

Geologic and Glacial Influences on Surface Water Chemistry, Lake Clark National Park and Preserve, Alaska

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The primary objective of our ongoing studies of surface water quality in Alaska's national parks is the establishment of baseline data. The initial phase of each study attempts to relate variation in surface water chemistry to regional geomorphology, while the second phase examines biological factors that may be responsible for observed seasonal variation. Most of the characteristics within a watershed or lake ecosystem cannot be sampled with true replication. Non-parametric statistical means must be employed to distinguish among sampling stations. Comparisons among watershed/lake ecosystems generally are done with co-variance analyses. The end result of such analyses permits us to locate the stations that are representative of the natural variation within the park and, perhaps, some of the ecosystem components or processes likely to be sensitive to natural or human-imposed ecosystem stress.

Lake Clark National Park and Preserve (LACL), (about 1.46 million ha.), is located about 340 km southwest of Anchorage. Geologically it lies at the southernmost end of the Alaska Range and the northernmost portion of the Aleutian Range. Lake Clark, 65 km long and up to 6 km wide, is the largest body of water in the park. LACL makes up a significant fraction of the watershed feeding Bristol Bay, one of the world's most valuable fisheries. The Tazimina River, which drains into the southeastern end of Lake Clark, is the largest spawning area for salmon in LACL. For some time it has been thought that migrating salmon might be a major nutrient source for Lake Clark. The relative proximity of LACL to the Anchorage area via small plane and the considerable private inholdings within the park and adjacent Lake Clark make the park subject to development in the very near future. A major concern is whether this will accelerate eutrophication of this largely oligotrophic lake and watershed system.

Runoff into Lake Clark is dominated by glacial meltwater and "flour" from the Tiikakila River and Current Creek located near the northeastern (NE) end of the lake (Fig.



Fig. 2. Eastern end of Turquoise Lake, one of the more northern lakes in Lake Clark National Park and Preserve.

1). These inputs generally peak in late July, resulting in a reduction of compensation depth (depth to which lake primary production by phytoplankton can occur) to 2 m while it remains at its pre-runoff value of 20 m at the southeastern (SE) end of the lake. During August and September, glacial flour input moves down the lake, resulting in decreasing compensation depths throughout.

This glacial flour and associated filterable solids could be a major source of phosphate. It's been hypothesized

that phosphate is the nutrient limiting primary productivity in this lake, thus the concern over cultural eutrophication. Our objective was to quantify some of these potential sources of natural variation in critical nutrients and primary production to better qualify our parkwide baseline data set.

We began our study in 1985. Lake Clark had 15 permanent stations located in it along with 7 additional stations periodically sampled. All major tributaries to the lake were sampled. Ten additional lakes along a 135 km north-south gradient which included Lake Clark also were monitored. Sampling was conducted monthly from June to September with an index station sampled more frequently. Data collected include complete chemical analyses of inorganics; dissolved carbon; total nitrogen; turbidity; filterable and non-filterable solids (suspended and non-suspended sediments); light, temperature, and dissolved oxygen profiles. Several carefully selected stations within Lake Clark also were measured for primary production rates and the effect on production of adding varying levels of phosphate and nitrate to the incubation bottles.

The lakes throughout the park show a pronounced trend in surface water chemistry that reflects change in bedrock mineralogy. Most evident is the ecologically important nutrient potassium, which sharply increases in lake concentration as one goes north in the park (Fig. 2). Conversely, nitrate input, which is mostly from biological fixation in this region of low atmospheric contamination, shows an opposite trend with the highest levels in the southern lakes and tributaries. This reflects differences in biological fixation especially the presence of alders in the lower elevation portions of the park. Inputs into Lake Clark proper also demonstrate this. For example, nitrate input is highest from those tributaries which have alders present. The tributary with the highest carbon input, the Chulitna River, has the lowest nitrate input

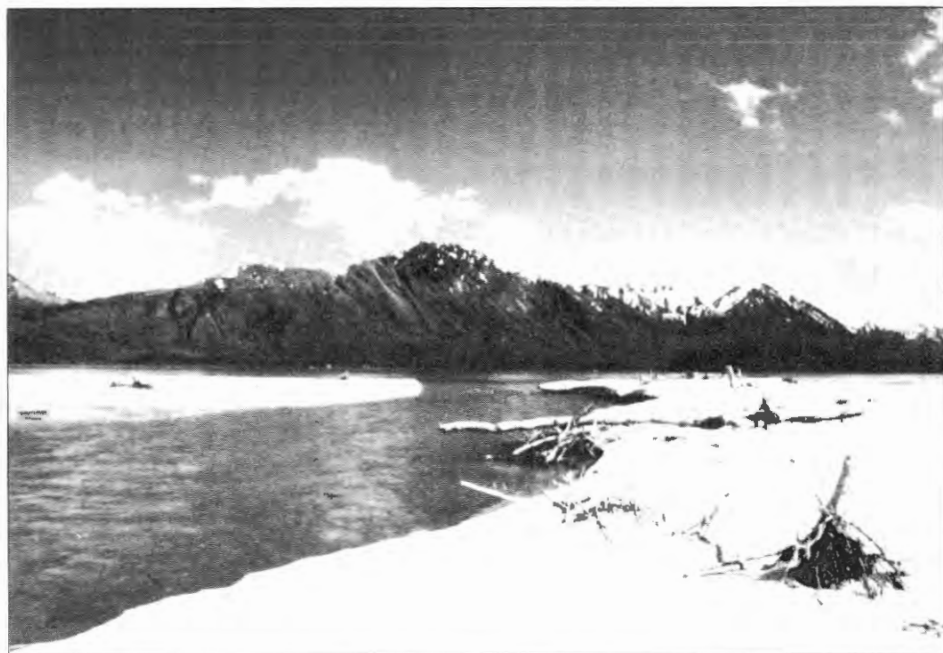


Fig. 1. Current Creek, one of the major sources of suspended and dissolved solids into Lake Clark.

as a result of little or no alders and likely denitrification in its extensive wetland areas.

In Lake Clark most chemical species had their highest concentrations early in the season and in the uppermost NE section of the lake. This was especially true for nitrate. Nitrate declined throughout the season and also down lake on each sampling date except in late summer, suggesting that nitrate was becoming more limiting throughout the season, especially in the lower SE section. Such a situation increases the advantage nitrogen-fixing aquatic species, such as blue-green algae, would have.

What about phosphate? Phosphate levels were always below the level of detection, which limits their direct measurement. However, one can get a relative idea of which nutrients are limiting over the season by inoculating the primary production incubation chambers with varying concentrations of phosphate and nitrate, both individually and in combination.

Most of the phosphate added to an aquatic ecosystem comes from weathering of minerals or possibly recycling from the lake bottom. However, Lake Clark's considerable depth (280m) makes recycling from deep sources unlikely. We hypothesized the following. The very high inputs of glacial flour early in the season would make phosphate relatively abundant in the NE section of the lake, and nitrate could then become limiting. Later in the season with the continued increase and spread of this glacial input of filterable solids throughout the lake, (which we quantified), nitrate would there, also, become more limiting. This might then result in a biological shift in species toward more planktonic nitrogen fixers. And that is essentially what happened.

In June at the most NE station the addition of high nitrate concentrations to the incubating bottles stimulated primary production 50 percent while the addition

of phosphate had no effect or slightly lowered productivity. Conversely, at the lower stations both nitrate and phosphate increased primary production by about 15 percent. By late summer (August), the period of maximum primary productivity (2 - 2.5x the rate observed in July and September), the only station that showed response to nutrient addition was the most NE station, which responded to nitrate. Interestingly, in August the nitrate concentration in Lake Clark shows no NE - SW decline in concentration. In fact it begins to increase in concentration south of mid-lake, suggesting the presence of aquatic nitrogen fixers. By September this lake nitrate concentration trend is gone and the most limiting nutrient generally was nitrate. However, here for the first time the addition of high concentration phosphate had a significant positive effect on primary productivity rates. By September, the filterable solid load had decreased and with it the likely phosphate load to the lake.

In sum, this two-phased approach has given us the following evidence regarding the character and variation of surface water chemistry in LACL. 1) Regional variation in geology is strongly reflected in surface water chemistry, and if one wanted to invest in the monitoring of "representative" ecosystems several would have to be selected. 2) Within Lake Clark proper the nutrients limiting primary productivity vary both spatially and seasonally. 3) Phosphate inputs appear dominated by glacial flour and not migrating salmon. 4) The high productivity response to nitrate addition means that significant portions of the lake's biota would likely respond to nitrate inputs, as from atmospheric contamination. 5) Overall, our evidence suggests that on a seasonal basis phosphate is not the limiting nutrient over much of Lake Clark.

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