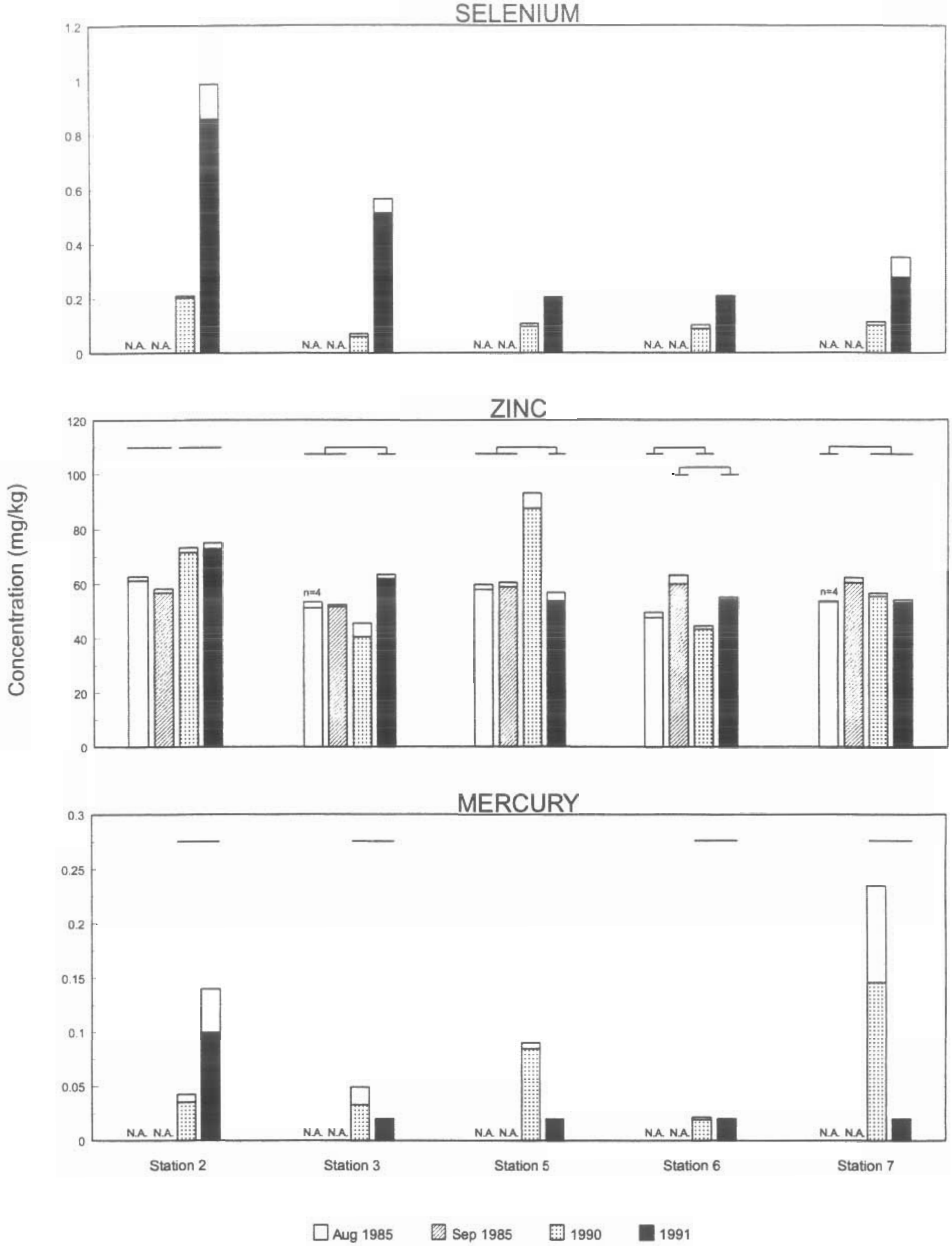

Figure 4.3 Mean (n = 5, unless otherwise indicated) concentrations of selenium, zinc, and mercury in the surface sediments of Contwoyto Lake. Clear, top portions of bars indicate one standard error. Overhead lines indicate means that did not differ significantly among sampling dates (SNK multiple comparison, p>0.05) after one-factor ANOVA on $\log_{10}(x+1)$ transformed data. See text for further explanation. N.A. = Not Analyzed.

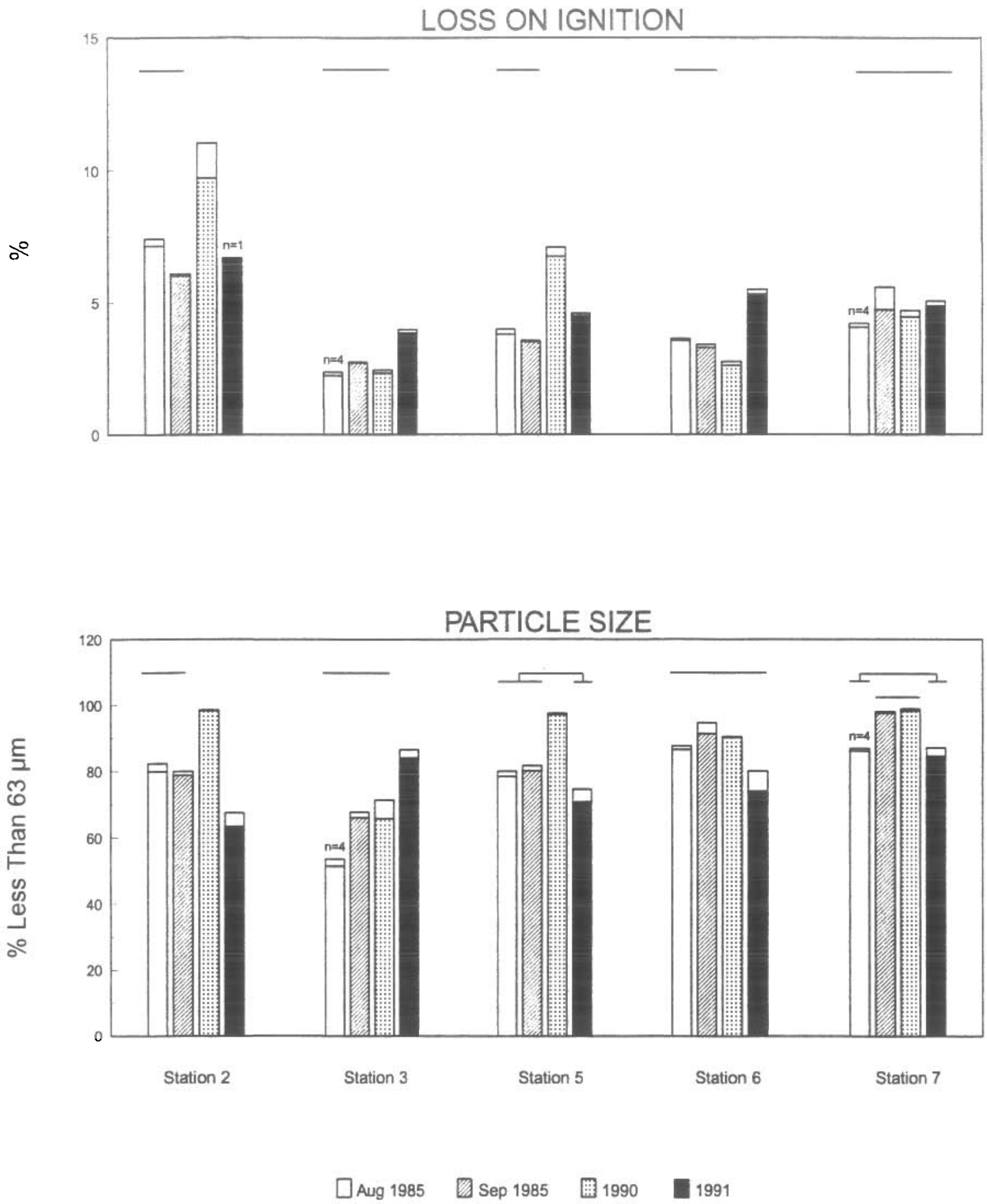

Figure 4.4 Mean (n = 5, unless otherwise indicated) percentages of loss on ignition and particle size in the surface sediments of Contwoyto Lake. Clear, top portions of bars indicate one standard error. Overhead lines indicate means that did not differ significantly among sampling dates (SNK multiple comparison, $p>0.05$) after one-factor ANOVA on arcsine square root transformed data. See text for further explanation.

and particle size were significantly ($p < 0.05$) greater during 1990 than during the two 1985 sample periods (Figure 4.4). Station 6 had significantly ($p < 0.05$) lower amounts of loss on ignition during 1990 than during August 1985 and September 1985. At station 3 and 7, loss on ignition did not differ significantly among the three surveys. At Station 7, particle size was significantly ($p < 0.05$) greater during 1990 than during August 1985; the 1990 and September 1985 samples had particle sizes that did not differ significantly.

1985 and 1990 Surveys vs. 1991

Mean arsenic concentrations at Station 3 were significantly ($p < 0.05$) greater during 1991 than during the three earlier sampling sessions (Figure 4.1). Stations 2 and 6 had arsenic concentrations that did not differ significantly among the August 1985, September 1985, and 1991 sampling dates; however, arsenic concentrations were significantly ($p < 0.05$) lower during 1990. Among the four sampling dates, mean arsenic concentrations were highly variable at Station 5; whereas arsenic did not vary at Station 7. Mean concentrations of cadmium and selenium were significantly ($p < 0.05$) greater at all stations during 1991 than during 1990 (Figure 4.1 and 4.2). Chromium was significantly ($p < 0.05$) greater at all stations, except Station 3, during 1990 than during 1991 (Figure 4.1). Station 3 had mean chromium concentrations that did not differ significantly between 1990 and 1991. Mean concentrations of mercury at all stations, except Station 5, did not differ significantly between 1990 and 1991 (Figure 4.3). At Station 5, mean mercury concentrations were significantly ($p < 0.05$) greater during 1990 than 1991. Mean copper concentrations at stations 2 and 3 were significantly ($p < 0.05$) greater during 1991 than during the three previous sampling periods (Figure 4.2). At Station 5, copper was significantly ($p < 0.05$) lower during 1991 than during 1990 and at stations 6 and 7 copper did not differ significantly among the four sampling dates. Mean lead concentrations (Figure 4.2) during 1991 tended not to differ significantly from one or both of the 1985 surveys; however, all concentrations were significantly ($p < 0.05$) greater during 1991 than during 1990. At stations 2, 5, and 7, nickel concentrations did not differ significantly among the four sampling dates (Figure 4.2). At Stations 3 and 6, mean nickel concentrations were significantly ($p < 0.05$) greater during 1991 than during 1990; however, nickel concentration during 1991 did not differ significantly from those obtained during August and/or September 1985. Mean zinc concentrations (Figure 4.3) at each of the sampling stations tended to be quite variable among the four sampling surveys; however, concentrations at Stations 3 and 5 did not differ significantly ($p < 0.05$) among the 1985 and 1991 sampling session.

Physical characteristics (loss on ignition and particle size) of the sediment samples at each monitoring station were, for the most part, quite variable (Figure 4.4). At stations 3, 5, and 6, loss on ignition was significantly ($p < 0.05$) greater during 1991 than during the two 1985 sampling session. During 1991, loss on ignition values at station 5 and 6 were significantly ($p < 0.05$) lower and higher than during 1990, respectively. The amount of loss on ignition in the samples collected at Station 7 did not differ significantly among the four sample dates. Sediment particle sizes at stations 2 and 3 were significantly ($p < 0.05$) larger and smaller, respectively, during 1991 than at all of the remaining sample dates. At Station 5, particle size was significantly ($p < 0.05$) greater during 1991 than during 1990; however, it did not differ significantly among August 1985, September 1985, and 1991. At

Station 6, particle sizes of the sediment samples did not differ significantly among the four surveys. Particle size of the sediments collected at Station 7 during 1991 were significantly ($p < 0.05$) greater than those of September 1985 and 1990, but did not vary significantly from August 1985.

Summary

At the time the 1991 sediment quality samples were collected, Lupin Gold Mine had been decanting effluent into Contwoyto Lake for a period of six years. During those six years, sediment quality samples had been periodically collected, including a sample session immediately prior to the initial release of effluent. This before and after sampling design is ideal for testing the hypothesis, "is there a change in sediment quality, or a given variable, over time or after onset of effluent release?" Depending on the quality of materials found in the effluent, one would have to observe sediment quality variables to either increase or decrease for the Lupin Gold Mine effluent to have an impact on the receiving environment.

Among the metals that have been analyzed over all four sampling periods, copper at stations 2 and 3, lead at Station 2, and zinc at Station 2, have significantly ($p < 0.05$) increased over time (Figures 4.2 and 4.3). Nonsignificant trends of increasing metal concentrations over time include lead at stations 3 and 7, copper at stations 6 and 7, nickel at stations 2, 3, 5, and 6, and zinc at Station 3. Arsenic had significant ($p < 0.05$) increases in concentration as the study periods progressed at Station 3, similar nonsignificant trends were observed at Stations 2 and 7. The amount of loss on ignition in the sediments collected at stations 3, 5, and 6 were significantly ($p < 0.05$) increasing with time (Figure 4.4). Particle sizes in the sediment samples at Station 2 significantly ($p < 0.05$) increased over the sample periods (Figure 4.4). Nonsignificant trends of increasing loss on ignition was evident at Station 7 and increasing particle size was evident at Station 6.

Significant and nonsignificant trends of decreasing concentrations or physical features among all four sample periods were observed for copper at Station 5, lead at stations 5 and 6, zinc at stations 5 and 7, and particle size at Station 3 (Figures 4.2, 4.3, and 4.4). Arsenic at Station 5, nickel at Station 7, zinc at Station 5, and particle size at stations 5 and 7 had concentrations or amounts of materials that were variable among all four sample periods; therefore, no temporal pattern could be described.

Cadmium, chromium, selenium, and mercury were analyzed during the 1990 and 1991 surveys only (Figures 4.1 and 4.3). Among all of the sampling stations, concentrations of these metals tended to be consistently greater, in most cases significantly, during one of the survey years. Whether or not these results are real is debatable. The 1990 samples were analyzed by Chemex Labs Alberta Inc. while the 1991 samples were analyzed by Environment Canada, EP laboratories. Analytical procedures that can affect or bias results among laboratories were identified and discussed in Section 4.1.2. Further evidence of analytical laboratory biased results can be seen with the lead and nickel concentrations (Figure 4.2). Mean lead concentrations were consistently and significantly ($p < 0.05$) lower at all of the monitoring stations during 1990 than during all of the remaining sampling periods.

Mean nickel concentrations had the similar results at stations 3 and 6. Stations 2, 5, and 7 had comparable mean nickel concentrations among the four survey periods; however, the 1990 data were highly variable (i.e., largest standard deviations) relative to the other three surveys.

The variability in data trends can be partly explained by natural variation, sampling methodologies, and analytical laboratory result biases (also see Section 4.1.2). Despite these observations, there does appear to be an impact on sediment quality due to Lupin Gold Mine effluent. Taking into consideration the variability associated with the 1990 data, most variables, especially at stations 2 and 3, tended to increase with time. Station 3 is the only Inner Sun Bay station that was monitored over all four sample periods. Its close proximity to Seep Creek (Figure 2.1), the point of effluent entry into Contwoyto Lake, relative to the Outer Sun Bay monitoring stations would result in relatively greater exposure to, and accumulation of, effluent. By the time the effluent plume reaches Outer Sun Bay it is diluted considerably, and would have a potentially lower impact on sediment quality relative to Inner Sun Bay. Mudroch and Sutherland (1988), described similar trends in water quality, that is, a spatial trend of decreasing concentrations of water quality variables with increasing distance from Seep Creek. They also described increases in mean concentrations of metals at Station 2, the proposed control site. Sediment quality at Station 2 tended to be affected to a greater extent than any of the other Outer Sun Bay stations. Station 2 may be receiving relatively more effluent materials than stations 5, 6, and 7 because of its depth and location. Station 2 is over 14 m deep (Table 4.5), only Station 9 was deeper (27.1 m). Sediment focussing (see Section 4.1.2) may be causing greater accumulations in Station 2 of sediments relative to stations 5, 6, and 7. In addition, localized lake currents, possibly caused by the coriolis force (i.e., the earth's rotation causes the deflection of moving bodies into a clock-wise direction in the Northern Hemisphere), and basin morphology may direct flows that enter Outer Sun Bay towards Station 2.

Mudroch and Sutherland (1988) and the present study have identified problems with Station 2 as a control site. Data suggest that this station is impacted by effluents released from Lupin Gold Mine and, therefore, cannot be a control site as originally designed. The absence of a proper control site does not allow for an evaluation of natural factors or sources of variation in assessing impacts. Use of proper controls is necessary for the identification of real cause and effects in environmental data (Green 1979). An example of the natural variability in sediment quality at Norma Lake during 1982, 1983, and 1984 is presented in Table 4.6. Norma Lake is located south of Lupin Gold Mine's effluent pond and did not receive any development or operational impacts at the time sediments were collected. Sediment quality in Norma Lake had considerable variation, not unlike what was observed in Contwoyto Lake during the present study; therefore, trends of decreasing sediment quality in Contwoyto Lake cannot be entirely attributed to impact from effluent quality.

Table 4.6 Mean (n=3, except during September 1983 where n=1) and standard deviation (in brackets) of selected variables in the sediments of Norma Lake. These data were obtained from Reid, Crowther and Partners Ltd. (1985). All concentrations are mg/kg, unless otherwise indicated.

Variable	Sample Period		
	September 1982**	September 1983	September 1984
Arsenic	18.4 (2.9)	13.7	26.1 (1.3)
Copper	81.9 (1.8)	127	82.7 (3.9)
Lead	9.9 (0.04)	5.9	6.1 (0.5)
Nickel	63.7 (1.9)	86.6	63.3 (1.1)
Zinc	104.5 (7.2)	133	70.1 (0.8)
TOC *	2.6	2.1	2.4 (0.05)

* TOC = total organic content, n=1 during September 1982.
** Laboratory analyses were conducted on whole samples during 1982; whereas, laboratory analyses on the 1983 and 1984 samples were conducted on sediments after passing through a 53 μm seine.

4.1.4 Vertical Assessment

Summary statistics on the analyses of the sub-sectioned, vertical core samples collected at Station 9 are summarized in Table 4.7 and raw data presented in Appendix B. Results of the statistical analyses on the 1 cm, vertical core samples collected during 1991 are presented in Table 4.8. Mean arsenic, cadmium, chromium, copper, nickel, and zinc concentrations did not differ significantly among the 1 cm, vertical depth sub-sections; however, all of these metals, except zinc, tended to have greater concentrations in the surface (0-5 cm) sediments than in deeper (5 to 10 cm) sediments. Zinc tended to have concentrations that were uniformly distributed throughout the core depth profiles. Mean lead and mercury concentrations were significantly ($p<0.05$) greater in the surface (to 2 to 5 cm) sub-sections than in the deeper (bottom 5 to 10 cm) sediment sections. Selenium had a significantly ($p<0.05$) greater concentration in the 1-2 cm, vertical sediment section than in all of the remaining sections. Particle size of the sediments at Station 9 tended to be significantly ($p<0.05$) smaller at the very surface (0-1 cm, vertical section) and lower sediment depths (3 to 10 cm) than at intermediate depths (1 to 3 cm).

These significant and nonsignificant trends of increased metal concentrations in the surface sediments suggest that natural or anthropogenic sources are affecting sediment quality. These results also suggest that the process of sediment focussing (Wetzel 1983) may be occurring in the deep 27.1 m basin of Station 9. Future monitoring of replicate cores, sub-sectioned at 1 cm intervals, should be continued at Station 9 to verify these results and to identify if trends are becoming increasingly significant (i.e., determine if impacts or accumulations of metals are increasing).

Table 4.7 Vertical sediment quality data (mg/kg, unless otherwise indicated) collected at Station 9 during 1990 (n=1) and 1991 (mean and standard deviation [S.D.], n=3, unless otherwise indicated).

Variable	Core Sub-Section (cm)														
	0 - 1			1 - 2			2 - 3			3 - 4			4 - 5		
	1990	1991		1990	1991		1990	1991		1990	1991		1990	1991	
		mean	S.D.		mean	S.D.		mean	S.D.		mean	S.D.		mean	S.D.
Arsenic	21	55.1	(61.4)	19.2	45.9	(13.0)	20	24.3	(7.07)	19.7	17.7	(1.56)	18.2	16.5	(3.76)
Cadmium	0.1	0.65	(0.41)	0.1	0.53	(0.28)	0.1	0.43	(0.14)	0.1	0.31	(0.10)	0.1	0.31	(0.06)
Chromium	100	56	(10)	89	53.3	(8.63)	86	54.7	(11.8)	88	48.8	(4.21)	98	49.6	(1.57)
Copper	76	48.2	(10.2)	79	69.9	(23.1)	87	53.0	(11.0)	71	49.9	(2.82)	71	46.5	(3.69)
Lead	6.9	23.0	(3.67)	7.6	22.7	(0.72)	12.4	19.7	(0.71)	7.4	18.4	(1.27)	13.5	19.2	(1.10)
Nickel	1	30.6	(2.60)	18	31.3	(4.97)	26	28.5	(1.18)	4	27.0	(2.79)	10	26.5	(2.57)
Selenium	0.65	0.3	(0.4)	0.38	1.0	(0.49)	0.22	0.9	(0.8)	0.23	0.5	(0.3)	0.18	0.3	(0.1)
Zinc	71	69	(7.0)	76	75.9	(9.37)	73	67.2	(3.51)	70	44	(31)	75	62.4	(2.84)
Mercury	0.097	0.03	(0.01)	0.16	0.06	(0.02)	0.21	0.04	(0.02)	0.1	0.03	(0.01)	0.14	0.02	(0.00)
P.S.	98.9	71.2	(17.9)	99.2	43.5	(12.8)	98	50	(8.0)	97.8	55.1	(1.61)	98.8	61.7	(1.22)
LOI	11.4	6.7	(4.23)	8.85	9.2*	NA	8.33	7**	(0)	7.59	7.5	(1.1)	6.9	6.2	(0.83)

Table 4.7 Continued.

Variable	Core Sub-Section (cm)														
	5 - 6			6 - 7			7 - 8			8 - 9			9 - 10		
	1990	1991		1990	1991		1990	1991		1990	1991		1990	1991	
		mean	S.D.		mean	S.D.		mean	S.D.		mean	S.D.		mean	S.D.
Arsenic	20.4	22.7	(8.14)	21.4	18.1	(1.95)	22.2	20.9	(5.77)	117	19.1	(3.03)	NA	27.7	(18.3)
Cadmium	0.1	0.29	(0.06)	0.1	0.38	(0.10)	0.1	0.3	(0.1)	0.1	0.27	(0.07)	NA	0.30	(0.11)
Chromium	95	47.6	(4.46)	101	50.7	(6.22)	100	50.7	(7.81)	97	50.4	(8.55)	NA	51.5	(0.91)
Copper	67	44.7	(8.35)	73	43.4	(11.4)	69	42.4	(8.11)	56	41.0	(8.32)	NA	41.4	(5.83)
Lead	8.9	18.0	(0.81)	4.8	19.2	(0.29)	9.7	19	(1.1)	8.9	18.7	(1.47)	NA	20	(1.0)
Nickel	1	27.7	(1.86)	11	28.7	(3.32)	10	29.9	(4.28)	36	30	(3.3)	NA	31.5	(1.32)
Selenium	0.17	0.2	(0.08)	0.18	0.2	(0.08)	0.15	0.1	(0.02)	0.05	0.1	(0.03)	NA	0.1	(0.03)
Zinc	75	64	(6.9)	87	65.4	(7.37)	85	65.7	(8.29)	79	65	(7.2)	NA	68	(3.6)
Mercury	0.12	0.02	(0.00)	0.1	0.02	(0.00)	0.11	0.02	(0.0)	0.43	0.02	(0.00)	NA	0.02	(0.00)
P.S.	98.1	71	(4.2)	98.7	71.9	(3.24)	99.1	75.1	(4.68)	86.3	75.2	(0.85)	NA	80	(2.99)
LOI	6.69	5.7	(0.35)	6.61	5.0	(0.53)	6.08	4.7	(0.04)	5.86	4	(0.4)	NA	4.0	(0.47)

* One replicate. ** Two replicates.
NA = Not analyzed or not available. P.S. = Particle Size (% $<63\mu m$). LOI = Loss on Ignition (%).

Table 4.8 Results of statistical analyses (one-factor ANOVA followed by SNK) on vertical sediment quality data collected at Station 9 during 1991. Data were transformed ($Log_{10}[x+1]$ for concentrations and arcsine $x^{-1/2}$ for percentages) prior to analysis. Groups linked by lines were not significantly ($p>0.05$) different from one another. Concentrations are mg/kg unless otherwise indicated.

Variable	Core Sub-Section (cm)									
Arsenic	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Cadmium	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Chromium	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Copper	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Lead	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Nickel	0-1	1- 2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Selenium	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Zinc	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Mercury	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Particle Size (% < 63μm)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Loss on Ignition (%)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10

4.1.5 Statistical Power Analyses

Statistical power is the probability that a study will yield significant results if the treatment is effective and is the function of three factors (Borenstein and Cohen 1988; Peterman 1990): 1) effect size, 2) sample size, and 3) alpha. Effect size is the distance and variation among means of the true sampling distribution, or in other words, magnitude of the true effect for which one is testing. In general, experiments with large effects or perturbations are more likely to generate high power. Sample size is the total number of samples collected or examined. Alpha (∝) is the stated value for p (the calculated probability) below which one rejects the null hypothesis. For the purposes of this report, power was calculated to assess the ability to detect significant differences among sediment quality variables and to evaluate the present study design. If the power of a test decreased little with a reduction in the number of replicates per station, then time and effort can be saved with a possible reallocation of resources. Conversely, the addition of one or two replicates per station may provide much more valuable information with little additional time and effort. Effect size was not manipulated (i.e., left as is for the present sampling design) and alpha was set at 0.05.

Spatial Assessment

Results of statistical power analysis on the ANOVAs that compare sediment quality among the six sampling stations during 1991 is presented in Table 4.9. Under the present sampling design, the null hypothesis was rejected when power was generally above 0.800; conversely, the null hypothesis was accepted when power was below approximately 0.800. Of the variables that demonstrated a significant difference (i.e., rejected the null hypothesis) among stations, arsenic, cadmium, and mercury had powers that were below 0.950. If the number of replicates were increased at Station 9 to five (i.e., five replicates per station) then the power of a statistical test on cadmium concentrations increases to 0.966. When six replicates are collected at each station, arsenic, cadmium, and mercury's statistical powers increase to 0.959, 0.983, and 0.971, respectively.

Table 4.9 Power (the ability to detect a difference, if in fact there is one) of the ANOVAs conducted to examine the means of surface sediment quality among six stations during 1991. The null hypothesis (Ho) was, "there is no difference in mean concentration or amount of a given variable among the six sampling stations." The sampling design included the collection of five replicates at all stations except Station 9 where three replicates were collected. To evaluate an optimal study design, power was calculated for various number of replicates (n) at $\alpha=0.05$ (Type I error = probability of rejecting Ho when it is, in fact, true). See text for further explanation.

Variables	Power When Ho Rejected						Power When Ho Accepted							
	n=6	n=5	Present Design	n=4	n=3	n=2	Present Design	n=5	n=6	n=7	n=8	n=9	n=10	(n)
Arsenic	0.959	0.875	0.832	0.788	0.575	0.279								
Cadmium	0.983	0.966	0.924	0.853	0.650	0.319								
Chromium							0.510	0.552	0.665	0.757	0.827	0.880	0.919	(11) 0.965
Copper	1.000	1.000	1.000	1.000	0.993	0.782								
Lead							0.541	0.584	0.698	0.788	0.854	0.903	0.937	(11) 0.959
Mercury	0.971	0.923	0.896	0.814	0.604	0.294								
Nickel							0.796	0.835	0.917	0.961	0.985	1.000	1.000	
Selenium	1.000	1.000	0.988	0.963	0.830	0.449								
Zinc	1.000	1.000	1.000	1.000	0.996	0.823								
Particle Size (% < 63μm)							0.586	0.631	0.745	0.829	0.889	0.930	0.957	
Loss on Ignition (%)							0.308	0.341	0.424	0.502	0.574	0.640	0.699	(19) 0.956

Of the variables that did not demonstrate a significant difference (i.e., accepted the null hypothesis) all had statistical power above 0.500, except loss on ignition. Loss on ignition had a power of 0.308. Nickel had the highest power (0.796) among the variables that accepted the null hypothesis. If seven replicates were collected at each station, nickel's power increases to 0.961. All of the other variables that accepted the null hypothesis require ten or more replicates to have a power of at least 0.950.

In summary, with the exception of loss on ignition, the power of the statistical analyses performed in the present study was moderate to high. The collection of five replicates at each station would moderately increase the power of statistical tests. Increasing the number of sediment quality replicates to six is recommended because it would bring arsenic's power above 0.950 and would likely result in a significant detection in the mean concentration of nickel among the six sampling stations. Increasing the number of replicates collected at each site would add minimal time, effort and expenses to subsequent monitoring studies.

Temporal Assessment

Results of statistical power analysis on the ANOVAs that compare sediment quality among the four sampling periods is presented in Table 4.10. With the exceptions of selenium at Station 7 (power=0.596) and loss on ignition at Station 2 (power=0.855) all of the remaining ANOVAs under the present sampling design, that rejected the null hypothesis had a power of at least 0.900. With the addition of one more replicate (i.e., n=6 at each station during each sample session), only loss on ignition increases its statistical power above 0.900. The present sampling design had 40 statistical tests that had a power of 0.900 or more when the null hypothesis was rejected. By reducing the number of replicates to four (i.e., four sediment samples per station per sample session), the number of statistical tests whose power is greater than 0.900 is only reduced to 38. This number decreases to 32 when the number of replicates per station per sample session is lowered to three. Under the present sampling design, statistical power for those ANOVAs that accepted the null hypothesis ranged from 0.102 to 0.630 and increasing the number of replicates to six does not appreciably increase statistical power (range=0.115 to 0.741).

In summary, the present sampling design provided high statistical power for the majority of ANOVAs that were conducted to assess differences among sampling sessions. Increasing the number of replicates from five to six per station per sample session did not greatly increase statistical power or the number of ANOVAs that would probably detect a significant difference. Decreasing the number of replicates per station per sample session to four will not greatly affect the number of statistical tests that should detect a significant difference among sampling dates.

Table 4.10 Power (ability to detect a difference if, in fact, there is one) of the ANOVAs conducted to examine the means of surface sediment quality among the four sampling sessions (August 1985, September 1985, August 1990, and August 1991). The null hypothesis (Ho) was, "at a given station, there is no difference in mean concentration or amount of a given variable among the four sampling sessions." The sampling design included the collection of five replicates at each station and survey except for stations 3 and 6 during August 1985 where four replicates were collected. There was only one replicate available for loss on ignition at Station 2 during 1991 and it was omitted from statistical analyses. To evaluate an optimal study design, power was calculated for various number of replicates (n) at $\alpha=0.05$ (α=Type I error, the probability of rejecting Ho when it is, in fact, true). See text for further explanation. Note that cadmium, chromium, mercury, and selenium were analyzed during August 1990 and August 1991, but not during August 1985 and September 1985.

Variable	Station	Power When Ho Rejected					Power When Ho Accepted						
		n=6	Present Design	n=4	n=3	n=2	Present Design	n=6	n=7	n=8	n=9	n=10	(n)
Arsenic	2	1.000	0.999	0.991	0.917	0.525							
	3	1.000	1.000	1.000	0.995	0.777							
	5	1.000	1.000	1.000	1.000	0.995							
	6	1.000	0.997	0.981	0.878	0.475							
	7						0.280	0.369	0.442	0.503	0.568	0.621	(22) 0.952
Cadmium	2	1.000	1.000	1.000	0.987	0.587							
	3	1.000	1.000	1.000	1.000	1.000							
	5	1.000	1.000	1.000	1.000	1.000							
	6	1.000	1.000	1.000	1.000	1.000							
	7	1.000	1.000	1.000	1.000	0.997							
Chromium	2	1.000	1.000	1.000	0.999	0.724							
	3						0.110	0.126	0.143	0.160	0.177	0.194	(100) 0.953
	5	1.000	1.000	1.000	0.991	0.610							
	6	1.000	1.000	0.996	0.942	0.471							
	7	1.000	1.000	1.000	1.000	0.903							
Copper	2	1.000	0.984	0.934	0.767	0.379							
	3	0.976	0.916	0.833	0.623	0.294							
	5	1.000	1.000	1.000	1.000	0.893							
	6						0.342	0.423	0.500	0.570	0.635	0.692	(19) 0.951
	7						0.544	0.687	0.774	0.841	0.890	0.925	(11) 0.950
Lead	2	1.000	1.000	1.000	0.998	0.823							
	3	1.000	1.000	1.000	1.000	0.998							
	5	1.000	1.000	1.000	1.000	1.000							
	6	1.000	1.000	1.000	1.000	1.000							
	7	1.000	1.000	1.000	1.000	0.997							
Mercury	2						0.309	0.369	0.432	0.491	0.545	0.605	(25) 0.952
	3						0.102	0.115	0.129	0.144	0.158	0.173	(102) 0.951
	5	1.000	1.000	1.000	1.000	0.910							
	6						0.102	0.115	0.129	0.144	0.158	0.173	(114) 0.950
	7						0.258	0.313	0.367	0.419	0.468	0.514	(31) 0.953
Nickel	2						0.374	0.461	0.542	0.616	0.681	0.738	(18) 0.958
	3	1.000	1.000	1.000	1.000	0.950							
	5						0.398	0.490	0.574	0.649	0.714	0.769	(17) 0.960
	6	1.000	1.000	1.000	1.000	1.000							
	7						0.320	0.422	0.498	0.568	0.633	0.690	(19) 0.950

Table 4.10 Continued.

Variable	Station	Power When Ho Rejected					Power When Ho Accepted						
		n=6	Present Design	n=4	n=3	n=2	Present Design	n=6	n=7	n=8	n=9	n=10	(n)
Selenium	2	1.000	1.000	0.996	0.948	0.480							
	3	1.000	1.000	1.000	1.000	0.831							
	5	1.000	1.000	1.000	1.000	0.787							
	6	1.000	1.000	1.000	0.996	0.662							
	7	0.700	0.596	0.468	0.314	0.164							
Zinc	2	1.000	1.000	0.999	0.985	0.695							
	3	1.000	0.984	0.948	0.795	0.400							
	5	1.000	1.000	1.000	0.987	0.704							
	6	1.000	1.000	0.997	0.956	0.595							
	7	0.986	0.941	0.869	0.669	0.318							
Particle Size (% <63μm)	2	1.000	1.000	1.000	0999	0.880							
	3	0.997	0.981	0.942	0.783	0.390							
	5	1.000	1.000	1.000	0.999	0.877							
	6						0.630	0.741	0.824	0.883	0.925	0.952	
	7	1.000	1.000	1.000	0.996	0.793							
Loss on Ignition	2	0.928	0.855	0.723	0.509	0.235							
	3	1.000	0.995	0.979	0.872	0.469							
	5	1.000	1.000	1.000	1.000	0.992							
	6	1.000	1.000	1.000	1.000	0.994							
	7						0.620	0.732	0.815	0.876	0.919	0.948	(11) 0.967

4.2 BENTHIC MACROINVERTEBRATES

4.2.1 1991 Quality Assessment

Macroinvertebrate samples were originally sorted by Mr. Bob Wissemann of Corvallis, Oregon. An independent sorter (Mr. Bruce Kilgour of Mackie and Associates Water Systems Analysis, Guelph, Ontario) resorted 10% of the samples to determine if sorting technique was efficient at finding all organisms. Greater than 5% (approximately 11%) of the organisms in the originally sorted samples had been missed by the first sorter, and subsequently all of the samples were resorted (EVS Consultants 1992). The organisms that were found during resorting were added to the totals of those originally sorted.

4.2.2 Spatial Assessment of the 1991 Data

There were a total of 52 taxa identified during the present, 1991 survey of Contwoyto Lake compared to 32 and 73 taxonomic groups during the two 1985 collections and the 1990 survey, respectively. The present survey found specimens of *Rhyacodrilus coccineus* (Tubificidae), *Lumbriculus variegatus* (Lumbriculidae), *Pseudodiamesa* spp. (Chironomidae), and a new species of *Pisidium* (Sphaeriidae) that were not identified during the three previous assessment periods. Some chironomid, mollusc, and Acari taxa identified in samples collected during the 1985 and 1990 surveys were not identified in samples from the present survey. These differences in number and types of taxa found are most likely due to annual variability, effort expended during identification, and in the case of sensitive mollusc species, because of incomplete preservation of some samples in the field. The complete set of raw data for invertebrate taxa identified from the Contwoyto Lake stations during 1991 (EVS Consultants 1992) is presented in Appendix C.

Community Similarity Comparisons Among Stations

Community data generally contain "outliers" or dissimilar samples because of disturbed or heterogeneous sites or because of gaps in sampling (Gauch 1982). Comparisons among the various stations based on taxa numbers or the use of biotic indices (e.g., pollution tolerant species/pollution sensitive species) are only valid if community composition is similar. As noted in the previous reports (Mudroch and Sutherland 1988; Porter et al. 1992), different benthic communities may imply different natural habitats rather than indicating the occurrence of benthic impacts. Two components of community composition are species composition and species dominance. Appendix C contains the results of comparisons of community composition (Tables C1, C2, and C3).

As with the 1985 and 1990 studies, the 1991 study showed that macroinvertebrate community composition at Station 3 was not similar to the other stations. The other stations were similar to each other, thus, allowing quantitative analysis of species abundance. Considering that Station 3 is the closest to the point where mine effluent enters Contwoyto Lake, changes in sediment quality and particle size, which may be the result of mine discharges, also may influence benthic community structure changes; therefore, Station 3 will be included in data analysis procedures. This station also was used in data analysis procedures by Porter et al. (1992). A comparison between respective stations during all four study periods indicated that certain chironomid species and nematodes are dominant at most stations; however, the differences in identification effort and other factors suggest that only general trends in species dominances and abundances among studies may be inferred; therefore, data examinations will be restricted to those taxa that contributed towards >1% of all invertebrates as a whole and found in the majority of samples.

Taxonomic Density Comparisons Among Stations

Six taxa accounted for ≥1% of the invertebrates collected and occurred in >50% of the samples (Table 4.11). These taxa, in addition to *Stictochironomus*, were analyzed using a one-factor ANOVA to compare differences in densities among sampling stations. *Stictochironomus* was included despite its low frequency of occurrence, because it ranked higher in terms of mean rank based on occurrence and abundance than several of the other taxa that were examined (EVS Consultants 1992).

Table 4.11 Abundance and occurrence of dominant taxa in Contwoyto Lake, August 1991. Table was adapted from EVS Consultants (1992).

Taxon	% Abundance	Rank	% Occurrence	Rank	Mean Rank
Nematoda	23.9	1	98	1	1.0
Stictochironomus	16.0	2	42	7	4.5
Lumbricillus	9.7	3	58	5	4.0
Heterotrissocladius	9.7	4	90	2	3.0
Pisidium	6.7	5	67	4	4.5
Diacyclops nanus	5.7	6	52	6	6.0
Tubificidae - imm. with cap. chaetae	4.1	7	38	8	7.5
Tanytarsus	3.7	8	25	9	8.5
Mesocricotopus	3.4	9	69	3	6.0
Valvata mergella	3.2	10	17	10	10.0

The results of ANOVA and SNK multiple comparison tests evaluating the densities of the dominant taxa is given in Table 4.12. Mean density per replicate differed significantly ($p < 0.0001$) among the stations. Abundance at Station 3 was significantly greater than at all other stations, and densities at Station 5 were significantly greater than at all other stations, except Station 3. The densities of all dominant taxa, except *Mesocricotopus* also were greatest at either Station 3 or 5. In most cases, abundance of dominant taxa differed greatly among stations, as indicated by the low ANOVA p-values. The exceptions were *Mesocricotopus*, and to a lesser extent, *Heterotrissocladius*, which occurred in most replicates and stations at fairly low abundances (see Section 4.2.3 and Appendix C).

Table 4.12 Results of ANOVA and SNK multiple comparison tests, on $\text{Log}_{10}(x+1)$ transformed data ($n=8$), evaluating densities of dominant taxa among stations, 1991. Table was adapted from EVS Consultants (1992). Underscores join stations that were not statistically different ($p > 0.05$).

Taxonomic Group	ANOVA	Station Rankings
Nematoda	0.007	3 9 2 7 6 5
Lumbriculidae/Enchytraeidae	<0.0001	2=9 3 7 6 5
Lumbricillus	<0.0001	3 2=9 7 6 5
Sphaeriidae	<0.0001	9 7 2 6 5 3
Pisidium	<0.0001	9 7 2 6 5 3
Cyclopidae		
Diacyclops	0.0004	3 7 2 6 9 5
D. nanus	0.0004	3 7 2 6 9 5
Chironomidae	<0.0001	2 9 6 7 5 3
Heterotrissocladius	0.018	2 7 3 6 9 5
Mesocricotopus	0.27	2 9 3 6 5 7
Stictochironomus	<0.0001	9 5 6 2 7 3
Density of all Invertebrates as a whole	<0.0001	2 9 7 6 5 3

In some cases, pooling taxa into higher level classifications did not alter the differences among stations. The higher taxonomic levels were usually dominated by only one taxon. The most extreme example was the genus *Diacyclops*, which consisted of 212 *D. nanus* individuals and only one *D. thomasi* individuals. The one exception was the Chironomidae, which consisted of several abundant genera with different spatial distributions (compare station rankings for the genera listed in Table 4.12). At stations 3 and 5, however, one or more genera were much more abundant than at other stations, so that the abundance of the family as a whole followed the same pattern as did total densities of invertebrates as a whole. These results suggest that taxonomic identifications, especially for chironomids, should be identified to genus or species.

To determine the lowest level of taxonomic classification needed to demonstrate significant differences between stations, data were subjected to Mantel's test (Mantel 1967; EVS Consultants 1992). This test is a randomization procedure that calculates the probability that two distance matrices are more similar than would be expected by chance alone (Jackson and Somers 1989). The rationale behind this exercise is to minimize the effort needed to determine "impact - no impact." The question of whether it is necessary to classify at the species level as opposed to higher levels of taxonomic classification was addressed at an Environment Canada Benthic Monitoring Workshop (Gibbons et al. 1992). This workshop as well as previous ones (see Porter et al. 1992) concluded that within the limited range of habitats that were studied, species-level and higher taxonomic classification levels (e.g., families) were equal in the ability to provide useful information for pollution monitoring. The application of this approach for any aquatic pollution monitoring study would preclude the need for labour-intensive and expert identification capability. To address this situation in data analysis and interpretation, the workshops recommended the use of Mantel's test. During the present study, the results of Mantel's test indicated that distance matrices calculated using species, genus and family level identifications were significantly different (Table 4.13). Similar results were reported by Porter et al. (1992) during their 1990 study; consequently, it is recommended that future investigations should continue examining the macroinvertebrate community at lower taxonomic levels (i.e., genus and species).

Table 4.13 Results of Mantel's Test comparing distance matrices on 1991 data, based on different taxonomic levels. Spearman's rank correlations above diagonal; p values below diagonal. Table was adapted from EVS Consultants (1992).

	Lowest Level	Genus	Family
Lowest Level	-	0.983	0.925
Genus	0.001	-	0.921
Family	0.003	0.004	-

4.2.3 Temporal Assessment

The total number of taxa identified during the 1991 survey was 52, whereas, 36 and 73 taxonomic groups were identified in 1985 and 1990, respectively (EVS Consultants 1992; Porter et al. 1992). To compare densities within respective stations among the four survey periods, taxonomic groups common to all periods should be used in statistical analyses. The list of taxa common to all four sampling sessions are summarized in Tables 4.14 through 4.18 and raw data are presented in Appendix C (Table C4). The number of taxonomic groups identified in all sampling sessions was 21, of which 12 were dominant (contributed ≥1% towards the overall total number invertebrates). In descending order of abundance, the four most dominant taxa were *Heterotrissocladius* (a midge, chironomidae), Nematoda (roundworms), *Pisidium* (a fingernail clam, Sphaeriidae), and *Tanytarsus* (a midge, Chironomidae).

Table 4.14 Mean (sample size given under sampling dates) density and standard deviation (in brackets) of common benthic macroinvertebrates identified at **Station 2**. Taxonomic groups in **boldface** contributed to ≥1% of the total number of invertebrates as a whole and were subjected to statistical analyses.

Taxonomic Group	August 1985 (n=3)	September 1985 (n=4)	August 1990 (n=8)	August 1991 (n=8)
Acarina				
Lebertiidae				
Lebertia sp.	1.67 (1.15)	1.25 (1.26)	0.37 (0.74)	0.00
Diptera				
Chironomidae				
Tanytarsini				
Paratanytarsus sp.	**1.00 (1.00)**	**0.25 (0.50)**	**0.37 (0.74)**	**0.13 (0.35)**
Tanytarsus sp.	**50.3 (29.9)**	**27.2 (18.7)**	**0.75 (0.89)**	**0.38 (1.06)**
Diamesinae				
Protanypus sp.	**1.33 (1.53)**	**0.75 (0.96)**	**1.50 (1.31)**	**0.00**
Monodiamesinae sp.	0.00	0.00	0.00	0.00
Orthocladiinae spp.	1.33 (1.53)	0.00	0.50 (1.41)	0.00
Abiskomyia sp.	0.33 (0.58)	3.25 (3.20)	0.50 (1.41)	0.50 (0.93)
Crictopus sp.	**0.00**	**0.00**	**0.13**	**0.00**
Heterotrissocladius sp.	**44.0 (6.56)**	**18.5 (4.51)**	**3.50 (1.69)**	**3.50 (3.85)**
Paracladius sp.	0.00	0.25 (0.50)	0.00	0.00
Parakiefferiella sp.	**0.00**	**0.25 (0.50)**	**0.37 (0.74)**	**0.00**
Psectrocladius sp.	0.00	0.00	0.00	0.00
Tanypodinae				
Ablabesmyia sp.	**0.00**	**0.00**	**0.00**	**0.00**
Procladius sp.	**2.33 (2.52)**	**3.00 (0.00)**	**0.75 (1.39)**	**0.13 (0.35)**
Thienemannimyia sp.	**0.00**	**0.00**	**0.00**	**0.00**
Mollusca				
Pelecypoda				
Sphaeriidae				
Sphaerium nitidium	0.00	0.00	0.00	0.00
Pisidium sp.	**5.67 (2.31)**	**8.50 (5.92)**	**1.87 (4.12)**	**1.13 (1.73)**
Nematoda	**14.3 (4.62)**	**13.5 (9.40)**	**16.2 (6.88)**	**11.6 (9.38)**
Oligochaeta				
Lumbriculidae	0.33 (0.58)	0.25 (0.05)	0.13 (0.35)	0.00
Tubificidae				
with capilliform chaetae	**0.00**	**0.00**	**0.00**	**0.50 (1.07)**
without capilliform chaetae	0.00	0.00	0.00	0.00
Total Common Taxa	**122.3 (36.5)**	**81.5 (22.2)**	**27.0 (10.7)**	**17.9 (13.6)**
Grand Total of all Species as a whole	**128.0 (36.8)**	**83.0 (25.7)**	**48.8 (18.6)**	**27.9 (23.6)**

Table 4.15 Mean (sample size given under sampling dates) density and standard deviation (in brackets) of common benthic macroinvertebrates identified at **Station 3**. Taxonomic groups in **boldface** contributed to ≥1% of the total number of invertebrates as a whole and were subjected to statistical analyses.

Taxonomic Group	August 1985 (n=3)	September 1985 (n=3)	August 1990 (n=8)	August 1991 (n=8)
Acarina				
Lebertiidae				
Lebertia sp.	0.33 (0.58)	0.67 (1.15)	1.5 (2.39)	0.38 (0.74)
Diptera				
Chironomidae				
Tanytarsini				
Paratanytarsus sp.	**0.00**	**0.00**	**4.87 (5.44)**	**6.00 (5.80)**
Tanytarsus sp.	**3.33 (1.53)**	**16.7 (4.73)**	**3.00 (3.02)**	**16.2 (11.9)**
Diamesinae				
Protanypus sp.	**6.67 (1.53)**	**5.33 (2.31)**	**5.75 (6.78)**	**0.50 (0.76)**
Monodiamesinae sp.	6.67 (1.53)	3.67 (2.52)	4.25 (3.88)	0.25 (0.46)
Orthocladiinae spp.	0.00	0.67 (1.15)	0.50 (1.41)	0.00
Abiskomyia sp.	0.00	0.00	0.00	0.63 (1.77)
Crictopus sp.	**0.00**	**0.00**	**0.62 (1.19)**	**0.25 (0.71)**
Heterotrissocladius sp.	**30.3 (20.6)**	**38.3 (5.69)**	**122 (73.7)**	**4.63 (2.39)**
Paracladius sp.	0.00	0.00	0.00	0.00
Parakiefferiella sp.	**0.00**	**0.67 (1.15)**	**12.8 (11.8)**	**1.13 (1.89)**
Psectrocladius sp.	0.00	0.33 (0.58)	0.62 (1.19)	0.63 (0.92)
Tanypodinae				
Ablabesmyia sp.	**1.67 (0.58)**	**1.33 (1.53)**	**23.2 (24.1)**	**4.13 (4.05)**
Procladius sp.	**1.33 (1.15)**	**2.33 (1.53)**	**7.13 (8.85)**	**4.88 (4.19)**
Thienemannimyia sp.	**0.33 (0.58)**	**0.67 (1.15)**	**0.13 (0.35)**	**2.88 (3.68)**
Mollusca				
Pelecypoda				
Sphaeriidae				
Sphaerium nitidium	2.33 (1.53)	3.00 (3.00)	3.13 (3.27)	1.88 (3.04)
Pisidium sp.	**80.7 (5.51)**	**62.7 (15.6)**	**40.5 (26.4)**	**22.4 (18.1)**
Nematoda	**0.67 (1.33)**	**0.67 (1.15)**	**15.2 (14.3)**	**15.3 (17.4)**
Oligochaeta				
Lumbriculidae	2.67 (1.52)	0.33 (0.58)	0.62 (0.92)	2.13 (1.81)
Tubificidae				
with capilliform chaetae	**18.3 (8.39)**	**8.00 (4.00)**	**4.25 (4.10)**	**16.5 (8.67)**
without capilliform chaetae	0.00	2.33 (1.53)	1.00 (1.19)	0.25 (0.46)
Total Common Taxa	**102 (29.1)**	**144 (20.5)**	**252 (132)**	**96.1 (49.0)**
Grand Total of all Species as a whole	**179 (30.0)**	**158 (21.2)**	**387 (174)**	**188 (74.6)**

Table 4.16 Mean (sample size given under sampling dates) density and standard deviation (in brackets) of common benthic macroinvertebrates identified at **Station 5**. Taxonomic groups in **boldface** contributed to ≥1% of the total number of invertebrates as a whole and were subjected to statistical analyses.

Taxonomic Group	August 1985 (n=3)	September 1985 (n=6)	August 1990 (n=8)	August 1991 (n=8)
Acarina				
Lebertiidae				
Lebertia sp.	1.33 (0.58)	1.33 (1.97)	0.13 (0.35)	0.38 (0.74)
Diptera				
Chironomidae				
Tanytarsini				
Paratanytarsus sp.	**0.00**	**2.83 (2.23)**	**17.9 (15.5)**	**0.00**
Tanytarsus sp.	**11.0 (3.46)**	**14.2 (5.91)**	**3.37 (3.07)**	**0.00**
Diamesinae				
Protanypus sp.	**0.33 (0.58)**	**3.33 (2.94)**	**0.75 (1.03)**	**0.50 (0.93)**
Monodiamesinae sp.	0.00	0.80 (0.84)	0.63 (0.74)	0.88 (0.64)
Orthocladiinae spp.	6.00 (1.73)	0.40 (0.55)	0.38 (0.52)	0.00
Abiskomyia sp.	1.00 (1.00)	3.33 (2.34)	1.00 (2.07)	0.13 (0.35)
Crictopus sp.	**1.00 (1.00)**	**0.00**	**9.75 (7.50)**	**0.75 (2.12)**
Heterotrissocladius sp.	**42.3 (19.9)**	**31.8 (21.1)**	**10.2 (9.69)**	**12.9 (5.96)**
Paracladius sp.	2.33 (2.31)	1.00 (1.26)	0.13 (0.35)	5.38 (4.50)
Parakiefferiella sp.	**0.67 (1.15)**	**1.67 (3.20)**	**0.50 (0.76)**	**4.13 (3.31)**
Psectrocladius sp.	0.33 (0.58)	0.00	0.50 (1.41)	0.13 (0.35)
Tanypodinae				
Ablabesmyia sp.	**0.00**	**0.00**	**1.75**	**0.13 (0.35)**
Procladius sp.	**0.67 (1.15)**	**1.67 (0.98)**	**0.25 (0.71)**	**0.13 (0.35)**
Thienemannimyia sp.	**0.00**	**2.50 (3.39)**	**9.13 (8.04)**	**0.00**
Mollusca				
Pelecypoda				
Sphaeriidae				
Sphaerium nitidium	0.00	0.00	0.00	0.00
Pisidium sp.	**7.67 (4.73)**	**10.2 (4.40)**	**4.37 (4.56)**	**4.50 (2.00)**
Nematoda	**8.67 (11.7)**	**18.5 (22.9)**	**22.4 (22.5)**	**37.8 (14.3)**
Oligochaeta				
Lumbriculidae	0.00	0.00	0.25 (0.46)	0.00
Tubificidae				
with capilliform chaetae	**7.33 (2.89)**	**2.16 (2.40)**	**3.50 (3.50)**	**0.13 (0.35)**
without capilliform chaetae	0.00	0.00	0.13 (0.35)	0.00
Total Common Taxa	**83.0 (29.3)**	**81.5 (28.8)**	**87.8 (72.9)**	**67.8 (16.2)**
Grand Total of all Species as a whole	**94.3 (28.9)**	**102 (39.6)**	**117 (151)**	**117 (27.6)**

Table 4.17 Mean (sample size given under sampling dates) density and standard deviation (in brackets) of common benthic macroinvertebrates identified at **Station 6**. Taxonomic groups in **boldface** contributed to ≥1% of the total number of invertebrates as a whole and were subjected to statistical analyses.

Taxonomic Group	August 1985 (n=3)	September 1985 (n=3)	August 1990 (n=8)	August 1991 (n=8)
Acarina				
Lebertiidae				
Lebertia sp.	1.33 (1.53)	1.67 (1.53)	0.13 (0.35)	0.00
Diptera				
Chironomidae				
Tanytarsini				
Paratanytarsus sp.	**1.67 (2.89)**	**2.33 (3.12)**	**0.00**	**0.00**
Tanytarsus sp.	**12.7 (1.53)**	**20.3 (1.53)**	**0.25 (0.71)**	**0.25 (0.46)**
Diamesinae				
Protanypus sp.	**0.67 (0.58)**	**2.00 (2.64)**	**1.13 (0.99)**	**0.13 (0.35)**
Monodiamesinae sp.	0.67 (0.58)	0.00	0.00	0.25 (0.46
Orthocladiinae spp.	1.33 (0.58)	0.33 (0.58)	0.38 (1.06)	0.13 (0.35)
Abiskomyia sp.	1.00 (1.73)	1.67 (2.08)	0.00	0.00
Crictopus sp.	**0.33 (0.58)**	**1.67 (1.53)**	**0.37 (0.74)**	**0.13 (0.35)**
Heterotrissocladius sp.	**66.7 (13.3)**	**48.3 (17.2)**	**4.0 (2.27)**	**8.88 (8.11)**
Paracladius sp.	0.67 (1.15)	1.67 (2.08)	0.00	0.63 (1.06)
Parakiefferiella sp.	**0.67 (1.15)**	**0.00**	**4.87 (4.01)**	**1.88 (2.23)**
Psectrocladius sp.	0.00	0.00	0.00	0.00
Tanypodinae				
Ablabesmyia sp.	**0.00**	**0.00**	**0.13**	**0.13 (0.35)**
Procladius sp.	**0.33 (0.58)**	**0.33 (0.58)**	**0.25 (0.71)**	**0.13 (0.35)**
Thienemannimyia sp.	**0.00**	**0.33 (0.58)**	**0.00**	**0.25 (0.46)**
Mollusca				
Pelecypoda				
Sphaeriidae				
Sphaerium nitidium	0.00	0.00	0.00	0.00
Pisidium sp.	**14.3 (3.79)**	**38.7 (49.6)**	**4.50 (3.74)**	**2.50 (1.93)**
Nematoda	**9.00 (2.65)**	**4.33 (2.08)**	**18.8 (2.66)**	**22.5 (14.0)**
Oligochaeta				
Lumbriculidae	0.33 (0.58)	0.67 (0.33)	0.00	0.13 (0.35)
Tubificidae				
with capilliform chaetae	**0.00**	**5.00 (8.66)**	**0.00**	**0.00**
without capilliform chaetae	0.00	0.00	0.00	0.00
Total Common Taxa	**103 (17.1)**	**100 (9.81)**	**34.8 (9.27)**	**37.8 (19.2)**
Grand Total of all Species as a whole	**112 (18.2)**	**103 (9.85)**	**66.8 (20.0)**	**54.2 (25.6)**

Table 4.18 Mean (sample size given under sampling dates) density and standard deviation (in brackets) of common benthic macroinvertebrates identified at **Station 7**. Taxonomic groups in **boldface** contributed to ≥1% of the total number of invertebrates as a whole and were subjected to statistical analyses.

Taxonomic Group	August 1985 (n=3)	September 1985 (n=3)	August 1990 (n=8)	August 1991 (n=8)
Acarina				
Lebertiidae				
Lebertia sp.	2.67 (1.53)	2.67 (1.53)	0.87 (1.25)	0.38 (0.74)
Diptera				
Chironomidae				
Tanytarsini				
Paratanytarsus sp.	**4.33 (5.13)**	**7.67 (13.28)**	**0.37 (0.74)**	**0.00**
Tanytarsus sp.	**26.3 (24.3)**	**8.33 (3.21)**	**0.37 (0.52)**	**0.00**
Diamesinae				
Protanypus sp.	**0.67 (0.58)**	**1.33 (1.53)**	**2.00 (1.31)**	**0.75 (0.71)**
Monodiamesinae sp.	0.67 (0.58)	0.33 (0.58)	0.00	0.50 (0.93)
Orthocladiinae spp.	11.0 (2.00)	0.33 (0.58)	3.00 (4.34)	0.00
Abiskomyia sp.	1.33 (2.31)	0.67 (1.15)	0.37 (0.74)	0.13 (0.35)
Crictopus sp.	**6.00 (3.46)**	**1.33 (1.53)**	**0.25 (0.46)**	**0.13 (0.35)**
Heterotrissocladius sp.	**48.3 (6.03)**	**28.3 (8.62)**	**3.00 (2.62)**	**5.63 (5.04)**
Paracladius sp.	3.33 (2.08)	0.33 (0.58)	0.00	0.88 (1.46)
Parakiefferiella sp.	**0.00**	**0.67 (1.15)**	**1.75 (1.39)**	**0.75 (1.39)**
Psectrocladius sp.	4.67 (4.51)	0.00	0.00	0.00
Tanypodinae				
Ablabesmyia sp.	**0.33 (0.58)**	**0.00**	**0.00**	**0.00**
Procladius sp.	**2.00 (1.73)**	**0.67 (0.58)**	**0.25 (0.46)**	**0.00**
Thienemannimyia sp.	**0.00**	**4.67 (4.16)**	**0.12 (0.35)**	**0.25 (0.46)**
Mollusca				
Pelecypoda				
Sphaeriidae				
Sphaerium nitidium	0.00	0.00	0.00	0.00
Pisidium sp.	**11.3 (1.53)**	**11.0 (1.73)**	**2.87 (1.13)**	**0.63 (1.06)**
Nematoda	**10.7 (2.52)**	**9.33 (5.13)**	**30.5 (8.03)**	**18.5 (13.8)**
Oligochaeta				
Lumbriculidae	0.00	1.00 (1.00)	0.13 (0.35)	0.88 (0.35)
Tubificidae				
with capilliform chaetae	**0.00**	**0.33 (0.58)**	**0.00**	**1.75 (1.49)**
without capilliform chaetae	0.00	0.00	0.00	0.00
Total Common Taxa	**123 (22.0)**	**70.7 (13.0)**	**45.9 (11.5)**	**30.2 (18.3)**
Grand Total of all Species as a whole	**127 (19.1)**	**84.0 (14.0)**	**85.2 (20.4)**	**49.6 (26.4)**

The 12 dominant taxa common to all sampling surveys were subjected to statistical analyses (one-factor ANOVA followed by SNK multiple comparisons) to compare densities within each station among the four sampling sessions (Table 4.19). In general, the majority of significant differences observed for densities of dominant benthic macroinvertebrates indicated decreased densities during 1991 compared to the 1990 survey as well as a decrease from August 1985 to September 1985, at all stations except Station 5. At Station 5, densities of dominant