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Zooplankton Community Structure in Lakes Near Mt. St. Helens, WA

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THESIS APPROVAL

The abstract and thesis of Larry Duane Scharnberg for the Master of Science in Biology were presented February 21, 1995, and accepted by the thesis committee and the department.

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Abstract

An abstract of the thesis of Larry Duane Scharnberg for the Master of Science in Biology presented February 21, 1995.

Title: Zooplankton Community Structure in Lakes Near Mt. St. Helens, WA.

Eighteen lakes around Mt. St. Helens (MSH) were sampled for zooplankton from September '92 until September '94. Samples were enumerated and identified to the species level in most cases. Standard deviation and t-tests were performed to determine the precision of enumeration methods and replication of duplicate tows. Palatability indexes based upon predator preferences were developed and coupled with length-frequency analyses as indicators of predation pressure. The weighted means of the summer samples were then subjected to cluster analysis in an attempt to categorize lakes with respect to zooplankton community structure. Lastly, the community compositions and abundances of MSH lakes were compared to those in lakes on Mt. Rainier and Mt. Hood in an attempt to assess recovery of MSH lakes from the 1980 eruption.

Results of analyses indicate the presence of three distinct groups of lakes:

1) A group of lakes with heavy predation resulting in simplified zooplankton communities dominated by *Keratella*, *Kellicottia*, and sometimes cyclopoid

species. Predation in these instances can be attributed to extremely high fish or *Chaoborus* abundance. 2) A second group of lakes characterized by great depth, high transparency, significant abundances of *Diaptomus kenai*, and moderate to light fish predation. These lakes support balanced zooplankton communities with substantial proportions of *Daphnid* and calanoid specimens attaining large size. Significant indications of size-specific niche differentiation among the cladocerans are notably absent from these first two groups. 3) A third group consists of lakes which appear to be more productive than the other two groups. This group has higher biovolumes of zooplankton in general, coexistence of several different sized cladoceran species, the highest diversity indices of all the lakes sampled, and moderate predation as indicated by length-frequency analysis.

Two conclusions are drawn from the data. First, it appears that predation and primary productivity are both significant factors affecting the abundance and composition of MSH zooplankton communities. Additionally, these data document a significant overlap in zooplankton species in lakes near Mt. Rainier and Mt. Hood, suggesting that the zooplankton communities in lakes around MSH have recovered from the effects of the 1980 eruption.

ZOOPLANKTON COMMUNITY STRUCTURE IN
LAKES NEAR MT. ST. HELENS, WA

by
LARRY DUANE SCHARNBERG

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
BIOLOGY

Portland State University
1995

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A. Introduction

Unlike communities composed of long-lived plants or animals, structure in zooplankton communities may change rapidly. Nevertheless, it is becoming clear that dynamic plankton communities must be monitored for many years before anything like a full range of system behaviors can be observed and described (W. T. Edmondson, 1980). This becomes especially important in a system which is in the midst of recovery such as the ecosystems surrounding Mt. St. Helens (MSH).

The lakes in the immediate blast zone of the 1980 eruption of MSH were stripped of most life temporarily¹. Many of the zooplankton probably produced resting eggs after the eruption, when the conditions became unfavorable (Wetzel, 1983). Some of these eggs probably survived to hatch when conditions improved. Other seed stock may have been airlifted in the feathers of ducks and other waterfowl from nearby lakes less heavily impacted. Slowly, with time, the land and the waters have been recovering. Each year has brought a slightly different set of circumstances to which the biota has responded. This thesis is written with the purpose of describing the succession of zooplankton communities in the lakes near MSH.

¹ That is, life as it existed before the eruption. The bacterial component became active soon after the eruption.

Many factors contribute to the dynamics of zooplankton community structure. Two major philosophies have developed: 1) Top-down control of the community by predators (Gliwicz, 1994; Hrbacek et al., 1961; Brooks and Dodson, 1965; Hall et al., 1976; Lazzaro, 1987; Evans, 1992), and 2) Bottom-up control of the community via nutrients and primary productivity (Tessier, 1990; Bradley et al., 1991; Hessen, 1992; McCauley and Kalff, 1981). Many limnologists now accept that both control mechanisms work simultaneously, and a complete analysis of the functioning of a zooplankton community should not exclude one component or the other (Sterner et al., 1992; Elsner and Goerge, 1993; O'Brien et al., 1992).

A potential driving force in community structure is that of interspecific competition. The effects of interspecific competition alone are often quite apparent. Competition may lead to competitive exclusion and a low level of species diversity. Hutchinson (1978) concluded that "Populations dependent on the same resource are not likely to coexist.....unless a certain amount of heterogeneity exists or is introduced." One of the ways heterogeneity may be increased is through predation. Competitive effectiveness and predation together are the basis of the size-efficiency hypothesis (Brooks and Dodson, 1975). They claim that large herbivores have the advantage of feeding efficiency and ability to consume large and small food particles (i.e., a wider array of resources) in

comparison to smaller zooplanktors which can only forage on smaller food particles. In the absence of predation, the community is expected to consist mostly of large-bodied cladocerans and other large, efficient filter feeders. If, on the other hand, a hungry and efficient vertebrate or large invertebrate predator is introduced, this keystone predator may disproportionately select larger zooplankton. This reduces the level of competition so that smaller, less efficient zooplankton may increase through competitive release. The result is an increase in community diversity.

Various measures of community diversity have been proposed. Factors which have been included as measures of diversity include the number of species present (species richness), the functional diversity represented by species within the community, and the proportional distribution of the populations (equitability). Additionally, since many of the lakes at MSH supported few forms of life other than bacteria shortly after the eruption, a diversity index might provide a measure of change since that time. Ideally, measurements of diversity would be compared to pre-eruption data. Unfortunately, few (if any) records exist on the species and abundance of zooplankton prior to the eruption. Therefore, one option available is to provide a general comparison of species overlap on seemingly similar volcanoes such as Mt. Rainier and Mt. Hood

The factors governing the distribution, diversity, and community structure of zooplankton are numerous and often interrelated. Competitive exclusion may be balanced by predation and quite possibly by seasonal fluctuations in weather patterns which shift advantages from one zooplankton to another. Therefore, diversity of environmental conditions (abiotic factors) and moderate predation may be expected to decrease the amount of interspecific competition and competitive exclusion permitting greater species diversity (Black and Hairston, 1988). In contrast, species diversity may decrease due to either very high or very low predation or to abiotic factors such as very high or very low nutrient concentrations. This thesis is an assessment of the interactions of these various factors in the zooplankton communities of MSH lakes.

B. Methods and Materials

1. Experimental design

Eighteen lakes were sampled over a period of 3 years with varying frequencies. Four of the lakes (Blue, June, McBride, and Merrill) were designated as control lakes. These lakes received minor ash fallout in 1980, but the vegetation in their respective watersheds was spared significant damage. In addition, recent data from alpine and subalpine lakes on Mt. Rainier (Larson, et al., 1992) and Mt. Hood (unpublished data courtesy of Allan Vogel) were reviewed for comparative purposes.

Lakes were sampled seasonally (excluding winter) beginning in the fall of 1992 and ending in the summer of 1994. Due to logistical and financial limitations, it was impossible to sample all the lakes within the same season, so summer data comparisons were performed using both 1993 and 1994 data. This did not appear, however, to be a serious impediment due to the general nature of the characterizations sought.

2. Sample collection

Samples were collected by towing a 64 μm (micrometer) mesh net with a 0.36 meter diameter vertically through the water column at approximately 0.5

meter per second. The one exception to this was the fall 1992 sample from Coldwater Lake which was obtained using a 64 μm mesh net with a diameter of 0.5 meter. Due to the oligotrophic nature of most of the lakes sampled, net clogging due to algal growth was not a problem. Filtering efficiency was assumed to be adequate and no explicit corrections were made for losses due to hydrodynamic effects. Replicate tows were gathered during the spring and fall of '93 and during the summer of '94.

Tows were collected over the deepest portions of each lake, with Merrill, Castle, and Coldwater lakes each having a second station. In Grizzly, June, and McBride lakes, tows were integrated from bottom to top due to shallowness (<6 m). In all the remaining lakes, epilimnetic and hypolimnetic samples were obtained using the thermocline as the effective division. Once secured, samples were placed in 250 ml Nalgene bottles and preserved with a 37% formalin solution to a final dilution of approximately 5% sample.²

3. Sample enumeration

Samples were filtered onto a 35 μm mesh screen, rinsed with tapwater, and placed in either a 50 ml or 250 ml graduated Erlenmeyer flask for dilution.

² Amount of formalin solution was increased in those samples with higher amounts of organic matter.

Dilutions were determined by abundance with the minimum number of individuals counted being 400 total organisms and 100 of the most abundant species for both the Crustacea and Rotifera. This provides a maximum statistical standard error of the mean of 5 and 10 percent respectively (Edmondson and Winberg, 1971). The only times these guidelines were not met was when entire undiluted samples were counted.

Rotifer and nauplii counts were obtained by subsampling 1 ml aliquots from the Erlenmeyer flask after thorough mixing and placing them in a Sedgwick-Rafter counting chamber. The counting was performed with a Nikon Alphaphot-2 compound microscope using 40x. Species identification was performed by the same Nikon scope under 400x.

Macrozooplankton were subsampled using a 5 ml adjustable pipette with the end enlarged to prevent damage to the larger individuals. Subsamples were placed in an acrylic counting tray and counted using a Bausch and Lomb dissecting microscope at approximately 11x. Initial identification of these species was also performed using the compound Nikon microscope at 400x.

Taxonomic references were Freshwater Invertebrates of the United States, second edition (Pennak, 1978) and Fresh Water Biology, second edition (Ward and Whipple, 1959). Additional advice and information was provided by Allan Vogel both orally and through the use his previous records of the zooplankton in

MSH's lakes. Results of the enumeration process are presented in Appendix A. Abundance and biovolumetric estimates (Wetzel and Likens, 1979) are graphically presented in figs. C1a-C1r.

4. Quality assurance

Twelve samples of zooplankton used in this project from various lakes were also counted by Dr. Allan Vogel. A comparison of results is presented in Appendix B along with the respective standard errors (Edmondson and Winberg, 1971).

5. Statistical analysis of the zooplankton counts

Several statistical procedures were applied to the data in an effort to validate methodologies and to determine similarities and differences among the lakes. Means and standard deviations were determined for the three replicate subsamples generated from each sample as a check on subsampling precision. On a few occasions (<5), a subsample count appeared that was numerically very different from the other two. In such instances, a fourth subsample was enumerated. The fourth subsample was always found to replicate two of the others and was substituted as the correct count. Since manual mixing of the sample was employed, it was reasoned that on these rare occasions the larger

zooplanktors had “settled” out before subsampling occurred. Results of subsampling variability can be found in Appendix C.

A paired *t*-test using Systat (1992) was performed on all replicate sample totals, i.e., total copepods, total cladocerans, totals rotifers, and total zooplankton. The statistic used was the standard error of the mean difference. With this test, a $P < 0.05$ would provide grounds to reject the hypothesis that the mean of sample 1 was equal to the mean of sample 2.³ Results can be found in table C4.

A palatability index was formulated using biovolume estimates from Wetzel and Likens (1979) and predator-prey preferences.⁴ This was accomplished by multiplying the number of specimens estimated per cubic meter by their estimated biovolumes. Since a range was reported for some of the genera, a specific value was chosen based on the general size of the specimens viewed. The combined biovolumes of those considered to have a low palatability (chiefly *Holopedium*, loricated rotifers, and cyclopoids) was then divided by the

³ A direct comparison of all species from tow 1 to tow 2 was not possible since the samples are not statistically independent (PSU statistical consulting lab, 1/20/95).

⁴ Predator preferences of *Chaoborus* and planktivorous fish were of main concern. Other predators may be present, but their influence is currently unknown. Citations of preferences are included in the section titled “Ecology of the Players”.

total biovolume. This number was subtracted from 1.00 and multiplied by 100 to yield a % of palatable species by biovolume. This index provided further evidence of the effects of predation. A low index, indicative of heavy predation, was the result of a proportionately high biovolume of less palatable species. These results are presented in table C5 and fig. C5.

A diversity index was generated using Hill's formula (Ludwig and Reynolds, 1988). The number generated from weighted seasonal means is an expression of the "effective number of abundant species" in the sample. It is generated from Shannon's index and provides an intermediate emphasis on rare species. This index can help to effectively categorize the heterogeneity of a community. These data are presented in table C6 and fig. C6.

Another measurement which is useful in estimating predation is the length frequency analysis (Edmondson and Winberg, 1971). Length measurements of *Daphnids* and calanoid copepods were determined for at least the first 30 specimens in a chosen sample and a frequency bar graph was generated. If more individuals clustered in the upper end (>1.5 mm), predation was considered light. If the large majority of specimens were <1.0 mm, predation was considered heavy. Results of this analysis are presented in figs. C7a-C7m.

Lastly, a cluster analysis was performed using Systat (1992) in an attempt to find any patterns among the zooplankton communities of the various lakes.

Both the “join” and “K-means” options were performed, with only the “join” option providing successful results. The “join” command produces hierarchical clusters of lakes that are displayed in a tree. All distance options and linkage options were performed in various combinations with varying degrees of success. The most useful interpretations are presented in Appendix E.

C. Results

1. Abundance and Biovolume Estimates

Graphs of the abundances and biovolumes of copepods, cladocerans and rotifers are presented in figs. C1a-C1r. A listing of dominant and subdominant zooplankton is included for each lake to enhance interpretation.

2. Results of the Analysis of Subsample Variation

A mean and coefficient of variation were determined for each of the three subsamples counted from each zooplankton tow. Results indicate that the subsampling technique demonstrated little variability in the total number of animals counted between subsamples. Of the 137 samples subsampled in triplicate, 103 displayed a coefficient of variation of the total count within 5% of the mean, 29 replicated within 10% of the mean, and 3 displayed variation greater than 10% of the mean. This analysis demonstrates that the subsampling technique provided consistent results.

Fig. C1a Dominant *Diaptomus*
Subdominant *Kellicottia*

Fig. C1b Dominant Subdominant *Holopedium* *Keratella*

Castle Lake Abundances

Castle Lake Biovolumes

Fig. C1c Dominant

Bosmina *Daphnia*

Coldwater L. Abundances

Coldwater L. Biovolumes

Fig. C1d Dominant *Daphnia* *Diaptomus*
 Subdominant *Bosmina*

Fawn Lake Abundances

Fawn Lake Biovolumes

Fig. C1e Dominant Subdominant *Asplanchna* *Daphnia*
Diaptomus

Grizzly Lake Abundances

Grizzly Lake Biovolumes

Fig. C1f Dominant Subdominant *Daphnia* *Keratella*

Hanaford Lake Abundances

Hanaford Lake Biovolumes

Fig. C1g Dominant
Subdominant

Fig. C1h Dominant Subdominant *Chydorus* Chironomid larvae

McBride Lake Abundances

McBride Lake Biovolumes

Fig. C1i Dominant *Daphnia* *Diaptomus* *Ceriodaphnia*
 Subdominant

Merrill Lake Abundances

Merrill Lake Biovolumes

Fig. C1j Dominant *Holopedium* *Daphnia* *Asplanchna*
 Subdominant *Ceriodaphnia* *Diaptomus*

Fig. C1k Dominant *Daphnia* *Diaptomus*
 Subdominant *Ceriodaphnia* *Holopedium* *Diaphanosoma*

Obscurity Lake Abundances

Obscurity Lake Biovolumes

Fig. C1L Dominant
Subdominant

Kellicottia

Panhandle L. Abundances

Panhandle Lake Biovolumes

Fig. C1m Dominant
Subdominant

Holopedium *Cyclops* *Kellicottia*

Ryan Lake Abundances

Ryan Lake Biovolumes

Fig. C1n Dominant Subdominant *Diaptomus* *Daphnia*

Fig. C10 Dominant *Cyclops*
 Subdominant

Fig. C1p Dominant Subdominant *Keratella*

St. Helens L. Abundances

St. Helens L. Biovolumes

Fig. C1q Dominant *Diaptomus*
 Subdominant *Daphnia* *Holopedium*

Venus Lake Biovolumes

Venus Lake Abundances

Fig. C1r Dominant *Holopedium*
Subdominant *Diaptomus* *Keratella*

3. Quality Assurance Verification

Twelve of the zooplankton samples enumerated for this thesis were also analyzed by Allan Vogel. There was close agreement on the majority of Crustacea, Ostracoda, and Diptera abundances. There was one instance of significant disagreement on crustacean abundance in Boot Lake. A second source of disagreement centered upon rotifer enumeration where the numbers which I generated were consistently higher. Although the precise cause for this disagreement has not been identified, we used two different techniques for counting rotifers, and this is probably the cause of the difference. This exercise also showed that the species *Cyclops varicans rubellus* probably exhibits broader distribution and greater abundances than estimated (further discussion in “Ecology of Players”). One last instance of disagreement lies with the identification of a population of *Daphnia schodleri* in Hanaford Lake by Dr. Vogel. In this thesis, the cladoceran in question is identified and enumerated as a morph of *Daphnia pulex*.

In summary, quality assurance comparisons indicate that species identifications and counts are reliable. For the majority of species identification,

there was agreement.⁵ Therefore, it can also be assumed that the data presented are an accurate representation of the pelagic zooplankton communities of the lakes sampled.

4. Paired *t*-test Results

The paired *t*-test results indicate that replicate tows exhibited a high degree of similarity to each other. The test was performed on 71 cases which made the degrees of freedom *n*=70. The results were as follows:

<u>Group</u>	<u>Mean Difference</u>	<u>SD Difference</u>	<u>T-score</u>	<u>Probability</u>
Copepod 1/Copepod 2	1659	13862	1.008	0.317
Cladoceran 1/Cladoceran 2	-156	2446	-0.538	0.592
Rotifer 1/Rotifer 2	3908	48856	0.674	0.502
Total zoo 1/Total zoo 2	3833	48794	0.662	0.510

The questions answered by this test were these: 1). Overall, did the replicate tows perform adequately as replicates? 2). Were enough samples obtained to adequately define a general limnetic zooplankton community structure? According to the *t*-test the answer is “yes”. To be rejected, the

⁵ Credit needs to be given here to Dr. Vogel for species verification of the genuses *Polyarthra*, *Asplanchna*, *Trichocerca*, *Filinia*, and *Conochilus*.

probability value would have to fall below 0.05, and in none of the cases did this occur. Although the samples passed this test, there were sometimes substantial differences in abundance between specific replicate pairs. This was a reflection of the true horizontal heterogeneity which exists in a fresh water lake with respect to the biota. Sampling, however, was sufficient to define a general community structure.

5. Results of Palatability Index

Table C5 presents the proportions of zooplankton biomass considered palatable during all of the sampling periods. Summer palatability figures are graphically presented in fig. C5. The lakes have been arranged in order (left to right) to exhibit the least proportion of palatable species moving toward the largest proportion of palatable species. A lower palatability index is suggestive of heavier predation.

6. Results of Diversity Analysis

Hill's N_2 diversity index estimates (Ludwig and Reynolds, 1988) are presented in table C6. The number is derived from Shannon's index and represents the number of abundant species which would be expected using the

corresponding zooplankton abundances reported for each lake during each sampling period. Additionally, a diversity index was calculated using the summer biovolume estimates of each zooplankton species (except *Chaoborus*). The summer diversity estimates using abundances and biovolumes are graphically compared in fig. C6.

7. Length-frequency analysis

Daphnid and *Diaptomus* length-frequency data are presented in figs. C7a-C7m. The graphs are arranged starting with the lakes exhibiting the largest proportions of large *Daphnid* and *Diaptomus* specimens to those exhibiting the smallest. Caution is suggested when interpreting these graphs for the following reasons: 1) Data was not available on each lake to determine whether spring or fall spawning occurs. Therefore, the timing of juvenile fish predation is unknown in those lakes containing fish. 2). Some samples contained very few *Daphnid* representatives. The chances of a sample providing non-representative length-frequency data on the population are consequently increased.

PERCENTAGES OF PALATABLE ZOOPLANKTORS

Lake	Fall '92	Spr. '93	Sum '93	Fall '93	Sum '94	Comb
Blue			76.7			76.7
Boot	5.8		5.7		1.6	4.4
Castle			96.3	91.8		94.1
Coldwater	81.9	92.8	96.1	93.0		91
Fawn	56.6	2.2	5.1	30.1		23.8
Grizzley					58.4	58.4
Hanaford	4.0	30.0	63.0	1.1		24.5
June		9.8	81.6	95.8		62.4
McBride		7.1	99.7	97.8		68.2
Merrill		86.1	49.0	51.6		62.2
Meta		56.6	97.3	73.2		75.7
Obscurity					0.0	0
Panhandle		0.8	2.0		2	1.3
Ryan		99.1	100.0	99.8		99.6
Shovel					0.0	0
Snow					8.8	8.8
St. Helens	82.9		74.9		88.3	82
Venus	23.9		11.4		11.3	15.5

Table C5

*All figures exclude Chaoborus spp.

Fig. C5

Lake	Div.Index Abund. Fall '92	Div.Index Abund. Sp '93	Div.Index Abund. Su '93	Div.Index Biovolume Su '93 or '94	Div.Index Abund. Fa '93	Div.Index Abund. Su '94
Blue			2.14	2.16		
Boot	3.23		2.63	2.78		1.22
Castle			1.63	1.8	5.38	
Coldwater	6.09	2.77	5.01	3.02	8.78	
Fawn	2.03	2.27	2.10	1.19	4.82	
Grizzley				2.62		2.32
Hanaford	3.37	2.35	2.45	1.34	3.69	
June		2.40	5.82	3.04	2.38	
McBride		2.07	3.85	4.92	5.13	
Merrill		1.90	4.97	2.98	4.89	
Meta		3.80	4.22	2.23	4.88	
Obscurity				5.39		2.07
Panhandle	4.33		2.45	4.17		1.65
Ryan		2.14	2.07	1.9	2.66	
Shovel				3.29		2.80
Snow				1.93		1.11
St. Helens	2.14		3.83	1.03		4.41
Venus	1.61		5.57	2.1		1.64
AVG	3.26	2.46	3.33	2.66	4.73	1.80

Table C6 Diversity indices for specified sampling dates.

Fig. C6 Comparison of summer diversity indices using biovolume and abundance data

Fig. C7a St. Helens Lake length-frequency analysis.

Fig. C7b Coldwater Lake length-frequency analysis.

Fig. C7c Venus Lake length-frequency analysis.

Fig. C7d Castle Lake length-frequency analysis.

Fig. C7e Blue Lake length-frequency analysis.

Fig. C7f Hanaford Lake length-frequency analysis.

Fig. C7f cont'd.

Fig. C7g Fawn Lake length-frequency analysis.

Fig. C7h Meta Lake length-frequency analysis.

Fig. C7i Merrill Lake length-frequency analysis.

Fig. C7j Ryan Lake length-frequency analysis.

Fig. C7k McBride Lake length-frequency analysis.

Fig. C7L Snow Lake length-frequency analysis.

Fig. C7m Grizzly Lake length-frequency analysis.

Note: Not enough specimens were present to perform length-frequency analysis on Boot, Obscurity, Panhandle, June, or Shovel lakes.

D. Discussion of Results

1. Ecology of the Players

A key ingredient in understanding zooplankton community structure is how each species functions within that community. The following is an outline of the species’ size, preferred habitat, and role in the food chain. The size/class categories devised by W. Gary Sprules (1980) were adapted for analyzing size/frequency characteristics of the populations. Both the herbivorous and carnivorous zooplankton categories are divided into 5 size classes as follows:

Size	Size(mm)	
Class	Herbivore	Carnivore
1	<0.3	<0.5
2	0.3-0.49	0.5-0.89
3	0.5-0.84	0.9-1.19
4	0.85-1.19	1.2-1.49
5	>1.2	>1.5

Table E1-1 Sprules’ (1980) size/class categories.

This classification system can be helpful in determining if niche partitioning is occurring. Herbivore populations are dispersed in several

herbivore size categories as long as the largest competitors (such as *Daphnia*) are held in check by fish or invertebrate predators (Brooks and Dodson, 1965).

Sprules' size-class categories and the diversity index distinguish between communities in which many species share resources and communities in which resources are monopolized by one or two species.

The lengths, habitat preferences, and food preferences were obtained from work by Ward and Whipple (1959). Volume estimates were modified from Wetzel and Likens (1991). Since geographic variation within a species is the rule rather than the exception, all lengths and biovolumes used are approximations of adult sizes.

I) Rotifera

Rotifers are substantial contributors to the zooplankton community in many of the lakes at MSH. All species identified with the exception of *Asplanchna* are considered herbivorous and, unless stated otherwise, the diets of these rotifers consist of algae, flagellates, and bacteria. With some rotifers, periphyton and scavenging may also provide nourishment. Many of the mechanisms used to avoid predation are exemplified among the rotifers reported at MSH. These include coloniality, mucus sheaths, spinous processes, hardened

loricas, small body size, transparency, active flight, and other behavioral responses (Stemberger and Gilbert, 1987). Table E1-2 provides a summary of rotifer length, size/class category, and volume factors.

Rotifer species	Length (μm)	Size/class category	Biovolume factors ($\mu\text{m}^3/\text{m}^3$)
<i>Asplanchna priodonta</i>			
<i>Asplanchna herricki</i>	100-500	carnivore 2	7×10^7
<i>Brachionus calyciflorus</i>	N.A.	herbivore 1	6×10^5
<i>Collotheca</i> sp.	N.A.	herbivore 1	5×10^5
<i>Conochilus unicornis</i>			
<i>Conochilus</i> sp. 2	1000 (± 500)	herbivore 1	5×10^5
<i>Epiphanes</i> sp.	500	herbivore 1	5×10^5
<i>Filinia longiseta</i>			
<i>Filinia terminalis</i>	up to 175	herbivore 1	1×10^5
<i>Euchlanis dilatata</i>	up to 500	herbivore 1	6×10^5
<i>Gastropus minor</i>	90-370	herbivore 1	5×10^5
<i>Harringia</i> sp.	N.A.	herbivore 1	5×10^5
<i>Kellicottia bostoniensis</i>			
<i>Kellicottia longispina</i>	up to 1000	herbivore 1	6×10^5
<i>Keratella quadrata</i>			
<i>Keratella cochlearis</i>	170-270	herbivore 1	1×10^5
<i>Lecane</i> sp.	up to 300	herbivore 1	1×10^5
<i>Lepadella</i> sp.	100-200	herbivore 1	1×10^5
<i>Monostyla lunaris</i>	up to 300	herbivore 1	2×10^5
<i>Polyarthra vulgaris</i>			
<i>Polyarthra dolichoptera</i>	N.A.	herbivore 1	5×10^5
<i>Synchaeta</i> sp.	200-600	herbivore 1	1×10^6
<i>Trichocerca rattus</i>	100-500	herbivore 1	5×10^5

Table E1-2 Summary of rotifer length, size/class, and biovolume factors.

1). *Asplanchna priodonta* and *Asplanchna herricki*

Asplanchna are a group of large, limnetic, omnivorous rotifers with widespread distribution. They are transparent and are not known to be a staple food for any other predator, although trophi of *Asplanchna* have been recovered from gut contents of some fish species (Gilbert, 1980). They prey primarily upon small rotifers, flagellates, and possibly upon bacteria. Some of the rotifer prey include *Polyarthra*, *Trichocerca*, *Synchaeta*, *Filinia*, *Brachionus*, and *Keratella* (even though ingestion of this species may be difficult). *Asplanchna* populations are robust in the lakes displaying increased zooplankton diversity, such as Merrill, Coldwater, Castle, Fawn, and Hanaford lakes. This increased diversity appears to be related to increased productivity. Therefore, it can be reasoned that *Asplanchna* play an important predatory role in the more productive lakes around MSH.

2). *Brachionus calyciflorus*

Brachionus calyciflorus is a highly variable loricate rotifer which expresses cyclomorphosis. Spine numbers and length vary from lake to lake and between seasons. They are mostly littoral in the lakes at MSH with occasional foraging in the limnetic areas. *B. calyciflorus* never appeared in enough abundance in the zooplankton tows to be considered a major limnetic player.

3). *Collotheca* sp.

Collotheca are small rotifers which can be either solitary or colonial.

They are soft-bodied, but provide protection for themselves by secreting a mucus sheath (Stemberger and Gilbert, 1987). The mucus sheath makes handling these and similar rotifers difficult, but not impossible. Therefore, the rate of predation is effectively slowed, but not stopped. This rotifer was moderately abundant in Boot Lake.

4). *Conochilus unicornis* and *Conochilus* sp. 2

Conochilus has attributes similar to *Collotheca*, but typically has fewer members in the colony. *Conochilus* was present in 7 of 18 lakes. Although it was never a dominant rotifer in the lakes of MSH, the mucus sheath appears to provide adequate protection for the rotifer and its eggs against predation by copepods, *Asplanchna*, and early instars of *Chaoborus* (Moore Rodenhouse, 1986). Additionally, mucus sheaths may reduce a species' specific gravity. Therefore, the sheath may save a substantial amount of the energy required to maintain position in the water column (Stemberger and Gilbert, 1987). In contrast to MSH lakes, *Conochilus* was the most abundant rotifer in the lakes sampled on Mt. Rainier.

5). *Epiphanes* sp.

Epiphanes represent a group of two-toed littoral rotifers. They are probably underrepresented in samples from MSH since only limnetic sampling occurred. These animals seldom appear in the plankton, usually creeping along the substrate or macrophytes consuming periphyton, algae, and detritus.

6). *Filinia longiseta* and *Filinia terminalis*

Filinia are a group of soft-bodied, limnetic rotifers which use their 3 long setae as a means of active escape from predators (Stemberger and Gilbert, 1987). They were found in 9 of 18 lakes, but only in the spring '93 sample from Fawn Lake were they captured in large numbers. *Filinia* is a common but not typically abundant species at MSH. No pattern of seasonality or trophic preference could be determined from their abundances.

7). *Euchlanis dilatata*

Euchlanis dilatata is a two-toed loricate rotifer, more commonly found in the littoral habitats. As might be expected, the sampling techniques did not produce many, and their contribution to the plankton was minor.

8). *Gastropus minor*

Gastropus minor can be either limnetic or littoral in habitat preference. It has an unusually etched lorica, and was found in small abundances in June Lake. This is probably a rare species around MSH.

9). *Harringia* sp.

Harringia sp. is an uncommon littoral rotifer with characteristics similar to the *Epiphanes* sp. discussed earlier. This species was only recorded from Coldwater Lake.

10). *Kellicottia bostoniensis* and *Kellicottia longispina*

Kellicottia bostoniensis and *longispina* represent one of the major rotifer genera present on MSH, being noted in 15 of the 18 lakes sampled. These two species appeared in greatest abundance in midsummer in lakes exhibiting moderate to intense fish predation. Their success can be partially attributed to their heavily spined loricas. Stemberger and Gilbert (1987) reported that greater spination, together with a relatively large body size are effective deterrents against *Asplanchna*. A rigid lorica must be added to these features for them to be effective against predatory copepods.

11). *Keratella quadrata* and *Keratella cochlearis*

Keratella was present in every sample counted from MSH, living up to its reputation as being one of the most common planktonic rotifers in the world. The spiny, hard lorica and small size make this animal a difficult meal. Abundances >100,00 per cubic meter were not uncommon in MSH lakes, notably in the lakes experiencing what appears to be heavy predation. *Keratella* is an important food source for *Asplanchna* and cyclopoid copepodites, but a high

fecundity rate and a high rate of rejection after capture combine to overcome significant predation pressures on the *Keratella* populations. In lakes where *Keratella* and *Kellicottia* are not numerically significant contributors to the zooplankton community, it is possible that the cladocerans are out-competing them for food resources or physically damaging them during filtering (Conde-Porcuna, et al., 1994; Wickam and Gilbert, 1991).

12). *Lecane* sp.

Lecane is a common loricate rotifer which prefers a littoral environment. It appeared in 9 of 18 limnetic tows. *Lecane* may be a significant contributor to the littoral communities of MSH lakes.

13). *Lepadella* sp.

This littoral, loricate rotifer was found only in small numbers in Coldwater Lake. This species does not appear to be a major influence in the limnetic zooplankton community.

14). *Monostyla lunaris*

Monostyla lunaris is a littoral, loricate rotifer identified by the shape of its lorica and fused toes. It was found in both Meta and McBride lakes in small quantities. It is not considered a major limnetic contributor.

15). *Polyarthra* sp.

Three of the ten recognized species of *Polyarthra* exist in the lakes at MSH. This genus is soft-bodied and has feathery appendages which can be used for active escape from predators such as *Chaoborus*, *Cyclops*, and *Asplanchna*. It is probable that *Polyarthra* abundance was underestimated. Remnants of feathers occurred in the samples on occasion, and the fact was later learned that formalin in excess strength will dissolve the soft tissues of this rotifer. No estimation of loss is presented here. *Polyarthra* sometimes reaches an abundance in the hundreds of thousands as noted in the data from Mt. Rainier. This may also occur at MSH though abundances of that magnitude were not recorded.

16). *Synchaeta* sp.

This soft-bodied planktonic rotifer was only found in Coldwater and Meta lakes in low abundance. Stemberger and Gilbert (1987) describe this genus as playing “deadman” and using small size to avoid predation. The small size of the specimens obtained in Coldwater and Meta Lake support this hypothesis. *Synchaeta* seem to be ideal prey for cyclopoids, *Asplanchna*, and early *Chaoborus* instars.

17). *Trichocerca* sp.

Trichocerca is a loricate rotifer with one long spine on the posterior end and several short spines on the anterior end used to deter predators such as

cyclopoids, *Asplanchna*, and *Chaoborus*. *Trichocerca* appeared in very high abundance in Meta lake in the summer. Similar blooms have been reported for lakes elsewhere (Hutchinson, 1967). Additionally, it was noted as having both littoral and planktonic capabilities. Modest abundances were exhibited in 6 of 18 lakes at MSH.

II). Copepoda

The Order Copepoda is divided into 3 suborders termed Calanoida, Cyclopoida, and Harpacticoda. The habitat of these animals varies between suborders, and may vary even within the species due to resource location within each lake. The calanoids are considered limnetic animals (Pennak, 1978) while the harpacticoids creep along the substrate. The cyclopoid populations at MSH displayed characteristics of being limnetic and benthic/littoral depending upon which lake was sampled. It appears that cyclopoids use both the limnetic and benthic habitats for food and protection depending upon niche availability, i.e. they display niche plasticity at MSH.

As a generalized rule, calanoid copepods are considered palatable and make good fish food when large enough to be seen. They are typically herbivorous with some evidence of selectivity in the size and kind of algae ingested. The larger calanoid species are considered predatory, but only

Diaptomus shoshone and possibly large adult *Diaptomus kenai* could fulfill this role at MSH.

Copepod species	Length(mm)	Size/class category	Biovolume factor (μm ³ /m ³)
			5*10e7 adults
<i>Diaptomus franciscanus</i>	1.2-2.0 female	herbivore 5	5*10e6 copepodids
	1.1-2.0 male		5*10e5 nauplii
	1.25-1.5 female		
<i>Diaptomus oregonensis</i>	1.25-1.4 male	herbivore 5	5*10e7 adults
			8*10e7 adults
<i>Diaptomus shoshone</i>	3.1-4.0 female	carnivore 4	5*10e6 copepodids
	2.59-3.3 male		1*10e5 nauplii
			5*10e7 adults
<i>Diaptomus tyrelli</i>	1.2-1.9 female	herbivore 5	5*10e6 copepodids
	1.1-1.8 male		5*10e5 nauplii
			6*10e7 adult
<i>Diaptomus kenai</i>	2.0-3.0 female	herbivore 5	5*10e6 copepodids
	1.8-2.5 male		5*10e5 nauplii
			4*10e7 adults
<i>Cyclops vernalis</i>	0.99-1.8 female	carnivore 3	5*10e6 copepodids
	0.8-1.5 male		5*10e5 nauplii
			3*10e7 adults
<i>Cyclops varicans rubellus</i>	0.51-0.96 female	carnivore 2	4*10e6 copepodids
	0.50 male		5*10e5 nauplii
			4*10e7 adults
<i>Eucyclops agilis</i>	0.80-1.5 female	carnivore 3	5*10e6 copepodids
	0.68-0.80 male		5*10e5 nauplii
			3*10e7 adults
<i>Orthocyclops modestus</i>	0.80-1.25 female	carnivore 2	4*10e6 copepodids
	0.75-0.90 male		5*10e5 nauplii

Table E1-3 Summary of copepod lengths, size/class categories, and biovolume factors.

Adult cyclopoids are not known to be a consistent staple for either fish or *Chaoborus*. However, no documentation was found concerning their role in an environment of extreme predation as may exist in several of the lakes at MSH. Typically, their populations are kept in check largely through cannibalism, primarily on the naupliar stages. Additional food sources consist of unicellular plants and animals, small metazoans, organic debris, and especially other crustaceans.

Typically, each lake sampled displayed one dominant calanoid species and one dominant cyclopoid species. Coexisting species of the same suborder occurred, but were the exception rather than the rule. A summarization of copepod species lengths, size/class categories, and biovolume factors is listed in table E1-3.

1). *Diaptomus franciscanus*

This calanoid copepod represents a mid-size range of copepods. Its presence was noted in at least 9 of 18 lakes, the most common calanoid copepod on MSH.

2). *Diaptomus oregonensis*

Diaptomus oregonensis is also a medium-sized calanoid copepod. Only 1 individual was found in all the samples counted. Therefore, this species can be considered uncommon in the MSH ecological system.

3). *Diaptomus shoshone*

Diaptomus shoshone was only found in Hanaford Lake samples coexisting with *Diaptomus franciscanus*. *D. shoshone* is one of the largest freshwater calanoids. According to Sprules (1980) it can switch from herbivory to carnivory, although in practice this copepod is probably omnivorous.

4). *Diaptomus tyrelli*

Diaptomus tyrelli is another mid-size representative and was found as the dominant *Diaptomid* in Coldwater and Meta Lakes. Coincidentally, those two lakes also represented two of the most diverse lakes sampled in this study.

5). *Diaptomus kenai*

This calanoid copepod represents the size class in between *D. franciscanus/tyrelli* and *D. shoshone*. It was the dominant calanoid population in Venus, St. Helens, and Blue lakes. These three lakes are the deepest and most transparent lakes included in this survey.

6). *Cyclops vernalis*

Cyclops vernalis represents the most common cyclopoid in the MSH lake system. Representatives were identified in 9 of the 18 lakes. Their dominance in several of the lakes is probably a result of extreme fish or *Chaoborus* predation on the more palatable species.

7). *Cyclops varicans rubellus*

The abundance of this cyclopoid was underestimated in the MSH samples. An adult of this species can have 11 or 12 segments in its swimming antennae and are approximately 0.8 mm in length. Both of these characteristics also apply to later copepodid stages of *C. vernalis*. After abundance comparisons with Dr. Vogel were complete, it was evident that some of these individuals in my counting process were missed. Therefore, the conclusion may be drawn that even though the counting practices were performed carefully, some adult specimens of *C. varicans rubellus* were probably confused with copepodid stages of *C. vernalis*. Since *C. varicans rubellus* still appeared as a relatively rare species in Dr. Vogel's counts, the assumption is made that this mistake did not have any significant impacts on diversity indexes or the overall conclusions drawn from abundance data.

8). *Eucyclops agilis*

Eucyclops agilis occurred in two lakes, and as with the other cyclopoid species, littoral sampling would probably provide evidence of a much broader distribution. This copepod is medium-sized, and is probably the most common littoral cyclopoid in North America.

9). *Orthocyclops modestus*

The distinguishing characteristic of this species was a swimming antennae with 16 segments. One adult specimen was identified in the Castle Lake sample and three specimens from a Fawn Lake sample. As with the other littoral inhabitants, its distribution and abundance is presumably greater than the species' list indicates.

III) **Cladocera**

The Order Cladocera in many lake ecosystems form a direct link from the algae (primary producer) to fish (secondary consumer). Since fish are a popular commodity, one of the preferred fish foods (cladocerans) has also received much attention. Pennak (1978) noted that various studies of the stomach contents of young fish show from 1 to 95 percent Cladocera by volume, and very few studies show less than 10 percent. Therefore, the importance of Cladocera in maintaining a self-propagating fish population should not be underestimated.

The larger cladocerans are noted for their ability to filter large quantities of water using their modified antennae. Algae, protozoans, bacteria, and organic detritus are common in the diets of cladocerans. Cladocerans are also noted for their importance in nutrient recycling. Lehman (1980) reported that the crustaceans cumulatively supplied 10 times more phosphorus and 3 times more nitrogen to the surface-mixed layer of Lake Washington during the summer

months than enters from all external sources combined. Additionally, the larger species have been implicated as playing a significant role in inhibiting rotifer populations through interference competition (Conde-Porcuna et al., 1994; Wickham and Gilbert, 1991).

Cladoceran species	Female length (mm)	Size/class category	Biovolume factor ($\mu\text{m}^3/\text{m}^3$)
<i>Alona costata</i>	0.4	herbivore 2	4×10^7
<i>Alona quadrangularis</i>	0.9	herbivore 3	5×10^7
<i>Alona guttata</i>	0.4	herbivore 2	4×10^7
<i>Alonella nana</i>	0.2-0.28	herbivore 1	3×10^7
<i>Bosmina longirostris</i>	0.4-0.6	herbivore 2 or 3	
<i>Eubosmina hagdmani</i>	0.4-0.6	herbivore 2 or 3	5×10^7
<i>Ceriodaphnia lacustris</i>	0.8-0.9	herbivore 3 or 4	7×10^7
<i>Ceriodaphnia quadrangularis</i>	up to 1.0	herbivore 3 or 4	7×10^7
<i>Ceriodaphnia reticulata</i>	0.6-1.4	herbivore 3 or 4	7×10^7
<i>Chydorus sphaericus</i>	0.3-0.5	herbivore 2	3×10^7
<i>Chydorus bicornutus</i>	up to 0.7	herbivore 2	4×10^7
<i>Daphia pulex</i>	1.3-2.2	herbivore 5	1×10^8
<i>Daphnia rosea</i>	up to 3.0	herbivore 5	1×10^8
<i>Diaphanosoma brachyurum</i>	0.8-0.9	herbivore 4	7×10^7
<i>Holopedium gibberum</i>	1.5-2.2	herbivore 5	2×10^8
<i>Pleuroxus denticulatus</i>	0.5-0.6	herbivore 2 or 3	1×10^7
<i>Polyphemus pediculus</i>	up to 1.5	carnivore 4	9×10^7
<i>Scapholeberis kingi</i>	0.8-1.0	herbivore 4	8×10^7
<i>Sida crystallina</i>	3.0-4.0	herbivore 5	3×10^8
<i>Simocephalus aurita</i>	up to 1.4	herbivore 4	9×10^7

Table E1-4. Summary of cladoceran lengths, size/class categories, and biovolume factors.

1). *Alona costata*, *Alona quadrangularis*, *Alona guttata*

The *Alona* species were identified in 6 of the 18 lakes at MSH. The genus is considered to be littoral and most of the species are quite small. They were captured in small abundances, and their contribution to the limnetic community is probably minute.

2). *Alonella nana*

This species' occurrence among the zooplankton at MSH would be considered rare. Only a trace population was found in the spring sample from Coldwater Lake. Because of their rarity of occurrence and small size, *Alonella nana* would not be considered a significant player in this zooplankton community.

3). *Bosmina longirostris* and *Eubosmina hagmanni*.

These two function as "sister species". They are the most common littoral species at MSH, but also occupy a limnetic habitat. Their size is moderately small, and they are difficult to distinguish. Usually, only one of these two will inhabit a lake. They can reproduce quickly, and are a potential food source for *Asplanchna*, fish fry, and the cyclopoid populations. *Bosmina longirostris* appeared in very large abundances in Castle lake.

4). *Ceriodaphnia lacustris*, *Ceriodaphnia quadrangularis*, and
Ceriodaphnia reticulata

These three species were common in several lakes at MSH. Their existence coincided with apparent niche differentiation and higher diversity indices in lakes such as Merrill and Meta. Along with the other small to medium-sized cladocerans, they are effective competitors if *Daphnid* populations are kept in check (Brooks and Dodson, 1965). What characteristics describe which species is still under debate (verbal communication, Allen Vogel, 12/94), but their functional roles as herbivores remain the same. They are a palatable species, with the larger adults being more susceptible to fish predation.

5). *Chydorus sphaericus* and *bicornutus*

Chydorus sphaericus is considered the most common cladoceran in the world (Ward and Whipple, 1959). Its contribution to the limnetic community at MSH is minimal, since it prefers a littoral habitat, but its low-level presence was consistent in many of the lakes. *C. bicornutus* was identified in June Lake only. It produces an unusual carapace with deep polygonal designs. This rare sighting needs to be confirmed.

6). *Daphnia pulex* and *rosea*

These two species are important in the fresh water zooplankton community, and were present in the majority of lakes sampled. They are large

and more effective at food collection than smaller filter-feeding species (Gliwicz, 1980). They are considered preferred food for planktivorous fish. These two species were often found to coexist in MSH lakes. The combined absence of *Daphnids* and calanoids in a lake could be an indication of either extremely low productivity or heavy predation.

7). *Diaphanosoma brachyurum*

This species showed up only in the most diverse lakes. *D. brachyurum* was identified in several lakes, but only occurred in significant numbers in Meta Lake.

8). *Holopedium gibberum*

This cladoceran was used as an important indicator of predation pressure (Stenson, 1987; Campbell, 1991). *H. gibberum* surrounds itself with a gelatinous sheath rendering itself unpalatable to *Chaoborus* and planktivorous fish. It cannot filter as efficiently as *Daphnia* species, but when *Daphnids* and the soft-bodied zooplankton are cropped by predation, *H. gibberum* can use the resources made available. This species often dominated or codominated with *Keratella* and *Kellicottia* in communities heavily impacted by *Chaoborus* and intense fish predation.

9). *Pleuroxus denticulatus*

Pleuroxus denticulatus should be considered a relatively rare littoral species at MSH. Specimens were found in Coldwater and Hanaford lakes in small abundance. It appears to fill a niche very similar to that of the *Bosminids* without having the pelagic tendencies.

10). *Polyphemus pediculus*

Polyphemus pediculus is one of two carnivorous cladocerans found at MSH. Specimens were identified from Fawn and Merrill lakes, two of the most productive lakes sampled. It has appendages modified for grasping and a very large eyespot which makes it susceptible to visual predation in relatively clear waters. Although an entertaining find, its contribution to the zooplankton community is probably limited.

11). *Scapholeberis kingi*

Scapholeberis kingi can be found in ponds and weeds or swimming on its back near the surface just about anywhere in a lake. Trace populations of this species along with *Simocephalus aurita* were found only in St. Helens Lake.

12). *Sida crystallina*;

Overall, this species could be considered rare in the MSH ecological system since it was found only in McBride Lake. *S. crystallina* is known to prefer a weedy habitat which probably provides safety from planktivorous

predators since it is a large cladoceran. The stained waters, lack of planktivorous fish, and plentiful macrophytes probably make McBride Lake an ideal habitat. Its abundances may be much higher in this lake than the samples indicate.

13). *Simocephalus aurita*

As discussed above, this species was only found in St. Helens Lake as a rare entity. Further sampling is required to determine if it is a stable participant in the community.

IV Other Players

1. *Chaoborus* spp.

Also known as the phantom midge, this Dipteran larvae makes its home in the bottom waters and mud of a lake or pond, usually migrating to the surface water at night to feed. The conspicuously pigmented air sacs at either end of its body allow it to extract oxygen from water with low concentrations. Individuals up to 12 mm in length were recorded from MSH lakes. This animal is an important component of the limnetic food web, because it is a consumer of zooplankton (Yan et al., 1982) and a food source for fish (Pastorok, 1980).

The life cycle during this aquatic phase of their life is characterized by instars, increasing in size with each molt. The food preferences also change during this process. The earlier instar stages select rotifers for the most part,

preferring the soft-bodied species (Havens, 1990; Neill and Peacock, 1980). The later instars select cladocerans and calanoid copepods while avoiding the loricate rotifers, cyclopoids, and *Holopedium* spp. (Pastorak, 1980). Allan (1973) found that *Chaoborus* prevented *Daphnia* from increasing, thereby providing an opportunity for an inferior competitor, *Holopedium*. Because *Chaoborus* larvae have a high feeding rate (Riessen et al., 1984), they can significantly affect crustacean zooplankton community structure when they are abundant (Kajak and Rybak, 1979), resulting in dominance by the most resistant prey species (Sprules, 1972). This appears to be the case in several of the lakes to be discussed in the next section.

2. Individual Lake Descriptions

The following is a brief characterization of the zooplankton community of each lake. Details of lake surface area, maximum depth, and elevation can be found in Appendix D. Mid-summer epilimnetic soluble reactive phosphorus, alkalinity, and conductivity values are also listed. Detailed estimates of fish species and their abundances are not available at this time. However, a compilation of stocking reports (Washington Dept. of Fish and Wildlife) and oral communication with Charlie Crisafulli (USFS, Amboy, WA) has provided limited information as to the general presence or absence of fish, some of the species present, and cases involving extreme abundances of fish. Although limited, this information has proven quite useful.

I). Blue Lake

Blue Lake lies on the southwest flank of MSH, has a maximum depth of 30+ m, and a surface area of 0.072 sq. km. The lake has previously been stocked and is open for public fishing. Therefore the dominant predators are fish. According to the Gifford Pinchot USFS map, Blue Lake does not receive input from any other lake sources.

Blue Lake was sampled once in the summer of '93. From this event two species of copepods, three species of cladocerans, and 5 species of rotifers were

recorded. Of these, *Diaptomus kenai* (herbivore 5) was dominant and *Kellicottia longispina* (herbivore 1) was subdominant. *Holopedium gibberum* was the most abundant cladoceran, but it was never recorded in excess of 20 per cubic meter.

This zooplankton community in Blue Lake appeared to be free from extremes even though it earned a diversity index of only 2.14. It showed no signs of severe invertebrate predation (no *Chaoborus* recorded), and the fish predation could be hypothesized as low to moderate due to the presence of a healthy, relatively large-bodied population of *Diaptomus kenai* (fig. C7e). Further support of this is the relatively high palatability index (table C5). Since this lake was only sampled once in early summer, there is a possibility that the cladoceran populations had not fully developed.

The presence of substantial numbers of large calanoid copepods along with the relative absence of a *Daphnid* population indicates one of two things. Either physico-chemical factors favor calanoids over cladocerans in Blue Lake, or preferential predation of *Daphnids* over calanoid copepods was occurring. Several more sampling events during the year and details of fish abundance would help clarify the annual cycles of the zooplankton community.

II). Boot Lake

Boot Lake lies within the blast zone on the northwest flank of MSH. It has a surface area of 0.065 sq. km. and a maximum depth of 21 m. This lake does not receive inflow from any other lakes. According to the USFS records Boot Lake has been stocked with rainbow trout (pre-eruption), but they do not appear to have survived. This has allowed *Chaoborus* to become top predator.

Boot Lake was sampled during the fall of '92, summer of '93, and summer of '94. Fourteen species of zooplankton appeared in the water column over this period. *Keratella cochlearis* (herbivore 1) appears to dominate in this lake with a fall surge by *Holopedium gibberum* (herbivore 5). *Chaoborus* (carnivore 5) predation may be intense because: 1) there was a relatively high *Chaoborus* presence during all sample periods; 2) the abundances of adult *Diaptomus* and *Daphnia* species⁴ were consistently low; 3) the macrozooplankton was dominated by *H. gibberum* and cyclopoids. A palatability rating of <10% was determined for each sampling period (table C5) due to the abundance of loricate rotifers.

Boot Lake appears to be functioning under extreme invertebrate predation. The zooplankton community consists of relatively non-palatable species with only

⁴Not enough *Daphnia* or *Diaptomus* were available to perform a length-frequency analysis.

small populations of *Daphnids* and soft-bodied rotifers surviving. Therefore, a diversity index of around 3.1 (table C6) provides a fair representation of this lake. This index was largely determined by rotifer abundances with very little input from the macrozooplankton community.

III). Castle Lake

Castle Lake lies on the northwest flank of the volcano, and has a surface area of 1.07 sq. km, making it the third largest lake in the survey. It was created by a mudflow during the 1980 eruption and has no other lakes feeding it. Castle has a maximum depth of 32 meters. Fish are the dominant predators in this system.

Eighteen species of zooplankton were recorded in this lake from the early summer and early fall samples. Cladocerans dominate the zooplankton community volumetrically (fig C1c). *Bosmina longirostris* (herbivore 2) showed an early spring bloom with *Daphnia pulex* (herbivore 5) accounting for the majority of biovolume in the fall. Eleven of the species recorded were rotifer species, but none of these ever attained the volumetric significance of the cladocerans. *Asplanchna priodonta* was consistently present throughout the season and should be considered a sub-predator. A striking peculiarity of Castle is the absence of a *Diaptomus* sp..

The zooplankton community of Castle Lake appears to be free of extreme predation by vertebrates or invertebrates. Length-frequency analysis (fig C7d) indicates moderate predation pressure in the June sample. The palatability index (table C5) further supports this with marks of 97% (early summer) and 92% (early fall). The diversity index averages around 2.3 with a low in spring (1.6) and a high in the fall (5.4). The fall number is largely due to rotifer populations which contribute only a small amount to the biovolume.

It is possible that zooplankton communities in Castle Lake have not stabilized. First, the lake was formed only 15 years ago. Second, it is possible that Castle Lake was stocked with rainbow trout a few years ago. These fish appear to be self-propagating at this point. The huge abundance of *B. longirostris* in the spring of '93 may be an indication of competitive release due to juvenile fish predation upon *Daphnia* sp. in the early spring. These juveniles typically switch to insects and aquatic insect larvae later in the season which could allow a recovery of *Daphnid* populations by fall. Predation is probably cyclic, reaching a maximum in spring and decreasing as the year progresses. The absence of a calanoid copepod is unusual.

IV). Coldwater Lake

Coldwater Lake, which lies northwest of the crater, has a surface area of 3.1 sq. km. Like Castle, Coldwater was formed as a result of a mudflow from the 1980 eruption of MSH. The maximum depth of Coldwater is 62 meters. Heart and Snow Lakes are part of the drainage system which feeds Coldwater. Coldwater Lake has been stocked for recreational fishing, and rainbow trout are the dominant predators.

Coldwater Lake produced at least 24 species of zooplankton in four separate sampling periods (fall '92, spring '93, summer '93, and all '93). The zooplankton community was co-dominated by *Daphnia pulex* and *Diaptomus tyrelli* throughout the period. Of the 12 species of rotifers noted, *Asplanchna* sp., *Filinia* sp., and both *Keratella* sp. remained present throughout the sampling period in modest abundances.

Coldwater Lake exhibits a balanced zooplankton community with low to moderate predation pressure from the fish community. Length-frequency analysis (fig. C7b) supports this interpretation because a large proportion of *Daphnids* attained a length of 2 mm and more. A range from 4 to 18% of the zooplankton were non-palatable (fig C5). Fish predation appears to maintain a check on *D. pulex* which allows small, but persistent populations of rotifers and *Bosmina longirostris* to flourish. Coldwater Lake had a high summer diversity index of

(5.01). Although Coldwater is far from being nutrient rich and did not have very large zooplankton biovolume per m³ water, the diversity of the zooplankton community indicates a relatively productive system for a MSH lake.

V). Fawn Lake

Fawn Lake is a cirque lake on the northwest side of the volcano within the blast zone. It has a maximum depth of 18 m, and a surface area of 0.096 sq. km. Samples were obtained from this lake on four sampling visits (fall '92, spring '93, summer '93, and fall '93). Brook trout survived the eruption and eastern brown and rainbow trout have been stocked since the eruption; together, they function as dominant predators on the zooplankton. No other lake sources flow into Fawn Lake.

This lake followed a more typical pattern of spring rotifer dominance followed by cladoceran dominance in late summer and fall. Twenty two species of zooplankton were recorded during the 4 sampling periods. A *Filinia terminalis* (herbivore 1) bloom developed during the spring with a gradual increase in *Daphnia pulex*, *Daphnia rosea*, *Alona costata*, and *Chydorus sphaericus* from summer into fall (respectively, herbivores 5, 5, 3, and 2). Small populations of *Cyclops vernalis* and moderate populations of *Diaptomus franciscanus* were present throughout the sampling periods. Additionally, high levels of *Asplanchna*

were recorded during all periods of sampling. *Chaoborus* was present sporadically, but not in large abundance. Fawn Lake was also one of only two lakes to contain *Polyphemus pediculus*, a cladoceran predator.

Fawn Lake appears to be a productive lake functioning under moderate predation. This predation appears to contribute to a very diverse zooplankton community for such a modest sized lake. Length-frequency analysis (fig. C7g) indicates a majority of *Daphnids* remaining <1.2 mm long with a few attaining lengths up to 1.8 mm. This indicates that the fish maintain pressure on the *Daphnid* populations. Another consequence of this appears to be the competitive release of small to moderate sized cladocerans. Meanwhile, the large populations of *Asplanchna* maintain predation pressure on the remaining rotifer and flagellate species. The low value of the palatability index (table C5) specifically reflects the influence of a large abundance of inedible *Asplanchna* (perhaps a biovolumetric over-estimate).

Overall, Fawn Lake appears to experience a rotifer bloom in the spring while being codominated by *Asplanchna*. During the summer and fall months, *D. rosea* and *D. pulex* co-dominate with *Asplanchna*. The large numbers and biovolume of zooplankton present (fig. C1e), along with the large proportion of predators within this total, indicate that Fawn is one of the more productive lakes on MSH.

VI). Grizzly Lake

Grizzly Lake has a surface area of 0.032 sq. km and a maximum depth of 6 m. It is a fishless lake lying on the northeast flank of MSH. It is not fed by any other lakes, and only one replicate sample from the summer of '94 was obtained from this lake.

The sample contained 14 different species of zooplankton. Dominant species in this lake include *Chaoborus*, an ostracod species, and *Keratella quadrata*. In general, abundances of zooplankton other than *Chaoborus* and ostracods are greatly reduced. This gives the lake the appearance of low productivity, although a significant proportion of the resources could be tied up in *Chaoborus* biomass. More sampling events would be required to verify this trophic supposition.

Grizzly Lake harbors an exceptionally imbalanced zooplankton community. Slightly over 40% of the zooplankton in this lake is considered non-palatable (table C5). However, this number is deceiving, and the true palatability index should be much lower. It was calculated using a mature *Daphnid* biovolume factor which was not the case in this lake; none of the *Daphnids* surpassed a length of 0.8 mm (fig. C7m). Therefore, due to the extremely low numbers of zooplankton as a whole, this over-estimation of *Daphnid* biovolume has a significant effect on the results of the palatability index. The large abundance of

Chaoborus certainly plays a role in the simplification of the zooplankton community, but nutrient limitation should be considered as a factor influencing zooplankton community structure in this lake.

VII). Hanaford Lake

Hanaford Lake is a cirque lake on the northeast flank of MSH. It has a surface area of 0.096 sq. km and has a maximum depth of 17 meters. No other lakes feed Hanaford which supports populations of eastern brown and cutthroat trout.

At least 20 species of zooplankton were identified in the samples from the four visits to Hanaford Lake. Notably, this was the only lake consistently to support two species of *Diaptomus* copepods in the same lake: *Diaptomus franciscanus* (approx. 1.5-1.8 mm length) and *Diaptomus shoshone* (often 3.0 mm long). Both species were present throughout the season. The dominant zooplankton was *Holopedium gibberum* with *Daphnia pulex*, *Daphnia rosea*, and *Keratella cochlearis* as subdominants. *Asplanchna* presence was minimal while *Chaoborus* was absent in all samples obtained.

Hanaford Lake is a productive lake and exhibits a relatively high diversity index (3.5) for a small lake. In contrast to many of the other lakes, the diversity rating for this lake was largely earned by the crustacean community rather than by

the rotiferan community. It is dominated volumetrically by cladocerans of which *Holopedium gibberum* contributes the greatest proportion (fig. C1g). The fact that 4 cladocerans and 2 diaptomids show up consistently throughout the sampling period indicates that competition and predation work together to shape the zooplankton community.

Fish predation is moderate. Length-frequency analysis (fig C7f) indicates a large grouping of *Daphnids* around the 1 mm mark, but a few attain lengths >2.0 mm. The majority of *D. shoshone* copepods measured an impressive 2-3 mm. Further evidence to support moderate predation comes from the palatability index (table C5) where the highest value (30%) occurs in summer during the *Daphnid* population growth. Apparently, the *Daphnids* were eaten in late summer and early fall, releasing valuable resources. *H. gibberum* responded with a fall bloom effectively lowering the palatability index to <10% in the fall.

VIII). June Lake

June Lake is a very small, fishless, shallow lake (<2 meters) formed by a lava flow on the southwest side of the mountain. It has a surface area of 0.008 sq. km. The turnover time for this lake is very rapid and the temperature remains cold (<6° C). Production of open-water zooplankton is likely to be limited. June Lake

was intended as a control lake, but provides such a unique physical and chemical environment that it should not be used as a control for zooplankton comparisons.

The samples from June Lake harbored 20 species of zooplankton of which the largest abundances consisted of chironomid larvae followed by *Chydorus sphaericus*. Three species of cyclopoid copepods were found to coexist in this tiny lake, but none occurred in large numbers in the water column. Five species of rotifers were found in the samples, but none of them attained significant abundances. This was also the only lake in which Hydracarina (water mites) were captured in significant numbers.

Overall, June Lake functions as a haven for insects requiring aquatic larval stages and as an abode for littoral, grasping species such as *Cyclops* and *Chydorus*. Apparently, the flushing rate is so fast that zooplankton with grasping abilities and benthic tendencies propagate with the most success.

IX). McBride Lake

McBride Lake is a humic lake which lies on the southwest side of MSH. The water levels fluctuate due to the swampy nature of the outlet and beaver activity. The maximum depth is about 2 meters and a surface area of 0.036 sq. km. There are no other lakes which serve as feeder lakes for McBride. No fish have been recorded from this lake.

Twenty one species of zooplankton were recorded during 3 separate sampling periods (spring, summer, and fall '93). Ostracods were the only zooplankton which appeared in large abundance in the spring tow. The summer tow had *Daphnia rosea* as a dominant zooplankton and *Polyarthra* sp. as subdominant. *Ceriodaphnia quadrangulata* and *Diaptomus franciscanus* were codominant during the fall season. *Sida crystallina* was present, and littoral sampling would probably prove it to be a larger contributor than the limnetic sampling indicates. A large *Chaoborus* population was indicated by the summer tow, but failed to show up in the fall tow.

The zooplankton community of this small lake can be described as relatively well balanced. Two factors which probably have influence on the zooplankton population in McBride Lake are *Chaoborus* and low visibility. The *Chaoborus* predation is probably not intense since it did not show up consistently in large numbers during the sampling periods, and there is a strong showing of soft-bodied rotifers throughout the summer and fall seasons (good food for *Chaoborus*). Additionally, the palatability index (fig C5) does not indicate heavy *Chaoborus* predation. On the other hand, the replacement of *Daphnia rosea* by *Ceriodaphnia quadrangulata* as the dominant herbivore in the fall indicates that something is probably consuming *Daphnia rosea*. Additionally, the length-frequency analysis (fig. C7j) indicates moderate to strong predation since very few

of the zooplanktors surpass 1.2 mm. Two likely explanations for this would be: 1) under-estimation of the abundance of *Chaoborus*; or 2) an unknown predator (possibly amphibians?).

The overall picture shows McBride Lake being dominated by ostracods in the spring and cladocerans in the summer and fall. It displays the influence of both predation and competition as shaping factors in the zooplankton community. Consideration must also be given to the fact that McBride is the only lake sampled with darkly stained, humic waters. This element may have an inhibitory effect on phytoplankton growth or visually feeding predators. Either way, it is likely that this lake has abiotic circumstances different from those of other sample lakes with reciprocal influence on the zooplankton community.

X). Merrill Lake

Merrill Lake is a large lake with a surface area of 1.392 sq. km and a maximum depth of 18 m. It is a popular recreational site positioned to the southwest of MSH. Fish have been stocked in this lake and function as dominant predators. One of the unique features of Merrill Lake is the dramatic fluctuation of water levels from spring to fall. It should be noted that these fluctuations may contribute to limnetic zooplankton diversity by creating a rather unstable environment. Hutchinson (1978) points out that constituent zooplankton species

may never reach a point of equilibrium (with implications regarding competitive exclusion), because they have a generation time of about the same duration as the intervals between significant seasonal changes in the environment. In Merrill, the seasonal climate changes result in the lake level fluctuations.

Merrill Lake was sampled in the spring, summer, and fall of '93. Twenty two species of zooplankton were recorded from those samples. The spring tow had *Diaptomus franciscanus* as the dominant zooplanktor. By the summer tow, *Daphnia pulex* had become the dominant zooplanktor with lesser numbers of *D. franciscanus*, *Holopedium gibberum*, *Kellicottia bostoniensis*, and *Asplanchna herricki*. *Ceriodaphnia lacustris* took over the top spot in the fall accompanied by *D. franciscanus* and *H. gibberum* as subdominants.

Merrill Lake displays a diverse zooplankton community, in part due to its high primary productivity (Carpenter, 1995). *D. franciscanus* dominates in the spring and codominates in summer and fall. The large *Daphnids* dominate in the summer giving way to medium size cladocerans in the fall. Length-frequency data (fig C7i) indicates that there is significant pressure placed upon the *Daphnid* population by visually preying fish. The presence of large numbers of *H. gibberum* also indicate moderately heavy predation. This cropping of the *Daphnids* appears to allow competitive release of the smaller cladoceran species. As with the other more productive lakes, a significant *Asplanchna* population

maintains predation pressure on the rotifer populations. This balance of competition and predation is expressed in the 50% palatability index (table C5) along with the diversity index of over 5.

Overall, Merrill Lake serves well as a control lake. Two factors which should be noted are that zooplankton variety may be increased slightly due to the unstable nature of the water level. Also, Merrill Lake receives a significant number of visitors for various recreational activities which might artificially increase productivity of this lake, thereby affecting the zooplankton community.

XI). Meta Lake

Meta has a surface area of 0.036 sq. km and is located northeast of the crater. Tows were obtained from a maximum depth of 8 meters. Meta Lake is not fed by any other lakes. Eastern brook trout have been stocked in this moderately productive lake.

Twenty three species of zooplankton were identified from the spring, summer, and fall sampling periods of '93. The spring sample was dominated by a bloom of *Keratella quadrata* with a strong showing from *Diaptomus tyrelli*. The summer tows contained 6 species of cladocera and 5 species of rotifers with significant abundances. Of these species, *Daphnia rosea*, *Diaphanosoma brachyurum*, *K. cochlearis*, and *Diaptomus tyrelli* would be considered

codominant with a strong showing from *Ceriodaphnia lacustris*. In the fall sample, *Diaptomus* was most abundant with *D. rosea*, *D. pulex*, *Ceriodaphnia lacustris*, and *Holopedium gibberum* functioning as subdominants.

Meta Lake displays a balanced, productive zooplankton community. The cladoceran populations which dominate in the summer (fig. C1k) represent a classic example of niche partitioning brought about by fish predation as described by Brooks and Dodson (1965). The palatability index ranged from a low of 56% to a high of 97%, indicative of seasonal predation (table C5). The low abundance of *H. gibberum* and length-frequency analysis (fig C7h) also indicate moderate predation pressure. The result of the interplay between trophic status, competition, and predation was a diversity factor of 4.22.

XII). Obscurity Lake

Obscurity Lake has a maximum depth of 17 m and a surface area of 0.028 sq. km. It lies to the northeast of MSH and is fed by Boot Lake. Eastern brook trout were stocked prior to the eruption and rainbow trout since the eruption.

The zooplankton community appeared to be simplified in this lake. Only eight species were collected, and of these *Cyclops vernalis*, *Kellicottia longispina*, and *Keratella quadrata* dominated. The only cladoceran represented was *Holopedium gibberum*.

Obscurity Lake appears to be functioning under extreme predation as evidenced by the dominance of cyclopoids and loricate rotifers. The palatability index was nearly 0.0% for this lake (table C5). The diversity index also reflected the simplified community. *Daphnids* and calanoid copepods were absent from the community (table C6). Fish abundance was noted as “extreme” (oral communication, Charlie Crisafulli), and is probably the cause of reduced zooplankton diversity and abundance.

XIII). Panhandle Lake

Panhandle Lake is one of the Mt. Margaret high country lakes. It has a surface area of 0.061 sq. km and has a maximum depth of 22 m. Panhandle Lake is fed by a stream from Shovel Lake. Many malnourished trout live in this lake and have a distinct influence on the zooplankton community.

Three tows were obtained from Panhandle Lake, in fall of '92, summer of '93, and summer of '94. Sixteen species of zooplankton were recorded. *Cyclops vernalis*, *Holopedium gibberum*, *Kellicottia longispina*, and *Keratella quadrata* were the dominant species. One surprise in this lake was the consistent trace of harpacticoid copepodids.

The zooplankton community in Panhandle Lake is strongly influenced by fish predation. The trout population displays stunted bodies with large heads, classic signs of malnutrition. They have virtually eliminated the palatable species of zooplankton. There were not even enough *Diaptomus* or *Daphnid* species to perform a length-frequency analysis. Panhandle received a diversity index of around 2.5 and a palatability rating of 1% (fig C5).

XIV). Ryan Lake

Ryan Lake lies to the northwest of MSH within the blowdown boundaries. It has a surface area of 0.016 sq. km and a maximum depth of 8 m. Ryan is not fed by other lakes, and is reportedly fishless.

Sixteen species of zooplankton were recorded from samples obtained during spring, summer, and fall of '93. The zooplankton community of this lake was dominated by *Diaptomus franciscanus* with a bloom of *Keratella cochlearis* in the spring and very modest abundances of *Daphnia rosea* throughout the entire year. Overall, the cladoceran community displays low abundances and low diversity. The top predator, *Chaoborus*, was present in large numbers with every tow obtained from Ryan Lake.

Ryan Lake is unusual in the fact that *Chaoborus* abundance appears to be high, but the lake's palatability index of greater than 99% does not indicate high

predation (table C5). The length-frequency analysis (fig. C7j) indicates moderate predation pressure on the *Daphnid* and *Diaptomid* communities. Therefore, this lake does not quite fit the predation pattern as exemplified by the other lakes. Ryan Lake may have a productivity level between that of Grizzly and Meta. By providing a larger resource base than Grizzly, the crustacean population in Ryan Lake is able to reproduce at a rate significantly greater than losses occurring via predation. On the other hand, niche partitioning is not occurring among the cladocerans. The cladoceran numbers are generally low, but rotifer abundances are not elevated. These facts indicate one of three things: 1) low nutrients and primary productivity restrain zooplankton production; 2) a large amount of resources are tied up in *Chaoborus* biomass; or 3) predation by amphibians limits zooplankton populations. If number 2 or 3 is the case, this would also help explain the apparent low productivities of Boot, Grizzly, and Snow lakes.

XV). Shovel Lake

Shovel Lake lies to the northeast of MSH. It has a surface area of 0.084 sq. km and a maximum depth of 30+ m. A large population of brook trout inhabit this lake.

A single sampling expedition during the summer of '94 produced a total of 6 zooplankton species in the zooplankton tow. *Cyclops vernalis* was the dominant

zooplankton with a meager representation of *Keratella quadrata*. Interestingly, only 6 zooplankton species were present in Shovel Lake of the 12 species that were present in its downstream neighbor, Panhandle Lake.

Shovel Lake appears to be experiencing severe fish predation just like Panhandle Lake. No cladoceran and no calanoid species were recorded. Additionally, a palatability index of <1% was recorded (table C5). The diversity index of 2.8 reflects the simplicity of this community.

The data suggest that Panhandle, Obscurity, and Shovel lakes are either unproductive, or the nutrients/resources are tied up in fish biomass. The large numbers of fish in each of these lakes argues for the second hypothesis.

VI). Snow Lake

Positioned north/northeast of the crater, Snow Lake has a surface area of 0.019 sq. km and a maximum depth of 9 m. Samples were obtained from this lake once in mid-September, 1994. Snow is one of a number of lakes which feeds Coldwater Lake. Cutthroat trout have been stocked in this lake after the eruption. Some large specimens are known to inhabit the lake (Cindy Baker, visual observation).

Eleven species of zooplankton were identified in the Snow Lake samples. By far, the dominant species was *Keratella cochlearis*. No *Diaptomus* sp. were

present, a few *Daphnia rosea* were present, and an extremely large population of *Chaoborus* instars was observed.

The zooplankton community of this lake was extremely simplified at the time of sampling. Even so, a diversity index of 1.1 actually underestimates the community diversity in Snow Lake. *K. cochlearis* were numerically so abundant (around 2×10^5 per m^3) that they overwhelmed the numerical contributions of all other zooplanktors. A diversity rating of 1.5-2.0 would be more representative.

The predation pattern in Snow Lake is unique. Since *Chaoborus* make good fish food, it is probable that the number of fish present is quite low considering the large numbers of *Chaoborus* present in the water column. A length-frequency analysis of the few *Daphnids* present (fig. C7L) indicate moderate predation (the source of which could be either fish or *Chaoborus*). With the exception of a few *Daphnia rosea* and *Polyarthra* sp., the zooplankton present were considered non-palatable. A palatability index of 8.8% was calculated as seen in figure C5. Therefore, the domination by a loricate rotifer, lack of *Diaptomus* sp., small *Daphnia* population in late summer, and large *Chaoborus* population leads to the conclusion that a few large fish together with a large number of *Chaoborus* maintain predation upon the palatable zoopankton species.

XVII). St. Helens Lake

St. Helens is a large and very deep lake north/northeast of the crater. It has an estimated maximum depth of 85 m and a surface area of 0.320 sq. km. No other lakes feed St. Helens. Large fish are known to inhabit this lake (visual observation) making them the dominant predators.

Nineteen species of zooplankton were reported for the 3 sampling periods (fall '92, summer '93, and summer '94). *Diaptomus kenai* was the dominant zooplankton throughout the period with the exception of fall '92 when *Daphnia pulex* codominated. *Conochilus unicornis* and *Holopedium gibberum* showed up consistently, but never in great numbers.

St. Helens Lake appears to reflect a balance between nutrient limitation and predation. Overall, the abundance and biovolume of zooplankton is not high (fig. C1q), but the primary productivity is high enough to maintain a population of naturally reproducing fish. Predation pressure on the zooplankton is probably high shortly after juvenile trout hatch in the spring, but appears to be rather low by mid-summer as indicated by length-frequency analysis (fig. C7a) and a palatability index of 75 to 88 percent (table C5). Consequently, *H. gibberum* was able to maintain small but persistent populations throughout the sampling period. This, together with the presence of two rare cladocerans, *Simocephalus aurita* and *Scapholeberis mucronata*, indicate that predation is heavy enough to open up

opportunities for other cladoceran species. A diversity index >4 was calculated for this lake. St. Helens is a deep, oligotrophic lake with a moderately diverse zooplankton community.

XVIII). Venus Lake

Venus Lake lies north/northeast of the volcano. It has a maximum depth of 38+ m and a surface area of 0.085 sq. km. Rainbow trout are known to exist in this lake which has no feeder lakes. Other species may also have survived the blast due to the lake's depth, but no data are available at present to clarify that question.

Three sampling trips were made to Venus Lake, and a total of 15 zooplankton species were recorded in those samples. This lake was consistently dominated by *Holopedium gibberum* in conjunction with a rotifer, usually *Keratella cochlearis*. *Diaptomus kenai* was consistently present in moderate abundance along with *Conochilus unicornis*. No *Chaoborus* were ever recorded in Venus Lake samples.

The community structure in Venus Lake indicates significant fish predation allowing the non-palatable *H. gibberum* to dominate along with loricate rotifers. Length-frequency analysis of *Diaptomus kenai* also suggests significant predation because the majority of calanoids are 1.0-1.2 mm in length, well below their

potential maximum length (fig. C7c). *Daphnid* length-frequency does not support the hypothesis that there is significant fish predation (fig C7c), but this may be due to the very low abundances from which the analysis was derived (65 total individuals from almost 5 cubic meters of water). Venus Lake shows no signs of niche partitioning among the cladoceran populations. The palatability index was 10% (table C5). The diversity index was just over 2, but may underestimate the overall diversity of the zooplankton community within this lake. The rotifer abundances were very high and overwhelmed Crustacean influence. If rotifers were ignored, a diversity index of 3.0-4.0 would result.

The *Diaptomus* and *Daphnid* populations in Venus Lake are kept low by fish predation, just as in St. Helens Lake. Unlike St. Helens Lake, in which there was some cladoceran niche differentiation, the rotifers in Venus Lake appear to be capitalizing on the resources not used by the cladocerans. Although these two lakes have many similarities, this would appear to represent a functional difference in the route by which energy travels within the lakes.

3. Lake Clusters

The results of cluster analysis support a pattern of relatedness based on the influences of trophic status (productivity) and predation pressure. Six cluster analyses created by using different analytical interpretations are presented in Appendix E. Some variation is evident among them indicating that the differences between the lakes are continuous rather than distinct.

In general, three main clusters can be distinguished. The first cluster is characterized by lakes experiencing heavy predation by *Chaoborus* and extreme abundances of fish. This group includes Grizzly, Snow, Boot, Shovel, Obscurity, Panhandle, Ryan, and McBride. Of these, Ryan and McBride are the least related to the rest of the group, and Shovel, Obscurity, and Panhandle appear to be the most similar to one another. Interestingly, most of the lakes in this group are located in the Mt. Margaret wilderness area in close proximity to one another. Obscurity, Panhandle, and Shovel are known to have populations of fish so high that many are developing with very large heads and small bodies (visual observation by author), indicative of malnutrition. Snow, Ryan, Boot, Grizzly, and McBride all have large *Chaoborus* populations. It appears that in the MSH vicinity, large populations of fish or *Chaoborus* have the same effect, simplifying zooplankton communities with a resulting dominance by loricate rotifers.

In general, these lakes were dominated by loricate rotifers, especially the *Keratella* and *Kellicottia* species, sometimes in conjunction with *Holopedium gibberum*. They produced relatively low diversity index values, and low palatability indexes. *Daphnid* and calanoid species were either non-existent or present in low abundances (except in McBride and Ryan lakes). Where applicable, the length-frequency analysis also supported the hypothesis of heavy predation. Snow, Shovel, Obscurity, and Panhandle had macrozooplankton dominance by cyclopoid copepods which indicates a distressed zooplankton community (Allan Vogel, oral communication). Grizzly and Boot did not display significant copepod populations of any class.

The effects of predators are well documented (Gliwicz, 1994; Hrbacek et al., 1961; Brooks and Dodson, 1965; Hall et al, 1976; Lazzaro, 1987; Evans, 1992). Neill and Peacock (1980) demonstrated that *Chaoborus* instars of all ages can have tremendous impacts on the zooplankton communities. Early instars concentrate upon the rotifer populations while later instars prefer the larger macrozooplankton. In Neill and Peacock's experiments, if early survivorship of *Chaoborus* is high, they can virtually eliminate all other species from a zooplankton community. Ryan appears to be experiencing heavy predation by *Chaoborus* with some simplification of community structure, but a possible hypothesis is that the productivity is somewhat greater than the other lakes. This

would enable the calanoid and *Daphnid* populations to reproduce at a rate greater than losses due to predation. McBride is the least related lake in this category. Either the *Chaoborus* populations in McBride are less than that of the other lakes in the same cluster, or else the darkly stained waters afford some degree of protection from predation. This latter hypothesis is unlikely since *Chaoborus* are known as tactile predators rather than visual predators.

Bottom-up control mechanisms appear to influence the MSH lakes, also. One common factor is the relative shallowness of those lakes with heavy influence of *Chaoborus* while the lakes with fish are in excess of 17 meters deep. These features are likely to enhance the survival of their respective predators. Although no figures are available for most of the lakes experiencing heavy predation by *Chaoborus*, nutrient analysis (Carpenter, 1995) of other lakes in the MSH vicinity indicate oligotrophic status accompanied by phosphorus and nitrogen limitations. If phytoplankton growth is limited by nutrient availability, it is probable that the reproduction of the macrozooplankton communities is also limited by food supplies. It may be that the nutrient base is constraining the phytoplankton and bacterial food supplies necessary for rapid reproduction in the cladoceran and calanoid populations. *Chaoborus* and fish predation in combination with nutrient shortage may prevent the growth of the zooplankton populations..

The second cluster of lakes include Venus, St. Helens, and Blue. Their common factors include great depth, a low coefficient of light extinction (Carpenter, 1995), and modest populations of fish. The depths of these lakes probably make the benthic habitat less accommodating to *Chaoborus* larvae, thereby restricting their influence in these lakes. Length-frequency analysis show a relatively large proportion of *Daphnids* and calanoid copepods reaching their mature lengths. This indicates relatively low predation for a period prior to sampling. St. Helens and Venus lakes are operating under conditions of natural fish propagation. This would create a potential for zooplankton predation during the larval fish hatch. The fish develop into fingerlings and move on to a diet of terrestrial insects and aquatic larvae, thereby reducing the predation pressure on the *Daphnid* and calanoid populations and allowing them to achieve adult size by mid-summer. Blue Lake, on the other hand, is more accessible to human traffic, and experiences a good deal of angling. It is frequently stocked (Washington State Dept. of Fish and Wildlife bulletins) which would make the timing of sample collection critical for evaluation of zooplankton community structure.

Venus, St. Helens, and Blue lakes are oligotrophic in nature (Carpenter, 1995) which helps to explain the low biomasses of zooplankton present. The community structure created modest diversity indices in the general range of 2-4. Large cladoceran and calanoid populations never exceeded a few thousand

individuals per cubic meter, and were usually much less. The rotifers populations in these lakes were never a significant contribution to the total biomass, but modest populations were consistent throughout the sampling periods. Therefore, fish are probably the nutrient sinks in these three systems which appear to be functioning with a balance between nutrient limitation and predation.

The third group of lakes can be characterized as displaying the greatest diversity of zooplankton due, in part, to increased nutrient availability. Hanaford, Fawn, Merrill, Coldwater, and Meta lakes fall into this cluster. They are all moderately deep and contain fish. They are generally more accessible than most of the other lakes, and anglers often frequent their shores. Length-frequency analyses of zooplankton in these lakes indicated moderate predation pressure. There was an increased frequency around 1 mm with a significant proportion of the *Daphnids* and calanoids attaining lengths between 1 and 2 mm. Community diversity indices were high and ranged from 3.4 to 7.00, in contrast with the lower diversity characteristic of the other clusters. In general, these lakes displayed the strongest trends toward niche differentiation. The *Daphnids* are eaten by fish, which in these productive systems allows populations of smaller sized cladocerans to coexist (Brooks and Dodson, 1965). The *Ceriodaphnia*, *Diaphanosoma*, and *Bosmina* species filled the niches opened by

fish predation. Persistent large populations of calanoid copepods also appeared able to exploit the resources available in these lakes.

The rotifer populations in these five lakes also indicate greater productivity and niche differentiation. In all the lakes of this cluster with the exception of Meta, *Asplanchna* spp. appear consistently as the dominant invertebrate predator. These lakes also contained significant populations of the soft-bodied rotifers such as *Polyarthra*, *Conochilus*, *Trichocerca*, and *Epiphanes* species, a trend which was not repeated in lakes experiencing heavy *Chaoborus* predation. In general, the habitat provided by Hanaford, Fawn, Merrill, Coldwater, and Meta lakes promoted a significantly more diverse community of rotifers than in the other lakes.

The combination of having the greatest biomasses of zooplankton while at the same time supporting populations of fish indicate that this cluster of lakes have a larger resource base compared to the other lakes sampled in this survey. The nutrient data (Carpenter, 1995), when combined with the zooplankton analyses, support the hypothesis that these 5 lakes are distinguished by greater nutrient availability and significant fish predation.

Two lakes which consistently appeared as outliers are Castle and June. Castle Lake is most closely allied with Hanaford, Fawn, Merrill, Coldwater, and Meta. It displays evidence of being moderately productive and produces large

populations of *Asplanchna* sp. What makes it different is the absence of a calanoid species and the tremendous abundances of *Bosmina longirostris*. June Lake is always cold (less than 8° C) and has a high flushing rate, conditions unfavorable for large populations of traditionally limnetic zooplanktors. June Lake functions primarily as a rookery for dipteran larvae. These conditions set it apart from the other lakes sampled.

4. Comparison of St. Helens zooplankton data to Mt. Rainier and Mt. Hood data

A generalized comparison to the data presented by Larson et al. (1992) from sampling 27 lakes on Mt. Rainier indicate that most of the same genera are present on Mt. Rainier as on MSH¹. Macrozooplankton abundances extend through a similar range of abundances with *Diaptomus* sp. around 1000-5000 individuals per cubic meter and *Holopedium* sp. generally from 0-5000 individuals per cubic meter. Three differences in the macrozooplankton were noted. First, *Daphnid* abundances were noted in excess of 5000 per cubic meter in 5 different lakes on Mt. Rainier. *Daphnid* abundances during the sampling period on MSH were never recorded in excess of 3000 individuals per cubic meter. Secondly, *Chaoborus* were not noted as frequently in the tows from Mt. Rainier, nor did they display the abundances that appeared on MSH². Thirdly, *Ceriodaphnia* and *Diaphanosoma* sp. were present in the samples from MSH, but not from Mt. Rainier.

A comparison of MSH to Mt. Rainier rotifer composition and abundances also produced more similarities than differences. *Keratella*, *Kellicottia*, *Polyarthra*, and *Conochilus* dominated the rotifer communities on Mt. Rainier as

¹ Identification to species level is not available as of yet.

² The one exception to this was GO2 lake. This was the only lake on Mt. Rainier to display large *Chaoborus* populations. *Daphnids* were coexisting here.

they did on MSH with frequent abundances in the range from 5000 to 150,000 individuals. One striking dissimilarity included dominance by *Conochilus* sp. of the rotifer community on Mt. Rainier, while *Keratella* was dominant on MSH. This may reflect the higher degree of *Chaoborus* predation evident in the lakes at MSH. A logical hypothesis to follow this observation is that loricate tests provide superior protection from *Chaoborus* predation compared to coloniality and the mucous sheath used by *Conochilus*.

The zooplankton communities of MSH appear to significantly overlap those of Mt. Hood, also. The data from Mt. Hood (unpublished data, Allan Vogel) indicate the presence of several cladoceran and copepod species not found in the lakes around MSH. However, most documented abundances of cladocerans and copepods are similar in the lakes on the flanks of the two volcanoes. As with the Mt. Rainier lakes, the rotifer abundances are lower in Mt. Hood lakes than in the lakes on MSH.

The lakes on Mt. Hood, Mt. Rainier, and MSH exhibit similar zooplankton species in their respective communities. The proportions between the mountains among cladocerans, copepods, and rotifers do vary significantly, indicating functional differences. These differences may be related to varying degrees of predation or nutrient status, but further research would be required to verify this hypothesis.

F. Conclusions

Analysis of the zooplankton communities in 18 lakes around MSH indicates that predation plays an important role in sculpting the community compositions. Extreme predation in Snow, Boot, Shovel, Obscurity, and Panhandle lakes created a community dominated by loricate rotifers, cyclopoids, and *Holopedium gibberum*, all of which are considered to be rather unpalatable species. These lakes were typified by low palatability indexes, low diversity indexes, low zooplankton biovolumes (not including *Chaoborus*), and the general absence of large *Daphnids* and calanoid copepods. Predation could be attributed to either *Chaoborus* or fish species. There was a tendency for the rotifer populations of lakes with heavy fish predation to be dominated by *Kellicottia* sp. while those lakes with heavy *Chaoborus* predation were dominated by *Keratella* sp. McBride and Ryan lakes also clustered in this category, but did not exhibit the extreme predation that the other lakes did. This may be related to elevated levels of productivity.

Venus, St. Helens, and Blue lakes comprise a cluster of deep lakes with moderate diversity in their zooplankton community. They all have *Diaptomus kenai* as the dominant calanoid copepod while palatability indexes range from 15-88%. The length-frequency data generated by these lakes are variable, but

generally indicate the ability of a few individuals to attain full body size. This would indicate predation levels varying from low (St. Helens) to moderate intensity (Venus). Venus and St. Helens lakes have a few large fish (visual observation), small abundances of large *Daphnids* and calanoid copepods, and relatively low overall abundances of zooplankton. A large proportion of the productivity of these lakes is apparently tied up in fish biomass. Since Blue Lake is stocked periodically, the time of sampling would create significant differences in zooplankton community structure from year to year.

The last cluster of lakes reflect the greatest diversity of zooplankton, along with the greatest abundances. This group consists of Meta, Merrill, Hanaford, Fawn, and Coldwater lakes. Moderate predation pressure by fish and *Asplanchna* sp. is reflected in their length-frequency analyses and palatability indices. The data on these lakes would seem to indicate that moderate predation can indeed create available niches through competitive release in the zooplankton community (Brooks and Dodson, 1965).

Cluster analysis sometimes portrayed Castle Lake as an outlier and sometimes grouped it with the diverse, productive lakes. It does not support a calanoid copepod species, in contrast to the other lakes in the productive lake cluster. June Lake consistently appeared as an outlier, a reflection of its unique physico-chemical characteristics.

The trophic status of these lakes appears to be strongly reflected in the community structure and abundances of the zooplankton. In general, the lakes sampled reflect varying degrees of oligotrophy with some approaching mesotrophic status. The more diverse the community, the higher is the hypothesized nutrient input. Overall, the lakes may be grouped into two trophic categories, productive and less productive. The productive group includes Meta, Merrill, Fawn, Hanaford, Castle, and Coldwater lakes. The less productive group includes the remaining lakes. Since absolute abundances and biovolumes of *Chaoborus* and fish are unknown, the true productivity status of these lakes is also unknown. However, other data from these lakes such as high water transparency (Carpenter, 1994; unpublished data, Richard Petersen, 1994), low zooplankton biovolumes (not including *Chaoborus*), and general lack of zooplanktonic diversity indicate a lower trophic state for these lakes.

Other factors were tested to elucidate the zooplankton community structure. The zooplankton displayed little or no correlation with cation or anion abundances (Vic Menting, 1995). Additionally, they displayed little correlation with algal species diversity figures (Appendix D) generated from phytoplankton samples taken simultaneously with the zooplankton samples (Cindy Baker, 1995).

Overall, zooplankton communities have largely recovered from the effects of the 1980 eruption. The majority of the genera present on Mt. Hood and Mt.

Rainier are currently present on MSH. Some differences are evident which may be related to stage of recovery, but these differences may also be due to the fact that these three mountains represent three different ecosystems.

In summary, predation and trophic status both appear to be significant factors in the shaping of the zooplankton communities on MSH. Abiotic factors such as surface area and depth also appear to have some influence on community structure, but the extent of that influence is unknown. The results presented in this thesis support the conclusion by Brooks and Dodson (1965) that niche differentiation among the cladoceran community occurs under the influence of moderate predation pressure on the more competitive, larger herbivores. The result of this is to maximize diversity among the community by opening niches and avoiding monopolization of resources. This occurs as long as the productivity of the lake is high enough to support this type of community, grounds which may not be satisfied by all the lakes in this survey.

Appendix A

Zooplankton Abundance Data

(expressed as #'s per cubic meter)

Lake sampled:	Blue	Blue
Sample date:	110793	110793
Sample depth(m):	10-->0	10-->0
Tow#(Station#):	1(1)	1(1)
<i>Diaptomus kenai</i>	425	1059
calanoid copepodids	165	539
<i>Cyclops vernalis</i>	2	0
cyclopoid copepodids	34	20
nauplii	2026	8922
Total copepods:	2652	10540
<i>Daphnia pulex</i>	2	0
<i>Eubosmina hagmanni</i>	5	0
<i>Holopedium gibberum</i>	2	13
Total cladocera:	9	13
<i>Brachionus calyciflorus</i>	8	33
<i>Conochilus unicornis</i>	1160	4412
<i>Kellicottia longispina</i>	8856	34216
<i>Keratella cochlearis</i>	0	65
<i>Keratella quadrata</i>	400	98
Total rotifers:	10424	38824
Total other zooplankton:	0	0
Total density/M^3:	13085	49377

Lake sampled:	Boot	Boot	Boot	Boot	Boot	Boot	Boot	Boot	Boot	Boot
Sample date:	Fall '92	Fall '92	150893	150893	150893	150893	190794	190794	190794	190794
Sample depth(m):	13-->5	5-->0	15-->10	15-->10	10-->0	10-->0	13-->5	13-->5	5-->0	5-->0
Tow#(Station#):	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	82	13	0	0	0	0	0	0	0	0
<i>Cyclops varicans rubellus</i>	0	0	0	0	4	8				
cyclopoid copepodids	0	0	7	26	8	16	2	5	1	3
nauplii	21	0	98	98	98	163	62	164	65	98
Total copepods:	103	13	105	124	110	187	64	169	66	101
<i>Alona quadrangularis</i>	8	13	0	0	0	0	0	0	0	0
<i>Bosmina longirostris</i>	0	26	7	0	0	0	0	0	0	0
<i>Daphnia rosea</i>	82	13	0	7	1	2	0	0	0	0
<i>Holopedium gibberum</i>	477	3320	0	0	7	14	2	2	29	33
Total cladocera:	567	3372	7	7	8	16	2	2	29	33
<i>Collotheca sp.</i>	514	51830	2157	5131	22141	23039	0	0	0	65
<i>Filinia sp.</i>	21	0	0	0	0	0	0	0	0	0
<i>Kellicottia longispina</i>	21	0	1111	1307	2010	751	0	0	65	0
<i>Keratella cochlearis</i>	3642	37124	3137	2386	7075	8202	164	103	196	196
<i>Keratella quadrata</i>	15494	6013	59347	65033	2761	8202	12119	11605	5948	4216
Total rotifers:	19692	94967	65752	73857	33987	40194	12283	11708	6209	4477
Chaoborus	0	105	20	0	5	8	12	14	1	0
Nematoda	0	0	0	7	0	0	1	0	1	0
Ostracod sp.	0	0	0	7	0	0	0	0	0	0
Total other zooplankton:	0	105	20	14	5	8	13	14	2	0
Total density/M^3:	20362	98457	65884	74002	34094	40368	12362	11893	6306	4611

Lake sampled:	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle	Castle
Sample date:	260693	260693	260693	260693	260693	260693	260693	260693	260693	170993	170993	170993	170993	170993
Sample depth(m):	29-->8	25-->8	8-->0	8-->0	25-->8	25-->8	8-->0	8-->0	10-->0	10-->0	25-->10	25-->10	10-->0	10-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(2)	2(2)	1(2)	2(2)	1(1)	2(1)	1(2)	2(2)	1(2)	2(2)
<i>Orthocyclops modestus</i>	0	0	0	0	0	0	0	0	0	0	0	0	11	0
cyclopoid copepodids	3	2	0	0	2	0	0	0	0	10	50	41	3	7
nauplii	54	69	0	0	29	19	62	21	65	49	87	109	16	0
Total copepods:	57	71	0	0	31	19	62	21	65	59	137	161	19	7
<i>Alona costata</i>	0	0	0	0	0	0	0	0	0	0	0	22	0	0
<i>Bosmina longirostris</i>	1495	960	112511	105267	5665	12360	77572	85926	33	49	55	33	33	65
<i>Chydorus sphaericus</i>	2	0	0	0	0	0	0	0	0	0	0	0	0	16
<i>Daphnia pulex</i>	2	4	148	148	6	19	123	86	2173	2637	1632	2113	3833	3925
Total cladocera:	1499	964	112659	105415	5671	12379	77695	86012	2206	2686	1687	2168	3866	4006
<i>Asplanchna priodonta</i>	78	32	3045	3498	97	376	1893	1872	621	621	76	174	245	310
<i>Brachionus calyciflorus</i>	0	0	0	21	19	0	0	21	0	0	0	0	0	0
<i>Branchionus angularis</i>	0	0	0	0	0	0	0	0	359	2680	0	0	0	0
<i>Conochilus unicornis</i>	8	6	0	0	106	19	0	0	0	0	0	0	0	0
<i>Euchlanis dilatata</i>	0	0	0	0	0	0	0	21	0	0	0	0	0	0
<i>Filinia terminalis</i>	86	106	0	0	10	0	0	0	33	33	0	65	0	0
<i>Keratella cochlearis</i>	117	62	1769	2325	289	192	905	1317	572	996	207	218	1242	1781
<i>Keratella quadrata</i>	5856	5258	411	473	5906	4566	123	62	278	212	152	163	0	0
<i>Lecane sp.</i>	0	0	21	0	0	0	0	41	16	0	0	0	16	0
<i>Pleosoma lenticulare</i>	0	0	0	0	0	0	0	0	3104	229	174	196	4101	4755
<i>Polyarthra doliochoptera</i>	132	249	782	576	1262	386	1132	1893	1111	964	294	305	523	343
Total rotifers:	6277	5713	6028	6893	7689	5539	4053	5227	6094	5735	903	1121	6127	7189
Hydracarina	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Total other zooplankton:	0	0	0	0	0	0	0	0	0	0	0	0	6	3
Total density/M^3:	7833	6748	118687	112308	13391	17937	81810	91260	8365	8480	2727	3450	10018	11205

Lake sampled:	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater	Coldwater
Sample date:	091092	091092	240393	240393	240393	240393	040893	040893	031093	031093	031093	031093	031093	031093
Sample depth(m):	58-->13	13-->0	30-->7	7-->0	30-->7	7-->0	45-->7	7-->0	55-->0	55-->0	45-->15	45-->15	15-->0	15-->0
Town#(Station#):	1(1)	1(1)	1(1)	2(1)	1(2)	2(2)	1(1)	2(1)	1(1)	2(1)	1(2)	2(2)	1(2)	2(1)
<i>Diaptomus oregonensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4
<i>Diaptomus tyrelli</i>	3	115	107	544	134	694	642	1963	33	42	5	7	113	135
calanoid copepodids	5	288	6	79	4	86	57	1361	41	50	2	11	235	248
cyclopoid copepodids	4	63	0	19	0	0	3	0	35	48	5	24	279	253
nauplii	334	360	1054	5798	491	379	203	1033	762	643	284	284	425	316
Total copepods:	346	826	1167	6440	629	1159	905	4357	871	783	296	326	1052	956
<i>Alonella nana</i>	0	0	0	0	0	0	0	0	1	3	0	0	0	0
<i>Bosmina longirostris</i>	401	1333	19	121	10	188	162	254	75	101	66	66	710	832
<i>Chydorus sphaericus</i>	3	11	0	4	1	0	0	0	5	10	0	0	13	39
<i>Daphnia pulex</i>	186	1255	13	56	8	66	851	2141	864	869	365	461	1011	1002
<i>Daphnia rosea</i>	0	0	0	0	0	0	0	66	43	45	0	0	174	69
<i>Holopedium gibberum</i>	0	0	0	0	0	0	0	0	5	3	0	0	13	9
Total cladocera:	590	2599	32	181	19	254	1013	2461	993	1031	431	527	1921	1951
<i>Asplanchna priodonta</i>	36	922	0	165	0	0	70	211	39	65	0	0	327	370
<i>Euchlanis dilatata</i>	0	0	0	23	0	0	0	0	0	0	5	0	0	0
<i>Filinia terminalis</i>	81	39	3882	8192	1061	5893	403	634	583	348	470	273	359	43
<i>Harringia sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	33	0
<i>Kellicottia longispina</i>	34	39	57	0	36	118	0	0	0	0	0	0	0	0
<i>Keratella cochlearis</i>	317	163	107	304	43	188	216	2793	173	185	60	93	1525	1362
<i>Keratella quadrata</i>	57	33	178	564	71	280	47	70	375	304	60	148	665	261
<i>Lecane sp.</i>	0	7	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepadella sp.</i>	0	0	0	0	0	0	0	23	0	0	0	0	0	0
<i>Polyarthra sp.</i>	0	0	0	0	0	0	170	305	0	0	0	0	0	0
<i>Synchaeta sp.</i>	0	0	0	0	0	0	0	0	223	241	0	38	1732	1841
<i>Trichocerca rattus</i>	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Total rotifers:	531	1203	4224	9248	1211	6479	906	4036	1393	1143	595	552	4641	3877
Chironomidae	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Nematoda	1	0	0	0	0	0	0	0	0	0	2	0	0	0
Ostracod sp.	0	0	0	0	0	0	0	0	3	0	0	7	0	0
Total other zooplankton:	1	0	0	0	0	0	0	0	3	0	4	7	0	0
Total density/M^3:	1468	4628	5423	15869	1859	7892	2824	10854	3260	2957	1326	1412	7614	6784

Lake sampled:	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn
Sample date:	111092	111092	220593	220593	220593	220593	050893	050893	021093	021093	021093	021093
Sample depth(m):	18-->10	10-->0	18-->9	18-->9	9-->0	9-->0	18-->8	8-->0	18-->8	18-->8	8-->0	8-->0
Tow#(Station#):	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	362	416	58	146	275	217	0	132	66	66	55	55
calanoid copepodids	889	525	203	510	1203	1406	39	675	88	22	193	28
<i>Cyclops vernalis</i>	82	0	0	0	29	29	0	477	0	0	55	55
cyclopoid copepodids	148	131	14	49	319	391	26	2403	44	0	248	221
nauplii	5745	197	580	1141	2928	3275	235	5301	525	350	1158	882
Total copepods:	7226	1269	855	1846	4754	5318	300	8988	723	438	1709	1241
<i>Alona costata</i>	0	0	14	24	14	29	0	16	7116	4291	4715	3833
<i>Chydorus sphaericus</i>	0	0	0	0	14	0	13	0	2036	394	1351	3998
<i>Daphnia pulex</i>	905	3810	0	24	0	14	131	461	876	153	4191	3722
<i>Daphnia rosea</i>	231	1730	0	0	14	43	366	2420	22	0	55	28
<i>Eubosmina hagmanni</i>	148	1007	29	146	232	348	13	856	0	0	0	28
<i>Holopedium gibberum</i>	0	0	0	0	0	0	0	88	0	0	0	0
<i>Polyphemus pediculus</i>	0	0	0	0	0	14	0	99	0	0	0	0
Total cladocera:	1284	6547	43	194	274	448	523	3940	10050	4838	10312	11609
<i>Asplanchna priodonta</i>	988	7190	6522	6884	53623	38225	35000	69630	14510	8431	23539	23704
<i>Epiphanes sp.</i>	0	0	0	362	543	181	0	0	65	0	0	82
<i>Filinia longiseta</i>	906	0	126087	113043	105978	75181	1552	329	12222	3856	165	0
<i>Kellicottia longispina</i>	165	0	362	0	906	906	0	576	0	131	247	329
<i>Keratella cochlearis</i>	823	135294	362	725	543	906	2778	1152	1438	392	1564	1810
<i>Keratella quadrata</i>	0	0	362	362	1449	725	0	0	0	65	0	0
<i>Lecane sp.</i>	0	0	0	362	0	0	0	0	0	0	0	0
<i>Polyarthra doliochoptera</i>	82	0	1449	725	7428	3804	0	0	457	327	165	247
<i>Trichocerca rattus</i>	82	0	0	0	0	0	0	82	0	0	82	0
Total rotifers:	3046	142484	135144	122463	170470	119928	39330	71769	28692	13202	25762	26172
<i>Chaoborus</i>	16	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	0	0	14	24	0	0	0	0	0	0	55	0
Hydracarina	0	0	0	0	0	0	0	0	0	22	0	0
Nematoda	0	0	14	24	0	0	13	0	22	0	0	0
Total other zooplankton:	16	0	28	48	0	0	13	0	22	22	55	0
Total density/M^3:	11572	150300	136070	124551	175498	125694	40166	84697	39487	18500	37838	39022

Lake sampled:	Grizzley	Grizzley
Sample date:	180794	180794
Sample depth(m):	6-->0	6-->0
Tow#(Station#):	1(1)	2(1)
calanoid copepodids	8	10
cyclopoid copepodids	5	3
nauplii	33	44
Total copepods:	46	57
<i>Acroperus harpae</i>	3	0
<i>Daphnia rosea</i>	28	16
Total cladocera:	31	16
<i>Filinia sp.</i>	0	11
<i>Kellicottia longispina</i>	33	0
<i>Keratella cochlearis</i>	0	33
<i>Keratella quadrata</i>	975	1989
<i>Lecane sp.</i>	213	120
Total rotifers:	1221	2153
Chaoborus	43	38
Chironomidae	7	7
Nematoda	0	2
Ostracod sp.	21	31
Tardigrada	0	2
Total other zooplankton:	71	80
Total density/M^3:	1369	2306

Lake sampled:	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford	Hanaford
Sample date:	111092	111092	220593	220593	220593	220593	050893	050893	021093	021093	021093	021093
Sample depth(m):	17-->8	8-->0	17-->8	17-->8	8-->0	8-->0	14-->8	8-->0	13-->8	13-->8	8-->0	8-->0
Tow#(Station#):	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	15	25	36	65	107	140	120	16	4	118	148	181
<i>Diaptomus shoshone</i>	0	0	43	80	823	1366	514	45	0	33	17	49
calanoid copepodids	15	0	7	29	132	0	295	144	35	373	412	691
<i>Cyclops vernalis</i>	0	0	0	0	0	0	0	29	0	0	0	0
cyclopoid copepodids	0	0	0	0	0	0	0	0	0	0	0	16
nauplii	36	329	36	36	206	123	55	144	45	98	82	164
Total copepods:	66	354	122	210	1268	1629	984	378	84	622	659	1101
<i>Bosmina longirostris</i>	0	0	15	0	107	41	0	198	1	7	0	0
<i>Ceriodaphnia reticulata</i>	0	0	0	0	0	0	0	663	0	0	0	0
<i>Chydorus sphaericus</i>	0	0	36	36	41	453	0	0	0	0	0	0
<i>Daphnia pulex</i>	7	74	65	101	255	222	1279	0	54	699	206	346
<i>Daphnia rosea</i>	109	91	29	29	148	156	1213	206	29	392	1160	1465
<i>Holopedium gibberum</i>	413	3482	43	138	2321	1177	1126	0	150	2216	6305	7358
<i>Pleuroxis denticulatus</i>	0	0	0	0	0	0	0	0	2	46	0	0
Total cladocera:	529	3647	188	304	2872	2049	3618	1067	236	3360	7671	9169
<i>Asplanchna priodonta</i>	73	41	0	0	0	0	0	0	0	0	0	0
<i>Filinia longiseta</i>	0	0	36	0	0	0	0	21	30	65	41	0
<i>Kellicottia longispina</i>	36	0	0	0	0	0	0	0	0	0	0	0
<i>Keratella cochlearis</i>	1486	3621	2355	7283	13416	19918	6776	15165	391	2059	3086	3498
<i>Keratella quadrata</i>	0	0	1522	1232	0	0	0	0	0	0	0	0
<i>Polyarthra major</i>	73	617	0	0	0	0	0	0	0	0	0	0
<i>Trichocerca rattus</i>	0	0	0	36	41	0	0	0	15	33	0	0
Total rotifers:	1668	4279	3913	8551	13457	19918	6776	15186	436	2157	3127	3498
Chironomidae	0	0	0	0	0	8	0	4	0	7	0	0
Hydracarina	7	0	0	0	0	0	0	0	0	0	0	0
Nematoda	7	0	0	0	8	0	0	0	1	0	0	0
Total other zooplankton:	14	0	0	0	8	8	0	4	1	7	0	0
Total density/M^3:	2277	8280	4223	9065	17605	23604	11378	16635	757	6146	11457	13768

Lake sampled:	June	June	June	June	June	June
Sample date:	280593	280593	090993	090993	171093	171093
Sample depth(m):	1.5-->0	1.5-->0	1.5-->0	1.5-->0	1.5-->0	1.5-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	0	0	13	0	7	13
calanoid copepids	0	0	7	0	7	7
<i>Cyclops varicans rubellus</i>	0	0	60	73	73	27
<i>Cyclops vernalis</i>	44	11	0	0	0	7
<i>Eucyclops agilis</i>	433	89	0	0	0	0
cyclopoid copepids	178	44	87	127	93	33
nauplii	1278	667	667	222	111	0
Total copepods:	1933	811	834	422	291	87
<i>Alona costata</i>	0	0	0	0	7	0
<i>Ceriodaphnia quadrangula</i>	0	0	13	0	7	13
<i>Ceriodaphnia reticulata</i>	0	0	0	0	0	0
<i>Chydorus bicornutus</i>	0	0	222	222	0	0
<i>Chydorus sphaericus</i>	189	44	1222	1889	13000	1333
<i>Eubosmina hagmanni</i>	0	0	0	0	0	111
Total cladocera:	189	44	1457	2111	13014	1457
<i>Gastropus minor</i>	0	0	333	0	0	0
<i>Kellicottia longispina</i>	0	0	444	445	111	0
<i>Keratella cochlearis</i>	167	56	222	0	333	0
<i>Keratella quadrata</i>	0	111	111	111	333	0
<i>Polyarthra</i> sp.	0	0	0	0	222	0
Total rotifers:	167	167	1110	556	999	0
Chironomidae	2833	5555	3667	1889	778	778
Collembola	11	0	111	0	0	0
Hydracarina	22	22	778	333	333	222
Nematoda	11	11	111	0	0	0
Ostracod sp.	89	22	0	2	7	0
Trichoptera larvae	0	22	0	0	0	0
Total other zooplankton:	2966	5632	4667	2224	1118	1000
Total density/M^3:	5255	6654	8068	5313	15422	2544

Lake sampled:	McBride	McBride	McBride	McBride	McBride	McBride
Sample date:	290593	290593	080993	080993	171093	171093
Sample depth(m):	2-->0	2-->0	2-->0	2-->0	2-->0	2-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	5	20	275	383	1567	300
calanoid copepodids	0	0	342	950	350	445
<i>Cyclops varicans rubellus</i>	0	20	0	0	0	0
cyclopoid copepodids	25	30	42	42	33	20
nauplii	0	0	92	225	917	750
Total copepods:	30	70	751	1600	2867	1515
<i>Alona costata</i>	0	0	0	0	17	0
<i>Ceriodaphnia quadrangula</i>	0	0	667	1533	2100	765
<i>Chydorus sphaericus</i>	0	0	0	0	8	10
<i>Daphnia rosea</i>	5	0	1825	3300	33	25
<i>Eubosmina hagmanni</i>	0	0	0	0	0	10
<i>Holopedium gibberum</i>	0	0	0	0	8	10
<i>Sida crystallina</i>	5	10	0	0	0	0
Total cladocera:	10	10	2492	4833	2166	820
<i>Conochilus unicornis</i>	0	0	3000	6417	250	417
<i>Kellicottia longispina</i>	0	0	1667	583	0	83
<i>Keratella cochlearis</i>	0	0	0	0	250	0
<i>Keratella quadrata</i>	0	0	83	0	167	0
<i>Monostyla lunaris</i>	0	0	0	0	83	0
<i>Polyarthra</i> sp.	0	0	6250	20833	1583	1667
<i>Trichocerca rattus</i>	0	0	0	0	167	167
Total rotifers:	0	0	11000	27833	2500	2334
Chaoborus	0	0	0	92	0	0
Chironomidae	5	35	8	25	0	0
Hydracarina	5	5	0	0	0	0
Nematoda	0	0	0	8	8	0
Ostracod sp.	305	485	0	0	25	5
Total other zooplankton:	315	525	8	125	33	5
Total density/M^3:	355	605	14251	34391	7566	4674

Lake sampled:	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill
Sample date:	170493	170493	170493	170493	170493	170493	170493	170493
Sample depth(m):	25-->10	25-->10	10-->0	10-->0	28-->10	28-->10	10-->0	10-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(2)	2(2)	1(2)	2(2)
<i>Diaptomus franciscanus</i>	617	1151	7817	6366	348	255	4335	3547
calanoid copepids	294	1076	18173	14863	769	605	16969	10926
<i>Cyclops vernalis</i>	0	0	0	0	0	0	0	0
cyclopoid copepids	4	2	44	0	0	22	22	44
nauplii	434	536	13728	9935	428	1719	12984	10378
Total copepods:	1349	2765	39762	31164	1545	2601	34310	24895
<i>Alona costata</i>	0	0	0	0	0	7	0	0
<i>Bosmina longirostris</i>	11	5	109	39	2	0	66	44
<i>Ceriodaphnia lacustris</i>	2	2	44	65	3	0	0	0
<i>Chydorus sphaericus</i>	0	0	0	0	2	0	0	0
<i>Daphnia pulex</i>	35	9	1117	627	24	15	722	372
<i>Daphnia rosea</i>	11	2	219	65	0	7	132	241
<i>Holopedium gibberum</i>	2	0	131	118	11	29	591	525
<i>Polyphemus pediculus</i>	0	0	0	0	0	0	0	0
Total cladocera:	61	18	1620	914	42	58	1511	1182
<i>Asplanchna herricki</i>	11	44	33	0	0	0	33	163
<i>Epiphanes sp.</i>	11	11	0	0	0	0	0	0
<i>Euchlanis dilatata</i>	0	0	0	0	0	0	0	0
<i>Kellicottia bostoniensis</i>	87	490	5229	5947	674	783	6716	5098
<i>Kellicottia longispina</i>	33	98	82	82	55	64	163	0
<i>Keratella cochlearis</i>	0	11	0	0	0	0	0	0
<i>Keratella quadrata</i>	0	0	0	0	0	0	0	0
<i>Lecane sp.</i>	0	0	0	0	0	0	0	0
<i>Polyarthra vulgaris</i>	0	0	0	0	0	0	0	0
<i>Trichocerca ruttus</i>	0	0	0	0	0	0	0	0
Total rotifers:	142	654	5344	6029	729	847	6912	5261
Chironomidae	0	0	0	0	0	0	44	22
Hydracarina	0	0	0	0	0	0	0	0
Total other zooplankton:	0	0	0	0	0	0	44	22
Total density/M^3:	1552	3437	46726	38107	2316	3506	42777	31360

Lake sampled:	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill
Sample date:	080993	080993	080993	080993	080993	080993	080993	080993
Sample depth(m):	10-->4	10-->4	4-->0	4-->0	12-->4	12-->4	4-->0	4-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(2)	2(2)	1(2)	2(2)
<i>Diaptomus franciscanus</i>	164	322	1398	1268	414	231	618	715
calanoid copepodids	453	377	5626	5138	1185	724	1984	2601
<i>Cyclops vernalis</i>	66	82	33	98	83	16	0	0
cyclopoid copepodids	355	415	813	1268	607	313	293	293
nauplii	317	219	2992	3610	2840	1235	3187	2894
Total copepods:	1355	1415	10862	11382	5129	2519	6082	6503
<i>Alona costata</i>	0	0	0	0	0	0	0	0
<i>Bosmina longirostris</i>	5	5	98	163	0	16	0	33
<i>Ceriodaphnia lacustris</i>	77	87	195	325	83	99	260	358
<i>Chydorus sphaericus</i>	0	0	0	0	28	0	0	0
<i>Daphnia pulex</i>	268	629	3025	3967	1737	889	3220	4228
<i>Daphnia rosea</i>	60	164	260	358	138	49	325	65
<i>Holopedium gibberum</i>	508	645	1659	976	1048	428	1724	2406
<i>Polyphemus pediculus</i>	0	0	0	0	0	0	0	0
Total cladocera:	918	1530	5237	5789	3034	1481	5529	7090
<i>Asplanchna herricki</i>	1803	1175	651	935	4342	4362	3699	732
<i>Epiphanes sp.</i>	0	0	0	0	0	0	0	0
<i>Euchlanis dilatata</i>	0	0	0	0	0	0	0	0
<i>Kellicottia bostoniensis</i>	4973	5437	29106	19471	6070	5370	15854	15203
<i>Kellicottia longispina</i>	1230	793	2439	1382	535	576	1463	1098
<i>Keratella cochlearis</i>	109	55	203	81	41	0	0	41
<i>Keratella quadrata</i>	27	0	0	0	0	0	0	0
<i>Lecane sp.</i>	0	0	0	0	0	0	0	0
<i>Polyarthra vulgaris</i>	27	27	0	41	82	103	41	41
<i>Trichocerca rattus</i>	27	0	41	0	21	41	0	0
Total rotifers:	8196	7487	32440	21910	11091	10452	21057	17115
Chironomidae	0	0	0	0	0	0	0	0
Hydracarina	0	0	0	0	0	0	0	0
Total other zooplankton:	0	0	0	0	0	0	0	0
Total density/M^3:	10469	10432	48539	39081	19254	14452	32668	30708

Lake sampled:	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill	Merrill
Sample date:	161093	161093	161093	161093	161093	161093	161093	161093
Sample depth(m):	9-->4	9-->4	4-->0	4-->0	11-->4	11-->4	4-->0	4-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(2)	2(2)	1(2)	2(2)
<i>Diaptomus franciscanus</i>	811	523	2179	2114	638	488	2146	2179
calanoid copepodids	2928	1856	7805	7512	2310	1784	7643	7642
<i>Cyclops vernalis</i>	0	0	0	33	0	0	65	33
cyclopoid copepodids	445	288	1073	1366	432	582	1106	715
nauplii	1307	1856	3187	5106	939	1127	3577	3968
Total copepods:	5491	4523	14244	16131	4319	3981	14537	14537
<i>Alona costata</i>	0	0	0	0	0	0	0	0
<i>Bosmina longirostris</i>	78	52	325	585	94	150	325	325
<i>Ceriodaphnia lacustris</i>	3216	2458	6211	8260	1916	1671	4683	5073
<i>Chydorus sphaericus</i>	0	0	0	0	0	0	0	0
<i>Daphnia pulex</i>	209	340	2081	2081	451	225	1041	1073
<i>Daphnia rosea</i>	0	26	98	0	37	0	130	98
<i>Holopedium gibberum</i>	209	288	1659	1626	319	413	1919	2602
<i>Polyphemus pediculus</i>	0	0	0	0	0	0	0	33
Total cladocera:	3712	3164	10374	12552	2817	2459	8098	9204
<i>Asplanchna herricki</i>	1765	882	4065	4025	775	775	3943	3090
<i>Epiphanes sp.</i>	0	0	0	0	0	0	0	0
<i>Euchlanis dilatata</i>	0	98	0	0	0	0	0	0
<i>Kellicottia bostoniensis</i>	33	33	41	325	23	23	203	163
<i>Kellicottia longispina</i>	0	0	0	0	0	0	0	0
<i>Keratella cochlearis</i>	65	98	122	0	0	0	0	0
<i>Keratella quadrata</i>	0	0	0	0	0	0	0	0
<i>Lecane sp.</i>	0	33	41	0	0	0	0	0
<i>Polyarthra vulgaris</i>	0	33	203	81	23	23	163	41
<i>Trichocerca rattus</i>	0	0	41	122	0	0	0	0
Total rotifers:	1863	1177	4513	4553	821	821	4309	3294
Chironomidae	0	0	0	0	19	19	33	0
Hydracarina	0	0	0	33	0	0	0	0
Total other zooplankton:	0	0	0	0	19	19	33	0
Total density/M^3:	11066	8864	29131	33236	7976	7280	26977	27035

Lake sampled:	Meta	Meta	Meta	Meta	Meta	Meta	Meta	Meta	Meta	Meta	Meta	Meta
Sample date:	170693	170693	170693	170693	260893	260893	260893	260893	091093	091093	091093	091093
Sample depth(m):	7.5-->4	7.5-->4	4-->0	4-->0	7.5-->4	7.5-->4	4-->0	4-->0	8-->4	8-->4	4-->0	4-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus tyrelli</i>	106	647	1691	1130	269	389	870	1707	63	312	4203	4033
calanoid copepids	94	658	1854	2618	961	908	4016	2594	0	24	32	57
cyclopoid copepids	61	42	130	236	37	139	90	187	0	2	24	24
nauplii	509	787	3455	3212	1343	1389	3943	2927	0	0	0	203
Total copepods:	770	2134	7130	7196	2610	2825	8919	7415	63	338	4259	4317
<i>Bosmina longirostris</i>	0	3	0	16	0	0	0	0	0	0	0	0
<i>Ceriodaphnia lacustris</i>	0	0	0	0	759	574	1553	2894	10	37	594	472
<i>Daphnia pulex</i>	11	8	16	0	65	65	171	358	39	71	870	796
<i>Daphnia rosea</i>	0	0	0	24	1241	1130	2629	5745	51	85	1065	943
<i>Diaphanosoma brachyurum</i>	0	0	0	0	759	639	1314	2873	0	0	0	0
<i>Eubosmina hagmanni</i>	0	0	0	0	74	83	41	154	0	0	0	0
<i>Holopedium gibberum</i>	31	150	374	295	0	37	73	114	20	63	829	683
Total cladocera:	42	161	390	335	2898	2528	5781	12138	120	256	3358	2894
<i>Conochilus unicornis</i>	139	324	1788	2927	185	417	2480	1544	0	0	285	81
<i>Kellicottia longispina</i>	46	0	0	0	130	0	0	122	0	0	0	0
<i>Keratella cochlearis</i>	1204	833	1423	1748	37824	52361	9919	13496	1382	1951	10610	7398
<i>Keratella quadrata</i>	34305	11898	5488	8293	1574	1065	203	81	203	122	122	81
<i>Lecane sp.</i>	0	93	41	0	0	0	0	0	0	0	0	0
<i>Monostyla lunaris</i>	0	0	0	0	0	0	163	122	0	0	0	0
<i>Polyarthra major</i>	2917	4769	5122	16463	2361	2268	1585	1423	41	122	935	935
<i>Synchaeta sp.</i>	93	0	0	81	0	0	0	0	0	0	0	0
<i>Trichocerca rattus</i>	0	0	0	0	556	1204	1301	1504	0	0	0	0
Total rotifers:	38704	17917	13862	29512	42630	57315	15651	18292	1628	2195	11952	8495
Chaoborus	0	0	0	0	0	0	0	0	7	0	8	0
Chironomidae	0	0	0	0	0	0	0	0	41	0	0	0
Hydracarina	0	0	0	0	0	0	0	0	0	2	0	0
Nematoda	8	0	0	0	0	0	0	0	773	1098	0	0
Ostracod sp.	0	0	0	8	0	0	0	0	7	7	0	0
Total other zooplankton:	8	0	0	8	0	0	0	0	828	1107	8	0
Total density/M^3:	39524	20212	21382	37051	48138	62668	30351	37845	2637	3896	19577	15706

Lake sampled:	Obscurity	Obscurity	Obscurity	Obscurity
Sample date:	200794	200794	200794	200794
Sample depth(m):	13-->5	13-->5	5-->0	5-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)
<i>Cyclops vernalis</i>	370	238	183	170
cyclopoid copepodids	1992	3519	1928	1454
nauplii	10782	16626	1307	1046
Total copepods:	13144	20383	3418	2670
<i>Holopedium gibberum</i>	0	0	13	0
Total cladocera:	0	0	13	0
<i>Kellicottia longispina</i>	271193	316954	139216	183791
<i>Keratella cochlearis</i>	1728	741	1700	784
<i>Keratella quadrata</i>	140658	171769	12680	13333
Total rotifers:	413579	489464	153596	197908
Chironomidae	0	0	0	3
Ostracod sp.	0	4	0	0
Total other zooplankton:	0	4	0	3
Total density/M^3:	426723	509851	157027	200581

Lake sampled:	Panhandle	Panhandle	Panhandle	Panhandle	Panhandle	Panhandle	Panhandle	Panhandle	Panhandle	Panhandle
Sample date:	Sept '92	Sept '92	140893	140893	140893	140893	190794	190794	190794	190794
Sample depth(m):	17-->6	6-->0	18-->10	18-->10	10-->0	10-->0	17-->4	17-->4	4-->0	4-->0
Tow#(Station#):	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	0	12	0	0	0	0	0	0	0	0
<i>Diaptomus kenai</i>	0	0	0	0	0	0	2	0	0	0
<i>Cyclops vernalis</i>	36	1780	637	601	55	55	39	188	5	5
<i>Eucyclops agilis</i>	0	0	0	0	0	0	0	0	0	0
<i>Orthocyclops modestus</i>	0	0	0	0	0	0	0	0	0	0
cyclopoid copepodids	89	2137	2310	2357	82	82	136	442	15	15
harpacticoid copep	0	0	0	0	0	0	0	0	2	2
nauplii	685	3631	4018	4018	301	246	51	732	5	5
Total copepods:	810	7560	6965	6976	438	383	228	1362	27	27
<i>Holopedium gibberum</i>	3649	0	0	0	192	290	4	3	15	15
Total cladocera:	3649	0	0	0	192	290	4	3	15	15
<i>Conochilus unicornis</i>	8839	327	0	0	1749	5355	0	0	81	122
<i>Filinia longiseta</i>	149	432	0	0	0	0	51	530	81	447
<i>Kellicottia longispina</i>	9405	5610	228125	130952	33825	27350	1465	1591	3171	4146
<i>Keratella cochlearis</i>	38185	4345	6845	4911	3197	2951	278	0	4024	3983
<i>Keratella quadrata</i>	714	2649	130208	61310	328	301	71288	75152	5772	28171
<i>Polyarthra vulgaris</i>	327	312	595	0	410	574	0	51	325	447
<i>Conochilus sp(2)</i>	0	0	0	0	0	0	0	0	285	203
Total rotifers:	57619	13675	365773	197173	39509	36531	73082	77324	13739	37519
Chironomidae	0	0	6	0	5	5	0	0	0	0
Nematoda	0	0	0	0	0	0	0	0	2	0
Total other zooplankton:	0	0	6	0	5	5	0	0	2	0
Total density/M^3:	62078	21235	372744	204149	40144	37209	73314	78689	13783	37561

Lake sampled:	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan	Ryan
Sample date:	170693	170693	170693	170693	240893	240893	240893	240893	091093	091093	091093	091093
Sample depth(m):	7-->4	7-->4	4-->0	4-->0	7-->4	7-->4	4-->0	4-->0	7-->4	7-->4	4-->0	4-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus franciscanus</i>	1828	1645	5366	3675	6	639	534	780	577	668	5610	5577
calanoid copepodids	7290	3645	23122	25333	13	348	461	973	184	277	1057	1130
cyclopoid copepodids	0	11	0	0	0	0	0	5	0	0	0	0
nauplii	3817	2204	21545	15244	0	107	407	244	1559	645	7276	5122
Total copepods:	12935	7505	50033	44252	19	1094	1402	2002	2320	1590	13943	11829
<i>Alona costata</i>	0	0	33	49	0	0	0	0	0	0	0	0
<i>Chydorus sphaericus</i>	0	0	0	0	0	0	0	0	0	54	0	0
<i>Daphnia rosea</i>	172	76	813	650	13	103	93	390	48	52	171	114
<i>Diaphanosoma brachyurum</i>	0	0	25	25								
Total cladocera:	172	76	846	699	13	103	93	390	48	106	171	114
<i>Filinia sp.</i>	0	0	0	0	54	0	0	0	0	0	0	0
<i>Kellicottia longispina</i>	0	0	0	0	0	0	0	41	0	0	0	0
<i>Keratella cochlearis</i>	4570	4247	53902	37276	215	54	0	0	1021	484	3821	5081
<i>Keratella quadrata</i>	0	54	0	0	0	0	0	0	430	215	163	569
<i>Lecane sp.</i>	0	0	244	122	0	0	0	0	0	0	0	0
<i>Platylabus quadricornis</i>	0	0	0	0	0	0	0	0	0	54	0	0
<i>Polyarthra doliochoptera</i>	0	0	0	285	0	0	0	0	0	0	41	163
Total rotifers:	4570	4301	54146	37683	269	54	0	41	1451	753	4025	5813
Chaoborus	32	21	44	59	0	13	29	73	23	35	307	261
Chironomidae	0	0	0	0	0	0	0	2	0	0	0	0
Hydracarina	0	0	0	0	0	0	0	0	0	3	0	0
Nematoda	11	11	0	0	0	0	0	0	376	1183	0	0
Total other zooplankton:	43	32	44	59	0	13	29	75	399	1221	307	261
Total density/M^3:	17720	11914	105069	82693	301	1264	1524	2508	4218	3670	18446	18017

Lake sampled:	Shovel	Shovel	Shovel	Shovel
Sample date:	210794	210794	210794	210794
Sample depth(m):	25-->5	25-->5	5-->0	5-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)
<i>Cyclops vernalis</i>	163	3219	10	0
cyclopoid copepodids	1451	363	31	0
nauplii	882	1258	98	0
Total copepods:	2496	4840	139	0
Total cladocera:	0	0	0	0
<i>Filinia sp.</i>	25	8	0	0
<i>Kellicottia longispina</i>	0	0	98	33
<i>Keratella cochlearis</i>	17	0	849	980
<i>Keratella quadrata</i>	2990	2582	359	33
Total rotifers:	3032	2590	1306	1046
Chironomidae	3	0	0	0
Total other zooplankton:	3	0	0	0
Total density/M^3:	5531	7430	1445	1046

Lake sampled:	Snow	Snow	Snow	Snow
Sample date:	160994	160994	160994	160994
Sample depth(m):	8-->4	8-->4	4-->0	4-->0
Tow#(Station#):	1(1)	2(1)	1(1)	2(1)
<i>Eucyclops agilis</i>	0	0	0	2
cyclopoid copepodids	28	172	93	93
nauplii	1301	5528	976	655
Total copepods:	1329	5700	1007	750
<i>Daphnia rosea</i>	22	22	7	27
Total cladocera:	22	22	7	27
<i>Keratella cochlearis</i>	401951	72846	154797	280651
<i>Keratella quadrata</i>	651	651	0	488
<i>Polyarthra sp.</i>	1789	0	976	976
Total rotifers:	404391	73497	155773	282115
Chaoborus	149	0	166	180
Chironomidae	2	7	0	0
Hydracarina	2	2	0	0
Mayfly larvae	0	2	0	0
Nematoda	2	15	0	2
Ostracod sp.	5	78	5	7
Total other zooplankton:	160	104	171	189
Total density/M^3:	405742	79219	156787	283081

Lake sampled:	St. Helens	St. Helens	St. Helens	St. Helens	St. Helens	St. Helens	St. Helens	St. Helens	St. Helens
Sample date:	Sept '92	100893	100893	100893	100893	190794	190794	190794	190794
Sample depth(m):	50-->10	65-->15	65-->15	15-->0	15-->0	50-->7	75-->7	7-->0	7-->0
Tow#(Station#):	1(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus kenai</i>	962	258	297	536	723	223	208	516	573
calanoid copepodids	0	130	160	457	471	146	109	1085	1014
cyclopoid copepodids	0	0	0	0	2	0	0	0	0
nauplii	49	3	16	11	131	42	12	0	47
Total copepods:	1011	391	473	1004	1327	411	329	1601	1634
<i>Daphnia pulex</i>	1024	28	20	33	61	68	45	66	51
<i>Daphnia rosea</i>	0	0	0	20	0	8	24	108	75
<i>Eubosmina hagmanni</i>	49	0	11	9	9	3	4	14	14
<i>Holopedium gibberum</i>	172	23	33	50	137	2	2	263	310
<i>Scapholeberis mucronata</i>	0	0	0	7	0	0	0	0	0
<i>Simocephalus aurita</i>	0	1	1	0	0	0	0	0	0
Total cladocera:	1245	52	65	119	207	81	75	451	450
<i>Conochilus unicomis</i>	8034	0	0	5044	2255	0	0	892	1033
<i>Kellicottia longispina</i>	8	102	115	1863	2004	0	0	0	0
<i>Keratella cochlearis</i>	0	13	10	44	65	4	0	94	47
<i>Keratella quadrata</i>	16	7	16	163	120	0	0	0	0
<i>Lecane sp.</i>	0	0	0	54	11	0	0	0	0
<i>Polyarthra vulgaris</i>	0	0	0	54	65	0	0	47	0
<i>Conochilus sp(2)</i>	0	0	0	0	0	0	0	751	657
Total rotifers:	8058	122	141	7222	4520	4	0	1784	1737
Chaoborus	0	0	0	0	0	0	0	5	0
Chironomidae	0	1	0	2	0	0	0	0	0
FW Oligochaete	0	1	0	0	0	0	0	0	0
Nematoda	0	1	0	0	0	0	0	0	0
Total other zooplankton:	0	3	0	2	0	0	0	5	0
Total density/M^3:	10314	568	679	8347	6054	496	404	3841	3821

Lake sampled:	Venus	Venus	Venus	Venus	Venus	Venus	Venus	Venus	Venus	Venus
Sample date:	Sept '92	Sept '92	100893	100893	100893	100893	160994	160994	160994	160994
Sample depth(m):	25-->10	10-->0	38-->12	38-->12	12-->0	12-->0	23-->11	23-->11	11-->0	11-->0
Tow#(Station#):	1(1)	1(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)	1(1)	2(1)
<i>Diaptomus kenai</i>	135	1431	443	740	617	547	104	164	625	661
calanoid copepodids	309	163	1565	2818	672	339	1672	3891	30	6
cyclopoid copepodids	0	0	0	15	0	0	0	11	0	0
nauplii	0	327	226	629	109	27	0	0	0	0
Total copepods:	444	1921	2234	4202	1398	913	1776	4066	655	667
<i>Daphnia pulex</i>	0	20	0	0	0	0	5	22	0	0
<i>Daphnia rosea</i>	0	0	0	0	0	0	27	11	6	6
<i>Eubosmina hagmanni</i>	2	7	30	10	0	0	0	0	0	0
<i>Holopedium gibberum</i>	85	1039	287	1127	1951	5891	317	404	3119	2381
Total cladocera:	87	1066	317	1137	1951	5891	349	437	3125	2387
<i>Conochilus unicornis</i>	218	10131	2214	6289	12240	465	3115	1311	32679	30357
<i>Kellicottia bostoniensis</i>	2941	490	11472	20063	820	96	0	0	0	0
<i>Kellicottia longispina</i>	53922	7516	17208	30440	519	260	1311	1093	60	0
<i>Keratella cochlearis</i>	71460	479412	1006	755	1066	1093	157377	168142	105179	98929
<i>Keratella quadrata</i>	218	0	3748	6855	55	27	0	0	0	60
<i>Lecane sp.</i>	0	0	0	63	0	0	0	0	0	0
<i>Polyarthra sp.</i>	0	817	0	1321	191	82	0	0	0	60
Total rotifers:	128759	498366	35648	65786	14891	2023	161803	170546	137918	129406
Chironomidae	0	0	0	0	0	0	0	0	6	0
Nematoda	0	0	0	0	5	0	0	0	0	0
Total other zooplankton:	0	0	0	0	5	0	0	0	6	0
Total density/M^3:	129290	501353	38199	71125	18240	8827	163928	175049	141698	132460

Appendix B

Quality Assurance

Venus	161094 Std Error Epi 2(1)		Std Error	
	Allan		Larry	
<i>Daphnia rosea</i>	0	0	11	8
<i>D. pulicaria</i>	52	27	22	11
<i>Holopedium gibberum</i>	419	74	404	47
total				
cladocerans	472	79	437	49
<i>Diaptomus kenai</i>	144	43	164	30
diaptomus copepodids	4310	238	3891	146
<i>Cyclops</i>				
<i>varicans rubellus</i>	26	19	0	0
cyclopoid copepodids	0	0	11	8
copepod nauplii	65	29	0	0
total				
copepods	4545	244	4066	150
<i>Kellicottia bostoniensis</i>	838	210	0	0
<i>K. longispina</i>	0	0	1093	251
<i>Keratella cochlearis</i>	50563	1628	168142	3031
<i>Conochilus unicornis</i>	0	0	1311	268
total				
rotifers	51401	1641	170546	3056
Total	56418	1528	175049	2793

St. Helens	190794 Std Error Epi 1(1)		Std Error	
	Allan		Larry	
<i>Daphnia rosea</i>	135	22	108	23
<i>D. pulicaria</i>	0	0	66	18
<i>Eubosmina hagmanni</i>	22	9	14	8
<i>Holopedium gibberum</i>	314	34	263	35
total				
cladocerans	472	42	451	46
<i>Diaptomus kenai</i>	49	13	516	49
diaptomus copepodids	1134	65	1085	71
copepod nauplii	97	19	0	0
total				
copepods	1280	69	1601	87
<i>Keratella cochlearis</i>	127	15	94	47
<i>Polyarthra vulgaris</i>	14	6	47	33
<i>Conochilus unicornis</i>	610	34	892	145
<i>C. sp. 2</i>	139	20	751	133
total				
rotifers	890	42	1784	205
<i>Chaoborus</i>	0	0	5	5
Total	2641	87	3841	169

Snow	161094 Std Error Epi 2(1) Std Error			
	Allan	Larry		
<i>Daphnia rosea</i>	49	11	27	8
<i>Scapholeberis kingi</i>	5	3	0	0
<i>Bosmina longirostris</i>	12	5	0	0
total				
cladocerans	66	13	27	8
<i>Cyclops</i>				
<i>varicans rubellus</i>	103	16	0	0
<i>Eucyclops agilis</i>	0	0	2	2
cyclopoid copepodids	61	12	93	15
copepod nauplii	270	26	655	328
total				
copepods	435	33	750	113
<i>Polyarthra doliochoptera</i>	0	0	976	398
<i>Keratella cochlearis</i>	96692	2880	280651	6755
<i>K. quadrata</i>	0	0	488	282
<i>Synchaeta sp.</i>	201	46	0	0
total				
rotifers	96893	2862	282115	6765
<i>Cypridopsis vidua</i>	5	3	7	4
<i>Chaoborus</i>	160	20	180	21
Chironomid larvae	27	8	0	0
Hydracarina	3	2	0	0
Nematode	12	5	2	1
FW Oligochaete	10	5	0	0
Total	97588	2573	283313	6550

Ryan	170693 Std Error Epi 2(1) Std Error			
	Allan	Larry		
<i>Diaphanosoma</i>				
<i>brachyurum</i>	79	79	25	25
<i>Daphnia rosea</i>	550	208	650	145
<i>Bosmina longirostris</i>	79	79	0	0
<i>Alona costata</i>	157	111	49	35
total				
cladocerans	865	261	724	151
<i>Diaptomus franciscanus</i>	5030	629	3675	346
diaptomus copepodids	23814	1368	25333	908
copepod nauplii	20906	1282	15244	787
total				
copepods	49751	1977	44252	1243
<i>Keratella cochlearis</i>	13931	599	32276	1066
<i>Polyarthra doliochoptera</i>	138	69	285	108
<i>Synchaeta sp.</i>	20	20	0	0
<i>Lecane sp.</i>	0	0	122	70
total				
rotifers	14088	603	37683	1238
<i>Chaoborus</i>	52	11	59	12
Mosquito larvae	7	4	0	0
Total	64762	1859	82721	1711

Panhandle	190794	Std Error	Epi 2(1)	Std Error
	Allan		Larry	
<i>Holopedium gibberum</i>	29	9	15	6
<i>Chydorus sphaericus</i>	2	2	0	0
total				
cladocerans	31	9	15	6
<i>Cyclops vernalis</i>	7	4	5	4
cyclopoid copepodids	17	6	15	6
harpacticoid copepodids	2	2	2	2
copepod nauplii	22	7	5	4
total				
copepods	49	11	27	8
<i>Kellicottia bostoniensis</i>	1827	134	0	0
<i>Kellicottia longispina</i>	0	0	4146	411
<i>Keratella cochlearis</i>	1523	122	3983	402
<i>K. quadrata</i>	9304	302	28171	1070
<i>Polyarthra vulgaris</i>	403	63	447	135
<i>Synchaeta sp.</i>	29	17	0	0
<i>Filinia longiseta</i>	59	24	447	135
<i>Conochilus unicornis</i>	49	21	122	70
<i>C. sp. 2</i>	0	0	203	91
total				
rotifers	13194	360	37519	1235
Total	13275	358	37561	1225

Meta	170693	Std Error	Epi 2(1)	Std Error
	Allan		Larry	
<i>Diaphnosoma</i>				
<i>brachyurum</i>	39	20	0	0
<i>Daphnia rosea</i>	39	20	24	14
<i>Ceriodaphnia</i>				
<i>pulchella</i>	10	10	0	0
<i>Eubosmina hagmanni</i>	10	10	16	11
<i>Holopedium gibberum</i>	481	69	295	60
total				
cladocerans	580	75	335	62
<i>Diaptomus tyrelli</i>	531	72	1130	76
diaptomus copepodids	2545	158	2618	116
cyclopoid copepodids	177	42	236	44
copepod nauplii	2053	142	3212	361
total				
copepods	5305	228	7196	247
<i>Keratella cochlearis</i>	3095	174	1748	267
<i>K. quadrata</i>	462	67	8293	581
<i>Polyarthra major</i>	1670	128	16463	818
<i>Synchaeta sp.</i>	4166	202	81	57
<i>Conochilus unicornis</i>	835	91	2927	345
unidentified rotifer	88	29	0	0
total				
rotifers	10316	318	29512	1095
<i>Cypridopsis vidua</i>	10	10	8	8
Total	16210	399	37051	929

Merrill	161093	Std Error	Epl 2(1)	Std Error
	Allan		Larry	
<i>Daphanosoma brachyurum</i>	79	79	0	0
<i>Daphnia rosea</i>	1808	377	0	0
<i>D. pulicaria</i>	236	136	2081	260
<i>Ceriodaphnia quadrangularis</i>	9982	886	8260	518
<i>Bosmina longirostris</i>	943	272	585	138
<i>Holopedium gibberum</i>	1650	360	1626	230
total				
cladocerans	14697	1075	12552	639
<i>Diaptomus franciscanus</i>	2987	484	2114	242
diaptomus copepodids	8410	813	7512	470
<i>Cyclops varicans rubellus</i>	157	111	0	0
<i>C. vernalis</i>	0	0	33	19
<i>Eucyclops agilis</i>	79	79	0	0
<i>Macrocyclus albidus</i>	314	157	0	0
cyclopoid copepodids	629	222	1366	206
copepod nauplii	4008	561	5106	408
total				
copepods	16584	1142	16131	1129
<i>Asplanchna herricki</i>	236	136	4025	403
<i>Kellicottia bostoniensis</i>	5	3	325	115
<i>Keratella cochlearis</i>	255	77	0	0
<i>Keratella quadrata</i>	5	3	0	0
<i>Polyarthra vulgaris</i>	34	9	81	57
<i>P. major</i>	2	2	0	0
<i>Synchaeta</i> sp.	20	7	0	0
<i>Conochilus</i> sp.	860	61	0	0
<i>Trichocerca</i> sp.	0	0	122	70
total				
rotifers	1417	92	4553	430
Hydracarina	0	0	33	33
Total	32698	1299	33236	1254

Hanaford	021093	Std Error	Epl 2(1)	Std Error
	Allan		Larry	
<i>Daphnia rosea</i>	1631	179	1465	155
<i>D. pulicaria</i>	0	0	346	76
<i>D. schlodleri</i>	255	71	0	0
<i>Holopedium gibberum</i>	9137	424	7358	348
total				
cladocerans	11023	465	9169	389
<i>Diaptomus franciscanus</i>	138	52	181	55
<i>D. shoshone</i>	373	86	49	28
diaptomus copepodids	884	132	691	107
cyclopoid copepodids	39	28	16	16
copepod nauplii	59	34	164	73
total				
copepods	1493	171	1101	146
<i>Keratella cochlearis</i>	1321	91	3498	379
<i>Polyarthra major</i>	22	16	0	0
<i>Filinia longiseta</i>	22	16	0	0
<i>Conochilus unicornis</i>	42	24	0	0
total				
rotifers	1407	96	3498	379
Hydracarina	20	20	0	0
Total	13943	477	13763	521

Coldwater	031093	Std Error	Epi 2(1)	Std Error
	Allan		Larry	
<i>Daphnia rosea</i>	178	43	174	28
<i>D. pulicaria</i>	933	99	1011	66
<i>Bosmina longirostris</i>	1740	135	710	56
<i>Holpedium gibberum</i>	21	21	13	8
<i>Chydorus sphaericus</i>	31	32	13	8
<i>Pleuroxus denticulatus</i>	21	15	0	0
total				
cladocerans	2924	175	1921	91
<i>Diaptomus tyrelli</i>	94	31	113	22
diaptomus copepodids	335	59	235	32
<i>Cyclops vernalis</i>	31	18	0	0
<i>C. varicans rubellus</i>	136	38	0	0
<i>Ectocyclops phaleratus</i>	10	10	0	0
cyclopoid copepodids	251	51	268	34
copepod nauplii	293	55	425	68
total				
copepods	1153	110	1052	78
<i>Asplanchna priodonta</i>	10	10	321	59
<i>Brachionus calyciflorus</i>	10	10	0	0
<i>Harringia</i> sp.	0	0	33	19
<i>Keratella cochlearis</i>	337	22	1525	129
<i>Keratella quadrata</i>	189	19	665	85
<i>Squatinella</i> sp.	10	4	0	0
<i>Trichocerca rattus</i>	8	3	0	0
<i>Polyarthra doliochoptera</i>	3	2	0	0
<i>Filinia terminalis</i>	71	20	359	62
<i>Conochilus unicornis</i>	141	14	0	0
<i>Synchaeta</i> sp.	0	0	1732	137
total				
rotifers	779	36	4641	225
Total	4856	166	7614	235

Fawn	050893	Std Error	Hypo 1(1)	
	Allan		Larry	
<i>Alona quadrangularis</i>	6	3	0	0
<i>Bosmina longirostris</i>	37	9	13	13
<i>Chydorus sphaericus</i>	6	3	13	13
<i>Daphnia pulicaria</i>	487	31	131	41
<i>D. rosea</i>	0	0	366	69
<i>Leptodora kindtii</i>	4	3	0	0
total				
cladocerans	540	33	523	83
diaptomus copepodids	6	3	39	23
<i>Cyclops vernalis</i>	2	2	0	0
<i>Orthocyclops modestus</i>	6	3	0	0
cyclopoid copepodids	20	6	26	18
copepod nauplii	204	20	235	53
total				
copepods	238	22	300	58
<i>Asplanchna priodonta</i>	6916	233	35000	756
<i>Kellicottia longispina</i>	8	6	0	0
<i>Keratella cochlearis</i>	241	17	2778	212
<i>Keratella quadrata</i>	1	1	0	0
<i>Lecane</i> sp.	10	5	0	0
<i>Polyarthra doliochoptera</i>	39	12	0	0
<i>Filinia longiseta</i>	349	33	1552	159
<i>Conochilus unicornis</i>	8	6	0	0
total				
rotifers	7572	217	39330	801
Chironomid larvae	4	3	0	0
Nematode	0	0	13	9
Total	8354	167	40166	808

Boot	150893	Std Error	Epi 2(1)	Std Error
	Allan	Larry		
<i>Diaphanosoma brachyurum</i>	2	2	0	0
<i>Daphnia rosea</i>	16	6	2	1
<i>Holopedium gibberum</i>	92	13	14	4
total				
cladocerans	110	15	16	4
<i>Diaptomus tyrelli</i>	96	14	0	0
diaptomus copepodids	485	31	0	0
<i>Cyclops</i>				
<i>varicans rubellus</i>	4	3	8	3
cyclopoid copepodids	31	8	16	4
copepod nauplii	367	27	163	73
total				
copepods	984	44	187	35
<i>Euchlanis dilatata</i>	16	16	0	0
<i>Kellicottia longispina</i>	244	61	751	157
<i>Keratella cochlearis</i>	1965	161	8202	519
<i>Keratella quadrata</i>	2413	173	8202	519
<i>Polyarthra dolichoptera</i>	1085	113	0	0
<i>Polyarthra major</i>	39	18	0	0
<i>Synchaeta pectinata</i>	2287	181	0	0
<i>Filinia terminalis</i>	31	22	0	0
<i>Conochilus unicornis</i>	1037	91	0	0
<i>Collotheca sp.</i>	0	0	23039	868
total				
rotifers	9117	333	40194	1146
<i>Chaoborus</i>	22	5	23	5
Total	10233	281	40435	1134

Castle	260693	Std Error	Epi 2(1)	Std Error
	Allan	Larry		
<i>Daphnia galeata mendotae</i>	157	157	0	0
<i>D. pulicaria</i>	472	273	123	22
<i>Bosmina longirostris</i>	84915	3654	77572	1265
total				
cladocerans	85543	3668	77695	1262
copepod nauplii	1099	148	62	36
total				
copepods	1099	148	62	36
<i>Asplanchna priodonta</i>	2850	608	1893	196
<i>Kellicottia longispina</i>	157	157	0	0
<i>Keratella cochlearis</i>	6290	995	905	136
<i>Keratella quadrata</i>	5	2	123	50
<i>Polyarthra dolichoptera</i>	1934	412	1132	153
<i>Pleosome truncatum</i>	314	222	0	0
total				
rotifers	11550	1231	4053	64
Total	98192	3813	81810	1329

Appendix C

Statistical Analysis of Subsampling Replicates

This table presents a summary of the variation within the 3 replicate subsamples counted from each sample. The standard deviation(s.d.) provides an estimate of the range of variability between the samples. The coefficient of variation(c.v.) is the standard deviation divided by the mean. This represents the influence of the variability upon the mean. To provide easier interpretation, the c.v. is presented as a % of the mean^{1 2}.

<u>Lake(sta/tow#)</u>		<u>Date</u>	<u>(s.d.) (c.v.)</u>		<u>(s.d.) (c.v.)</u>		<u>(s.d.) (c.v.)</u>		<u>(s.d.) (c.v.)</u>	
			<u>Copepods</u>		<u>Cladocerans</u>		<u>Rotifers</u>		<u>Total count</u>	
Blue	[1(1)] hyp	110793	140	5.3	*		232	2.2	365	2.8
	[1(1)] epi	110793	418	4.0	*		1577	4.1	1838	3.7
Boot	[1(1)] hyp	0992	*		85	15.0	465	2.4	371	1.8
	[1(1)] epi	0992	*		171	5.1	2066	2.2	2064	2.1
	[1(1)] hyp	150893	*		*		344	0.5	334	0.5
	[1(2)] hyp	150893	*		*		2818	3.8	2900	3.9
	[1(1)] epi	150893	*		*		1134	3.3	1168	3.4
			<u>(s.d.) (c.v.)</u>		<u>(s.d.) (c.v.)</u>		<u>(s.d.) (c.v.)</u>		<u>(s.d.) (c.v.)</u>	

¹ A “*” represents a situation for which there were fewer than 200 estimated individuals. In such cases, the dilution factors created unusually large standard deviations which were not representative of the subsampling technique. However, these numbers were included in the total count.

² The designation “w.s.” indicates that the whole sample was counted for a particular type of organism. Therefore, no standard deviation would be available for that category.

<u>Lake(sta/tow#)</u>		<u>Date</u>	<u>Copepods</u>		<u>Cladocerans</u>		<u>Rotifers</u>		<u>Total count</u>	
	[1(2)] epi	150893	*		*		519	1.3	576	1.4
	[1(1)] hyp	190794	*		*		650	5.3	652	5.3
	[1(2)] hyp	190794	*		*		583	5.0	479	4.0
	[1(1)] epi	190794	*		*		503	8.1	505	8.0
	[1(2)] epi	190794	*		*		113	2.5	98	2.1
Castle	[1(1)] hyp	260693	*		47	3.1	79	1.3	216	2.8
	[1(2)] hyp	260693	*		222	18.4	176	2.5	327	3.9
	[1(1)] epi	260693	*		2865	2.5	234	3.9	2648	2.2
	[1(2)] epi	260693	*		2005	1.9	248	3.6	1894	1.7
	[2(1)] hyp	260693	*		98	1.7	306	4.0	373	2.8
	[2(2)] hyp	260693	*		208	1.7	177	3.2	338	1.9
	[2(1)] epi	260693	*		4077	5.2	71	1.8	3982	4.9
	[2(2)] epi	260693	*		1140	1.3	72	1.4	1164	1.3
	[1(1)] epi	170993	*		128	5.8	718	11.8	789	9.4
	[1(2)] epi	170993	*		45	1.7	483	8.4	540	6.4
	[2(1)] hyp	170993	*		99	5.9	185	20.5	84	3.1
	[2(2)] hyp	170993	*		113	5.2	191	17.0	81	2.3
	[2(1)] epi	170993	*		45	1.2	196	3.2	158	1.6
	[2(2)] epi	170993	*		173	4.3	491	6.8	348	3.1
Coldwater	[1(1)] hyp	091092	11	3.2	2	0.3	33	6.2	27	1.8

(s.d.) (c.v.) (s.d.) (c.v.) (s.d.) (c.v.) (s.d.)(c.v.)

Lake(sta/tow#)		Date	Copepods		Cladocerans		Rotifers		Total count	
	[1(1)] epi	091092	83	10.0	102	3.9	133	11.1	292	6.3
	[1(1)] hyp	240393	84	2.2	*		163	1.2	107	0.6
	[1(1)] epi	240393	221	11.3	*		297	10.6	89	1.8
	[1(1)] hyp	240393	32	1.5	*		653	17.9	182	3.0
	[2(1)] epi	240393	93	7.4	*		43	2.2	85	2.6
	[1(1)] hyp	040893	49	5.4	20	2.0	33	2.9	39	1.3
	[1(1)] epi	040893	134	3.1	161	6.5	425	9.8	317	2.8
	[2(1)] hyp	040893	17	2.3	49	4.9	26	2.9	87	3.3
	[2(1)] epi	040893	304	7.7	145	6.8	285	7.1	571	5.6
	[1(1)] wc	031093	62	7.1	35	3.5	39	2.8	36	1.1
	[1(2)] wc	031093	35	4.5	40	3.9	0	0.0	60	2.0
	[2(1)] hyp	031093	25	8.5	33	7.7	26	4.4	21	1.6
	[2(2)] hyp	031093	41	12.6	8	1.5	33	5.9	15	1.1
	[2(1)] epi	031093	154	14.6	81	4.2	32	0.7	92	1.2
	[2(2)] epi	031093	33	3.5	102	5.2	189	4.9	114	1.7
Fawn	[1(1)] hyp	111092	399	5.5	100	7.8	377	12.4	675	5.8
	[1(1)] epi	111092	266	20.9	1084	16.6	5990	4.2	5488	3.7
	[1(1)] hyp	220593	140	16.4	0	0.0	8159	6.0	8265	6.1
	[1(2)] hyp	220593	210	11.4	*		10942	8.9	11169	9.0
	[1(1)] epi	220593	272	6.4	140	44.0	17794	9.1	17811	8.9

(s.d.) (c.v.) (s.d.) (c.v.) (s.d.) (c.v.) (s.d.)(c.v.)

<u>Lake(sta/tow#)</u>	<u>Date</u>	<u>Copepods</u>		<u>Cladocerans</u>		<u>Rotifers</u>		<u>Total count</u>	
	[1(2)] epi 220593	181	3.4	139	31.1	11170	9.3	11094	8.8
	[1(1)] hyp 050893	23	7.6	23	4.3	1035	2.6	1068	2.7
	[1(1)] epi 050893	727	8.1	351	8.9	2640	3.7	3099	3.7
	[1(1)] hyp 021093	113	15.7	859	8.5	3146	11.0	2537	6.4
	[1(2)] hyp 021093	38	8.7	422	8.7	1864	14.1	1569	8.5
	[1(1)] epi 021093	505	29.6	1308	12.7	2593	10.1	2381	6.3
	[1(2)] epi 021093	361	29.1	95	0.8	1131	4.3	1484	3.8
Grizzley	[1(1)] wc 180794	ws		ws		14	1.2	ws	
	[1(2)] wc 180794	ws		ws		68	3.2	ws	
Hanaford	[1(1)] hyp 111092	*		111	21.1	167	10.0	77	3.4
	[1(1)] epi 111092	71	20.1	240	6.6	285	6.7	478	5.8
	[1(1)] hyp 220593	*		*		188	4.8	176	4.2
	[1(2)] hyp 220593	103	49.2	115	37.8	62	0.7	214	2.4
	[1(1)] epi 220593	71	5.6	296	10.3	964	7.2	1251	7.1
	[1(2)] epi 220593	219	13.5	150	7.3	1236	6.2	1433	6.1
	[1(1)] hyp 050893	261	26.5	233	6.4	682	10.1	943	12.2
	[1(1)] epi 050893	38	10.0	40	3.7	803	5.3	77.1	5.0
	[1(1)] hyp 021093	*		409	173.2	69	15.8	531	70.2
	[1(2)] hyp 021093	108	17.4	167	5.0	170	7.9	181	2.9
	[1(1)] epi 021093	136	20.7	201	2.6	142	4.6	198	1.7

(s.d.) (c.v.) (s.d.) (c.v.) (s.d.) (c.v.) (s.d.)(c.v.)

<u>Lake(sta/tow#)</u>		<u>Date</u>	<u>Copepods</u>		<u>Cladocerans</u>		<u>Rotifers</u>		<u>Total count</u>	
	[1(2)] epi	021093	39	3.5	350	3.8	257	7.3	478	3.5
June	[1(1)] wc	280593	321	16.6	*		*		482	9.2
	[1(2)] wc	280593	367	45.3	*		*		962	14.5
	[1(1)] wc	090993	ws		ws		ws		ws	
	[1(2)] wc	090993	ws		ws		ws		ws	
	[1(1)] wc	171093	ws		ws		ws		ws	
	[1(2)] wc	171093	ws		ws		ws		ws	
McBride	[1(1)] wc	290593	ws		ws		ws		ws	
	[1(2)] wc	290593	ws		ws		ws		ws	
	[1(1)] wc	080993	132	17.6	202	8.1	1090	9.9	1056	7.4
	[1(2)] wc	080993	90	5.6	194	4.0	1041	3.7	931	2.7
	[1(1)] wc	171093	423	14.8	123	5.7	250	10.0	142	1.9
	[1(2)] wc	171093	423	14.8	123	5.7	250	10.0	142	1.9
Merrill	[1(1)] hyp	170493	64	4.8	*		*		88	5.7
	[1(2)] hyp	170493	30	1.1	*		57	8.7	97	2.8
	[1(1)] epi	170493	920	2.3	311	19.2	294	5.5	452	1.0
	[1(2)] epi	170493	924	3.0	91	9.9	273	4.5	592	1.6
	[2(1)] hyp	170493	14	0.9	*		57	7.8	61	2.6
	[2(2)] hyp	170493	153	5.9	*		98	11.6	237	6.7
	[2(1)] epi	170493	1419	4.1	348	23.0	419	6.1	1908	4.5
	[2(2)] epi	170493	2194	8.8	114	9.7	221	4.2	1886	6.0

(s.d.) (c.v.) (s.d.) (c.v.) (s.d.) (c.v.) (s.d.)(c.v.)

Lake(sta/tow#)	Date	Copepods		Cladocerans		Rotifers		Total count	
[1(2)] hyp 260893		181	6.4	127	5.0	1622	2.8	1573	2.5
[1(1)] epi 260893		851	9.5	42	0.7	71	0.5	896	3.0
[1(2)] epi 260893		423	5.7	624	5.1	422	2.3	621	1.6
[1(1)] hyp 091093		ws		ws		372	22.9	ws	
[1(2)] hyp 091093		ws		ws		122	5.6	ws	
[1(1)] epi 091093		61	1.4	185	5.5	440	3.7	594	3.0
[1(2)] epi 091093		136	3.2	166	5.7	899	10.6	808	5.1
Obscurity[1(1)] hyp 200794		1809	13.8	*		1542	0.4	2295	0.5
[1(2)] hyp 200794		1155	5.7	*		1568	0.3	2679	0.5
[1(1)] epi 200794		201	5.9	*		2491	1.6	2376	1.5
[1(2)] epi 200794		535	20.0	*		7019	3.5	6760	3.4
Panhandle[1(1)] hyp 0992		152	18.8	241	6.6	1091	1.9	1275	2.1
[1(1)] epi 0992		469	6.2	*		605	4.4	1012	4.8
[1(1)] hyp 140893		809	11.6	*		6160	1.7	5364	1.4
[1(2)] hyp 140893		1366	19.6	*		4405	2.2	4748	2.3
[1(1)] epi 140893		109	25.0	*		751	1.9	755	1.9
[1(2)] epi 140893		127	33.3	9	3.2	171	0.5	100	0.3
[1(1)] hyp 190794		ws		ws		1361	1.9	ws	
[1(2)] hyp 190794		ws		ws		516	0.7	ws	
[1(1)] epi 190794		ws		ws		693	5.0	ws	

(s.d.) (c.v.) (s.d.) (c.v.) (s.d.) (c.v.) (s.d.)(c.v.)

<u>Lake(sta/tow#)</u>		<u>Date</u>	<u>Copepods</u>		<u>Cladocerans</u>		<u>Rotifers</u>		<u>Total count</u>
	[1(2)] epi	190794	ws		ws		1152	3.1	ws
Ryan	[1(1)] hyp	170693	1064	8.2	*		1167	25.5	122 0.7
	[1(2)] hyp	170693	440	5.9	*		728	16.9	375 3.1
	[1(1)] epi	170693	2808	5.6	282	33.3	679	1.3	2482 2.4
	[1(2)] epi	170693	1326	3.0	149	22.9	1649	4.4	1164 1.4
	[1(1)] hyp	240893	ws		ws		186	69.4	ws
	[1(2)] hyp	240893	ws		ws		ws		ws
	[1(1)] epi	240893	ws		ws		ws		ws
	[1(2)] epi	240893	ws		ws		ws		ws
Shovel	[1(1)] hyp	091093	98	3.9	*		150	4.9	48 0.9
	[1(2)] hyp	091093	114	2.4	*		124	4.8	71 1.0
	[1(1)] epi	091093	ws		ws		247	18.9	ws
	[1(2)] epi	091093	ws		ws		150	14.3	ws
Snow	[1(1)] hyp	160994	308	23.2	ws		3872	1.0	ws
	[1(2)] hyp	160994	1837	32.2	ws		4399	6.0	ws
	[1(1)] epi	160994	199	19.8	ws		1730	1.1	ws
	[1(2)] epi	160994	258	22.0	ws		2455	0.9	ws
St Helens	[1(1)] hyp	0992	67	6.7	62	5.0	219	2.7	94 0.9
	[1(1)] hyp	100893	22	5.6	*		*		45 7.9
	[1(2)] hyp	100893	38	8.0	*		*		34 5.0

(s.d.) (c.v.) (s.d.) (c.v.) (s.d.) (c.v.) (s.d.)(c.v.)

<u>Lake(sta/tow#)</u>		<u>Date</u>	<u>Copepods</u>		<u>Cladocerans</u>		<u>Rotifers</u>		<u>Total count</u>	
	[1(1)] epi	100893	78	7.8	*		314	4.4	361	4.3
	[1(2)] epi	100893	146	11.0	42	20.3	50	1.1	86	1.4
	[1(1)] hyp	180794	7	1.7	*		*		4	0.7
	[1(2)] hyp	180794	11	3.4	*		*		18	4.4
	[1(1)] epi	180794	188	11.7	78	17.3	146	8.2	80	2.1
	[1(2)] epi	180794	75	4.6	14	3.1	108	6.2	33	0.9
Venus	[1(1)] hyp	0992	30	6.8	*		1498	1.2	1524	1.2
	[1(1)] epi	0992	157	8.1	126	11.8	7631	1.5	7900	1.6
	[1(1)] hyp	100893	138	6.2	99	31.2	1253	3.5	1297	3.4
	[1(2)] hyp	100893	211	5.0	92	8.1	1325	2.0	1232	1.7
	[1(1)] epi	100893	176	12.6	183	9.4	207	1.4	143	0.8
	[1(2)] epi	100893	76	8.3	74	1.3	95	4.7	127	1.4
	[1(1)] hyp	160994	100	5.6	25	7.1	5329	3.3	5404	3.3
	[1(2)] hyp	160994	150	3.7	50	11.5	6422	3.8	6538	3.7
	[1(1)] epi	160994	81	12.3	89	2.8	8470	6.1	8402	5.9
	[1(2)] epi	160994	125	18.8	10	0.4	515	0.4	612	0.5

Appendix D

Lake Parameters

and

Biological Statistics from the Summer of '93

Lake	Max. Lake depth (m)	Surface Area (sq. km)	Elevation (m)	Extinction Coefficient During Stratification	Surface SRP (ug)	Alkalinity (microequivalents)	Conductivity	Chl Diversity Index	FISH?
Blue	30+	0.072	1200	N.A.	6	N.A.	N.A.	N.A.	y
Boot	21	0.065	1415	-0.339	0.9	91	31	2.67	n
Castle	32	1.070	740	-0.312	3	444	58	2.27	y
Coldwater	62	3.100	740	-0.343	1.5	313	90	3.09	y
Fawn	18	0.096	1200	-0.38	0.8	350	72	2.08	y
Grizzley	6	0.032	1307	N.A.	N.A.	N.A.	N.A.	N.A.	n
Hanaford	16	0.096	1260	-0.162	1	187	76	1.35	y
June	2	0.008	985	-0.241	51	683	100	3.69	n
Mcbride	2	0.036	862	-0.937	4	413	45	4.14	n
Merrill	18	1.392	474	-0.288	2	212	27	1.66	y
Meta	8	0.036	1088	-0.831	2.3	347	39	2.6	y
Obscurity	17	0.028	1323	N.A.	N.A.	N.A.	N.A.	N.A.	y
Panhandle	22	0.061	1415	-0.206	0.2	76	27	1.7	y
Ryan	7	0.016	1018	-0.602	2.6	271	61	0.73	n
Shovel	30+	0.084	1419	N.A.	N.A.	N.A.	N.A.	N.A.	y
Snow	9	0.019	1433	N.A.	N.A.	N.A.	N.A.	N.A.	n
St. Helen's	85	0.320	1405	-0.119	3.7	151	78	2.91	y
Venus	36	0.085	1415	-0.13	0.1	78	23	1	y

Appendix E

Results of Cluster Analysis

JOINING DISTANCES ARE NOT MONOTONICALLY INCREASING.
NO HORIZONTAL DISTANCE SCALE USED FOR THIS TREE.
TO SEE JOINING DISTANCES, USE PRINT=LONG OPTION.

Name	Cumulative Probability (Start)	Cumulative Probability (End)
JUNE	0.00	0.05
MCBRIDE	0.05	0.65
SNOW	0.65	0.80
BOOT	0.80	0.90
RYAN	0.90	0.95
GRIZZLEY	0.95	1.00
SHOVEL	0.00	0.40
OBSCURIT	0.00	0.30
PANHANDL	0.00	0.45
BLUE	0.00	0.35
STHELENS	0.00	0.25
VENUS	0.00	0.20
META	0.80	0.95
COLDWATE	0.95	1.00
MERRILL	0.70	0.85
FAWN	0.60	0.75
HANAFORD	0.90	1.00
CASTLE	1.00	1.00

DISTANCE METRIC IS NORMALIZED PERCENT DISAGREEMENT
WARD MINIMUM VARIANCE METHOD

TREE DIAGRAM

DISTANCE METRIC IS 1-GAMMA COEFFICIENT
CENTROID LINKAGE METHOD

JOINING DISTANCES ARE NOT MONOTONICALLY INCREASING.
NO HORIZONTAL DISTANCE SCALE USED FOR THIS TREE.
TO SEE JOINING DISTANCES, USE PRINT=LONG OPTION.

DISTANCE METRIC IS 1-GAMMA COEFFICIENT
COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOR)

TREE DIAGRAM

DISTANCE METRIC IS 1-GAMMA COEFFICIENT
AVERAGE LINKAGE METHOD

TREE DIAGRAM

DISTANCE METRIC IS 1-GAMMA COEFFICIENT
WARD MINIMUM VARIANCE METHOD

TREE DIAGRAM

DISTANCES

2.000

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