
This study looked at the lethal and sublethal effects of exposing juvenile salmon to total dissolved solids (TDS). Little work has been done on the effects of TDS on salmon. This study looked at their health, growth and development as biological indicators of water quality.

Brief summary:
Successful egg fertilization was the most sensitive to short-term exposure to TDS, with effects seen at levels as low as 250 ppm. The lowest concentration tested was 250 mg/l, so it is possible that there are measureable toxic responses at even lower concentrations.

Different species had different levels of sensitivity, with King, Pink, and Coho as the most sensitive, and Artic char as the least sensitive. Long-term exposure to TDS effected both fertilization and hatching success of eggs. One of the most important aspects of this research is that it included exposure during fertilization, where most bioassays start exposure after fertilization. This research is profound because it documented a very brief, highly susceptible period (two minutes) just after fertilization, before the egg hardens up. Most of the toxic response was measured during this two minute period. Eggs are much more resistant to pollutants after they harden up.

Standard bioassays used for years to assess toxicity of pollutants do not include exposure to the eggs as they are being fertilized, and thus do not assess toxicity at this most sensitive life stage. If you don’t look for harm, you won’t find it. This research shows that standard bioassays may greatly underestimated the toxicity of pollutants.

Study vulnerabilities: The study may be questioned about direct applicability to the Red Dog Mine project because they did not use fish taken from the streams adjacent to the mine discharge. It is possible that different fish stocks may react differently to TDS. I am uncertain if ASTF will continue with their plans to repeat this work in 2003 using fish from Red Dog Creek.

Take home message: This research shows that TDS effects salmon survival and development at lower concentrations than ever thought before (250 ppm). This research is directly relevant to EPA’s proposed modification to the current Red Dog mine NPDES permit and DEC’s current proposal to make the Water Quality Standard for TDS less stringent. The study’s findings show that the proposed change to the WQS is wrong, and in fact, the WQS for TDS are not protective enough. These results can be used to support our argument that the WQS should be made more stringent to fully protect salmon survival and development. It has major implications for all mining projects, and any other industrial discharge that contains TDS.

Study details: The study used a TDS composition modeled after the Tech Cominco’s Red Dog Mine effluent near Kotzebue, Alaska. The study conducted both acute (96
hours or less) and chronic (continuous) exposure to TDS at various stages of embryo development. The study was conducted at the DIPAC hatchery in Juneau, Alaska.

Acute studies:
- Coho were exposed for 96 hours to TDS solutions ranging from 250-2500 at several life stages of development from fertilization through button-up (emergence). Following the 96 hour exposure, all fish were cultured to completion of embryonic development. Four effects were observed: short-term mortality, long-term mortality, a higher proportion of eggs that were unfertilized than the control group, and cumulative mortalities.
- The ASTF study tested the toxicity of the individual components of the TDS mixture and found that most toxicity was attributed to calcium and sulfate. Potassium and magnesium ions showed no toxicity at even the highest concentrations, 2500 ppm.
- A new short-term acute fertility test was developed that can be used to compare toxic responses between species to determine the most sensitive species. The test uses epiboly (eight cell division stage of the embryo) as the end point. The test is able to determine whether TDS had its effect at fertilization or during water hardening, and determines which of the two developmental stages is more sensitive to the pollutant.

Chronic Studies:
- Coho eggs were exposed to TDS in flow through systems and grown for over a year. This experiment was repeated in two consecutive years, 2001 and 2002.
- Embryos in the two highest concentrations hatched earlier than other treatments. Environmental conditions like freezing, low oxygen, and toxins can cause salmon to hatch earlier than they would in favorable conditions. Differences in hatch timing can reduce fitness in wild populations. In wild populations of coho salmon, high mortalities are observed during their early life history. Salmon adapt to local weather conditions including freezing, flooding, and low water flow events. With hatch timing altered, higher than normal mortalities could be expected from salmon hatching at times other than ones they have adapted to over generations.
- Eggs exposed to high levels of TDS showed a statistically significantly lower fertilization rate. Fertilization is clearly the most sensitive stage for TDS exposure in juvenile coho salmon but not the only sensitive stage. Higher mortality rates were observed within a week after hatching in fish exposed to the higher concentrations of TDS solutions. These findings imply that coho salmon exposed to high concentrations of TDS during incubation were harmed in a manner that is expressed shortly after hatching when fish are adjusting to being outside of their protective eggshells. They are challenged specifically by osmoregulation and metabolism changes.
- Prehatch mortality, eggs that were fertilized by died between fertilization and hatch, was higher (statistically) in eggs exposed to high TDS concentrations. Posthatch mortalities were statistically higher in fish exposed to high levels of TDS.
Fish that were exposed to high TDS concentrations weighed less and grew slower. Such a decrease at the time of swim up may have serious consequences in subsequent survival of these fish in their natural streams. Smaller fish may be less competitive in catching prey and more susceptible to being prey themselves.

Fish exposed to higher concentrations of TDS were slower in absorbing their yolks, in spite of hatching earlier than those fish exposed to lower concentrations. One component of an individual’s fitness is outmigration timing. The time at which salmon in a particular stream emerge from the gravel and begin feeding is selected for over generations. Alteration of outmigration timing can cause a reduction in fitness.

Histology does not appear to be affected by TDS exposure. Ted Meyers (ADF&G Pathology Lab) concluded that if the TDS exposures are causing developmental aberrations during organogenesis prior to hatching, it is likely these changes will affect organ function rather than tissue architecture and therefore would not be discernable by histological examination.

It is clear from the results that exposure of high levels of TDS during fertilization and hatch is harmful to juvenile Coho salmon. What remains unclear is what the effect would be of exposing juvenile Coho salmon to high levels of TDS only in between those developmental stages. This question may be relevant to the proposed timing of the TDS discharges in the NPDES permit.

The report cautions that these results only apply to Coho salmon from Macaulay Hatchery broodstock exposed to this specific simulated TDS mixture. Extensions to other populations of Coho salmon may or may not apply. Drawing conclusions based on this data for other species is even less likely to apply. Applying this work to situations with different TDS mixtures, especially differing ratios of ions, additions or deletions of ions, and additional toxicants like heavy metals, is problematic. It is likely that other species will be adversely affected by TDS, especially during fertilization, but it is not possible to extrapolate these results to predict the effects at a given concentration.

The report concludes that in an environment where demands for juvenile salmon (competition for food, predator avoidance and physiological challenges) are low, TDS-related size variation may not be important, but in more challenging environments, size differences may lead to lower survival rates in fish exposed to higher concentrations of TDS during incubation.

Site-specific tests may be the best method to use to set limits for TDS in issuing discharge permits. Such tests should include short term bioassays at critical stages, such as fertilization or hatch. Other long-term assays should be employed for understanding effects to critical populations.

The results described here are relevant only directly to salmonid populations. The effects of TDS on other organisms in an ecosystem in question may also play an important role in the growth and survival of salmonids.