# THE DISTRIBUTION OF THE WATER FLEA 

# (CLADOCERA: DAPHNIDAE) IN A CENTRAL TEXAS RESERVOIR 

## THESIS

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## By

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## INTRODUCTION

Zooplankton populations are affected by top-down controls (predation) and bottom-up controls (food quantity and quality). Predation by planktivorous fishes can play a large role in determining the composition and competitive interactions of zooplankton communities (Brooks and Dodson 1965). Recently, increasing attention has been paid to the bottom-up control mechanisms of food quantity and food quality. Food quantity is commonly expressed as algal carbon concentrations required to maintain a population of zooplankton. Each organism has a threshold food concentration, defined by Lampert (1977) to be the quantity of food an organism requires to maintain its mass and balance metabolic losses. Most lakes (with the exception of some oligotrophic lakes with chlorophyll concentrations less than $1.8 \mu \mathrm{~g} / \mathrm{L}$ ) have carbon levels well above threshold concentrations (Sterner and Schulz 1998). Food quality may be determined by several factors including the size and shape of food particles, digestion resistance, toxicity, and nutritional composition. The effects of elemental (phosphorus, nitrogen) and biochemical (fatty acid) content on growth and reproduction of zooplankton has recently been studied intensively. Although significant evidence for both phosphorus and poly-unsaturated fatty acid (PUFA) limitation of zooplankton growth and reproduction has been established, PUFA content of food has been shown to be reduced under phosphorus limiting conditions (Gulati and DeMott 1997). As the element most limiting
in aquatic systems, phosphorus is of great importance in the determination not only of the quantity of food present in an ecosystem, but also its nutritional quality.

The results of elemental analyses of freshwater zooplankton show the ratio of the elements carbon, nitrogen and phosphorus ( $\mathrm{C}: \mathrm{N}: \mathrm{P}$ ) is relatively constant within taxa and is species-specific for most metazoan zooplankton (Hessen 1990, Andersen and Hessen 1991, Hessen and Lyche 1991), varying only 10\%, although ingested food varies over $700 \%$ in N:P ratio (Sterner et al. 1992). The phosphorus content in species of Daphnia is high compared to other cladocera such as Bosmina. Daphnia possesses a low body $\mathrm{N}: \mathrm{P}$ ratio (12.3 to 12.9 for various Daphnia species) while other cladocerans, such as Bosmina, possess a high body $\mathrm{N}: \mathrm{P}$ ratio (29.3 for Bosmina longispina) (Andersen and Hessen 1991, Hessen and Lyche 1991, Sterner et al. 1992, Main et al. 1997).

Daphnia's high phosphorus content is thought to be due to a high specific growth rate and subsequent need for a large amount of rRNA for rapid protein synthesis (Hessen 1990, Sterner and Schulz 1998). This hypothesis was tested by Main et al. (1997) who found that, as predicted, growth rate was negatively correlated with N:P. Due to Daphnia's high phosphorus content and because phosphorus is the most common nutrient limiting biological productivity in aquatic systems (Wetzel 1983), it is thought that Daphnia should experience phosphorus-limited growth in nature. In an experiment by Urabe et al. (1997), inorganic phosphorus fed directly to Daphnia magna increased growth rate significantly. Further evidence for phosphorus limitation of Daphnia has been reported in lake surveys and other laboratory and field studies (Hessen 1992, Sommer 1992, Sterner 1993, Sterner and Hessen 1994, Urabe et al. 1997, DeMott and Gulati 1999, Schulz and Sterner 1999). Threshold C:P ratios ranging from 140 to 385
have been reported above which Daphnia becomes phosphorus limited rather than carbon limited (Urabe and Watanabe 1992, Sterner and Hessen 1994).

Elemental limitation of aquatic organisms such as cladoceran zooplankton may affect the process of nutrient recycling and shape the aquatic community through competition for limiting resources. In elementally homeostatic consumers, nutrients should be recycled in accordance with their body $\mathrm{N}: \mathrm{P}$ ratios. In most lakes the $\mathrm{N}: \mathrm{P}$ ratio of zooplankton is lower than that of seston, Urabe et al. (1995) observed phosphorus to be taken up more efficiently by zooplankton than nitrogen, thus maximizing their production. Elser et al. (1988) observed zooplankton assemblages dominated by Daphnia retained phosphorus and recycled nitrogen at a relatively higher rate, shifting phytoplankton towards phosphorus limitation. Similar results were obtained by Urabe et al. (1995) in Lake Biwa where $50 \%$ of ingested nutrients excreted by zooplankton consisted of nitrogen while only $15 \%$ of phosphorus was released. Olsen et al. (1986) found that phosphorus released by Daphnia decreased to almost zero at C:P ratios above 320 to 430 . When applied to elementally homeostatic organisms such as cladocera, Tilman's (1982) resource ratio competition theory asserts that the ratio of body $\mathrm{N}: \mathrm{P}$ will influence ecological interactions and requirements for these key elements. The supply ratio of resources determines which species will dominate in competitive interactions (Tilman et al. 1982). For example, phosphorus limitation should allow Bosmina to outcompete Daphnia, as it requires less phosphorus.

Reservoirs are divided longitudinally into three zones characterized by differing physical, chemical and biological components imparted by flow regime and basin morphometry (Thornton et al. 1981). According to Kimmel and Groeger (1984), the
most upstream portion of the reservoir, where the reservoir meets the inflowing river, is generally more eutrophic than the other zones and is called the riverine zone. The riverine zone is high in flow, suspended solids, turbidity, and nutrients. As flows decrease downstream as the reservoir basin widens in the transition zone, sedimentation of suspended matter occurs, nutrients are still in relatively high supply and the light climate improves allowing for increased primary production. The zone nearest the dam is called the lacustrine zone and is most lake-like. The lacustrine zone is more oligotrophic than the rest of the reservoir and it is generally low in flow, turbidity and nutrients (Kimmel and Groeger 1984).

Investigations into the dynamics of phosphorus and primary productivity in Canyon Reservoir, Texas reveal phosphorus limitation to be prevalent throughout the reservoir. The lacustrine zone of the reservoir exhibits lower total phosphorus concentrations and primary productivity than the transitional zone (Werkenthin 1980, Caldwell 1983). The longitudinal gradient in nutrient concentrations is imparted by the widening of the reservoir basin and subsequent decreasing flow and increasing sedimentation (Kennedy and Walker 1990). This gradient makes Canyon Reservoir an ideal location for field studies examining spatial variation in phosphorus limitation of cladoceran zooplankton.

Marzolf (1990) discusses a hypothetical model of longitudinal gradients in chemical and biological components within reservoirs. Marzolf proposes that the distribution of zooplankton within reservoirs is the result of hydraulic regime and the import of inorganic and organic materials from the inflowing river. The model predicts that zooplankton should be most abundant at the border of the riverine and transitional
zones where current velocity decreases, sedimentation increases, and nutrients exported from the river are still in adequate supply for phytoplankton growth.

The longitudinal distribution of zooplankton populations in reservoirs has not been well studied. Several studies in the longitudinal distribution of zooplankton in reservoirs have agreed with Marzolf's model of a gradual downstream decline in density of zooplankton (Urabe 1989, 1990, Hart 1990). In these studies Daphnia spp., unlike other zooplankton, were most abundant near the dam and declined in abundance upreservoir. A possible explanation of such a gradient is the size efficiency hypothesis of Brooks and Dodson (1965). This hypothesis states that when predation is intense, sizedependent predation on larger-sized zooplankters such as Daphnia spp. and calanoid copepods essentially eliminates these organisms from the zooplankton community, allowing smaller zooplankters such as Bosmina and rotifers to become dominant. Urabe (1990) performed experiments to determine if predation or competition were factors maintaining a stable distributional pattern with respect to Daphnia. The study concluded that although Daphnia galeata mendotae had the potential to be the dominant zooplankter throughout the reservoir, its high mortality rate at the headwaters was due to predation by planktivorous fishes. Due to the high turbidity of riverine zones, sight-dependent predators may not be as effective at selectively preying upon the larger members of the zooplankton community. Eccles (1986) found that the quantity of zooplankton in the diet of the major planktivore in P.K. le Roux Dam, South Africa, was most related to light intensity and water transparency. Although predation may be shaping the distribution of certain zooplankton within reservoirs, studies have not thoroughly examined food quantity and quality constraints on zooplankton populations.

Daphnia growth, feeding and reproduction have been significantly correlated to total phosphorus (TP) concentrations and the $\mathrm{C}: \mathrm{P}$ and $\mathrm{N}: \mathrm{P}$ ratios of seston in both field and laboratory examinations. Although the longitudinal distribution of zooplankton was not examined, Pinto-Coelho (1998) observed changes in the zooplankton community structure in Pampulha Reservoir, Brazil after several years of increasing eutrophication. Pinto-Coelho found a strong positive correlation between TP and Daphnia biomass, while seasonal patterns in Daphnia biomass were inversely related to sestonic C:P ratios. In another field study, Daphnia rosea had significantly higher growth and reproduction rates when fed seston from phosphorus-rich rather than phosphorus-poor lakes (MacKay and Elser 1998).

Buzan (1979) described the seasonal and longitudinal distribution and abundance of zooplankton in Canyon Reservoir. The examination revealed Bosmina longirostris to be the most abundant cladoceran, reaching peak abundance in the lacustrine zone with a secondary maxima in the transitional zone. Daphnia parvula and Diaphanosoma birgei (formerly D. leuchtenbergianum), although much lower in abundance than $B$. longirostris, were second and third most abundant, respectively. Peak abundances of $D$. parvula occurred in the lacustrine zone while $D$. birgei peaked in abundance in the transitional zone (Buzan 1979). Since the examination by Buzan in 1979, Daphnia lumholtzi, an exotic zooplankter has been observed in Canyon Reservoir. Main et al. (1997) found the growth rate of $D$. lumholtzi species to be positively related to body phosphorus content and negatively related to body $\mathrm{N}: \mathrm{P}$ ratio.

Daphnia are important to the ecology of lake ecosystems through their ability to efficiently filter large quantities of water, regenerate limiting nutrients selectively under
stratified conditions, and serve as food for planktivorous and young fish. If, as proposed, these organisms sequester phosphorus in their bodies preferentially over nitrogen, their impact on the nutrient budget of a water body may be highly important in determining the functioning of that ecosystem. The purpose of this study was to determine if the distribution, abundance and biomass of Daphnidae were related to the seasonal and longitudinal concentrations of TP within Canyon Reservoir, Texas. Daphnidae distribution and population parameters were examined longitudinally along the reservoir from January to October, 2000. Laboratory growth experiments were performed in order to determine if Daphnidae growth was positively related to phosphorus concentration in Canyon Reservoir. Daphnidae distribution and population parameters were analyzed via two-way ANOVA on the factors of reservoir station and month while the relationship of Daphnidae to physical, chemical, and biological parameters were evaluated using multiple regression models.

## STUDY AREA

Canyon Reservoir ( $29^{\circ} 52^{\prime} 077^{\prime \prime} \mathrm{N}, 98^{\circ} 11^{\prime} 55^{\prime \prime} \mathrm{W}$ ) is a bottom-draining, deep-storage impoundment on the Guadalupe River located in Comal County in central Texas. Construction of the reservoir by the United States Army Corps of Engineers began in 1958; impoundment began in 1964 and was completed in 1968 (Hannan et al. 1979).

Historical physical and chemical characteristics of Canyon Reservoir are summarized in Table 1.

Table 1. Physical and chemical characteristics of Canyon Reservoir, Texas and its drainage basin (Summarized from Groeger and Tietjen (1998) and Ground and Groeger (1994). Data on chemical characteristics represent four year means collected from near surface samples at the dam site).

| Surface area | $33.4 \mathrm{~km}^{2}$ |
| :--- | ---: |
| Volume | $471.2 \times 10^{6} \mathrm{~m}^{3}$ |
| Mean depth | 14.3 m |
| Maximum depth | 48 m |
| Drainage basin area | $3,709 \mathrm{~km}^{2}$ |
| Range of annual precipitation | $47-163 \mathrm{~cm}$ |
| Mean annual residence time | 1.64 yr |
| Specific conductance | $417 \mu \mathrm{~S} / \mathrm{cm}$ |
| Chlorophyll $a$ | $3.9 \mu \mathrm{~g} / \mathrm{l}$ |
| Total phosphorus | $17 \mu \mathrm{~g} / \mathrm{l}$ |
| Secchi disk transparency | 2.8 m |
| Trophic classification | Oligomesotrophic |

## MATERIALS AND METHODS

Eight fixed sampling stations located along the thalweg and following the longitudinal axis of the reservoir (Figure 1) were sampled once monthly from January to October, 2000. Zooplankton were collected by making duplicate vertical tows using a 60 $\mu \mathrm{m}$ Wisconsin plankton net from one meter above the substrate to the surface at each station. Temperature, pH , specific conductance and dissolved oxygen at each station was determined vertically at one meter intervals utilizing a Hydrolab Surveyor II multiprobe, calibrated before use (Hydrolab 1985). Water samples for chlorophyll a, alkalinity, turbidity, and phosphorus analyses were collected at each station using a PVC Kemmerer water sampler. During stratification, water samples were collected from the epi-, meta-, and hypolimnion. Water clarity was determined at each station using a Secchi disk while light penetration was determined using a Li-Cor spherical model photometer at one meter intervals from the surface. All samples were preserved on ice in the field for transportation to the laboratory. Zooplankton samples were preserved in a 1:1 ratio with $10 \%$ formalin-sucrose solution.

Chlorophyll a, alkalinity and turbidity were determined following the methods of Wetzel and Likens (1991). Total phosphorus (TP) was determined using the ascorbic acid method following persulfate digestion (APHA 1992).


Figure 1. Map of Canyon Reservoir, Texas showing sampling stations in kilometers from the dam.

Stratification may be important in creating a refuge for zooplankton from predators, therefore an index of stratification was calculated as the difference between surface and bottom water temperatures (Tessier and Horwitz 1990). The ratio of light to phosphorus was determined from the light in the epilimnion from 1 m to 4 m depth to total phosphorus concentrations in $\mu$ moles/L according to the methods of Sterner et al. (1997). Light in the mixed layer $\left(\mathrm{I}_{\mathrm{m}}\right)$ was calculated from the equation:

$$
I_{m}=\left(1-e^{-K z m}\right) / K z_{m}
$$

Where $K z_{m}$ is the extinction of light in the mixed layer calculated from 1 m to 4 m depth. When photometer measurements were unavailable, the extinction coefficient was estimated from Secchi disk transparency using the equation:

$$
\mathrm{K}=1.54 / \mathrm{z}_{\mathrm{sd}}
$$

where $z_{s d}$ is the Secchi disk depth. This index may be used to estimate seston $\mathrm{C}: \mathrm{P}$ ratios. A light :TP ratio of 1.00 approximates a seston $\mathrm{C}: \mathrm{P}$ ratio of 300 (Figures 2 and 3 in Sterner et al. 1997), the point at which Daphnia are predicted to become phosphorus limited.

Each plankton sample was allowed to sediment in a graduated cylinder for at least 10 hours prior to processing. The top 5 ml of sample usually contained filamentous bluegreen algae which were drawn off and enumerated in five 1 ml subsamples using a Sedwick-Rafter cell. Next, the preservative was drawn off from the top using a widebore pipette and decanted into a petri dish until the sample volume had decreased to $\leq 10$ ml . The decanted portion of the sample was examined to ensure no organisms had inadvertently been decanted. Subsamples were taken so that at least 200 organisms were enumerated in each sample. Cladoceran zooplankton were identified to species while all
other plankton were identified to the lowest possible taxonomic classification. Copepods were categorized as adult Calanoida, adult Cyclopoida, copepodids or nauplii. Keys used in identification included those of Prescott (1954), Brooks (1957), Edmondson (1959), and Pennak (1989). Body lengths of cladocerans and head capsules of Chaoborus punctipennis were measured using an ocular micrometer so that at least 25 individuals of each species found were measured per subsample. Body lengths of cladocera were converted to biomass using published regression equations from Bottrell et al. (1976). In order to evaluate the nutritional state of cladocera, a lipid-ovary index (L-O index) was calculated for each individual measured based on the methods of Tessier and Goulden (1982). The L-O index is a measure of feeding success which is a modified method of visually indexing the amount of lipid stored by cladocera to include an index of ovary condition based on ovary size and opaqueness. The L-O index is a sum of the lipid index and ovary index which each range from 0 to 3 . The L-O index is dependent on food concentration and is positively correlated to clutch size since cladocerans shunt much of their stored lipid reserves into egg production (Tessier and Goulden 1982). Nutritional and reproductive success was evaluated by determining clutch size (number eggs per gravid female) and egg age per gravid female (Threlkeld 1979). Egg age distribution is dependent on adult mortality and is generally dominated by younger eggs in a population where adult mortality is high (Threlkeld 1979). Egg age was determined for each brood of eggs of measured females using the criteria published by Threlkeld (1979) in which egg stages range from one to five. Clutch size, like L-O index, is positively related to food concentration and is therefore and indirect measurement of feeding success. Instantaneous birth rates were estimated using the egg-ratio method where the finite per
capita birth rate ( $\beta$ ) was first calculated by dividing the egg ratio (number of eggs per female) by egg development time (Edmondson 1960, Downing and Rigler 1984).

Development time for Daphnidae was estimated from Bottrell et al. (1976) from the equation:

$$
\ln \mathrm{D}=3.3956+0.2193 \ln \mathrm{~T}-0.3414(\ln \mathrm{~T})^{2}
$$

 determined, the instantaneous birth rate (b) was calculated from:

$$
b=\ln (1+\beta)
$$

Sampling times were not short enough for the calculation of the instantaneous rate of increase (r) and therefore the instantaneous rate of mortality (d).

In order to examine if nutrients and/or reservoir location were factors controlling the distribution, abundance and biomass of Daphnia species within Canyon Reservoir, a two-factor experiment consisting of eight treatments was conducted during the months of July, August and October 2000. Each treatment was replicated three times with the exception of the October experiment in which each treatment was replicated four times. The factors included 1) reservoir location, and 2) nutrient level. Treatments included two reservoir locations (water collected from 1 km and 27 km from the dam) and four nutrient treatments (control - no nutrients added, phosphorus alone, nitrogen alone, and nitrogen and phosphorus added together). Nutrients concentrations were $50 \mu \mathrm{~g} / \mathrm{L}$ phosphorus as a $\mathrm{K}_{2} \mathrm{HPO}_{4}$ solution and $100 \mu \mathrm{~g} / \mathrm{L}$ nitrogen as a $\mathrm{NH}_{4} \mathrm{Cl}$ solution. Each water sample was filtered through a $80 \mu \mathrm{~m}$ screen to eliminate large zooplankton and then immediately treated with nutrients as the experimental design prescribed. Daphnia parvula used in the July and August experiments were clones from individuals collected from Canyon

Reservoir and cultured in a 10 liter aquarium on Selenastrum capricornutum. Daphnia pulex from laboratory cultures were used in the October experiment after the Daphnia parvula culture crashed prior to the start of the experiment. Individuals used in the experiments consisted of neonates born within 24 hours of the beginning of the experiment. Neonates were collected from mature individuals carrying late-stage embryos isolated 24 hours prior to the start of the experiment. The July experiment was conducted in an experimental pond on the campus of Southwest Texas State University, San Marcos, Texas. Twenty-four hours after collection, 250 ml of filtered and nutrienttreated water from each reservoir location was placed in 300 ml polypropylene containers and inoculated with 10 neonates each. The experiments conducted in August and October were conducted in an incubator under 12 hour light/dark cycles at $23^{\circ} \mathrm{C}$. In these experiments, 50 ml of filtered and nutrient treated water was placed in 50 ml beakers and inoculated with 10 neonates each in the August experiment and 8 neonates each in the October experiment. Neonates were transferred using a wide-bore pipette with care not to transfer more than 0.5 ml of water along with each daphnid. Every other day daphnids were fed 5 ml of the filtered and nutrient treated water. Initial dry weight and lengths of neonates were determined by measuring and weighing individuals from the initial culture of neonates. After 7 days, growth rate and survival were determined for each of the treatments. Growth rate was calculated as the difference between initial and final dry weights after the experimental duration of 7 days:

$$
\mathrm{g}=\left[\ln \mathrm{W}_{0}-\ln \mathrm{W}_{\mathrm{t}}\right] / \mathrm{T}
$$

Where g is the growth rate $(\mathrm{d}), \mathrm{W}_{0}$ is the initial dry weight $(\mu \mathrm{g}), \mathrm{W}_{\mathrm{t}}$ is the final dry weight ( $\mu \mathrm{g}$ ) after time $\mathrm{T}(\mathrm{d})$. In addition, final lengths were measured as well as clutch size, egg age, and L-O index per individual.

Algal nutrient bioassays were conducted in July, August and October in conjunction with growth experiments in order to identify limiting nutrients in surface water samples collected 1 km and 27 km from the dam. Water samples were treated with nutrients including a control in which no nutrients were added, addition of $100 \mu \mathrm{~g} / \mathrm{L}$ nitrogen ( N ) as a $\mathrm{NH}_{4} \mathrm{Cl}$ solution, addition of $50 \mu \mathrm{~g} / \mathrm{L}$ phosphorus ( P ) as a $\mathrm{K}_{2} \mathrm{HPO}_{4}$ solution, and a metals treatment (M) consisting of $100 \mu \mathrm{~L}$ of Woods Hole MBL algal growth media micronutrients solution. In addition, water samples were treated with the following combinations of nutrients: nitrogen and phosphorus (NP), nitrogen and metals (NM), phosphorus and metals (PM) and nitrogen phosphorus and metals (NPM). Water samples collected from both reservoir stations were not large enough for the metals only treatment to be performed in July and all metals treatments in Aưgust.

Two-way ANOVAs were used to assess the factors of nutrient addition and reservoir station on Daphnia growth in laboratory experiments as well as on phytoplankton growth in nutrient bioassays. Two-way ANOVAs were performed to determine the importance of spatial, temporal, and spatial-temporal interaction effects on total phytoplankton, total zooplankton, Cladocera and Daphnidae distribution. In addition, two-way ANOVAs were performed to determine the importance of spatial, temporal, and spatial-temporal interaction effects on Daphnidae biomass, lipid-ovary index, clutch size, egg age and percent ovigerous females. Post hoc analyses on all ANOVAs were conducted using Tukey's Studentized HSD test. Multiple regression
analyses on Daphnidae abundance and biomass were run against factors found in the literature known to be related to zooplankton distribution and population patterns.

Factors included in multiple regressions included temperature, chlorophyll a, alkalinity, turbidity, total phosphorus, stratification index, phytoplankton abundance and reservoir location.

## RESULTS

Net plankton were rarely observed in samples collected 39 km from the dam. In addition, this most upstream station was inaccessible from August through October 2000, therefore this station was not included in statistical analyses. To meet the assumptions of normality and homogeneity of variances for statistical analyses, plankton data were $\log$ ( x $+1)$ transformed. It is believed the assumption of independence of samples was met since: 1) sampling locations were far enough apart that migration of animals between sampling locations could not occur during a sampling period and 2) the life cycles of most animals are shorter than the three to four week interval between sampling periods. Results of plankton two-way ANOVAs are presented in Table 2. Total net phytoplankton abundance, total zooplankton abundance, total cladoceran abundance and Daphnidae abundance and population parameters were significant spatially and temporally with significant interaction effects ( $\mathrm{p}<0.002$ ) in all but Daphnidae L-O index.

## Plankton community characteristics

Mean abundances of all organisms identified for each month at each sampling location are included in Appendix I. Net phytoplankton, those individual cells, filaments and colonies large enough to be trapped in the $60 \mu \mathrm{~m}$ net, were identified to genus. Four divisions of net phytoplankton including fifteen taxa were identified over the study period (Table 3). With the exception of January, February, and April, net phytoplankton was highest 1 km from the dam and declined upstream (Figure 2). Sub-Division

Table 2. Two-way ANOVA summary on net plankton taxonomic categories and Daphnidae population parameters.

| Taxonomic Category | Parameter | Source | df | S S | MS | $\begin{gathered} \mathrm{F} \\ \text { Value } \end{gathered}$ | $p$ value |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Total | Abundance | Station | 6 | 77.67 | 12.95 | 431.19 | <0.0001 |
| Phytoplankton |  | Month | 9 | 37.42 | 4.16 | 138.48 | <0.0001 |
|  |  | Interaction | 54 | 36.12 | 0.67 | 22.28 | <0.0001 |
|  |  | Error | 70 | 2.10 | 0.03 |  |  |
|  |  | Total | 139 | 153.31 |  |  |  |
| Total Zooplankton | Abundance | Station | 6 | 408158.42 | 68026.40 | 181.46 | <0.0001 |
|  |  | Month | 9 | 227747.94 | 25305.33 | 67.50 | < 0.0001 |
|  |  | Interaction | 54 | 498268.20 | 9227.19 | 24.61 | <0.0001 |
|  |  | Error | 70 | 26241.17 | 374.87 |  |  |
|  |  | Total | 139 | 1160415.73 |  |  |  |
| Total Cladocera | Abundance | Station | 6 | 71.24 | 11.87 | 66.86 | < 0.0001 |
|  |  | Month | 9 | 27.00 | 3.00 | 16.89 | <0.0001 |
|  |  | Interaction | 54 | 45.28 | 0.84 | 4.72 | <0.0001 |
|  |  | Error | 70 | 12.43 | 0.18 |  |  |
|  |  | Total | 139 | 155.95 |  |  |  |
| Daphnidae | Abundance | Station | 6 | 75.19 | 12.53 | 41.88 | < 0.0001 |
|  |  | Month | 9 | 29.07 | 3.23 | 10.79 | <0.0001 |
|  |  | Interaction | 54 | 64.65 | 1.20 | 4.00 | <0.0001 |
|  |  | Error | 70 | 20.94 | 0.30 |  |  |
|  |  | Total | 139 | 189.85 |  |  |  |
|  | Biomass | Station | 6 | 23.52 | 3.92 | 23.03 | <0.0001 |
|  |  | Month | 9 | 20.64 | 2.29 | 13.48 | <0.0001 |
|  |  | Interaction | 54 | 187.46 | 3.47 | 20.40 | <0.0001 |
|  |  | Error | 70 | 11.91 | 0.17 |  |  |
|  |  | Total | 139 | 243.53 |  |  |  |
|  | Lipid- | Station | 6 | 1.40 | 0.23 | 2.08 | < 0.0736 |
|  | Ovary | Month | 9 | 10.74 | 1.19 | 10.59 | <0.0001 |
|  | Index | Interaction | 44 | 6.92 | 0.16 | 1.40 | <0.1296 |
|  |  | Error | 48 | 5.41 | 0.11 |  |  |
|  |  | Total | 107 | 24.01 |  |  |  |
|  | Clutch Size | Station | 4 | 0.13 | 0.03 | 6.07 | < 0.0014 |
|  |  | Month | 7 | 0.09 | 0.01 | 2.39 | <0.0502 |
|  |  | Interaction | 20 | 0.42 | 0.02 | 3.91 | <0.0007 |
|  |  | Error | 26 | 0.13 | 0.01 |  |  |
|  |  | Total | 57 | 0.83 |  |  |  |
|  | Egg Age | Station | 4 | 0.17 | 0.04 | 5.58 | < 0.0021 |
|  | Distribution | Month | 7 | 0.29 | 0.04 | 5.47 | <0.0005 |
|  |  | Interaction | 22 | 0.49 | 0.02 | 2.93 | <0.0044 |
|  |  | Error | 27 | 0.21 | 0.01 |  |  |
|  |  | Total | 60 | 1.12 |  |  |  |

Table 3. Taxonomic list of net plankton collected in Canyon Reservoir, Texas from January through October, 2000 by month and reservoir location.

Phytoplanton:<br>Division Chlorophyta<br>Sub-Division Chlorophyceae<br>Order Chlorococcales<br>Family Hydrodictyaceae<br>Pediastrum<br>Family Oocystaceae<br>Closteriopsis<br>Order Zygnematales<br>Family Zygnemataceae<br>Mougeotia<br>Spirogyra<br>Zygnema<br>Family Desmidiaceae<br>Closterium<br>Division Chrysophyta<br>Sub-Division Bacillariophyceae<br>Order Pennales<br>Family Fragilariaceae<br>Fragalaria<br>Tabellaria<br>Family Naviculaceae<br>Navicula<br>Sub-Division Chrysophyceae<br>Order Chrysomonadales<br>Family Ochromonadaceae Dinobryon<br>Order Chrysocapsaceae<br>Family Chrysocapsaceae<br>Chrysocapsa<br>Division Cyanophyta<br>Sub-Division Myxophyceae<br>Order Chroococcales<br>Family Chroococcales<br>Anacystis<br>Gomphospearia<br>Merismopedia<br>Order Homogonales<br>Family Oscillatoriaceae<br>Lyngbya<br>Oscillatoria<br>Division Pyrrhophyta<br>Sub-Division Cryptophyceae<br>Order Péridiniales<br>Family Ceratiaceae<br>Ceratium

Table 3.-(Cont.).

## Zooplankton:

Phylum Sarcomastigophora
Subphylum Mastigophora
Order Euglenida
Peranema
Phacus
Subphylum Sarcodina
Class Lobosea
Order Arcellinida
Family Nebelidae
Class Filosea
Order Gromiida
Family Euglyphidae
Phylum Cnidaria
Hydra
Phylum Platyhelminthes
Class Turbellaria
Phylum Nematoda
Phylum Annelida
Class Oligochaeta
Phylum Rotifera
Class Monogononta
Order Flosculariacea
Family Filiniidae
Filinia
Order Ploima
Family Synchaetidae
Polyarthra
Ploeosoma
Family Gastropodidae
Ascomorpha
Chromogaster
Trichocerca
Family Asplanchidae
Asplancha
Family Brachionidae
Brachionus
Keratella
Platyias
Family Lecanidae
Lecane
Phylum Arthropoda
Subphylum Chelicerata
Class Arachnida
Water mite
Subphylum Crustacea
Class Branchiopoda
Order Cladocera
Family Bosminidae
Bosmina longirostris
Eubosmina sp.

Table 3.-(Cont.).

Family Chydoridae Alona costata<br>Family Daphnidae Ceriodaphnia quadrangula Ceriodaphnia reticulata Daphnia ambigua Daphnia galeata mendotae Daphnia lumholtzi<br>Daphnia parvula<br>Daphnia rosea<br>Simocephalus serratulus<br>Family Sididae Diaphanosoma birgei<br>Order Ostracoda<br>Class Maxillopoda<br>Order Copepoda<br>Sub-Order Calanoida<br>Sub Order Cyclopoida<br>Copepodid<br>Nauplii<br>Subphylum Uniramia<br>Class Insecta<br>Order Diptera<br>Family Chaoboridae<br>Chaoborus punctipennis<br>Family Chironomidae<br>Order Trichoptera<br>Family Polycentropodidae<br>Order Ephemeroptera<br>Family Caenidae



Figure 2. The longitudinal distribution of mean abundances of net phytoplankton subdivisions by month.

Bacillariophyceae (diatoms) dominated the net phytoplankton assemblage over most of the study. Ceratium sp., in Sub-Division Cryptophyceae dominated the net phytoplankton in January and was most abundant 27 km from the dam. Dinobryon sp., a colonial algae in Sub-Division Chrysophyceae dominated the net phytoplankton in February, 17 km from the dam. In May and September, the net phytoplankton assemblage was dominated by Sub-Division Myxophyceae (blue-green algae) and were most abundant 1 km from the dam. Net phytoplankton was highest in April, while the lowest abundances were observed in July and August.

Forty-two net-zooplankton taxa were identified within seven phyla (Table 3). Rotifera, Copepoda and Cladocera were the most common net-zooplankton taxa. Rotifera were dominant numerically for most of the study period with the exception of May, June and October when Copepoda became dominant numerically. Mean peak abundance of total zooplankton occurred 27 km from the dam while the lowest mean total zooplankton abundance occurred 31 km from the dam (Figure 3). As with total net phytoplankton, total net zooplankton abundance was highest in April, while the lowest abundance occurred in June. Over the course of the study period, Keratella was the most abundant rotifer, copepod nauplii were the most abundant stage of Copepoda and Bosmina longirostris was the most abundant cladoceran observed in Canyon Reservoir. Chaoborus punctipennis, the only pelagic insect and a zooplankton predator, was first observed in samples in March (Figure 4). C. punctipennis was rarely observed in the lacustrine zone ( 1 to 17 km from the dam). C. punctipennis was most abundant in the transition zone ( 22 to 34 km from the dam). High abundances of instar I C. punctipennis


Figure 3. The longitudinal distribution of mean abundance of dominant net zooplankton taxa by month.


Figure 4. The longitudinal distribution of Chaoborus punctipennis larval instar mean abundance by month.
$\left(8 / \mathrm{m}^{3}\right)$. occurred in August and of instars II ( $153 / \mathrm{m}^{3}$ ) and III ( $165 / \mathrm{m}^{3}$ ) in September.
High abundances of instar IV C. punctipennis larvae occurred in May and August. Peak abundance of instar IV C. punctipennis larvae occurred in May $\left(156 / \mathrm{m}^{3}\right), 22 \mathrm{~km}$ from the dam while a secondary peak in abundance occurred in May $\left(57 / \mathrm{m}^{3}\right) 22 \mathrm{~km}$ from the dam.

## Cladoceran distribution, abundance and biomass

Cladoceran species were pooled into families for analysis since their distribution was patchy both spatially and temporally. Peak total cladoceran abundance occurred 22 km from the dam while the lowest abundances occurred 34 km from the dam. Peak total cladoceran abundance occurred in April while the lowest abundances occurred in September (Figure 5). Peak abundances of family Bosminidae occurred 27 km from the dam while peak abundance of family Daphnidae occurred 1 km from the dam, declining upstream. Highest abundances of Daphnidae occurred in February, 17 km from the dam while Daphnidae abundance was lowest in October, 10 km from the dam (Figure 6). With the exception of April, May and October, Daphnidae abundance was higher in the lacustrine zone and declined upreservoir. Unlike all other months, Daphnidae abundance was highest at the most upstream station ( 34 km from the dam) in October when Daphnia lumholtzi was the dominant species of Daphnidae. Daphnia galeata mendotae was the most common species of Daphnidae, reaching peak abundance in March, 1 km from the dam.

Total Cladocera biomass was higher 1 km from the dam than at all other stations (Figure 7). Total Cladocera biomass was highest in March and lowest in October. Bosminidae biomass was highest in February, 27 km from the dam while Daphnidae biomass was highest in March, 1 km from the dam. With the exception of the month of


Figure 5. The longitudinal distribution of mean abundance of cladoceran families by month.


Figure 6. The longitudinal distribution of Daphnidae abundance by month.







Km from Dam
$\square$ Sididae $\quad$ Chydoridae $\quad$ Daphnidae $\square$ Bosminidae

Figure 7. The longitudinal distribution of mean biomass of cladoceran families by month.

October, Daphnidae biomass was highest 1 km from the dam and declined up-reservoir (Figure 8).

## Daphnidae population parameters

Daphnidae population parameters are summarized in Table 4. Mean Daphnidae lipid-ovary (L-O) index, clutch size and egg age two-way ANOVAs were significant spatially and temporally ( $\mathrm{p}<0.001$, Figure 9 ). Significant interaction effects were observed in clutch size and egg age two-way ANOVAs ( $\mathrm{p}<0.005$ ). Daphnidae birth rates and mean lengths were not statistically analyzed.

Daphnidae L-O index for January was significantly lower than all other months (p $<0.0001$ ), however, no significant differences in L-O indices among reservoir locations was evident (Figure 9). In September and October, mean clutch size and egg age per gravid female at reservoir stations 31 and 34 km from the dam were potentially artifacts of small sample size since less than 10 individuals were found bearing eggs, therefore these stations and months were not included in statistical analysis. Mean clutch size was lowest 10 km from the dam increased upstream. Mean egg age was low overall, with a mean for the enitre reservoir of 1.09 for the study. Birth rates were low throughout the study period ( $\left.<0.15^{-} \mathrm{d}\right)$. Highest birth rates were observed in May ( $0.09{ }^{-} \mathrm{d}$ ) while lowest birth rates $\left(0.01{ }^{-} \mathrm{d}\right)$ occurred in January and September (Figure 9). Longitudinally, birth rates were lowest 10 km from the dam $\left(0.02{ }^{-} \mathrm{d}\right)$ and increased upstream. Mean lengths were highest 1 km from the dam and declined upstream to the lowest value 34 km from the dam. Highest mean lengths were observed in March while lowest mean lengths were observed in August and September. Males were present in samples from January through May, however, their numbers were extremely low. The highest percentage of male









| $\otimes$ Simocephalus | $\square$ Daphnia galeata mendotae |  |
| :--- | :--- | :--- |
| $\mathbb{Q}$ Daphnia rosea | $\square$ Daphnia ambigua |  |
| $\square$ | Daphnia parvula | $\square$ Ceriodaphnia reticulata |
|  | Daphnia lumholtzi | $\square$ Ceriodaphnia quadrangula |

Figure 8. The longitudinal distribution of Daphnidae species biomass by month.

Table 4. Mean values ( $\pm 1 \mathrm{SD}$ ) of Daphnidae population parameters by month and reservoir station.



Figure 9. The longitudinal distribution of Daphnidae population parameters (lipid-ovary index $\boldsymbol{\square}$, clutch size $\boldsymbol{\Delta}$, egg age $\boldsymbol{\bullet}$, birth rate $\uparrow$, and mean length $\boldsymbol{\nabla}$ ) by month.
cladocerans occurred in one species, Daphnia rosea in January ( $22 \%$ male) and February (15\% male).

## Physical and chemical parameters

Mean values for physical and chemical parameters by month and reservoir station are included in Table 5, these values are means of water column values from surface to bottom. Mean values for the ten-month study period for temperature, chlorophyll a, alkalinity, turbidity, and conductivity were generally higher in the transitional zone of the reservoir (22 to 34 km from the dam) and declined downstream towards the lacustrine zone (1 to 17 km from the dam). Mean values for the study period for Secchi disk transparency and stratification index were highest 1 km from the dam and generally declined upstream, although lowest values for each parameter were found 21 km from the dam. Mean reservoir Secchi disk transparency was highest in March ( 2.54 m ) and lowest in January ( 1.42 m ). Mean values of temperature, chlorophyll a and stratification index for all reservoir stations generally increased from the beginning of the study period in January to peak values in late summer. Mean reservoir values for alkalinity, turbidity, dissolved oxygen (D.O.) and conductivity generally declined from the beginning of the study period in January to lowest values in mid to late summer (July to September). However, peak mean turbidity for the entire study period occurred in June (6.14 NTU). Bottom D.O. concentrations became anoxic (< $1 \mathrm{mg} /$ L D.O.) in April at stations 17, 27 and 31 km from the dam. Bottom D.O. concentrations at all reservoir stations became anoxic in May when mean concentrations dropped to $0.35 \mathrm{mg} / \mathrm{L}$. By July the mean D.O. concentration for the reservoir's hypolimnion had decreased to $0.59 \mathrm{mg} / \mathrm{L}$. Bottom D.O.

Table 5. Means ( $\pm 1 \mathrm{SD}$ ) of physical and chemical parameters by month and reservoir station.

|  | Temperature <br> $\left({ }^{\circ} \mathbf{C}\right)$ | Chlorophyll <br> $\mathbf{a}(\mu \mathrm{g} / \mathrm{L})$ | Alkalinity <br> $(\mathrm{meq} / \mathbf{L})$ | Turbidity <br> $(\mathbf{N T U})$ | TP $(\mu \mathrm{g} / \mathrm{L})$ |
| ---: | :---: | ---: | ---: | ---: | ---: |
| January | $11.86 \pm 0.89$ | $1.89 \pm 1.06$ | $3.57 \pm 0.54$ | $5.90 \pm 2.18$ | $20.74 \pm 56.87$ |
| February | $14.42 \pm 1.38$ | $1.76 \pm 0.54$ | $3.37 \pm 0.36$ | $5.06 \pm 2.15$ | $61.28 \pm 47.05$ |
| March | $17.60 \pm 2.38$ | $2.52 \pm 0.53$ | $3.27 \pm 0.30$ | $4.38 \pm 1.91$ | $1.91 \pm 2.39$ |
| April | $18.60 \pm 2.28$ | $3.06 \pm 0.64$ | $3.20 \pm 0.37$ | $4.38 \pm 2.19$ |  |
| May | $22.36 \pm 3.59$ | $4.47 \pm 3.38$ | $3.00 \pm 0.36$ | $3.89 \pm 2.12$ | $86.44 \pm 57.56$ |
| June | $21.75 \pm 3.09$ | $5.24 \pm 5.00$ | $2.76 \pm 0.19$ | $6.14 \pm 5.45$ | $10.49 \pm 11.79$ |
| July | $23.86 \pm 3.84$ | $11.68 \pm 13.78$ | $2.69 \pm 0.33$ | $3.58 \pm 1.87$ | $2.37 \pm 2.83$ |
| August | $24.18 \pm 3.61$ | $8.53 \pm 9.80$ | $2.69 \pm 0.33$ | $4.16 \pm 1.85$ | $21.82 \pm 48.24$ |
| September | $24.69 \pm 4.19$ | $10.22 \pm 6.83$ | $2.81 \pm 0.37$ | $3.33 \pm 1.82$ |  |
| October | $19.27 \pm 0.96$ | $7.19 \pm 3.85$ | $2.77 \pm 0.24$ | $4.53 \pm 2.04$ | $2.91 \pm 3.15$ |
| 1 | $17.27 \pm 2.71$ | $2.84 \pm 1.98$ | $2.61 \pm 0.23$ | $1.84 \pm 0.41$ | $38.18 \pm 58.56$ |
| 10 | $19.07 \pm 3.50$ | $3.67 \pm 2.93$ | $2.66 \pm 0.23$ | $2.83 \pm 0.48$ | $59.87 \pm 86.51$ |
| 17 | $21.82 \pm 4.46$ | $2.67 \pm 1.33$ | $2.76 \pm 0.30$ | $4.52 \pm 1.06$ | $16.65 \pm 21.13$ |
| 22 | $22.90 \pm 5.80$ | $3.87 \pm 1.21$ | $2.42 \pm 1.16$ | $7.29 \pm 0.52$ | $32.44 \pm 48.08$ |
| 27 | $23.00 \pm 5.94$ | $7.13 \pm 5.62$ | $3.19 \pm 0.37$ | $5.14 \pm 1.77$ | $32.14 \pm 47.07$ |
| 31 | $22.29 \pm 6.22$ | $14.67 \pm 12.40$ | $3.45 \pm 0.33$ | $4.94 \pm 1.60$ | $32.28 \pm 49.86$ |
| 34 | $22.98 \pm 6.69$ | $9.82 \pm 9.43$ | $3.40 \pm 0.36$ | $6.27 \pm 5.17$ | $22.39 \pm 33.45$ |
|  |  |  |  |  |  |
| Annual | $20.04 \pm 5.00$ | $5.83 \pm 7.05$ | $2.99 \pm 0.44$ | $4.87 \pm 4.17$ | $34.58 \pm 53.59$ |


| Light: Total | Dissolved | Secchi Disk | Stratification | Conductivity <br> Phosphorus |
| :---: | :---: | :---: | :---: | :---: |
| Oxygen | $(m)$ | Index | $(\mu \mathrm{S} / \mathrm{cm})$ |  |


| January | 1.05 | $9.63 \pm 0.42$ | $1.42 \pm 0.63$ | 0.59 | $395 \pm 43$ |
| ---: | ---: | ---: | ---: | ---: | ---: |
| February | 0.33 | $8.46 \pm 0.51$ | $1.84 \pm 1.19$ | 4.98 | $397 \pm 37$ |
| March | 11.72 | $7.90 \pm 0.48$ | $2.54 \pm 1.91$ | 7.07 | $396 \pm 34$ |
| April |  | $6.01 \pm 0.46$ | $1.81 \pm 0.93$ | 5.94 | $373 \pm 30$ |
| May | 0.25 | $4.32 \pm 0.18$ | $2.04 \pm 1.29$ | 8.65 | $383 \pm 27$ |
| June | 1.82 | $3.99 \pm 0.85$ | $2.09 \pm 1.48$ | 6.30 | $369 \pm 20$ |
| July | 9.41 | $3.01 \pm 0.46$ | $2.45 \pm 1.65$ | 9.06 | $369 \pm 19$ |
| August | 0.97 | $3.45 \pm 0.82$ | $2.24 \pm 1.69$ | 7.77 | $354 \pm 15$ |
| September |  | $3.98 \pm 1.06$ | $2.38 \pm 1.51$ | 6.45 | $360 \pm 21$ |
| October | 6.81 | $5.59 \pm 1.43$ | $2.01 \pm 1.46$ | 2.87 | $372 \pm 25$ |
| 1 | 0.69 | $5.14 \pm 2.41$ | $4.69 \pm 1.11$ | 9.08 | $362 \pm 9$ |
| 10 | 0.41 | $5.57 \pm 2.48$ | $2.91 \pm 0.61$ | 8.85 | $360 \pm 10$ |
| 17 | 1.29 | $5.52 \pm 2.15$ | $1.71 \pm 0.28$ | 7.19 | $365 \pm 12$ |
| 22 | 0.53 | $6.18 \pm 1.94$ | $1.04 \pm 0.08$ | 2.69 | $379 \pm 20$ |
| 27 | 0.60 | $5.66 \pm 1.86$ | $1.32 \pm 0.29$ | 4.47 | $426 \pm 28$ |
| 31 | 0.61 | $5.64 \pm 1.99$ | $1.31 \pm 0.27$ | 5.59 | $435 \pm 31$ |
| 34 | 0.85 | $6.68 \pm 1.86$ | $1.34 \pm 0.44$ | 3.91 | $428 \pm 37$ |
|  |  |  |  |  |  |
| Annual | 0.65 | $5.59 \pm 2.30$ | $1.99 \pm 1.35$ | 5.97 | $377 \pm 32$ |

concentrations increased in August and were above $1 \mathrm{mg} / \mathrm{L}$ for all reservoir locations in October as stratification began to break down.

Water samples for phosphorus analyses were not taken in April or September. Longitudinally, mean TP concentrations were highest 10 km from the dam ( $60 \mu \mathrm{~g} / \mathrm{L}$ ) and lowest 17 km from the dam ( $17 \mu \mathrm{~g} / \mathrm{L}$ ). Overall, high mean reservoir TP concentrations occurred in May ( $86 \mu \mathrm{~g} / \mathrm{L}$ ) and February ( $61 \mu \mathrm{~g} / \mathrm{L}$ ), while low mean reservoir TP concentrations occurred in March ( $2 \mu \mathrm{~g} / \mathrm{L}$ ), July ( $2 \mu \mathrm{~g} / \mathrm{L}$ ) and October (3 $\mu \mathrm{g} / \mathrm{L}$ ). Overall, lowest mean light:TP occurred 10 km from the dam (0.41) while highest light:TP occurred 17 km (1.29) from the dam (Figure 10). Light:TP exceeded 1.00 in January (1.05), March (11.72), June (1.82), July (9.41) and October (6.81). The mean light:TP ratio for the entire study period, however, was 0.65 .

## Algal nutrient bioassays

Results of two-way ANOVAs on algal bioassays are summarized in Table 6. In algal bioassays, final chlorophyll a concentrations were significantly higher in reservoir water taken 27 km from the dam than 1 km from the dam ( $\mathrm{p}<0.0001$ ). In July, nitrogen, phosphorus and metals (NPM) and nitrogen and metals (NM) treatments were significantly higher than the control ( $\mathrm{p}<0.0001$, Figure 11 ). Nitrogen $(\mathrm{N})$ and nitrogen and phosphorus (NP) treatments were significantly higher than the control in the August algal bioassay ( $p<0.0005$, Figure 12). In October, NPM and NP treatments were significantly higher than the control ( $\mathrm{p}<0.0001$, Figure 13).


Figure 10. Light:total phosphorus ratio for Canyon Reservoir, Texas from January through October, 2000 by (a) month and (b) reservoir station. Total phosphorus samples were not taken in April and September.

Table 6. Two-way ANOVA summary for algal nutrient bioassays conducted on Canyon Reservoir study sites 1 and 27 km from the dam.

| Month | Source | df | SS | MS | F value | p value |
| :--- | :--- | ---: | ---: | ---: | ---: | ---: |
| July | Station | 1 | 0.75 | 0.75 | 89.20 | $<0.0001$ |
|  | Treatment | 7 | 0.79 | 0.11 | 13.47 | $<0.0001$ |
|  | Interaction | 7 | 0.13 | 0.02 | 2.27 | $<0.0442$ |
|  | Error | 48 | 0.40 | 0.01 |  |  |
|  | Total | 63 | 2.07 |  |  |  |
|  |  |  |  |  |  |  |
| August | Station | 1 | 0.27 | 0.27 | 32.93 | $<0.0001$ |
|  | Treatment | 4 | 0.23 | 0.06 | 7.17 | $<0.0005$ |
|  | Interaction | 4 | 0.10 | 0.02 | 3.01 | $<0.0370$ |
|  | Error | 25 | 0.20 | 0.01 |  |  |
|  | Total | 34 | 0.80 |  |  |  |
|  |  |  |  |  |  |  |
|  |  | 1 | 2.15 | 2.15 | 156.37 | $<0.0001$ |
|  | Station | 8 | 1.94 | 0.24 | 17.59 | $<0.0001$ |
|  | Treatment | 8 | 0.71 | 0.09 | 6.48 | $<0.0001$ |
|  | Interaction | 52 | 0.72 | 0.01 |  |  |
|  | Error | 69 | 5.52 |  |  |  |
|  | Total |  |  |  |  |  |



Figure 11. Algal nutrient bioassay conducted from 25 July to 1 August 2000 from water samples collected (a) 1 km and (b) 27 km from the dam. Boxes indicate medians and middle two quartiles, whiskers indicate $10^{\text {th }}$ and $90^{\text {th }}$ percentiles. Initial (I) chlorophyll $a$ concentrations were measured prior to the beginning of the bioassay. Treatments were: control-no nutrients (C), nitrogen ( N ), nitrogen and metals (NM), nitrogen and phosphorus (NP), nitrogen phosphorus and metals (NPM), phosphorus alone (P) and phosphorus and metals (PM). Nitrogen phosphorus and metals (NPM) and nitrogen and metals (NM) treatments were significantly higher than controls at both reservoir stations ( $\mathrm{p}<0.0001$ ).


Figure 12. Algal nutrient bioassay conducted from 10 August to 17 August 2000 from water samples collected (a) 1 km and (b) 27 km from the dam. Boxes indicate medians and middle two quartiles, whiskers indicate $10^{\text {th }}$ and $90^{\text {th }}$ percentiles. See Fig. 14 for explanation of treatments. Nitrogen (N) and nitrogen and phosphorus (NP) were significantly higher than the control at both reservoir stations ( $\mathrm{p}<0.0005$ ).


Figure 13. Algal nutrient bioassay conducted from 12 October to 19 October 2000 from water samples collected (a) 1 km and (b) 27 km from the dam. Boxes indicate medians and middle two quartiles, whiskers indicate $10^{\text {th }}$ and $90^{\text {th }}$ percentiles. See Fig. 14 for explanation of treatments. Nitrogen phosphorus and metals (NPM) and nitrogen and phosphorus (NP) treatments were significantly higher than the control at both reservoir stations ( $\mathrm{p}<0.0001$ ).

## Laboratory experiments

No daphnids were recovered from the polyethylene bottles used in the July experiment. Growth rates and lipid-ovary indices were not significantly different in treatments from the control in both August (Figure 14) and October (Figure 15) experiments. However, by two-way ANOVA on the factors nutrient addition and reservoir station, survival was significantly higher in phosphorus $(\mathrm{P})$ treatment from the control in the October experiment ( $\mathrm{p}<0.0001$, Table 7, Figure 16). Survival in the nitrogen (N) treatment was lower (37.8\%) than the control treatment (55.0\%), P (84.8\%) and NP (70.6\%) treatments.

## Multiple regression analyses

All eight explanatory variables included in the multiple regression models (temperature, chlorophyll a, alkalinity, turbidity, total phosphorus, stratification index, phytoplankton abundance and station) had to be transformed for normality with the exception of temperature. Total phosphorus was square root transformed while the remaining parameters were $\log (x+1)$ transformed. Fifty-four percent of the variability in Daphnidae abundance and $63 \%$ of the variability in Daphnidae biomass was accounted for by the combination of factors (Table 8). However, only one factor, net phytoplankton abundance, had statistical significance at the 0.05 level in both models. Both Daphnidae abundance and biomass increased with increasing phytoplankton abundance (Figure 17).


Figure 14. Mean growth rate of Daphnia parvula grown in filtered and treated water samples collected August $10^{\text {th }}, 2000$ from Canyon Reservoir, Texas: (a) 1 km and (b) 27 km from the dam. Treatments were: control-no nutrients (C), nitrogen ( N ), phosphorus $(\mathrm{P})$ and nitrogen and phosphorus (NP). Growth rate of Daphnia parvula in treated water was not significantly different ( $\mathrm{p}<0.06$ ) from controls at both reservoir stations.



Figure 15. Mean growth rate of Daphnia pulex grown in filtered and treated water samples collected from Canyon Reservoir, Texas: (a) 1 km from the dam October $11^{\text {th }}$, 2000 and (b) 27 km from the dam October $13^{\mathrm{th}}, 2000$. See Fig. 17 for explanation of treatments. Growth rate of Daphnia pulex in treated water was not significantly different ( $\mathrm{p}<0.09$ ) from controls at both reservoir stations.

Table 7. Two-way ANOVA on survival in October growth experiment conducted using Canyon Reservoir water collected from study sites 1 and 27 km from the dam. Factors included four nutrient treatments (no nutrients, nitrogen, phosphorus, and nitrogen and phosphorus) and two reservoir locations ( 1 and 27 km from the dam).

|  | Source | df | SS | MS | F value | P value |
| :--- | :--- | ---: | ---: | ---: | ---: | ---: |
| October | Reservoir | 1 | 488.28 | 488.28 | 2.02 | $<0.1683$ |
| Survival | location |  |  |  |  |  |
|  | Treatment | 3 | 9832.09 | 3277.36 | 13.54 | $<0.0001$ |
|  | Interaction | 3 | 3244.84 | 1081.61 | 4.47 | $<0.0125$ |
|  | Error | 24 | 5807.75 | 241.99 |  |  |
|  | Total | 31 | 19372.96 |  |  |  |




Figure 16. Percent survival of Daphnia pulex grown in filtered and treated water samples collected from Canyon Reservoir, Texas: (a) 1 km from the dam October $11^{\text {th }}, 2000$ and (b) 27 km from the dam October $13^{\text {th }}, 2000$. See Fig. 17 for explanation of treatments. Survival was significantly higher in phosphorus treatments ( P ) than controls ( $\mathrm{p}<0.0001$ ).

Table 8. Multiple regression summary for Daphnidae abundance ( $\mathrm{n}=53, \mathrm{r}^{2}=0.54$ ) and biomass $\left(n=53, r^{2}=0.63\right)$ against eight potential predictors.

|  |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | :--- | :---: |
|  | $\beta$ | SE $(\beta)$ | t for $\mathrm{H}_{0}:$ <br> Parameter <br> $=0$ | Partial $\mathrm{r}^{2}$ | plevel |  |
| Abundance |  |  |  |  |  |  |
| Intercept | 0.429 | 2.350 | 0.18 |  | $<0.8559$ |  |
| Temperature | 0.025 | 0.028 | 0.91 | 0.0068 | $<0.3674$ |  |
| Chlorophyll a | -0.212 | 0.481 | -0.44 | 0.0020 | $<0.6613$ |  |
| Alkalinity | 3.237 | 3.385 | 0.96 | 0.0051 | $<0.3441$ |  |
| Turbidity | -0.948 | 0.813 | -1.17 | 0.0175 | $<0.2497$ |  |
| Total Phosphorus | 0.033 | 0.021 | 1.57 | 0.0205 | $<0.1229$ |  |
| Stratification Index | -0.692 | 0.363 | -1.91 | 0.0222 | $<0.0629$ |  |
| Phytoplankton Abundance | 0.402 | 0.157 | 2.57 | 0.4370 | $<0.0137$ |  |
| Station | -0.136 | 0.118 | -1.15 | 0.0294 | $<0.2554$ |  |

## Biomass

| Intercept | -1.609 | 2.931 | -0.55 |  | $<0.5858$ |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Temperature | 0.034 | 0.035 | 0.98 | 0.0041 | $<0.3337$ |
| Chlorophyll a | 0.046 | 0.600 | 0.08 | 0.0000 | $<0.9390$ |
| Alkalinity | 4.966 | 4.224 | 1.18 | 0.0142 | $<0.2460$ |
| Turbidity | -0.537 | 1.014 | -0.53 | 0.0039 | $<0.5993$ |
| Total Phosphorus | 0.041 | 0.026 | 1.54 | 0.0164 | $<0.1305$ |
| Stratification Index | -0.594 | 0.453 | -1.31 | 0.0074 | $<0.1960$ |
| Phytoplankton Abundance | 0.604 | 0.195 | 3.10 | 0.5443 | $<0.0034$ |
| Station | -0.287 | 0.147 | -1.94 | 0.0442 | $<0.0583$ |



Figure 17. Only net phytoplankton abundance was significantly correlated to (a)
Daphnidae abundance and (b) Daphnidae biomass in multiple regression analyses ( $\mathrm{p}<$ $0.05)$.

## DISCUSSION

Although Canyon Reservoir is classified as an oligomesotrophic lake, mean TP concentrations during this study were in the mesoeutrophic to eutrophic range (Wetzel 1983). The results of laboratory experiments and multiple regression analyses indicate there was no relation between total phosphorus concentrations and Daphnidae distribution within Canyon Reservoir during this study. A light:TP ratio of one approximates a seston C:Pratio of 300 , a point above which Daphnia are estimated to become phosphorus limited and below which Daphnia may suffer carbon limitation (Figures 2 and 3 in Sterner et al. 1997, Sterner and Schulz 1998). Light:TP ratios calculated during this study suggest phosphorus limitation of Daphnidae may have occurred during the months of March, June, July and October (Figure 10). The results of algal nutrient bioassays failed to show phosphorus limitation in Canyon Reservoir during July, however. Algal nutrient bioassays indicate nitrogen to be the main limiting nutrient, although nitrogen was co-limiting with metals in July and phosphorus in October.

Plankton Distribution-Spatially, the distribution of total zooplankton in Canyon Reservoir conformed to Marzolf’s (1990) reservoir zooplankton distribution model with peak total zooplankton abundance in the transition zone ( $22-34 \mathrm{~km}$ from the dam). Daphnidae, unlike other zooplankton, were concentrated in the lacustrine zone (1-17 km from the dam). Similar distribution patterns for Daphnidae were observed in other reservoir zooplankton studies (Urabe 1989, 1990, Hart 1990). Contrary to Marzolf's
model which predicts phytoplankton abundance to be highest in the transition zone, net phytoplankton were highest in abundance near the dam, declining upstream. Chlorophyll $a$ concentrations agreed with Marzolf's model, however, being highest in the transition zone (31 km from the dam). Unlike the distribution of cladocera found in Buzan's (1979) examination of zooplankton in Canyon Reservoir, in this study Bosmina longirostris and Diaphanosoma birgei were most abundant in the transition zone. The distribution of Daphnia parvula, however, remained most abundant in the lacustrine zone. The seasonal distribution of total zooplankton followed that of other studies on lake and reservoir zooplankton populations in which a spring peak in zooplankton abundance was followed by a summer minimum and a second smaller peak in abundance in the fall (Hall 1964, Cummins et al. 1969, Work and Gophen 1999).

Algal bioassays-Algal bioassays conducted in late summer and mean values for the two reservoir stations for the entire study period show that, overall, chlorophyll $a$ concentrations were higher 27 km from the dam than 1 km from the dam. Food was probably less limiting at the upstream reservoir station throughout the study period. The August algal bioassay clearly indicates algal growth to have been limited by nitrogen only. August TP concentrations for reservoir locations 1 km from the dam and 27 km from the dam were $54 \mu \mathrm{~g} / \mathrm{L}$ and $288 \mu \mathrm{~g} / \mathrm{L}$ respectively. TP concentrations were much lower in July and October. Algal bioassays indicate phytoplankton growth was colimited by nitrogen and metals in July and nitrogen and phosphorus in October.

Laboratory experiments-No organisms were recovered from the July experiment. It is difficult to determine if nutrient regime or reservoir location contributed to the disappearance of daphnids or if it was simply the size of the organisms which made
them impossible to recover from the large containers of treatment water. It is unlikely that experimental daphnids suffered food limitation in July since chlorophyll $a$ concentrations measured for this month were the highest for the entire study period. High temperatures and light intensity may also have been factors which were detrimental to experimental daphids.

The absence of significant differences in growth rates among treatments in the August experiment is not surprising given that the water samples were taken from two reservoir stations with mean TP concentrations well above $50 \mu \mathrm{~g} / \mathrm{L}$. The lack of significant differences in growth rates among treatments in the October experiment, however, when TP concentrations from the reservoir stations studied were low, seems to disprove the hypothesis that phosphorus limits Daphnia growth. There were significant differences in survival, however, in the October experiment with survival being significantly higher in the phosphorus treated reservoir water than the control. Apparently the addition of phosphorus to an already phosphorus limited algal pool allowed Daphnia pulex to escape starvation, however, it was not enough to allow significant growth.

Based on empirical and laboratory data collected in this study, the factors which contributed to structuring Daphnidae distribution in Canyon Reservoir are highly complex. Factors which may have constrained Daphnidae populations in this study include food limitation both in terms of food quantity and food quality, and predation. Table 9 summarizes evidence which support factors which may have worked to structure Daphnidae populations in Canyon Reservoir.

Figure 9. Summary of evidence supporting alternative factors (food quantity limitation, food quality limitation, and predation) which may have structured the distribution of Daphnidae abundance and biomass in Canyon Reservoir, Texas from January through October, 2000.

| Food limitation |  | Food quality |
| :--- | :--- | :--- |$\quad$ Predation

## Food limitation

Food quantity limitation-The only potential predictor of Daphnidae abundance or biomass in the multiple regression models was net phytoplankton abundance. Net phytoplankton, however, were those individual cells, filaments or colonies large enough to be trapped in a $60 \mu \mathrm{~m}$ plankton net. The optimal size range of food items for cladoceran zooplankton to efficiently feed is $<30 \mu \mathrm{~m}$ (Muller-Navarra and Lampert 1996), however daphnids commonly filter food items between 1 and $53 \mu \mathrm{~m}$ in diameter (Brooks and Dodson 1965, Kreeger et al. 1997). In this study, sub-division Bacillariophyceae (diatoms) dominated the net phytoplankton assemblage throughout much of the study (Figure 2) and were composed mainly of Fragalaria spp. which are colonial diatoms which may be broken apart and therefore may have existed in a size range small enough for Daphnidae to have fed upon. DeMott and Moxter (1991) found Daphnia to ingest filamentous algae over 1 mm in length and Repka (1997) sustained Daphnia galeata mendotae in laboratory experiments solely on a filamentous algae, Oscillatoria limnetica. It is possible, therefore, that daphnids fed effectively on the net phytoplankton observed in this study. Interestingly, there was no relationship between Daphnidae abundance or biomass and chlorophyll $a$ concentration. The lack of a relationship between Daphnidae abundance and biomass with chlorophyll $a$ concentration may be due to the fact that chlorophyll $a$ concentrations are not dependent on algal biomass alone but may change with species composition and physiological state (Reynolds 1984).

Light:TP ratios suggest Daphnidae may have experienced food limitation during much of the study (Figure 10). For many months, light:TP ratios were below one, the
point at which Daphnidae may become carbon limited. Prior to the dramatic decline in Daphnidae in June, light:TP ratio was lowest for the entire year in May (0.25) suggesting limitation of zooplankton populations by food quantity.

Food quality limitation-Food quality may have contributed to the declines in Daphnidae abundance and biomass observed in June and September. Diatoms are considered a high quality food since they are high in essential omega-3 highly unsaturated fatty acids whereas most green algae (sub-division Chlorophyceae) are low in these essential fatty acids, and blue-greens (sub-division Myxophyceae) may lack them altogether (Muller-Navarra 1995). Diatoms dominated net phytoplankton abundance in April when Daphnidae abundance was highest. Daphnidae abundance drastically declined from in June after blue-green algae became dominant in May. A second decline in Daphnidae abundance and biomass occurred in September when blue-green algae once again dominated the net phytoplankton assemblage.

## Predation

The fact that net phytoplankton only explained half of the variation in Daphnidae abundance and biomass and the fact that low $r^{2}$ values were observed in the multiple regressions of Daphnidae abundance and biomass with net phytoplankton abundance may be due to the fact that a large proportion of the phytoplankton present were not collected in the $60 \mu \mathrm{~m}$ mesh net. Alternatively, the remaining variation might be explained by factors, such as predation, which were not measured in this study. Evidence that Daphnidae populations were controlled by predation in this study include a young egg age distribution throughout the study (Table 4) as well as the longitudinal distribution of
the following factors: Chaoborus punctipennis, chlorophyll $a$, daphnid mean lengths, and birth rates.

Chaoborus punctipennis-The spring and fall declines in Daphnidae abundance may be due to predation by the phantom midge larvae, Chaoborus punctipennis, the only zooplankton predator collected in this study. C. punctipennis is the smallest species in this genus of gape-limited plankton predators. Most adult Daphnia are too large for small C. punctipennis to ingest, only the fourth instar larvae are able to feed efficiently on daphnids (Moore 1988). It is possible C. punctipennis was responsible for the decline in Daphnidae populations observed in June and September as densities of fourth instar larvae were highest the months previous in May and August (Figure 4). The distribution of fourth instar larvae was highest up-reservoir, 22 km from the dam suggesting predation pressure was higher up-reservoir.

Mean lengths-Predation pressure is probably most intense in the riverine and transitional zones of Canyon Reservoir. Brooks and Dodson's (1965) Size-Efficiency Hypothesis states that when predation is intense, larger sized zooplankton will be eliminated, shifting the size structure of zooplankton toward smaller forms. Largest daphnids occurred 1 km from the dam and mean lengths decreased up-reservoir to smallest mean lengths 34 km from the dam. Tessier and Horwitz (1990) found lake stratification to explain a significant amount of the variation in the size of zooplankton in a survey of 146 lakes. During periods of stratification, D.O. concentrations in deeper waters may drop below tolerance levels for many fish predators thus creating a refuge for large zooplankton (Kitchell and Kitchell 1980, Shapiro et al. 1982). The stratification indices calculated in this study were highest 1 km from the dam and decreased up-
reservoir (Table 5). The longitudinal distribution of Daphnidae abundance, biomass and mean lengths suggest the stratified deep waters of the lacustrine zone may have afforded large daphnids a refuge from predation.

Distribution of Chlorophyll a--Results of algal bioassays suggest the reservoir station 27 km from the dam supports a larger supply of food than 1 km from the dam. Low abundance and biomass of Daphnia were found at the reservoir sites where chlorophyll $a$ concentrations were highest. If food limitation was the only mechanism controlling daphnid distribution, their abundance and biomass should have been higher in these upstream reservoir stations.

Egg age distribution-Higher mortality rates of egg bearing adults is evidenced by a predominance of young eggs, while a slowing in egg production results in a more even or older distribution in egg age (Threlkeld 1979). Using these criteria for assessing cladoceran population dynamics, mortality of egg-bearing adults may have been higher in January and March than later in the summer (June through August). However, the mean egg age distribution was young overall, reaching a maximum of only 1.67 in June. The egg age distribution in this study suggests adult mortality was high throughout the study period.

Birth rates-Higher birth rates in Cladocera occur under intense predation as populations attempt to compensate for high mortality (Dodson and Frey 1991). Highest birth rates were observed in April and May prior to the decline in Daphnidae abundance and biomass in June and once again in October after Daphnidae abundance and biomass decreased in September. In addition, birth rates increased longitudinally upstream from 1
and 10 km from the dam once again suggesting higher predation pressure up-reservoir (Figure 9).

Although predation by fishes was not examined in this study, it is likely that fish predation, primarily during the spring spawn, affected Daphnidae populations in Canyon Reservoir. Fish surveys on Canyon Reservoir list sunfishes (redbreast and bluegill) and gizzard shad as the dominant forage fishes for the dominant predator fishes: largemouth bass, white bass, and striped bass (Texas Parks and Wildlife 1997). Shad are effective at depressing zooplankton densities (Dettmers and Stein 1992, DeVries and Stein 1992). Several studies show that peak larval shad densities are followed by a decline in crustacean zooplankton (DeVries et al. 1991, Dettmers and Stein 1992, DeVries and Stein 1992). During the spring spawn, larval fish present in large numbers would exert a high predation pressure on zooplankton and may explain the decline in total zooplankton abundance in May. Predation on zooplankton over the summer months also would have lessened as the young of piscivorous fishes grew to a size that no longer preyed upon zooplankton. Hirst and DeVries (1994) found larval black basses to switch to insect prey in June as they reached 15 mm in total Iength in West Point Reservoir, Alabama. Although a severe decline in cladoceran abundance and biomass occurred in May, the decline in daphnid abundance was not observed until June. There are two explanations for this disparity. First, the planktivorous young of spawning fishes may have fed more efficiently on the smaller sized Bosmina longirostris until they had grown to efficiently prey upon the larger sized daphnids, causing their decline a month later. Secondly, high reproductive rates are needed to balance high predatory mortality (DeMott and Gulati
1999). Daphnidae birth rates were highest in May which may have compensated for the decline caused by predation.

A possible source of error in this study was the analysis for total phosphorus which is highly susceptible to contamination. Inaccurate phosphorus data may have made the relationship between daphnids and phosphorus unclear. This study would have benefited from nutrient bioassays conducted earlier in the year to determine if phosphorus was limiting algal growth in January, March and June as predicted by light:TP ratios. Taking more frequent zooplankton samples would have allowed for the calculation of population growth and death rates that would have been beneficial in interpreting the extent of predation pressure.

## Conclusions

Daphnidae distribution, abundance and biomass were unrelated to TP concentrations in this study. Phosphorus-limited growth of Daphnidae within Canyon Reservoir did not occur as phosphorus was not a limiting factor during most of the study. Tietjen (1996) found nitrogen and phosphorus concentrations responded differently in Canyon Reservoir during years of varying rainfall. During a dry year, nitrogen was limiting in Canyon Reservoir while soluble reactive phosphorus (SRP) concentrations were relatively high. During 1992, a wet year, nitrogen concentrations were high and SRP concentrations were at or below detection limits ( $<1 \mu \mathrm{~g} / \mathrm{L}$ ). Rainfall during this study was low, total phosphorus concentrations high, and nitrogen limitation occurred in algal nutrient bioassays conducted in July, August and October.

Factors suspected of shaping Daphnidae populations during this study include food limitation and predation pressure. Evidence for food quantity limitation include the
results of multiple regression analyses, and light:TP ratios while evidence for food quality limitation is apparent in the distribution of high and low quality phytoplankton during peak and low abundances of Daphnidae. The fact that net phytoplankton abundance failed to explain a large amount of variation in the regression models suggests unmeasured factors were at work structuring the distribution of Daphnidae in this study. Evidence for predator control of Daphnidae populations in this study include the distribution of Chaoborus punctipennis larvae up-reservoir where Daphnidae were noticeably lacking, the distribution of smaller mean lengths of Daphnidae up-reservoir, an absence of Daphnidae up-reservoir where chlorophyll $a$ concentrations are highest, a young egg age distribution throughout the study and increased birth rates up-reservoir. Future studies into Canyon Reservoir zooplankton, particularly Daphnidae distribution, should focus on food limitation and predation. Predation by fishes is undoubtedly important in shaping Daphnidae populations in Canyon Reservoir. Future zooplankton predation studies should also focus on larval fish predation during the spring spawn. In order to test the hypothesis that Daphnidae populations are limited by phosphorus, this study should be repeated in Canyon Reservoir during a wet year, when phosphorus concentrations are more likely to be limiting.

## SUMMARY

The elemental composition of freshwater zooplankton is relatively constant, varying only $10 \%$ in C:N:P ratio, although ingested food may vary over $700 \%$. The elemental $\mathrm{N}: \mathrm{P}$ content of Daphnia is lower than that of other cladoceran species. The higher phosphorus content is believed to be due to a higher specific growth rate and subsequent need for a larger amount of rRNA for rapid protein synthesis. In laboratory and field studies, Daphnia exhibit phosphorus-limited growth. I analyzed Daphnia population parameters within Canyon Reservoir, Texas from January through October, 2000 and measured various physical and chemical parameters including total phosphorus (TP) concentrations. In addition, laboratory experiments were conducted in July, August and October, 2000 to evaluate Daphnia growth rate in nutrient treated reservoir water from two reservoir locations. Multiple regression models of Daphnidae abundance and biomass with physical, chemical, and biological variables were significant ( $\mathrm{p}<0.0001$ ), however, TP concentrations and Daphnidae population parameters were not significantly correlated. Only net phytoplankton abundance was significantly correlated to Daphnidae abundance ( $\mathrm{p}<0.014, \mathrm{r}^{2}=0.44$ ) and biomass $\left(\mathrm{p}<0.004, \mathrm{r}^{2}=0.54\right)$. Significant differences in growth rate among treatments and controls were not observed in experiments, however, in the October experiment, survival was significantly higher in the phosphorus treated reservoir water ( $\mathrm{p}<0.0001$ ). Results of algal bioassays, laboratory growth experiments, TP concentrations, and light:TP ratios indicate phosphorus limitation in Canyon Reservoir did not occur over most of the study, rather, Daphnia may
have been food limited in terms of quantity and quality or controlled top-down via predation by fourth instar Chaoborus punctipennis larvae (Diptera: Chaoboridae).

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Appendix I. Mean abundance (Individuals $/ \mathrm{m}^{3}$ ) of all reservoir plankton by month and reservoir station ( km from dam). A complete set of all data collected in this study is on file as a series of Excel spreadsheets with Dr. Alan W. Groeger, Aquatic Station,
Department of Biology, Southwest Texas State University, San Marcos, Texas, 78666.

| January | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 5357 | 7750 | 1839 | 231 | 2957 | 100 | 52 |
| Closteriopsis | 0 | 0 | 501 | 0 | 0 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 55 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 0 | 0 | 7 | 0 |
| Fragalaria | 4201 | 5688 | 597 | 202 | 729 | 168 | 16 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 24 | 76 |
| Navicula | 0 | 0 | 106 | 0 | 0 | 0 | 0 |
| Dinobryon | 10114 | 27279 | 40400 | 9792 | 17909 | 636 | 0 |
| Chrysocapsa | 0 | 0 | 164 | 0 | 0 | 0 | 0 |
| Anacystis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphospearia | 0 | 0 | 0 | 395 | 0 | 0 | 0 |
| Merismopedia | 0 | 0 | 10 | 0 | 0 | 0 | 8 |
| Lyngbya | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillatoria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceratium | 32197 | 110338 | 107769 | 23031 | 325077 | 3 | 4 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Euglyphidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polyarthra | 3480 | 6620 | 4814 | 183 | 4016 | 0 | 0 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 4684 | 2127 | 10 | 0 | 179 | 0 | 4 |
| Chromogaster | 673 | 0 | 395 | 10 | 55 | 0 | 0 |
| Trichocerca | 0 | 0 | 48 | 0 | 0 | 0 | 0 |
| Asplancha | 63 | 77 | 125 | 58 | 674 | 0 | 0 |
| Brachionus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Keratella | 1348 | 4761 | 6075 | 809 | 21155 | 17 | 20 |
| Platyias | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Lecane | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water mite | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bosmina longirostris | 1586 | 2246 | 5825 | 1983 | 6712 | 0 | 0 |
| Eubosmina sp. | 0 | 0 | 530 | 48 | 289 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Ceriodaphnia quadrangula | 137 | 268 | 87 | 48 | 28 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Ceriodaphnia reticulata | 133 | 0 | 10 | 77 | 0 | 0 | 0 |
| Daphnia ambigua | 146 | 38 | 106 | 10 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 19 | 0 | 0 | 0 | 14 | 0 | 0 |
| Daphnia parvula | 564 | 592 | 289 | 116 | 0 | 0 | 0 |
| Daphnia rosea | 0 | 315 | 0 | 0 | 0 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diaphanosoma birgei | 38 | 38 | 0 | 0 | 0 | 0 | 0 |
| Ostracoda | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| Calanoida | 784 | 1491 | 520 | 96 | 193 | 10 | 0 |
| Cyclopoida | 521 | 1713 | 703 | 173 | 2270 | 0 | 0 |
| Copepodid | 829 | 1172 | 472 | 96 | 509 | 24 | 8 |
| Nauplii | 8111 | 12486 | 6326 | 1733 | 11691 | 316 | 32 |
| Chaoborus punctipennis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chironomidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| February | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 2484 | 1858 | 5498 | 5141 | 13351 | 261 | 11 |
| Closteriopsis | 746 | 1974 | 1406 | 828 | 359 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 19 | 0 | 14 | 0 |
| Fragalaria | 3880 | 1348 | 4727 | 847 | 1438 | 96 | 3 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Navicula | 0 | 0 | 0 | 0 | 0 | 38265 | 1690 |
| Dinobryon | 13797 | 200547 | 716371 | 86250 | 9294 | 1375 | 8 |
| Chrysocapsa | 289 | 645 | 616 | 135 | 0 | 0 | 0 |
| Anacystis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphospearia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 0 | 0 | 0 | 77 | 0 | 0 |
| Lyngbya | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillatoria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceratium | 17779 | 50202 | 173915 | 155516 | 365874 | 2146 | 35 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 101 | 96 | 0 | 0 | 0 | 28 | 0 |
| Euglyphidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nematoda | 0 | 0 | 0 | 0 | 0 | 55 | 0 |
| Oligochaeta | 0 | 0 | 0 | 39 | 51 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polyarthra | 34 | 376 | 193 | 5392 | 23955 | 1169 | 0 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 722 | 0 | 231 | 2773 | 4262 | 0 | 0 |
| Chromogaster | 323 | 106 | 751 | 1598 | 5212 | 14 | 0 |
| Trichocerca | 0 | 0 | 67 | 0 | 0 | 0 | 0 |
| Asplancha | 5 | 10 | 19 | 154 | 488 | 0 | 0 |
| Brachionus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Keratella | 1386 | 1695 | 3524 | 2349 | 126554 | 1939 | 27 |
| Platyias | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lecane | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water mite | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bosmina longirostris | 2725 | 3014 | 10158 | 14038 | 28166 | 413 | 5 |
| Eubosmina sp. | 58 | 10 | 106 | 58 | 642 | 261 | 5 |
| Alona costata | 0 | 0 | 0 | 0 | 26 | 55 | 0 |
| Ceriodaphnia quadrangula | 0 | 77 | 712 | 154 | 282 | 28 | 0 |
| Ceriodaphnia reticulata | 14 | 0 | 1021 | 58 | 77 | 0 | 0 |
| Daphnia ambigua | 270 | 106 | 481 | 19 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 29 | 19 | 202 | 19 | 0 | 0 | 0 |
| Daphnia lumholtzi | 0 | 0 | 10 | 0 | 26 | 0 | 0 |
| Daphnia parvula | 144 | 106 | 2282 | 58 | 0 | 0 | 0 |
| Daphnia rosea | 144 | 241 | 5055 | 424 | 26 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diaphanosoma birgei | 5 | 0 | 77 | 39 | 0 | 0 | 0 |
| Ostracoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calanoida | 168 | 173 | 1030 | 712 | 3980 | 28 | 3 |
| Cyclopoida | 313 | 308 | 2561 | 2099 | 2208 | 275 | 3 |
| Copepodid | 414 | 376 | 1319 | 578 | 1335 | 757 | 0 |
| Nauplii | 2845 | 2754 | 12459 | 7106 | 27755 | 3191 | 246 |
| Chaoborus punctipennis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chironomidae | 0 | 0 | 0 | 0 | 0 | 248 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| March | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 13076 | 11096 | 14596 | 13323 | 13353 | 1655 | 275 |
| Closteriopsis | 0 | 0 | 10 | 331 | 0 | 0 | 0 |
| Mougeotia | 103 | 0 | 0 | 120 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Spirogyra | 0 | 0 | 0 | 36 | 0 | 0 | 45 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 475 | 0 | 0 | 45 |
| Fragalaria | 1357753 | 865580 | 370322 | 81648 | 2052 | 0 | 115 |
| Tabellaria | 282 | 0 | 0 | 0 | 0 | 0 | 70 |
| Navicula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dinobryon | 5044 | 35702 | 7972 | 62758 | 36088 | 39552 | 70 |
| Chrysocapsa | 494 | 3473 | 5556 | 3851 | 3599 | 0 | 0 |
| Anacystis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gomphospearia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 85 | 0 | 0 | 0 | 0 | 45 |
| Lyngbya | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillatoria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceratium | 34530 | 64968 | 85085 | 49200 | 28241 | 1811 | 160 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Euglyphidae | 0 | 0 | 655 | 2714 | 1878 | 555 | 0 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polyarthra | 041 | 574 | 1646 | 9195 | 28223 | 3542 | 4584 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 188 | 387 | 847 | 2894 | 5705 | 3752 | 3632 |
| Chromogaster | 0 | 0 | 96 | 0 | 0 | 0 | 0 |
| Trichocerca | 0 | 0 | 0 | 84 | 265 | 617 | 91 |
| Asplancha | 0 | 36 | 318 | 144 | 1276 | 123 | 0 |
| Brachionus | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Keratella | 178 | 0 | 0 | 0 | 0 | 0 | 0 |
| Platyias | 0 | 1276 | 5815 | 14773 | 93418 | 13088 | 5948 |
| Lecane | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Water mite | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bosmina longirostris | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Eubosmina sp. | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 0 | 18 | 105 | 0 |
| Ceriodaphnia quadrangula | 0 | 0 | 106 | 0 | 42 | 0 | 0 |
| Ceriodaphnia reticulata | 0 | 0 | 10 | 0 | 0 | 0 | 0 |
| Daphnia ambigua | 1587 | 725 | 520 | 12 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 1625 | 186 | 308 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 03 | 39 | 12 | 18 | 0 | 0 |  |
| Daphnia parvula | 10 | 84 | 18 | 0 | 0 |  |  |
|  |  |  |  |  |  |  |  |

Appendix I.-(Cont.).

| Daphnia rosea | 460 | 61 | 96 | 307 | 84 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 18 | 0 | 0 |
| Diaphanosoma birgei | 47 | 88 | 48 | 0 | 120 | 0 | 415 |
| Ostracoda | 0 | 0 | 10 | 12 | 18 | 0 | 139 |
| Calanoida | 244 | 635 | 1011 | 1474 | 1294 | 167 | 139 |
| Cyclopoida | 2593 | 1839 | 2330 | 6613 | 16272 | 3175 | 1059 |
| Copepodid | 197 | 187 | 404 | 1222 | 1149 | 1716 | 618 |
| Nauplii | 5739 | 5197 | 8608 | 19190 | 14286 | 7809 | 5887 |
| Chaoborus punctipennis | 0 | 0 | 0 | 18 | 18 | 0 | 0 |
| Chironomidae | 0 | 0 | 10 | 0 | 0 | 62 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| April | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 9505 | 11857 | 18149 | 11971 | 13841 | 2156 | 927 |
| Closteriopsis | 0 | 0 | 0 | 289 | 770 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragalaria | 13415970 | 9574765 | 12691775 | 8169415 | 610431 | 9418 | 9175 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 505 |
| Navicula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dinobryon | 0 | 0 | 0 | 24664 | 35528 | 41 | 313 |
| Chrysocapsa | 49 | 0 | 0 | 0 | 1541 | 0 | 0 |
| Anacystis | 1678 | 0 | 8497 | 0 | 2985 | 0 | 0 |
| Gomphospearia | 75676 | 0 | 26333 | 0 | 3346 | 0 | 0 |
| Merismopedia | 10 | 55 | 241 | 0 | 0 | 0 | 0 |
| Lyngbya | 537 | 0 | 9026 | 0 | 1300 | 0 | 0 |
| Oscillatoria | 507435 | 0 | 65376 | 0 | 770 | 0 | 0 |
| Ceratium | 10900 | 81207 | 1084743 | 156106 | 17379 | 777 | 750 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 410 | 0 | 0 | 834 | 0 | 0 | 0 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 215 | 1238 | 1276 | 0 | 0 | 0 | 0 |
| Euglyphidae | 0 | 2104 | 12950 | 3530 | 9171 | 578 | 0 |
| Turbellaria | 20 | 28 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 16 | 0 | 14 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polyarthra | 117 | 2352 | 13167 | 9323 | 5633 | 1874 | 654 |

Appendix I.-(Cont.).

| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Ascomorpha | 683 | 564 | 3081 | 2070 | 3177 | 0 | 0 |
| Chromogaster | 0 | 0 | 0 | 0 | 1685 | 0 | 0 |
| Trichocerca | 68 | 977 | 867 | 594 | 1300 | 0 | 0 |
| Asplancha | 0 | 0 | 193 | 449 | 2311 | 14 | 20 |
| Brachionus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Keratella | 2957 | 7758 | 24624 | 29671 | 171335 | 2211 | 806 |
| Platyias | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lecane | 0 | 0 | 0 | 0 | 96 | 0 | 0 |
| Water mite | 0 | 0 | 0 | 0 | 0 | 45 | 0 |
| Bosmina longirostris | 117 | 385 | 10567 | 21567 | 11939 | 144 | 64 |
| Eubosmina sp. | 0 | 0 | 0 | 16 | 0 | 14 | 0 |
| Alona costata | 0 | 14 | 0 | 0 | 0 | 0 | 0 |
| Ceriodaphnia quadrangula | 0 | 28 | 337 | 289 | 48 | 0 | 0 |
| Ceriodaphnia reticulata | 0 | 0 | 24 | 0 | 0 | 0 | 0 |
| Daphnia ambigua | 429 | 234 | 505 | 144 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 507 | 261 | 867 | 16 | 0 | 0 | 0 |
| Daphnia lumholtzi | 20 | 69 | 48 | 16 | 0 | 0 | 0 |
| Daphnia parvula | 0 | 0 | 144 | 257 | 241 | 28 | 20 |
| Daphnia rosea | 127 | 69 | 265 | 1027 | 578 | 55 | 265 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diaphanosoma birgei | 10 | 14 | 72 | 225 | 481 | 175 | 205 |
| Ostracoda | 0 | 0 | 24 | 160 | 96 | 0 | 0 |
| Calanoida | 49 | 330 | 891 | 850 | 674 | 272 | 44 |
| Cyclopoida | 439 | 867 | 5633 | 19048 | 17283 | 5667 | 3871 |
| Copepodid | 49 | 371 | 2046 | 1958 | 1974 | 1733 | 1107 |
| Nauplii | 2440 | 3576 | 5825 | 17058 | 20508 | 12967 | 22558 |
| Chaoborus punctipennis | 0 | 0 | 24 | 16 | 78 | 72 | 0 |
| Chironomidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 20 | 28 | 24 | 0 | 0 | 0 | 0 |
| May | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 10654 | 5705 | 5760 | 7767 | 7967 | 2507 | 1622 |
| Closteriopsis | 0 | 0 | 176 | 0 | 0 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 358 | 103 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 160 | 0 | 0 | 0 |
| Fragalaria | 557972 | 259285 | 266393 | 15020 | 574 | 1382 | 881 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Navicula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Dinobryon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chrysocapsa | 1216 | 182 | 712 | 0 | 440 | 0 | 0 |
| Anacystis | 1899 | 12267 | 3742 | 0 | 0 | 0 | 0 |
| Gomphospearia | 36328 | 16278 | 24221 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lyngbya | 800917 | 318297 | 30986 | 0 | 0 | 0 | 0 |
| Oscillatoria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceratium | 7951 | 8821 | 2001 | 706 | 3315 | 206 | 0 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 0 | 120 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 0 | 20 | 0 | 0 | 0 | 0 | 29 |
| Euglyphidae | 7026 | 1654 | 4169 | 9163 | 11317 | 0 | 0 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 0 | 28 | 0 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polyarthra | 833 | 214 | 452 | 209 | 739 | 970 | 1117 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 409 | 0 | 184 | 0 | 385 | 279 | 0 |
| Chromogaster | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichocerca | 409 | 0 | 0 | 177 | 38 | 0 | 0 |
| Asplancha | 233 | 155 | 218 | 899 | 131 | 10 | 0 |
| Brachionus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Keratella | 1100 | 1002 | 1013 | 2391 | 1448 | 330 | 0 |
| Platyias | 0 | 0 | 0 | 0 | 0 | 0 | 130 |
| Lecane | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water mite | 0 | 0 | 0 | 32 | 28 | 0 | 0 |
| Bosmina longirostris | 1957 | 466 | 134 | 963 | 141 | 93 | 19 |
| Eubosmina sp. | 0 | 9 | 0 | 32 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceriodaphnia quadrangula | 77 | 61 | 67 | 257 | 0 | 0 | 0 |
| Ceriodaphnia reticulata | 0 | 7 | 0 | 48 | 0 | 0 | 0 |
| Daphnia ambigua | 479 | 53 | 17 | 16 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 474 | 28 | 0 | 32 | 0 | 0 | 0 |
| Daphnia lumholtzi | 0 | 0 | 33 | 979 | 168 | 62 | 0 |
| Daphnia parvula | 0 | 28 | 50 | 706 | 0 | 0 | 0 |
| Daphnia rosea | 26 | 33 | 67 | 2102 | 0 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 55 | 0 | 10 |
| Diaphanosoma birgei | 75 | 55 | 134 | 1476 | 113 | 41 | 34 |
| Ostracoda | 15 | 0 | 128 | 28 | 0 | 10 |  |
| Calanoida | 958 | 561 | 3274 | 533 | 52 | 72 |  |
|  |  |  |  |  |  | 0 |  |

Appendix I.-(Cont.).

| Cyclopoida | 1297 | 1214 | 904 | 5793 | 1025 | 165 | 173 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Copepodid | 934 | 948 | 201 | 2471 | 334 | 144 | 144 |
| Nauplii | 7387 | 4996 | 4689 | 18390 | 12654 | 4230 | 1916 |
| Chaoborus punctipennis | 0 | 9 | 4 | 156 | 113 | 113 | 371 |
| Chironomidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 38 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  |  |  |  |  |  |  |  |
| June | $\mathbf{1}$ | $\mathbf{1 0}$ | $\mathbf{1 7}$ | $\mathbf{2 2}$ | $\mathbf{2 7}$ | $\mathbf{3 1}$ | $\mathbf{3 4}$ |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 15354 | 9489 | 5385 | 6507 | 9360 | 4986 | 3605 |
| Closteriopsis | 0 | 0 | 41 | 0 | 83 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Spirogyra | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| Fragalaria | 284849 | 219394 | 25499 | 4606 | 1183 | 0 | 0 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula | 9 | 0 | 10 | 16 | 0 | 0 | 13 |
| Dinobryon | 18 | 0 | 0 | 0 | 0 | 1087 | 0 |
| Chrysocapsa | 649 | 375 | 0 | 0 | 0 | 0 | 0 |
| Anacystis | 202 | 355 | 144 | 0 | 0 | 0 | 0 |
| Gomphospearia | 45020 | 21978 | 78 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lyngbya | 964 | 247 | 117 | 0 | 0 | 0 | 0 |
| Oscillatoria | 1079 | 520 | 29 | 0 | 0 | 0 | 0 |
| Ceratium | 5030 | 2111 | 356 | 0 | 0 | 0 | 0 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 265 | 0 | 0 | 13 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 0 | 0 | 92 | 658 | 0 | 0 | 0 |
| Euglyphidae | 0 | 0 | 0 | 0 | 16 | 0 | 0 |
| Hydra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Turbellaria | 0 | 0 | 24 | 0 | 0 | 0 |  |
| Nematoda | 0 | 0 | 0 | 88 | 0 | 0 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Polyarthra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chromogaster | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichocerca | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  | 0 | 0 | 0 | 0 | 0 | 0 |  |

Appendix I.-(Cont.).

| Asplancha | 45 | 44 | 115 | 24 | 124 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Brachionus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Keratella | 1163 | 878 | 324 | 273 | 413 | 316 | 484 |
| Platyias | 0 | 0 | 0 | 0 | 0 | 124 | 94 |
| Lecane | 477 | 0 | 440 | 2696 | 5543 | 316 | 1677 |
| Water mite | 9 | 8 | 0 | 0 | 0 | 0 | 0 |
| Bosmina longirostris | 728 | 592 | 211 | 185 | 0 | 0 | 0 |
| Eubosmina sp. | 0 | 35 | 0 | 0 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceriodaphnia quadrangula | 262 | 52 | 0 | 0 | 0 | 0 | 0 |
| Ceriodaphnia reticulata | 0 | 0 | 0 | 32 | 0 | 0 | 0 |
| Daphnia ambigua | 576 | 56 | 0 | 0 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 695 | 43 | 9 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 9 | 0 | 0 | 96 | 34 | 0 | 8 |
| Daphnia parvula | 9 | 8 | 0 | 0 | 0 | 0 | 0 |
| Daphnia rosea | 36 | 0 | 9 | 32 | 34 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diaphanosoma birgei | 27 | 71 | 110 | 1500 | 364 | 41 | 0 |
| Ostracoda | 0 | 0 | 30 | 80 | 34 | 0 | 0 |
| Calanoida | 535 | 948 | 425 | 762 | 440 | 7 | 13 |
| Cyclopoida | 1347 | 1194 | 1143 | 1532 | 763 | 337 | 72 |
| Copepodid | 385 | 375 | 258 | 385 | 186 | 213 | 0 |
| Nauplii | 5419 | 4042 | 4904 | 5584 | 8741 | 1348 | 324 |
| Chaoborus punctipennis | 1 | 0 | 19 | 16 | 62 | 227 | 40 |
| Chironomidae | 0 | 0 | 0 | 0 | 0 | 7 | 13 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 14 | 51 |
| July | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 53737 | 31133 | 14013 | 5191 | 5227 | 8626 | 7818 |
| Closteriopsis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 16 | 9 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 9 | 0 | 0 | 0 | 0 |
| Fragalaria | 94453 | 43871 | 7212 | 1035 | 183 | 0 | 0 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 116 |
| Navicula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dinobryon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chrysocapsa | 162 | 0 | 0 | 0 | 0 | 0 | 0 |
| Anacystis | 393 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Gomphospearia | 12501 | 0 | 0 | 0 | 0 | 0 | 0 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Merismopedia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lyngbya | 12074 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillatoria | 10029 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceratium | 578 | 1699 | 123 | 104 | 0 | 0 | 0 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 0 | 289 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 0 | 152 | 70 | 177 | 0 | 0 | 0 |
| Euglyphidae | 220 | 2549 | 2757 | 4838 | 2274 | 5302 | 11888 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 12 | 0 | 0 | 8 | 9 | 0 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 73 | 0 | 0 |
| Polyarthra | 35 | 286 | 53 | 666 | 1256 | 1295 | 1331 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 185 | 515 | 709 | 1228 | 605 | 855 | 1399 |
| Chromogaster | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichocerca | 381 | 558 | 114 | 24 | 0 | 0 | 0 |
| Asplancha | 35 | 573 | 560 | 32 | 46 | 117 | 635 |
| Brachionus | 0 | 0 | 0 | 674 | 0 | 701 | 847 |
| Keratella | 1525 | 3570 | 1330 | 3314 | 13617 | 7235 | 903 |
| Platyias | 0 | 0 | 0 | 16 | 0 | 0 | 0 |
| Lecane | 266 | 554 | 656 | 4670 | 3833 | 1444 | 2551 |
| Water mite | 12 | 0 | 9 | 32 | 18 | 14 | 7 |
| Bosmina longirostris | 1964 | 1962 | 376 | 297 | 9 | 0 | 0 |
| Eubosmina sp. | 12 | 36 | 9 | 0 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Ceriodaphnia quadrangula | 185 | 229 | 18 | 8 | 0 | 0 | 0 |
| Ceriodaphnia reticulata | 0 | 34 | 9 | 0 | 0 | 0 | 0 |
| Daphnia ambigua | 1225 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 936 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 0 | 12 | 0 | 40 | 37 | 12 | 36 |
| Daphnia parvula | 208 | 36 | 0 | 0 | 0 | 0 | 0 |
| Daphnia rosea | 185 | 12 | 0 | 16 | 0 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 8 | 0 | 0 | 29 |
| Diaphanosoma birgei | 81 | 116 | 140 | 514 | 37 | 0 | 82 |
| Ostracoda | 0 | 0 | 0 | 40 | 0 | 14 | 0 |
| Calanoida | 566 | 1004 | 656 | 385 | 28 | 14 | 0 |
| Cyclopoida | 2819 | 4157 | 3160 | 1099 | 458 | 552 | 221 |
| Copepodid | 1075 | 2624 | 1050 | 345 | 46 | 77 | 26 |
| Nauplii | 7175 | 8114 | 4945 | 5103 | 1614 | 2766 | 2332 |
|  |  |  |  |  |  |  |  |

Appendix I.-(Cont.).

| Chaoborus punctipennis | 2 | 17 | 9 | 8 | 37 | 110 | 34 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Chironomidae | 0 | 0 | 0 | 0 | 0 | 14 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| August | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 45311 | 26587 | 9214 | 10110 | 1197 | 6042 | 12767 |
| Closteriopsis | 128 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 16 | 0 | 0 | 0 |
| Fragalaria | 76002 | 24341 | 14693 | 1777 | 41 | 0 | 0 |
| Tabellaria | 0 | 73 | 0 | 0 | 0 | 0 | 0 |
| Navicula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dinobryon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chrysocapsa | 0 | 91 | 0 | 0 | 0 | 0 | 0 |
| Anacystis | 621 | 173 | 58 | 0 | 0 | 0 | 0 |
| Gomphospearia | 390 | 0 | 0 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 0 | 0 | 48 | 2476 | 48 | 0 |
| Lyngbya | 24399 | 12664 | 4333 | 5452 | 0 | 0 | 0 |
| Oscillatoria | 71 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceratium | 1582 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 0 | 250 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 173 |
| Nebelidae | 0 | 0 | 0 | 622 | 0 | 0 | 0 |
| Euglyphidae | 0 | 82 | 1309 | 8080 | 42791 | 5829 | 11804 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 36 | 309 | 0 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 124 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 0 | 0 | 0 | 116 |
| Polyarthra | 10 | 82 | 308 | 369 | 2043 | 1451 | 3389 |
| Ploeosoma | 0 | 0 | 0 | 0 | 3487 | 0 | 0 |
| Ascomorpha | 370 | 320 | 558 | 1625 | 3961 | 1461 | 982 |
| Chromogaster | 0 | 0 | 0 | 209 | 0 | 0 | 0 |
| Trichocerca | 20 | 0 | 125 | 0 | 0 | 0 | 0 |
| Asplancha | 83 | 64 | 48 | 32 | 41 | 96 | 308 |
| Brachionus | 0 | 27 | 0 | 1039 | 516 | 138 | 2388 |
| Keratella | 2259 | 0 | 982 | 1167 | 11017 | 6895 | 6663 |
| Platyias | 0 | 155 | 29 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Lecane | 0 | 520 | 751 | 2018 | 0 | 3848 | 7260 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Water mite | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bosmina longirostris | 1313 | 895 | 356 | 273 | 0 | 17 | 0 |
| Eubosmina sp. | 12 | 9 | 0 | 0 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceriodaphnia quadrangula | 955 | 146 | 10 | 0 | 0 | 0 | 0 |
| Ceriodaphnia reticulata | 139 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia ambigua | 920 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 1449 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 0 | 0 | 0 | 36 | 62 | 0 | 0 |
| Daphnia parvula | 95 | 9 | 0 | 0 | 0 | 0 | 0 |
| Daphnia rosea | 544 | 55 | 0 | 0 | 0 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 20 | 722 | 151 | 193 |
| Diaphanosoma birgei | 621 | 119 | 212 | 991 | 0 | 14 | 0 |
| Ostracoda | 0 | 0 | 0 | 40 | 743 | 28 | 0 |
| Calanoida | 1916 | 484 | 164 | 798 | 0 | 0 | 19 |
| Cyclopoida | 2452 | 3369 | 3630 | 3715 | 640 | 203 | 270 |
| Copepodid | 5291 | 1488 | 616 | 654 | 103 | 17 | 212 |
| Nauplii | 7686 | 4830 | 6258 | 12601 | 1320 | 4333 | 11130 |
| Chaoborus punctipennis | 10 | 0 | 19 | 76 | 172 | 138 | 1656 |
| Chironomidae | 0 | 0 | 10 | 0 | 21 | 0 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |


| September | $\mathbf{1}$ | $\mathbf{1 0}$ | $\mathbf{1 7}$ | $\mathbf{2 2}$ | $\mathbf{2 7}$ | $\mathbf{3 1}$ | $\mathbf{3 4}$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 113625 | 74766 | 59119 | 7214 | 2545 | 4949 | 16518 |
| Closteriopsis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mougeotia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragalaria | 95435 | 64552 | 1764 | 0 | 378 | 0 | 0 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dinobryon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chrysocapsa | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Anacystis | 237 | 0 | 0 | 87 | 0 | 0 | 0 |
| Gomphospearia | 16532 | 0 | 0 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 0 | 0 | 0 | 34 | 0 | 0 |
| Lyngbya | 260884 | 39362 | 37414 | 2571 | 172 | 0 | 0 |
| Oscillatoria | 18605 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Ceratium | 2374 | 219 | 0 | 0 | 0 | 0 | 0 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 168 | 1850 |
| Phacus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nebelidae | 0 | 125 | 1635 | 982 | 0 | 0 | 0 |
| Euglyphidae | 455 | 366 | 3455 | 32308 | 3783 | 2313 | 16028 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oligochaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 433 | 0 | 0 | 0 | 0 | 0 | 0 |
| Polyarthra | 320 | 83 | 137 | 953 | 413 | 36 | 4649 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 0 | 354 | 404 | 1278 | 1857 | 7026 | 10606 |
| Chromogaster | 605 | 0 | 0 | 0 | 0 | 0 | .0 |
| Trichocerca | 0 | 31 | 480 | 260 | 0 | 0 | 0 |
| Asplancha | 43 | 21 | 37 | 397 | 103 | 173 | 0 |
| Brachionus | 0 | 0 | 0 | 744 | 7393 | 12240 | 14716 |
| Keratella | 947 | 869 | 2514 | 3777 | 16746 | 6704 | 30275 |
| Platyias | 0 | 0 | 0 | 0 | 1479 | 0 | 0 |
| Lecane | 0 | 796 | 1264 | 3582 | 4814 | 5488 | 14090 |
| Water mite | 0 | 0 | 0 | 0 | 103 | 0 | 0 |
| Bosmina longirostris | 538 | 546 | 646 | 0 | 69 | 0 | 0 |
| Eubosmina sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 0 | 0 | 34 | 45 |
| Ceriodaphnia quadrangula | 79 | 75 | 56 | 22 | 0 | 0 | 0 |
| Ceriodaphnia reticulata | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia ambigua | 136 | 19 | 0 | 0 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 459 | 27 | 0 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| Daphnia parvula | 92 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia rosea | 84 | 13 | 14 | 0 | 0 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diaphanosoma birgei | 57 | 173 | 93 | 419 | 0 | 34 | 93 |
| Ostracoda | 0 | 0 | 0 | 29 | 69 | 34 | 0 |
| Calanoida | 4740 | 2075 | 8412 | 166 | 34 | 0 | 0 |
| Cyclopoida | 1759 | 2092 | 328 | 2080 | 1169 | 693 | 45 |
| Copepodid | 247 | 708 | 2278 | 643 | 688 | 0 | 48 |
| Nauplii | 9845 | 3693 | 6763 | 11243 | 10763 | 2951 | 2458 |
| Chaoborus punctipennis | 8 | 40 | 25 | 29 | 2132 | 0 | 0 |
| Chironomidae | 0 | 0 | 0 | 29 | 0 | 0 | 45 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|  |  |  |  |  |  |  |  |

Appendix I.-(Cont.).

| October | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 109644 | 68072 | 47206 | 26357 | 30480 | 18444 | 33889 |
| Closteriopsis | 0 | 0 | 0 | 265 | 0 | 0 | 0 |
| Mougeotia | 0 | 0 | 12 | 0 | 0 | 0 | 0 |
| Spirogyra | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 0 | 0 | 0 | 30 | 0 |
| Fragalaria | 1139336 | 700223 | 260385 | 47395 | 1623 | 0 | 1057 |
| Tabellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navicula | 0 | 0 | 0 | 0 | 523 | 0 | 0 |
| Dinobryon | 0 | 0 | 0 | 0 | 0 | 0 | 289 |
| Chrysocapsa | 0 | 0 | 217 | 0 | 0 | 0 | 0 |
| Anacystis | 327 | 217 | 108 | 0 | 0 | 0 | 0 |
| Gomphospearia | 282 | 177 | 54 | 0 | 0 | 0 | 0 |
| Merismopedia | 0 | 8 | 0 | 24 | 28 | 0 | 0 |
| Lyngbya | 11244 | 11233 | 5287 | 0 | 0 | 0 | 0 |
| Oscillatoria | 1483 | 770 | 60 | 0 | 0 | 0 | 0 |
| Ceratium | 1624 | 1268 | 719 | 3009 | 853 | 0 | 0 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phacus | 0 | 0 | 0 | 72 | 0 | 0 | 0 |
| Nebelidae | 0 | 88 | 54 | 1011 | 1100 | 512 | 0 |
| Euglyphidae | 3036 | 1396 | 765 | 9388 | 1541 | 0 | 0 |
| Turbellaria | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 0 | 0 | 0 | 0 | 28 | 0 | 0 |
| Oligochaeta | 9 | 8 | 0 | 0 | 0 | 0 | 0 |
| Filinia | 0 | 0 | 0 | 24 | 0 | 0 | 0 |
| Polyarthra | 26 | 297 | 1090 | 6307 | 6272 | 0 | 4116 |
| Ploeosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ascomorpha | 750 | 417 | 302 | 3562 | 275 | 4357 | 4744 |
| Chromogaster | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichocerca | 221 | 201 | 1538 | 2287 | 0 | 0 | 0 |
| Asplancha | 35 | 88 | 284 | 3659 | 55 | 0 | 0 |
| Brachionus | 0 | 0 | 84 | 217 | 0 | 0 | 0 |
| Keratella | 1712 | 1741 | 3522 | 10374 | 9188 | 2876 | 3327 |
| Platyias | 0 | 0 | 0 | 0 | 55 | 0 | 0 |
| Lecane | 0 | 0 | 0 | 96 | 413 | 0 | 303 |
| Water mite | 9 | 0 | 0 | 72 | 0 | 0 | 0 |
| Bosmina longirostris | 4051 | 2792 | 3851 | 4188 | 2586 | 259 | 72 |
| Eubosmina sp. | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| Alona costata | 0 | 0 | 0 | 24 | 0 | 0 | 0 |
| Ceriodaphnia quadrangula | 97 | 24 | 0 | 0 | 0 | 0 | 0 |

Appendix I.-(Cont.).

| Ceriodaphnia reticulata | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Daphnia ambigua | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia lumholtzi | 9 | 16 | 91 | 144 | 83 | 126 | 354 |
| Daphnia parvula | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Daphnia rosea | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| Simocephalus serratulus | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diaphanosoma birgei | 79 | 177 | 513 | 530 | 55 | 0 | 0 |
| Ostracoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calanoida | 3133 | 1878 | 1007 | 2046 | 138 | 1480 | 104 |
| Cyclopoida | 2039 | 3458 | 3938 | 10206 | 9408 | 1396 | 383 |
| Copepodid | 653 | 1693 | 2437 | 4140 | 1651 | 415 | 106 |
| Nauplii | 3469 | 6130 | 15363 | 36347 | 20687 | 21032 | 13044 |
| Chaoborus punctipennis | 0 | 0 | 0 | 0 | 55 | 0 | 0 |
| Chironomidae | 0 | 0 | 0 | 0 | 28 | 0 | 0 |
| Trichoptera | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caenidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annual | 1 | 10 | 17 | 22 | 27 | 31 | 34 |
| Phytoplankton: |  |  |  |  |  |  |  |
| Pediastrum | 37875 | 24831 | 18078 | 9381 | 10028 | 4973 | 7749 |
| Closteriopsis | 87 | 197 | 213 | 171 | 121 | 0 | 0 |
| Mougeotia | 10 | 0 | 1 | 14 | 1 | 0 | 7 |
| Spirogyra | 0 | 0 | 0 | 4 | 41 | 10 | 9 |
| Zygnema | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Closterium | 0 | 0 | 1 | 67 | 0 | 5 | 5 |
| Fragalaria | 1702985 | 1175905 | 1364337 | 832195 | 61863 | 1107 | 1125 |
| Tabellaria | 28 | 7 | 0 | 0 | 0 | 2 | 77 |
| Navicula | 1 | 0 | 12 | 2 | 52 | 3827 | 170 |
| Dinobryon | 2897 | 26353 | 76474 | 18346 | 9882 | 4269 | 68 |
| Chrysocapsa | 730 | 477 | 726 | 399 | 558 | 0 | 0 |
| Anacystis | 536 | 1301 | 1255 | 9 | 298 | 0 | 0 |
| Gomphospearia | 51363 | 3843 | 5069 | 39 | 335 | 0 | 0 |
| Merismopedia | 1 | 15 | 25 | 7 | 261 | 5 | 5 |
| Lyngbya | 111102 | 38180 | 8716 | 802 | 147 | 0 | 0 |
| Oscillatoria | 53870 | 129 | 6546 | 0 | 77 | 0 | 0 |
| Ceratium | 11454 | 32083 | 145471 | 38767 | 74074 | 494 | 95 |
| Zooplankton: |  |  |  |  |  |  |  |
| Peranema | 41 | 0 | 0 | 110 | 0 | 0 | 31 |
| Phacus | 1 | 0 | 0 | 7 | 0 | 17 | 239 |
| Nebelidae | 32 | 172 | 313 | 345 | 110 | 54 | 3 |
| Euglyphidae | 1225 | 1098 | 2747 | 7581 | 7652 | 1458 | 3992 |

Appendix I.-(Cont.).

| Hydra |  | 0 | 0 | 0 | 2 | 0 | 0 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Turbellaria | 2 | 3 | 0 | 0 | 0 | 0 | 0 |
| Nematoda | 1 | 0 | 0 | 8 | 37 | 7 | 5 |
| Oligochaeta | 1 | 1 | 0 | 13 | 18 | 0 | 0 |
| Filinia | 43 | 0 | 0 | 2 | 7 | 0 | 12 |
| Polyarthra | 553 | 1116 | 2186 | 3412 | 7424 | 1118 | 2050 |
| Ploeosoma | 0 | 0 | 0 | 0 | 349 | 0 | 0 |
| Ascomorpha | 799 | 468 | 671 | 1593 | 2228 | 1773 | 2137 |
| Chromogaster | 160 | 11 | 124 | 182 | 695 | 1 | 0 |
| Trichocerca | 110 | 177 | 324 | 343 | 160 | 62 | 9 |
| Asplancha | 54 | 107 | 192 | 585 | 525 | 53 | 96 |
| Brachionus | 18 | 3 | 8 | 267 | 791 | 1308 | 1795 |
| Keratella | 1525 | 2355 | 4972 | 6890 | 46489 | 4161 | 4845 |
| Platyias | 0 | 16 | 3 | 2 | 153 | 13 | 22 |
| Lecane | 74 | 187 | 311 | 1306 | 1470 | 1110 | 2588 |
| Water mite | 4 | 1 | 1 | 14 | 15 | 6 | 1 |
| Bosmina longirostris | 1665 | 1342 | 3514 | 5348 | 5650 | 142 | 30 |
| Eubosmina sp. | 11 | 12 | 64 | 15 | 93 | 28 | 1 |
| Alona costata | 2 | 1 | 0 | 3 | 4 | 19 | 5 |
| Ceriodaphnia quadrangula | 179 | 96 | 139 | 78 | 40 | 3 | 0 |
| Ceriodaphnia reticulata | 30 | 4 | 107 | 22 | 8 | 0 | 0 |
| Daphnia ambigua | 577 | 123 | 163 | 20 | 0 | 0 | 0 |
| Daphnia galeata mendotae | 619 | 56 | 139 | 7 | 0 | 0 | 0 |
| Daphnia lumholtzi | 6 | 12 | 24 | 132 | 44 | 20 | 40 |
| Daphnia parvula | 111 | 78 | 278 | 122 | 26 | 3 | 2 |
| Daphnia rosea | 161 | 81 | 551 | 391 | 72 | 6 | 26 |
| Simocephalus serratulus | 0 | 0 | 0 | 3 | 80 | 15 | 23 |
| Diaphanosoma birgei | 104 | 85 | 140 | 569 | 117 | 31 | 83 |
| Ostracoda | 0 | 2 | 6 | 49 | 99 | 7 | 15 |
| Calanoida | 1332 | 998 | 1468 | 1057 | 731 | 203 | 39 |
| Cyclopoida | 1558 | 2021 | 2433 | 5236 | 5150 | 1246 | 610 |
| Copepodid | 1007 | 994 | 1108 | 1249 | 797 | 510 | 227 |
| Nauplii | 6012 | 5582 | 7614 | 13436 | 13002 | 6094 | 5993 |
| Chaoborus punctipennis | 2 | 7 | 10 | 32 | 267 | 66 | 210 |
| Chironomidae | 0 | 0 | 2 | 3 | 5 | 33 | 6 |
| Trichoptera | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| Caenidae | 2 | 3 | 2 | 0 | 0 | 1 | 5 |
|  |  |  |  |  |  |  |  |

