Trends in Water Quality of Buttle Lake and the Campbell River - Continuing Decreases in Metal Concentrations from 1987 through 1990

by

John Deniseger and Lloyd Erickson

Ministry of Environment
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Abstract

Since 1966, a copper-lead-zinc mine operated by Westmin Resources Limited has been a source of heavy metal input into Buttle Lake. Metal levels increased in the lake, peaking in 1980/81; thereafter improved treatment and collection systems at the mine site have resulted in steadily decreasing metal levels throughout the lake system. The increase in metal concentrations in the lake water was accompanied by increased metal concentrations in salmonid muscle and liver tissues, by elevated levels of hepatic metallothionein and by declines in both species diversity and population for phytoplankton, periphyton and zooplankton.

As metal concentrations decreased through the mid 1980's, the phytoplankton community began to change so that a continuous phytoplankton bloom, dominated by *Rhizosolenia eriensis*, was present from 1983 through late 1985. By late 1985, some metal sensitive species of phytoplankton and zooplankton began to reappear in the lake. In addition, metal levels in rainbow trout muscle tissue had improved significantly, while only copper and cadmium liver tissue levels remained significantly higher than for the control lakes through 1986. Hepatic metallothionein levels had also declined to significantly lower levels.

Since 1986, metal concentrations have continued to decrease throughout the lake system. Hepatic metallothionein, an indicator of biological stress upon fish has been reduced to levels believed

to be representative of minimal biological stress. Concentrations of metals in rainbow trout muscle tissue indicate that levels of metals have decreased to background. In liver tissue, cadmium has decreased significantly since 1986, while only copper remains elevated. The apparent health of the fisheries resource is further illustrated by the dramatic improvement in angler success and catch statistics. The zooplankton community is also showing encouraging signs of recovery as several sensitive species have returned to prominence. The phytoplankton community appears to be at a less advanced stage of "recovery" as sensitive species continue to remain virtually absent from recent samples.

Introduction

Buttle Lake has been subject to long term heavy metal contamination as a result of a copper/lead/zinc mine which began operation in 1966 (Westmin Resources Ltd.) and is located 6 km west of the south end of the lake adjacent to Myra Creek (Figure 1). Metal levels increased in the lake, peaking in 1980/81, reaching levels as high as 0.370 mg/L zinc, 0.040 mg/l copper, 0.025 mg/L lead and 0.0036 mg/L cadmium in the surface waters. Thereafter, improved treatment and collection systems at the mine site have reduced loadings to the lake by an estimated 80% (Norecol, 1984). In addition, an on-land tailings disposal method replaced the system of lake disposal in July 1984. A further reduction in loadings was achieved by the gradual removal of the acid generating "tailings line road" through the late 1980's. As a result of the reduced loadings, concentrations of metals throughout the lake had declined substantially by 1986. Nordin et al. (1985) recommended the following objectives for Buttle Lake: 0.05 mg/L zinc, 0.0025 mg/L copper, 0.0013 mg/L cadmium and 0.005 mg/L lead. Deniseger et al. (1990) found that while there had been considerable improvement by 1986, particularly in surface waters, zinc, copper and possibly cadmium (lower detection limit needed), continued to exceed the objectives at depth.

The increases in metal concentrations in the lake water through 1980/81 were accompanied by increased metal concentrations in salmonid muscle and liver tissue, by elevated levels of hepatic metallothionein, and by declines in both species diversity and abundance for phytoplankton, periphyton and zooplankton.

More recently, metal levels in rainbow trout muscle tissue have improved significantly, although copper and cadmium liver tissue levels remained significantly higher than for the control lakes through 1986 (Deniseger et al., 1990). Hepatic metallothionein concentrations in rainbow trout, an indicator of metal stress, have decreased by 76%, from a high of 269 (±23) nanograms/gram wet liver in August 1981 to a low of 64 (±22) nanograms/gram in June 1985. Roch and McCarter (1984) proposed a metallothionein concentration of 100 nmol/gram as a safe level for salmonids which correlates to 0.050 mg/L zinc, 0.0025 mg/L copper and less than 0.0005 mg/L cadmium.

As metal concentrations decreased through the mid 1980's, the phytoplankton community began to change so that from 1983 through 1985, a continuous phytoplankton bloom dominated by Rhizosolenia eriensis was present throughout the lake. Accompanying the bloom was a scarcity of zooplankton. However, as levels of R. eriensis began to decline in 1985, species of zooplankton and other phytoplankton gradually began to reappear.

The present study is a follow-up upon previous work and covers the period from 1987 through June 1990. This study examines the rate and extent of recovery of the lake ecosytem by examining the water chemistry, phytoplankton, zooplankton, and fish in Buttle Lake and Myra Creek. It further expands upon previous work by examining fish tissue lead levels and ambient cadmium through the use of lower detection limits. Because of concern as to metal levels in the downstream watershed, the monitoring program has also been extended into the Campbell River.

Site Description

Buttle Lake lies in a "U" shaped valley in the mountains of Strathcona Park, Vancouver Island, British Columbia at an altitude of 218 m. With a length of 35 km, surface area of 35.3 km2 and mean depth of 45 m, it is the largest in a chain of lakes in the Campbell River watershed (area 1404 km2). Buttle Lake drains northward through a short channel into Upper Campbell Lake. The water levels of both lakes are controlled by B.C. Hydro at Strathcona Dam. The maximum drawdown is generally 8.4 m but, the lake can be drawn down as much as 12 m (Clark and Morrison, 1982; Nordin et al., 1985). The Campbell system continues eastward some 20 km through Lower Campbell Lake, John Hart Lake and the Campbell River which flows to sea (Discovery Passage). For further lake morphometry information see Nordin et al. (1985).

Nutrient levels throughout Buttle Lake are characteristic of oligotrophic lakes on Vancouver Island (typically total phosphorus 2-5 ug/L, and nitrate/nitrite <100 ug/L). The region has a maritime climate and considerable precipitation of 150-300 cm per annum with rapid runoff.

Native fish in Buttle Lake are rainbow trout (*Oncorynchus mykiss*), cutthroat trout (*Oncorynchus clarkii clarkii*), Dolly Varden char (*Salvelinus malma*), stickleback (*Gasterosteus aculeatus*) and prickly sculpin (*Cottus asper*). Anadromous salmonids have never had access to the system upsteam of a major waterfall near John Hart Dam.

Methods

Chemical and biological samples were obtained at specific stations in Myra Creek, Buttle Lake and the Campbell River (Figure 1).

Water Chemistry

Samples were taken using a non-metallic Van Dorn water bottle and placed in clean, polyethylene bottles for analysis; those bottles intended for metals analyses were acid washed prior to use. Samples for total metals analyses were field acidified (4 mL HNO3 per liter of sample). Samples for dissolved metals analyses were filtered through a 0.45 micron millipore filter, followed by preservation with 4 mL HNO3 per litre of sample. Samples for all other parameters were submitted unfiltered and unpreserved. All samples were sent in coolers to the Environmental Laboratory prior to January 1989 and to Zenon Environmental Inc. since that time, where analyses were performed by standard procedures (Clark and Shera, 1985).

Aquatic Biota

Zooplankton were sampled qualitatively utilizing horizontal surface tows and qualitatively using 25 m vertical tows with 64 micron mesh plankton nets. Discrete quantitative samples for phytoplankton and chlorophyll a were collected using a non-metallic Van Dorn water bottle. All samples were preserved with 5% buffered formalin.

Salmonids were collected utilizing two gill nets consisting of a gang of three different mesh sizes (2.5 cm, 5.0 cm, 7.5 cm) each approximately three metres deep, 75 metres long with a weighted bottom line and buoyant mainline. An anchor was utilized to sink the nets at the deep end. The nets were generally deployed at one site, located on the east side of Buttle Lake opposite Myra Creek. Tissue samples were immediately after dissection frozen over dry ice. Livers for metallothionein analysis were taken from freshly killed fish and immediately frozen. Fish lengths, weights, sex, and species were recorded and scale samples taken.

To assess trends over time within Buttle Lake and to compare Buttle Lake to data for other B.C. Lakes, the fish tissue metals data was grouped into four time periods; 1966-73, the initial period of mine development and operation; 1979-81, the period of greatest impact and highest ambient concentrations; 1983-86, the transition period following implementation of the groundwater collection and treatment system and decreasing ambient metal levels; 1987-89, the period following the initial decreases in metal concentrations in Buttle Lake. In addition, similar data for fish collected in 1967-86 from uncontaminated lakes in British Columbia were combined and used as a control (Clark, 1987). Statistical comparisons were by student's t-test to determine differences significant at $p < 0.05$ except small data sets which were excluded from consideration.

Results

A. Metal Concentrations

Prior to the implementation of the collection and treatment system in 1983, concentrations in Myra Creek, downstream of the minesite, were as high as 2.31 mg/L zinc, 0.170 mg/L copper, 0.0045 mg/L cadmium and 0.004 mg/L lead (figure 2). Concentrations tend to be highest during the winter months when high rainfall and rapid runoff results in greater quantities of water percolating through the mine site and a reduced residence time in the treatment system. In spring, concentrations in Myra Creek begin to decrease as high elevation snow-melt contributes to higher flows and dilution. Since that time, levels of cadmium, copper and zinc have decreased gradually so that by 1986, levels tended to remain below 0.100 mg/L zinc, 0.007 mg/L copper, and less than 0.0005 mg/L cadmium through the summer months and 0.5 mg/L zinc, 0.04 mg/L copper, and 0.0015 mg/L cadmium, through the winter. By 1989/90, summer levels tended to remain below 0.07 mg/L zinc, 0.006 mg/L copper, and 0.0004 mg/L cadmium. Winter levels tended to remain below 0.300 mg/L zinc, 0.030 mg/L copper, and 0.0008 mg/L cadmium.

Figure 3 and table 1 illustrate the pattern of decreasing zinc concentrations at south Buttle Lake since 1980/81. Concentrations of metals tend to increase with depth and follow a seasonal pattern with highest surface concentrations tending to occur over the winter months. For example in April 1981, total zinc levels peaked at 0.230 mg/L at the surface and at 0.370 mg/L at 45 meters. By 1985, levels of zinc exceeding 0.09 mg/L were limited to depths greater than 40 meters during the winter months, while surface concentrations decreased to 0.030-0.050 mg/L during the summer months. Levels continued to decrease so that by 1989 all data for the upper 10 meters of the water column indicated zinc concentrations at or less than 0.030 mg/L, while at depth, virtually all data ranged from 0.030-0.050 mg/L.

Copper concentrations have decreased considerably since 1980/81 at site 0130082 in south Buttle (figure 4, table 1). Concentrations of copper continue to increase with depth and follow a seasonal pattern with highest surface values tending to occur through the winter months. In the early 80's, concentrations at depth peaked at >0.040 mg/L, while values ranging 0.010 to 0.020 mg/L were common throughout the water column. By 1987, surface waters ranged from 0.001 to 0.005 mg/L, while at depth copper peaked at 0.007 mg/L. By 1989/90, values less than 0.002 mg/L were common through the summer months, while only occasionally exceeding 0.005 mg/L through the remainder of the year.

Nordin <u>et al.</u> (1985) recommended objectives for Buttle Lake as follows: 0.05 mg/L zinc, 0.0025 mg/L copper, and 0.0013 mg/L cadmium as well as 0.005 mg/L lead. In south Buttle, the objective of 0.05 mg/L zinc has been met continuously from March 1988 through June 1990 in the upper 20 meters of the water column. Available data for 1989/90 indicate that the zinc objective is rarely exceeded at depth and was in fact met in 96% of all samples taken in 1989/90. The cadmium objective is now met continuously at all depths as levels are less than 0.0004 mg/L at depth and less than 0.0003 mg/L at the surface. The lead objective is also met consistently at all depths throughout the year as levels are now routinely less than 0.003 mg/L. The copper objective is now met in the surface waters during the summer months, but is exceeded at depth and through the winter at the surface. However, it should be noted that levels have decreased substantially from a peak of 0.03 mg/L in 1980/81 to levels generally less than 0.005 mg/L in 1989/90, with only occasionally higher levels.

At site 0130088, at the north end of Buttle Lake, zinc concentrations have also decreased considerably through the 1980's (table 1). In 1980/81, levels throughout the water column typically ranged from 0.100 - 0.180 mg/L zinc, 0.004 - 0.020 mg/l copper, 0.001 - 0.006 mg/L lead, and < 0.0005 - 0.0013 mg/L cadmium. By 1989/90, zinc was consistently at or below the objective of 0.03 mg/L, while copper ranges <0.001 - 0.002 mg/L at the surface and < 0.005 at depth. Lead is consistently at <0.001 - 0.002 mg/L, while cadmium ranges <0.0001 - 0.0003 mg/L.

At site 0130080, Buttle Lake at Gold River bridge, concentrations in 1980/81 ranged from 0.07 - 0.150 mg/L zinc, 0.003 - 0.010 mg/L copper, and <0.001 - 0.013 mg/L lead. By 1989/90 concentrations had decreased substantially to 0.01 - 0.055 mg/L zinc, <0.001 - 0.005 mg/L copper and <0.001 to 0.003 lead (figure 5, table 1).

Sampling at site E207772, Campbell River just upstream of

Quinsam River, was limited to 1989/90 and indicated low levels of metals. Concentrations generally ranged from <0.005 to 0.015 mg/L zinc (one value at 0.05 mg/L), 0.001 to 0.004 mg/L copper (one value at 0.01 mg/L), <0.001 to 0.002 mg/L lead and <0.0001 to 0.0002 mg/L cadmium.

B. Nutrients

Historical sampling has indicated that nutrients follow seasonal patterns typical of oligotrophic lakes of the area. Nutrients peak during the winter months and are at their lowest through the summer. One exception to this pattern was during 1984 when total dissolved phosphorus reversed its seasonal pattern so that maxima were maintained through the summer months (Deniseger et al., 1990). Since that time, nutrients have followed historical patterns.

C. Water Clarity

The switch to on-land tailings disposal in 1984 removed a major source of turbidity and/or suspended sediments from south Buttle Lake. It was thought that during the winter months, there was some resuspension of tailings through the water column resulting in decreased light penetration and very shallow extinction depths (estimated by secchi depth) of less than 2 meters. Since 1984, extinction depth is no longer reduced to such low levels. Furthermore, summer extinction depth estimates have increased dramatically (up to 16 meters in depth at site 0130082), indicating improved water clarity (figure 6). The improved summer water clarity was initially obscured by a phytoplankton bloom in

1984 and 1985. From 1980-1983, secchi depth ranged from 1.5 to 13.5 meters with a mean of 6.1 meters, while from 1987-1989, secchi depth ranged from 5.5 to 18.5 meters averaging 10.2 meters.

D. Fish Data

Previous work utilized hepatic metallothionein as an indicator of biological stress on rainbow trout (Roch and McCarter, 1984). Rainbow trout collected in the south basin of Buttle Lake indicated substantially decreasing levels by 1985 (Deniseger et al., 1990). Levels had decreased from a high of 269 (±23) nanograms/g wet liver in August, 1981 to a low of 64 (±22) nanograms/g wet liver June 1985. More recent data confirms that the lower levels have been maintained as levels were 69 (±23) in 1988 and 71 (±32) nanograms/g wet liver in 1989 (table 2).

Rainbow trout tissue metal concentrations for 1987-89 were compared to earlier data as well as a control data set (Clark, 1987), (tables 3a, 3b). Earlier data indicated that by 1983-86, muscle tissue metal levels had decreased significantly, while copper and cadmium liver tissue levels had not shown a significant decreasing trend. In 1987-89, it was confirmed that muscle tissue copper and zinc had decreased significantly. Furthermore, it was found that muscle tissue lead levels were no longer significantly different from the control (previous lead data was insufficient for analysis). Trends in liver metal concentrations were also confirmed as zinc levels remained lower in 1987-89. In addition, lead for 1987-89 was significantly lower than for previous Buttle Lake data (1966-73) and was not significantly different from the control. While cadmium liver levels remain higher than that of the control, there is nevertheless a decreasing trend as levels in 1987-89 were significantly lower than in 1979-81.

E. Zooplankton

Historical zooplankton data for Buttle Lake is rather sparse as it is limited to scattered data. McMynn and Larkin (1953) indicated the presence of *Daphnia* and *Leptodora*, while Sinclair (1965) found *Daphnia*, *Leptodora*, *Holopedium* and *Polyphemus* in Buttle Lake. Whately (1969) reports that *Diaptomus* and *Daphnia* were common throughout Buttle Lake prior to commencement of mining. Data for 1966/67 indicated *Bosmina*, *Daphnia*, *Polyphemus*, *Cyclops*, and *Diaptomus* as well as *Alona karua*, *Alonella*, and *Chydorus*. It should be noted that due to the sparse nature of the historical data, comparisons between historical and more recent data can be difficult. Nevertheless, by 1980/81, the zooplankton community indicated a trend to decreasing numbers of cladocerans and calanoid copepods as the mine was approached. In 1984, zooplankton were present in extremely low numbers. It wasn't until 1985 that zooplankton gradually became more abundant and diverse. Through 1985/86, cladocerans such as *Daphnia*, *Holopedium gibberellum*, *Polyphemus pediculus*, and *Bosmina longirostris* gradually increased in abundance as did the calanoid copepod *Diaptomus* and other zooplankters such as *Kellicotia cochlearis* and *Cyclops bicuspidatus*. More recent data through 1990 indicate a continuing trend toward a more diverse, abundant community beginning to resemble historical species composition. Rotifers, while difficult to sample quantitatively using plankton nets, appear to be increasing in importance as species such as Kellicotia longispina, Keratella quadrata, Keratella cochlearis, Testudinella sp., Conochilus sp., and Trichotia tetactis are becoming more abundant. Cladocerans such as Daphnia rosea and Bosmina longirostris frequently dominated the community during 1989/90 as did Diaptomus oregonensis and Cyclops bicuspidatus. In fact, it appears that by 1989/90, species composition may be quite similar to that found historically in Buttle Lake.

F. Phytoplankton

Historical phytoplankton data were limited to 1966-68, when the dominant association throughout Buttle Lake, consisted of Rhizosolenia eriensis, Asterionella formosa, Tabellaria fenestrata, Tabellaria flocculosa, Peridinium and Ceratium hirundinella. In 1980/81, the phytoplankton community was dominated by Navicula cryptocephala, Synedra acus, and Synedra filiformis. In 1980, after 13 years of mining activity, species intolerant to higher metal levels such as T. fenestrata, T. flocculosa, R. eriensis and A. formosa had virtually disappeared from Buttle and Upper Campbell Lakes (Austin and Munteanu, 1984). Species of Chlorophyta, Chrysophyta and Pyrrhophyta had declined substantially. The reduction or disappearance Rhizosolenia and Asterionella was particularly noteworthy because they continued to appear in significant numbers in Lower Campbell and John Hart Reservoir and in nearby Upper Quinsam Lake (Nordin et al., 1985). This pattern is likely related to metals sensitivity as metals levels were considerably lower than in south Buttle.

Gradually as metal levels began to decrease, S. acus, and S. filiformis began to increase in dominance (figures 7 and 8). In late 1983, Rhizosolenia eriensis began to become more abundant and by early 1984 through June 1985, constituted a virtual monoculture at levels (up to 26,000 cells/mL) previously unheard of in Buttle Lake. R. eriensis remained generally dominant through 1986 and much of 1987, while other species such as Dinobryon sertularia gradually become more abundant. By 1989/90, R. eriensis was only a spring dominant, while Dinobryon spp. and S. filiformis were also abundant. During the summer, the community was dominated by small chlorophytes such as Sphaerocystis schroeteri, Elakatothrix gelatinosa and Gloeocystis ampla. The community then shifted to one dominated by Cryptomonas, Cyclotella glomerata, Crucigenia rectangularis and Dinobryon divergens. Metal intolerant species such as T. fenestrata, T. flocculosa and A. formosa which were dominants in 1966 remain virtually absent from 1989/90 samples. Overall species number has substantially improved as numerous species of diatoms, Chlorophyta, Chrysophytes and Pyrrhophytes were present in smaller quantities. With the exception of the spring abundance of R. eriensis, cell numbers remained fairly low, similar to historical levels (less than 100 cells/mL). The abundance of genera such as Cryptomonas, and Gloeocystis is of note in that they were absent from Buttle Lake in 1980/81, but were important contributors in Upper Campbell, Lower Campbell and John Hart Lakes at that time, likely as a result of lower metal levels.

DISCUSSION

Earlier trends to improving water quality appear to have been confirmed as levels of the metals of concern have continued to decrease since 1986. The objectives recommended for Buttle Lake by Nordin et al. (1985) are now routinely met for zinc, cadmium and lead throughout Buttle Lake, including south Buttle. Copper levels, while substantially lower than that found during the early 1980's, continue to exceed the objectives during the winter months and at depth. The metals data while illustrating further decreases in concentrations also show the continuing gradient with depth and with distance from the minesite. It is thought that the levels of metals in Buttle Lake have not yet stabilized and will continue to decrease with time as the lake reaches equilibrium. However, the mine remains a significant source of heavy metal input as indicated by the levels in Myra Creek. Given the present loadings to Buttle Lake, it is unlikely that background concentrations can be reached as predicted by Norecol (1984).

Other studies examining background copper concentrations in central Vancouver Island have found that the highly mineralized nature of the region may have contributed to higher than normal background copper concentrations (Deniseger and Erickson, 1988). Background copper concentrations are thought to range 0.003 to 0.005 mg/L in the Tsolum River, higher than the recommended objective for Buttle Lake. Natural mineralization, particularly near the south end of the lake, may be contributing significantly to the apparent continuing elevated copper levels.

Previous work indicated that the biota of Buttle Lake, particularly the phytoplankton and zooplankton were not following a simple reversal of earlier trends. However, the period 1983-86, appears to have been a transition period characterizing a shift toward a community more typical of the region's oligotrophic lakes. As part of that shift, a moderately tolerant species of diatom completely dominated the phytoplankton community for a prolonged period taking advantage of a set of environmental conditions associated with decreasing heavy metals, nutrient increases and the long term effects of heavy metal contamination. The conditions appear to have been ideal for the growth of R. eriensis. Continuing decreasing metal levels permitted other perhaps more metal sensitive species to become more abundant. As a result, the phytoplankton community in 1989/90 was beginning to show similarities to that found typically in the region's oligotrophic lakes. However, several large lotic species such as T. fenestrata, T. flocculosa and A. formosa which were important in 1966-68, remain absent from Buttle Lake.

Paralleling the decline of R. eriensis and the decreasing metal levels was the gradual and continuing recovery of the zooplankton community. Sensitive species which had all but disappeared in 1980/81, have once again returned to prominence by 1989/90. Of particular importance is the return to prominence of larger species such as Daphnia rosea, Bosmina longirostris and Polyphemus pediculus.

The reappearance of these important zooplankton species is likely of substantial benefit to fisheries. It has been shown that Daphnia was a major dietary component of rainbow trout in Upper Campbell Lake (Nilsson and Northcote, 1981). Our field observations of stomach contents in Buttle Lake through 1987-90 confirm the importance of large zooplankters in the diet of rainbow trout, as well as smaller Dolly Varden Char and cutthroat trout. Field observations and angler success, while somewhat subjective and anecdotal in nature, nevertheless indicate an apparently more abundant fish population. In fact, angler use and catch statistics for Buttle lake indicate substantial improvements in angler success and total catch in 1990 compared to 1982 data (table 4).

Metallothionein levels in rainbow trout livers indicate significantly lower levels of metal stress affecting fish in Buttle Lake. Roch and McCarter (1984) proposed a metallothionein objective of 100 nmol per g wet liver as a safe level for salmonids which correlates to approximately 0.05 mg/L zinc, 0.0025 mg/L copper and less than 0.0005 mg/L cadmium. Metallothionein levels in Buttle Lake have remained remarkably consistent since 1985, ranging from 64 to 71 nmol per g wet liver, a decrease of approximately 76% over 1981. By comparison, McKean and Deniseger (1991) examined a group of control lakes on Vancouver Island and found that rainbow trout hepatic metallothionein levels ranged from 18.4 to 36.2 nmoles/g wet liver, substantially lower than Buttle Lake levels.

Despite continuing improvements in metal concentrations in

Buttle Lake since 1985, metallothionein levels have not continued to parallel decreases in ambient metal concentrations. This is likely related to metallothionein's high sensitivity to slightly elevated copper (and cadmium). This phenomenon may also explain why zinc and lead levels in rainbow trout have decreased to levels not significantly different from the control lakes, while copper, and to a lesser extent, cadmium levels remain elevated in rainbow trout livers. Furthermore, it is likely the explanation for the rapid increase in liver copper levels in 1966-73, during the initial start-up of the mining operation. The continuing high liver copper levels confirm the likelihood that ambient levels have not yet reached background. By comparison, liver cadmium levels while remaining higher than background, have significantly decreased since 1979-81.

While it appears that the water quality of Buttle Lake is continuing to improve, it is apparent that the different trophic levels are at various stages of recovery. Hepatic metallothionein levels indicate that biological stress upon fish has been reduced considerably. Tissue concentrations of metals in rainbow trout indicate that in muscle tissue, levels of metals have decreased to background. In liver tissue, lead and zinc levels are at background while cadmium has decreased significantly and only copper remains elevated. The relative health of the fisheries resource in Buttle Lake is further illustrated by the dramatic improvement in angler success and catch statistics. The zooplankton community is also showing encouraging signs of recovery as several species such as Daphnia rosea, Bosmina longirostris and Polyphemus pediculus return to prominence. The return of these key species is likely of substantial benefit to fisheries as these species are of significance in the diet of rainbow trout. The phytoplankton community appears to be at less advanced stage of "recovery" as sensitive species such as Asterionella formosa, Tabellaria fenestrata and Tabellaria flocculosa continue to remain virtually absent from 1989/90 samples. While the improvement in water quality since 1980/81 in Buttle Lake has been dramatic it is apparent that heavy metal concentrations will have to decrease further before previously dominant sensitive species will return.

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Table 1. Summarized Concentrations of heavy metals in surface waters of Buttle Lake. Range of values throughout year with upper values generally found during the winter months. All values in ug/L.

Total cadmium	station 0130082	station 0130088	station 0130080
1980	<0.5-1.3	<0.5-1.3	<0.5-0.8
1981	0.6	0.6	<0.5
1982	<0.5-0.6	<0.5	<0.5-0.5
1983	<0.5	<0.5	<0.5-0.7
1984	<0.5-0.5	<0.5-0.5	<0.5
1985	<0.5	<0.5-1.5	<0.5-0.6
1986	<0.5	<0.5	<0.5
1987	<0.5	<0.5	<0.5
1988	<0.5-0.6	<0.5-0.6	<0.5
1989	0.1-0.3	<0.1-0.3	<0.5

Total copper	station 0130082	station 0130088	station 0130080
1980	5-30	5-10	3-10
1981	4-30	2-7	2-10
1982	4-15	4-7	3-6
1983	3-9	2-9	2-4
1984	2-20	3-4	2-4
1985	<1-7	<1-6	<1-4
1986	<1-10	2-10	<1-6
1987	1-5	2-4	2-5
1988	1-5	1-13	<1-3
1989	<1-6	<1-5	<1-4

Total zinc	station 0130082	station 0130088	station 0130080
1980	110-370	85-143	70-150
1981	100-280	40-130	40-130
1982	30-170	100	50-80
1983	18-120	14-100	<10-100
1984	10-140	40-80	20-70
1985	30-70	24-50	30-90
1986	20-50	12-40	10-57
1987	20-80	20-30	17-30
1988	11-60	10-30	15-50
1989	12-40	7-30	10-55

Table 1 (cont.)

Total lead	station 0130082	station 0130088	station 0130080
1980	<1-4	<1-1	<1-13
1981	<1-4	<1-3	<1-5
1982	<1-4	<1	<1-1
1983	<1-3	<1-3	<1-14
1984	<1-2	<1-2	<1-1
1985	<1-1	<1-4	<1-2
1986	<1-4	<1-2	<1-3
1987	<1-9	<1-4	<1-5
1988	<1-1	<1-3	<1-6
1989	<1-2	<1-2	<1-3

Table 2. Concentrations of hepatic metallothionein in rainbow trout captured in the south basin of Buttle Lake.

Date	Metallothionein (nmoles/g wet liver)
July 1981	213 ± 61 (n=6)
August 1981	269 ± 23 (n=5)
June 1983	205 ± 23 (n=2)
June 1984	105 ± 50 (n=17)
June 1985	64 ± 22 (n=12)
June 1988	69 ± 23 (n=10)
June 1989	71 ± 32 (n=10)

Table 3 a) Statistical Comparisons of Buttle Lake Rainbow Trout Tissue for 1987-89 to Other Time Periods [X=no significant difference ($P \leq 0.05$)]

a) Liver

	Copper	Cadmium	Lead	Zinc
1966-73	X	-	66-73>87-89	X
1979-81	X	79-81>87-89	-	X
1983-86	X	X	-	X
control	But>B.C.	But>B.C.	X	X

b) Muscle

	Copper	Cadmium	Lead	Zinc
1966-73	66-73>87-89	-	-	X
1979-81	79-81>87-89	-	-	X
1983-86	X	-	X	X
control	X	-	X	X

Table 3b) Statistical Comparison of Buttle Lake Rainbow Trout Tissue to Control Group of B.C. Lakes (Clark, 1987) [X=no significant difference ($p \leq 0.05$)]

a) copper	muscle	liver
1966-73	BUT>BC	BUT>BC
1979-81	BUT>BC	-
1983-86	X	BUT>BC
1987-89	X	BUT>BC

b) zinc	muscle	liver
1966-73	X	BUT>BC
1979-81	BUT>BC	-
1983-86	X	X
1987-89	X	X

c) cadmium	muscle	liver
1966-73	-	-
1979-81	-	-
1983-86	-	BUT>BC
1987-89	-	BUT>BC

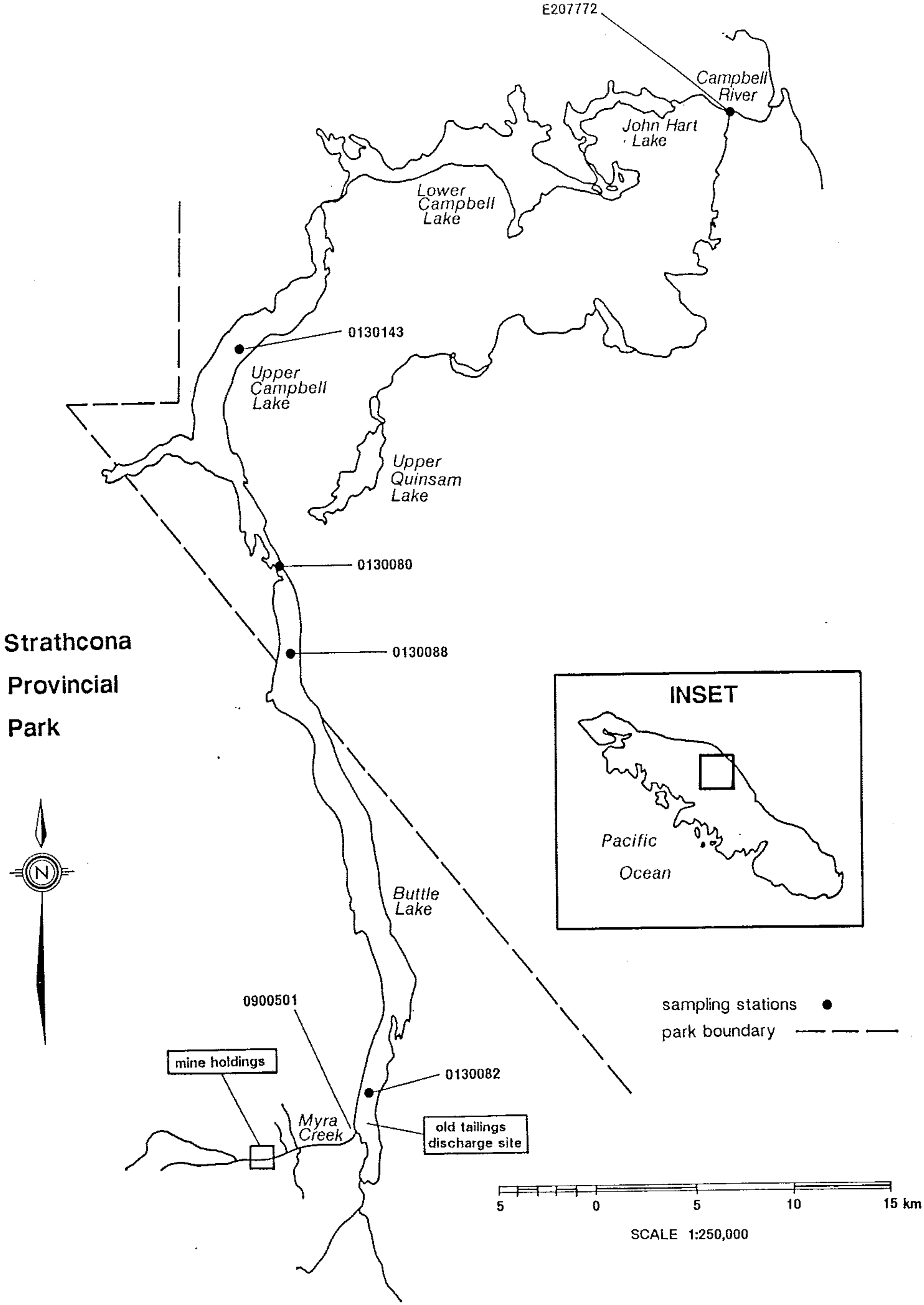
d) lead	muscle	liver
1966-73	-	BUT>BC
1979-81	BUT>BC	-
1983-86	-	-
1987-89	X	X

Table 4. Angler Use and Catch Statistics for Buttle Lake

Year	Anglers	Angler Days	Catch Per Day	Total Catch
1982	580	2355	1.8	4330
1990	1366	5331	2.4	12993
Increase	+235%	+126%	+33%	+300%

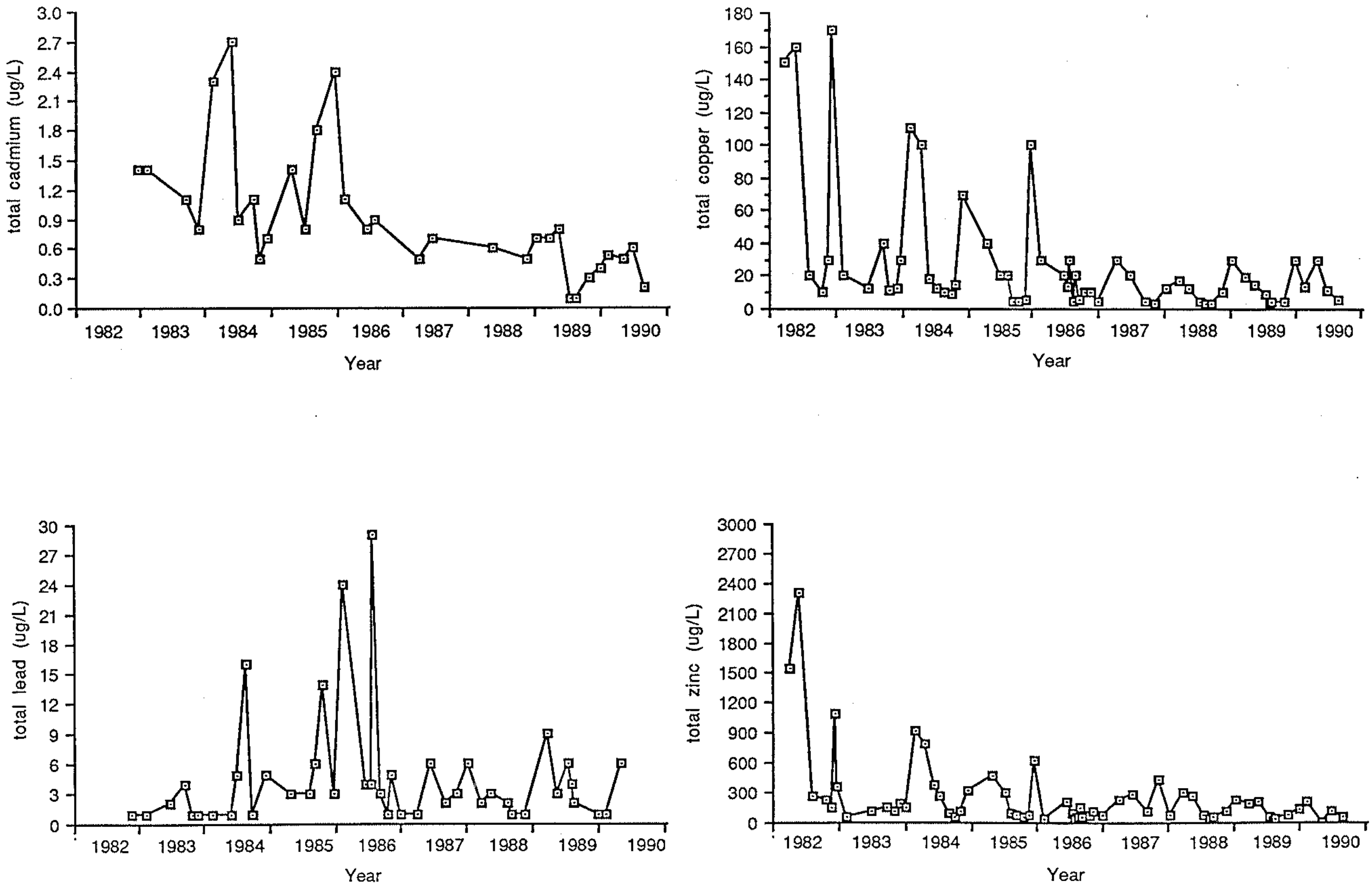
Figures

Figure 1. Map of Buttle Lake showing position of sampling stations and some features of the surrounding watershed.


E207772
Campbell River
John Hart Lake
Lower Campbell Lake
0130143
Upper Campbell Lake
Upper Quinsam Lake
0130080
Strathcona Provincial Park
0130088
INSET
Pacific Ocean
Buttle Lake
sampling stations
park boundary
0900501
mine holdings
0130082
Myra Creek
old tailings discharge site
5 0 5 10 15 km
SCALE 1:250,000

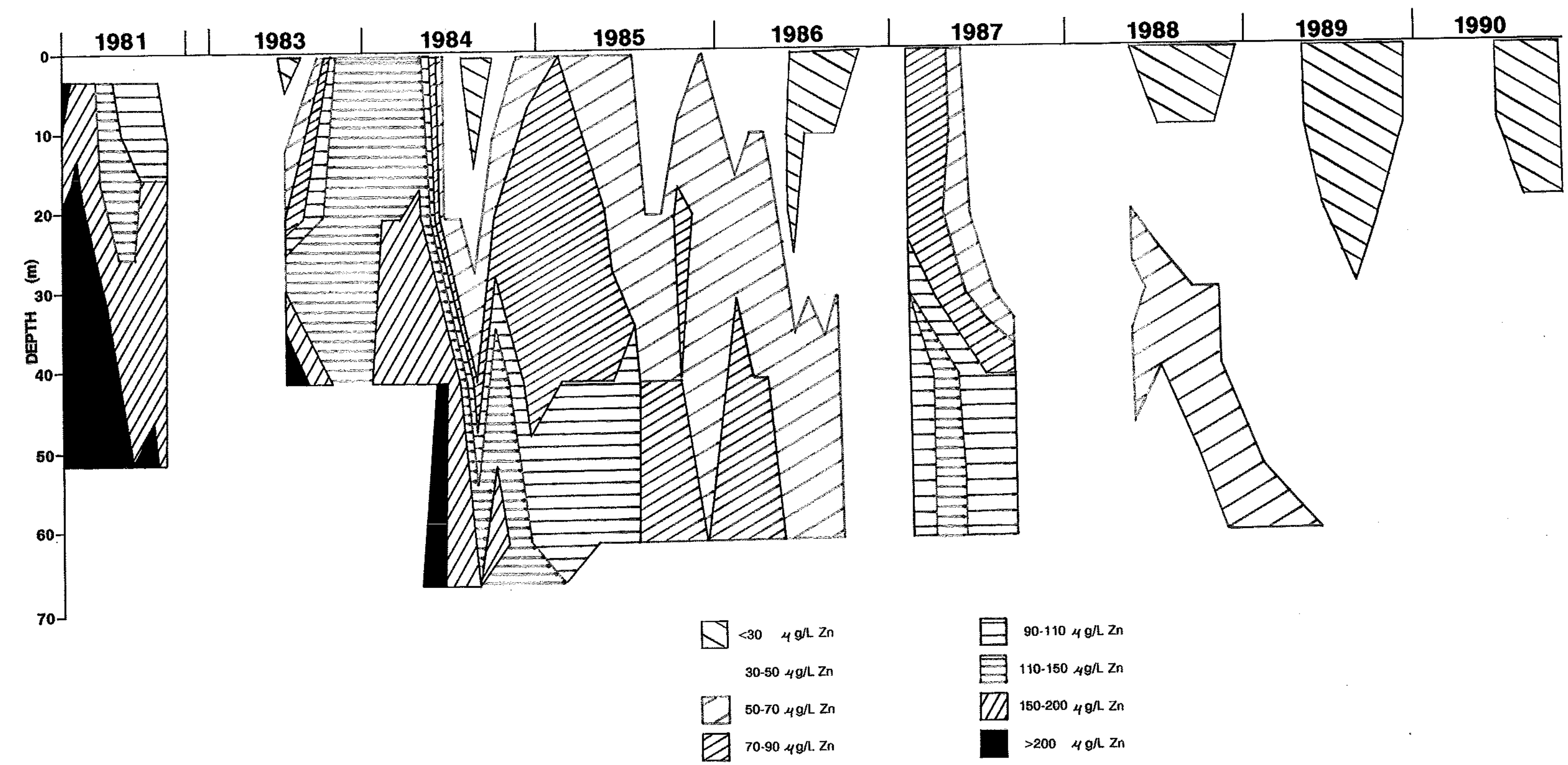
Figures

Figure 2. Graph illustrating the range and seasonality of total cadmium, copper, lead and zinc in Myra Creek at site 0900501.


total cadmium (ug/L)
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
1982
1983
1984
1985
1986
1987
1988
1989
1990
Year
total copper (ug/L)
180
160
140
120
100
80
60
40
20
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
Year
total lead (ug/L)
30
27
24
21
18
15
12
9
6
3
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
Year
total zinc (ug/L)
3000
2700
2400
2100
1800
1500
1200
900
600
300
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
Year

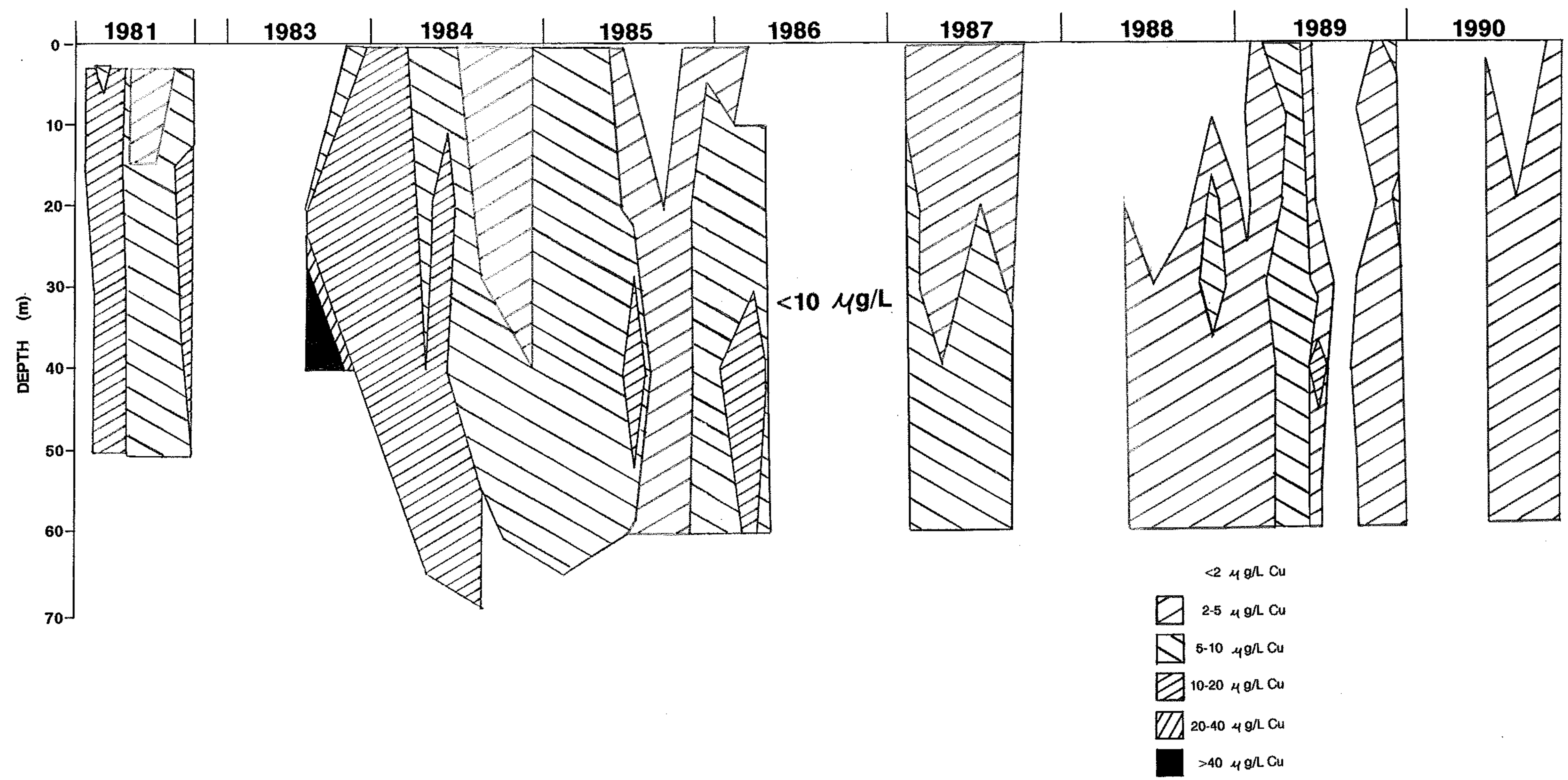
Figures

Figure 3. Time-depth diagram for total zinc at site 0130082, in the south basin of Buttle Lake.


1981
1983
1984
1985
1986
1987
1988
1989
1990
DEPTH (m)
0
10
20
30
40
50
60
70
<30 µg/L Zn
30-50 µg/L Zn
50-70 µg/L Zn
70-90 µg/L Zn
90-110 µg/L Zn
110-150 µg/L Zn
150-200 µg/L Zn
>200 µg/L Zn

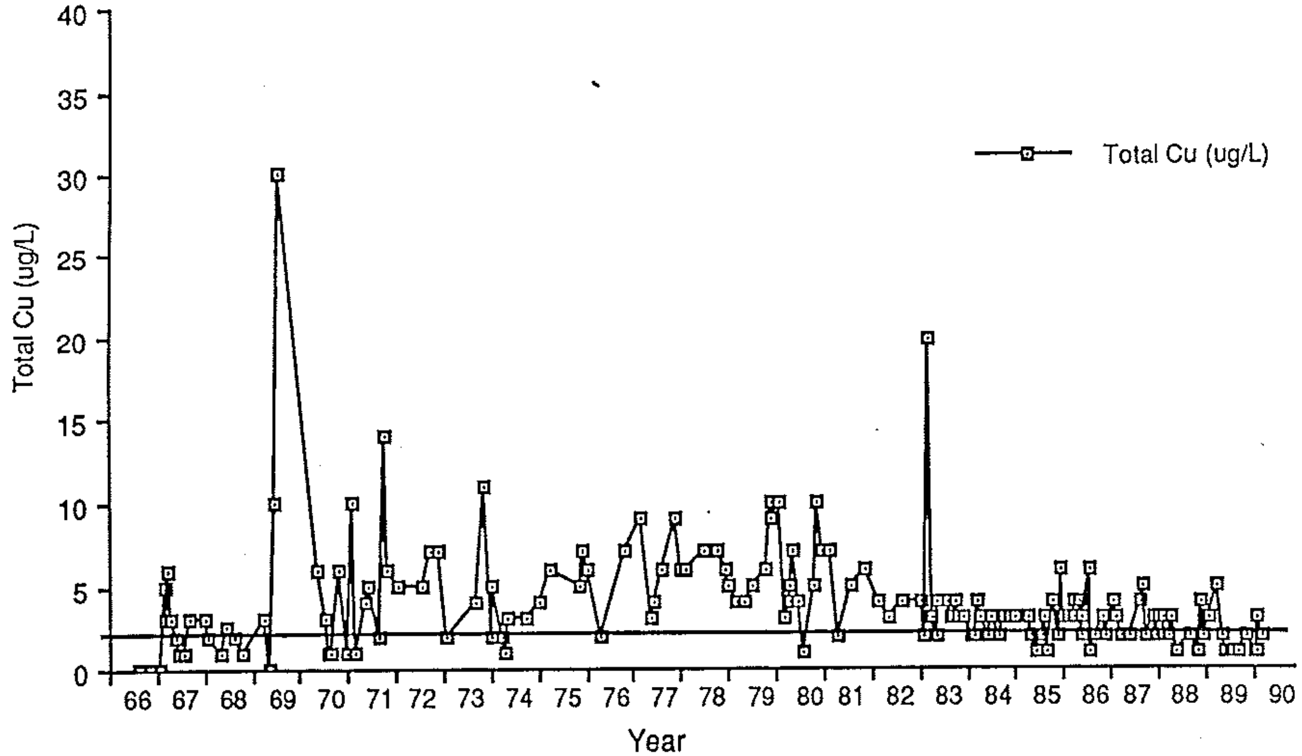
Figures

Figure 4. Time-depth diagram for total copper at site 0130082, in the south basin of Buttle Lake.

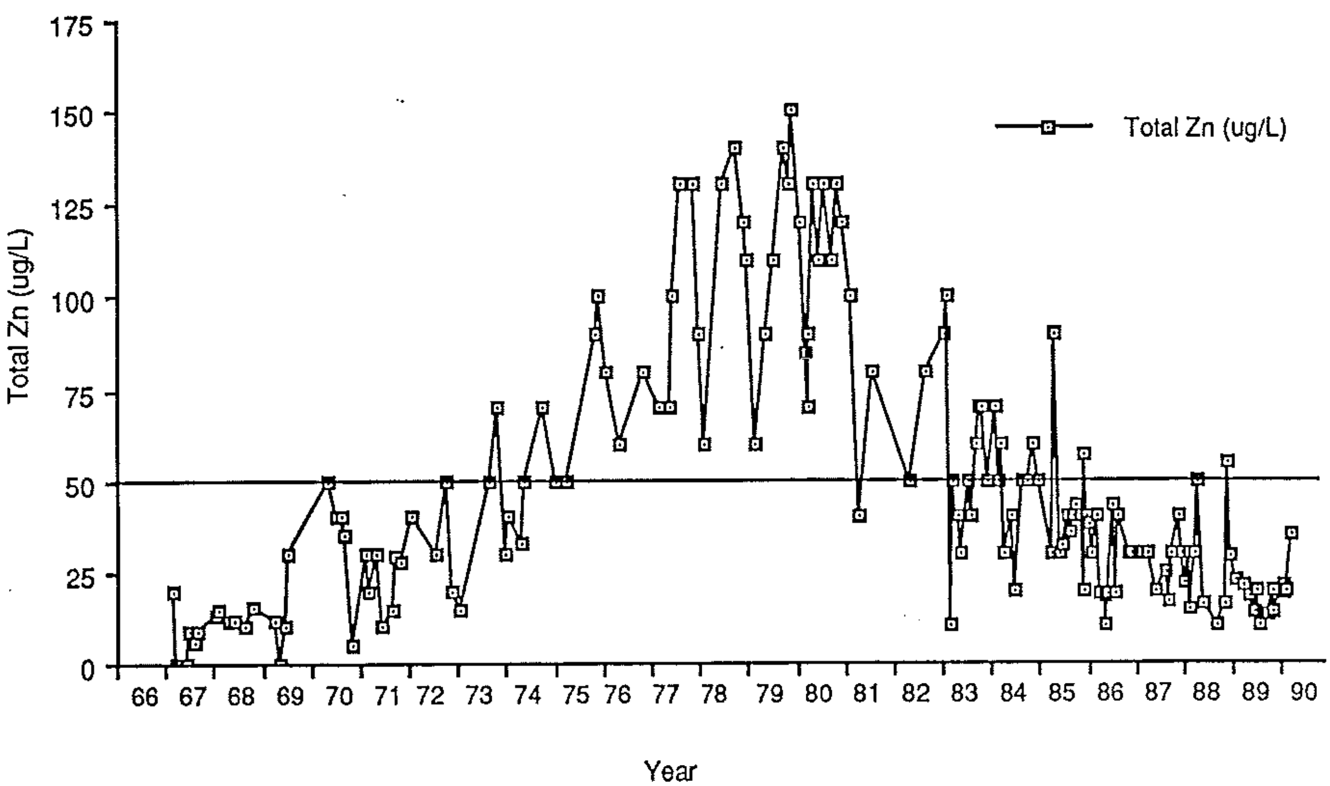

1981
1983
1984
1985
1986
1987
1988
1989
1990
0
10
20
30
40
50
60
70
DEPTH (m)
<10 µg/L
<2 µ g/L Cu
2-5 µ g/L Cu
5-10 µ g/L Cu
10-20 µ g/L Cu
20-40 µ g/L Cu
>40 µ g/L Cu

Figures

Figure 5. Graph illustrating the range and seasonality of total copper and total zinc (surface) at station Buttle Lake at Gold River bridge from 1970 to 1990.



Total Cu (ug/L)
40
35
30
25
20
15
10
5
0
66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
Year
Total Cu (ug/L)



Total Zn (ug/L)
175
150
125
100
75
50
25
0
66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
Year
Total Zn (ug/L)

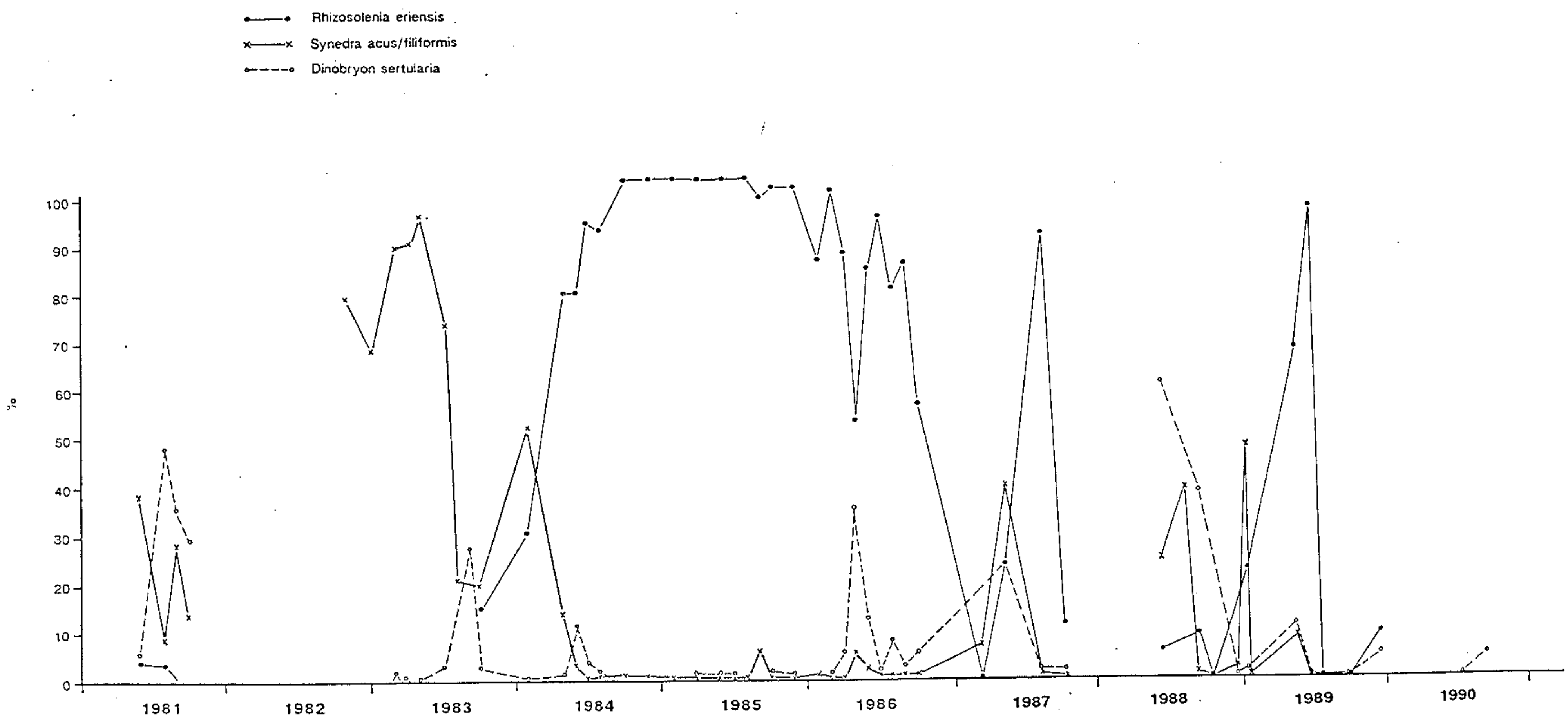
Figures

Figure 6. Graph illustrating extinction depth (as measured by secchi disc) from 1980 to 1990 at site 0130082, situated in the south basin of Buttle Lake.


Extinction Depth (m)
0
2
4
6
8
10
12
14
Year
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

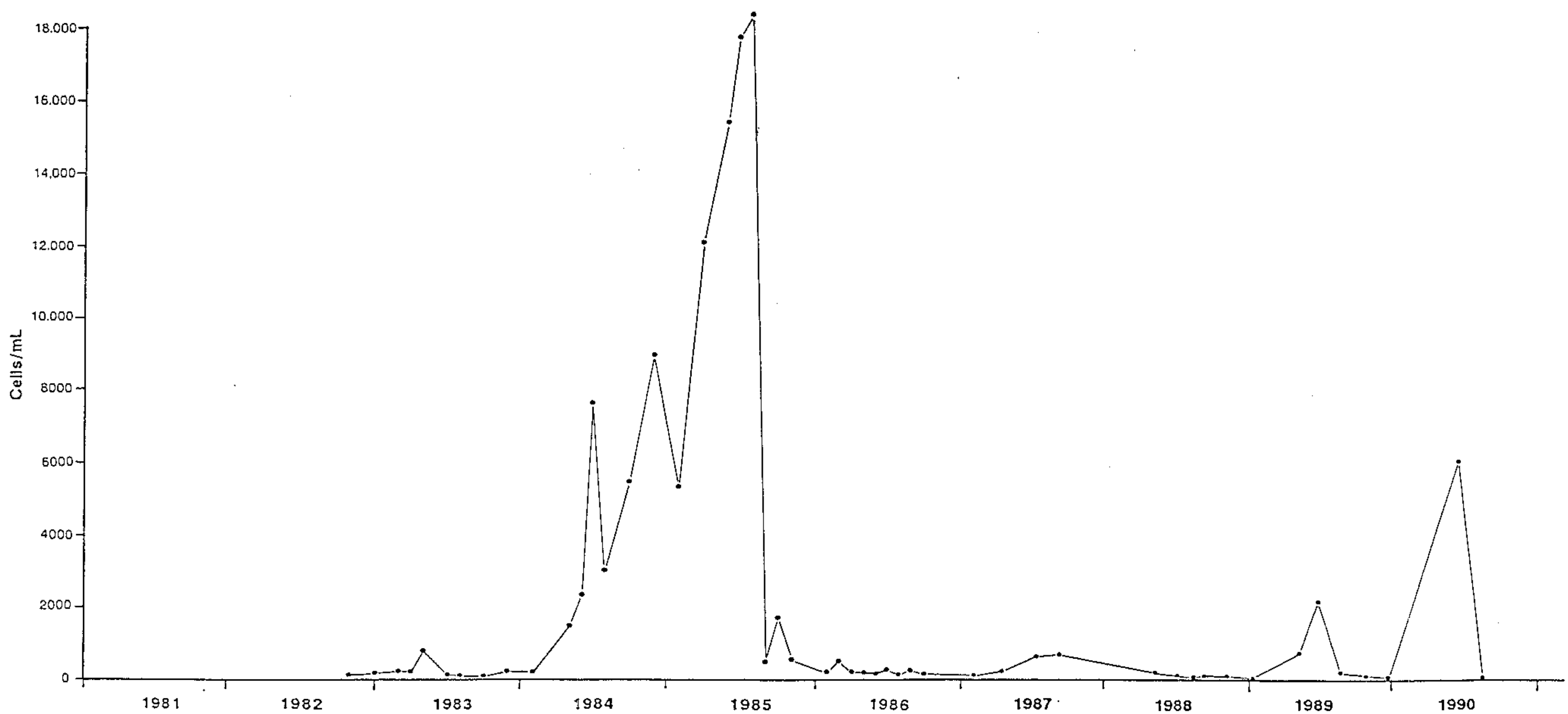
Figures

Figure 7. Graph illustrating % composition of phytoplankton community over time at site 0130082 situated in the south basin of Buttle Lake.


Rhizosolenia eriensis
Synedra acus/filiformis
Dinobryon sertularia
%
0
10
20
30
40
50
60
70
80
90
100
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990

Figures

Figure 8. Phytoplankton cell numbers (no/ml) over time at site 0130082, situated in the south basin of Buttle Lake.


Cells/mL
18,000
16,000
14,000
12,000
10,000
8000
6000
4000
2000
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990