Chapter 8
Invertebrate Productivity of the Chilko-Chilcotin River System

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Abstract

Research concerning the aquatic invertebrate assemblage and secondary productivity of the Chilko-Chilcotin River is sparse. To help predict the possible insect assemblage and secondary production of the river, a conceptual model was assembled. This model will be an integral part of a larger model concerned with the physical and biological processes of the Chilko-Chilcotin River. Trophic, physical, and chemical drivers are accounted for within the model. These drivers will affect the range and proportion of functional feeding groups (FFGs), and are an important indicator of chironomid dominance or sensitive taxa depression. FFGs, sensitive taxa and chironomid dominance will help predict the insect assemblage and secondary productivity of key areas in the Chilko-Chilcotin River.

Introduction

The Chilko-Chilcotin River is located in the interior of British Columbia, Canada and is a tributary of the Fraser River. From the outlet of Chilko Lake, to its confluence with the Fraser River, the Chilko-Chilcotin River varies in habitat. This variation in habitat will influence the organisms within the system. Although there is abundant literature on the Chilko-Chilcotin fish assemblage, there is little information on aquatic invertebrates. Aquatic invertebrates play an essential role in a functioning river ecosystem. Not only do they act as food resources for fish, but they are also important in nutrient cycling between terrestrial and aquatic systems. Due to the life history traits of aquatic invertebrates, many can be put in designations such as functional feeding groups or sensitive taxa. Similarly, the insect family chironomidae (non-biting midges) is ubiquitous in aquatic ecosystems and plays a major role in its functioning. Feeding group and sensitivity designations and chironomids are influenced by certain habitat parameters within the stream. This model will incorporate key drivers of the aquatic insect assemblage to help spatially predict the insect secondary productivity within the Chilko-Chilcotin River.

CONCEPTUAL MODEL

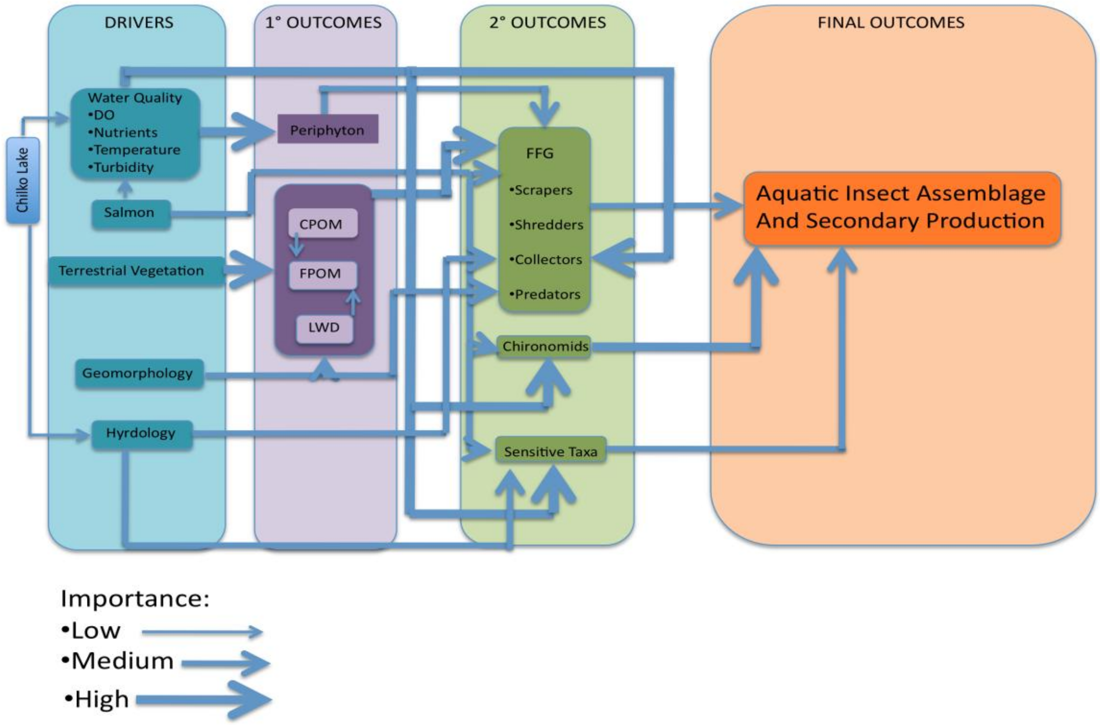

FIGURE 8.1: Aquatic invertebrates provide forage for fish and are an important link between terrestrial and aquatic ecosystems. By understanding the drivers of the aquatic insect community within the Chilko-Chilcotin River, broad estimates of secondary productivity on a spatial scale can be made. This model, which attempts to predict the invertebrate assemblage throughout the Chilko-Chilcotin River system, takes into account the biological, chemical, and physical attributes of the system. Characteristics of the system will be placed into drivers: water quality, Chilko Lake, geomorphology, hydrology, terrestrial vegetation, and salmon. Drivers will directly affect primary and secondary outcomes. The primary outcomes are largely invertebrate food and habitat resources, such as, periphyton, coarse particulate organic matter, fine particulate organic matter, and large woody debris. Secondary outcomes include the insect functional feeding groups (FFG) and the abundance of chironomids and sensitive taxa. Primary and secondary outcomes influence the aquatic insect assemblage, and, in turn, the secondary productivity of the system.

Drivers

Chilko Lake:

Chilko Lake provides important nursery habitat for juvenile sockeye salmon (Hoff, Ch. 11; Jauregui, ch. 10). The lake is host to a zooplankton community of copepods and cladocerans (Mortan and MacLellan, 1992). Earlier research has found that the ratio of copepods to cladocerans in Chilko Lake is 1:1 (Mortan and MacLellan, 1992). The abundance of zooplankton is heavily influenced by the availability of phytoplankton and predation (Horne and Goldman, 1994). Mixing within the lake will increase nutrient levels in the upper water column allowing for increased phytoplankton growth (Horne and Goldman, 1994). This in turn will increase zooplankton abundances (Horne and Goldman, 1994). Chilko Lake will influence the water quality and hydrology of the Chilko River (Winters ch. 5; Burley, ch. 3).

Water Quality:

Water quality (i.e. turbidity, dissolved oxygen, nutrients, and temperature) within a system will be important for aquatic invertebrates. Aquatic insects have long been used as indicators of degraded water quality. Many species, or even entire families, have aversions to polluted water or suspended sediment. The latter will be of greatest importance in the Chilko-Chilcotin River after its confluence with the Taseko River (Winters, ch. 5). Sediments from the Taseko River may negatively affect gill-breathing insects (Merritt and Cummins, 2006; Lenat, 1984). FFGs may be directly or indirectly affected by sediment. Directly, sediments may clog substrates by accumulating in the interstitial spaces between grains. A lack of habitat may leave invertebrates exposed to predation and drift, as well as deficient in food resources (Rosenberg and Resh, 1984). Covering of the substrates may decrease periphyton growth, the main food resource for scraping insects. In slower depositional areas, sediment may cover CPOM and FPOM that has collected, making it unavailable to aquatic insects (Rempel et al, 2000). Insects that use filtering apparatuses to feed on FPOM in suspension may also suffer negative impacts, as sediment may interfere with their filters or nets. Suspended sediment will decrease light attenuation, which will again lead to a decrease in periphyton production (Rosenberg and Resh, 1984). Although sediment has negative consequences for many taxa, tolerant taxa can persist in sediment-laden areas. Within the Chilko-Chilcotin River, sediment will most likely have the largest effect on the aquatic invertebrate community, however, other water quality parameters will be significant.

Dissolved oxygen (DO) and nutrients are important facets of water quality for aquatic invertebrates. The majority of invertebrates within the Chilko-Chilcotin River will respire by obtaining DO from the water. Sufficient concentrations of dissolved oxygen will be essential for the respiration of most of the aquatic invertebrates; however, some aquatic insects such as chironomid midges have the ability to survive in areas with low DO concentrations (Merritt and Cummins, 2006). Being cold and turbulent, the Chilko-Chilcotin River will most likely have ample DO concentrations for invertebrate respiration, but DO concentrations may decrease after confluences with tributaries containing agricultural runoff (Winters, ch. 5). Nutrients will indirectly affect aquatic insects. Increased nutrient levels may bolster primary production increasing the abundance of invertebrates. Conversely extreme nutrient loads may lead to eutrophication, which can decrease DO levels at night (due to algal respiration) or through the microbial respiration of decaying algal material (Rosenberg and Resh, 1984). This may be important at the confluence of the Chilcotin River with the Chilko River, as the Chilcotin drains agricultural lands, and may have elevated nutrient levels (Winters, ch. 5). Salmon carcasses may also increase nutrient levels in spawning areas, increasing periphyton growth (Kiernan et al, 2010).

The life histories of aquatic invertebrates are heavily influence by temperature. Temperature can constrain growth, development, reproduction, and food resources (Merritt and Cummins, 2006). Aquatic invertebrates have a large spectrum of temperature tolerances, from - 20 °C to nearly 50 ° C (Merritt and Cummins, 2006). Most aquatic invertebrates cannot persist in water temperatures greater than 30 ° C (Merritt and Cummins, 2006). Nevertheless, a large number of aquatic insects are adapted to cold water conditions, and are capable of growing and develop in water at 0 ° C (Merritt and Cummins, 2006). Below freezing, most aquatic taxa or their eggs enter a state of diapause, or a resting state, until temperatures increase enough for activity (Merritt and Cummins, 2006). Water temperatures within the Chilko-Chilcotin River are expected to increase as the river decreases in elevation.

Spawning Salmon and Carcasses:

The Chilko-Chilcotin River is known for one of the largest sockeye salmon runs in the world (Hoff ch. 11; Jauregui, ch. 10). Undoubtedly, the presence of sockeye salmon will have a significant effect on the aquatic insects of the river system. The largest and most noticeable effect on aquatic insects may be seen directly where salmon are spawning and subsequently dying. In the process of reproduction and senescence, sockeye salmon will have both beneficial and negative impacts on the aquatic insect community. When adult salmon return to their natal streams to spawn they bring with them marine derived nutrients (MDN) and resources from the ocean (Naiman et al, 2002). MDN may be especially important in oligotrophic systems such as the upper Chilko-Chilcotin River (Winter, ch. 5; Kiernan et al, 2010).

Salmon carcasses may also represent an important food resource for many aquatic insects (Chaloner and Wipfli, 2002, Naiman et al, 2002). However, it is questionable to what extent and proportion aquatic insects use salmon carcasses as a direct resource (Lessard and Merritt, 2006). In the process of excavating their redds, salmon may disturb the benthos to such a degree that much of the aquatic insect taxa is lost to passive drift (Lessard and Merritt, 2006). This leaves the carcasses only accessible to aquatic insects that can re-colonize the stream in time to capitalize on the resource (Lessard and Merritt, 2006). Such insects would most likely be chironomids due to their advantageous life history traits (Merritt and Cummins, 2006). Nevertheless, in experimental treatment streams it has been found that salmon carcasses increase invertebrate biomass and diversity (Kiernan et al, 2010). Collector gatherers may be most strongly influenced by the presence of salmon carcasses, as they are the only FFG seen to increase in abundance or utilize salmon carcasses directly (Lessard and Merritt, 2006; Kiernan et al, 2010).

Terrestrial Vegetation:

Aquatic insects link terrestrial primary production with higher trophic levels within the stream. The amount and type of inputs from the terrestrial environment are extremely important in predicting the proportions of aquatic insect functional feeding groups (Vannote et al, 1980). Terrestrial inputs will directly or indirectly affect all of the functional feeding groups in the Chilko-Chilcotin River . Riparian vegetation flanking the Chilko-Chilcotin River and island vegetation will contribute resources to the aquatic system. Coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM), and large woody debris (LWD), are derived from the terrestrial system and will themselves be important drivers of the invertebrate community.

Geomorphology:

The geomorphology of the stream will have implications for aquatic insects, especially in relation to habitat. For instance, substrate provides areas of refuge for aquatic insects (Rempel et al, 2000). Similarly, substrate can affect FFGs, as it influences the deposition and retention of detritus and provides a stratum for periphyton growth (Rempel et al, 2000; Rosenberg and Resh, 1984). Thus, substrate size will have the greatest affect on collector gatherers, scrapers and shredders (Rempel et al, 2000). Larger mean grain size often increases insect diversity as more microhabitats are created due to increased heterogeneity of the benthos (Erman and Erman, 1984). The creation of additional microhabitats for aquatic insects may increase abundance, however, this has not been proven to be true for all cases (Erman and Erman, 1984). Characteristics of the substrate will also be important for aquatic insects. Roughness may have an affect on FFGs such as collector filterers who feed in the current (Rempel et al, 2000). The ability to physically grip or adhere to the substrate will be important for taxa such as hydropsychid caddisflies or heptageniid mayflies (Rempel et al, 2000).

Hydrology:

The hydrology of the Chilko-Chilcotin River will have numerous effects on the aquatic insect community. Peak flows can represent disturbances that may decrease insect abundance due to shifting bedload or displacement from the benthos (Rosenberg and Resh, 1984). Similarly, these large flows may scour much of the detritus retained in the sediments, which could negatively affect collecting insects and shredders. Insect densities are usually highest in areas where hydraulic stress is the lowest. This trend is probably due to the reduced risk of being lost into the current and increased resource deposition (Rempel et al., 2000). In larger rivers, taxa richness is the highest in areas of intermediate depth, with deeper water being dominated by chironomids (Rempel et al, 2000). Depending on substrate, deep water usually harbors the greatest amount of collector gathering insects (Rempel et al, 2000). Turbulent flow is needed for collector filtering insects, as they consume FPOM in suspension (Merritt and Klug, 1979).

PRIMARY OUTCOMES

Coarse Particulate Organic Matter:

Coarse particulate organic matter falls into two main categories, woody debris (branches, stems, logs) and non-woody debris (leaves, needles, flowers, etc.) (Cummins and Klug, 1979). Aquatic insects, for the most part utilize non-woody CPOM. Although it may superficially appear that shredding insects eat CPOM directly, they are actually eating the microorganisms (mostly fungi) that colonize its surfaces (Cummins and Klug, 1979). Due to the incessant actions of microorganism, shredding insects and current, CPOM is destine to be broken down in to smaller components such as FPOM, UPOM (ultrafine particulate organic matter), and DOM (dissolved organic matter) (Cummins and Klug, 1979). The amount of CPOM entering and being retained within certain areas of the stream will affect the abundance of shredding insects, and will also eventually affect the abundance of collecting insects when CPOM is broken down to FPOM (Vannote et al, 1980).

Large Woody Debris:

Large woody debris (LWD) will increase available habitat for aquatic invertebrates and influence their food resources. LWD may provide stable stratum for scraping insects to feed upon, or for hydropsychid caddisflies to build their nets (Collier and Halliday, 2000). The presence of LWD can change channel morphology, increasing depositional areas (Lemly and Hidlerbrand, 2000). By increasing depositional areas, more FPOM will be trapped, which will have a significant effect on collector gathering insects (Lemly and Hilderbrand, 2000; Collier and Halliday, 2000). LWD itself will produce FPOM as it decays; the state of decomposition will be important for invertebrate feeding groups (Collier and Halliday, 2000). Initially LWD is colonized by chironomids, but as the wood develops biofilm communities scrapers and collectors begin to colonize (Collier and Halliday, 2000). With sufficient decay, woody debris can be consumed by xylophagous invertebrates (McKie and Cranston, 2001; Collier and Halliday, 2000). Of the taxa that can potentially colonize woody debris, Tichopterans, Ephemeropterans, and Dipterans typically dominate (Collier and Halliday, 2000).

Periphyton:

Periphyton growth is typically influenced by light, nutrients, and substrate (Merritt and Klug, 1979). In the Chilko-Chilcotin River, sediment will most likely have the largest effect on periphyton growth. Sediment from the Taseko River's confluence with the Chilko-Chilcotin River will increase the suspended sediment load, and, thus, increase the turbidity of the water (Winters, ch. 5). Increased turbidity will decrease light attenuation, which will decrease photosynthesis and concurrently periphyton growth (Rosenberg and Resh, 1984). Sediment can clog and cover stream substrates covering periphyton and retard growth (Arkel et al, 2010). Periphyton growth may be bolstered by marine derived nutrients from decaying salmon carcasses (Niaman et al, 2002). Salmon carcasses may drive periphyton growth in spawning areas such as the outlet of Chilko Lake due to the low nutrient levels found in the lake (Winters, ch. 5). The abundance of scraping insects will be directly affected by the standing crop of periphyton, as it is their main food resource (Cummins and Klug, 1979).

Fine Particulate Organic Matter:

Fine particulate organic matter (FPOM) originates from both allochthonous and autochthonous sources. FPOM may directly enter the aquatic system from the terrestrial environment (Cummins and Klug, 1979). However, the greatest proportion of FPOM comes from the break down of CPOM and LWD. CPOM, as previously mentioned, eventually breaks down into FPOM due to biotic and abiotic processes (Vannote et al, 1980; Cummins and Klug, 1979). LWD will also increase the amount of FPOM within the river. As LWD decays it produces significant amounts of FPOM, increasing with age and degree of decomposition (Collier and Halliday, 2000). Periphyton, through its consumption and eventual senescence, will contribute to the pool of FPOM present (Klug and Cummins, 1979, Vannote et al, 1980). Frass or insect feces are considered to be a component of FPOM as well (Cummins and Klug, 1979). The amount of FPOM produced and retained within the environment will directly influence collecting insect abundance. Collecting insects that utilize FPOM will either retrieve FPOM from the water column (collector filterers) or consume depositional FPOM (collector gatherers).

SECONDARY OUTCOMES

All the drivers will directly or indirectly affect functional feeding groups, as each driver can alter the amount, quality, or type of food resources available to aquatic invertebrates. Some drivers will negatively affect invertebrates that are sensitive to certain environmental conditions, while tolerant invertebrates will not be affected. These tolerant taxa will most likely be dipterans, primarily in the family Chironomidae. All intermediate invertebrate outcomes will eventually influence the aquatic insect community assemblage and the secondary productivity of the stream.

Scraping Insects:

Areas conducive to biofilm growth will be favorable for scraping insects due to their obligatory use of periphyton. Such areas have less tree cover, are shallow or clear enough for light to reach the benthos, and have sufficient nutrients (Vannote et al, 1980; Cummins and Klug, 1979). LWD may provide a surface for periphyton growth; in such situations scraping insect abundance would be increased (Collier and Halliday, 2000). Scraping insects, depending on species, will utilize different components of periphyton. Some scrapers remove the entire section of biofilm from the surface of the substrate (Rosenberg and Resh, 1984), while other scrapers may graze upon particular components of periphyton, such as diatoms (Rosenberg and Resh, 1984).

Shredding Insects:

Shredding insect abundance will be greatly affected by the deposition and retention of CPOM, as this is their primary food resource. The greatest abundance of shredding insects are located within areas where CPOM inputs are high, such as around islands or areas of deposition.

Substrate that allows for the retention or adherence of CPOM will allow shredders to persist. LWD will increase depositional areas for CPOM, increasing shredder abundance; similarly shredders may utilize LWD in some situations. Suspended sediment of the Taseko will most likely have a negative affect on shredders by covering CPOM in depositional areas. It is possible that shredding insects may use salmon carcasses as a food resource (Naiman et al, 2002).

Gathering and Filtering Collectors:

FPOM deposition heavily influences collector gatherer abundance, while FPOM in suspension is crucial to collector filterer abundance. Collector gatherers may also retrieve detritus from the water column. The amount CPOM and LWD entering and retained in the stream may have a sizeable effect on the amount of FPOM within the stream, and, thus, the abundance of collectors. Places of high CPOM input, such as areas around islands, may increase collector abundance in the immediate vicinity of the island and further down stream. Collecting insects colonize LWD once there has been sufficient growth of algae and fungi (Collier and Halliday, 2000). Similarly, LWD provides stable habitat for net attachment for some collector filters (Collier and Halliday, 2000). Modification of channel morphology by LWD will create depositional areas for the retention of FPOM (Lenat and Hilderbrand, 2006). Depositional areas created by LWD will increase density and abundance of collector gatherers due to increased FPOM (Collier and Halliday, 2010). Salmon carcasses, as they break down, will provide detritus for collector gatherers, which can increase growth rates and, in some cases, abundance (Naiman et al, 2002; Chaloner and Wipfli, 2002; Kiernan et al, 2010). Collector gatherers, such as chironomids, have been noted to feed directly on salmon carcasses (Lessard and Merritt, 2006; Niaman et al, 2002). Sediment will have a large effect on both collector invertebrate guilds. Depositional sediment may infill interstitial spaces in the substrate where FPOM would be retained (Arkel et al, 2010). Suspended sediment may clog the nets or filtering apparatuses of collector filterers decreasing their abundance.

Predators:

Predators utilize other animals as food resources, and will be found through out the Chilko-Chilcotin River system. Invertebrate predators for the most part feed on other invertebrates (Cummins and Klug, 1979). However, large aquatic invertebrate predators may feed on small or larval fish (Rosenberg and Resh, 1984). All aquatic insect orders have predatory representatives (Rosenberg and Resh, 1984). Although invertebrate predators will have large effects on the evolution of life histories of other invertebrates and the community as a whole, their proportions do not usually change spatially down stream (Rosenberg and Resh, 1984; Vannote et al, 1980).

Chironomids:

Chironomids occur in high densities and diversity, and are thus an important component of most aquatic ecosystems. There are 1200 known species of chironomids found in the Neartic Region alone, with estimates up to 2000 species actually occurring (Merritt and Cummins, 2006). Chironomids are found in large ranges of pH, salinity, dissolved oxygen, water velocity, depth, primary productivity, and altitude, which is partly why they are most wide spread of all aquatic insect families (Merritt and Cummins, 2006). With such a wide spectrum of tolerances, it is not surprising that many chironomids are sediment tolerant and are used as indicators of sediment load in Europe and England (Merritt and Cummins, 2006). The sediment tolerance of some chironomids may make them the dominant aquatic invertebrate after the Chilko-Chilcotin River's confluence with the Taseko River. Chironomids are also trophically diverse with species within each FFG; however, many are considered collector gatherers (Merritt and Cummins, 2006). Thus all drivers that affect collector gatherers will be reasoned to affect chironomids within this model. The life cycles of chironomids, like their life histories, are diverse. Many species are multivoltine, having many generations within a season, which is advantageous in locations with short growing seasons. Multivoltinism also allows for rapid re-colonization of disturbed habitats and gives chironomids a high productive value (Merritt and Cummins, 2006).

Chironomids are often the most productive invertebrates within stream (Berg and Hellenthal, 1992). Secondary productivity is heavily influenced by chironomids, as they are multivoltine, have high total biomass, and are able to grow and colonize areas quickly (Berg and Hellenthal, 1992, Merritt and Cummins, 2006). In temperate streams it has been noted that 80% of the insect secondary production is due to chironomids (Berg and Hellenthal, 1992). This may be due to chironomids having an extremely high production to biomass ratio (P/B). P/B ratios are indicative of productivity, with most aquatic insect taxa having a P/B of around 10 (Malison and Baxter, 2010). Chironomids have P/B of 120 (Malison and Baxter, 2010). Salmon carcasses may increase chironomid abundance, as they can colonize and directly utilize the material (Kohler and Taki, 2010; Niaman et al, 2002; Chaloner and Wipfli, 2002). Detritus from decaying salmon may increase chironomid growth rates, increasing their productivity (Chaloner and Wipfli 2002). With a high productive capacity chironomids may be the greatest driver of secondary productivity and over shadow the contributions of the other invertebrates present.

Sensitive Taxa:

The term sensitive taxa can refer to many different aquatic insect sensitivities. In this model, insect intolerance to sediment and disturbance is the most important. Spawning salmon, in the creation of their redds, may disturb the benthos to such an extent that many insects could be lost to the current (Lessard and Merritt, 2006). For insects that can re-colonize quickly and regain population size by feeding on carcasses, this disturbance may not have a noticeable effect on their population (Lessard and Merritt, 2006). However, some taxa, which are not multivoltine or have slow growth rates, may not be able to re-colonize the area (Lessard and Merritt, 2006). It is probable that during spawning, sensitive insect abundance decreases, and remains depressed for subsequent weeks (Lessard and Merritt, 2006). Suspended sediment, like that found in the Taseko River, interferes with the gas exchange of aquatic insects (Merritt and Cummins, 2006). Areas with high levels of sediment have a significantly less sensitive gill breathing insects and lower taxa diversity (Lenat, 1984). It is reasonable to conclude that most of the abundant insect groups upstream of the Taseko confluence will not be seen after the confluence due to sediment and its interference with their gills.

FINAL OUTCOMES

Aquatic insect assemblage and secondary productivity*:*

The aquatic insect assemblage seen at different points within the river will be a reflection of FFGs and the abundance of chironomids and sensitive taxa. Functional feeding groups will allow us to visualize what insects may be present given certain habitat parameters. Although functional feeding group predictions do not indicate diversity, we can infer in areas where multiple functional feeding groups are accommodated for will have a greater variety of insects. Presence or absence of sensitive taxa will give insight to whether there will only be tolerant taxa, namely chironomids, or a larger array of invertebrates. Invertebrates, which are sensitive to disturbance, may be absent if there has recently been large peak flows, as this can lead to a shifting of the bedload and cause catastrophic drift. Areas with conditions conducive to insect success will have greater insect biomass. The insect assemblage as a whole will lend its self to the productivity of the stream. However, secondary productivity will rely on taxa specific characteristics. Chironomids, due to their life history traits, may be the greatest driver of secondary productivity on the Chilko-Chilcotin system.

UNCERTAINTIES

Uncertainties included the disturbance caused by spawning salmon, spatial effects of sediment, and the use of salmon carcasses by other functional feeding groups. The disturbance caused by spawning salmon and the detriment to benthic organisms has mainly been observed in Alaskan streams with extremely large salmon runs. The size of the run will be most important for the amount of disturbance. Because we cannot accurately predict the size of the runs, we cannot be certain of their effect on the benthos. Collector gatherers and chironomids are most strongly associated with salmon carcasses in nature. However, it is not known what other FFGs or invertebrates may be using salmon carcasses within this system. The effects of sediment on aquatic invertebrates are well known, but in our system it is not known for how long downstream sediment from the confluence with the Taseko will negatively impact invertebrates.

SUMMARY

The aquatic insect assemblage will vary spatially within the Chilko-Chilcotin River. Biological, physical, and chemical drivers will influence both primary and secondary outcomes. FFG proportions, sensitive taxa, and the dominance of chironomids will contribute to the invertebrate assemblage within the river. This model is a crucial link between physical and biological models, as well as a link between the terrestrial and aquatic systems. The insect secondary productivity will greatly affect both resident and anadromous fish. Although many of the linkages in this model are well understood, there are some key uncertainties.

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