Coquitlam Reservoir: Preliminary Sediment Coring Results.

Prepared by
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Water and Watershed Management Program
University of Victoria

Prepared for
the BC Hydro Bridge Coastal Restoration Program

March 2005

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Introduction

Lake sediment coring can provide a means of looking at the past lake and watershed conditions especially when no direct long term or historical data exist. For all three of the reservoirs (Coquitlam, Seymour and Capilano) that supply drinking water to the GVRD system, the amount of water quality and fisheries information that exists is very limited.

Paleolimnology can use a wide variety of indicators in sediments to reconstruct the past history of the water body. Researchers have used a variety of chemistry (individual elements, nutrients or metals, organic constituents such as algal pigments, fatty acids, stable isotopes) and biology (pollen, diatoms, zooplankton and many other organisms). The choice of which indicators to use is determined by budget and by the likely utility of the data obtained from different types of analyses. For Coquitlam Reservoir, it was initially planned to do a number indicators including sedimentation rates, geochemistry and stable isotopes and diatoms and zooplankton. The latter two were, after some discussion, not pursued as it was felt they would be of lower priority and yield less information than the sedimentation analyses, geochemistry and stable isotope analyses.

Coquitlam Reservoir was created when a dam was constructed on the outlet of a pre-existing lake in order to provide additional water storage. At present full elevation (152m) Coquitlam has a surface area of 1202 ha and a maximum depth of 187m (Stockner 2003). It was dammed initially in 1905 and then the dam raised again in 1914. The dam resulted in an increase in lake level of 20m (original lake level 132.5) but the salmon runs into this watershed were blocked as a consequence of the dam. The effects of this blockage of fish passage have been identified as an issue for future management of the lake. The initial dam had a fishway, the 1914 dam does not. There is some pressure to reestablish these anadromous fish runs. At present what is being considered is construction of fishways or other facilities that would allow the passage of fish and allow species which formerly had access to these systems (especially sockeye) to again use these reservoirs as spawning and rearing habitat (Bengeyfield et al 2001, Bocking and Gaboury 2002).

The high precipitation of the area results in a flushing rate typical of coastal lakes. The lake volume of 1,044,000 dam^3 (mean depth 87m and surface area 12 km^2) and an inflow of 725,000 dam^3 (James 2000, cites a mean inflow value of $23 m^3/s$) results in a water exchange rate of 0.69 per year or an exchange time of 1.4 years using present full pool volume. Using the predam elevation, the lake would have a volume of 9% less (950,000 dam^3) and an exchange (filling) time of 1.3 years.

The key question that was to be addressed by the analysis of the cores was if there was any indication of a change in the lake processes as a consequence of putting the dams in place – especially if there was evidence of the effects of the exclusion of anadromous fish from these systems.

The GVRD reservoirs are primarily used as sources of drinking water, there is some concern that introduction of fish might negatively affect drinking water quality (Mazumder 2002). An issue that needs to be considered in these plans is the effects of the reintroduction of fish on the food chain of these lakes. A concern is that increased number of juvenile fish might exert heavy predation pressure on the zooplankton of the system, reducing their numbers. With lower zooplankton there would be less grazing pressure on the phytoplankton and they would increase in numbers. Numbers and species mix of phytoplankton are a major drinking water quality concern since higher numbers can cause taste and odour problems, can lessen the efficiency of disinfection and cause increased concentrations of disinfection by-products since the phytoplankton can serve as the precursor material for these compounds which are of serious human health concerns. One group of disinfection by products (haloacetic acids) is already a concern in the GVRD system.

A second concern raised by research on Alaska lakes is the delivery of pollutants into the lakes by returning salmon (Krummel et al 2003). They found that the sockeye salmon accumulated a number of persistent organic pollutants (particularly PCB's) during their growth in the marine environment and delivered them to the lakes when they returned to spawn and die. No attempt was made to examine the change in these contaminants in the cores that were taken but this might be considered in the future.

Methods

Multiple cores were taken with a gravity corer in 22 May 2002 in Coquitlam Reservoir in the centre of the deep basin (200m). The core used to report the data in this report was 252mm long. The cores were 77mm in diameter and were extruded the same day as collected into 125ml plastic cups and purged with nitrogen gas. On return to the lab they were frozen either in minus 20 degree or minus 80 degree freezers depending on the analyses to be done (geochemistry, lead 210 and stable isotopes for the former and pigments for the latter).

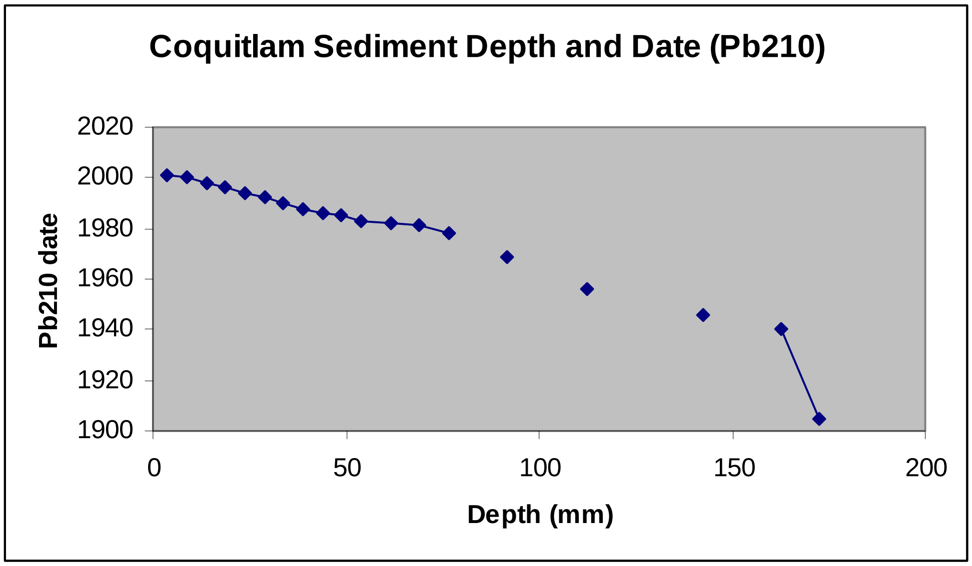
Sediments were dated using the lead 210 technique by Mycore Scientific Inc, Dunrobin Ontario. Geochemistry was analyzed by PSC of Burnaby BC. Stable isotope analyses were performed at the University of Victoria.

Results

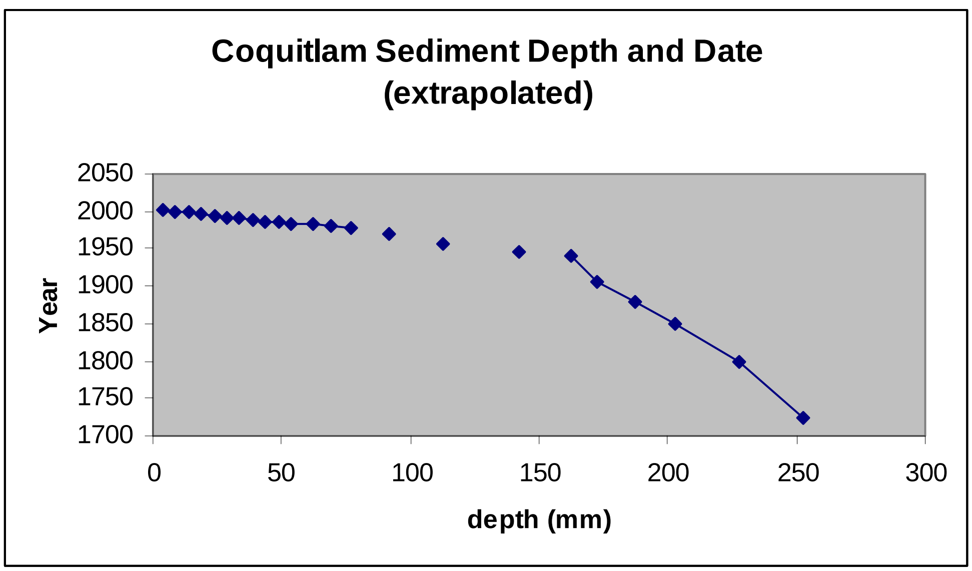
(a) Sediment Dating and Accumulation Rates

A key set of data that are needed for interpreting the results of the cores is the dating of the different depths of the core. Sediments are deposited into the bottom of lakes at different rates that depend on a variety of factors including lake productivity, watershed soils, geology, topography, climate and hydrology. The range of sedimentation can be from 0.5 mm to 10mm a year.

Coquitlam Reservoir sediments showed low concentrations of lead 210 and as a result only the past 100 years of deposited sediment could be accurately dated. The following figures show the relation between depth of sediment and date from lead 210 analyses. The data show the oldest dateable depth to be 1905 at 172mm. This is different from the data of James (2000) who indicated for a core taken in the same area (her core N) that a depth of 150mm corresponded to approximately 1800 – and that 1889 was at 100mm.



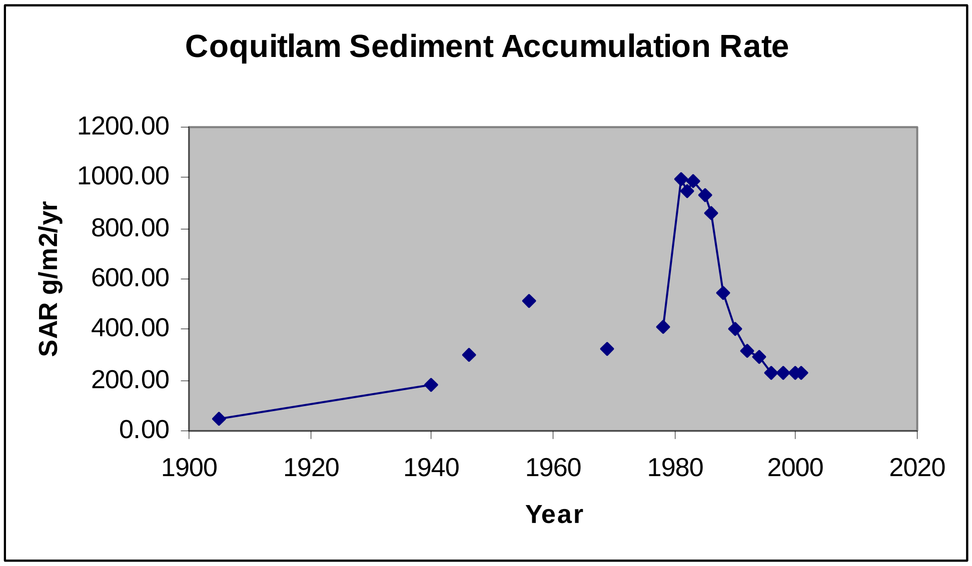
For depths deeper than 172mm (1905) for Coquitlam, dates had to be estimated using regressions from the more recent core sediments. The estimates of dates to the bottom of the core is about the year 1725 .It appears that the sediment accumulation rates for Coquitlam Reservoir have increased significantly after 1905.



The recent sediment dating would indicate a sedimentation rate 1.8mm a year for Coquitlam Reservoir. This is an average sedimentation rate but there is considerable variation over time. What appears to be the case is that sedimentation rates were considerably higher in the 1970's and 80's. This pattern was also observed by James (2000) for her core from the same area.

Sedimentation areal rates for Coquitlam range from 200-300 g/m^2/yr for back ground to amounts approaching 1000g/m2.yr in the 1980's. The rates are much less than rates reported by James (2000) who reported sediment accumulation rates of 0.01 g/cm^2/yr to 0.065 g/cm^2/yr in the

1980's (0.01 $g/cm^2/yr$ = 1000$g/m^2/yr$). Macdonald et al (2000) reported rates of 0.18$g/cm^2/yr$ (1800$g/m^2/yr$) for Harrison Lake.

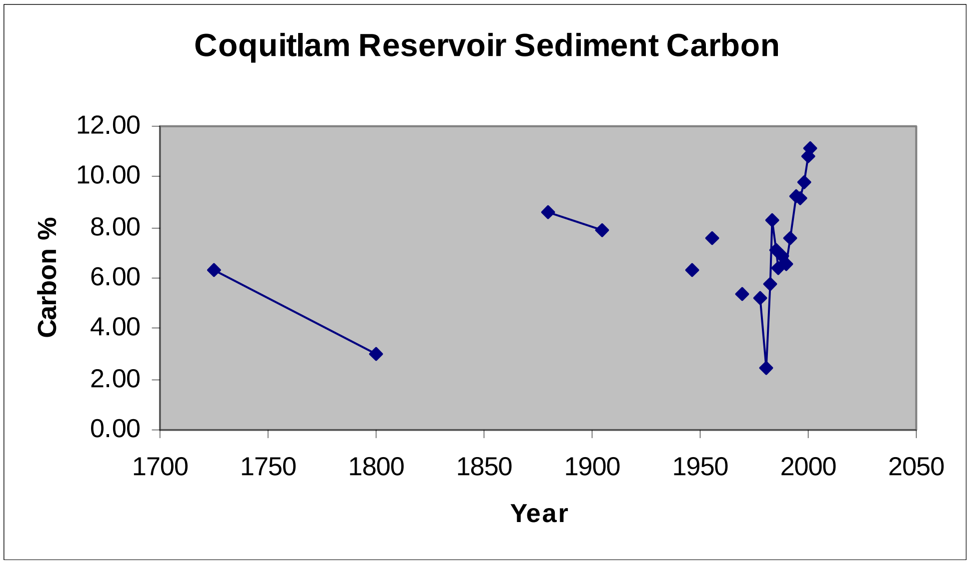


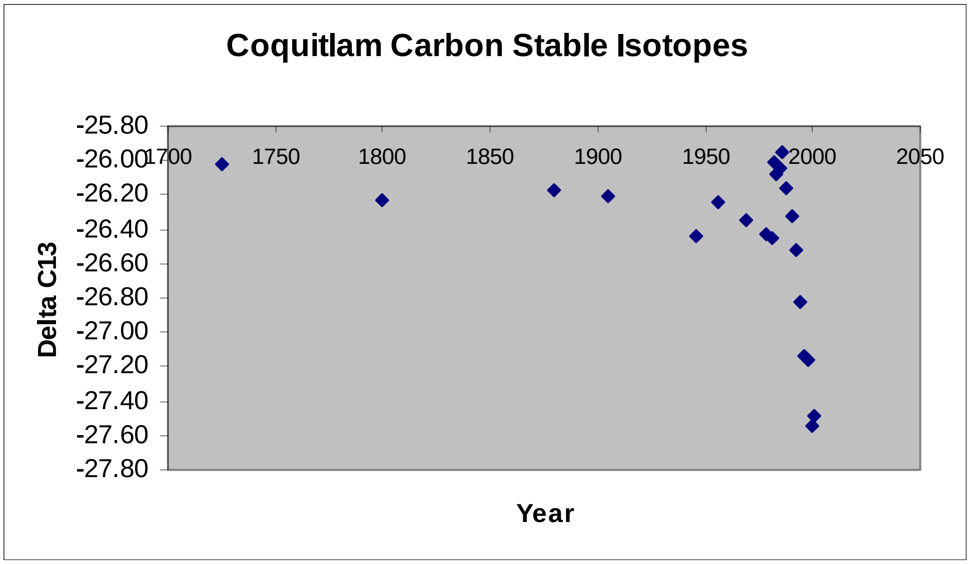
(b) Nitrogen and Carbon Stable Isotopes

The stable isotope analyses was of particular interest to examine the effects of the dam closures particularly on the on the amount of δN^{15} which can be raised by numbers of returning salmon which bring with them marine derived nitrogen which can increase the concentration of δN^{15}. It should be noted that the amounts of nitrogen overall were extremely low in these two systems.

Carbon stable isotopes in aquatic systems can be used for a number of purposes. One typical use is to distinguish the origin of carbon – whether it might be terrestrial or aquatic. Carbon from terrestrial vegetation has a different stable isotope signature from carbon fixed by phytoplankton.

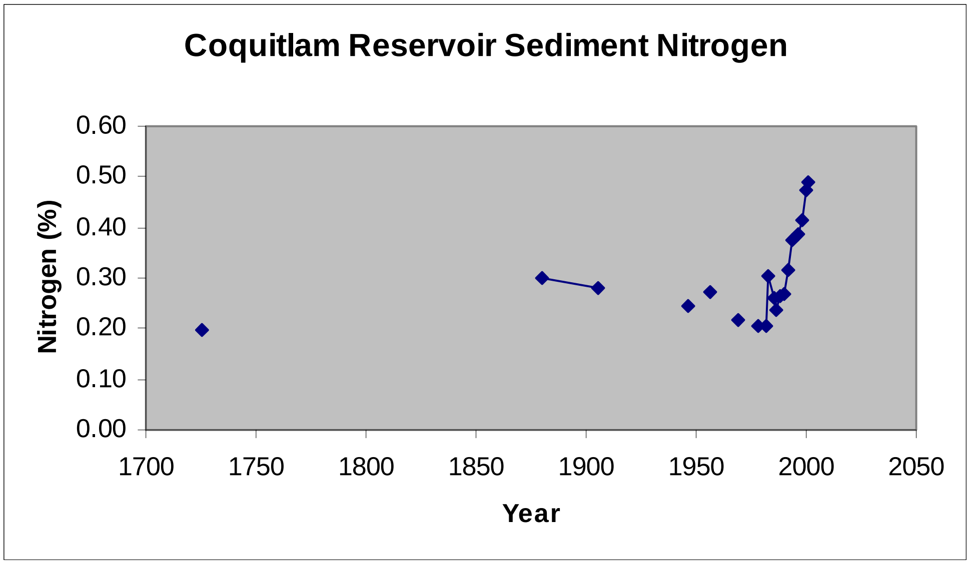
The concentration of total carbon can be used as an indicator of changes in productivity. The figures below show the concentrations of total carbon in the sediments and the changes in the concentrations of the carbon stable isotope.

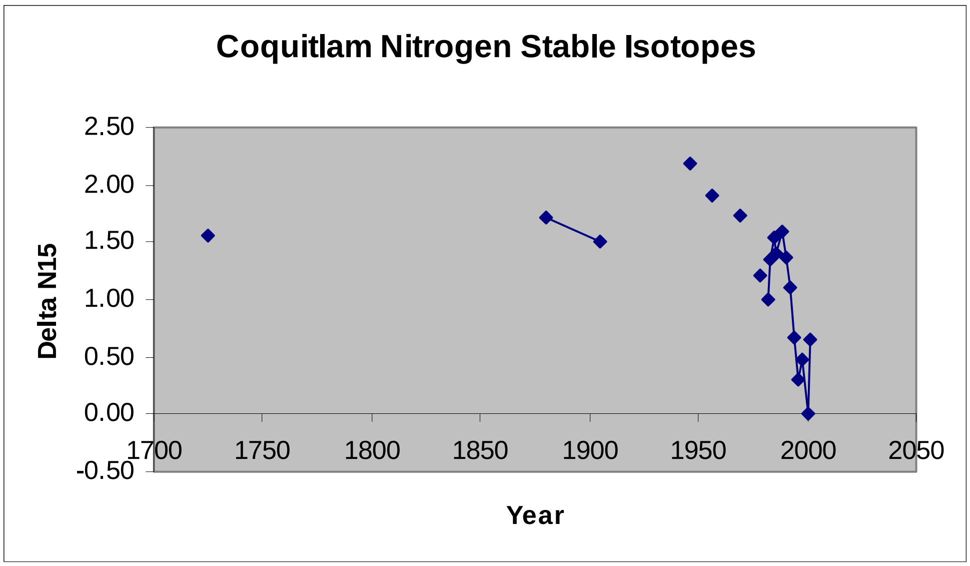




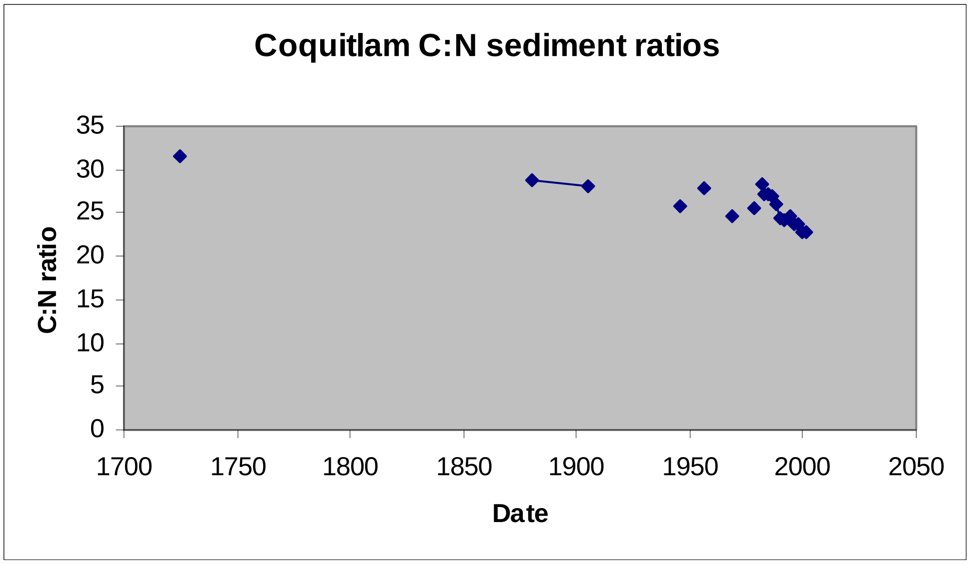
What these data show is that in Coquitlam, there seems to be an increase in the concentration of carbon in the sediment at the top of the core – toward the present. The stable isotope data shows a noticeable change in recent years from the background level of δC^{13} about -26.3 per mil to about -27.6 per mil.

The nitrogen sediment geochemistry concentration data are also interesting. Coquitlam Reservoir shows significant increases in recent years (after 1975) in nitrogen concentration of sediments. The δN^{15} also shows a major change in the same period and substantially decreased signature. However the timing of this change does not seem to be related to the 1905-1920 dam period but rather to the past 25 years and it is difficult to know what might have been the cause of this change. Certainly the climate was different in this period (wetter) and this was also the period during which forest harvesting activities and road building in the watershed were at the highest level.



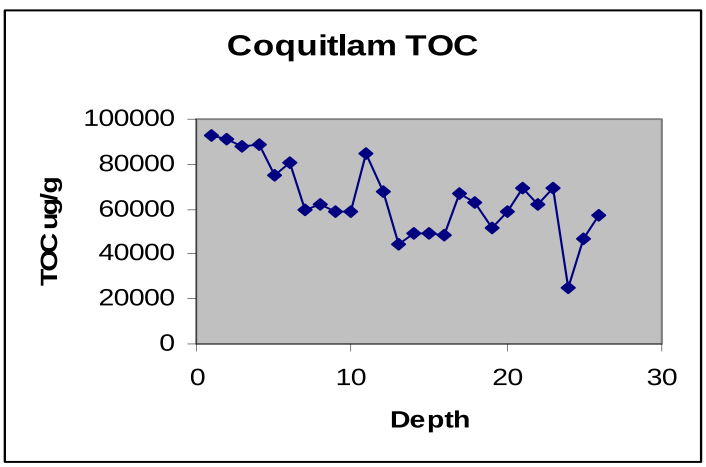


When the parameters of Total Nitrogen and Carbon in sediment are looked at in terms of relative ratios, there is an obvious trend.

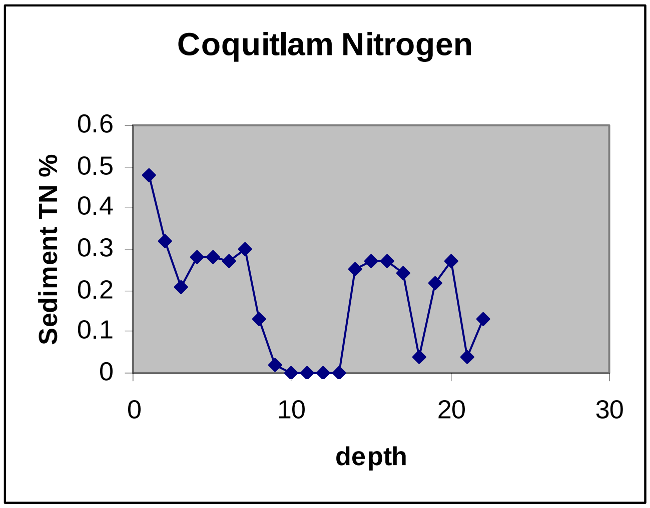


(c) Sediment Geochemistry

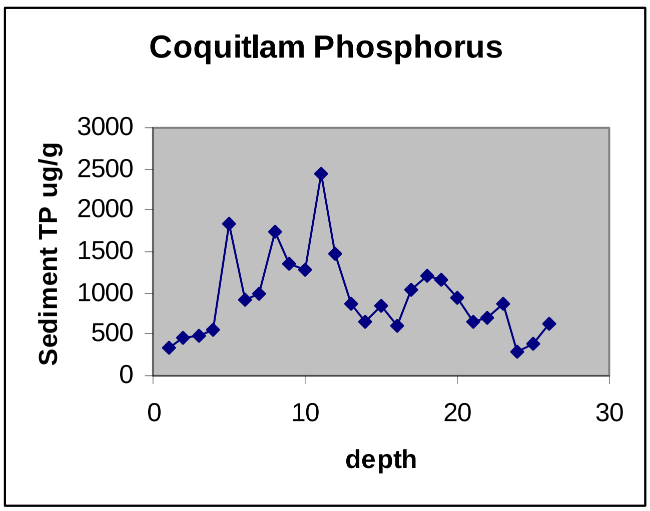
Changes in the delivery or deposition of different elements can be used to evaluate change in a lake or reservoir and its catchment. Total Organic Carbon in Coquitlam reservoir (below) seems to increase with time (as shown in the carbon data presented earlier).

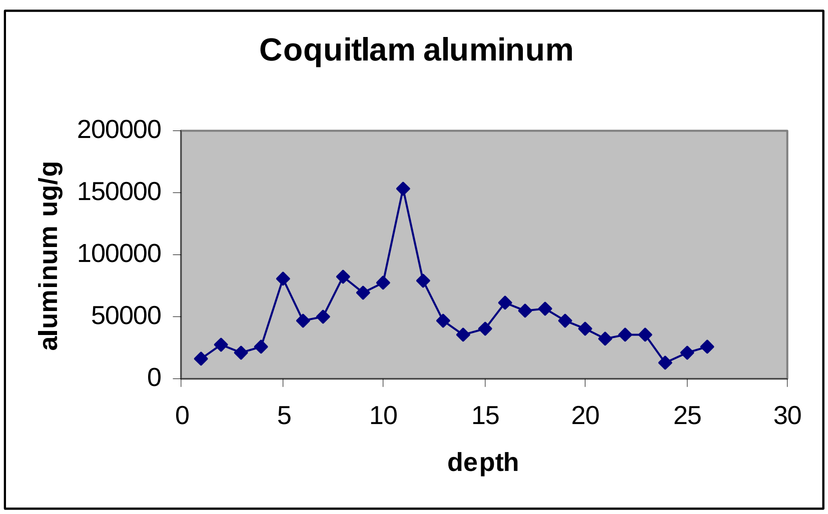


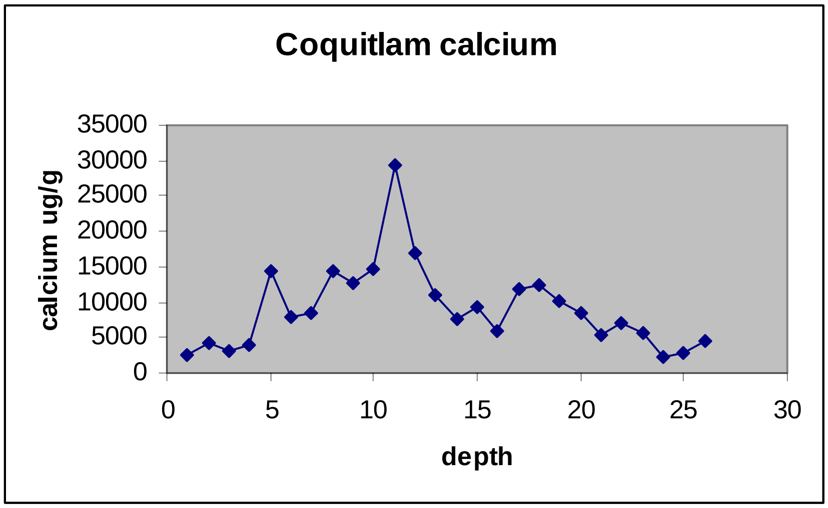
Nitrogen seems to show an increase in very recent years (past 25 years) as previously noted.

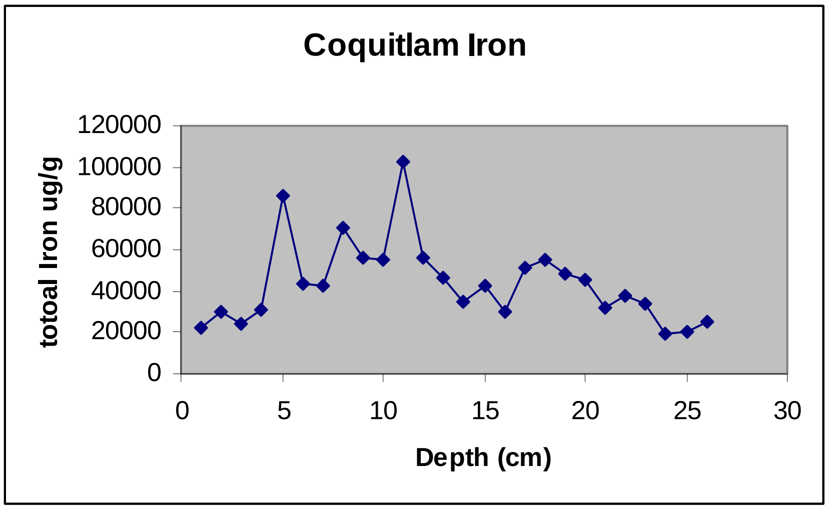


Iron, aluminum and calcium (and sometime phosphorus) have been used as general indicators of watershed disturbance and all show a peak of concentration at about 10 cm that corresponds to a date of about 1965 (1905 and dam construction are at about 17cm for Coquitlam).





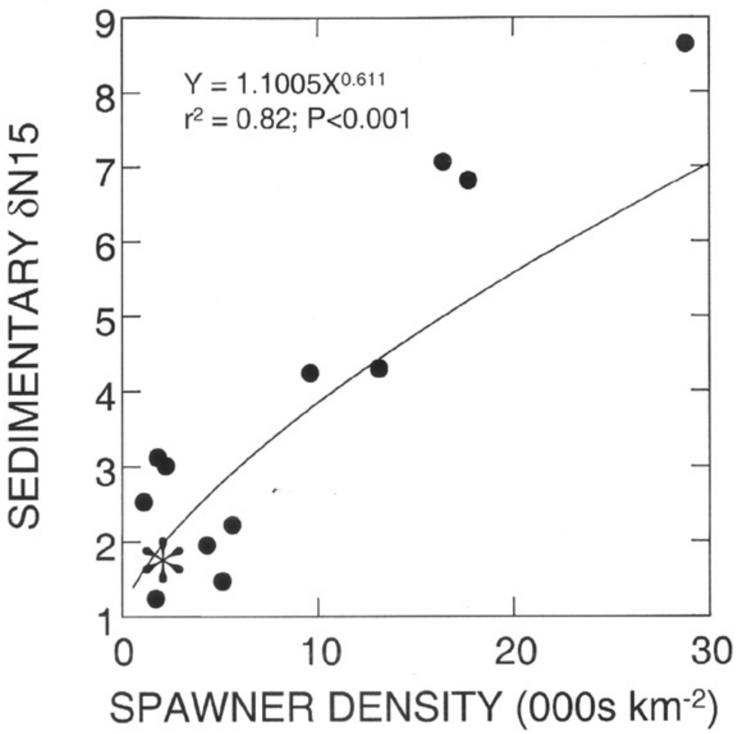




Discussion

To address the question of the changes in the sediment record that might be used to understand the effects of the dam and the exclusion of anadromous fish from these two reservoirs, it is necessary to look at what some other research has shown that bears on this problem. The most relevant work is that of Finney et al (2002 a, b). They showed that the δN^{15} concentration in the sediment was a good surrogate for the number of returning salmon to the lake. For Karluk Lake, they saw a decrease in δN^{15} from about 9 per mil before fishing pressure (at an escapement of about 2500 fish per km^2 of lake surface) which dropped to an δN^{15} of 6.5 to 7 per mil at escapements of about 1000 fish per km^2.

For Coquitlam there seems to have been a decline in the amount of δN^{15} in the sediments. For the samples prior to 1905, the levels are about 1.5 per mil. The decline does not appear to coincide with the dam construction, rather it appears to happen in about 1970. The surface sediments contain δN^{15} at concentrations of 0.5 per mil or less. This is at the very bottom of the scale that Finney et al (2000, 2002) gives for a range of Alaskan lakes – and that corresponds to the lowest numbers of returning salmon. From their data, the escapement would represent only a few hundred fish (possibly a few thousand) per km^2 at this concentration of δN^{15} in the sediment. Many other coastal lakes with low δN^{15} similar to this often have no anadromous fish runs. However the high flushing rate and extremes in hydrology also tend to result in low δN^{15} in coastal lakes.



Average $\delta^{15}N$ signature in the surface sediments of 12 sockeye nursery lakes in Alaska as a function of their average spawner density. Figure reproduced from Finney et al (2000).

The conclusion drawn from these data is that the population of salmon in Coquitlam Lake was likely very low (as it is now) and there seems no evidence that the marine derived nitrogen in the sediments of Coquitlam Lake changed as a result of the dam construction. The number of fish represented by the δN^{15} concentrations would probably be representative of a few thousand fish. The very low phytoplankton and zooplankton productivity in this ultraoligotrophic lake would not likely support very much fish productivity.

In Colorado, Wolfe et al (2001) looked at changes in δN^{15} in lake sediments of two lakes in Colorado. They found that the δN^{15} decreased significantly in about 1950. They attributed the decrease to enhanced atmospheric deposition of fixed nitrogen from anthropogenic sources.

In Florida, δN^{15} was used as an indicator of productivity in lakes, with decreases in δN^{15} being associated with increasing eutrophication (Brenner et al 1999). The trophic levels of the Florida lakes are much higher than Coquitlam but the same principle might apply. The decrease in δN^{15} seen especially in Coquitlam would then represent increase in productivity in the lake – something that would seem to be unlikely.

Recommendations

From the analysis of sediment core data, it appears that there are few changes that might be coincident with the expected major changes in sediment geochemistry that might be caused by dam construction. Changes in Coquitlam seem to have occurred in the past 30 years and not related to impoundment.

There seems little evidence that the existence of the dams has caused a major change in the δN^{15} which is used as a measurement of numbers of returning anadromous salmon bringing marine derived nitrogen into the lake systems. The low levels of pre-settlement δN^{15} would indicate that numbers of salmon in these systems were low.

Acknowledgments

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A number of people assisted in the collection of the samples and their analysis. Dave Dunkley of the GVRD assisting with field logistics and support for the program. The UBC Department of Earth and Ocean Sciences loaned personnel and a boat to do the coring on Coquitlam Reservoir. Lab analyses for lead 210 were done by Shapna Mazumder, coring and sample preparation were done with the assistance of Roel Groeneveld, Ian Patchett and Marsha Spaffard.

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