Impacts of Sediment to Aquatic Habitats

How do salmonids cope with naturally occurring sediment?

Large rivers, such as the Fraser River, and small local tributaries are subject to different hydrological conditions (i.e. timing of peak flow, water temperatures, and sediment loads) due to their different catchment characteristics. For instance, the Fraser River is dominated by snow – melt, while local streams (i.e. Clayburn Creek, Marshall Creek, etc) are affected primarily by local meteorological conditions. Salmonids have adapted their life cycles to these varying conditions in order to avoid poor conditions. For instance, out-migration of fry and juvenile salmonids is of relatively short duration, and usually precedes peak flows associated with freshets in large rivers (Brown 2002). Throughout the more sensitive stages of their life cycle (i.e. fry and smolt), salmonids seek out clearer, lower velocity water; which is typically found in near-shore margins, tributaries, side-channels, and floodplain habitats (Rempel 1997, Bash et al 2001). During adult migration back to the natal streams, the adults are physiologically much more resilient to higher turbidity.

How does turbidity affect salmonids?

Sediment is a broad based pollutant affecting most aspects of the food chain of aquatic environments and all freshwater stages of the salmonid life cycle. Although sediment is generated naturally in streams, increases over natural levels usually have a detrimental impact. In small streams, effects are more pronounced since juvenile salmonids that remain in these streams are wholly dependant on their natal stream for meeting their life cycle needs. The negative impacts of turbidity are best summarized by Newcombe (2003):

> *Cloudiness reduces the volume of the photic zone; reduces local primary production; and triggers a cascade of impacts, from one trophic level to the next, involving phytoplankton, zooplankton, insects, freshwater molluscs, and fish. At each trophic level, excessive concentration of clay can cause direct effects (mortality, reduced physiological function, and habitat alienation) and indirect effects (decreased rates of growth, reproduction and recruitment) linked to reduced food supply.*

Impacts on Aquatic Invertebrates:

- Aquatic plants are a major source of food for invertebrates. Some invertebrates (herbivores) feed directly on plants (e.g. algae); others (carnivores) may feed on herbivorous invertebrates.
- Invertebrates, such as aquatic insects like black fly, stonefly and mayfly, are the main source of fish food.
- Suspended sediment reduces the amount of light penetration into the water column and hence reduces the energy available for aquatic plant photosynthesis. A reduction in algae results in a major loss of food for invertebrates (Sorenson et al. 1977). A 5 NTU increase in

turbidity in a clear stream 0.5m deep may reduce aquatic plant photosynthesis by 13% or more, depending on stream depth (Lloyd et al. 1987).

- Sediment directly affects invertebrates. Some invertebrates are filter feeders and sediment clogs their filter mechanisms; sediment also abrades (harms) the gills of some invertebrates, impairing respiration (Newcombe and MacDonald 1991).
- Many invertebrates live on and in coarse gravel substrates; excess deposition of sediment in these areas will cover and inundate the gravels thereby eliminating their habitat (Sorenson et al. 1977, Gammon 1970).

Impacts on Salmonids:

- The most sensitive stage of the salmon life cycle with respect to sediment is the egg incubation period. Sediment deposits account for the greatest mortality to salmon eggs. Relatively small increases in sediment levels in streams have been shown to reduce egg survival (Levasseur et al. 2006).
- Sediment can reduce hyporheic (i.e. the saturated zone under a river or stream, comprising substrate with the interstices filled with water) upwelling, which is critical for proper water exchange around the eggs (Baxter and Hauer 2000, Sedell et al. 1990). By reducing clean water flow and oxygen from reaching the eggs, sediment may coat the surface of eggs, resulting in reduced oxygen exchange. It can also reduce the flushing of metabolic wastes generated by the egg, which reduces survival rates (Bash et al. 2001).
- Sediment can reduce survival of eggs by infilling gravels and physically covering the eggs with a hardened cap of material, such that newly hatched fish, referred to as alevin, are unable to migrate through the gravel and emerge as fry (Everest et al. 1987).
- Fish, particularly salmon, are sight feeders. A significant delay in the response of fish to introduced prey was noted at turbidities of 20 - 60 NTUs (Berg 1982, Berg and Northcote 1985). As little as 25 NTUs of turbidity caused a reduction in coho and steelhead growth in comparison to those living in clear water (Sigler et al. 1984).
- Juvenile fish will emigrate to turbidity refuges when exposed to turbidity ranges of 37 – 70 NTUs (Servizi and Martens 1992, Bisson and Bilby 1982). However, due to anthropogenic channel modifications, turbidity refuges are often no longer available or are not in close proximity, thereby resulting in large energy expenditures to reach suitable refuge.
- A greater variety of microhabitats exist when large sediment fractions (i.e. gravel, cobble, and boulders) dominate the substrate than when fine sediment (i.e. sand, silt, and clay) dominates the substrate profile (Rosenau and Angelo 2000). Young fish often use pools and the interstitial spaces between gravels, cobbles, and boulders for refuge. Sedimentation can fill up pools and inundate the interstitial spaces, thereby eliminating quality habitats.
- Fish gills are delicate and easily damaged by fine sediment. As sediment accumulates in the gills, fish respond by excessively opening and closing their gills to try to remove the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over gills and hence interfere with respiration (Berg 1982). Under extreme or prolonged exposure to sediments, fish may actually die due to physically damaging and clogging their gills. For example, levels of 800mg/l over a prolonged period (i.e. 10 days) have caused mortality in rainbow trout.
- Turbid water results in a stress response in salmonids (Servizi and Martens 1987, Redding et al 1987), which may result in reduced growth, reduced ability to tolerate additional stressors, compromised immune system, impaired out-migration behaviour, reduced osmoregulatory competence, etc; all of which further decrease survival rates (Wedemeyer and McLeay 1981, and USFWS 1998).

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- Hyporheic upwelling buffers against high water temperatures (Poole and Berman 2001). Fine sediment deposition inhibits upwelling, thereby reducing this input of cool water into the stream flow.
- Spawning migration may be delayed (Cordone and Kelley 1961) and the associated increased energy expenditure may reduce spawning success (Berman and Quinn 1991).
- Increased embeddedness (i.e. the degree to which fine sediment is mixed in with spawning gravels) reduces the availability of spawning habitat.

Synergistic Effects:

Many of the effects are synergistic in nature (i.e. one effect can lead to a host of other effects) and may affect the growth, reproduction and survival of fish. The following are factors that mediate the effects of sediment on salmonids:

- duration of exposure
- frequency of exposure
- toxicity
- temperature
- life stage of fish (eggs and juveniles are typically more sensitive than adults)
- angularity of particle
- size of particle
- type of particle
- severity/magnitude of pulse
- natural background turbidity of area
- time of occurrence
- other stressers and general condition of biota
- availability of and access to refugia

An example of a synergistic effect of sediment is examining the avoidance response of salmonids to turbid water. At more sensitive life stages, salmonids will be forced to move to "turbidity refuges" (i.e. tributaries, sloughs, off-channel habitat, lakes, etc) in the watershed to avoid negative effects on survival. Anthropogenic disturbances have unfortunately reduced salmonids ability to cope with turbidity. In systems lacking adequate number, distribution, and connectivity of refugia, salmonids may need to travel longer distances to reach refugia or move to less desirable habitat. This increased travel distance is an additional bioenergetic demand that may affect the growth or reproductive success of the individual.

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