

**Coquitlam Reservoir: 2004 Assessment of Source
Water Quality and Limnology – Year 1 Results**

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**Water and Watershed Management Program
University of Victoria**

Prepared for:
the BC Hydro Bridge Coastal Fish and Wildlife Restoration Program

March 2005



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EXECUTIVE SUMMARY

Data from a 2004 study of the limnology of Coquitlam Reservoir indicate an oligotrophic (unproductive) lake, with good source water quality for use by GVRD. Low concentrations of key nutrients contribute to low algal biomass and good water clarity.

Physical conditions (water temperature and dissolved oxygen concentrations) indicate excellent water quality for resident coldwater fishes. However, very low densities and biomass of food resources (zooplankton) in Coquitlam Reservoir may be a limiting factor in fish production, and this problem could be compounded by introduction of more plankton-eating fishes. Additionally, previous research on other lakes indicates the potential for undesirable changes in water quality if large densities of Sockeye salmon are added to the reservoir.

Because our data show only a one-year snapshot of the limnology of the reservoir, further research is warranted to clarify relationships among water quality, algae, zooplankton and zooplankton-eating fishes, thus allowing a more informed decision on the potential effects of reintroducing salmonids on the water quality of the reservoir.

INTRODUCTION

Coquitlam Reservoir is a medium-sized (12 km²) lake with a maximum depth of 200m. The lake pre-existed the construction of a dam in 1905, and as a consequence of the dam, salmon runs to the lake were blocked. Although the initial dam had a fish-way, there is currently no access for anadromous fishes to the lake, and thus there is pressure to reestablish these fish runs.

However, because Coquitlam Reservoir is a source of drinking water for the GVRD, there is concern as to whether the introduction of fishes might have negative effects on drinking water quality (Mazumder 2002). Previous research has found strong interactions among planktivorous (zooplankton-eating) fishes, zooplankton, phytoplankton (algae) and water clarity (Brooks and Dodson 1965; Carpenter *et al.* 1985; Mazumder *et al.* 1990; Mazumder 1994; Mazumder and Edmonson 2002). The primary concern with addition of Sockeye salmon fry to Coquitlam Reservoir is the possible effects of increased fish predation on the zooplankton and phytoplankton (algal) communities, and on overall water quality of the reservoir.

GOALS & OBJECTIVES

The purpose of this portion of the study was to assess the current limnology (physical variables, water chemistry, phytoplankton and zooplankton) of Coquitlam Reservoir to help make a more informed decision on the potential effects of reintroduction of Sockeye salmon on water quality of the reservoir. Results are presented below for Year 1: January to December 2004.

METHODS

Sampling Sites

Limnological characteristics were sampled at four sites in Coquitlam Reservoir: Site 1 was located at 49° 21' 24'' N, 122° 47' 11'' W; Site 2 was located at 49° 22' 34'' N, 122° 47' 58'' W; Site 3 was located at 49° 23' 35'' N, 122° 47' 36'' W; and Site 4 was located at 49° 24' 53'' N, 122° 46' 26'' W. Locations were confirmed with GPS, and marked using fixed rafts. These sites were located in areas of depth ranging from 9 m to 200 m, and covering the entire length of the lake (Figure 1).

Physical Measurements

Temperature, conductivity, turbidity, and radiation measurements were collected hourly, and downloaded monthly throughout the year, at a depth of 4.5 m at all sites using YSI model

6600 sondes (Hoskin Scientific). Turbidity measurements were also collected hourly, and downloaded monthly throughout the year, at depths of 15m, 30 m and 40 m at Sites 2, 3 and 4 respectively, using YSI model 600 sondes (Hoskin Scientific).

Monthly, vertical profiles of temperature, turbidity, chlorophyll, specific conductivity and dissolved oxygen were taken *in situ* with a YSI model 6600 sonde (Hoskin Scientific) at each site at 1-m intervals between October and April, and at 0.5-m intervals between May and September, from the surface to a maximum depth of 18 m.

Secchi disk readings of water transparency were measured monthly at each site using a standard 22 cm Secchi disk, to the nearest 0.25 m, without a viewing chamber.

Samples were also collected monthly in epilimnetic (surface), metalimnetic (middle) and hypolimnetic (bottom) waters at each site from January to December, using a Van Dorn water bottle for analysis of turbidity and chlorophyll.

Air temperature, wind direction, wind speed, relative humidity and light saturation measurements were collected hourly at each site from January to December using a Li-Cor-190 SA Quantum Sensor (Hoskin Scientific), and downloaded monthly.

Water Chemistry & Nutrients

Samples were collected monthly, from January to December, for water chemistry and nutrient analysis at all sites in epilimnetic (surface) waters, and at Site 2 in metalimnetic (middle) and hypolimnetic (bottom) waters, using a Van Dorn water bottle.

Handling and analysis of samples followed standard water sampling guidelines of the NSERC-IRC laboratory in Victoria. Water samples were analysed for total phosphorous (TP), total dissolved phosphorous (TDP), soluble reactive phosphorous (SRP), ammonia-N (NH_4^+), total Kjeldahl nitrogen (TKN), nitrate-N (NO_3), nitrite-N (NO_2), and sulphate-S (SO_4). Samples were collected monthly at a depth of 4 m at each site for carbon measurement from January to December.

All water to be analysed for nutrients and chemistry was collected in clean dark 2-L Nalgene bottles pre-rinsed with sample water, stored on ice and processed within 2 hours of collection. Processing consisted of filtering samples through ashed GFF filters into acid washed bottles for later analysis. Carbon samples, including total and dissolved (organic and inorganic) were filtered similarly into glass vials with no head space. All samples were kept cool during transport to the University of Victoria, where nutrient samples were frozen and carbon samples were refrigerated until analysed.

All water samples were analyzed at the NSERC-IRC laboratory in Victoria. Carbon samples were processed immediately using a Shimadzu Total Organic Carbon Analyzer. Carbon data collected by the University of Victoria at Site 2 in Coquitlam Reservoir were consistently lower (approximately 0.5 mg/L) than data generated from GVRD sampling near the reservoir

intake. The consistent differences possibly may be explained by location of sampling (our Site 2 is about 3 km north of the reservoir intake), or variation in analytical methods. To determine whether or not the observed differences are real, both University of Victoria and GVRD field teams will sample at the GVRD site on our April 2005 sampling trip. Then, samples will be analysed at both the University of Victoria and GVRD water labs, and we will compare values to ensure that there are no methodological differences between the water labs.

Nutrient samples (TP, TDP, TN, NO₂ and NO₃) were analyzed using a Zellweger Analytics Lachat QuickChem autoanalyzer. The SRP and chemical anion samples were processed using a High Performance Liquid Chromatography (HPLC) analyzer made by Dionex Industries. The NH₄⁺ samples were analyzed using a Pharmacia photospectrometer.

Phytoplankton

To assess the seasonal fluctuation of algal populations and predict potential bloom problems, phytoplankton cells in whole water samples were identified and enumerated. Samples were settled in Utermohl settling chambers. An Olympus IMT-2 inverted research microscope was used to view the samples. Individual cells were identified to genus or species, measured and counted. QA/QC was done on randomly chosen samples monthly.

Chlorophyll a

Chlorophyll a (Chl a) was measured hourly at a depth of 4.5 m at each site from January to December using a YSI 6600 sonde (Hoskin Scientific), and downloaded monthly. To validate monitoring by the sonde, Chl-a samples were collected monthly in epilimnetic (surface), metalimnetic (middle) and hypolimnetic (bottom) waters at each site. Within hours of sample collection, 1 litre of water from each sample site is filtered through a 47-mm diameter, 0.45-µm Millipore AA filter. Samples were filtered and kept in the dark to prevent chlorophyll from degrading in light. Filters were then folded and placed in acid-washed 15 ml conical tubes and kept cool during transport to the NSERC-IRC laboratory in Victoria, where they were frozen until analysis.

Chlorophyll-a samples were analysed with a Turner Designs Fluorometer. Extraction of samples was carried out 18-24 hours prior to analysis using 95% ethanol added to the conical tubes. The ethanol extracts the chlorophyll from the filter in the tube and the sample can be decanted off and analysed using the fluorometer.

Zooplankton

Macrozooplankton (excluding rotifers) density and biomass were monitored at Coquitlam Reservoir monthly from January to December, 2004. Vertical plankton hauls were conducted at Sampling Site 2 using a 64-µm-mesh net with a mouth diameter of 30 cm. A standard downrigger was used to lower and retrieve the plankton net from a depth of 27 m to the surface

at a constant speed of 1ms^{-1} . All zooplankton collected were emptied into a 60 mL plastic bottle and kept cool until preserved using a 10% sugared formalin solution.

Zooplankton samples were analysed for species composition, abundance, and length at the NSERC-IRC laboratory in Victoria. Samples were passed through a 64- μm Nitex mesh sieve and carefully rinsed with tap water to remove preservative. Whole samples were then either enumerated, or if zooplankton density indicated, diluted and a sub-sample analysed.

When possible, zooplankton were identified to species using the keys of Pennak (1978) and Clifford (1991). Enumeration was conducted on a petri-dish using a binocular compound microscope connected to a CCD video monitor. This apparatus is run through a PC using Z-Count software developed for the NSERC-IRC laboratory in Victoria. This software counts and determines lengths, and from this calculates zooplankton biomass (mg/m^3) based on empirical sampling of reservoirs (J. Edmundson, Alaska Dept. of Fish and Game, Soldotna, AK, pers. comm.). Lengths were converted to biomass using species-specific regression equations relating wet length to mean dry mass.

RESULTS

Physical Measurements

Coquitlam Reservoir displayed thermal stratification by April at Sites 2, 3 and 4, while Site 1 exhibited weak thermal stratification only in July. At Sites 2, 3 and 4, stratification was weak in April and May, with surface temperatures between 10 and 15 °C. From June to July, epilimnetic waters warmed to a maximum of 24 °C, before beginning to cool in August. By October, the stratification was weak, and by November the reservoir was isothermal at 8 °C (Figure 2).

Dissolved oxygen (DO) concentrations generally remained above 8 mg/L at all sites on all sampling dates, except on July 29, when the DO probe reported values near 5 mg/L. Because a DO concentration of 5 mg/L is extremely unlikely in Coquitlam Reservoir, the data from July 29 were removed from analysis due to the likelihood of probe malfunction. Seasonal trends indicate that DO concentrations are generally lowest (8 to 9 mg/L) from January through May, and reach a maximum of 11 to 13 mg/L from June through December. The only exception to this seasonal trend was October, when the DO concentration was 9 mg/L (Figure 3).

Secchi Depth & Turbidity

Water clarity was very good in Coquitlam Reservoir throughout 2004. Secchi depth ranged from 6 to 12 m at all four sampling sites throughout the year (Figure 4). The only exception to this trend occurred at the shallow Site 1, where Secchi depths decreased to 4.5 m in August, 5 m in October and 3 m in November.

Data from the permanent sampling platforms and lab analysis of grab water samples indicate that Coquitlam Reservoir waters are very clear. Turbidity was generally less than 1.0 NTU at all depths, at all sites, on all dates. Notable exceptions occurred at Site 3 in mid-December when platform data showed peaks as high as 6.3 NTU and lab analyses verified peaks up to 2.6 NTU. Platform data did show occasional spikes as high as 16.6 NTU, but these were generally not verified by grab water samples, indicating the need for regular maintenance of platform sondes and continued verification of grab water samples by lab analysis.

Water Chemistry & Nutrients

Nutrient samples were collected from Site 2 from January to December, 2004. Total phosphorous (TP) concentrations were very low, typical of an ultra-oligotrophic (unproductive) lake (Figure 5). TP remained below 8 µg/L at all depths throughout the year, and yearly mean epilimnetic (surface) TP was 2.91 µg/L, which is near the chemical detection limit for phosphorus.

Total nitrogen (TN) concentrations were also very low, typical of ultra-oligotrophic lakes (Figure 6). TN remained below 200 µg/L at all depths throughout the year, and yearly mean epilimnetic TN was 142 µg/L.

The nitrogen to phosphorus ratio (TN:TP) is a good indicator of which of these two nutrients is the limiting factor in lake productivity (algal growth); TN:TP > 20 indicates phosphorus limitation, while TN:TP < 20 indicates nitrogen limitation. TN:TP was > 20 throughout the year (phosphorus limitation), with the exception of June, when TN:TP = 20, indicating that on this date, the limiting nutrient may have temporarily shifted from phosphorus to nitrogen (Figure 7).

Total organic carbon (TOC) concentrations were also very low, typical of ultra-oligotrophic lakes (Figure 8). TOC was similar at all depths at all sites throughout the year. Yearly mean TOC in epilimnetic waters was 1.64 mg/L, which is just above the chemical detection limit of 1 mg/L.

Chlorophyll a

Chlorophyll a concentrations remained below 2 µg/L all year at Site 2, with peak readings in May and October (Figure 9). As with nutrients, values this low are common in ultra-oligotrophic lakes.

Phytoplankton

Like nutrient and chlorophyll a concentrations, phytoplankton biomass was low, following the pattern seen in ultra-oligotrophic lakes. Total phytoplankton biomass varied substantially through the year, with peaks in April (250 µg/L) and September (300 µg/L), and a

minimum in July (75 µg/L) (Figure 10). For most of the year, the phytoplankton community was dominated by Cyanophyta (blue-green algae) and Dinophyceae (dinoflagellates). In March, Chlorophyta were co-dominant with Dinophyceae, and in November, Chlorophyta and Chrysophyta were co-dominant (Figure 10).

Zooplankton

The zooplankton community (excluding rotifers) within Coquitlam Reservoir was numerically dominated by small taxa, principally copepod nauplii (larvae), with densities ranging from 1 to 4 animals per litre. Total densities of all other species combined remained below 1 animal per litre throughout the year (Figure 11). These low densities are typical of ultra-oligotrophic systems.

Zooplankton biomass exhibited seasonal variation, with minimum biomass in February (< 0.5 µg/L) and peaks in August (4.5 µg/L) and November (2.5 µg/L) (Figure 12). Small taxa (nauplii, cyclopoid copepods, *Bosmina*) comprised the majority of zooplankton biomass all year except in July and August, when the larger *Daphnia* species contributed at least 50% to total biomass (Figure 12). The low values observed for zooplankton biomass are typical of ultra-oligotrophic systems.

Diet of Sport-Fishes

The depth distribution of fishes analysed for stomach contents indicate that Cutthroat Trout preferentially feed in surface waters, while Kokanee will feed at all depths. Kokanee are by far the numerically dominant species in mid- and bottom waters (Figure 13).

The diet of Kokanee is comprised primarily of larger zooplankton taxa, such as daphnia (Figure 14), while Cutthroat trout appear to be more generalist feeders, eating substantial numbers of several zooplankton taxa, as well as terrestrial insects (Figure 15).

DISCUSSION

Limnological Assessment - Implications for Water Quality

Although it is very difficult to generalize on the limnology of a lake from one year of data, Coquitlam Reservoir displays the limnology typical of oligotrophic (unproductive) lakes (Wetzel 2001). Our data agree well with previous data from 2000 and 2001 that showed very low concentrations of phosphorus (P) and nitrogen (N), and low phytoplankton (algal) biomass, indicating an unproductive state in Coquitlam Reservoir (Basu 2001). In addition, our data support sediment-coring (paleolimnological) data which show that the reservoir has been an unproductive lake since at least before construction of the dam in 1905 (Nordin & Mazumder

2005).

Phosphorus (P) and nitrogen (N) have been shown to be significant factors limiting phytoplankton (algal) biomass and water clarity in surface waters (Schindler et al. 1971; Dillon and Rigler 1974). Low P and N concentrations likely play a major role in the low algal biomass and good water clarity observed in Coquitlam Reservoir. Coquitlam Reservoir also showed low concentrations of total organic carbon (TOC), which in combination with low algal biomass and good water clarity, indicate good source water quality. Good quality source water is crucial as it generally requires lower treatment intensities than poor source water, and results in healthier, better-tasting finished drinking water with fewer disinfection by-products (DBP's) (Davies and Mazumder 2003; Davies *et al.* 2004).

Although overall algal biomass in Coquitlam Reservoir is low, a substantial portion of the algal community consists of cyanobacteria (blue-green algae). Several types of blue-greens that were observed at low biomass in Coquitlam Reservoir (E.g. *Microcystis*, *Anabaena*) have the potential to cause problems of taste and odour, and/or toxicity at higher biomass (Davies and Mazumder 2003). The low water temperatures and nutrient concentrations normally observed in the reservoir make the likelihood of a large bloom of blue-greens unlikely, and for this reason, it was deemed unnecessary to sample for specific taste and odour compounds in 2004. However, continued regular monitoring of key nutrients and algae are indicated because an increase in nutrients has the potential to trigger a shift in the algal community to greater biomass of obnoxious species such as blue-greens (Reynolds, 1984; Carmichael, 2001). Should blooms of blue-greens or other obnoxious algae be observed in future, sampling for taste and odour compounds may be warranted.

Previous research has shown strong linkages among planktivorous (zooplankton-eating) fishes and zooplankton, algae and overall water quality. In both enclosure experiments and natural lakes, the presence of high densities of planktivorous fishes has been found to result in a decrease of the average size of zooplankton, and a shift from dominance by larger taxa (E.g. *Daphnia*) to dominance by smaller taxa (E.g. *Bosmina*, cyclopoid copepods) (Brooks and Dodson 1965; Carpenter *et al.* 1985; Mazumder *et al.* 1990; Mazumder and Edmundson 2002). As a result of a shift to smaller zooplankton, researchers have observed an increase in algal biomass, a decrease in water clarity, and a shift in the algal community structure to larger taxa, including obnoxious algae, including taxa associated with taste and odour problems (E.g. *Dinobryon*, *Anabaena*) (Hrbacek et al. 1961; Mazumder *et al.* 1990). The presence of larger zooplankton taxa such as *Daphnia* also can act as a buffer for nutrient addition by reducing the effect of the added nutrients on the algal community (Mazumder 1994, Mazumder and Lean 1994).

Based on the above evidence, introduction of large numbers of Sockeye salmon (*Oncorhynchus nerka*) fry into Coquitlam Reservoir may have the potential to negatively affect water quality. Sockeye fry are zooplankton-eaters with a preference for larger zooplankton, such as *Daphnia*. If large numbers of fry are introduced to Coquitlam Reservoir, previous research predicts a possible shift in the zooplankton community to smaller taxa, leading to an increase in algal biomass, reduced water clarity, and the potential increase in biomass of larger, undesirable algal taxa. All of these effects are unwanted from the standpoint of drinking water quality, and

thus further research on the limnology of Coquitlam Reservoir is necessary to better understand the linkages among zooplankton-eating fishes, zooplankton, algae and water quality.

Limnological Assessment - Implications for Sport-Fishes

In eutrophic lakes, coldwater fishes may be subjected to a temperature-oxygen squeeze, where warm surface waters push fish to deeper water, while depleted oxygen in deep waters force fish to the surface. As an unproductive lake, Coquitlam Reservoir exhibits cool temperatures and well-oxygenated waters that are very favourable for coldwater sport-fishes, such as salmon, and the resident Cutthroat Trout and Kokanee. As a result, the entire water column is likely available as usable habitat for these fishes.

While habitat availability may not be limiting for fishes, there is some concern as to whether fishes may be food-limited. Analysis of stomach contents of Kokanee and Cutthroat Trout indicate that both species are zooplankton-eaters, and thus the very low densities of zooplankton observed in our study may be a limiting factor for these fish species. In addition, sediment core data suggest that Coquitlam Reservoir never had a large population of resident salmonids prior to construction of the dam in 1905 (Nordin & Mazumder 2005). However, in order to draw valid conclusions regarding food limitation for zooplankton-eating fishes in Coquitlam Reservoir, more information is necessary on the interaction between the zooplankton community and zooplankton-eating fishes.

RECOMMENDATIONS

In summary, we recommend further research for Coquitlam Reservoir, including continued assessment of limnological parameters. Research should also focus on the interactions among the algal and zooplankton communities and the resident zooplankton-eating fishes (Kokanee and Cutthroat Trout). Better understanding of these processes will allow a more informed decision on the potential effects of reintroduction of salmonids on the limnology of Coquitlam Reservoir.

ACKNOWLEDGMENTS

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Figure 1. Aerial view of Coquitlam Reservoir showing the four sampling sites. Site 2 was the main site for sampling of water quality, phytoplankton (algae) and zooplankton.

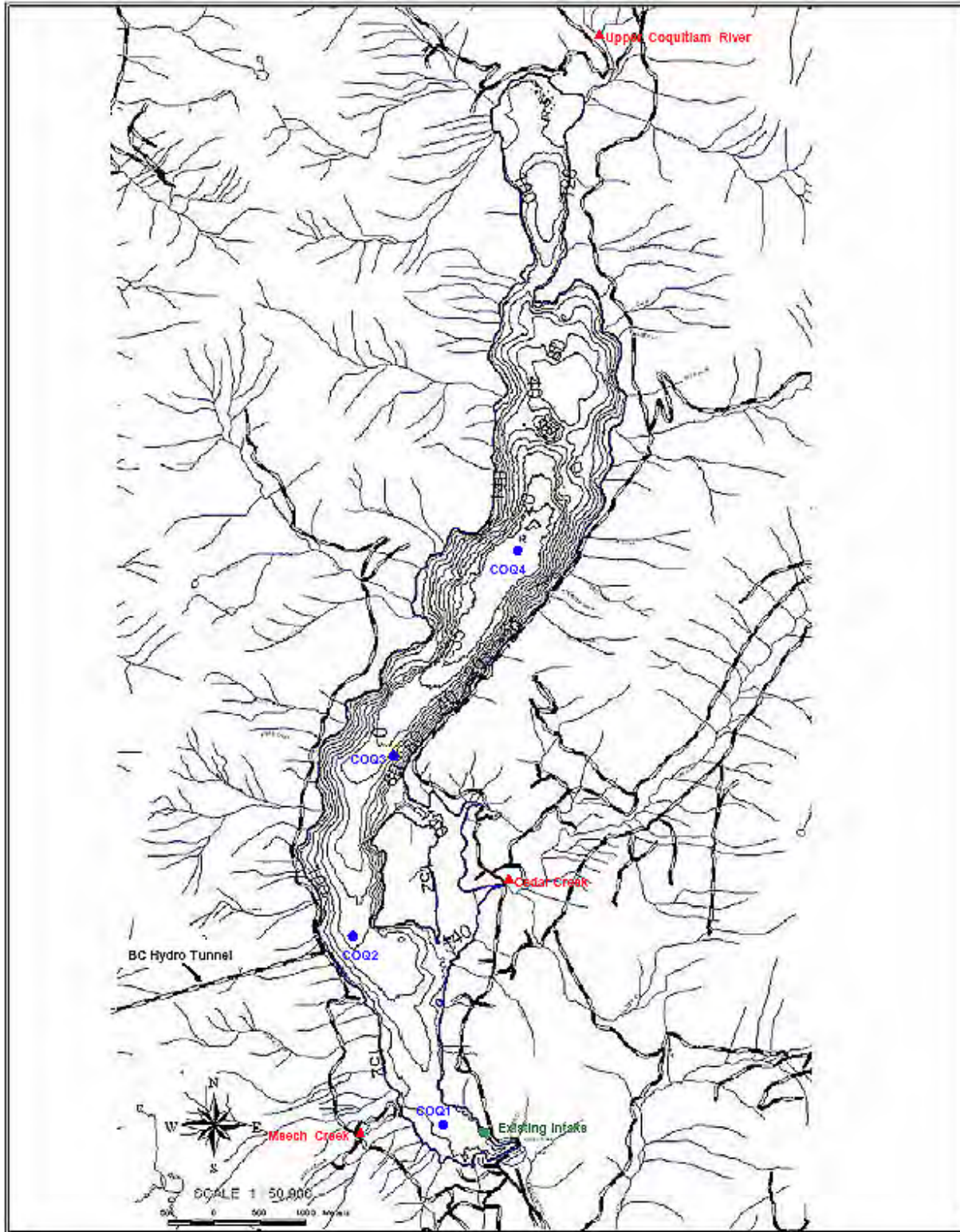


Figure 2. Variation in temperature with depth at Site 2 in Coquitlam Reservoir, January to December, 2004. The depths of the three lake zones are also listed for July and August stratification: EPI = epilimnion (surface waters); META = metalimnion (middle waters); and HYPO = hypolimnion (bottom waters).

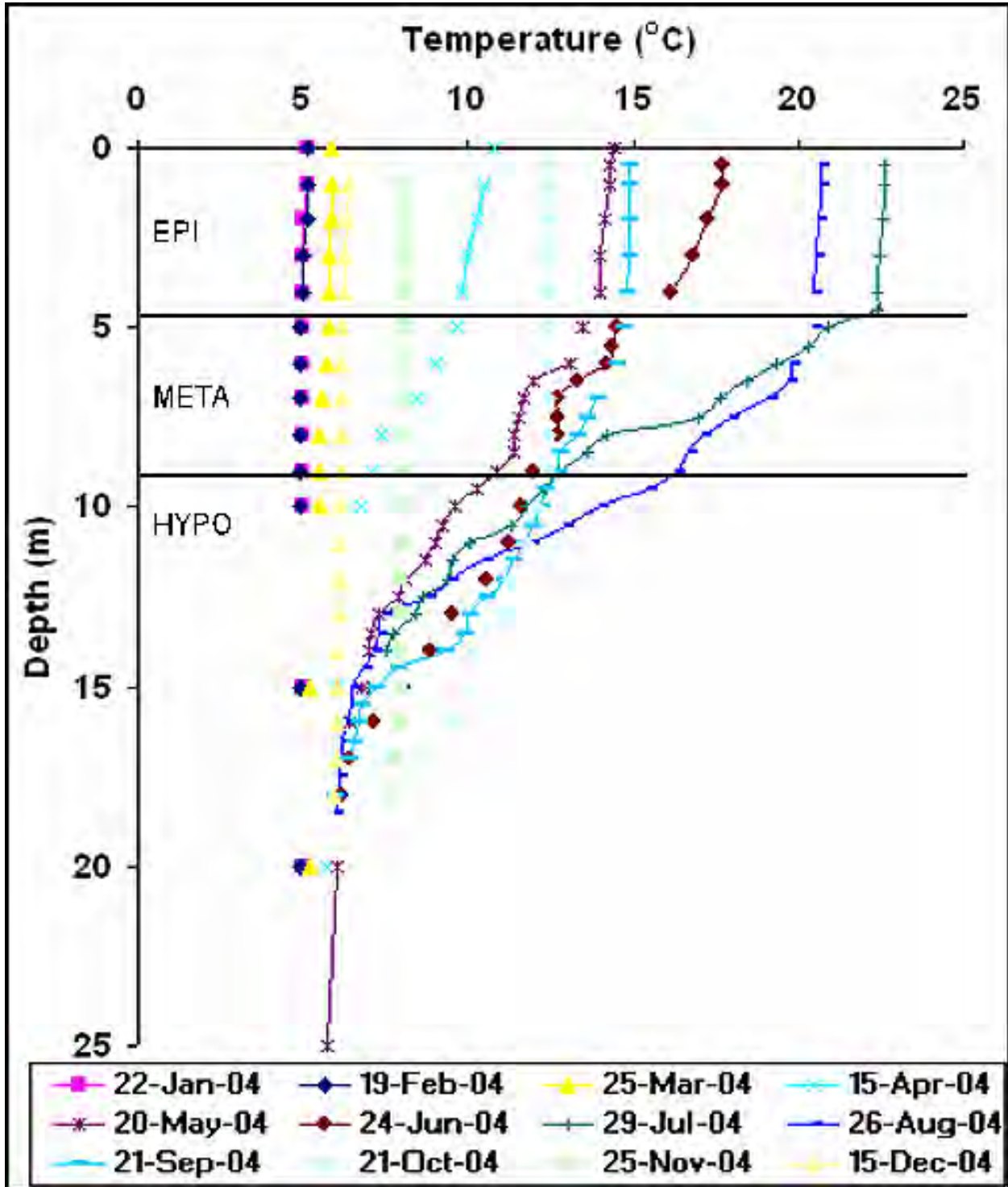


Figure 3. Variation in dissolved oxygen (DO) concentration with depth at Site 2 in Coquitlam Reservoir, January to December, 2004.

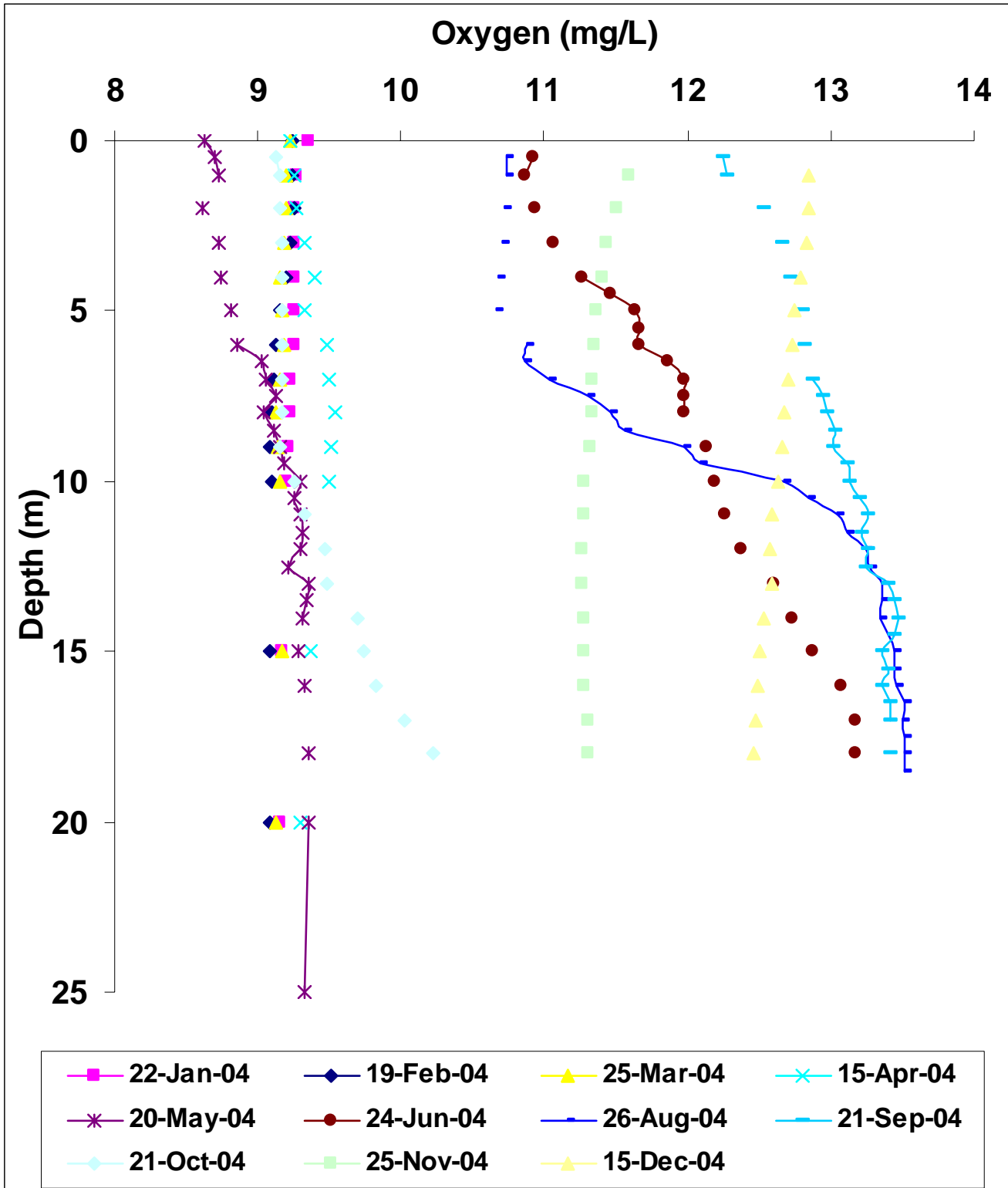


Figure 4. Water transparency as Secchi depth at Site 2 in Coquitlam Reservoir, January to December, 2004.

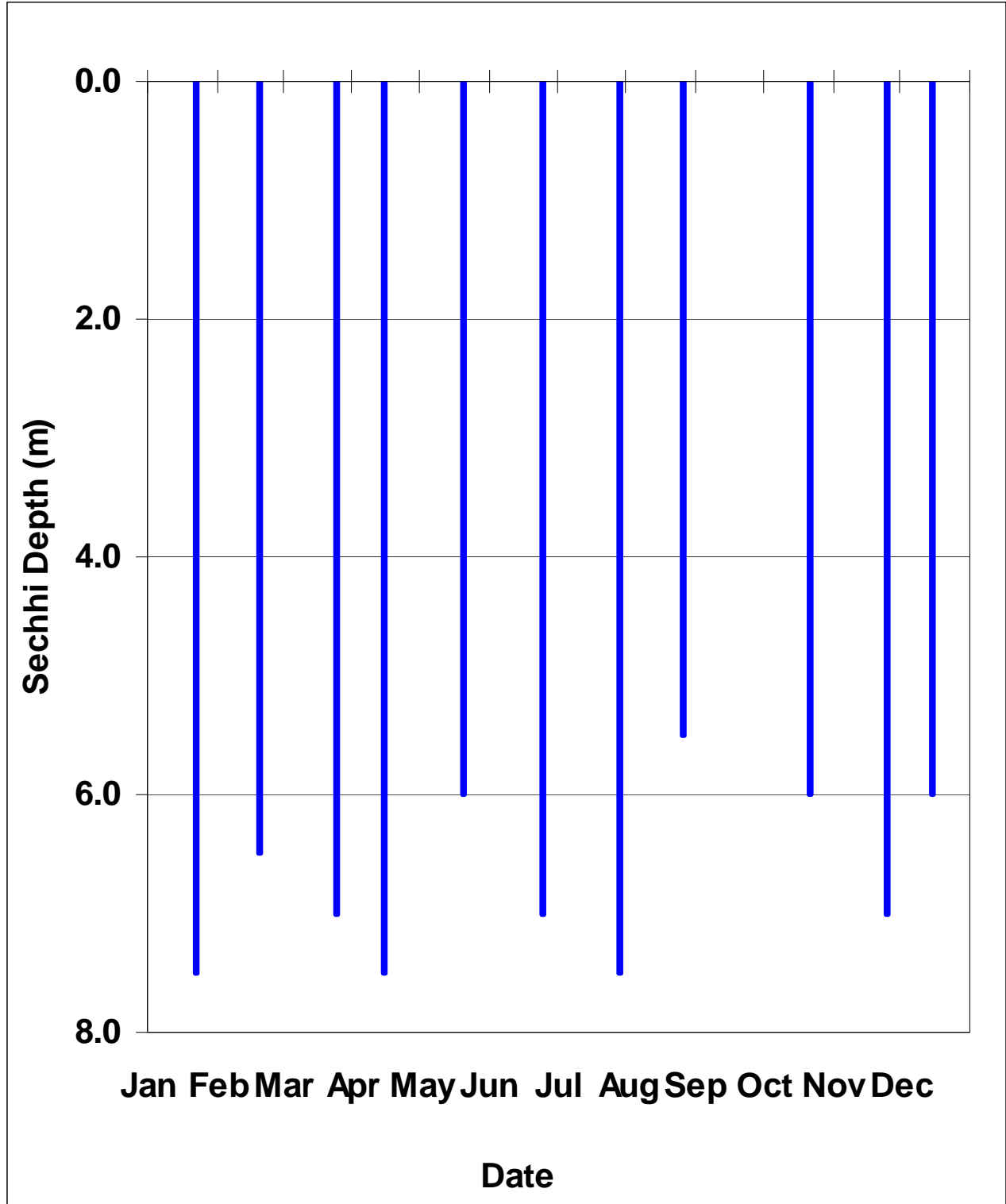


Figure 5. Total Phosphorus (TP) at Site 2 in surface (epilimnetic), middle (metalimnetic) and bottom (hypolimnetic) waters in Coquitlam Reservoir, January to December, 2004.

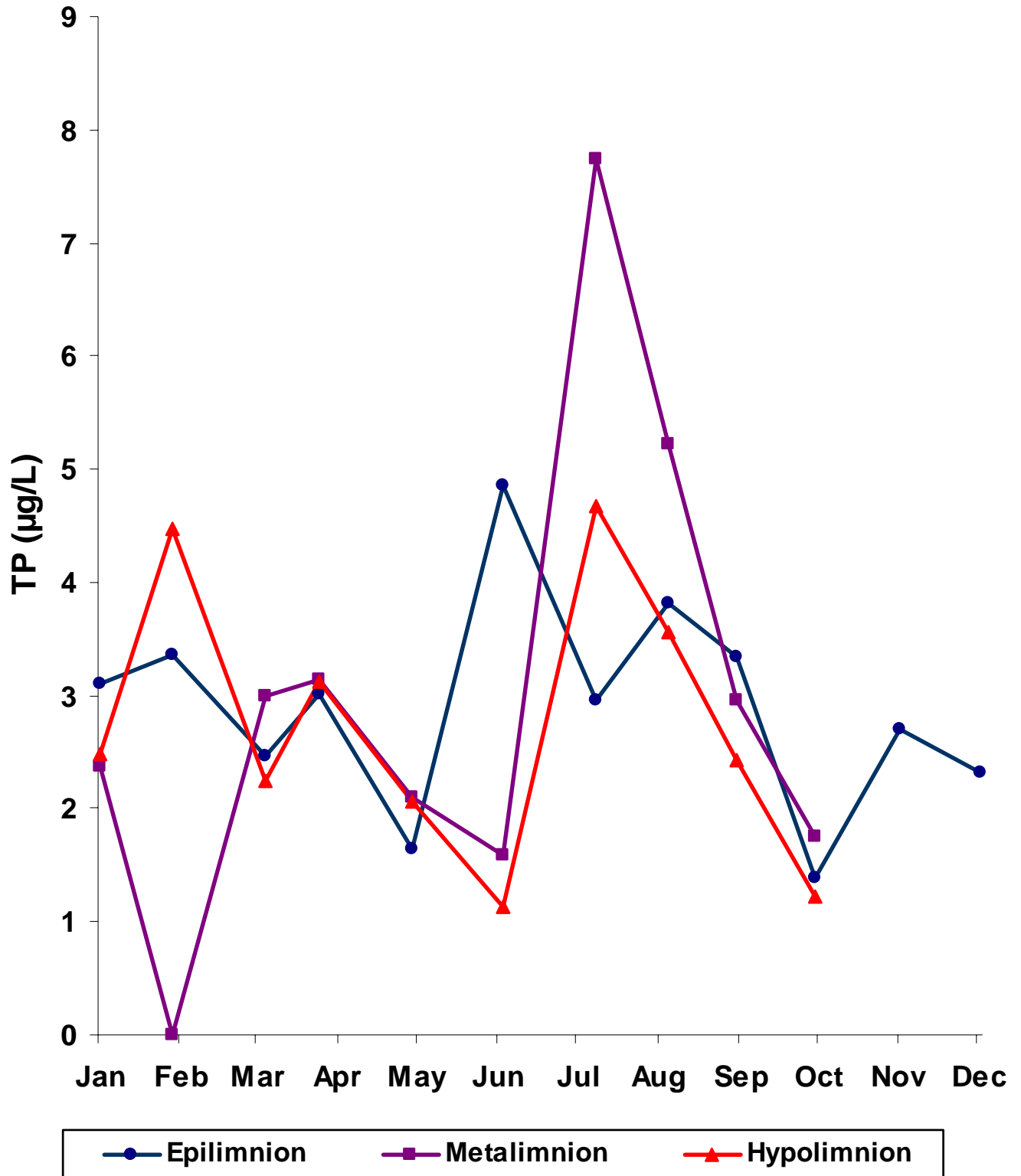


Figure 6. Total Nitrogen (TN) at Site 2 in surface (epilimnetic), middle (metalimnetic) and bottom (hypolimnetic) waters in Coquitlam Reservoir, January to December, 2004.

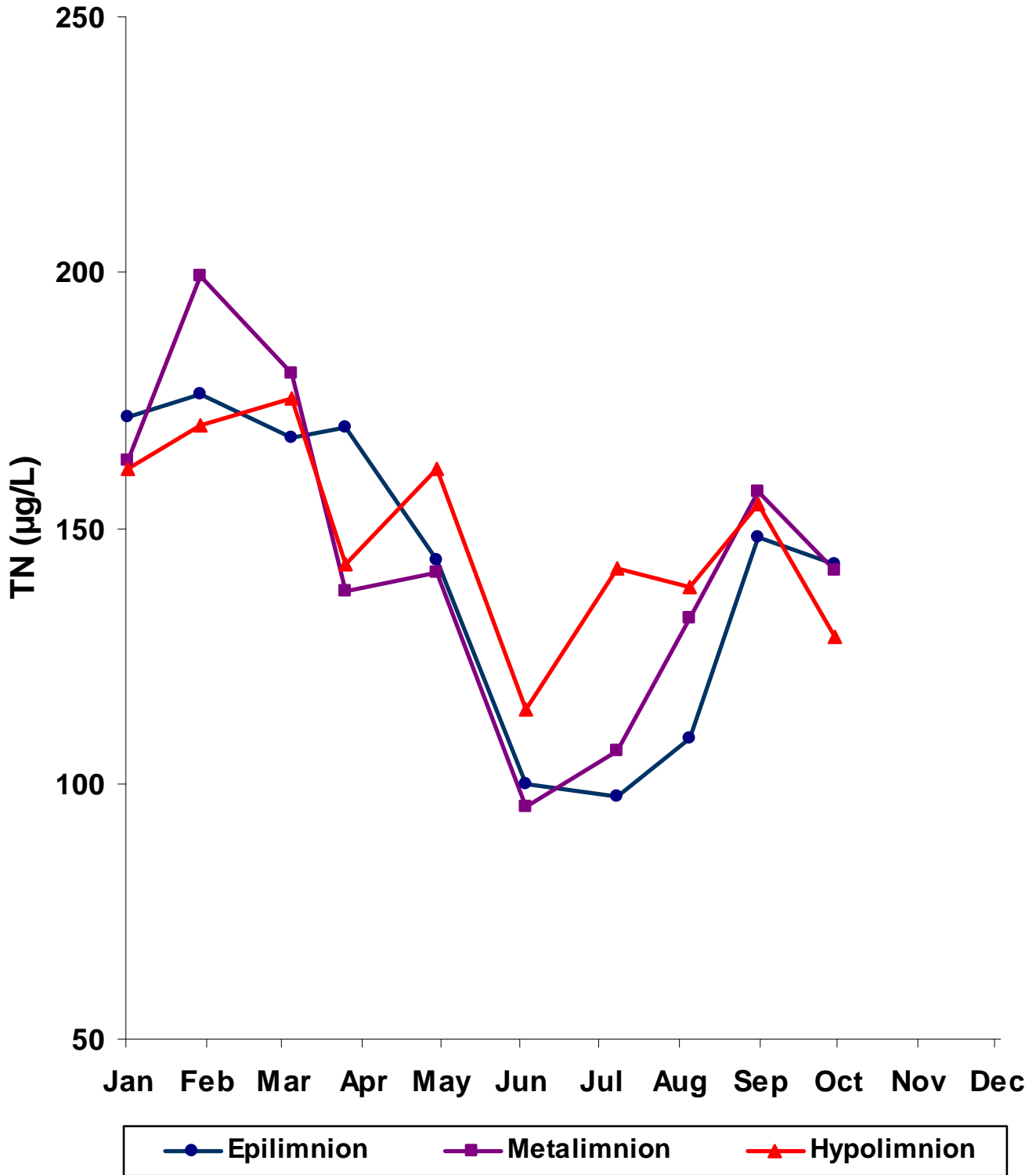


Figure 7. Ratio of Total Nitrogen to Total Phosphorus (TN:TP) in surface (epilimnetic) waters at Site 2 in Coquitlam Reservoir, January to December, 2004.

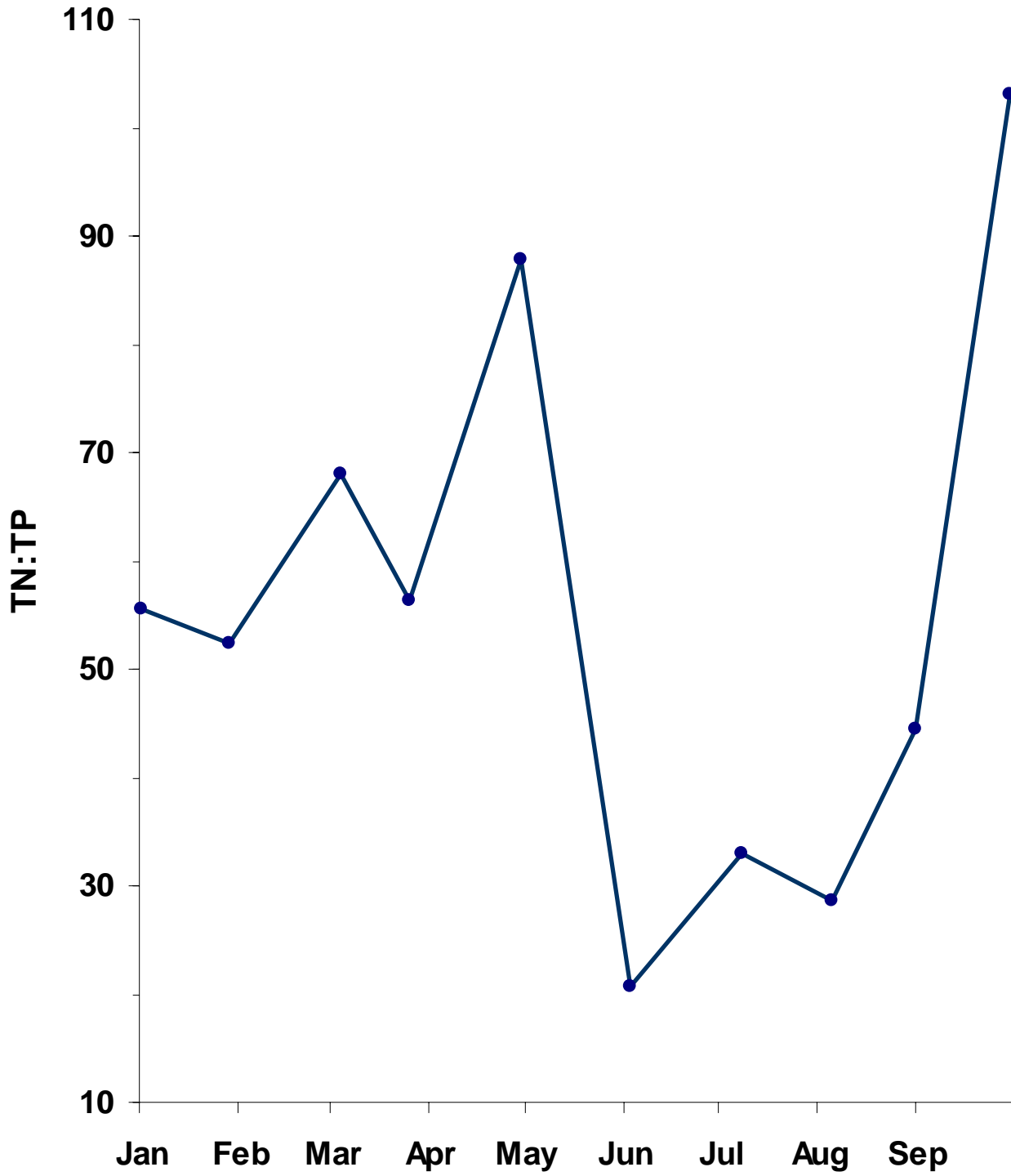


Figure 8. Total Organic Carbon (TOC) in surface (epilimnetic), middle (metalimnetic) and bottom (hypolimnetic) waters at Site 2 in Coquitlam Reservoir, January to December, 2004.

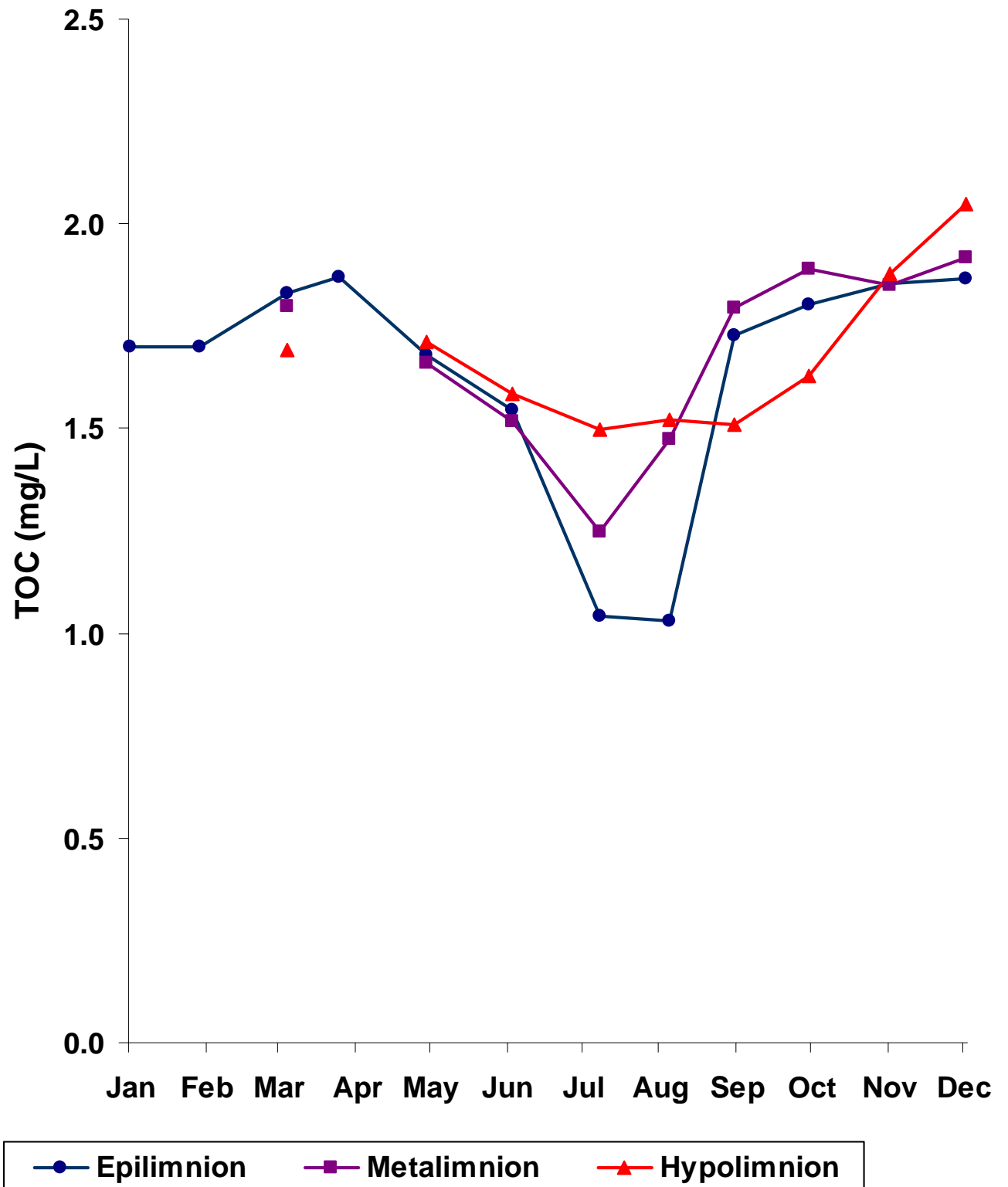


Figure 9. Chlorophyll *a* in surface (epilimnetic) waters at Site 2 in Coquitlam Reservoir, January to December, 2004. Green line graph indicates data from YSI chlorophyll probe on Site 2 platform; blue triangles indicate laboratory verified chlorophyll values.

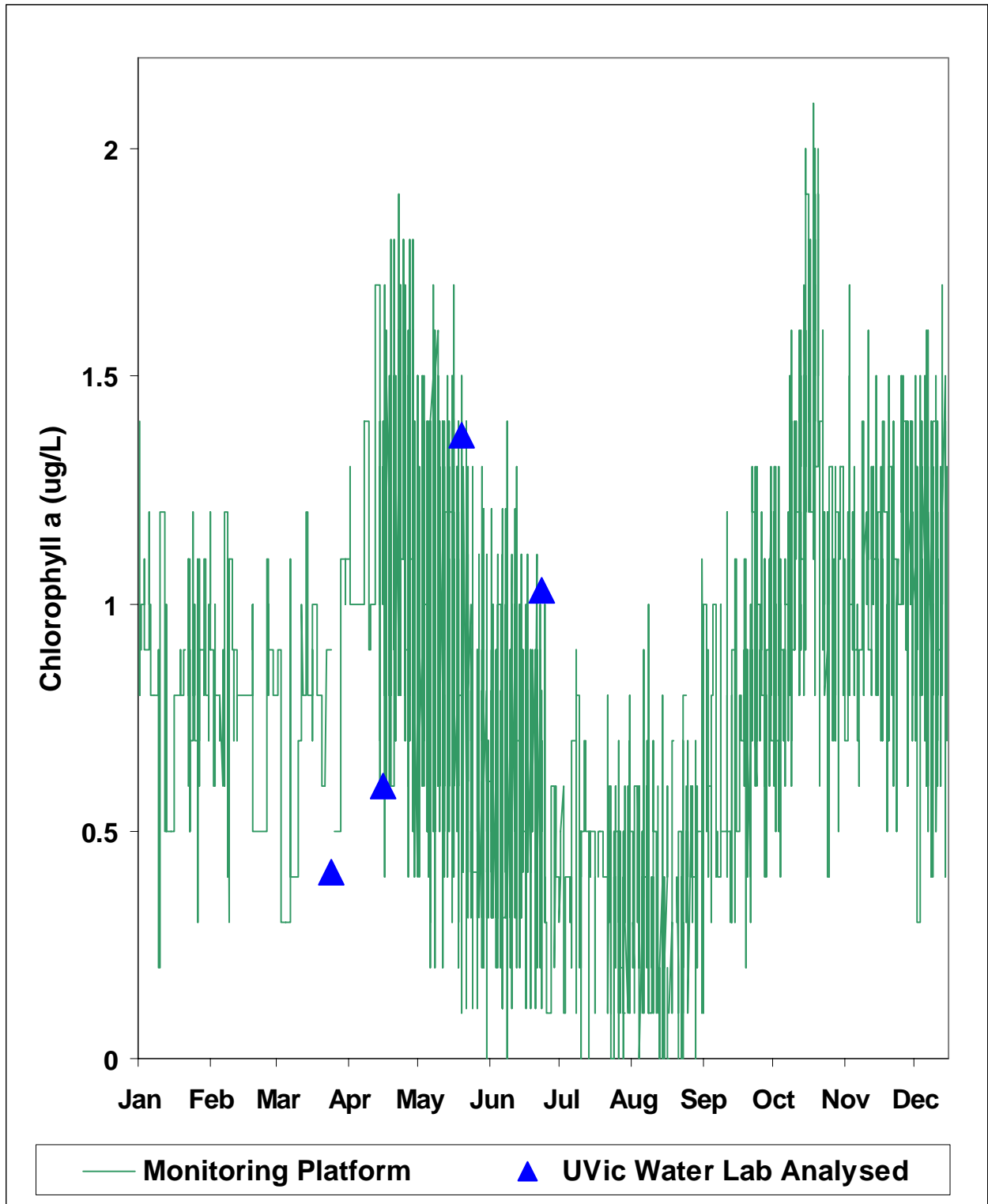


Figure 10. Phytoplankton biomass at Site 2 in Coquitlam Reservoir, March to December, 2004.

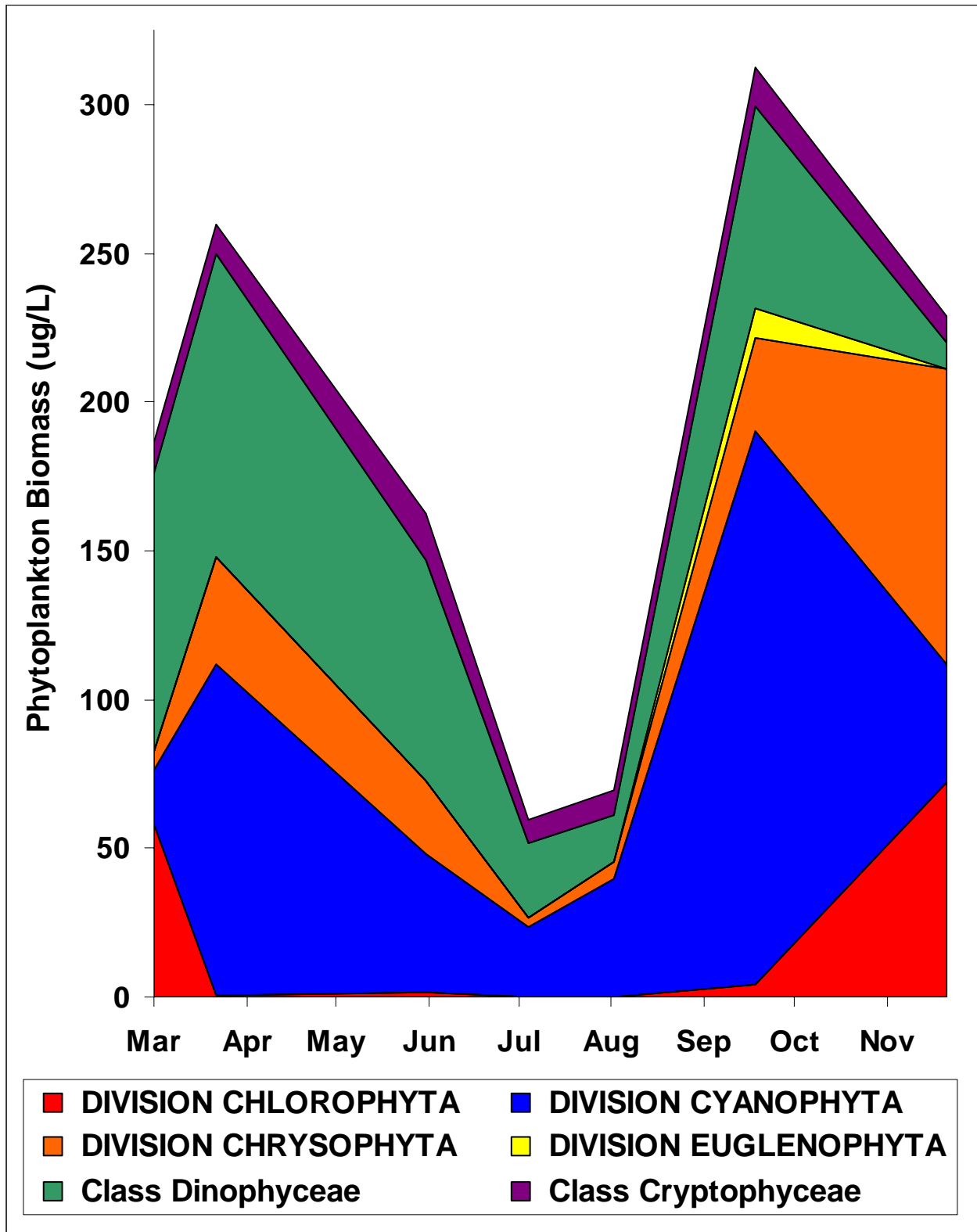


Figure 11. Zooplankton density at Site 2 in Coquitlam Reservoir, January to November, 2004.

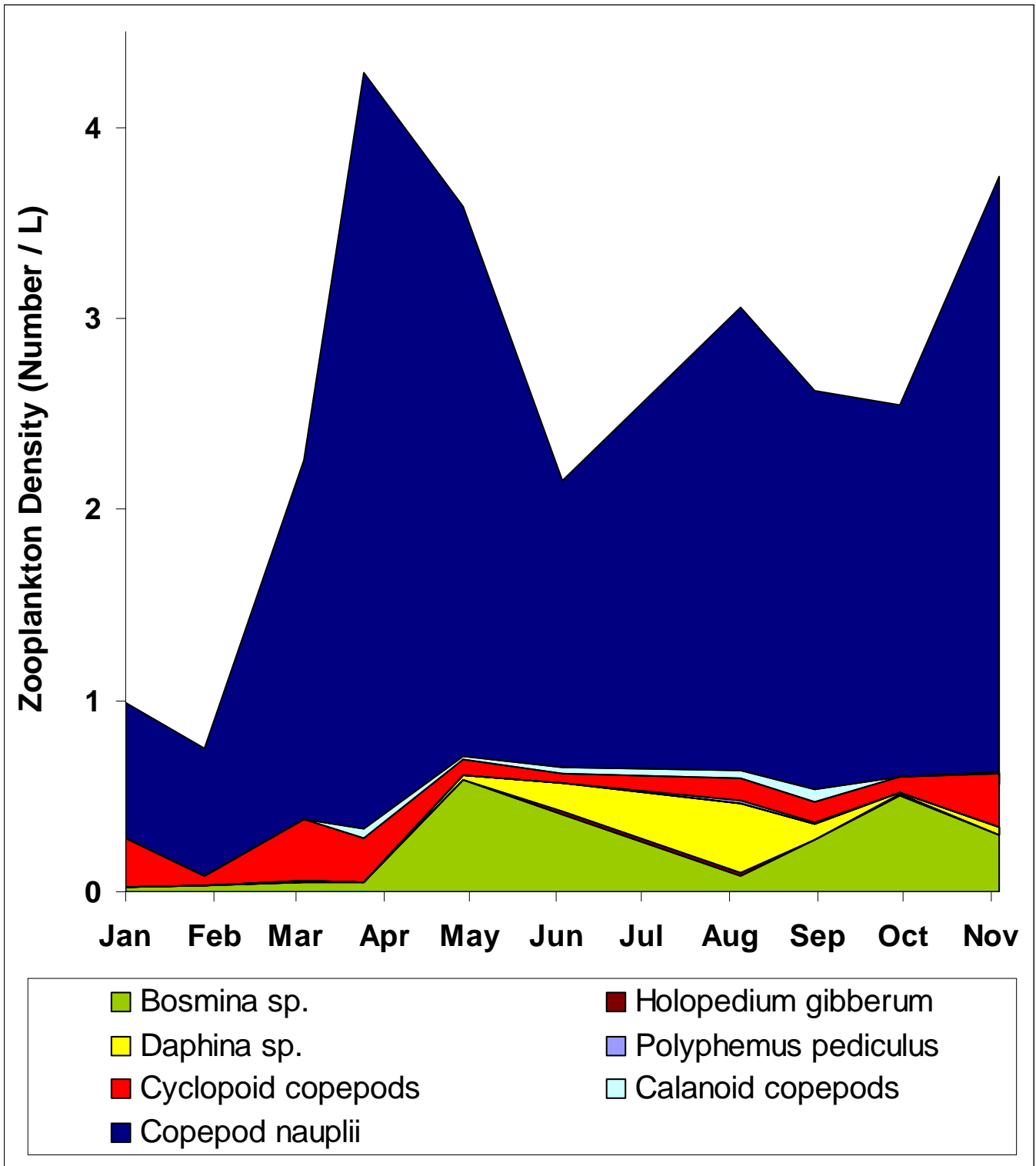


Figure 12. Zooplankton biomass at Site 2 in Coquitlam Reservoir, January to November, 2004.

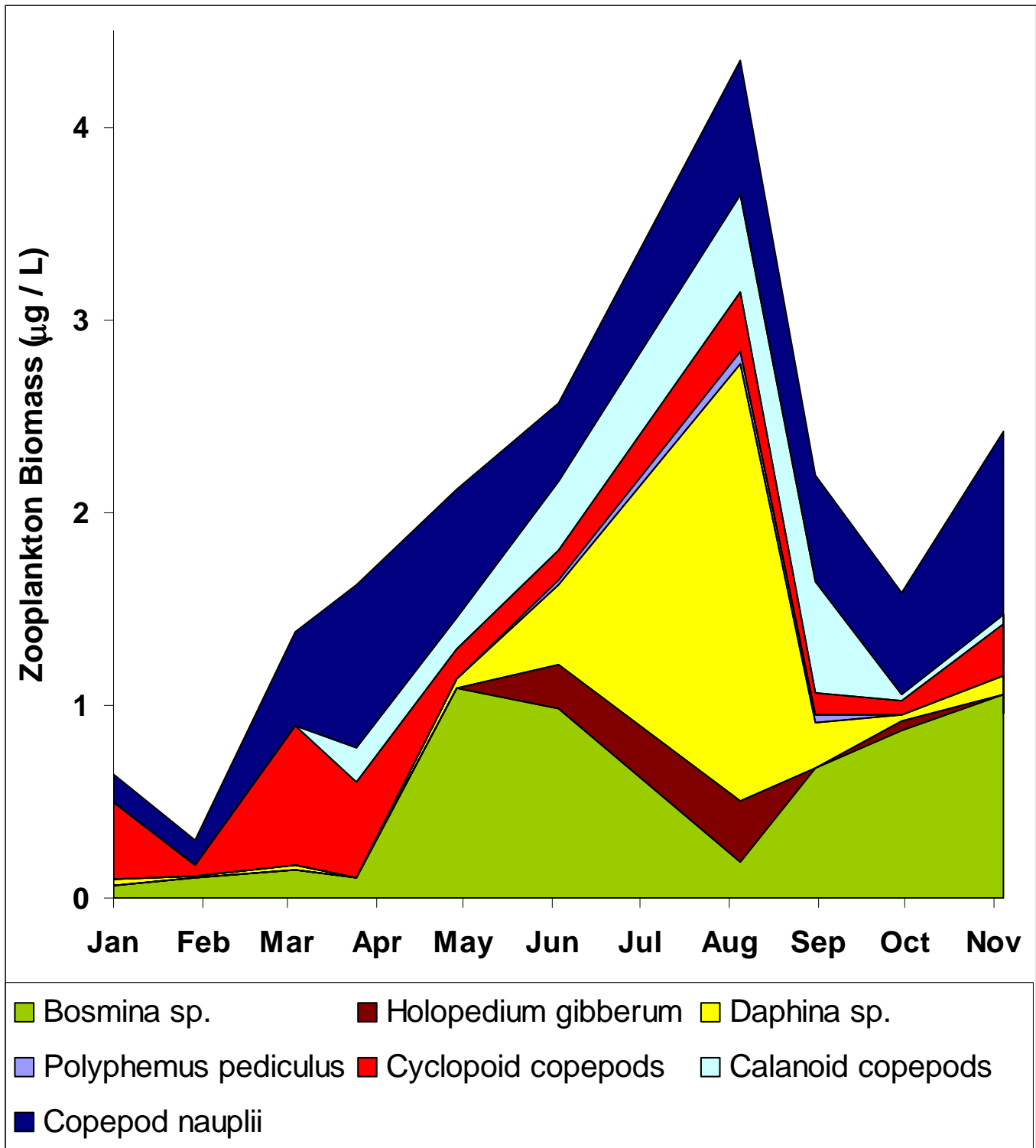


Figure 13. Depth at which fishes analyzed for gut contents were caught Coquitlam Reservoir, September, 2004.

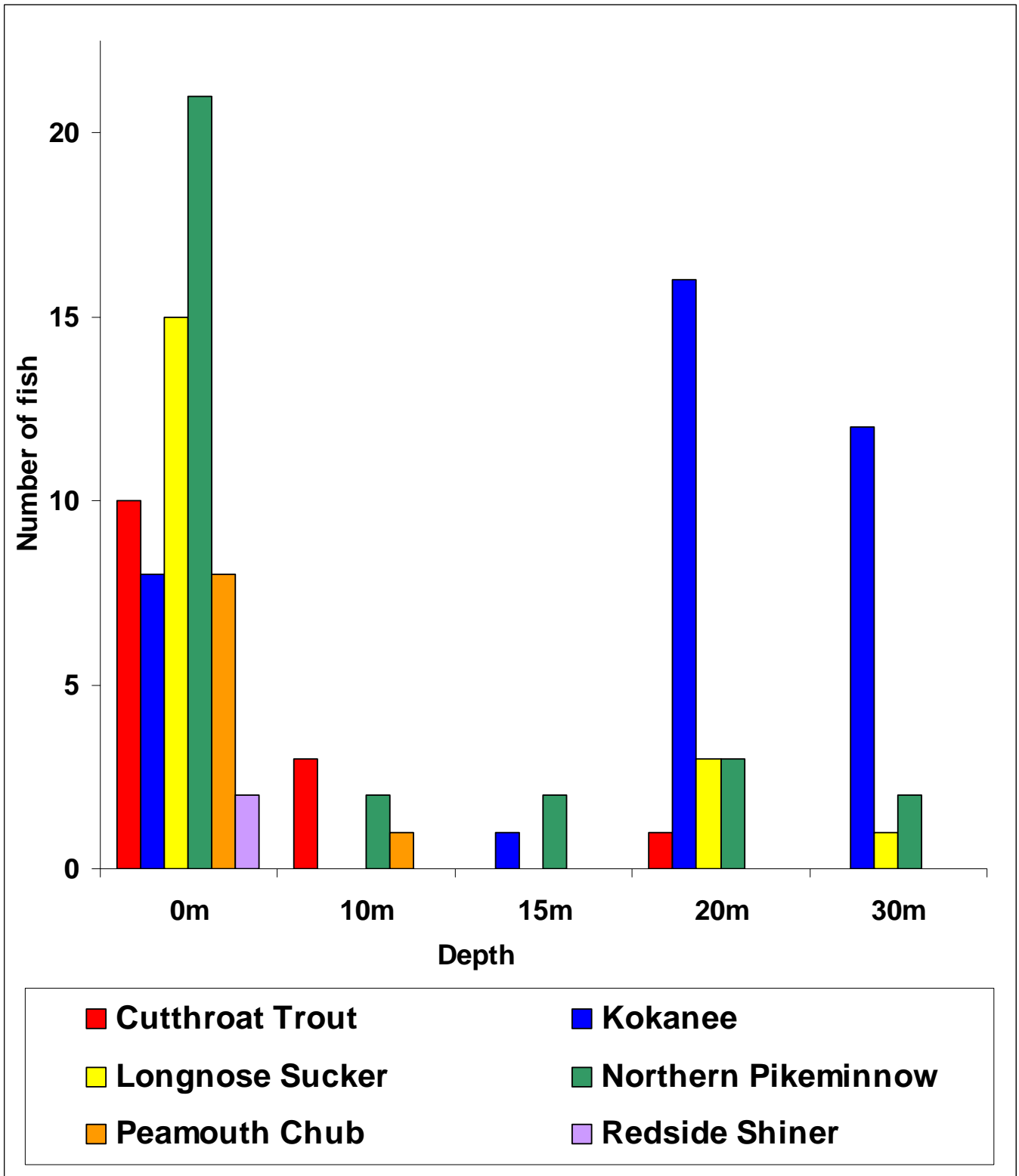


Figure 14. Gut contents of Kokanee caught in Coquitlam Reservoir, September, 2004.

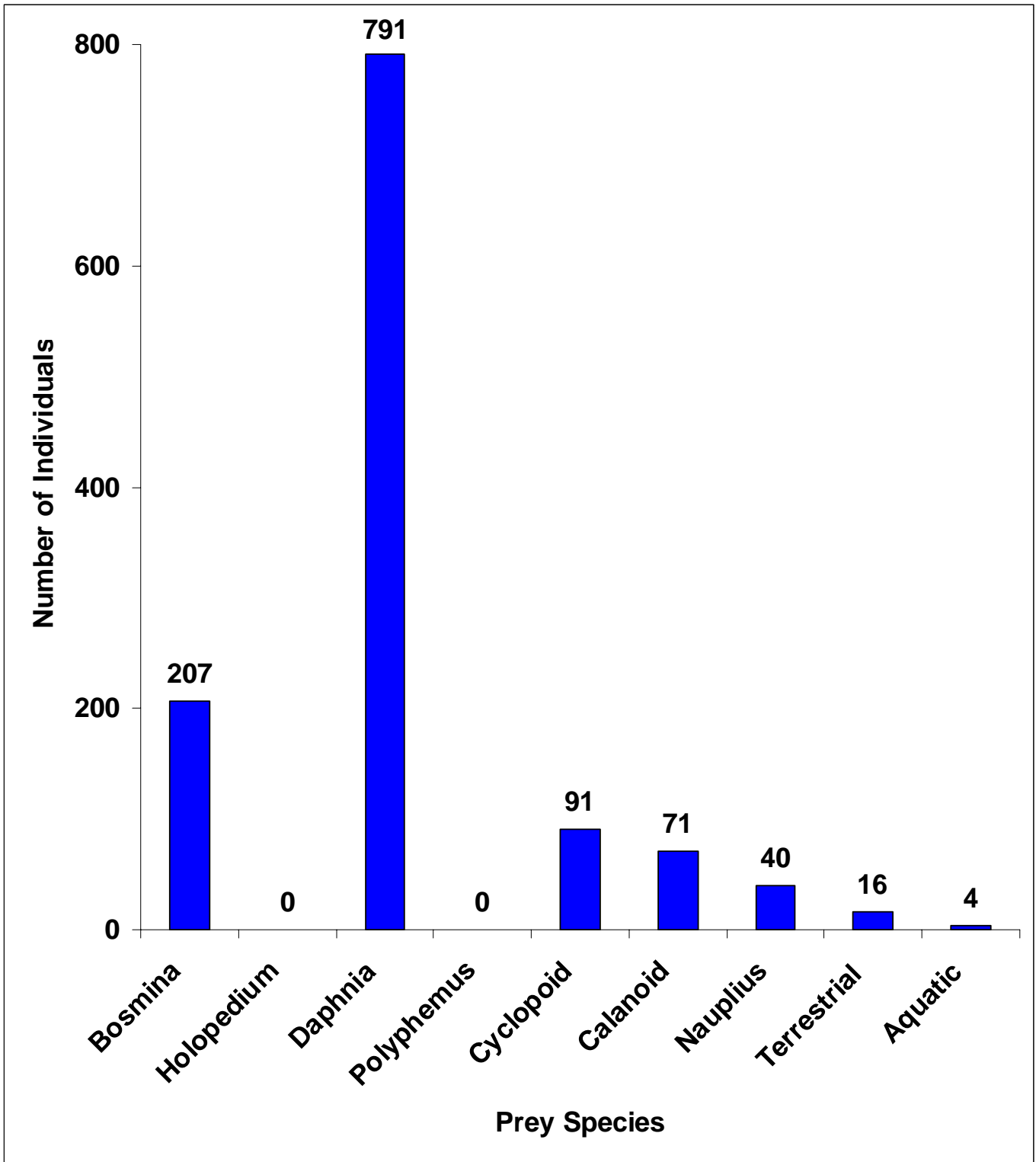


Figure 15. Gut contents of Cutthroat Trout caught in Coquitlam Reservoir, September, 2004.

