THE DISTRIBUTION OF THE WATER FLEA

(CLADOCERA: DAPHNIDAE) IN A CENTRAL TEXAS RESERVOIR

THESIS

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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 $1.8 \,\mu g/L$) 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

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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 (C:N: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 N:P ratio (12.3 to 12.9 for various *Daphnia* species) while other cladocerans, such as *Bosmina*, possess a high body N: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 N:P ratios. In most lakes the N: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 N: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 C:P and N: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 N: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 distribution and population and population 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°52'07"N, 98°11'55"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.

1 /	
Surface area	33.4 km ²
Volume	$471.2 \text{ x } 10^6 \text{ m}^3$
Mean depth	14.3 m
Maximum depth	48 m
Drainage basin area	3,709 km ²
Range of annual precipitation	47-163 cm
Mean annual residence time	1.64 yr
Specific conductance	417 µS/cm
Chlorophyll a	3.9 µg/l
Total phosphorus	17 µg/l
Secchi disk transparency	2.8 m
Trophic classification	Oligomesotrophic

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).

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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 μ 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).

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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 μ moles/L according to the methods of Sterner et al. (1997). Light in the mixed layer (I_m) was calculated from the equation:

$$I_{m} = (1 - e^{-Kzm}) / Kz_{m}$$

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

$$K = 1.54/z_{sd}$$

where z_{sd} is the Secchi disk depth. This index may be used to estimate seston C:P ratios. A light :TP ratio of 1.00 approximates a seston C: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 ≤ 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 (β) 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:

$$\ln D = 3.3956 + 0.2193 \ln T - 0.3414 (\ln T)^2$$

where D is egg development time (⁻d) and T is temperature (°C). After β was 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 μ g/L phosphorus as a K₂HPO₄ solution and 100 μ g/L nitrogen as a NH₄Cl solution. Each water sample was filtered through a 80 μ 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°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:

$$g = [\ln W_0 - \ln W_t]/T$$

Where g is the growth rate ('d), W_0 is the initial dry weight (μ g), W_t is the final dry weight (μ g) after time T (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 μ g/L nitrogen (N) as a NH₄Cl solution, addition of 50 μ g/L phosphorus (P) as a K₂HPO₄ solution, and a metals treatment (M) consisting of 100 μ 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 August.

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

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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.

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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 (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 μ 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

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Taxonomic	Parameter	Source	df	SS	MS	F	p value
Category						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	Abundance	Station	6	408158.42	68026.40	181.46	< 0.0001
Zooplankton		Month	9	227747.94	25305.33	67.50	< 0.0001
F		Interaction	54	498268.20	9227.19	24.61	< 0.0001
		Error	70	26241.17	374.87		
		Total	139	1160415.73			
Total	Abundance	Station	6	71.24	11.87	66.86	< 0.0001
Cladacara	Abundance	Month	0	27.00	3.00	16.80	< 0.0001
Claudeera		Interaction	54	45.28	0.84	4 72	< 0.0001
		Frror	70	12 43	0.04	7.72	< 0.0001
		Total	139	155.95	0.10		
		1000	157	155.75			
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	0.01	1010007
		Total	57	0.83			
	De- A-	Q4-4	A	0.17	0.04	E E 0	< 0.0001
	Egg Age	Station	4	0.17	0.04	5.58	< 0.0021
	Distribution	Month Tetars at a	1	0.29	0.04	5.47	< 0.0005
		Interaction	22	0.49	0.02	2.93	< 0.0044
		Error	21	0.21	0.01		
		Total	60	1.12			

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

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

Phytoplanton: Division Chlorophyta Sub-Division Chlorophyceae **Order Chlorococcales** Family Hydrodictyaceae Pediastrum **Family Oocystaceae** Closteriopsis **Order Zygnematales** Family Zygnemataceae Mougeotia Spirogyra Zygnema **Family Desmidiaceae** Closterium **Division Chrysophyta** Sub-Division Bacillariophyceae **Order Pennales** Family Fragilariaceae Fragalaria Tabellaria Family Naviculaceae Navicula Sub-Division Chrysophyceae **Order Chrysomonadales Family Ochromonadaceae** Dinobryon **Order Chrysocapsaceae** Family Chrysocapsaceae Chrysocapsa **Division Cyanophyta Sub-Division Myxophyceae Order Chroococcales Family Chroococcales** Anacystis Gomphospearia Merismopedia **Order Homogonales** Family Oscillatoriaceae Lyngbya Oscillatoria **Division Pyrrhophyta** Sub-Division Cryptophyceae **Order Péridiniales Family Ceratiaceae** 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 Platvias **Family Lecanidae** Lecane **Phylum Arthropoda** Subphylum Chelicerata **Class Arachnida** Water mite Subphylum Crustacea **Class Branchiopoda Order Cladocera Family Bosminidae** Bosmina longirostris Eubosmina sp.

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

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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 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.

(8/m³). occurred in August and of instars II (153/m³) and III (165/m³) 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 (156/m³), 22 km from the dam while a secondary peak in abundance occurred in May (57/m³) 22 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.



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 (p < 0.001, Figure 9). Significant interaction effects were observed in clutch size and egg age two-way ANOVAs (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 entre reservoir of 1.09 for the study. Birth rates were low throughout the study period (< 0.15 ⁻d). Highest birth rates were observed in May (0.09 ⁻d) while lowest birth rates (0.01 ⁻d) occurred in January and September (Figure 9). Longitudinally, birth rates were lowest 10 km from the dam (0.02 -d) 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



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

	Abundance (Individuals/m ³)		Biomass (µg/L)	Length (mm)	Lipid-Ovary Index		Clutch Size (# eggs/ gravid	Egg Age	Percent Ovigerous Females
							female)		Females
	Mean	n				n	,		
Month:									
January	428 ± 499	162	228 ± 313	0.58 ± 0.11	0.002 ± 0.007	26	0.69 ± 0.31	0.69 ± 0.47	10.22 ± 7.31
February	1726 ± 3555	377	2769 ± 5761	0.69 ± 0.27	1.059 ± 0.181	70	1.13 ± 0.72	0.89 ± 0.64	14.85 ± 10.10
March	907 ± 1298	184	2186 ± 3901	0.86 ± 0.21	1.179 ± 0.244	44	1.15 ± 0.59	0.68 ± 0.46	11.83 ± 9.84
April	988 ± 761	288	1326 ± 1492	0.73 ± 0.20	0.808 ± 0.382	80	1.07 ± 0.60	1.05 ± 0.42	19.33 ± 9.85
May	848 ± 1493	257	1079 ± 1676	0.73 ± 0.16	0.919 ± 0.306	58	1.38 ± 1.04	1.52 ± 1.38	29.99 ± 35.70
June	286 ± 578	119	415 ± 921	0.75 ± 0.09	0.549 ± 0.462	28	0.70 ± 0.27	1.67 ± 1.67	10.58 ± 13.37
July	468 ± 1007	149	607 ± 1509	0.63 ± 0.22	0.511 ± 0.358	33	1.46 ± 1.21	1.45 ± 0.39	13.84 ± 17.94
August	787 ± 1484	230	1043 ± 2618	0.54 ± 0.16	0.692 ± 0.577	42	0.78 ± 0.17	1.57 ± 0.86	20.93 ± 35.78
September	156 ± 310	60	203 ± 461	0.55 ± 0.26	0.585 ± 0.356	2	0.44 ± 0.33	0.54 ± 0.19	4.70 ± 8.04
October	140 ± 100	49	68 ± 42	0.61 ± 0.06	1.04 ± 0.386	8	1.20 ± 0.65	1.58 ± 0.87	14.56 ± 10.71
Reservoir									
location:									
1	1682 ± 1351	720	3314 ± 3283	0.86 ± 0.16	0.852 ± 0.412	160	0.87 ± 0.64	0.98 ± 0.44	14.87 ± 7.01
10	450 ± 396	231	546 ± 639	0.72 ± 0.16	0.687 ± 0.336	33	0.63 ± 0.29	1.25 ± 0.87	11.05 ± 7.55
17	1400 ± 3019	383	2185 ± 4933	0.66 ± 0.18	0.870 ± 0.423	86	1.07 ± 0.22	1.03 ± 0.33	24.04 ± 28.44
22	774 ± 1292	373	757 ± 1328	0.60 ± 0.16	0.753 ± 0.446	85	1.22 ± 0.55	1.48 ± 1.27	15.34 ± 11.46
27	269 ± 317	102	90 ± 100	0.60 ± 0.18	0.707 ± 0.521	21	1.50 ± 1.14	0.76 ± 0.62	13.85 ± 18.98
31	46 ± 57	26	18 ± 25	0.61 ± 0.25	0.765 ± 0.641	4	2.33 ± 1.41	2.25 ± 1.06	14.44 ± 19.63
34	91 ± 135	40	36 ± 71	0.54 ± 0.13	0.555 ± 0.371	2	2.00 ± 0.00	1.00 ± 0.00	17.95 ± 40.31
Annual:	612 ± 1376	1875	902 ± 2404	0.67 ± 0.19	0.754 ± 0.473	391	1.09 ± 0.67	1.24 0.89	15.94 ± 19.72

Table 4. Mean values (± 1 SD) of Daphnidae population parameters by month and reservoir station.



Figure 9. The longitudinal distribution of Daphnidae population parameters (lipid-ovary index \blacksquare , clutch size \blacktriangle , egg age \bigcirc , birth rate \diamondsuit , and mean length \bigtriangledown) 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 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 mg/L. By July the mean D.O. concentration for the reservoir's hypolimnion had decreased to 0.59 mg/L. Bottom D.O.

	Temperature	Chlorophyll	Alkalinity	Turbidity	TP (μg/L)
	(°C)	a (μg/L)	(meq/L)	(NTU)	
January	11.86 ± 0.89	1.89 ± 1.06	3.57 ± 0.54	5.90 ± 2.18	20.74 ± 56.87
February	14.42 ± 1.38	1.76 ± 0.54	3.37 ± 0.36	5.06 ± 2.15	61.28 ± 47.05
March	17.60 ± 2.38	2.52 ± 0.53	3.27 ± 0.30	4.38 ± 1.91	1.91 ± 2.39
April	18.60 ± 2.28	3.06 ± 0.64	3.20 ± 0.37	4.38 ± 2.19	
May	22.36 ± 3.59	4.47 ± 3.38	3.00 ± 0.36	3.89 ± 2.12	86.44 ± 57.56
June	21.75 ± 3.09	5.24 ± 5.00	2.76 ± 0.19	6.14 ± 5.45	10.49 ± 11.79
July	23.86 ± 3.84	11.68 ± 13.78	2.69 ± 0.33	3.58 ± 1.87	2.37 ± 2.83
August	24.18 ± 3.61	8.53 ± 9.80	2.69 ± 0.33	4.16 ± 1.85	21.82 ± 48.24
September	24.69 ± 4.19	10.22 ± 6.83	2.81 ± 0.37	3.33 ± 1.82	
October	19.27 ± 0.96	7.19 ± 3.85	2.77 ± 0.24	4.53 ± 2.04	2.91 ± 3.15
1	17.27 ± 2.71	2.84 ± 1.98	2.61 ± 0.23	1.84 ± 0.41	38.18 ± 58.56
10	19.07 ± 3.50	3.67 ± 2.93	2.66 ± 0.23	2.83 ± 0.48	59.87 ± 86.51
17	21.82 ± 4.46	2.67 ± 1.33	2.76 ± 0.30	4.52 ± 1.06	16.65 ± 21.13
22	22.90 ± 5.80	3.87 ± 1.21	2.42 ± 1.16	7.29 ± 0.52	32.44 ± 48.08
27	23.00 ± 5.94	7.13 ± 5.62	3.19 ± 0.37	5.14 ± 1.77	32.14 ± 47.07
31	22.29 ± 6.22	14.67 ± 12.40	3.45 ± 0.33	4.94 ± 1.60	32.28 ± 49.86
34	22.98 ± 6.69	9.82 ± 9.43	3.40 ± 0.36	6.27 ± 5.17	22.39 ± 33.45
Annual	20.04 ± 5.00	5.83 ± 7.05	2.99 ± 0.44	4.87 ± 4.17	34.58 ± 53.59
	Light : Total	Dissolved	Secchi Disk	Stratification	Conductivity
	Phosphorus	Oxygen	(m)	Index	(µS/cm)
Tomport	1.05	(mg/L)	1 42 + 0.62	0.50	205 + 42
January	1.05	9.03 ± 0.42 8 46 ± 0.51	1.42 ± 0.03 1.84 ± 1.10	0.39	393 ± 43 307 + 37
March	11 72	7.90 ± 0.31	2.54 ± 1.19	7.07	396 + 34
April		6.01 ± 0.46	1.81 ± 0.93	5.94	373 ± 30
May	0.25	4.32 ± 0.18	2.04 ± 1.29	8.65	383 ± 27
June	1.82	3.99 ± 0.85	2.09 ± 1.48	6.30	369 ± 20
July	9.41	3.01 ± 0.46	2.45 ± 1.65	9.06	369 ± 19
August	0.97	3.45 ± 0.82	2.24 ± 1.69	7.77	354 ± 15
September	6.01	3.98 ± 1.06	2.38 ± 1.51	6.45	360 ± 21
October	6.81	5.59 ± 1.43	2.01 ± 1.46	2.87	372 ± 25
1	0.69	5.14 ± 2.41	4.69 ± 1.11	9.08	362 ± 9
10	0.41	5.57 ± 2.48	2.91 ± 0.61	8.85	360 ± 10
17	1.29	5.52 ± 2.15	1.71 ± 0.28	7.19	365 ± 12
22	0.53	6.18 ± 1.94	1.04 ± 0.08	2.69	379 ± 20
27	0.60	5.66 ± 1.86	1.32 ± 0.29	4.47	426 ± 28
31		F (1) 100	121 + 0.07	5 50	435 + 31
	0.61	5.64 ± 1.99	1.51 ± 0.27	5.59	$+55 \pm 51$
34	0.61 0.85	5.64 ± 1.99 6.68 ± 1.86	1.31 ± 0.27 1.34 ± 0.44	3.91	433 ± 31 428 ± 37

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

concentrations increased in August and were above 1 mg/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 ($60 \mu g/L$) and lowest 17 km from the dam ($17 \mu g/L$). Overall, high mean reservoir TP concentrations occurred in May ($86 \mu g/L$) and February ($61 \mu g/L$), while low mean reservoir TP concentrations occurred in March ($2 \mu g/L$), July ($2 \mu g/L$) and October ($3 \mu g/L$). 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 (p < 0.0001). In July, nitrogen, phosphorus and metals (NPM) and nitrogen and metals (NM) treatments were significantly higher than the control (p < 0.0001, Figure 11). Nitrogen (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 (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.

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			
October	Station	1	2 15	2 15	156 37	< 0.0001
October	Treatment	8	1 0/	0.24	17 50	< 0.0001
	Internetion	0	1.54	0.24	17.J 9 6 40	< 0.0001
	Interaction	8	0.71	0.09	0.48	< 0.0001
	Error	52	0.72	0.01		
	Total	69	5,52			

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



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^{th} and 90^{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 (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^{th} and 90^{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 (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^{th} and 90^{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 (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 (P) treatment from the control in the October experiment (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 (Figure 17).



Figure 14. Mean growth rate of *Daphnia parvula* grown in filtered and treated water samples collected August 10^{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 (P) and nitrogen and phosphorus (NP). Growth rate of *Daphnia parvula* in treated water was not significantly different (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^{th} , 2000 and (b) 27 km from the dam October 13^{th} , 2000. See Fig. 17 for explanation of treatments. Growth rate of *Daphnia pulex* in treated water was not significantly different (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
Reservoir	1	488.28	488.28	2.02	< 0.1683
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			
	Source Reservoir location Treatment Interaction Error Total	SourcedfReservoir1location7Treatment3Interaction3Error24Total31	SourcedfSSReservoir1488.28location7Treatment39832.09Interaction33244.84Error245807.75Total3119372.96	SourcedfSSMSReservoir1488.28488.28locationTreatment39832.093277.36Interaction33244.841081.61Error245807.75241.99Total3119372.96	SourcedfSSMSF valueReservoir1488.28488.282.02location7713.54Treatment39832.093277.3613.54Interaction33244.841081.614.47Error245807.75241.997Total3119372.9619372.9619372.96

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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^{th} , 2000 and (b) 27 km from the dam October 13^{th} , 2000. See Fig. 17 for explanation of treatments. Survival was significantly higher in phosphorus treatments (P) than controls (p < 0.0001).

	β	SE (β)	t for H_o : Parameter = 0	Partial r ²	p level
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

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



Figure 17. Only net phytoplankton abundance was significantly correlated to (a) Daphnidae abundance and (b) Daphnidae biomass in multiple regression analyses (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:P ratio 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 km from the dam). Daphnidae, unlike other zooplankton, were concentrated in the lacustrine zone (1 - 17km 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 μ g/L and 288 μ g/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 μ g/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 lin	Predation	
Food quantity	Food quality	
• Net phytoplankton abundance significantly correlated to Daphnidae abundance and biomass	• High quality food items (diatoms) dominated net phytoplankton assemblage in April when Daphnidae abundance at its highest	• Net phytoplankton abundance only explained half of the variation in Daphnidae abundance and biomass in multiple regression analyses
• Light:TP ratios below 1.00 at most reservoir stations	• Low quality food items (blue-green algae) dominated the net phytoplankton assemblage in May prior to the decline in abundance and biomass of Daphnidae in June and again in September when Daphnidae abundance and biomass once again decreased	• Distribution of fourth instar <i>Chaoborus</i> <i>punctipennis</i> up- reservoir while Daphnidae abundance and biomass were concentrated at near- dam stations
		 Highest mean lengths 1 km from the dam, declining up-reservoir Distribution of <i>chlorophyll a</i> peak up- reservoir (31 km from the dam) Young egg age distribution throughout study Increased birth rates up- reservoir

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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 μ m plankton net. The optimal size range of food items for cladoceran zooplankton to efficiently feed is $< 30 \ \mu m$ (Muller-Navarra and Lampert 1996), however daphnids commonly filter food items between 1 and 53 μ 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 μ 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 length 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 μ g/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 N: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 (p < 0.0001), however, TP concentrations and Daphnidae population parameters were not significantly correlated. Only net phytoplankton abundance was significantly correlated to Daphnidae abundance (p < 0.014, $r^2 = 0.44$) and biomass (p < 0.004, $r^2 = 0.54$). 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 (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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LITERATURE CITED

- American Public Health Association. 1992. Standard methods for the examination of water and wastewater. 18th ed. APHA. 1100 pp.
- Andersen, T., and D. O. Hessen. 1991. Carbon, nitrogen, and phosphorus content of freshwater zooplankton. Limnol. Oceanogr. 36:807-814.
- Bottrell, H. H., A. Duncan, Z. Gliwicz, E. Grygierek, A. Herzig, A. Hillbricht-Illkowska,
 H. Kurasawa, P. Larsson, and T. Weglenska. 1976. A review of some problems in zooplankton production studies. Norw. J. Zool. 24:419-456.
- Brooks, J. L. 1957. The systematics of North American *Daphnia*. Connecticut Academy of Arts and Sciences, Connecticut. 180 pp.
- Brooks, J. L., and S. I. Dodson. 1965. Predation, body size, and composition of plankton. Science 150:28-35.
- Buzan, D. 1979. Seasonal and longitudinal distribution of the plankton community in a deep-storage reservoir in central Texas. M. S. Thesis. Southwest Texas State University. 63 pp.
- Caldwell, B. D. 1983. Trophic assessment of Canyon Reservoir using chlorophyll a and total phosphorus indices and models. M. S. Thesis. Southwest Texas State University. 82 pp.
- Cummins, K. W., R. R. Costa, R. E. Rowe, G. A. Moshiri, R. M. Scanlon, and R. K. Zajdel. 1969. Ecological energetics of a natural population of the predaceous zooplankter *Leptodora kindtii* Focke [Cladocera]. Oikos 20:189-223.
- DeMott, W. R., and Gulati, R. D. 1999. Phosphorus limitation in *Daphnia*: Evidence from a long term study of three hypereutrophic Dutch lakes. Limnol. Oceanogr. 44:1557-1564.

- DeMott, W. R., and F. Moxter. 1991. Foraging on cyanobacteria by copepods: Responses to chemical defenses and resource abundance. Ecology 72:1820-1834.
- Dettmers, J. M., and R. A Stein. 1992. Food consumption by larval gizzard shad: zooplankton effects and implications for reservoir communities. Trans. Am. Fish. Soc. 121:494-507.
- DeVries, D. R., and R. A. Stein. 1992. Complex interactions between fish and zooplankton: quantifying the role of an open water planktivore. Can. J. Fish. Aquat. Sci. 49:1216-1227.
- DeVries, D. R., R. A. Stein, J. G. Miner and G. G. Mittelbach. 1991. Stocking threadfin shad: consequences for young of year fishes. Trans. Am. Fish. Soc. 120:368-381.
- Dodson, S. J., and D. G. Frey. 1991. Cladocera and other Branchiopoda, pp. 723-786 InJ. H. Thorp and A. P. Covich [eds.] Ecology and Classification of NorthAmerican Freshwater Invertebrates. Academic Press, Inc., San Diego, CA.
- Downing, J. A., and F. H. Rigler. 1984. A manual on methods for the assessment of secondary productivity in fresh waters. Blackwell Scientific Publications, Oxford. 501 pp.
- Eccles, D. H. 1986. Diet of the cyprinid fish *Barbus aeneus* (Burchell) in the P. K. le
 Roux Dam, South Africa, with special reference to the effect of turbidity on
 zooplanktivory. S. Afr. J. Zool. 21:257-263
- Edmondson, W. T. 1959. Fresh-water Biology. John Wiley and Sons, Inc., New York. 1248 pp.
- Edmondson, W. T. 1960. Reproductive rates of rotifers in natural populations. Mem. Ist. Ital. Idrobiol. 12:21-77.
- Elser, J. J., M. M. Elser, N. A. MacKay, and S. R. Carpenter. 1988. Zooplanktonmediated transitions between N and P limited algal growth. Limnol. Oceanogr. 33:1-14.

- Goulden, C. E., and L. L. Hornig. 1980. Population oscillations and energy reserves in planktonic Cladocera and their consequences to competition. Proc. Natl. Acad. Sci. 77:1716-1720.
- Groeger, A. W., and T. E. Tietjen. 1998. Hydrological and thermal regime in a subtropical reservoir. Internat. Rev. Hydrobiol. 83:83-92.
- Ground, T. A., and A. W. Groeger. 1994. Chemical classification and trophic characteristics of Texas reservoirs. Lake and Reserv. Manage. 10:189-201.
- Gulati, R. D., and W. R. DeMott. 1997. The role of food quality for zooplankton: remarks on the state-of-the-art, perspectives and priorities. Freshwater Biol. 38:753-768.
- Hall, D. J. 1964. An experimental approach to the dynamics of a natural population of *Daphnia galeata mendotae*. Ecology 45:94-112.
- Hannan, H. H., I. R. Fuchs, and D. C. Whitenberg. 1979. Spatial and temporal patterns of temperature, alkalinity, dissolved oxygen and conductivity in an oligomesotrophic, deep-storage reservoir in central Texas. Hydrobiologia 66:209-221.
- Hart, R. C. 1990. Zooplankton distribution in relation to turbidity and related environmental gradients in a large subtropical reservoir: patterns and implications. Freshwater Biol. 24:241-263.
- Hessen, D. O. 1990. Carbon, nitrogen, and phosphorus status in *Daphnia* at varying food conditions. J. Plankton Res. 12:1239-1249.
- Hessen, D. O., and A. Lyche. 1991. Inter- and intraspecific variations in zooplankton element composition. Arch. Hydrobiol. 121:343-353.
- Hessen, D. O. 1992. Nutrient element limitation of zooplankton production. Am. Nat. 140:799-814.
- Hirst, S. C., and D. R. DeVries. 1994. Assessing the potential for direct feeding interactions among larval black bass and larval shad in two southeastern reservoirs. Trans. Am. Fish. Soc. 123:173-181.

Hydrolab. 1985. Surveyor II operating manual. Hydrolab Corp., 99 pp.

- Kennedy, R. H. and W. W. Walker. 1990. Reservoir nutrient dynamics, p. 109-131. *In*K. W. Thornton, *B.* L. Kimmel, and F. E. Payne [eds.], Reservoir limnology: ecological perspectives. John Wiley and Sons, Inc., New York. 246 pp.
- Kimmel, B. L., and A. W. Groeger. 1984. Size distribution of planktonic autotrophy and microheterotrophy in DeGray Reservoir, Arkansas, p. 297-326 *In* R. H.
 Kennedy and J. Nix [eds.] Proceedings of the DeGray Lake Symposium. Tech.
 Report E-87-4, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Kitchell, J. A., and J. F. Kitchell. 1980. Size-selective predation, light transmission, and oxygen stratification: Evidence from the recent sediments of manipulated lakes. Limnol. Oceanogr. 25:389-402.
- Kreeger, D. A., C. E. Goulden, S. S. Kilham, S. G. Lynn, S. Datta and S. J. Interland. 1997. Seasonal changes in the biochemistry of lake seston. Freshwater Biol. 38:539-554.
- Lampert, W. 1977. Studies on the carbon balance of *Daphnia pulex* de Geer as related to environmental conditions. IV. Determination of the "threshold" concentration as a factor controlling the abundance of zooplankton species. Arch. Hyrdobiol. Beih. 48:361-368.
- MacKay, N. A., and J. J. Elser. 1998. Factors potentially preventing a trophic cascade: food quality, invertebrate predation, and their interaction. Limnol. Oceanogr. 43: 339-347.
- Main, T. M., D. R. Dobberfuhl, and J. J. Elser. 1997. N:P stoichiometry and ontogeny of crustacean zooplankton: A test of the growth rate hypothesis. Limnol. Oceanogr. 42:1474-1478.
- Marzolf, G. R. 1990. Reservoirs as environments for zooplankton, p. 195-208. In K.W. Thornton, B. L. Kimmel, and F. E. Payne [eds.], Reservoir limnology: ecological perspectives. John Wiley and Sons, Inc., New York. 246 pp.
- Moore, M. V. 1988. Differential use of food resources by the instars of *Chaoborus punctipennis*. Freshwater Biol. 19:249-268.
- Muller-Navarra, D. 1995. Biochemical versus mineral limitation in *Daphnia*. Limnol. Oceanogr. 40:1209-1214.
- Muller-Navarra, D. and W. Lampert. 1996. Seasonal patterns of food limitation in Daphnia galeata: separating food quantity and food quality effects. J. Plankton Research 18:1137-1157.
- Olsen, Y., A. Jensen, H. Reinertsen, K. Y. Barsheim, M. Heldal and A. Langeland.
 1986. Dependence of the rate of release of phosphorus by zooplankton on the P:C ratio in the food supply, as calculated by a recycling model. Limnol. Oceanogr. 31: 34-44.
- Pennak, R. W. 1989. Fresh-water invertebrates of the United States. The Ronald Press Company, New York. 769 pp.
- Pinto-Coelho, R. M. 1998. Effects of eutrophication on seasonal patterns of mesozooplankton in a tropical reservoir: a 4-year study in Pampulha Lake, Brazil. Freshwater Biol. 40:159-173.
- Prescott, G. W. 1954. How to know the fresh-water algae. W. C. Brown Company, Dubuque, IO. 211 pp.
- Repka. S. 1997. Effects of food type on the life history of *Daphnia* clones from lakes differing in trophic state. I. *Daphnia galeata* feeding on *Scenedesmus* and *Oscillatoria*. Freshwater Biol. 37:675-683.
- Reynolds, C. S. 1984. The Ecology of Freshwater Phytoplankton. Cambridge University Press, New York, 373 pp.
- Schulz, K. L., and R. W. Sterner. 1999. Phytoplankton phosphorus limitation and food quality for *Bosmina*. Limnol. Oceanogr. 44:1549-1556.
- Shapiro, J., B. Forsburg, V. Lamarra, G. Linkmark, and M. Lynch. 1982. Experiments and experiences in biomanipulation. U. S. E. P. A. EPA-600/3-82-096.

- Sommer, U. 1992. Phosphorus-limited *Daphnia*: Intraspecific facilitation instead of competition. Limnol. Oceanogr. 37:966-973.
- Sterner, R. W. 1993. Daphnia growth on varying quality of Scenedesmus: mineral limitation of zooplankton. Ecology 74:2351-2360.
- Sterner, R. W., J. J. Elser, E. J. Fee, S. J. Guildford, and T. H. Chrzanowski. 1997. The light:nutrient ratio in lakes: the balance of energy and materials affects ecosystem structure and process. Am. Nat. 150:663-684.
- Sterner, R. W., J. J. Elser, and D. O. Hessen. 1992. Stoichiometric relationships among producers, consumers and nutrient cycling in pelagic ecosystems. Biogeochemistry 17:49-67.
- Sterner, R. W., and D. O. Hessen. 1994. Algal nutrient limitation and the nutrition of aquatic herbivores. Annu. Rev. Ecol. Syst. 25:1-29.
- Sterner, R. W. and K. L. Schulz. 1998. Nutrition: recent progress and a reality check. Aquatic Ecol. 32:261-279.
- Tessier, A. J., and C. E. Goulden. 1982. Estimating food limitation in cladoceran populations. Limnol. Oceanogr. 27:707-717.
- Tessier, A. J., and R. J. Horwitz. 1990. Influence of water chemistry on size structure of zooplankton assemblages. Can. J. Fish. Aquat. Sci. 47:1937-1943.
- Texas Parks and Wildlife. 1997. Survey Report for Canyon Reservoir, 1997. Texas Parks and Wildlife, Inland Fisheries Division, Austin, Texas.
- Thornton, K. W., R. H. Kennedy, J. H. Carrol, W. W. Walker, R. C. Gunkel, and S. Ashby. 1981. Reservoir sedimentation and water quality: a heuristic model. p. 654-661 *In* H. G. Stefen [ed.] Proceedings of the symposium on surface water impoundments. Amer. Soc. Civil. Engr., New York, NY.
- Threlkeld, S. T. 1979. Estimating cladoceran birth rates: The importance of egg mortality and the egg age distribution. Limnol. Oceanogr. 24:601-612.

- Tietjen, T. E. 1996. Influence of advection on the ecosystem structure of Canyon Lake Reservoir. M. S. Thesis Southwest Texas State University. 87 pp.
- Tilman, D., S. S. Kilham, and P. Kilham. 1982. Phytoplankton community ecology: the role of limiting nutrients. Annu. Rev. Ecol. Syst. 13:349-372.
- Urabe, J. 1989. Relative importance of temporal and spatial heterogeneity in the zooplankton community of an artificial reservoir. Hydrobiologia 184:1-6.
- Urabe, J. 1990. Stable horizontal variation in the zooplankton community structure of a reservoir maintained by predation and competition. Limnol. Oceanogr. 35:1703-1717.
- Urabe, J., J. Clasen, and R. W. Sterner. 1997. Phosphorus limitation of *Daphnia* growth: Is it real? Limnol. Oceanogr. 42:1436-1443.
- Urabe, J., M. Nakanishi, and K. Kawabata. 1995. Contribution of metazoan plankton to the cycling of nitrogen and phosphorus in Lake Biwa. Limnol. Oceanogr. 40:232-241.
- Urabe, J. J., and Y. Watanabe. 1992. Possibility of N or P limitation for planktonic cladocerans: An experimental test. Limnol. Oceanogr. 37:244-251.
- Werkenthin, Jr., F. B. 1980. The relationship of nutrients and morphometry to productivity in Canyon Reservoir, Texas. M. S. Thesis Southwest Texas State University. 52 pp.
- Wetzel, R. G. 1983. Limnology, 2nd ed. Saunders College Publishing. Philadelphia, PA. 860 pp.
- Wetzel, R. G., and G. E. Likens. 1991. Limnological Analyses. 2nd ed. Springer-Verlag, New York, 391 pp.
- Work, K. A., and M. Gophen. 1999. Factors which affect the abundance of an invasive cladoceran, *Daphnia lumholtzi*, in U.S. reservoirs. Freshwater Biol. 42:1-10.

January **Phytoplankton:** Pediastrum *Closteriopsis* Mougeotia Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon Chrysocapsa Anacystis Gomphospearia *Merismopedia* Lyngbya **Oscillatoria** Ceratium **Zooplankton:** Peranema Phacus Nebelidae Euglyphidae Turbellaria Nematoda Oligochaeta Filinia Polyarthra Ploeosoma Ascomorpha Chromogaster Trichocerca Asplancha **Brachionus** Keratella *Platyias* Lecane Water mite Bosmina longirostris Eubosmina sp. Alona costata

Appendix I. Mean abundance (Individuals/m³) 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.

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
Fahmany	1	10	17	22	27	31	34
rebruary	•	10	11			01	01
Phytoplankton:	2494	1050	5400	6141	12251	2(1	1.1
Pediastrum	2484	1858	5498	5141	13351	261	11
Closteriopsis	/40	19/4	1406	828	339	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	4/2/	847	1438	96	3
Tabellaria	0	0	0	0	0	0	3
Navicula	0	0	0	0	0	38265	1690
Dinobryon	13797	200547	/163/1	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	//	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.).

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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	4941	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	441	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	178	0	0	0	0	0	0
Keratella	855	1276	5815	14773	93418	13088	5948
Platyias	0	0	0	0	0	0	0
Lecane	0	0	0	0	0	0	0
Water mite	9	0	0	0	0	0	0
Bosmina longirostris	1672	519	3014	9983	6878	490	139
Eubosmina sp.	28	12	0	0	0	0	0
Alona costata	19	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	0	23	39	12	18	0	0
Daphnia parvula	0	0	10	84	18	0	0

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Appendix I.—(Cont.).

Daphnia rosea	460	61	96	307	84	0	C
Simocephalus serratulus	0	0	0	0	18	0	С
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	C
Chironomidae	0	0	10	0	0	62	(
Trichoptera	0	0	0	0	0	0	(
Caenidae	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	(
Mougeotia	0	0	0	0	0	0	(
Spirogyra	0	0	0	0	0	0	(
Zvgnema	0	0	0	0	0	0	(
Closterium	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	(
Dinobryon	0	0	0	24664	35528	41	313
Chrysocapsa	49	0	0	0	1541	0	(
Anacystis	1678	0	8497	0	2985	0	(
Gomphospearia	75676	0	26333	0	3346	0	(
Merismopedia	10	55	241	0	0	0	(
Lyngbya	537	0	9026	0	1300	0	(
Oscillatoria	507435	0	65376	0	770	0	(
Ceratium	10900	81207	1084743	156106	17379	777	750
Zooplankton:							
Peranema	410	0	0	834	0	0	(
Phacus	0	0	0	0	0	0	(
Nebelidae	215	1238	1276	0	0	0	C
Euglyphidae	0	2104	12950	3530	9171	578	(
Turbellaria	20	28	0	0	0	0	(
Nematoda	0	0	0	16	0	14	(
Oligochaeta	0	0	0	0	0	0	0
Filinia	0	0	0	0	0	0	0
Polvarthra	117	2352	13167	9323	5633	1874	654

Appendix I.—(Cont.).

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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
Mav	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
Zvgnema	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

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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	363228	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	0	15	0	128	28	0	10
Calanoida	1187	958	561	3274	533	52	72

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	1	10	17	22	27	31	34
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
Öscillatoria	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	1512	2831	1413	5793	3769	0	201
Hydra	0	0	0	16	0	0	0
Turbellaria	0	0	0	0	0	0	0
Nematoda	0	0	0	24	0	0	0
Oligochaeta	0	0	0	88	0	0	0
Filinia	0	0	0	0	0	0	0
Polyarthra	232	271	0	1524	1692	846	663
Ploeosoma	0	0	0	0	0	0	0
Ascomorpha	0	0	383	497	1878	0	0
Chromogaster	0	0	0	0	0	0	0
Trichocerca	0	0	0	0	0	0	0

Appendix I.—(Cont.).

Asplancha	45	44	115	24	124	0	(
Brachionus	0	0	0	0	0	0	C
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	C
Bosmina longirostris	728	592	211	185	0	0	C
Eubosmina sp.	0	35	0	0	0	0	C
Alona costata	0	0	0	0	0	0	C
Ceriodaphnia quadrangula	262	52	0	0	0	0	C
Ceriodaphnia reticulata	0	0	0	32	0	0	C
Daphnia ambigua	576	56	0	0	0	0	C
Daphnia galeata mendotae	695	43	9	0	0	0	C
Daphnia lumholtzi	9	0	0	96	34	0	8
Daphnia parvula	9	8	0	0	0	0	C
Daphnia rosea	36	0	9	32	34	0	(
Simocephalus serratulus	0	0	0	0	0	0	(
Diaphanosoma birgei	27	71	110	1500	364	41	(
Ostracoda	0	0	30	80	34	0	(
Calanoida	535	948	425	762	440	7	13
Cyclopoida	1347	1194	1143	1532	763	337	72
Copepodid	385	375	258	385	186	213	(
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	(
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	C
Mougeotia	0	0	0	16	9	0	C
Spirogyra	0	0	0	8	0	0	C
Zygnema	0	0	0	0	0	0	(
Closterium	0	0	9	0	0	0	(
Fragalaria	94453	43871	7212	1035	183	0	(
Tabellaria	0	0	0	0	0	0	116
Navicula	0	0	0	0	0	0	(
Dinobryon	0	0	0	0	0	0	(
Chrysocansa	162	0	0	0	0	0	C.
Anacustic	393	0	0	0	0	ů 0	ſ

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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

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
Ċlosterium	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
Öscillatoria	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
Platvias	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
Sentember	1.	10	17	22	27	31	34
Phytonlankton.							
Pediastrum	113625	74766	59119	7214	2545	4949	16518
Closterionsis	0	0	0	0	0		
Mougeotia	-	-	~ ~ ~	0	0	0	0
	0	0	0	0	0	0	0
Snirogyra	0 0	0 0	0	0 0	0	0 0 0	0 0 0
Spirogyra Zvgnema	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0 0	0 0 0 0
Spirogyra Zygnema Closterium	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
Spirogyra Zygnema Closterium Fragalaria	0 0 0 95435	0 0 0 64552	0 0 0 0 1764	0 0 0 0 0	0 0 0 0 378	0 0 0 0 0 0	0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria	0 0 0 95435 0	0 0 0 64552 0	0 0 0 0 1764 0	0 0 0 0 0 0	0 0 0 0 378 0	0 0 0 0 0 0 0	0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula	0 0 0 95435 0 0	0 0 0 64552 0 0	0 0 0 0 1764 0 0	0 0 0 0 0 0 0 0	0 0 0 0 378 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon	0 0 0 95435 0 0 0	0 0 0 64552 0 0 0	0 0 0 0 1764 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 378 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon Chrysocapsa	0 0 95435 0 0 0	0 0 0 64552 0 0 0 0	0 0 0 0 1764 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 378 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon Chrysocapsa Anacystis	0 0 0 95435 0 0 0 0 0 237	0 0 0 64552 0 0 0 0 0 0	0 0 0 0 1764 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 87	0 0 0 0 378 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon Chrysocapsa Anacystis Gomphospearia	$ \begin{array}{c} 0\\ 0\\ 0\\ 95435\\ 0\\ 0\\ 0\\ 0\\ 237\\ 16532\\ \end{array} $	0 0 0 64552 0 0 0 0 0 0 0 0	0 0 0 0 1764 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 87 0	0 0 0 0 378 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon Chrysocapsa Anacystis Gomphospearia Merismopedia	$\begin{array}{c} 0\\ 0\\ 0\\ 95435\\ 0\\ 0\\ 0\\ 0\\ 237\\ 16532\\ 0\\ \end{array}$	0 0 0 64552 0 0 0 0 0 0 0 0 0	0 0 0 0 1764 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 87 0 0	0 0 0 0 378 0 0 0 0 0 0 0 0 0 34		0 0 0 0 0 0 0 0 0 0 0 0 0 0
Spirogyra Zygnema Closterium Fragalaria Tabellaria Navicula Dinobryon Chrysocapsa Anacystis Gomphospearia Merismopedia	$\begin{array}{c} 0\\ 0\\ 0\\ 0\\ 95435\\ 0\\ 0\\ 0\\ 0\\ 0\\ 237\\ 16532\\ 0\\ 260884 \end{array}$	0 0 0 64552 0 0 0 0 0 0 0 0 0 39362	0 0 0 0 1764 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 87 0 0 2571	0 0 0 0 378 0 0 0 0 0 0 0 0 0 0 0 34 172		

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

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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
Öscillatoria	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 auadrangula	97	24	0	0	0	0	0

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
Zvgnema	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
Öscillatoria	53870	129	6546	0	77	0	0
Ceratium	11454	32083	145471	38767	74074	494	95
Zooplankton:							
Zooplankton: Peranema	41	0	0	110	0	0	31
Zooplankton: Peranema Phacus	41 1	0 0	0 0	110 7	0 0	0 17	31 239
Zooplankton: Peranema Phacus Nebelidae	41 1 32	0 0 172	0 0 313	110 7 345	0 0 110	0 17 54	31 239 3

Appendix I.—(Cont.).

Hydra	0	0	0	2	0	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