the warming effect increases and accelerates. By some accounts the current warming trend could result in an increase in temperature of between 4 and 8°C globally before 2100 (Roeckner).

Human activity released approximately 145 billion metric tons (7.4×10^{13} m^3) of carbon dioxide (CO_2) into the earth's atmosphere in the period 1970-1999. There are natural process that will scrub CO_2 and other greenhouse gases out of the atmosphere but these processes have been overwhelmed by the sheer volume of contamination. The buildup of CO_2 is indicated by an ~ 20 percent rise in the concentration of CO_2 in the atmosphere from 310 ppm in 1958 when measurements were begun on the summit of Mauna Loa, Hawaii to 370 ppm at the same site in 1999. According to glacial records the level of CO_2 in the earth's atmosphere has been relatively constant in the recent past, so any change can be seen as unusual if not related to a large natural event such as widespread volcanism or fire. Thus, this change in CO_2 levels must be the result of human action.

On a human level, a change of 1°F is not very large and can even be thought of as a good thing. What needs to be taken into consideration, though, is that a change of this magnitude means that less snow will fall in the mountains, flowers will bloom a week earlier, and fewer salmon will survive their migration to the ocean.   To the natural balance of the Columbia River Basin a change of 1°F signals the beginnings of a radical shift in the way the basin operates. This change is not quick or very noticeable on a human time scale without thorough investigation, but is set to affect the biota, river, and human usage of the Columbia River Basin in the decades and centuries to come.

The Columbia River is a snow-melt river fed in the winter by rain fall and run-off from lower elevations and in the spring and summer experiences an elevated flow due to rain fall and the melting of the snow pack at higher altitudes. This annual peak flow cycle is dependent on the amount of snow that fell during the winter and the amount of precipitation that falls as rain year round. The factor that affects these precipitation patterns most is the temperature of the atmosphere. Changes to this cycle due to global warming and related climate changes in the Columbia River Basin have been the focus of several climate prediction models (Lettenmaier, Hamlet, Peterson, Regonda) over the last 10 years.

The basic premise of these studies is to use existing data about the Columbia River Basin to model climate and river flow patterns during the next 50 to 100 years, taking into account the effects of global warming and other emergent conditions in the basin. The conclusions drawn by each of these studies is remarkably similar to the others.

Though the details vary by degrees, the overall conclusion of each of these studies is that in the next century the flow pattern of the Columbia River will be radically altered. The river will be transformed from a primarily snow-melt fed river to one supported by a mix of rainfall and diminished snow-melt. This is caused by an increase in temperatures year round such that the snow pack will be diminished and melt earlier, there will be more winter rain, and the region as a whole will become dryer that it is today. The increase in winter rain (which would normally fall as snow) will lead to increased winter flow of the Columbia River and a weaker snow-melt increase during the spring and summer. This will serve to even out the flow cycle of the river, but is far from ideal for both the ecosystem and human used of the river.

The diminishing precipitation predicted by these models coupled with the changed flow cycle raises the question not only of how the river will flow but if it will flow. According to Hamlet et al. the first change that will be seen is the seasonal shift in snow-melt flow within 25 years followed by diminishing total water volume and river flow observable 50 years from now. At 95 years from present the river is predicted to be unable to support human activity, which means that the amount of water will not be sufficient for navigation, power generation, or recreation. Although these projections are based on mathematical models of the basin, the implications of what is being said are concerning. If these things were to occur the existence of the river is already threatened.

If the river is threatened, the ecosystem that it supports is also in danger. The web of life that the Columbia River Basin harbors is too complex to analyze in its entirety, but looking at how climate global warming will potentially affect some of the basin's native species provides a good example. Thought there are a number of invasive species in the basin these are usually hearty generalists that survive in a wide range of climates. The endemic species of the basin do not universally share these characteristics. An experiment to see how an endemic species fares under projected global warming conditions was performed by Moore et al. in 1998 looking at the Chelan rockmat. The rockmat is endemic to the Hanford Reach area and during this experiment was subjected to global warming projected day/night temperature cycles. Although the plant continued to survive, its rate of growth and photosynthetic activity was greatly diminished compared to controls under normal condition. The plant failed to adapt to the changed temperature regime. This was a small scale study over the course of 6 months that implies that if the rockmat and endemic plant species in general are to continue to survive, genetic and adaptive changes must occur in the next 100 years.

Animals faced with changing conditions usually have the choice to move elsewhere to a more suitable habitat, but this is not the case with some of the endemic inhabitants of the Columbia River Basin. The salmonid species of the basin are already diminished and under pressure from human and environmental threats. Salmonids are extremely sensitive to changes in water temperature and flow rates as these factors guide their migration and mating cycles. They can survive only within a relatively narrow water temperature range which evolutionary processes have adapted the fish to handle. Increasing atmospheric temperature implies that the water temperature of the basin will rise accordingly, threatening the salmonids. Peterson and Kitchell discovered that it is not only the temperature change that threatens the fish, but also what that same change in water temperature has the potential to do with salmonids’ predators. It was found that under elevated water temperature conditions the northern pikeminnow would increase in size considerably such that it become a more voracious and effective predator of salmonid smolts migrating to the ocean. This would lead to further decreases in the number of salmonids surviving long enough to making it into the ocean. This could be disastrous for an already diminished species. This is just one small example of how changing the temperature a few degrees could result in the endangerment of an endemic animal species.

The dumping of toxic materials and other environmental problems are generally considered to affect the river negatively, but the environmental problems in the basin do not all have a negative impact when it comes to global warming. The logging of the basin's forests has created large open places that have a number of effects on the hydrology of the Columbia River as it relates to changing climate patterns. Runoff due to deforestation has usually been construed as a negative byproduct of logging, but under a changing global climate the fact that water will not be retained by the forest and surrounding is good news for the river in the short term as transpiration is reduced.

In winter, clearcuts essentially become frozen reservoirs that will be released into the Columbia River in the spring to maintain the snow-melt driven peak spring flow. This is important when considering that climate models predict a lower level of overall precipitation and drastically reduced snow fall for the Basin in the next century as temperatures increase (Hamlet and Lettenmaier). Large snow fields also act to cool the surrounding area and atmosphere due to a higher degree of reflected solar radiation compared to a forested area. This allows for more snow to accumulate relative to forested areas and hence more runoff. During spring and summer months the clearcuts act as semiarid regions within the forest that do not hold moisture in the soil well compared to forested areas and do not have large amounts of evapotranspiration occurring. This means that most of the water is either run-off the land or evaporates, but a larger portion of the water is running off compared to forested areas. So the total water running off into the river is increased. These effects will help artificially maintain the river flow in the short term, but the effects of seasonal shifting and reduced total precipitation will eventually mean that the river will suffer reduced flows.

The dams on the main stem of the Columbia River and its tributaries could potentially play an even greater role in the regulation of water than they do now if in the future the Columbia River Basin begins to receive less and less precipitation. Already having in place a system of water catchment facilities could facilitate the short term maintenance of river flow, but more importantly provide a source of water for the population centers and industry within the basin. In the long run and under the worse case scenario the dams would no longer serve effectively to generate electricity or serve as reservoirs due to lack of water because of upstream use similar to what has occurred in the Colorado River Basin. It would be a dire situation indeed if the at some point the Columbia River stopped flowing to the Pacific Ocean. This has not been predicted to occur in the foreseeable future, but it is important to keep in mind that the effects of climate change function on many levels such that unexpected situation can arise suddenly.

In January 2005 Regonda et al. published “Seasonal Cycle Shifts in Hydroclimatology over the Western United States” in the *Journal of Climate*. This paper is significant because unlike the papers previously mentioned here on climate change modeling this paper deals with the real situation as it is today. It was predicted in 1999 and in the following years that there would be an observable shift in the timing of the spring snow-melt event in the Columbia River Basin (Hamlet and Lettenmaier) resulting in an earlier onset of peak flows. What was observed in looking at data from 1950-1999 was that there has indeed been a trend toward an earlier spring flow brought about by slightly higher temperatures earlier in the year. It must be emphasized that these changes were small, but they begin the validation of climate prediction models in helping to understand the future condition of the Columbia River Basin.

That prediction has become reality in this situation is most distressing. Seeing the potential effects to the river, the ecosystem, and human beings one must wonder what it is that can be done. In all probability many species of plant and animal will go extinct, the river will no longer support the biological and human burden placed upon it, and some new system will emerge different from what came before. Looking at the possibility that the whole Columbia River Basin is threatened by something that has only recently been observed and measured leaves one with a sense of helplessness. The process of global warming that has been set off by the activity of human beings is staggering. A phenomenon that can change the temperature of the entire planet and continue to do so into the foreseeable future is beyond the dams, beyond the pollution, and is beyond immediate human intervention. It is not something we can knock down or dredge up, but in the long term changes can be made.

It is important to remember that although this paper focuses on only the effect of global warming on the Columbia River that this problem will occur around this country (Lettenmaier et al.) and world wide. The tundra in the northern Arctic is already melting, glaciers are retreating around the world, migratory animals are changing patterns unchanged in hundreds of thousands of years, and plants are expanding their ranges further northward. This is truly a global problem with global solutions. The implementation of the Kyoto Protocol is a good first step but in order to reverse the damage done much more needs to occur. A decrease in the use of fossil fuels and the release of greenhouse gases into the atmosphere is also needed. The ultimate solution is to return the planet to the way it was before humans began intervening, but that is a goal that can only be achieved through long term vision and planning. It will not be until the whole of the human race realizes that we are all in this together and that a potential catastrophe is slowly creeping up faster and faster towards us that we take effective action. In this way it will not be asteroid or tectonic disruption that stirs us to action, but the rising mercury of a thermometer.

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