Chapter 5
Physical Properties of the Water in Chilko-Chilcotin River System

BRETT WINTERS

DEPARTMENT OF ENVIRONMENTAL TOXICOLOGY
UNIVERSITY OF CALIFORNIA, DAVIS, CA 95616
BRWINTERS@*UCDAVIS.EDU*

Abstract

The physical properties of water are a vital link between the geologic features of the Chilko-Chilcotin River (CCR) system and its ecosystem. However, information regarding water quality of specific importance to sockeye salmon and other fish was rarely regional-specific to the Chilko watershed. A conceptual model is presented (FIG 1 below) to help forecast what to expect of water quality in the CCR, and its role within the aquatic ecosystem. The drivers shown below (climate, human impacts and topographic features) either directly or indirectly control the properties of water in the system: turbidity, dissolved oxygen and nutrients, and water temperature. A majority of the information currently available on these properties in the Chilko-Chilcotin watershed focused solely on Chilko Lake, rather than the CCR. While Chilko Lake is a significant factor in water quality of the Chilko River, the characteristics of the river change drastically after the confluence with the Taseko River. Trends of similar nearby systems are used to make up for this data gap and conceptualize outcomes of water quality, which will have substantial impacts on various physical and biological aspects of the CCR system.

Introduction

The Chilko-Chilcotin River (CCR) system, a tributary of the Fraser River of Central Interior British Columbia, is an exceptionally important stream for sockeye salmon (*Oncorhynchus nerka*). While numerous factors contribute to the success of *O. Nerka* stocks, water quality characteristics such as temperature, dissolved oxygen, turbidity and nutrient levels are the primary determinants in their success in the freshwater environment. Water quality also affects insect life, resident fishes, macrophytes and mammals. Topographic features, climate and human impacts, referred to here as drivers, primarily dictate water quality in the CCR system. The links between these drivers and water quality are rarely well defined or well studied in the Chilko-Chilcotin system. In the conceptual model, the intermediate outcomes are not drivers in themselves, but provide indirect pathways for the drivers to interact with the final outcomes, and eventually to O. *Nerka*. The intermediate outcomes are glacial activity, climate change, and forest alteration. In this conceptual model, there is great uncertainty surrounding the effects of global climate change, and how this may

impact the final outcomes. Climate change interacts with both of the other intermediates. The final outcomes for this sub-model are turbidity, dissolved oxygen and nutrients, temperature, which all eventually impact primary productivity and habitat availability for invertebrates and fish.

Drivers

Climate

Climate of the Chilko-Chilcotin watershed heavily impacts the four major aspects of water quality, albeit through different mechanisms. The cold past climate resulted in formation of glaciers which, along with snowmelt, provide steady runoff of cold water into the two main headwater lakes, the Chilko and Taseko (Burley, in this volume). Glaciers also heavily eroded much of the watershed surface, forming glacial till (Austin, in this volume). Not only does the weather directly cool headwater lakes and the CCR system, but winds also increase upwelling of colder water in the headwater lakes, specifically the Chilko (Bradford, Pyper, & Shortreed, 2000). While a weak thermocline in Chilko lake does form in the summertime, the epilimnion is kept relatively cool due to the strong winds, which constantly mix the water column, bringing colder and denser water to the surface (Bradford, Pyper, & Shortreed, 2000). This mixing ensures that the temperature of water leaving Chilko lake and entering the CCR system exceeds 14° C (Bradford, Pyper, & Shortreed, 2000).

Topographic Features

Much of the Chilko Lake watershed is glacial till or covered by glaciers, and drains into the southern end of the lake through the Edmond River. The final 20 kilometers of the Edmond River has a very low gradient, and splits and braids before entering Chilko Lake (Desloges, & Gilbert, 1998). The anabranched characteristics of Edmond River allows for storage of fine-grain sediments. The Edmond River and Ramose Creek meet in a wide valley with a very low gradient, where a delta-like fan allows for storage of coarser sediments such as gravel and sand (Desloges, & Gilbert, 1998). The settling of smaller suspended particles is also likely due to the exceptional size and depth of the lake relative to the catchment size. The residence time of water in Chilko Lake is approximately 13 years, giving sediments time to settle out of water column before entering the CCR (Burley, in this volume). The watershed of Taseko Lake, the other primary headwater lake, has similar geologic features as Chilko Lake. However, Taseko Lake is much shallower, and has a much shorter residence time, which prevents suspended solids from settling out of the water column before entering the CCR system (Burley, in this volume). Past the Chilko-Chilcotin confluence, hillslope erosion will likely affect water quality (Selander, in the volume).

The relatively high gradient of Chilko River in Lava canyon may have an impact on dissolved oxygen (DO) concentration due to aeration of water caused by rapids. While dissolved oxygen is primarily dependent on water temperature, the aeration may slightly affect DO concentration.

Human impacts

In the late 1980's, Chilko Lake was artificially fertilized with phosphorus and nitrogen to test whether this would increase the size and survival rate of juvenile sockeye. Due to the increased food availability, juvenile sockeye were significantly larger when leaving the lake and had a higher survivability rate (Bradford, Pyper, & Shortreed, 2000). In the future, lakes with dwindling salmon returns may be artificially fertilized to replace nutrients that were originally introduced by the spawning salmon.

With an exception to the artificial fertilization of Chilko Lake in the late 1980's, humans have had little direct impact on the upper reaches of the CCR system. However, there is increasing evidence that human-induced climate change may adversely affect regions such as the upper parts of CCR system. The potential effects of climate change will be discussed later in the "Intermediate Outcomes" section.

Prior to the confluence with the Chilko River, the Chilcotin River passes near farming and ranching properties. While the significance and magnitude of ranching and agriculture on water quality remain to be seen, there is potential for runoff to increase nutrient levels, which could also increase turbidity and temperature. In all likelihood, the effects of agricultural land on turbidity will not be noticeable due to the overwhelming impact of suspended sediment from the Taseko River.

Intermediate Outcomes

Climate Change, Glacial, and Forest Alteration

In recent decades, there has been a growing concern on the potential effects of climate change on the region, and how this might affect the CCR ecosystem. Models of the CCR basin have shown a potential atmospheric temperature change between 2.5-4° C in coming decades (Henderson et al., 1992). Climate change has led to a global reduction in glaciers, including those within the Chilko Lake watershed. If these glaciers disappear, the potential effects on turbidity of the lake, and hence the river, are unknown. In combination with rising atmospheric temperatures, more rain may fall on previously unexposed glacial till. If this till has high levels of fine particulate matter, it may eventually lead to higher suspended sediments in the CCR though runoff. In addition, climate change would directly warm both main headwater lakes and rivers, and may decrease the amount of cold snow and glacial runoff that normally cools both lakes (Rousse, et al., 1997). If the lake temperatures increase, the dissolved oxygen concentration would fall. This may be an important factor in Taseko Lake. Since Taseko Lake is relatively shallow and small, it would be vulnerable to potential temperature increases. However the size and depth of Chilko Lake would most likely mitigate possible temperature increases in the upper reaches of the Chilko River.

Climate change may also have led to the spread of the mountain pine beetle (MPB) into areas previously uninhabited due to winter temperatures (Carroll, et al., 2007). An infestation of MPB combined with salvage logging in the CCR watershed would lead to reduced water use and storage along with destabilized topsoil, which increases susceptibility to erosion (Amman, & Schmitz, 1988). Death of trees surrounding Chilko River and its tributaries can also decrease shading of the river, which may lead to warmer water temperatures (Larson, & Larson, 1996). If MPB increases suspended sediment in the Chilko River, it may also be responsible for higher water temperatures due to the ability of the water to absorb more heat from sunlight. The extent of potential of the MPB to alter turbidity is largely dependent on the susceptibility of trees surrounding the CCR system (Brown & Schreier, 2009).

Final Outcomes

Turbidity

Turbidity is a measurement of how well light passes through water. A more turbid system is one in which light is unable to penetrate as far into the water column. The level of turbidity is important to anadromous fish, resident fish and aquatic invertebrates. High levels of suspended sediment can interrupt filtering apparatuses of collector filterers, which may lead to changes in the insect assemblage below the confluence of the Chilko and Taseko Rivers (Corline, in this volume). In salmon, excess turbidity increases the hormone cortisol, which is a biomarker of stress in salmon (Redding, *e*t. al., 1987). Juvenile salmon exposed to high levels of turbidity are also at greater risk for infection (Redding, et. al., 1987). If suspended sediments settles in salmon redds, it may reduce water flow, which reduces available oxygen to salmon eggs (Greig, et al., 2005). More turbid water is also able to absorb more sunlight, leading to higher temperatures. However, slightly turbid waters can be beneficial to salmon and resident fish by providing cover from predators. While in some systems, humans play a pivotal role in determining turbidity, in the CCR system the level of clarity will be primarily dictated by suspended sediment in runoff and phytoplankton activity. Chilko Lake has exceptionally low suspended sediment and plankton growth (Desloges, & Gilbert, 1998). The turbidity seen in the CCR is largely attributable to the Taseko River, which flows from the very turbid Taseko Lakes (Burley, in this volume). Once the Taseko joins the Chilko River, the turbidity of the system is increased drastically.

Temperature

Temperature is arguably the most important factor for spawning salmon and resident fish, and is also at the greatest risk of being altered over the next century. Salmon typically need cold, clear water for successful spawning, and may actually be adapted to migrate best in temperatures that fit their natal stream (English et al., 2005). The relatively cold epilimnion is important for juvenile salmon feeding in the lake because most of the feeding is spent close to the surface. If the epilimnion temperature is too high, the fish may have to go deeper to find cooler water (Barraclough &Robinson, 1972). Once the water leaves Chilko Lake, it will likely continue to increase in temperature as the river lowers in elevation. The Chilcotin River will likely introduce warmer water to the system, which will not affect important sockeye salmon redds, but may be important to salmon as they make their journey to the upper part of the Chilko river. Due to the small flows of the Chilcotin relative to the Chilko River, the warmer water of the Chilcotin will likely have a limited effect on the water temperature below the Chilko-Chilcotin confluence. Below the Chilko-Chilcotin confluence, the river enters a desert environment, where air temperatures will be elevated. This will lead to increased water temperatures as the river continues to descend in altitude.

In the past twenty years, water temperatures have increased 2° in the CCR system (Hume, 2011). The Chilko river *O. Nerka* stock has been illustrated to be particularly resilient to change, but if water temperatures increase significantly, there may be higher rates of mortality in spawning fish (Hoff, in this volume). Warmer water simultaneously increases rate of metabolism in fish and reduces amount of dissolved oxygen, making the spawning journey even more difficult.

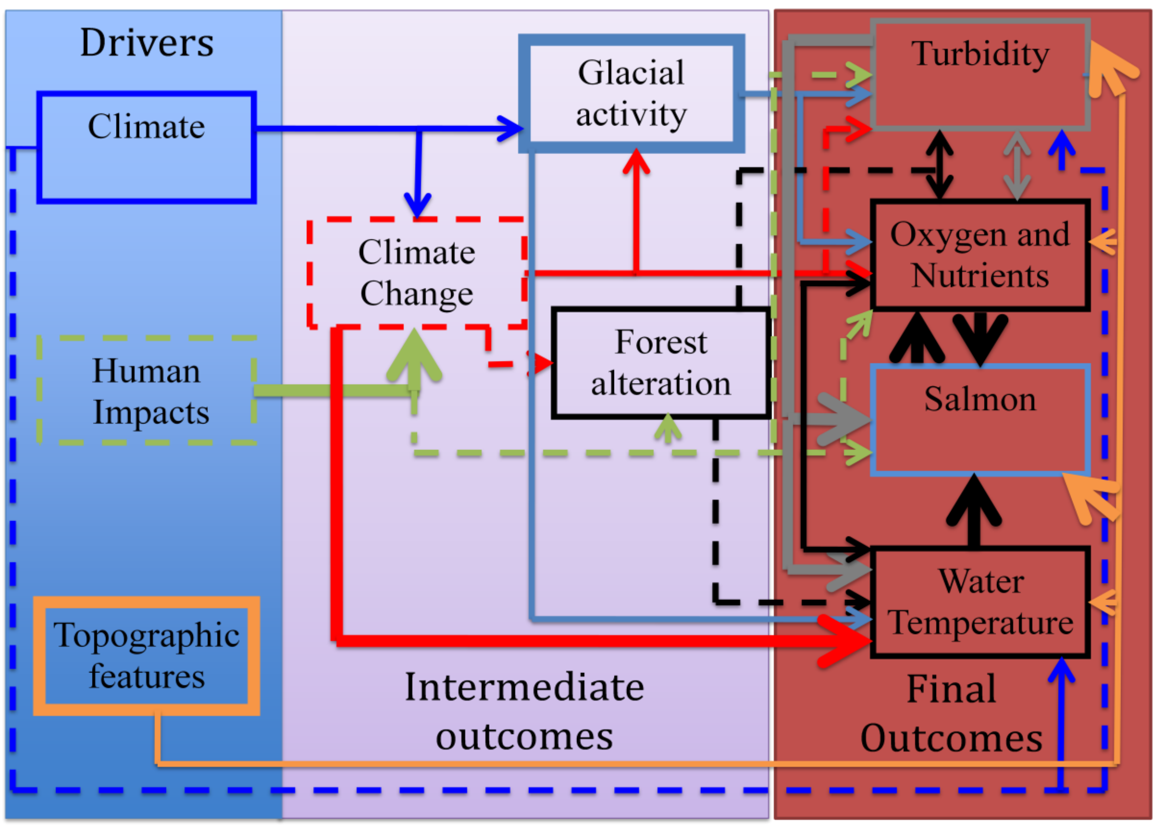
Nutrients and Dissolved Oxygen

Nutrients are vital to an aquatic ecosystem because they affect the rate of primary productivity, which in turn affects the amount of food for juvenile *O. Nerka* and aquatic organisms. Population of zooplankton and aquatic insects, which salmon and resident fish depend on for food, thrive when phytoplankton activity increases due to higher nutrient levels (Bradford, Pyper, & Shortreed, 2000). Much of the nutrients in the CCR system are introduced when salmon spawn and die, leaving the nutrients accumulated from the ocean in the river system (Naiman et al., 2002). However Chilko Lake is still exceptionally oligotrophic and is depleted in both phosphorus and nitrogen, meaning there is little primary productivity (Bradford, Pyper, & Shortreed, 2000).

Dissolved oxygen is extremely important to resident fishes, aquatic insects and spawning salmon. Oxygen is dissolved by aeration (mixing through rapid movement) and diffusion at the surface. The amount of oxygen that water can effectively hold is directly related to water temperature. Colder water is able to dissolve more oxygen than warmer water. Dissolved oxygen (DO) may also be indirectly influenced by excess nutrients, which can produce algal blooms, which may lead water to become oxygen deprived in what is called a "dead zone". However, the CCR system is extremely nutrient limited, so algal blooms are not expected, even in areas with high agricultural runoff. Because dissolved oxygen is directly related to water temperature, the greatest level of DO will likely be found in the upper reaches of the Chilko River. Below the Chilko-Chilctoin confluence, we should expect to see lowered DO concentration due to the warmer water.

Conceptual Model

Fig. 1



Summary

The physical properties of water in the CCR are paramount to the configuration and health of the aquatic ecosystem. In the conceptual model, climate, human impacts and topographic features primarily dictate the physical properties of water in the CCR system. The primary drivers act heavily on Taseko and Chilko Lakes, the main headwater lakes. Due to the limited number of sizeable tributaries, the physical properties of water leaving the headwater lakes determines water quality throughout the CCR system. The primary drivers may impact water quality either directly or through intermediate outcomes. Characteristics of water quality such as temperature, dissolved oxygen and turbidity will likely become increasingly affected by intermediate outcomes as climate change will play a growing role in the coming decades within the conceptual model. The effects of climate change on water quality in the CCR system, and how this will affect the anadromous fish, resident fish and insect assemblage, remains unclear.

References

Amman, G.D., & Schmitz, R.F. (1988). Mountain pine beetle: lodgepole pine interactions and strategies for reducing tree losses. AMBIO, 15(1), 62-68.

Barraclough, W. E., and D. Robinson. 1972. The fertilization of Great Central Lake. III. Effect on juvenile sockeye salmon. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 70:37-48.

Bisson, P.A.; Bilby, R.E. 1982. Avoidance of suspended sediment by juvenile coho salmon.

Bradford, M.J., Pyper, B.J., & Shortreed, K.S. (2000). Biological responses of sockeye salmon to the fertilization of chilko lake, a large lake in the interior of british columbia.

Brown, S.Y., & Schreier, H. Faculty of Land and Food Systems University of British Columbia, Faculty of Land and Food Systems. (2009). Water quantity and quality related to rates of pine beetle infestation and salvage logging: a regional comparison. Vancouver, Canada:

Carroll, Allan L.; Taylor, Steve W.; Regniere, Jacques; and Safranyik, Les, "Effect of climate change on range expansion by the mountain pine beetle in British Columbia" (2003). The Bark Beetles, Fuels, and Fire Bibliography. Paper 195

Desloges, J.R., & Gilbert, R. (1998). Sedimentation in chilko lake: a record of the geomorphic environment of the eastern coast mountains of british columbia, canada. Geomorphology, 25(1-2), 75-91.

English K.K., W.R. Koski, C. Sliwinski, A. Blakley, A. Cass, and J.C. Woodey. 2005. Migration timing and river survival of late-run Fraser River sockeye salmon estimated using radiotelemetry techniques. Trans Am Fish Soc 134:1342–1365.

Greig, S.M., Sear, D.A., & Carling, P.A. (2005). The impact of fine sediment accumulation on the survival of incubating salmon progeny: implications for sediment management. Science of the Total Environment, 344(1-3), 241-258.

Henderson, M.A., Levy, D.A., and Stockner, J.G. 1992. Probable consequences of climate change on freshwater production of Adams River sockeye salmon. GeoJournal, 28: 51.59.

Hume, M. (2011, March 8). Rising temperature in fraser river affecting salmon population. Globe and Mail

Hume JMB, Shortreed KS, Morton KF. 1996. Juvenile sockeye Pacific Salmon, Nutrients, and Ecosystem Dynamics 415 rearing capacity of three lakes in the Fraser River system. Fish Aqua Sci 53:719–33.

Larson, L.L., & Larson, S.L. (1996). Riparian shade and stream temperature: a perspective. Rangelands, 18(4), 149-152.

Martins EG, Hinch SG, Patterson DA, Hague MJ, Cooke SJ, Miller KM, Lapointe MF, English KK, Farrell AP. 2011. Effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River sockeye salmon (Oncorhynchus nerka). Glob. Change Biol. 17(1): 99-114.

NAIMAN, R. J., BILBY, R. E., SCHINDLER, D.E. & HELFIELD, J.M. (2002a). Pacific salmon, nutrients, and the dynamics of freshwater ecosystems. Ecosystems 5, 399–417.

Redding, J.M., Schreck, C.B., and Everest, F.H. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Trans. Am. Fish. Soc. 116: 737–744.

Rouse,W. R., Douglas, M., Hecky, R. E., Hershey, A., Kling, G.W., Lesack, L., Marsh, P., McDonald, M., Nicholson, B., Roulet, N., and Smol, J.: 1997, 'Effects of climate change on the fresh waters of arctic and subarctic North America', Hydrol. Process. 11, 873–902.