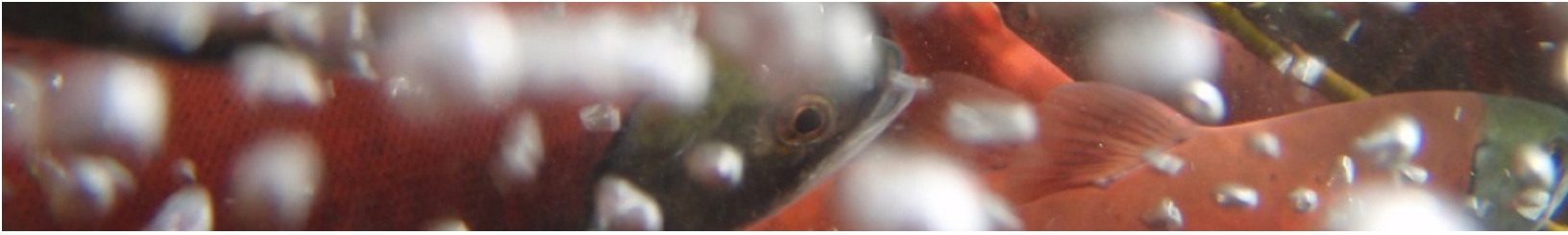

# ARROW LAKES RESERVOIR NUTRIENT RESTORATION PROGRAM MEASUREMENTS

All measurements below are provided by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development that manages the Nutrient Restoration Program in Arrow Lakes Reservoir. The nutrient additions in Arrow Lakes Reservoir are primarily funded by the Fish & Wildlife Compensation Program (FWCP), with additional funding (approximately 25% of the total costs) coming from the Arrow Lakes Power Corporation (ALPC).

## Secchi disc measurements

### What: Measures water clarity

Comments:

- Note that the depth (metres) decreases as you go up the 'Y' axis. The way to look at this, therefore, is to imagine that the title of the graph is close to the surface of the lake and you are looking down into the water – thus the further away the Secchi disk is viewed, the deeper it is in the water. The higher the number, the clearer the water is. E.g., the average depth the Secchi disc in 2016 was deeper than in 2017.
- These are averages for the season (April to November). Secchi disk measurements vary throughout the year: they will be deeper in the winter then tend to be shallower in the spring and summer with increased sunlight, warmth and phytoplankton growth.
- As seen below, the clarity of the water in Arrow Lakes Reservoir decreased in 2015 and 2017. This could be the result of high turbidity in the Illecillewaet River and, given the warm summer, it was a high algae year.
- With phytoplankton - the microscopic plant matter at the base of the food chain, that the nutrient additions are targeting - there are "good" and "bad" types. What makes a good edible vs. inedible phytoplankton is based on size as zooplankton can eat only a particular size of phytoplankton. Some phytoplankton (e.g. blue-green algae) are too large or form chains that make it hard for zooplankton to consume.

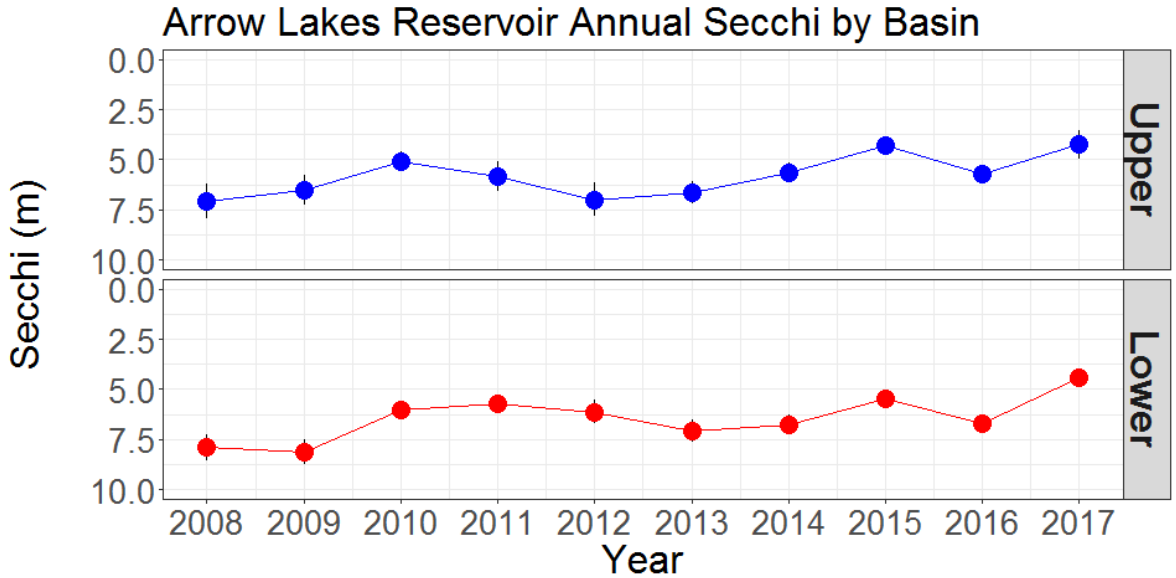


Figure 1. Arrow Lakes Reservoir annual monthly Secchi (m) by Basin from 2008-2017. Sampled monthly April-November. Upper Arrow (blue) and Lower Arrow (red). Note: no November sampling in 2017. Means ± Standard Error.

FWCP Fish & Wildlife COMPENSATION PROGRAM

BRITISH COLUMBIA

## Turbidity

**What: As with the Secchi disc, it provides a measurement of water clarity, but turbidity metrics provide precise measure of suspended particles in the water.**

Comments:

- The 'NTU' stands for Nephelometric Turbidity Unit (measure light refraction)
- Turbidity is also a measurement of water clarity by measuring the amounts of total suspended particles.
- This has to meet standard provincial water quality guidelines (for drinking water)
- Can be affected by landslides in the tributaries (reducing clarity and increasing turbidity)
- While an increase in sediments might seem like a positive impact for the food chain, high turbidity actually decreases the efficiency of the nutrients being taken up by the food chain. The nutrients can attach themselves to the particulates and may sink.
- While turbidity can impact fish, the levels in the graph below do not come close to conditions where fish cannot see their prey.

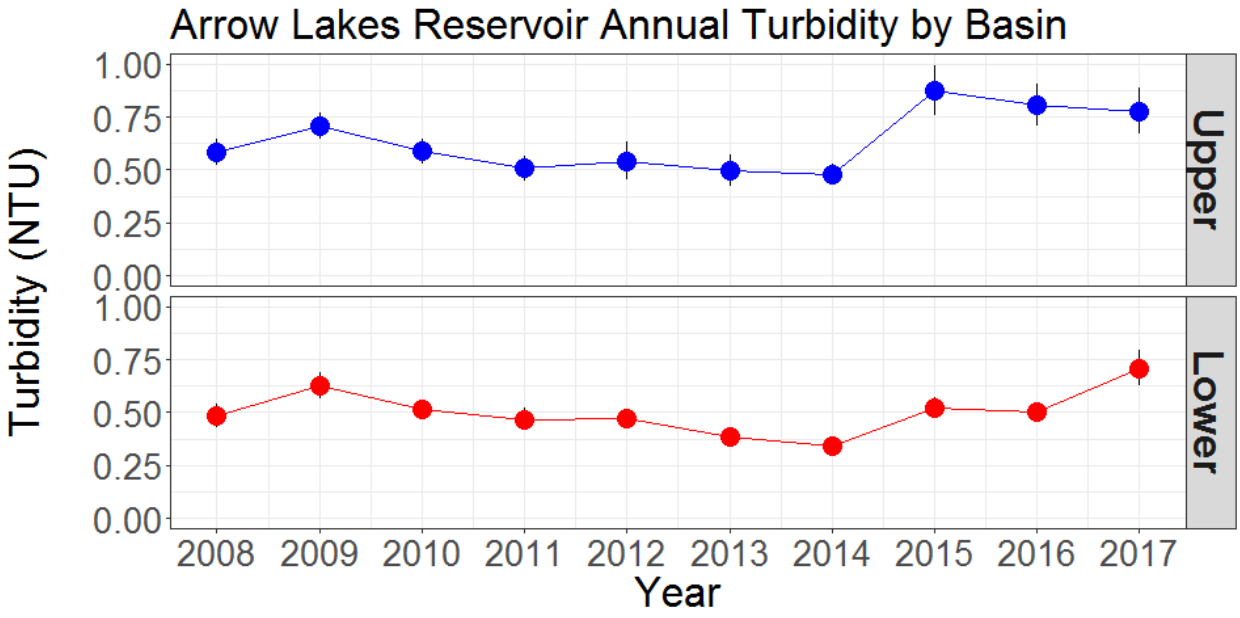


Figure 2. Arrow Lakes Reservoir annual monthly turbidity (NTU) by Basin from 2008-2017. Sampled monthly April-November. Upper Arrow (blue) and Lower Arrow (red). Note: no November sampling in 2017. Means ± Standard Error.

## Arrow Lakes Reservoir phosphorus measurements

**What: Measures the level of phosphorus in the water; phosphorus is one of the essential nutrients for productivity.**

Comments

- Measurement is mass by volume: micrograms of phosphorus per litre of water.
- Phosphorus is added as part of the Nutrient Restoration Program, in the form of liquid agricultural grade fertilizer: 10-34-0.
- Adding too much phosphorus may not be a benefit to the ecosystem because it will not be taken up by the food chain and/or can lead to unwanted algae blooms.
- Water quality guidelines in B.C. allow a maximum of 10 µg/L.
- Phosphorus is typically higher in the water in the spring from freshet, or spring run-off.
- The Arrow Lakes Reservoir phosphorus measurements are less variable, and lower (i.e. less productive), than Kootenay Lake. This is likely due to the higher flow rates and lower water retention time in the Reservoir.
- The difference between phosphorus and nitrogen:
    - Phosphorus typically comes from the land through natural erosion
    - Nitrogen comes from the atmosphere, through rain and snow fall
    - If nitrogen is too low relative to phosphorus, the wrong type of algae can be produced. The balance between nitrogen and phosphorus is closely monitored in the NRP program.

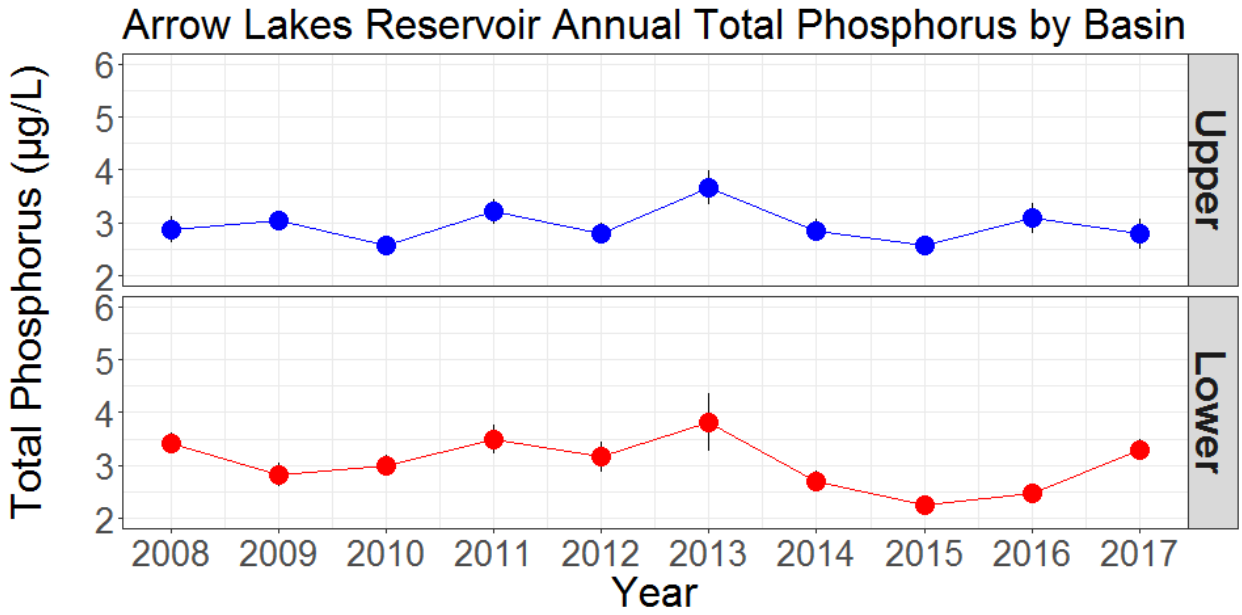


Figure 3. Arrow Lakes Reservoir annual monthly Total Phosphorus (µg/L) by Basin from 2008-2017. Sampled monthly April- November. Upper Arrow (blue) and Lower Arrow (red). Note: no November sampling in 2017. Means ± Standard Error.

## Arrow Lakes Reservoir Zooplankton biomass

**What: Measures the monthly (Apr-Oct) annual average biomass of Zooplankton in the water, to help determine the level of food source in the system available for Kokanee.**

Comments

- Zooplankton biomass largely consists of large-bodied *Daphnia* and are a primary food source for Kokanee
- Measurement is biomass of Zooplankton per litre of water
- As can been seen in the graph, low Zooplankton measurements occurred in 2017, and could likely be a result of grazing pressure from Kokanee (which were numerous in the fall of 2017)
- Higher flows through the Arrow Lakes Reservoir (compared with Kootenay Lake) in 2012, 20152017 may also be related to the lower zooplankton biomass.

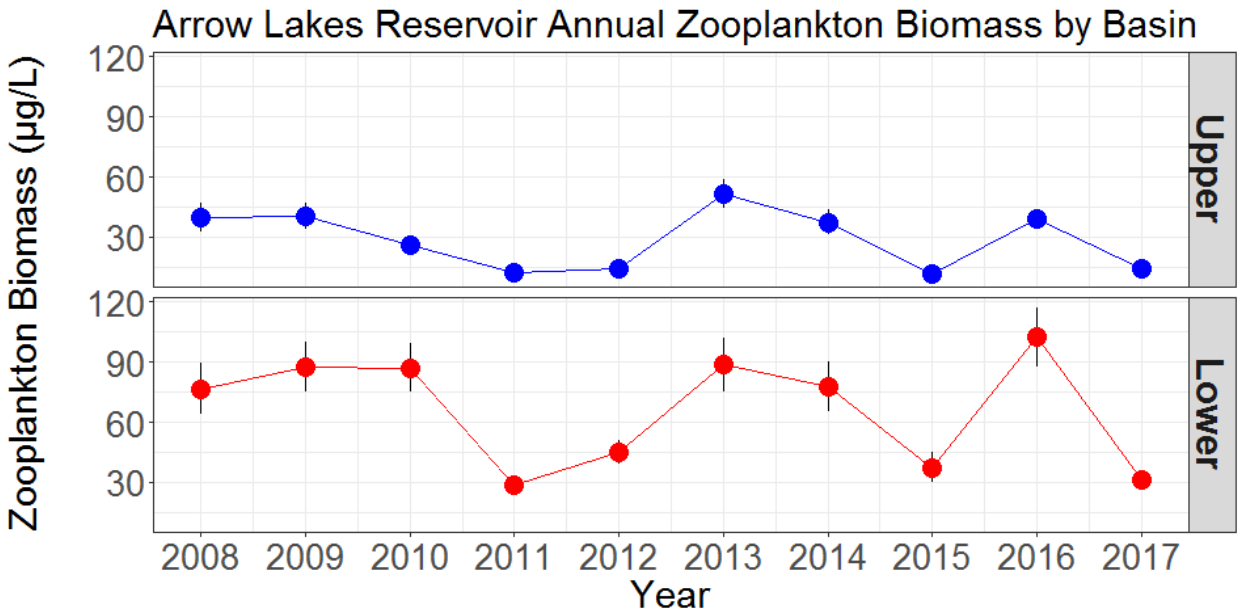


Figure 4. Annual monthly (April-Oct) zooplankton biomass (µg/L) in Arrow Lakes Reservoir from 2008-2017. Upper Basin (blue), Lower Basin (red). Means ± Standard Error.

## Arrow Lakes Reservoir mysid density

**What: Measures the monthly (Apr-Oct) annual average density of mysids in the lake.**

Comments

- Mysids are the species *Mysis diluviana*, an exotic crustacean introduced into Arrow Reservoir in 1968 as a food source for fish, after the perceived success of the Kootenay Lake introduction in 1949.
- Measurement is in number of individuals per square metre of water
- Fish predation on mysids is limited by the daily vertical migration of mysids in deep lakes and reservoirs. Mysids spend daylight hours at the bottom, rising to feed after dusk (when fish have finished feeding) and descending before dawn.
- Mysids also prey on zooplankton, and as a result *compete* with kokanee for the zooplankton food source.

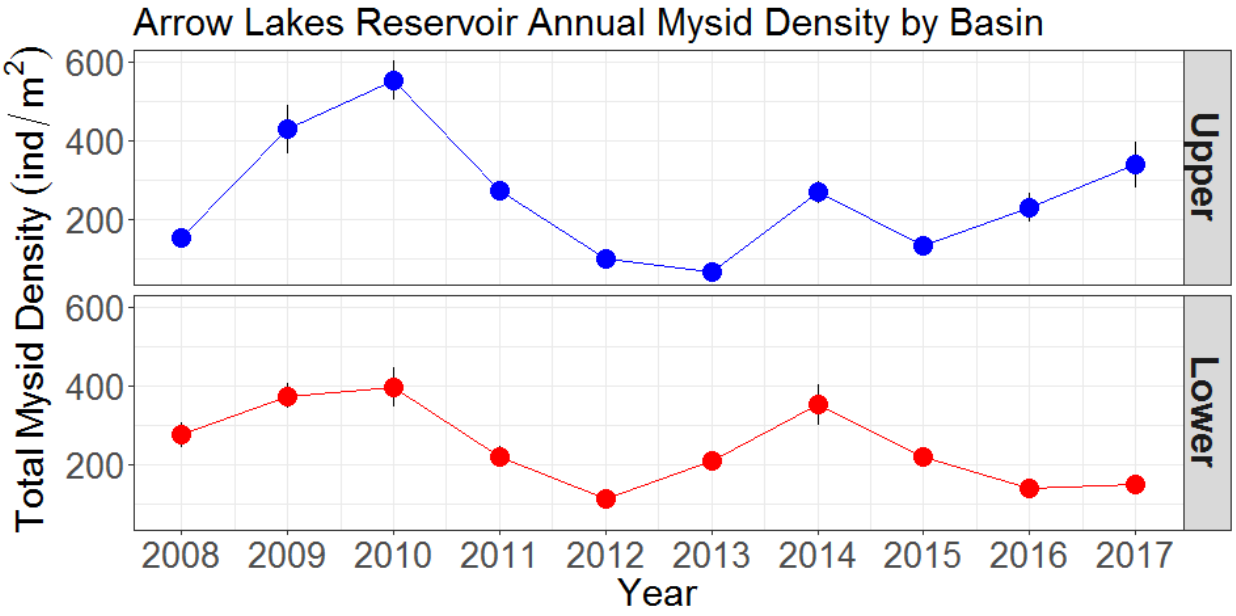


Figure 5. Annual monthly (April-Oct) mysid density (individual/$m^2$) in Arrow Lakes Reservoir from 2008-2017. Upper Basin (blue), Lower Basin (red). Means ± Standard Error.