

# **Dworshak Reservoir Nutrient Enhancement Project: 2009 Progress Report and Data Summary**

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## **EXECUTIVE SUMMARY**

In 2009, the nutrient enhancement program that began in 2007 was continued on Dworshak Reservoir. The project implemented by Idaho Fish and Game (IDFG) and US Army Corps of Engineers (USACE) has two goals. The first goal is to improve carbon flow through the food web to benefit resident fisheries. The stimulation of lower trophic levels with the careful addition of nutrients should increase the edible phytoplankton and create concomitant increases in zooplankton and zooplanktivorous fish. The desired impacts for kokanee (an important resident sport fish) include increases in mean size, fecundity, and catch-ability. The second goal of the project is to reduce blue-green phytoplankton by slightly altering nutrient ratios to favor more edible phytoplankton species that can out-compete blue-green algae under conditions similar to those found within Dworshak Reservoir.

To stimulate pelagic primary production in 2009, bio-available nitrogen was added to the epilimnion of Dworshak Reservoir. Beginning on May 7 urea ammonium nitrate was added to the reservoir once per week until October 8. The urea ammonium nitrate was applied in precise amounts according to the different sections of the reservoir. A total of 42,829 gallons of Urea ammonium nitrate were added to the reservoir in 2009. No liquid ammonium phosphate was applied in 2009.

Monitoring of Dworshak Reservoir was continued in 2009 to observe the effects of nutrient application. IDFG continued sampling of physico-chemistry, nutrients, picoplankton, phytoplankton, zooplankton, and chlorophyll *a*. Samples were taken either once or twice per month depending on the measurement and date. Sampling began on March 22, 2009 and concluded on November 8, 2009. Composite samples were taken in the epilimnion and single grab samples were taken from the hypolimnion.

This report focuses mainly on the monitoring results from 2009. However, 2009 data were compared to past years when methodologies were similar. Over the past years some monitoring methods and laboratory analyses have varied, making some comparisons inappropriate. Considering the naturally large variability of conditions in a reservoir such

as Dworshak, definitive conclusions on the effects of nutrient application were not made since this report summarizes only the third year of the project.

Climate conditions for the years 2004 to 2009 indicated that 2009 received more solar radiation than other years and had the second highest mean air temperature. Precipitation accumulation in the Dworshak Reservoir watershed was moderate in 2009, producing moderate reservoir inflows. Annual mean reservoir inflow in 2009 was 5.70 kcfs. Reservoir inflow in 2009 was highest in mid May at 24.7 kcfs. As a result of moderate reservoir inflows the spring drawdown was minimal in 2009.

Surface water temperatures were moderate in 2009 compared to other years, with a mean of 18.0°C at 1 m depth from May to October. The more typical runoff in 2009 produced thermal stratification similar to recent past years other than 2008. Hypolimnetic dissolved oxygen depletion in 2009 was more pronounced than in 2008 but similar to recent years with similar runoff quantities. Hypolimnetic dissolved oxygen concentrations fell below 5 mg/L at all locations mainly during late summer and fall. Hypolimnetic dissolved oxygen concentrations were lowest at RK-66, RK-72, LNF-3, and EC-6.

Water clarity tended to be lower in 2009 compared to recent years as measured by Secchi disk depth. Median Secchi depth at consistently sampled stations and times was 3.05 m in 2009. Median Secchi disk values ranged from 3.05 m in 2006 to 4.88 m in 2005. The year 2006 is notable because this was a pre-nutrient application year, showing that reduced water clarity can occur naturally. The water year in 2006 was not exceptionally high, implying that in addition to turbidity from spring runoff, turbidity from other sources such as biological production may have been important.

Descriptive statistics for nutrient and chlorophyll *a* concentrations are given in table E-1. 2009 data from all dates within given depth strata as well as the North Fork Clearwater (NFC) station were used to characterize overall conditions within Dworshak Reservoir. Epilimnetic total phosphorus concentrations in 2009 were similar to past years at consistently sampled stations. Differences in total phosphorus concentrations by depth

strata in 2009 were also not apparent. Like total phosphorus, epilimnetic total dissolved phosphorus concentrations in 2009 were similar to past years and there was not a distinct difference between depth strata. Total phosphorus and total dissolved phosphorus concentrations showed no apparent differences between RK-2 hypolimnetic samples and downstream NFC samples.

Epilimnetic nitrate + nitrite concentrations in 2009 were similar to values from stations consistently sampled in past years. Nitrate + nitrite concentrations within the hypolimnion appear to be higher than in the epilimnion, likely related to nutrient uptake by phytoplankton and nitrification processes. Curiously, nitrate + nitrite concentrations from RK-2 hypolimnetic samples were considerably lower than concentrations measured at NFC.

Table E-1 Summary statistics for 2009. Data includes all sampling stations and dates.

	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Nitrate + Nitrite (mg/L)	Chlorophyll a (µg/L)	Total Dissolved Solids (mg/L)
<b>Dworshak Reservoir Epilimnion</b>					
Minimum	0.001	0.001	0.001	0.20	14.0
Maximum	0.021	0.019	0.170	5.69	26.0
Median	0.007	0.004	0.005	1.94	20.0
Arithmetic Mean	0.008	0.004	0.013	2.12	20.3
<b>Dworshak Reservoir Hypolimnion</b>					
Minimum	0.001	0.001	0.001		
Maximum	0.027	0.013	0.087		
Median	0.007	0.004	0.015		
Arithmetic Mean	0.008	0.004	0.025		
<b>North Fork Clearwater</b>					
Minimum	0.001	0.001	0.003	0.04	14.0
Maximum	0.013	0.008	0.069	1.44	25.0
Median	0.006	0.003	0.031	0.39	18.0
Arithmetic Mean	0.007	0.003	0.031	0.45	19.4

The median planktonic chlorophyll *a* concentration in 2009 was 1.9 µg/L, which was below the consent order concentration of 3.0 µg/L. Chlorophyll *a* concentrations in 2009 were similar to past years. At NFC chlorophyll *a* concentrations were considerably lower than epilimnetic sample concentrations from the nearest upstream site, RK-2.

Total phytoplankton densities in 2009 were markedly greater than in past years. The increase in 2009 was mostly driven by increases in flagellates, blue-greens, and coccoid green algae. The flagellates were mostly comprised of nanoflagellates, followed by *Komma sp.*, and *Cryptomonas sp.* The blue-greens were mainly comprised of *Synechococcus sp.*, *Chroococcus sp.*, and *Microcystis sp.* The increase in coccoid greens was exclusively due to the occurrence of *Stichococcus minutissimus*, which has not been observed in previous years.

Densities of *Microcystis sp.* in 2009 as measured by cells/mL were the highest yet observed in Dworshak Reservoir. *Microcystis sp.* densities reached as high as 38,782 cells/mL on June 23, 2009 at RK-31. Higher *Microcystis sp.* densities were not restricted to one station in 2009. A discrepancy exists in how densities for *Microcystis sp.* are reported. In past years *Microcystis sp.* density has been recorded in NCU/mL (colonies/mL), but the most recent densities have been recorded in cells/mL because colony size or cells per colony has been seen to vary widely. For this reason *Microcystis sp.* densities counted in NCU/mL appear to drop in 2009 compared to 2008, whereas *Microcystis sp.* densities counted in cells/mL appear to increase from 2008 to 2009. We believe counting cells/mL is more accurate. For data from previous years when cells/mL were not recorded, an estimation of cells/mL based on cell to colony ratios from known years may be used to convert past year's data to cells/mL to allow for a rough comparison to earlier years.

Phytoplankton edibility in 2009 showed a considerable increase compared to previous years. The increase in edible phytoplankton was largely due to the increased numbers of nanoflagellates and *S. minutissimus*. Approximately 92% of the edible phytoplankton were attributed to four species; in order of contribution these were nanoflagellates, *S. minutissimus*, *Synechococcus sp.*, and *Komma sp.*. Inedible phytoplankton densities in 2009 may have decreased compared to past years but this comparison may be less certain granted how reporting inedible *Microcystis sp.* densities in NCU/mL rather than cells/mL may obscure actual increases in density.

Pico-cyanobacterial densities in 2009 were similar to past years but most different from 2006, a pre-nutrient application year. Heterotrophic bacterial densities were higher in 2009 compared to 2006, but similar to 2007 and 2008. Both pico-cyanobacteria and heterotrophic bacteria may show a weak longitudinal gradient in the reservoir, with generally decreasing densities at upper reservoir stations. Statistically pico-cyanobacteria and heterotrophic bacteria densities in 2009 were similar across stations, including non treatment stations EC-6 and LNF-3.

In 2009, three groups of zooplankton accounted for approximately 83% of the overall relative abundance. These groups in order of contribution were cyclopoid copepods, *Daphnia sp.*, and calanoid copepods. Cyclopoids peaked twice in 2009, once in June and again in September. *Daphnia sp.* and calanoids peaked once in September, coinciding with the second cyclopoid peak. *Daphnia sp.* densities in 2009 were greater than densities observed in 2006 from consistently sampled stations. *Daphnia sp.* lengths in 2009 were greater than lengths observed in 2005 and 2006. Mean annual *Daphnia sp.* length across consistently sampled stations was 1.11 mm in 2009. *Daphnia sp.* biomass in 2009 was greater than biomass estimates in 2006. Increased *Daphnia sp.* lengths and biomass in 2009 could be expected to supply zooplanktivorous fish such as kokanee with better food resources.

## **SECTION 1.0 INTRODUCTION**

The objective of this report is to examine the changes in the biological, chemical, and physical conditions within Dworshak Reservoir due to controlled nutrient additions to the system in 2009. A review of historical limnological data revealed that Dworshak reservoir was experiencing a nutrient imbalance through much of the growing season (Stockner and Brandt 2006). The system was experiencing severe nitrogen limitation, which was promoting the production of inedible blue-green algae and limiting edible algae, thereby short-circuiting the food web or carbon pathways within the reservoir. Using the information compiled in the 2006 report, the Idaho Department of Fish and Game (IDFG), United States Army Corps of Engineers (USACE), and TG Eco-Logic, LLC determined that Dworshak Reservoir was a good candidate for nutrient supplementation.

The goal of the nutrient supplementation program is to improve carbon flows within the reservoir by increasing total lake productivity, increasing the abundance of the edible phytoplankton community, and subsequently promoting an abundant community of large-bodied zooplankton. Increased zooplankton biomass should increase the forage base for kokanee, rainbow trout, and smallmouth bass fry. An increased abundance of high quality food should also result in increased kokanee growth rates, fecundity, and abundances. Secondary goals of this project are to decrease blue-green algae abundance and improve late season water clarity. The carefully controlled application of nitrogen fertilizer to portions of Dworshak Reservoir was initiated in 2007 and has continued through 2008 and 2009. The limnologic monitoring plan was also continued in 2009 to track biological and chemical changes within the reservoir. This report presents the results of the 2009 nutrient supplementation and the impact to the reservoir.

## **SECTION 2.0 APPLICATION**

TG Eco-Logic developed a series of tables that indicated the appropriate application rates of nitrogen and phosphorus by date and reservoir section. Scheduled application amounts by reservoir sector and date are provided in Appendix A. The three reservoir sectors are displayed in Figure 1. The applications were based on: sector area, historical nitrogen (N) and phosphorus (P) concentrations, targeted N:P ratios, temporal epilimnetic productivity as a function of temperature, and fertilizer formulations. Applications were made using a 60-foot barge that was loaded with a 2,800-gallon tank of urea ammonium nitrate (32-0-0). No application of liquid ammonium phosphate (10-34-0) was made in the 2009 season.

The fertilizer tank was mounted on a dump truck for easy loading and unloading. The tank was connected to a metering system calibrated to deliver a set volume of liquid fertilizer per minute. The fertilizer was applied 1.5 meters (m) below the water surface immediately in front of two 1 m diameter propellers centered 2 m below the water surface. The prop wash was used to help distribute the fertilizer into the water column. The barge traveled up the center of the reservoir as much as possible. The barge traveled at 9.5 km/hr, which resulted in a total travel time of 8 hours for each application. Application of ammonium nitrate began on May 7 and was conducted approximately once a week until October 8 (Table 1). A total of 42,829 gallons (~232.7 tons) of urea ammonium nitrate was added to the reservoir in 2009.

Figure 1 Dworshak Reservoir and sampling stations in 2009.

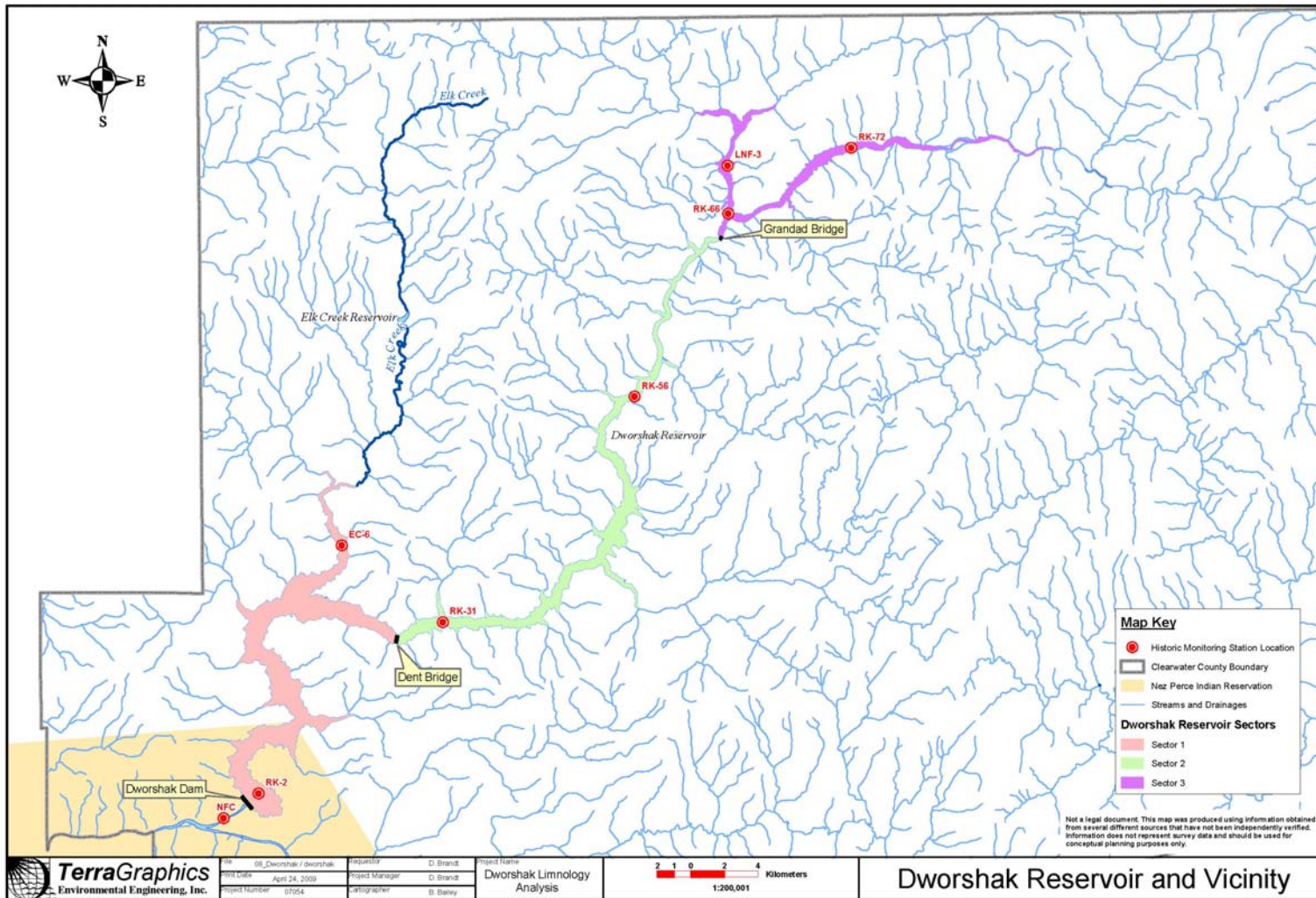


Table 1 Urea ammonium nitrate application amounts (total gallons) shown by date and sector on Dworshak Reservoir in 2009.

<b>Date</b>	<b>Sector 1</b>	<b>Sector 2</b>	<b>Sector 3</b>	<b>Total by Date</b>
May 7	462	317	119	<b>898</b>
May 14	475	338	128	<b>941</b>
May 21	488	354	139	<b>981</b>
May 28	528	367	152	<b>1,047</b>
Jun 4	544	382	172	<b>1,098</b>
Jun 11	683	467	230	<b>1,380</b>
Jun 18	683	485	232	<b>1,401</b>
Jun 25	702	504	242	<b>1,447</b>
Jul 2	773	522	251	<b>1,546</b>
Jul 9	773	538	260	<b>1,571</b>
Jul 16	736	522	237	<b>1,495</b>
Jul 23	1,113	784	352	<b>2,249</b>
Jul 30	1,113	784	352	<b>2,249</b>
Aug 6	1,113	784	352	<b>2,249</b>
Aug 13	1,329	934	345	<b>2,608</b>
Aug 20	1,329	934	345	<b>2,608</b>
Aug 27	1,329	934	345	<b>2,608</b>
Sep 3	1,329	934	345	<b>2,608</b>
Sep 10	1,233	863	274	<b>2,369</b>
Sep 17	1,233	863	274	<b>2,369</b>
Sep 24	1,233	863	274	<b>2,369</b>
Oct 1	1,233	863	274	<b>2,369</b>
Oct 8	1,233	863	274	<b>2,369</b>
<b>Total by Sector</b>	<b>21,668</b>	<b>15,196</b>	<b>5,965</b>	<b>42,829</b>

## SECTION 3.0 ENVIRONMENTAL CONDITIONS

### 3.1 Climate

Climatic conditions set the stage for river flows and the exchange of reservoir water for the year, which greatly affects reservoir limnology. Climatic data were acquired from Agrimet (2009) and NRCS (2009). The Agrimet station is located at Dent Acres on Dworshak Reservoir. The North Fork Clearwater River drainage data originate from three SNOTEL stations: Cool Creek, Crater Meadows, and Elk Butte. Precipitation accumulation data represent the total precipitation observed between October 1 and June 30 of a given water year.

At Dent Acres during the period from 2004 to 2009, mean annual solar radiation was highest in 2009 and mean annual air temperature in 2009 was second highest (Table 2). Precipitation accumulation values for 2009 at both Dent Acres and the SNOTEL stations were moderate compared to other years, with respective accumulations of 62.9 cm and 166.6 cm (Table 2). In summary, 2009 appeared to be slightly warmer and sunnier compared to recent years, with a moderate level of precipitation accumulation in the watershed.

Table 2 Mean solar radiation, air temperature, and precipitation accumulation at Dent Acres or from the North Fork Clearwater River drainage

Year	Dent Acres, ID Agrimet Station			North Fork of the Clearwater River SNOTEL Stations
	Mean Solar Radiation (langleys)	Mean Air Temperature °C	Precipitation Accumulation (cm)	Precipitation Accumulation (cm)
2004	334	10.9	62.8	172.5
2005	326	9.9	40.9	138.4
2006	333	10.2	75.1	180.1
2007	322	10.2	58.5	165.1
2008	321	9.0	64.3	207.0
2009	370	10.8	62.9	166.6

### 3.2 Hydrology

Hydrologic data were acquired from DART (2009). Reservoir inflows in 2009 reflected the moderate levels of precipitation accumulation for the year. Reservoir inflows peaked in mid-May 2009 at 24.7 thousand cubic feet per second (kcfs), as shown in Figure 2.

Mean annual inflow ranged from 4.02 kcfs to 6.16 kcfs during 2004 – 2009. Mean annual inflows in 2009 were the third highest during this time period (Table 3). Reservoir inflows for 2009 stabilized to summer base flow levels by July as was often the case in past years (Figure 2). Summer base flows in 2009 were less than 4.5 kcfs and averaged 1.41 kcfs from July to mid-November. Reservoir inflows in 2009 were most similar to 2006 and considerably less than inflows in 2008.

In 2009 reservoir elevation fluctuated between 1524 and 1540 ft above MSL from January until early May. Beginning in May the reservoir was allowed to fill until full pool (1600 ft MSL) was reached by July 1. Within a few days of reaching full pool, reservoir elevation was gradually dropped until mid-September, leveling off at a reservoir elevation of about 1519 ft MSL and remaining relatively steady during the rest of fall 2009 (Figure 3). The reservoir fluctuation in 2009 was similar to 2006 and had a much smaller spring runoff drawdown than 2008.

Table 3 Dworshak Reservoir inflow summary data from 2004 – 2009

<b>Year</b>	<b>Peak Inflow (kcfs)</b>	<b>Date of Peak Inflow</b>	<b>Annual Mean Inflow (kcfs)</b>
2004	28.78	May 29	5.47
2005	18.29	May 11	4.02
2006	28.08	May 21	5.89
2007	19.69	March 17	4.32
2008	40.08	May 20	6.16
2009	24.70	May 19	5.70

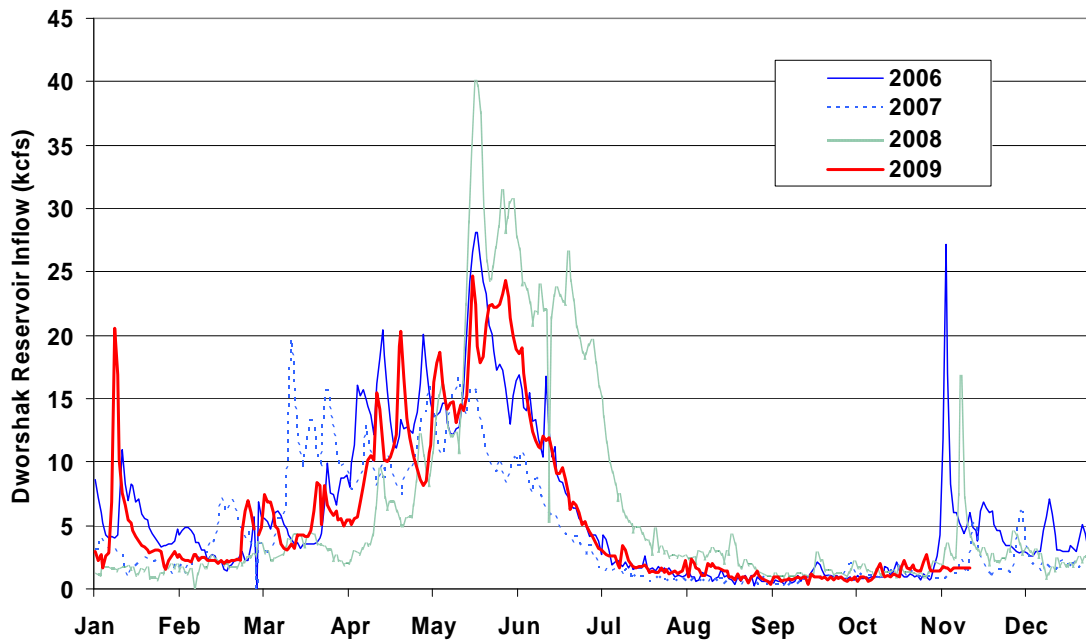


Figure 2 Dworshak Reservoir inflow hydrographs from multiple years

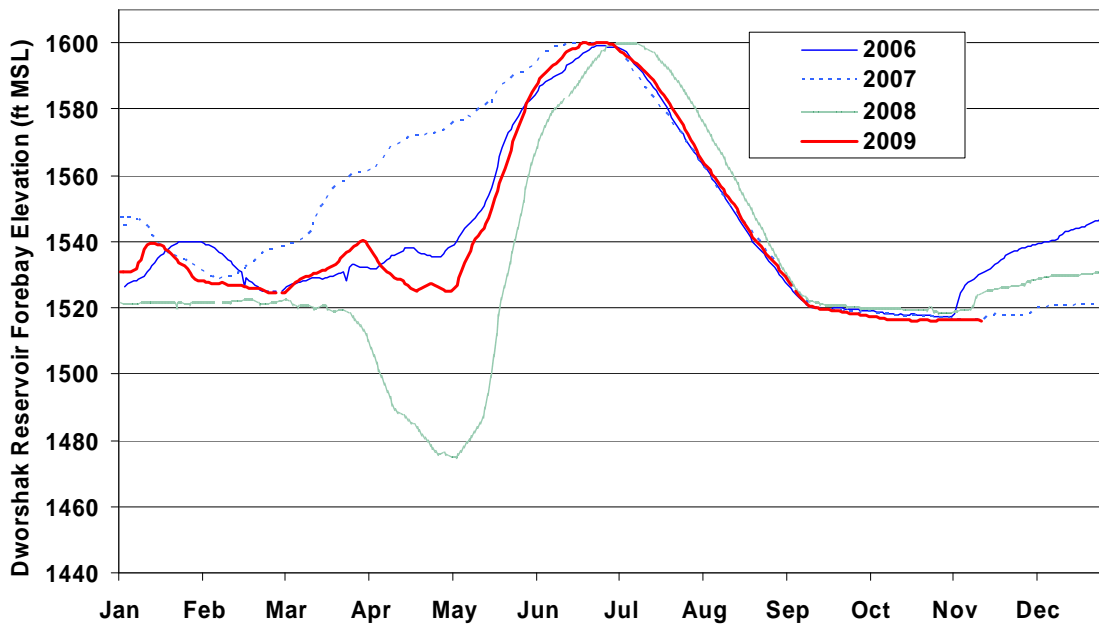


Figure 3 Dworshak Reservoir forebay pool elevation levels from multiple years

## **SECTION 4.0 MONITORING METHODS AND RESULTS**

### **4.1 Data Analysis**

Project data were stored and manipulated in Microsoft Office 2003 Excel and Access. Descriptive statistics were generated using both Excel and Systat v.12. All other statistical analyses were conducted using Systat v.12. Box plots were generated using Systat v.12 with default settings. Differences in means were tested using ANOVA and the *post hoc* Tukey pairwise comparison with an alpha level of 0.05. Normality of data was tested using the Kolmogorov–Smirnov and Shapiro-Wilk tests. If data were non-normally distributed the data were transformed using the natural logarithm; then the ANOVA was applied to the transformed data. The use of transformed data is noted in the text. The sampling frame for most ANOVAs included data from stations RK-2, RK-31, RK-56, and RK-72 (Figure 1) during the months of May to November since these stations and months were sampled consistently over several years. Sampling frames that deviated from this are noted in the text.

### **4.2 Physical Limnology**

During each sample event and at each reservoir station, temperature and dissolved oxygen readings were collected from the surface, at 1 m, and every even meter from 2 m to 60 m or bottom, whichever was less. Secchi readings were recorded as well as reservoir elevation, station depth, weather conditions, and sample date and time. Light intensity measurements were taken and recorded from the surface to 15 m for each station. Most stations were located on the mainstem (North Fork Clearwater River) of Dworshak Reservoir (Figure 1). Two stations were located in different reservoir arms, one in the Elk Creek arm at the downstream end of Dworshak Reservoir and the other in the Little North Fork Clearwater River arm at the upstream end of Dworshak Reservoir.

### **4.3 Lake Temperature**

Vertical temperature profiles were measured during 2006, 2007, 2008, and 2009. Temperature profiles were conducted twice per month in all years. At sites RK-2, RK-31, and RK-72, temperature at 1 m depth generally peaked in July between approximately 22°C and 27°C in all years (Figure 4). Water temperatures at 1 m in 2009 were quite typical compared to other years. Mean water temperatures (°C) from the

surface to 4 m at RK-2, RK-31, RK-56, and RK-72 from May to November were respectively 18.0, 17.0, 19.9, and 18.3 in 2009, 2008, 2007, and 2006. In 2009 stratification appeared most distinct (most uniform epilimnial temperatures and greatest temperature difference between epilimnion and hypolimnion) at RK-2, where the epilimnion reached a maximum depth of 8 m on August 10. Water temperatures at this site and date ranged from 23.6°C to 24.1°C through the epilimnion (surface to 8 m), then dropped to 16.3°C at 10 m.

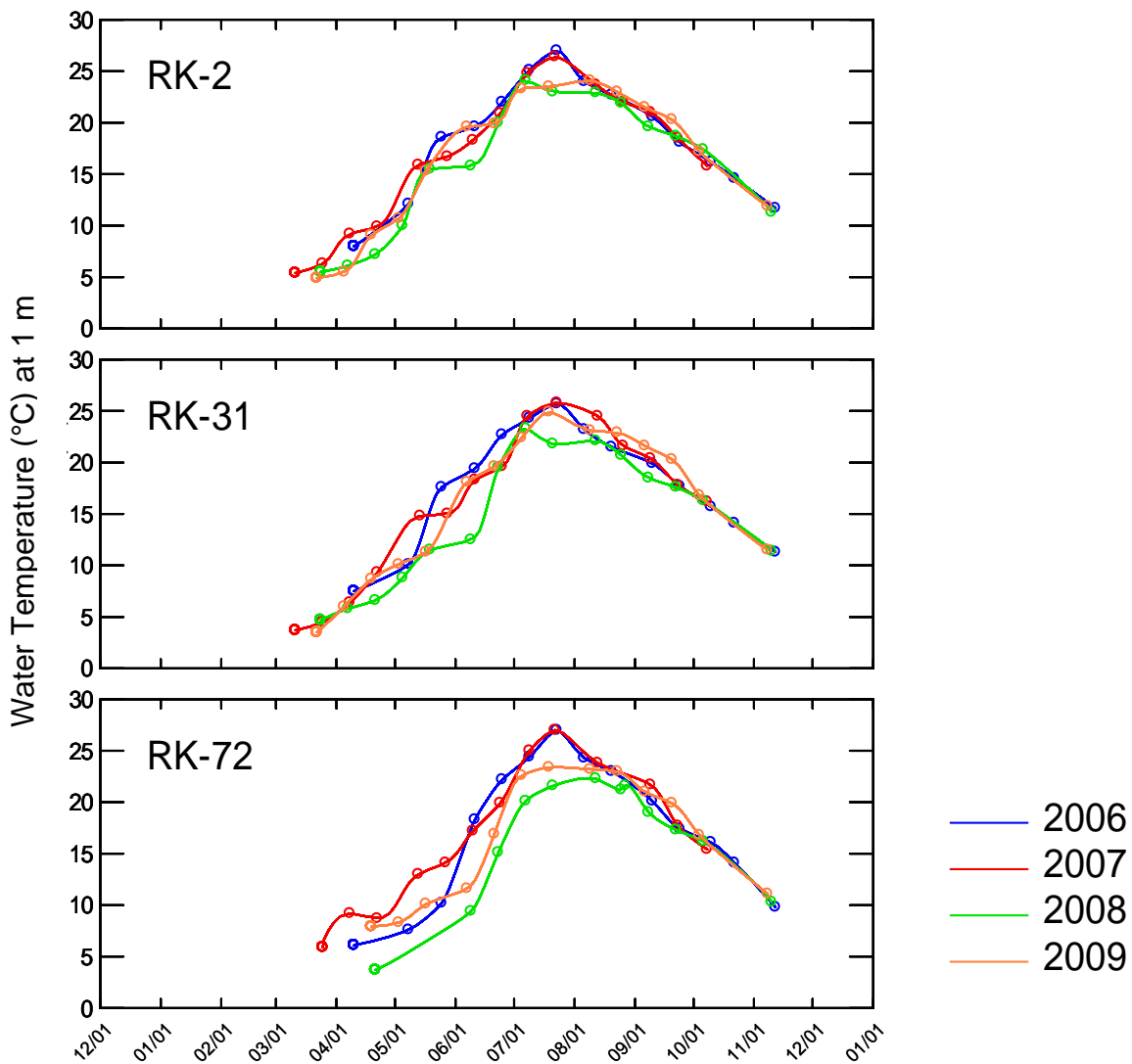


Figure 4 Water temperature at 1 m for three stations. The x-axis indicates date in the MM:DD format.

#### 4.4 Dissolved Oxygen

Vertical dissolved oxygen profiles were measured simultaneously with temperature. Due to an equipment malfunction, erroneous dissolved oxygen data were collected from March to May in 2009. These data were removed prior to analyses except for descriptive statistics in appendix C. Dissolved oxygen concentrations were generally high year round in the epilimnion and lowest in the hypolimnion during late summer and fall.

Dissolved oxygen concentrations less than 5 mg/L were observed at all locations, usually from the hypolimnion, during summer and fall. Hypolimnetic dissolved oxygen concentrations were most depressed at RK-66, RK-72, LNF-3, and EC-6 (Table 4, Figure 5).

Dissolved oxygen minima were lower in 2009 compared to 2008 but similar to 2006 and 2007 (Figure 6). Vertical depth profile dissolved oxygen concentrations from 2009 were significantly greater than concentrations in 2006 (ANOVA,  $P < 0.001$ ) but significantly lower than concentrations in 2008 (ANOVA,  $P < 0.001$ ). Differences between years are likely due in part to water year and how soon the water column stratifies. Earlier stratification allows hypolimnetic water to stagnate longer and have dissolved oxygen consumed via decomposition of organic material. Dissolved oxygen isopleths from 2009 are available in Appendix B.

Table 4 Minimum dissolved oxygen concentrations observed in 2009.

Location	Jul 6	Jul 20	Aug 10	Aug 24	Sep 7	Sep 21	Oct 5	Nov 9
EC-6	8.9	8.3	6.9	0.5	4.8	2.5	3.3	4.1
LNF-3	7.3	7.6	5.4	2.4	2.8	6.4	4.9	9.1
RK-2	7.3	8.3	7.2	7.1	5.6	4.6	6.5	8.3
RK-31	9.2	8.1	9.4	7.2	5.7	5.2	6.9	6.0
RK-56	7.7	8.5	6.8	6.7	5.8	3.8	3.6	5.3
RK-66	7.6	5.9	5.3	2.8	1.3	0.3	0.1	9.0
RK-72	7.8	4.7	5.0	0.1	0.1	6.1	7.6	9.2

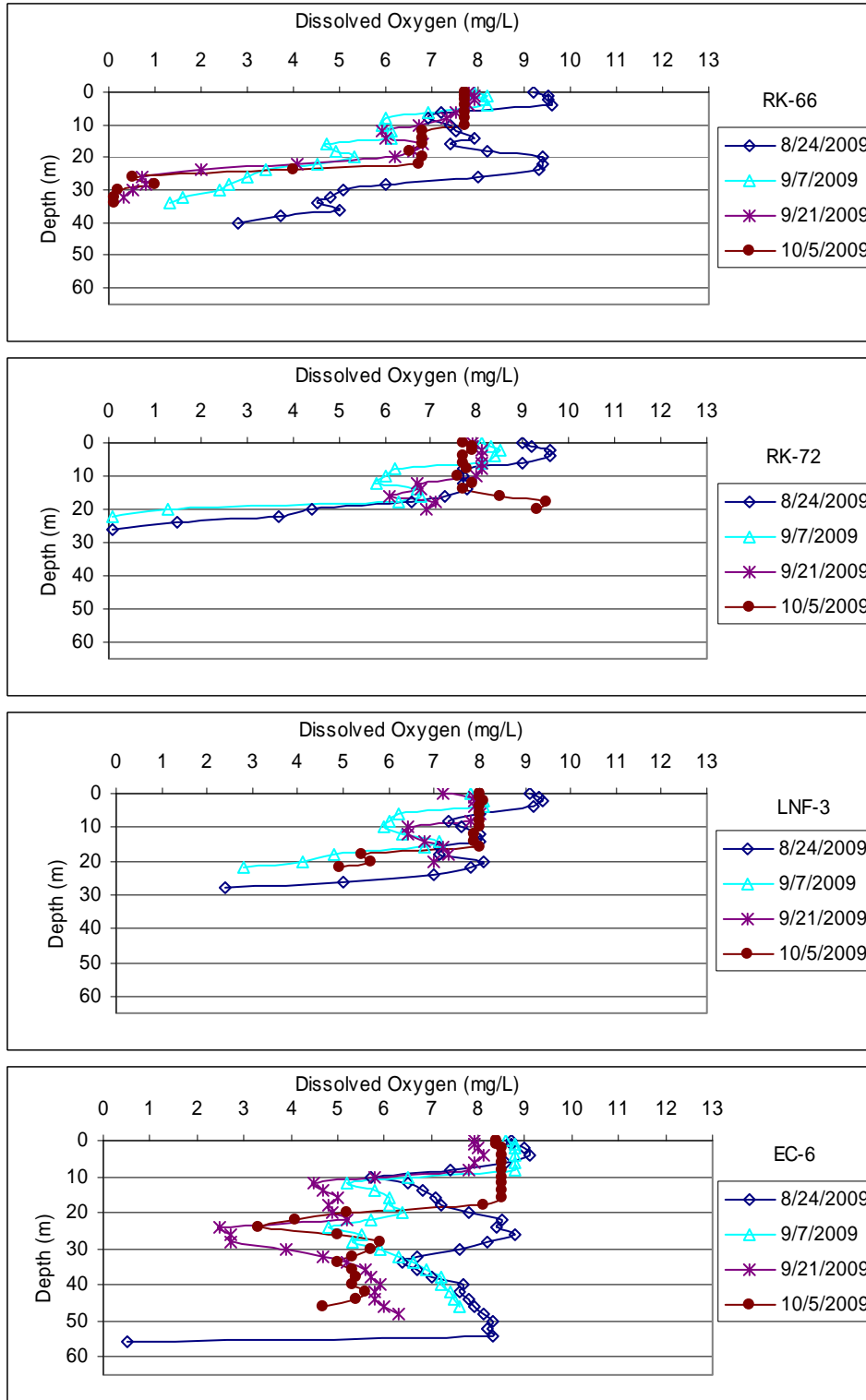


Figure 5 Dissolved oxygen profiles at Dworshak stations RK-31, RK-56, RK-66, and RK-72

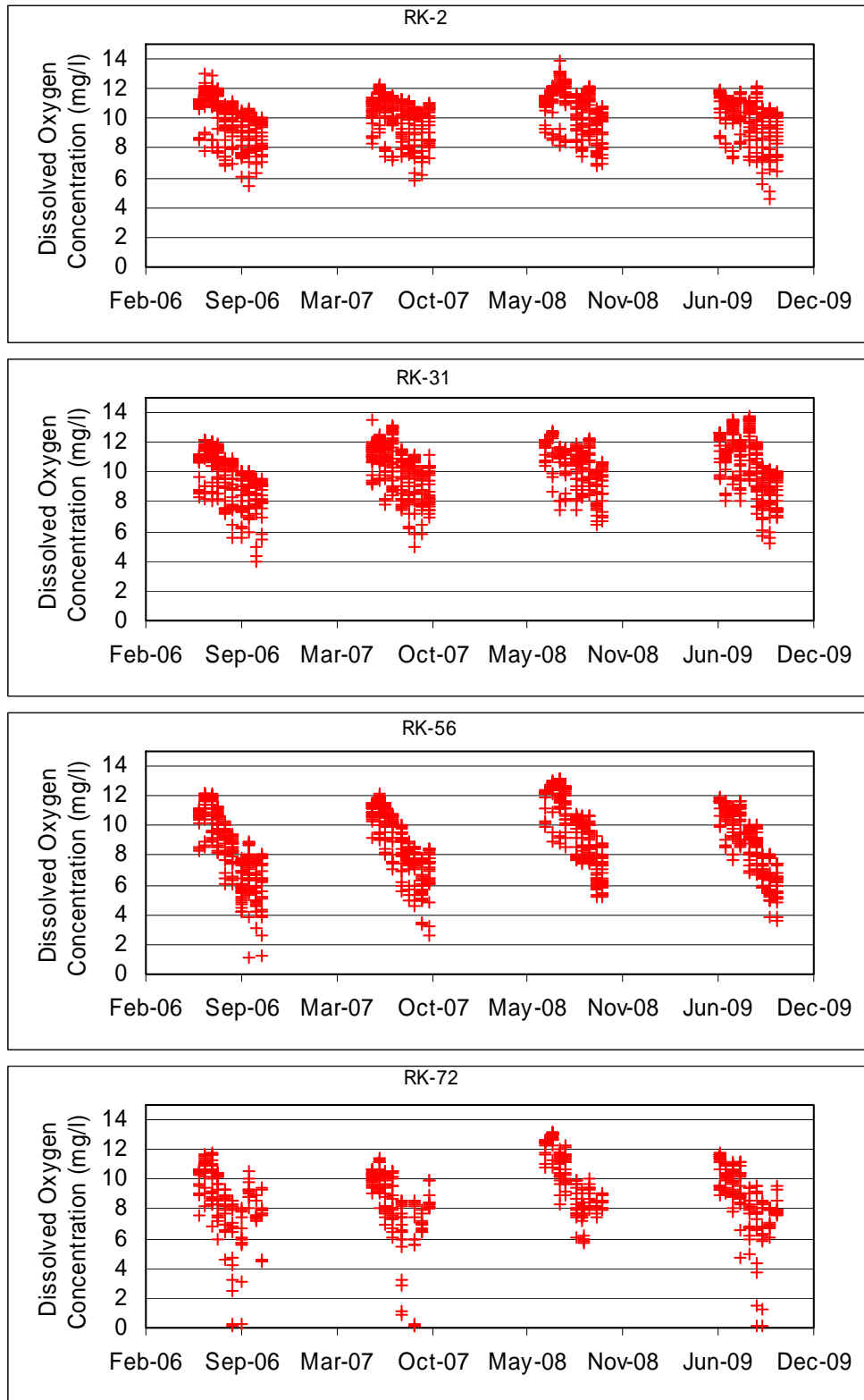


Figure 6 Scatter plots of dissolved oxygen concentrations from different Dworshak sampling stations during 2006, 2007, 2008, and 2009 during the months of June through November. X-axis indicates date in MMM-YY format.

## 4.5 Water Clarity

Water clarity was measured with a standard 20 cm diameter Secchi disk. The Secchi disk was lowered over the shady side of the boat until it disappeared and then slowly raised until it reappeared. This depth was then recorded to the nearest tenth meter.

Secchi disk depths in 2009 tended to be lower than past years (Figure 7). As in past years Secchi disk depths in 2009 were lowest during early summer coinciding with peak inflows into Dworshak Reservoir (Figure 8). Mean and median Secchi depths in 2009 were lower compared to most past years (Table 5). However, the median value from the non-treatment year 2006 was equal (3.05 m) to the treatment year 2009. Using ANOVA confirmed that Secchi disk values in 2009 were not significantly different from values measured in 2006, 2007, and 2008 ( $P \geq 0.615$ ). Secchi disk depths were transformed for ANOVA. Secchi disk values from 2009 were, however, significantly less than values measured in 2004 and 2005 (ANOVA,  $P \leq 0.002$ ). Contour plots (isopleths) of percent light transmission by location and date in 2009 are available in Appendix B.

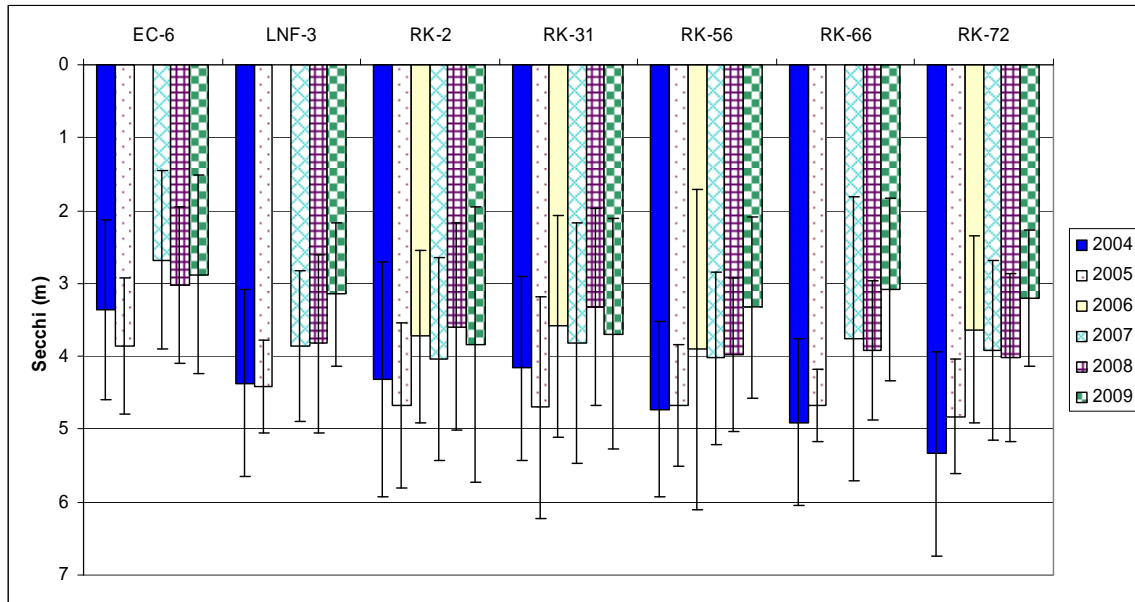


Figure 7 Mean Secchi disk depths by station from 2004 to 2009. Error bars represent  $\pm 1$  standard deviation.

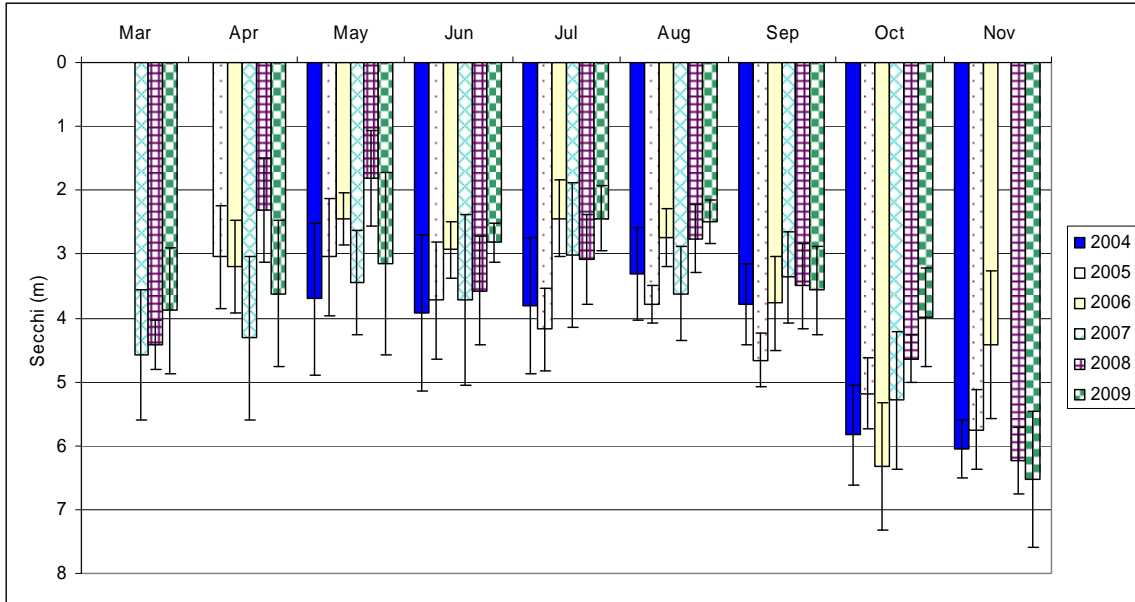


Figure 8 Mean Secchi disk depths by month from 2004 to 2009. Error bars represent  $\pm 1$  standard deviation.

Table 5 Descriptive statistics from Secchi disk measurements (m) from stations RK-2, RK-31, RK-56, and RK-72 during May to October.

Data	2004	2005	2006	2007	2008	2009
<b>Mean</b>	4.57	4.69	3.52	3.77	3.51	3.44
<b>Median</b>	4.27	4.88	3.05	3.68	3.20	3.05
<b>SD</b>	1.36	1.03	1.50	1.08	1.31	1.41
<b>Min</b>	2.74	2.90	1.83	2.13	0.76	1.83
<b>Max</b>	6.71	6.71	8.53	6.70	6.70	8.53
<b>n</b>	28	25	52	40	46	47

#### 4.6 Water Chemistry

Values for total phosphorus, total dissolved phosphorus, and nitrite plus nitrate were collected from each of the reservoir stations in both the epilimnion and the hypolimnion. The epilimnion sample was a composite from 1 m, 3 m, 5 m, and 7 m. The hypolimnion sample was a single grab sample taken from a depth of 25 m or 3 m above the bottom if the total depth was less than 28 m. These sample depths were maintained regardless of stratification. Total dissolved solids (TDS) were analyzed from the composite epilimnetic sample only. The North Fork Clearwater (NFC) sample consisted of a surface grab

sample downstream of Dworshak Dam (Figure 1) and was analyzed for the same water chemistry parameters as the reservoir's epilimnetic samples. For analytes measured below the report limit concentration, the report limit value was substituted as the analyte concentration. The percentage of concentrations below the report limit for total phosphorus, nitrate + nitrite, and total dissolved phosphorus in 2009 were respectively 7% (12/170), 31% (52/170), and 24% (41/170).

#### ***4.6.1 Phosphorus***

Total phosphorus concentrations in 2009 were relatively similar to those from past years (Figure 9). Differences in 2009 total phosphorus concentrations between depth strata have also remained small (Figure 9). This is consistent with past years where differences in total phosphorus concentrations between depth strata have been minor. Appendix B contains figures displaying total phosphorus concentrations for the entire 2009 sampling season separated by station and date.

Comparisons of total phosphorus concentrations by year were complicated by changes in the analytical lab's reporting limits for total phosphorus. In 2004 and 2006 the reporting limits for total phosphorus were 0.01 mg/L and 0.005 mg/L, respectively. From 2007 to 2009 the reporting limit was 0.001 mg/L. Considering this, statistical comparisons were only made between years 2007 through 2009. An ANOVA of transformed epilimnetic total phosphorus concentrations indicated no significant difference between those years ( $P \geq 0.822$ ).

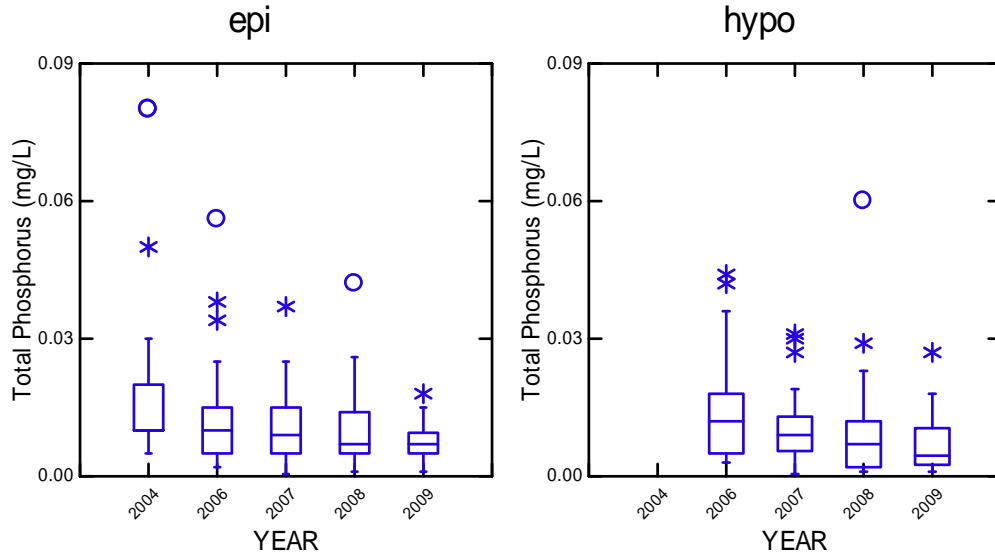


Figure 9 Total phosphorus concentrations by year at RK-2, RK-31, RK-56, and RK-72 from May to November for both epilimnetic (epi) and hypolimnetic (hypo) depth strata.

The distribution of total dissolved phosphorus concentrations observed in 2009 was similar to concentrations observed in 2008 (Figure 10). As with total phosphorus, changes in laboratory reporting limits across various years restricted statistical comparison to certain years. Comparable years include 2006 to 2009 since the reporting limit for total dissolved phosphorus was consistently 0.001 mg/L. In 2004 the reporting limit was higher, at 0.005 mg/L, so 2004 data were not included in the statistical analysis. The only statistically significant differences in epilimnetic total dissolved phosphorus concentrations across these years were the differences between 2006 and 2007 values (ANOVA,  $P < 0.001$ ). Data were transformed prior to the ANOVA. The distributions of total dissolved phosphorus concentrations between depth strata were quite similar for 2006 through 2009 (Figure 10).

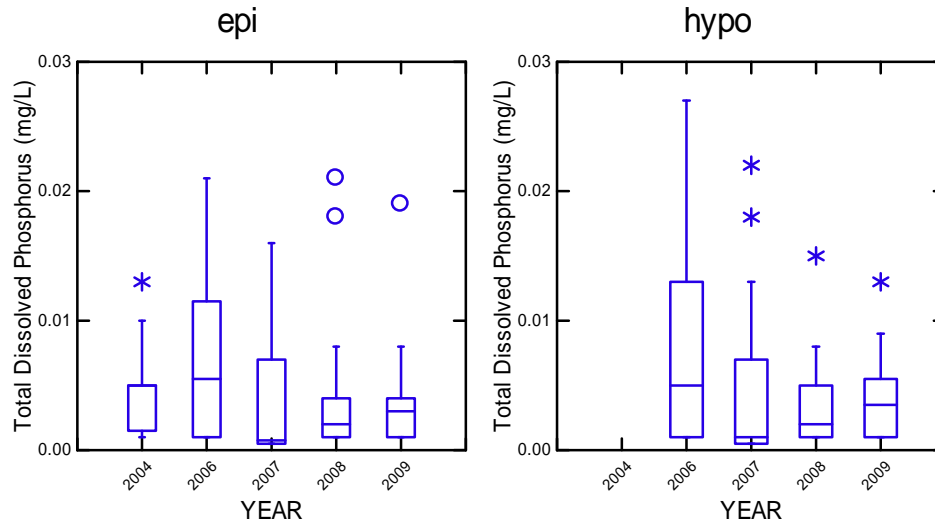


Figure 10 Total dissolved phosphorus concentrations by year at RK-2, RK-31, RK-56, and RK-72 from May to November for both epilimnetic (epi) and hypolimnetic (hypo) depth strata.

Water samples were collected at one station (NFC) downstream of Dworshak Reservoir and analyzed for total phosphorus and total dissolved phosphorus. Nutrient concentrations would be expected to be quite similar between NFC measurements and RK-2 hypolimnetic measurements because of their close proximity. Concentrations for both total phosphorus and total dissolved phosphorus between the NFC and RK-2 hypolimnion samples across years and depth strata were indeed quite similar (Figure 11, Figure 12). An ANOVA of combined 2007 to 2009 data indicated that differences between total phosphorus concentrations measured at NFC and RK-2 hypolimnion were insignificant ( $P = 0.616$ ). Likewise, differences in total dissolved phosphorus at NFC and RK-2 hypolimnion were insignificant using an ANOVA ( $P = 0.566$ ). For both the total phosphorus and the total dissolved phosphorus ANOVAs, data were transformed and only data from May to November were used. Mean total phosphorus and total dissolved phosphorus concentrations at NFC and RK-2 hypolimnion for 2007 through 2009 are presented in Table 6.

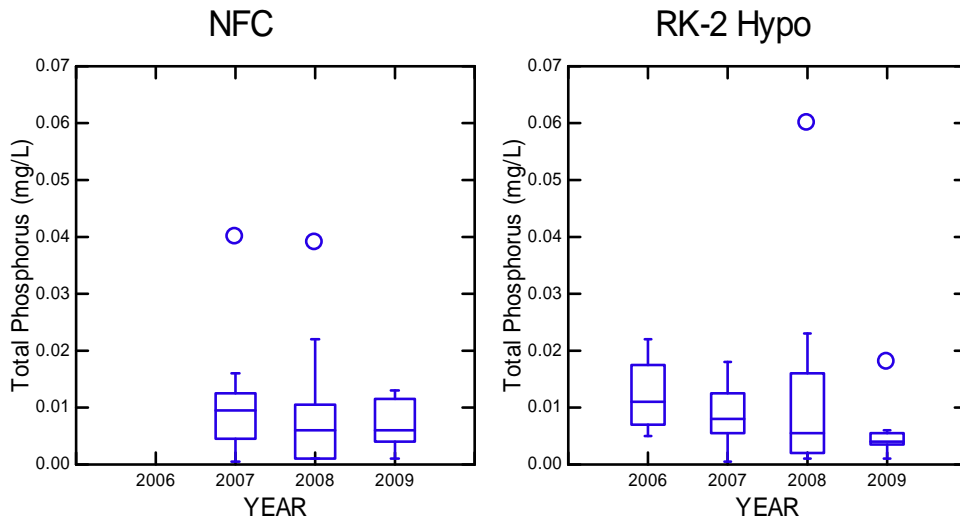


Figure 11 Total phosphorus concentrations by year from RK-2 hypolimnion and the NFC station from May to November.

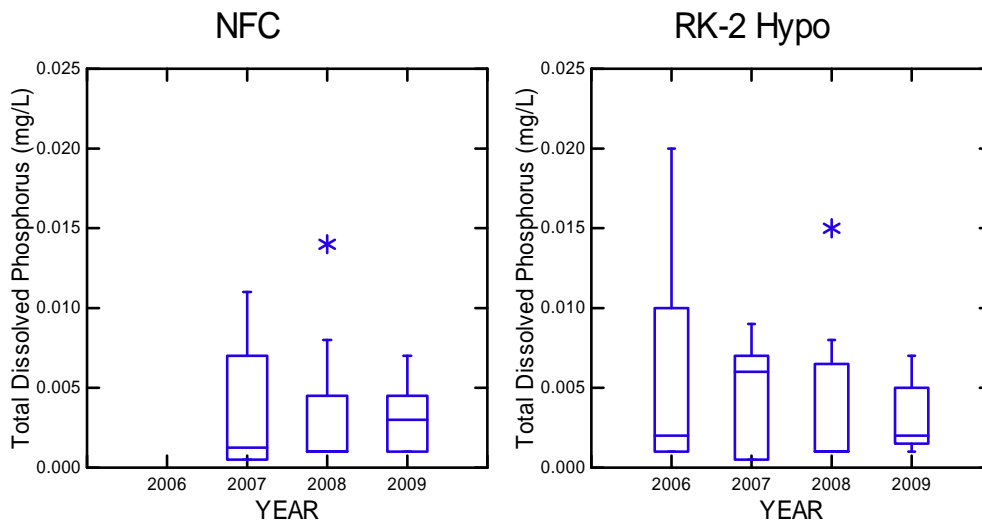


Figure 12 Total dissolved phosphorus concentrations by year from RK-2 hypolimnion and the NFC station from May to November.

Table 6 Mean nutrient concentrations in mg/L from NFC and RK-2 hypolimnion from May to November during years 2007, 2008, and 2009. Values in parentheses are standard deviations.

Site / Year	TP	TDP	NO <sub>3</sub> + NO <sub>2</sub>
NFC 2007	0.010 (0.095)	0.003 (0.004)	0.037 (0.017)
RK-2 Hypo 2007	0.008 (0.005)	0.004 (0.003)	0.031 (0.021)
NFC 2008	0.017 (0.025)	0.003 (0.004)	0.059 (0.030)
RK-2 Hypo 2008	0.014 (0.018)	0.003 (0.004)	0.048 (0.039)
NFC 2009	0.007 (0.004)	0.003 (0.002)	0.026 (0.019)

RK-2 Hypo 2009	0.006 (0.006)	0.003 (0.002)	0.004 (0.005)
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#### 4.6.2 Nitrogen

In contrast to the phosphorus analytes, nitrate + nitrite concentrations showed more variation between depth strata and years (Figure 13). The statistical analysis of nitrate + nitrite concentrations by year was affected by changes in laboratory reporting limits across different years. In 2004, 2008, 2009, and the latter half of 2007, a reporting limit of 0.001 mg/L was listed. In 2006 and for the first half of 2007 a reporting limit of 0.01 mg/L was listed. Considering this, only 2004, 2008, and 2009 data were included in the ANOVA. The ANOVA indicated no significant differences in transformed epilimnetic nitrate + nitrite concentrations between the tested years ( $P \geq 0.998$ ).

Hypolimnetic nitrate + nitrite concentrations were generally greater than epilimnetic concentrations, likely due to a combination of nitrification within the water column and uptake by planktonic primary producers located within the epilimnion (Figure 13). An ANOVA of transformed nitrate + nitrite concentrations by depth strata was significant, indicating higher hypolimnetic concentrations ( $P < 0.001$ ).

Nitrate + nitrite concentrations between NFC and RK-2 hypolimnion samples were most distinctly different in 2009 compared to past years (Figure 14). Nitrate + nitrite concentrations at NFC were significantly greater than RK-2 hypolimnion concentrations (ANOVA,  $P = 0.001$ ). Data were transformed and included only measurements from May to November during the years 2007 to 2009. The difference was mostly driven by the values observed in 2009. Mean nitrate + nitrite concentrations have been higher from 2007 to 2009 but most distinctly in 2009 (Table 6). Appendix B contains figures displaying nitrate + nitrite concentrations for the entire 2009 sampling season separated by station and date.

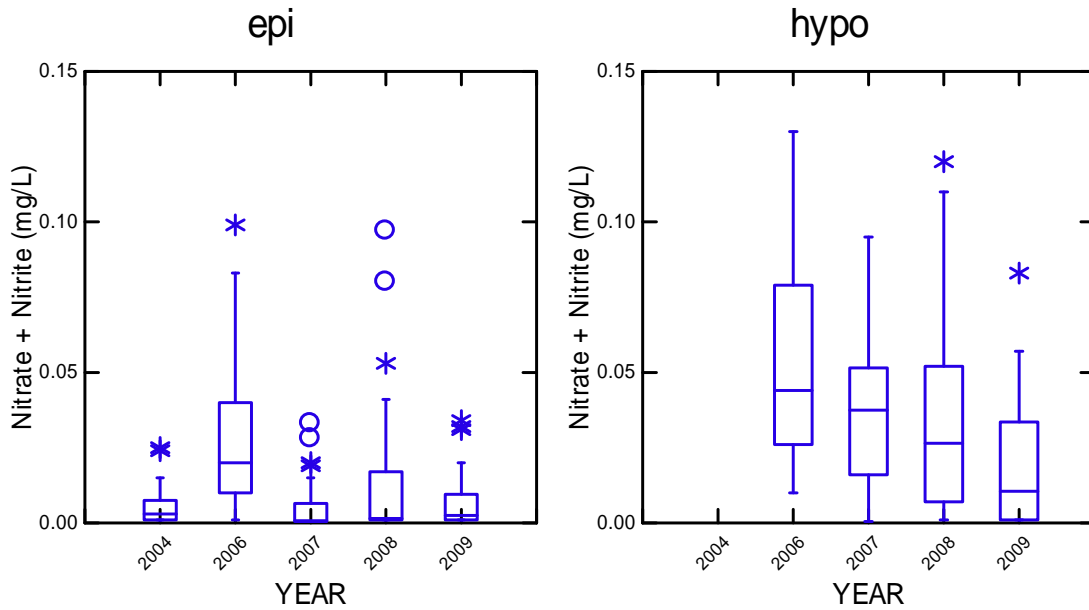


Figure 13 Nitrate + nitrite concentrations by year at RK-2, RK-31, RK-56, and RK-72 from May to November for both epilimnetic (epi) and hypolimnetic (hypo) depth strata.

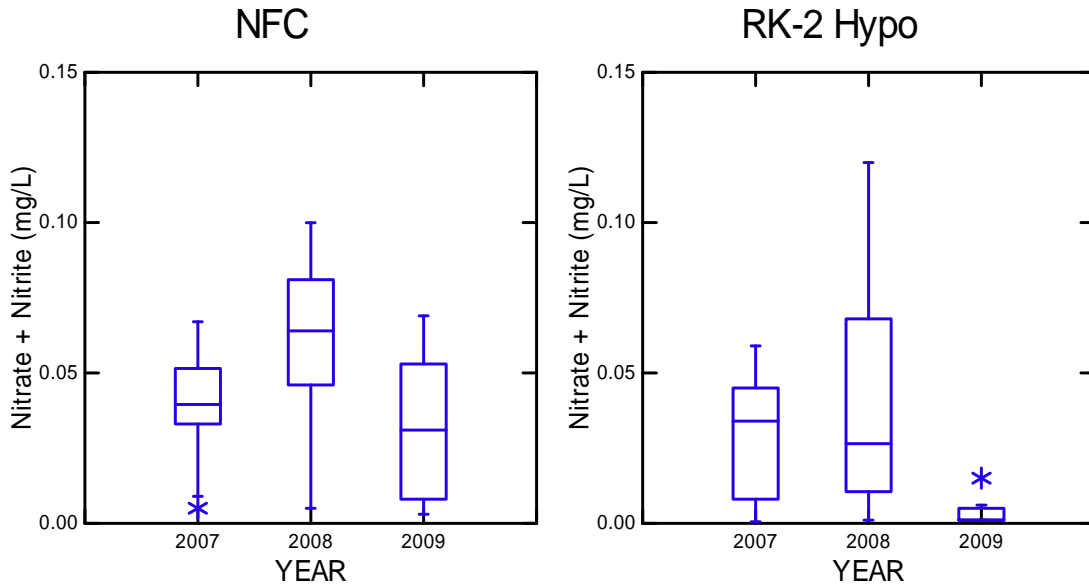


Figure 14 Nitrate + nitrite concentrations by year from RK-2 hypolimnion and the NFC station from May to November.

## 4.7 Biological Indicators

### 4.7.1 Planktonic Chlorophyll *a*

Planktonic chlorophyll *a* was analyzed from composite epilimnion samples taken during each event. The composite consisted of discrete grabs from 1 m, 3 m, 5 m, and 7 m; this was the same composite used for nutrient samples. After collection, samples were filtered immediately, frozen, and shipped overnight to TG Eco-Logic for fluorometric chlorophyll *a* analysis.

Chlorophyll *a* concentrations in 2009 were quite similar to those for past years (Figure 15). An ANOVA of transformed chlorophyll *a* concentrations indicated 2009 was not significantly different from observations taken in 2004, 2006, 2007, and 2008 ( $P = 0.256$ ). As in past years, median chlorophyll *a* in 2009 was below the consent order of  $3.0 \mu\text{g/L}$ . The respective median concentrations ( $\mu\text{g/L}$ ) were 2.00, 2.10, 2.29, 1.57, and 2.03 in 2004, 2006, 2007, 2008, and 2009. As of yet it appears the nutrient addition efforts have not increased chlorophyll *a* concentrations by a discernable level.

The median chlorophyll *a* concentration in 2009 at NFC ( $0.39 \mu\text{g/L}$ ) was considerably lower than the median from RK-2 epilimnion samples ( $2.08 \mu\text{g/L}$ ), the nearest upstream station. Chlorophyll *a* concentrations at NFC have typically been lower than concentrations from RK-2 epilimnion (Table 7) during 2009. Presumably chlorophyll *a* concentrations are lower at NFC since these concentrations represent hypolimnetic water and phytoplankton concentrate in the photic zone contained by epilimnetic waters.

Seasonally, chlorophyll *a* concentrations are quite variable by station and sampling event (Figure 16). The variability across stations and sampling events appears to be obscuring any potential differences that may be observed between years. In 2009 RK-2 and RK-31 tended to have higher chlorophyll *a* concentrations earlier in the year. Conversely, RK-56, RK-66, RK-72, and LNF-3 had higher concentrations later in the year. Different factors likely influence chlorophyll *a* concentrations seasonally at each station. For example, at RK-2 and RK-31 higher chlorophyll *a* concentrations early in the year represent a spring bloom before peak runoff has occurred. The higher chlorophyll *a* concentrations at upper reservoir stations may represent a fall bloom possibly triggered by reduced grazing pressure as temperatures cool off.

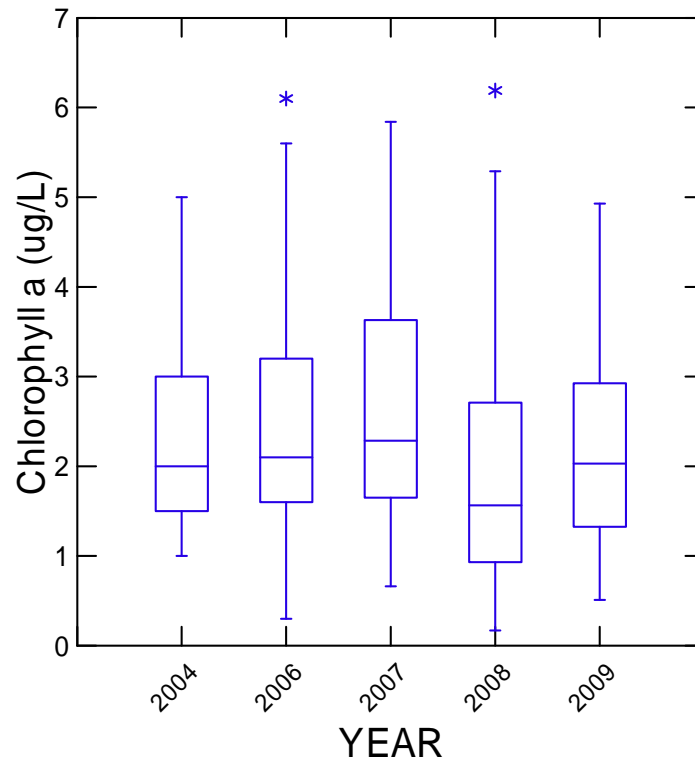


Figure 15 Planktonic chlorophyll a concentrations by year at RK-2, RK-31, RK-56, and RK-72 during May to November.

Table 7 Median chlorophyll a concentrations ( $\mu\text{g/L}$ ) by year at NCF and RK-2 epilimnion from the months of May to November.

Year	NFC	RK-2 Epi
2004		3.00
2006		2.40
2007	0.48	3.19
2008	0.61	2.03
2009	0.39	2.08

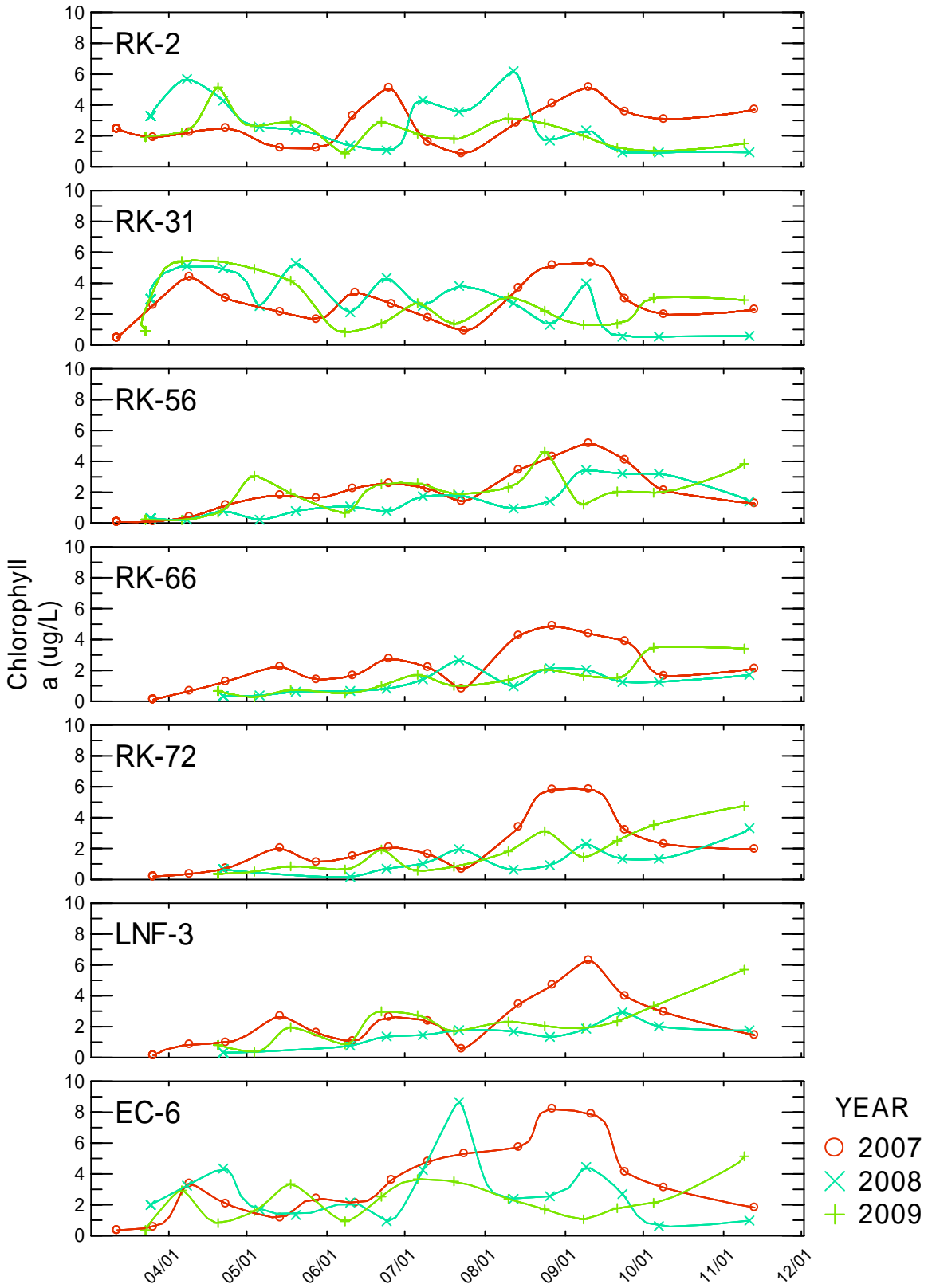


Figure 16 Seasonal planktonic chlorophyll a concentrations by station and year. The x-axis indicates date in the MM:DD format.

#### 4.7.2 Phytoplankton Community

In 2009 phytoplankton samples were collected twice per month from April to September and once per month in March, October, and November. At each sampling event an epilimnetic (composite sample from 1 m, 3 m, 5 m, and 7 m) and hypolimnetic (grab sample from 25 m or taken at 3 m above bottom if total depth < 28 m) sample were taken. Phytoplankton samples were taken from the same composite and grab samples used in nutrient analysis. Phytoplankton composition and density were determined from each sample. See Appendix C for a complete species list and relative abundance by major taxonomic group for all phytoplankton samples analyzed in 2008 and 2009. In most cases phytoplankton densities are reported in natural counting units (NCU) per mL to facilitate multiyear comparisons. Natural counting units refer to how different algae species are counted depending on their form. For colonial forms with cells difficult to differentiate a single colony is counted as one NCU. For single cell forms or colonial forms with easily distinguishable cells each cell is counted as one NCU. Some data show density in cells per mL. In either case units are noted.

Mean epilimnetic total phytoplankton density across all mainstem stations was 7,998 NCU/mL in 2009. Total phytoplankton densities in 2009 were considerably greater than most past years (Figure 17). Transformed total phytoplankton density in 2009 was significantly greater than total density in any other year (ANOVA,  $P < 0.001$ ). The increase in phytoplankton density in 2009 was not uniform across the major taxonomic groups. Increases were most apparent in the flagellates, blue-greens, and coccoid greens (Figure 18). The 2009 annual mean densities for each group were: 3,256 NCU/mL flagellates, 2,153 NCU/mL blue-greens, and 1,591 NCU/mL coccoid greens. Annual mean densities for diatoms and dinoflagellates were 266 and 11 NCU/mL, respectively.

Most flagellates observed in 2009 were nanoflagellates. Nanoflagellates contributed approximately 40.5% to the overall relative abundance in 2009. Mean annual nanoflagellate density in 2009 was 3,279 NCU/mL. The next most common flagellates in 2009 were *Komma sp.* at 3.4% and *Cryptomonas sp.* at 1.0% of the overall relative abundance. *Komma sp.* and *Cryptomonas sp.* had mean annual densities of 275 and 90 NCU/mL, respectively. These were also the most common flagellates in 2008. In the

2008 report (TG Eco-Logic 2009) *Komma sp.* is actually *Boda sp.* renamed. Flagellates typically provide high food quality to grazing zooplankton.

Blue-green algae in 2009 were mainly composed of *Synechococcus sp.*, *Chroococcus sp.*, and *Microcystis sp.*, with overall relative abundances of 9.3%, 5.9%, and 1.7%, respectively (Please note the relative abundance of *Microcystis sp.* is based on NCU/mL and not cells/mL). *Synechococcus sp.* was observed in both rod and coccoid form, with respective overall relative abundances of 6.6% and 2.8%. Mean annual *Synechococcus sp.* rod and coccoid densities were 538 and 275 NCU/mL, respectively in 2009. Mean annual densities for *Chroococcus sp.* and *Microcystis sp.* were 745 and 143 NCU/mL, respectively in 2009. The food quality of blue-greens for zooplankton is mixed. *Synechococcus sp.* typically is edible and *Microcystis sp.* is inedible, while the edibility of *Chroococcus sp.* is unknown.

The observed densities of *Microcystis sp.* were notable in 2009. Some samples in mid summer showed relatively high densities and 2009 maximum densities were higher than those observed in 2008 (Figure 19). Transformed *Microcystis sp.* densities in 2009 were significantly greater than those observed in 2008 (ANOVA,  $P < 0.001$ ). Please note these densities were in cells per mL rather than NCU per mL. Unfortunately, *Microcystis sp.* densities in cells per mL are unavailable for years prior to 2008, so comparisons are limited to 2008 and 2009 at this point. For years prior to 2008, cells per mL could be estimated using the ratio of cells to colonies from known years. However, the phytoplankton database is not yet capable of this operation. *Microcystis sp.* densities reached as high as 38,782 cells/mL at RK-31 on June 23, 2009. The next highest *Microcystis sp.* density of 29,025 cells/mL was observed at EC-6 on July 20, 2009.

When counting *Microcystis sp.* in cells/mL rather than NCU/mL the overall relative abundance of *Microcystis sp.* jumps to 40.8% (compared to 1.7% using NCU/mL), which makes *Microcystis sp.* the dominant phytoplankton species in 2009. The discrepancy in relative abundance numbers is likely due to the apparent difference in cells per colony between 2008 and 2009 for *Microcystis sp.* In 2008 there were on average 26 cells/colony while in 2009 there were 41 cells/colony. Measuring *Microcystis sp.* density in cells per mL may be more accurate than via NCU per mL. For this reason most

colonial blue-green species have been counted by cells and colonies per mL since 2008. The counting method used for colonial blue-green species can drastically change abundance densities and relative densities. Therefore, the counting method should always be noted.

The increase in 2009 coccoid green phytoplankton density was almost exclusively attributed to the occurrence of *Stichococcus minutissimus*. In 2009 *S. minutissimus* contributed 24.9% to the overall relative abundance, making it the second most common species by density. Interestingly, *S. minutissimus* has not been observed in prior years. Mean annual *S. minutissimus* density in 2009 was 3,395 NCU/mL. The next most common coccoid green in 2009 was *Coelastrum sp.*, contributing 1.4% to the overall relative abundance. Mean annual *Coelastrum sp.* density in 2009 was 262 NCU/mL.

The most common diatom in 2009 was *Fragilaria crotonensis*, contributing 2.2% to the overall relative abundance. Mean annual *F. crotonensis* density in 2009 was 370 NCU/mL. *Asterionella formosa* contributed 1.0% to relative abundance in 2009, the second greatest amount for diatoms. *A. formosa* had an overall mean density of 220 NCU/mL in 2009. *Gymnodinium sp. 1* was the most common dinoflagellate, contributing only 0.1% to the overall relative abundance in 2009, with an annual mean density of 25 NCU/mL.

Densities of edible phytoplankton increased considerably in 2009 compared to past years (Figure 20). Transformed edible phytoplankton densities in 2009 were significantly greater than years from 2005 to 2008 (ANOVA,  $P < 0.001$ ). The increase in edible phytoplankton density was largely due to the increase in nanoflagellates and *S. minutissimus* densities. Mean annual edible phytoplankton density was 4,594 NCU/mL in 2009. Nearly 92% of the overall edible phytoplankton relative abundance in 2009 originated from four taxa. These taxa were nanoflagellates, *S. minutissimus*, *Synechococcus sp.* (rod), and *Komma sp.*, with respective edible phytoplankton relative abundances of 49.3%, 30.2%, 8.0%, and 4.1% in 2009 (Table 8).

Densities of inedible phytoplankton in 2009 appeared to decrease relative to past years (Figure 21). Transformed inedible phytoplankton densities in 2009 were significantly less than densities in 2006 and 2007 (ANOVA,  $P < 0.001$ ). Box plots of percent edible

and inedible phytoplankton in 2009 show the changes in densities relative to one another (Figure 22). The percent contributions made by phytoplankton with mixed edibility and unknown edibility are not shown in these box plots. Inedible phytoplankton were comprised mainly of *F. crotonensis*, *Microcystis sp.*, *A. formosa*, and *Anabaena sp.* Overall inedible phytoplankton relative abundances in 2009 for these species were 39%, 29%, 17%, and 8%, respectively. Presumably, total inedible phytoplankton density decreased in 2009 because mean annual *Microcystis sp.* density decreased from 584 NCU/mL in 2008 to 143 NCU/mL in 2009. Both inedible diatoms had increasing mean annual densities from 2008 to 2009; where *F. crotonensis* increased from 177 to 370 NCU/mL and *A. formosa* increased from 133 to 220 NCU/mL. Please note that the decrease in mean *Microcystis sp.* density measured in NCU per mL between 2008 and 2009 is contrary to the results given by *Microcystis sp.* density in cells per mL (Figure 19). The discrepancy is likely due to the difference in the number of *Microcystis sp.* cells per colony between 2008 and 2009.

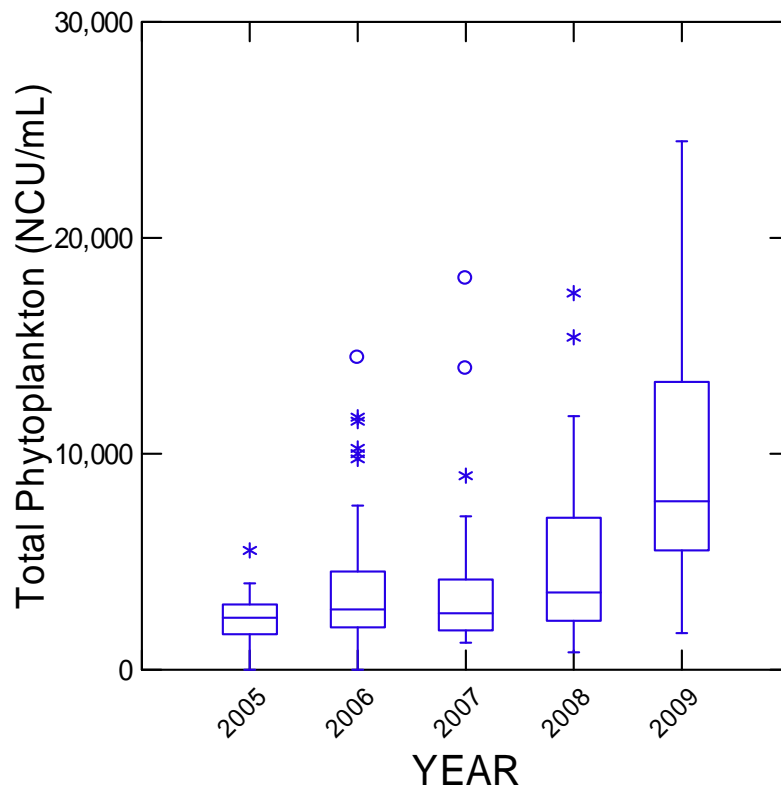


Figure 17 Total phytoplankton density by year from epilimnetic samples at RK-2, RK-31, RK-56, and RK-72 during May to November. NCU = natural counting unit.

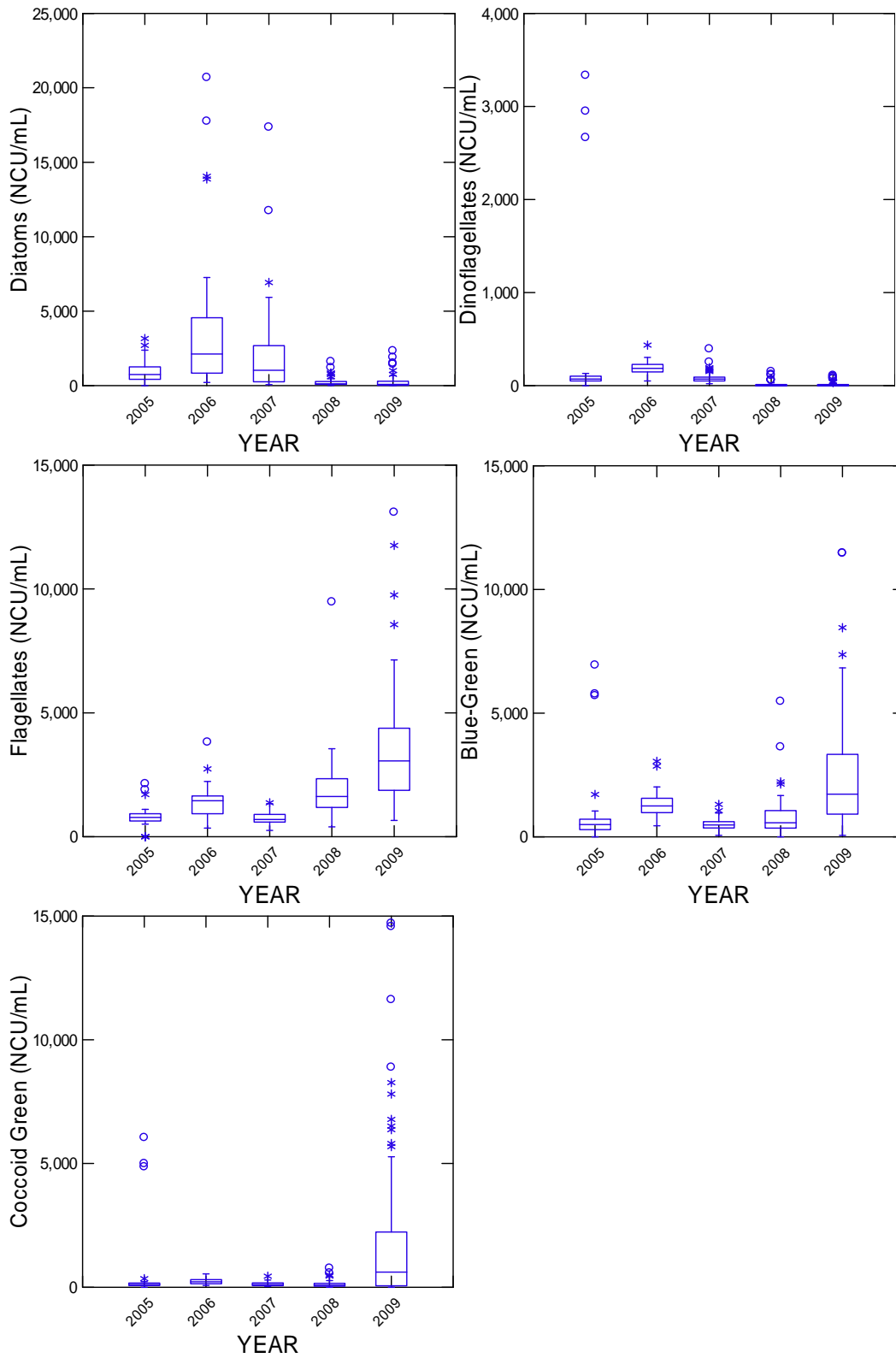


Figure 18 Epilimnetic phytoplankton density for major taxonomic groups by year from RK-2, RK-31, RK-56, and RK-72 during May to November. NCU = natural counting unit.

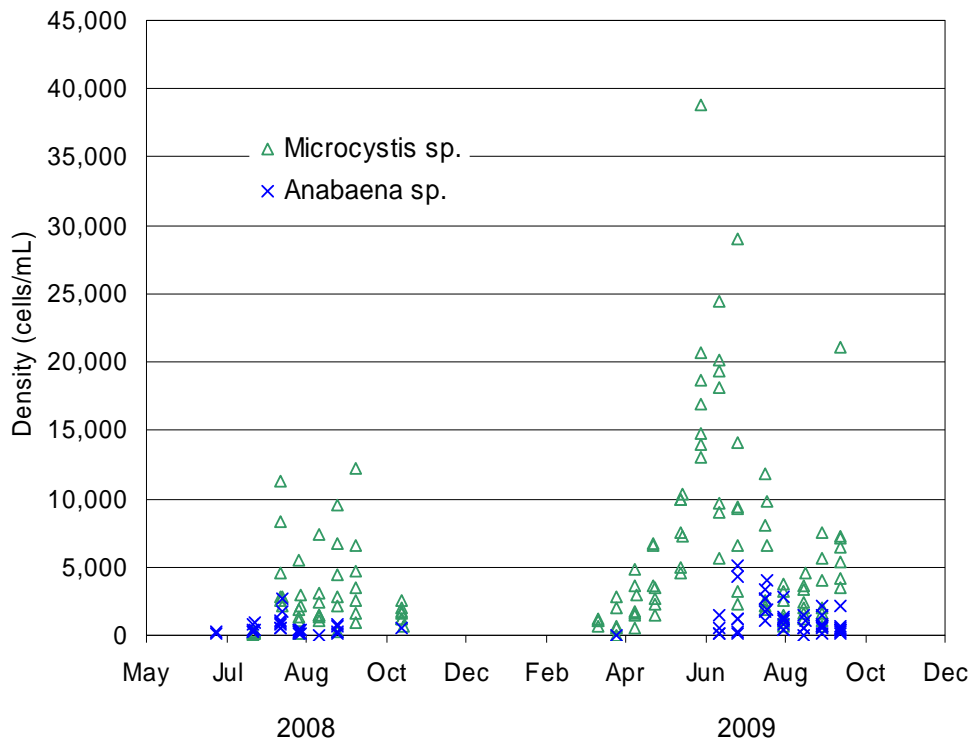


Figure 19 *Anabaena* sp. and *Microcystis* sp. densities (cells/mL) from epilimnetic samples and all stations.

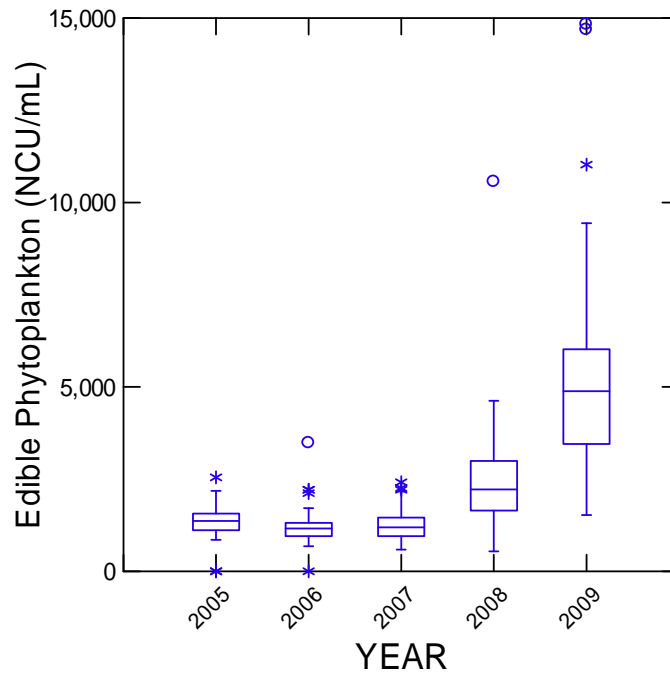


Figure 20 Epilimnetic density for edible phytoplankton taxa by year from RK-2, RK-31, RK-56, and RK-72 during May to November. NCU = Natural counting unit.

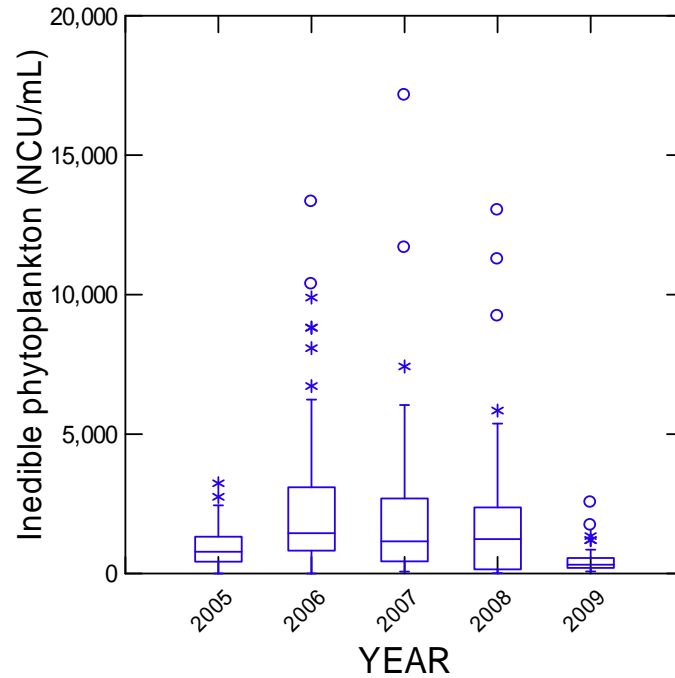


Figure 21 Epilimnetic density for inedible phytoplankton taxa by year from RK-2, RK-31, RK-56, and RK-72 during May to November. NCU = Natural counting unit.

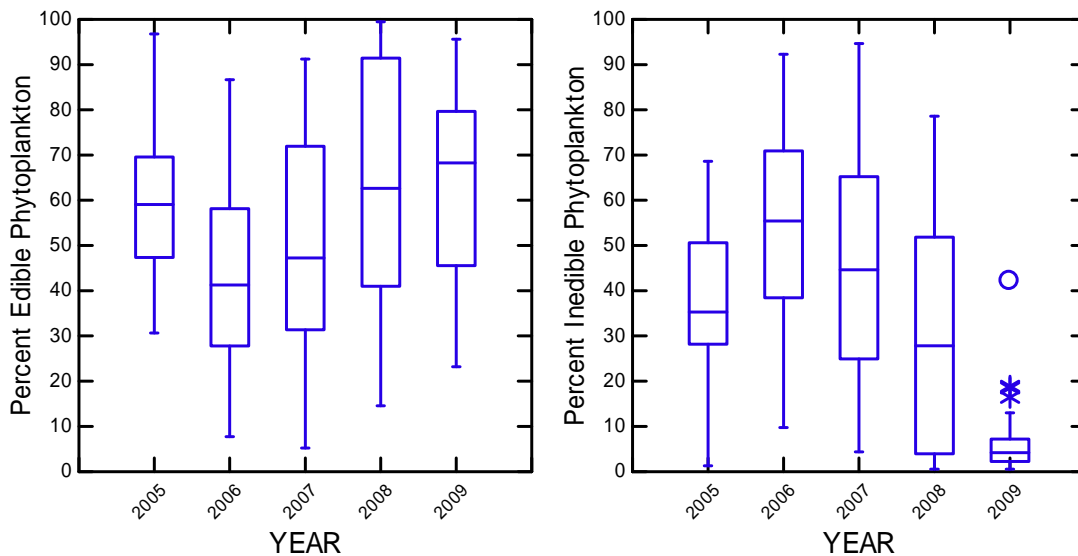


Figure 22 Box plots of percent edible and inedible phytoplankton taxa. Based on natural counting unit densities from stations RK-2, RK-31, RK-56, and RK-72 during May to November.

Table 8 Relative abundance of edible phytoplankton species by major taxonomic group from all stations in 2009

<b>Major Taxonomic Group</b>	<b>Lowest Practical Taxon</b>	<b>%</b>
<b>Blue-greens</b>	<i>Merismopedia sp.</i>	0.213
	<i>Synechococcus sp.</i> (coccoid)	3.413
	<i>Synechococcus sp.</i> (rod)	8.003
	<b>Blue-green Total</b>	<b>11.629</b>
<b>Coccoid Greens, Desmids, etc.</b>	<i>Ankistrodesmus sp.</i>	0.036
	<i>Chlorella sp.</i>	0.094
	<i>Coccomyxa sp.</i>	0.030
	<i>Cosmarium sp.</i>	0.080
	<i>Crucigenia sp.</i>	0.127
	<i>Elakatothrix sp.</i>	0.067
	<i>Monoraphidium sp.</i>	0.069
	<i>Oocystis sp.</i>	0.365
	<i>Paulschultzia sp.</i>	0.002
	<i>Planctonema sp.</i>	0.021
	<i>Scenedesmus sp.</i>	0.032
	<i>Stichococcus minutissimus</i>	30.215
	<i>Tetraedron spp.</i>	0.013
	<b>Coccoid Green Total</b>	<b>31.151</b>
<b>Diatoms</b>	<i>Achnantheidium sp.</i>	0.043
	<i>Cyclotella glomerata</i>	0.011
	<i>Cyclotella stelligera</i>	0.004
	<i>Cymbella sp.</i>	0.026
	<b>Diatom Total</b>	<b>0.084</b>
<b>Dinoflagellates</b>	<i>Gymnodinium sp. 1</i>	0.159
	<i>Peridinium spp.</i>	0.013
	<b>Dinoflagellate Total</b>	<b>0.172</b>
<b>Flagellates</b>	<i>Bitrichia sp.</i>	0.022
	<i>Chromulina sp.</i>	0.702
	<i>Chrysochromulina sp.</i>	0.168
	<i>Cryptomonas sp.</i>	1.250
	<i>Dinobryon sp.</i>	0.303
	<i>Kephyrion sp.</i>	0.118
	<i>Komma sp.</i>	4.141
	<i>Mallomonas sp. 1</i>	0.004
	<i>Mallomonas sp. 2</i>	0.032
	<i>Ochromonas sp.</i>	0.848
	Nanoflagellates	49.301
	<i>Synura sp.</i>	0.075
	<b>Flagellate Total</b>	<b>56.963</b>

#### 4.7.3 Picoplankton

Pico-cyanobacteria and heterotrophic bacteria were enumerated from aliquots of composited epilimnetic samples from 1 m, 3 m, 5 m, and 7 m depths. Picoplankton samples were then preserved until enumeration by epifluorescence microscopy by TG

Eco-Logic, LLC. During most months of 2009, pico-cyanobacterial abundances were similar to abundances in 2007, but higher than abundances in 2006 and 2008 (Figure 23). Statistically, transformed pico-cyanobacterial abundance was not significantly different in 2009 compared to past years (ANOVA,  $P \geq 0.061$ ). As in past years with fertilizer addition, pico-cyanobacterial abundance peaked in July 2009 with a mean abundance of 256,444 cells/mL.

Pico-cyanobacterial abundance in 2009 appears to show an upstream to downstream gradient, with higher mean abundances being observed at lower reservoir stations (Figure 24). A similar gradient in abundances was observed in 2008. Annual mean pico-cyanobacterial abundance in 2009 doubled between RK-72 (65,586 cells/mL) and RK-2 (116,520 cells/mL). However, an ANOVA of transformed pico-cyanobacterial abundance indicated no significant differences between stations in 2009 ( $P = 0.659$ ). Notably, this included stations EC-6 and LNF-3 where no direct nutrient application occurred.

In 2009 mean monthly heterotrophic bacterial abundances were higher than most months in both 2006 and 2008, but lower than mean abundances in 2007 (Figure 25). An ANOVA of transformed data confirmed that 2009 abundances were significantly greater than 2006 ( $P < 0.001$ ). Mean monthly heterotrophic bacterial abundance in 2009 peaked in September at 1,676,918 cells/mL, lagging two months behind the pico-cyanobacterial peak. Mean monthly heterotrophic bacterial abundance peaked a month earlier in 2007 and a month later in 2008.

By station, mean heterotrophic bacterial abundance in 2009 was highest at RK-2 (1,282,113 cells/mL) and lowest at upstream stations RK-72 (1,018,387 cells/mL) and LNF-3 (1,041,587 cells/mL). The lower abundances at upstream reservoir stations suggest a potential gradient in heterotrophic bacterial abundance similar to that for pico-cyanobacteria (Figure 26). However, the ANOVA of transformed heterotrophic bacterial abundances by station in 2009 indicated no significant differences between stations ( $P = 0.517$ ). Like pico-cyanobacterial abundances, heterotrophic abundances might be expected to be lower at non-fertilized stations EC-6 and LNF-3 yet this does not appear to be the case.

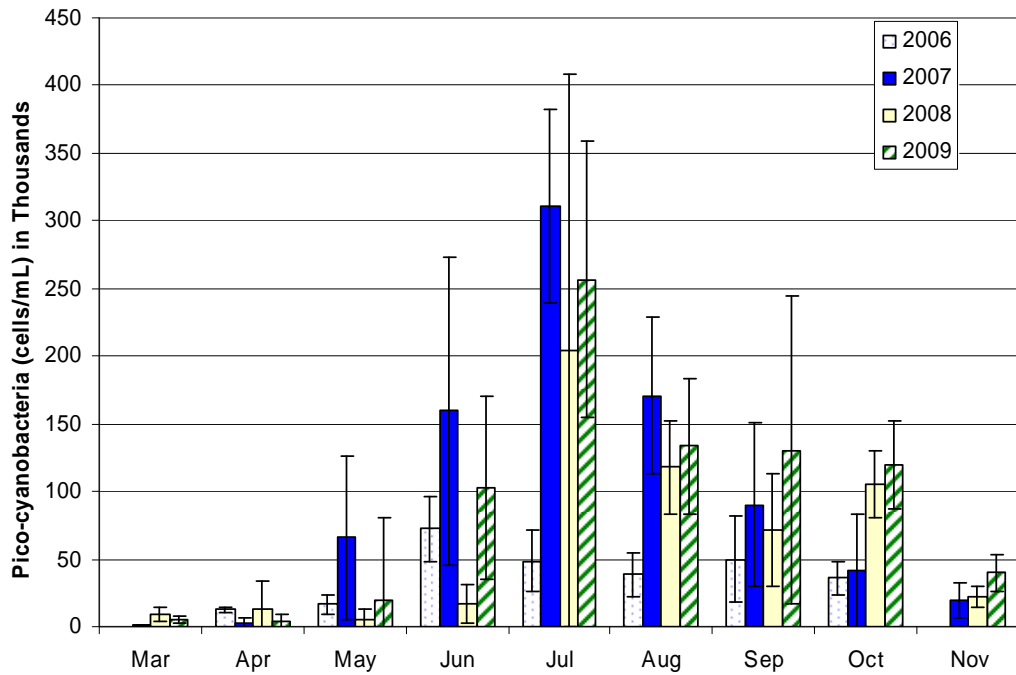


Figure 23 Mean pico-cyanobacteria abundance (thousands) by month for different years. Error bars represent  $\pm 1$  standard deviation.

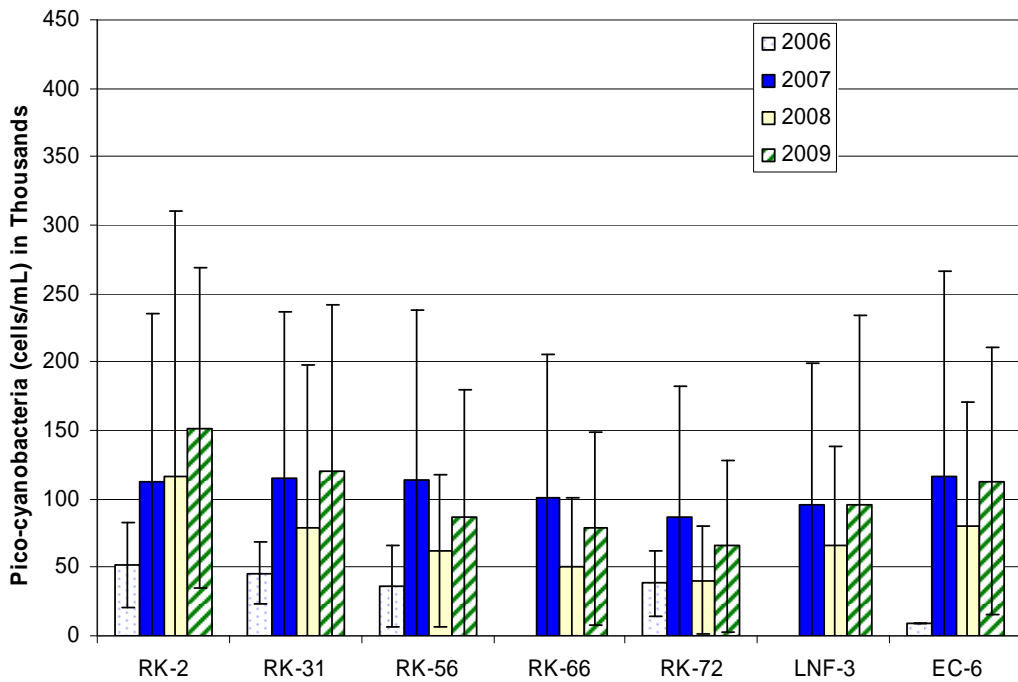


Figure 24 Mean pico-cyanobacteria abundance (thousands) by station for different years. Error bars represent  $\pm 1$  standard deviation.

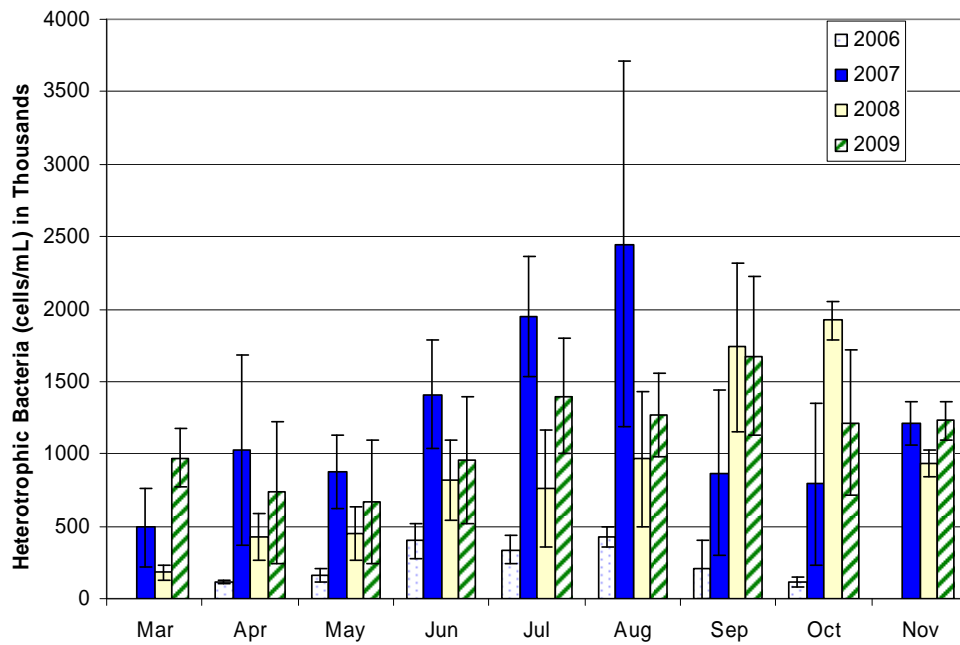


Figure 25 Mean heterotrophic bacteria abundance (thousands) by month for different years. Error bars represent  $\pm 1$  standard deviation.

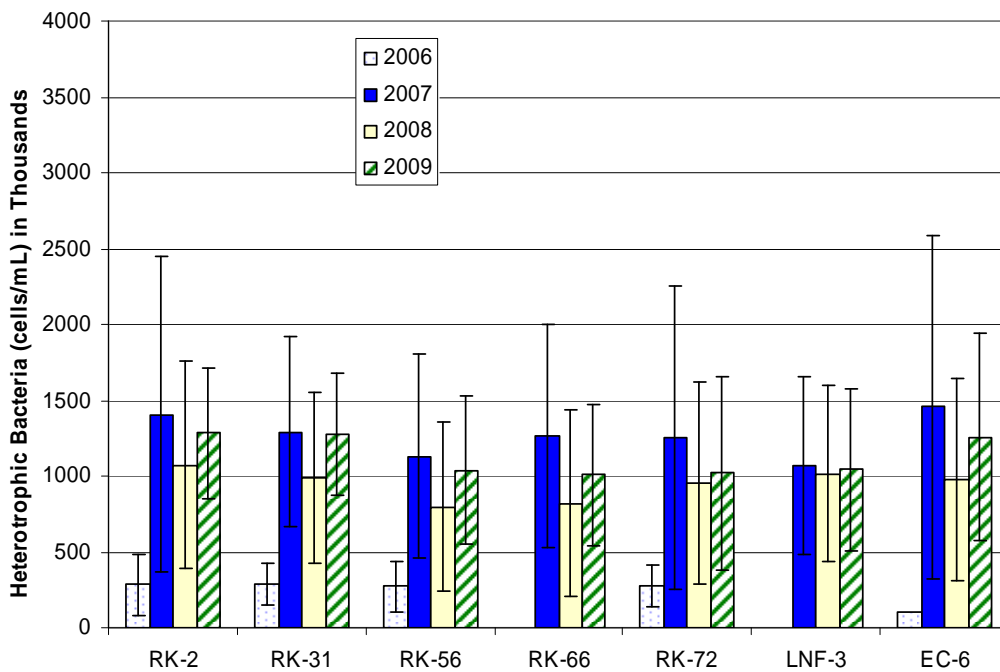


Figure 26 Mean heterotrophic bacteria abundance (thousands) by station for different years. Error bars represent  $\pm 1$  standard deviation.

#### 4.7.4 Zooplankton

Vertical zooplankton tows were taken using a high efficiency, Wisconsin style net with an 80  $\mu\text{m}$  mesh. The mouth net diameter was 50 cm and the ring diameter was 75 cm. The skirt was 50 cm in length and the net portion was 3 m in length, giving an overall mouth to length ratio of 1:6. A flow gauge was mounted in the mouth of the net and calibrated to a known number of revolutions for a given tow with no net present. The number of revolutions for each tow was recorded and used to determine net efficiency for each sample. However, the reported densities have not been corrected for net efficiency so comparisons can be made to past years when net efficiencies were not determined. Net efficiencies from 2009 are listed in Appendix C. The net was slowly lowered to 10 m, or to 3.5 m above bottom if the total water depth was less than 13.5 m. The net was hauled up at approximately 0.5 m/sec. Tows were taken twice per month except for March, October, and November, which were sampled once. For multi-year comparisons one must note differences in vertical tow depths. In 2005 and 2006 vertical tow depth was actually from the photic zone depth to the surface. In 2007 tow depth was from 30 m to the surface. Mean photic zone depths were estimated to be 11.4 m in 2005 and 11.7 m in 2006. In 2008 there were paired 30 m to 10 m tows and 10 m to surface tows. The most comparable years, with consistent tow depths, net mesh size, and sample timing, were 2005, 2006, 2008, and 2009, with a tow depth of either 10 m to surface or photic zone to surface. Data from 2007 were not as comparable to other years because of the greater tow depth.

On most sampling events in 2009 zooplankton were mainly comprised of cyclopoid copepods, *Daphnia sp.*, or calanoid copepods (Figure 27). Cyclopoid copepods, *Daphnia sp.*, and calanoid copepods respectively contributed 56.7%, 15.9%, and 10.2% to the overall annual relative abundance in 2009. The next highest relative abundance was from *Diaphanasoma sp.* at 5.3%. Cyclopoid density peaked twice in 2009, first on June 8 at 31 individuals/L and second on September 21 at 29 individuals/L. *Daphnia sp.* and calanoid densities peaked on September 21 at 16 individuals/L and 10 individuals/L, respectively.

Cyclopoid densities appear to have increased in recent years including 2009 (Figure 28). However, an ANOVA of transformed cyclopoid density by year indicated no significant

difference between densities observed in 2009 and densities observed in 2005, 2006, and 2008 ( $P \geq 0.245$ ). *Daphnia sp.* densities appeared greater in 2009 and 2008 (Figure 29). An ANOVA confirmed that transformed *Daphnia sp.* densities in both 2009 and 2008 were significantly greater than densities in 2006 ( $P \leq 0.021$ ), but not 2005 ( $P \geq 0.448$ ).

Mean annual *Daphnia sp.* length in 2009 was 1.11 mm, quite similar to values for 2008 and 2007 (Table 9). All mean *Daphnia sp.* lengths during fertilizer application years were greater than mean lengths in pre-nutrient application years. A considerable portion of the interquartile range of all *Daphnia sp.* lengths has shifted above 1 mm in fertilizer application years compared to years before treatment started (Figure 30). Transformed *Daphnia sp.* lengths in 2009 were significantly greater than lengths in 2005 and 2006 (ANOVA,  $P < 0.001$ ).

*Daphnia sp.* biomass being a function of density and length responded as a combination of these two measures. In 2009 mean *Daphnia sp.* biomass peaked with *Daphnia sp.* density on September 21 at 110  $\mu\text{g/L}$ . *Daphnia sp.* biomass steadily increased from June 8 at 24  $\mu\text{g/L}$  to September 8 at 48  $\mu\text{g/L}$ . *Daphnia sp.* biomass peaked approximately two weeks later and then dropped quickly to 20  $\mu\text{g/L}$  by November 11. Mean *Daphnia sp.* biomass in 2009 at 32  $\mu\text{g/L}$  was considerably higher than biomass in 2005 at 18  $\mu\text{g/L}$  and 2006 at 11  $\mu\text{g/L}$  (Table 10). The interquartile ranges of *Daphnia sp.* biomass in both 2009 and 2008 were considerably higher than the ranges in 2005 and 2006 (Figure 31). The 2009 transformed *Daphnia sp.* biomass was significantly greater than biomass in 2006 ( $P < 0.001$ ), but not biomass in 2005 ( $P = 0.235$ ). Like density, biomass measurements are quite variable, with respective coefficients of variation at 0.91 for 2009, 1.17 for 2006, and 1.41 for 2005.

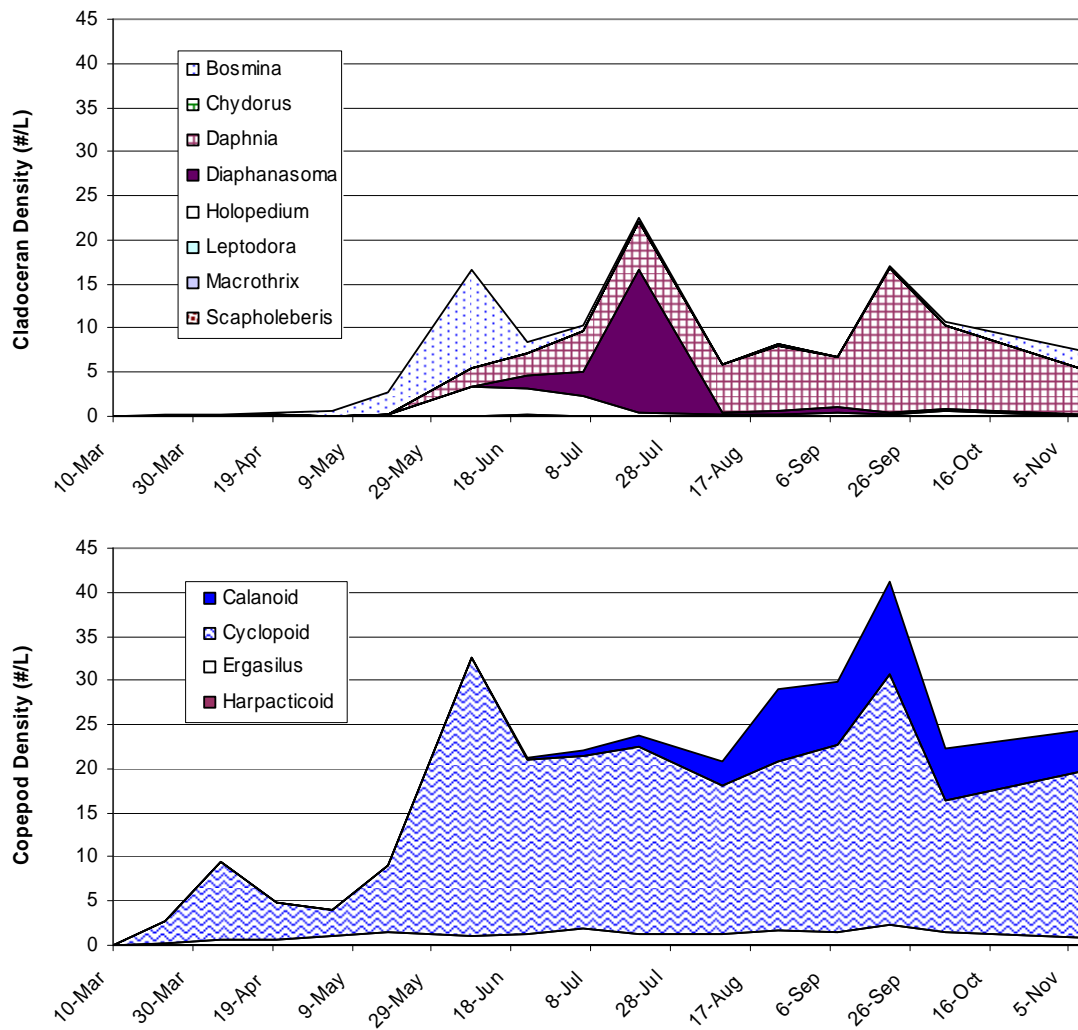


Figure 27 Mean cladoceran and copepod density by date from all reservoir stations in 2009.

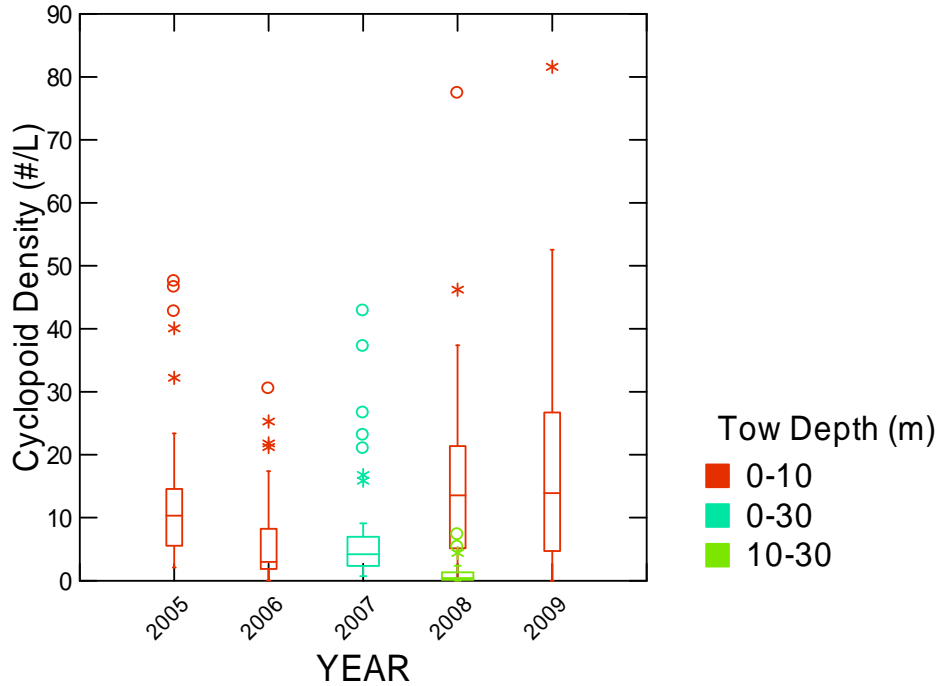


Figure 28 Cyclopoid density copepod density from RK-2, RK-31, RK-56, and RK-72 during May to November. Tow length in 2005 and 2006 were actually from 0 m – photic zone depth but are most comparable to 0 m – 10 m tows conducted in 2008 and 2009.

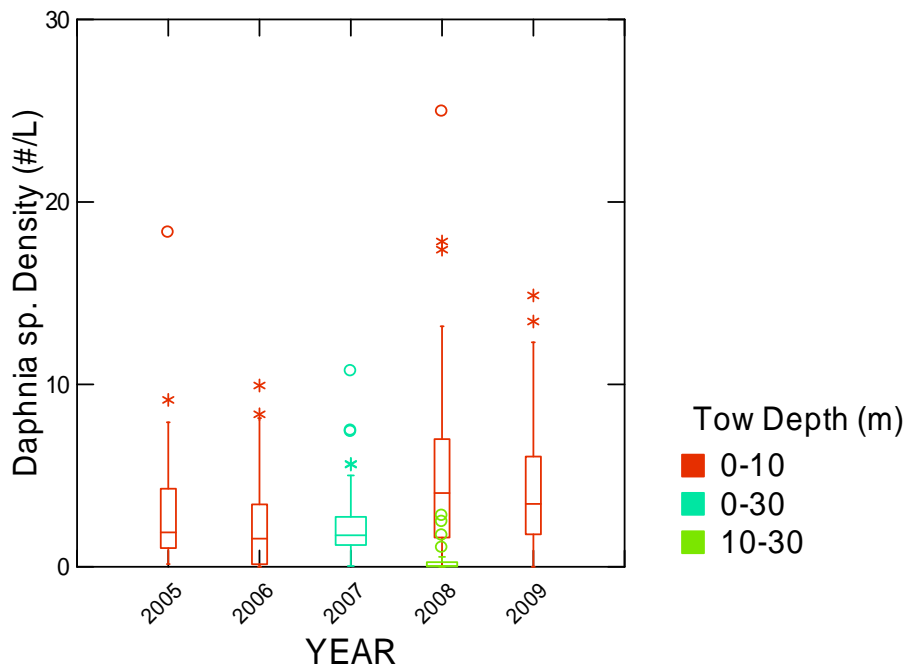


Figure 29 Daphnia sp. density from RK-2, RK-31, RK-56, and RK-72 during May to November. Tow length in 2005 and 2006 were actually from 0 m – photic zone depth but are most comparable to 0 m – 10 m tows conducted in 2008 and 2009.

Table 9 Mean Daphnia sp. length (mm) from RK-2, RK-31, RK-56, and RK-72 during May to November. Note standard deviation in parentheses.

Tow Depth (m)	2005	2006	2007	2008	2009
0 - 10	0.91 (0.25)	0.96 (0.31)		1.13 (0.36)	1.11 (0.37)
0 - 30			1.11 (0.36)		
10 - 30				1.18 (0.34)	

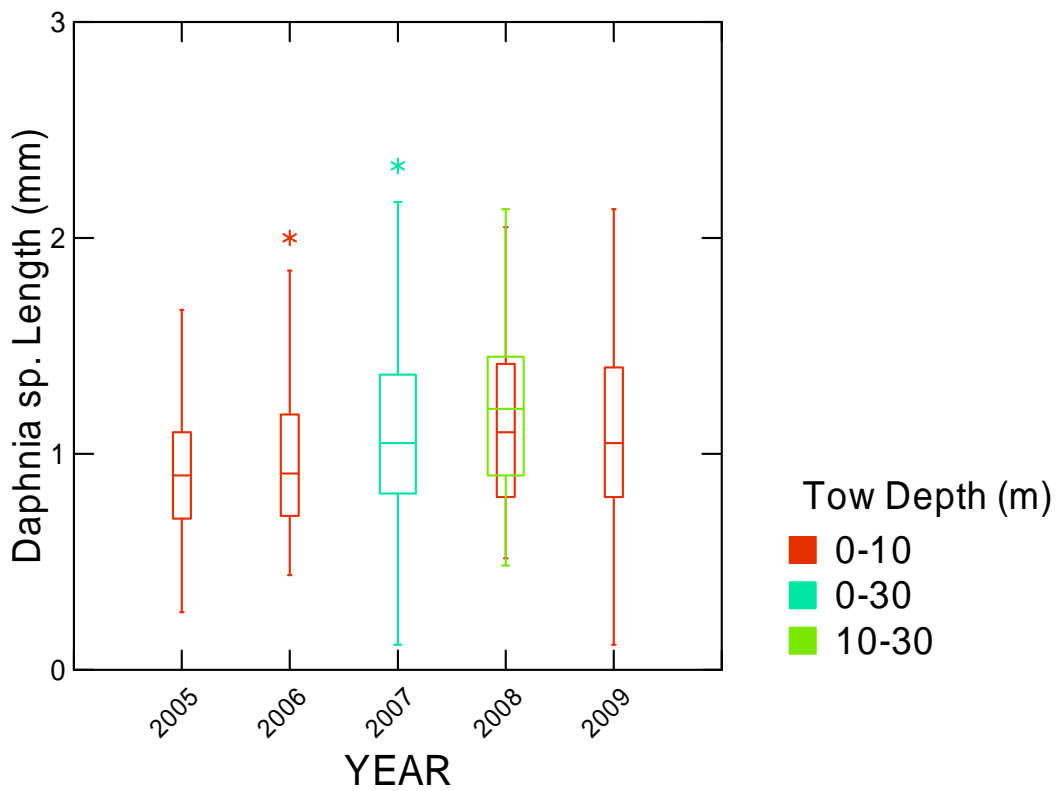


Figure 30 Daphnia sp. lengths from RK-2, RK-31, RK-56, and RK-72 during May to November. Tow length in 2005 and 2006 were actually from 0 m – photic zone depth but are most comparable to 0 m – 10 m tows conducted in 2008 and 2009.

Table 10 Mean Daphnia sp. biomass ( $\mu\text{g/L}$ ) from RK-2, RK-31, RK-56, and RK-72 during May to November. Note standard deviation in parentheses.

Tow Depth (m)	2005	2006	2007	2008	2009
0 - 10	17.5 (24.7)	11.3 (13.2)		39.2 (42.4)	32.1 (29.5)
0 - 30			14.4 (10.0)		
10 - 30				2.7 (5.4)	

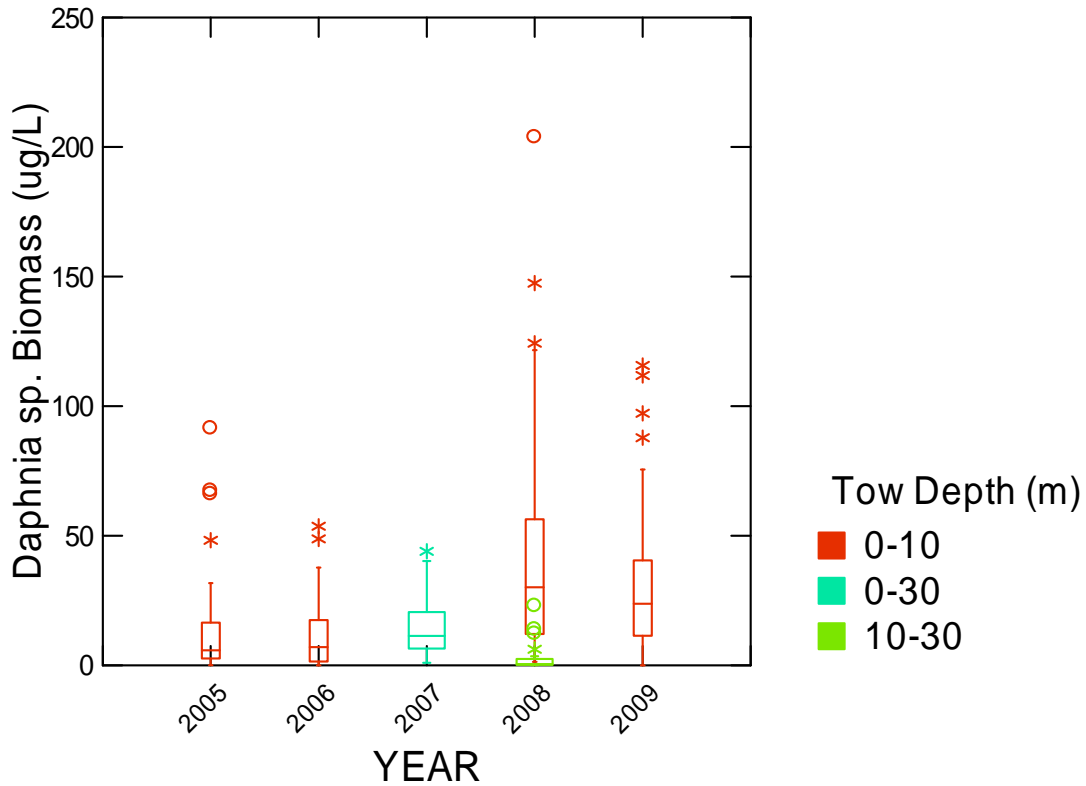


Figure 31 Daphnia sp. biomass from RK-2, RK-31, RK-56, and RK-72 during May to November. Tow length in 2005 and 2006 were actually from 0 m – photic zone depth but are most comparable to 0 m – 10 m tows conducted in 2008 and 2009.

## SECTION 5.0 DISCUSSION

Climatic conditions and precipitation accumulation in the Dworshak Reservoir watershed in 2009 were more typical of long term averages compared to 2008 (TG-Eco-Logic 2009). Spring runoff in 2009 reflected the moderate levels of precipitation accumulation. Inflows to Dworshak Reservoir set the stage for the onset and duration of thermal stratification. The greater water column stability in 2009 compared to 2008 allowed hypolimnetic dissolved oxygen concentrations to deplete to levels more comparable to 2006 and 2007 (Stockner and Brandt 2006; TG Eco-Logic 2008). The water year in 2006 was quite similar to 2009; in 2007 reservoir inflows were generally similar but peak flows were lower. As a result of the earlier onset of water column stability in these years, the hypolimnion was isolated longer from surface aeration. Microbial metabolism of organic material within the hypolimnion consumed dissolved oxygen for a greater period of time, resulting in the lower dissolved oxygen concentrations observed during these moderate to low water years.

Water transparency also appears to be closely related to water year in Dworshak Reservoir. During peak runoff in early summer water transparency decreases with increased amounts of light attenuating particles suspended in the water column (TG Eco-Logic 2009). However, during the summer and fall biologic productivity likely influences water transparency, as evidenced by Secchi disk depths in moderate to lower water years such as 2006, 2007, and 2009. If turbidity from spring runoff was the dominant mechanism controlling transparency in Dworshak Reservoir it might be expected that turbidity would be highest in high water years such as 2008. However, this does not appear to be the case since Secchi disk depths in 2008 were quite similar to depths in 2006, 2007, and 2009. The higher densities of picoplankton and phytoplankton in Dworshak Reservoir during the growing season, especially in 2009, would generally be expected to reduce water transparency by some degree.

Interestingly, Dworshak Reservoir planktonic chlorophyll *a* levels in 2009 did not appear any higher than in past years. With higher densities of photosynthesizing planktonic organisms, chlorophyll *a* could also be expected to increase. However, pigments should be used with some caution as direct measures of phytoplankton biomass (Wetzel 2001). The relationship between chlorophyll and algal biomass has been found to be highly

variable and can fluctuate depending on species composition, timing of year, temperature, and light availability (Kalchev et al. 1996; Felip and Catalan 2000). Phytoplankton species composition has shifted quite dramatically over recent years and could in part explain the relatively unchanged planktonic chlorophyll *a* levels. The phytoplankton community appears to have changed from an inedible diatom dominated community in 2006 and 2007 to a nanoflagellate, coccoid green (*S. minutissimus*), and blue-green dominated community in 2008 and 2009. Nanoflagellates, *S. minutissimus*, and *Synechococcus sp.* typically provide good food quality to grazing zooplankton.

The blue-greens included *Microcystis sp.*, which is of low food quality to grazing zooplankton. *Microcystis sp.* has been found to inhibit *Daphnia sp.* feeding (Ghadouani et al. 2004). Depending on whether *Microcystis sp.* densities were reported in cells/mL or NCU/mL, overall relative abundance of *Microcystis sp.* in 2009 was respectively 40.8% or 1.7%. Obviously, the interpretation of *Microcystis sp.* densities and overall relative abundance could change drastically depending on which counting method is used. The use of NCU/mL or colonies/mL for *Microcystis sp.* was favored to make multiple year comparisons since in years prior to 2008 *Microcystis sp.* was enumerated by the colony per mL (NCU/mL) only. However, this has been found to be problematic because colony size appears to vary by year, which makes the data less comparable. *Microcystis sp.* colony size was smaller in 2008 at 26 cells/colony compared to 41 cells/colony in 2009. In 2008 *Microcystis sp.* did not appear until July, whereas in 2009 *Microcystis sp.* appeared much earlier, in April, likely a result of the different water years. In 2008 the late and high spring runoff likely did not allow the water column to stabilize and become favorable to *Microcystis sp.* establishment until later in the season compared to 2009. Additionally, in 2008 the *Microcystis sp.* colonies likely had less time to mature and grow in size compared to 2009, resulting in fewer cells per colony in 2008.

Counting *Microcystis sp.* in cells/mL is more time consuming than counting in NCU/mL but it should provide a better measure of density. Counting *Microcystis sp.* and other colonial blue-greens this way will likely change the overall relative abundance numbers considerably, given the example of *Microcystis sp.* going from 1.7% to 40.8% of the relative abundance in 2009 using the different methods. Colony disaggregation techniques could facilitate the enumeration of cells per unit volume for colonial blue-

greens such as *Microcystis sp.* and give a better indication of density trends in the future (Bernard et al. 2004). Since phytoplankton can vary drastically in size, large densities may or may not be significant; this is why biovolumes often get reported. Biovolumes were not provided in the current report because of the previously discussed changes across years in how densities for colonial phytoplankton have been calculated and the associated issue of how biovolumes are assigned depending on if a phytoplankter was enumerated by the cell or colony.

Obtaining accurate densities and biovolumes of colonial blue-greens like *Microcystis sp.* is important in assessing how they might affect the overall edibility of phytoplankton. Additionally, *Microcystis sp.* sometimes produces microcystins that can cause liver and neurological toxicity in mammals. The production of microcystins and other cyanotoxins in blue-green algae such as *Microcystis sp.* is not well understood (Graham et al. 2008). If *Microcystis sp.* densities observed in 2009, reaching as high as 38,782 cells/mL did have microcystins present at 0.2 pg/cell, these densities could be considered to pose a potential moderate health risk during recreational contact with lake or river water (Graham et al. 2009, Table 11). These World Health Organization guidelines assume the presence of microcystin in *Microcystis sp.*; however, it is unknown if *Microcystis sp.* from Dworshak Reservoir contained microcystin. Test strip kits used to qualitatively test for microcystin did not indicate detectable levels of microcystin at sites tested on Dworshak Reservoir in 2009 (Paul Pence 2009, pers. comm.).

Table 11 Relative probability of acute health effects from blue-green algae exposure during recreational contact in lakes, reservoirs, or rivers developed by the World Health Organization.

Relative Probability of Acute Health Effects	Blue-Green Algae <sup>1</sup> (cells/mL)
Low	< 20,000
Moderate	20,000 - 100,000
High	100,000 - 10,000,000
Very High	> 10,000,000

<sup>1</sup> The WHO guidelines were developed for *Microcystis sp.* dominated samples with an assumed toxin content of 0.2 pg of microcystin per *Microcystis sp.* cell or 0.4 µg of microcystin per µg of chlorophyll *a* with a minimum criteria of at least blue-green algae dominance (Graham et al. 2009).

The pico-cyanobacteria and heterotrophic bacteria did not show as dramatic an increase in densities as did phytoplankton in 2009. Pico-cyanobacteria and heterotrophic bacteria likely experienced considerable top-down effects by the grazing of nanoflagellates, ciliates, and some larger zooplankton. Nanoflagellates readily and efficiently graze upon the bacterioplankton and can limit their numbers to some degree (Jurgens and DeMott 1995; Wetzel 2001). The nanoflagellates then in turn provide zooplankton, especially *Daphnia sp.*, with good food quality that supports growth and reproduction (Sanders and Porter 1990; Sanders et al. 1996). The coccoid green alga *S. minutissimus* that first appeared in Dworshak Reservoir during the 2009 field season is small, similar in size to *Synechococcus sp.*, and is edible to *Daphnia sp.* (Brendelberger 1991). The increased numbers of flagellates and edible coccoid green algae in Dworshak Reservoir in 2009 would be expected to translate into increased zooplankton biomass via trophic cascade.

Dworshak Reservoir *Daphnia sp.* densities, lengths, and biomasses appeared to increase in 2009 compared to 2005 or 2006, both pre-nutrient application years. *Daphnia sp.* are often an important prey item to zooplanktivorous fish such as kokanee because of their size, digestibility, and ability to be “packed” into the stomach relative to copepods (Clarke and Bennett 2004). Dworshak Reservoir *Daphnia sp.* continued to have an annual mean length greater than 1.0 mm in 2009. Cladocerans including *Daphnia sp.* greater than 1.0 mm in length are considered to be an indicator of a good forage base for zooplanktivorous fish such as kokanee (Mills and Schiavone 1983). *Daphnia sp.* lengths less than 1.0 mm can indicate considerable top down grazing by zooplanktivorous fish (Brooks and Dodson 1965; Tabor et al. 1996). Watching *Daphnia sp.* lengths in conjunction with kokanee abundances will be an important indication as to whether the nutrient addition efforts are translating into more forage for zooplanktivorous fish.

Given the complexity of the inner workings of a reservoir such as Dworshak and that we are only in the third year of data collection, definitive conclusions on the effects of nutrient application have not been reached. Yet, some preliminary results of the monitoring efforts may be showing the desired effects of nutrient application. Notably, increases in the densities of edible phytoplankton such as nanoflagellates and *Stichococcus minutissimus*, a coccoid green, were observed in 2009. *Daphnia sp.*, a prime food item for zooplanktivorous fish such as kokanee, may have responded to the

increased food resources with the increased densities and mean body length observed in 2009. Concurrent water quality measures such as water clarity and planktonic chlorophyll *a* have not negatively deviated from established benchmarks in 2009. Additionally, dissolved oxygen concentrations in 2009 appeared similar to concentrations in 2006, a pre-nutrient application year. The most notable exception to the apparent positive responses to nutrient application was the observation of moderately high *Microcystis sp.* densities in 2009. *Microcystis sp.* densities from 2009 were at least higher than densities observed in 2008. Differences in counting techniques beginning in 2008 do not allow easy comparisons to past years so it is difficult to assess if these *Microcystis sp.* densities are something new or have always occurred. Obviously *Microcystis sp.* is of concern because of its potential ability to produce microcystins, a group of cyanotoxins which can pose a health risk. Additionally, *Microcystis sp.* is a poor food source for zooplankton and can affect aesthetics of a water body. Efforts should be made to understand if the *Microcystis sp.* densities we have observed in 2009 are different from past years, especially the pre-nutrient application years.

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## **Appendix A**

### 2009 Application Tables

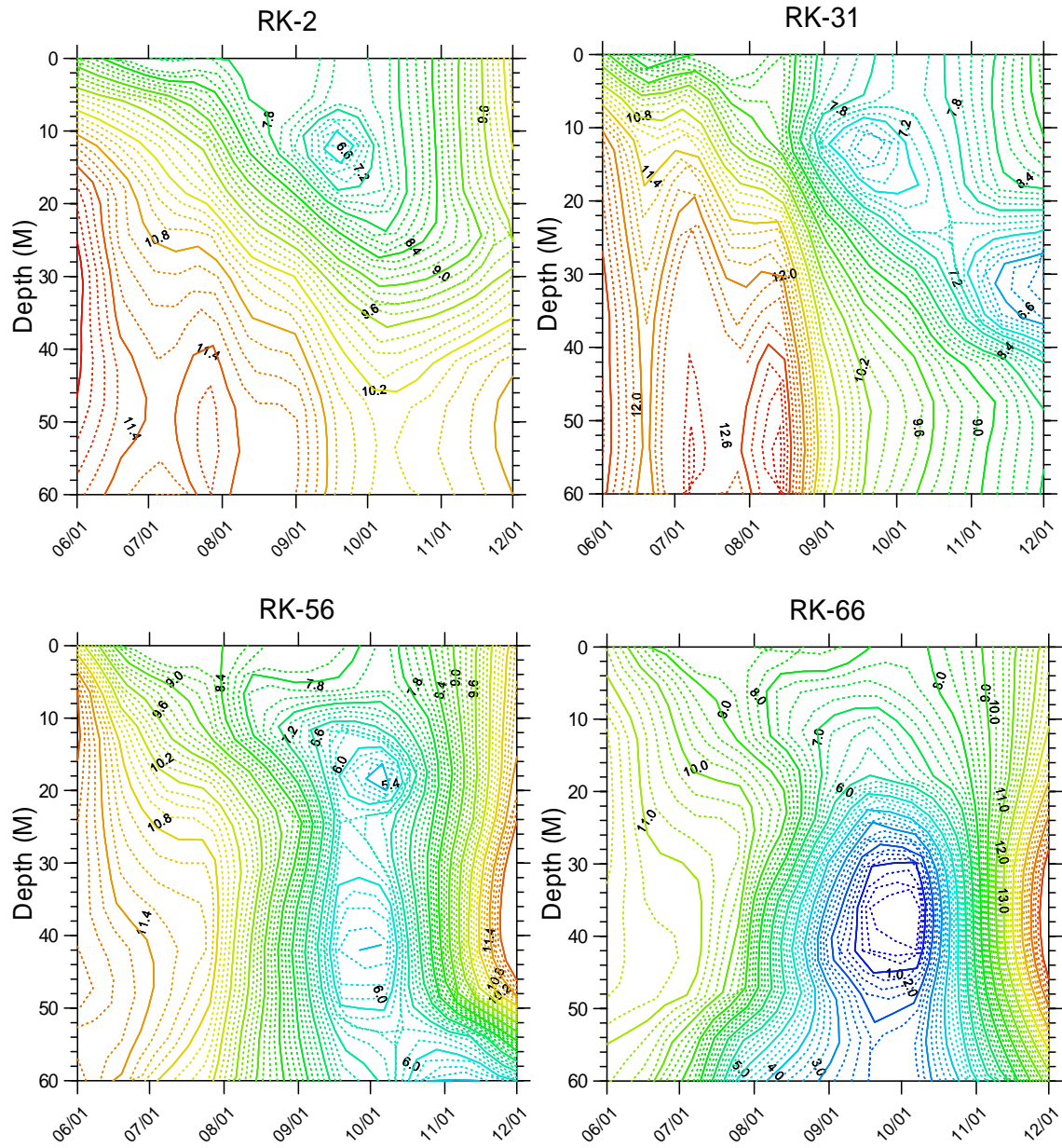
Scheduled Ammonium Nitrate Spread Rates										
Date	Section	Section Miles	Section Feet	Miles per Hour	Feet per Minute	Trip Time	Gallons to Spread	Gallons per Foot	Gallons per Minute	Check
7-May	1	9.5	50160	6	528	95	462	0.00921053	4.86	462
7-May	2	22.6	119328	6	528	226	317	0.00265487	1.40	316.8
7-May	3	9.2	48576	6	528	92	119	0.00244565	1.29	118.8
14-May	1	9.5	50160	6	528	95	475	0.00947368	5.00	475
14-May	2	22.6	119328	6	528	226	338	0.00283186	1.50	338
14-May	3	9.2	48576	6	528	92	128	0.00263587	1.39	128
21-May	1	9.5	50160	6	528	95	488	0.00973684	5.14	488
21-May	2	22.6	119328	6	528	226	354	0.0029646	1.57	354
21-May	3	9.2	48576	6	528	92	139	0.00285326	1.51	139
28-May	1	9.5	50160	6	528	95	528	0.01052632	5.56	528
28-May	2	22.6	119328	6	528	226	367	0.00307522	1.62	367
28-May	3	9.2	48576	6	528	92	152	0.003125	1.65	152
4-Jun	1	9.5	50160	6	528	95	544	0.0108453	5.73	544
4-Jun	2	22.6	119328	6	528	226	382	0.00320126	1.69	382
4-Jun	3	9.2	48576	6	528	92	172	0.00354084	1.87	172
11-Jun	1	9.5	50160	6	528	95	683	0.01361842	7.19	683
11-Jun	2	22.6	119328	6	528	226	467	0.00391274	2.07	467
11-Jun	3	9.2	48576	6	528	92	230	0.00473485	2.50	230
18-Jun	1	9.5	50160	6	528	95	683	0.01361842	7.19	683
18-Jun	2	22.6	119328	6	528	226	485	0.00406694	2.15	485
18-Jun	3	9.2	48576	6	528	92	232	0.0047822	2.53	232
25-Jun	1	9.5	50160	6	528	95	702	0.01398525	7.38	702
25-Jun	2	22.6	119328	6	528	226	504	0.00422114	2.23	504
25-Jun	3	9.2	48576	6	528	92	242	0.00497159	2.63	242
2-Jul	1	9.5	50160	6	528	95	773	0.0154067	8.13	773
2-Jul	2	22.6	119328	6	528	226	522	0.00437534	2.31	522
2-Jul	3	9.2	48576	6	528	92	251	0.00516098	2.73	251
9-Jul	1	9.5	50160	6	528	95	773	0.0154067	8.13	773
9-Jul	2	22.6	119328	6	528	226	538	0.00451026	2.38	538
9-Jul	3	9.2	48576	6	528	92	260	0.00535038	2.83	260
16-Jul	1	9.5	50160	6	528	95	736	0.01467305	7.75	736
16-Jul	2	22.6	119328	6	528	226	522	0.00437534	2.31	522
16-Jul	3	9.2	48576	6	528	92	237	0.00487689	2.58	237
23-Jul	1	9.5	50160	6	528	95	1113	0.02219298	11.72	1113
23-Jul	2	22.6	119328	6	528	226	784	0.00657264	3.47	784
23-Jul	3	9.2	48576	6	528	92	352	0.00724432	3.83	352

Scheduled Ammonium Nitrate Spread Rates (continued)										
Date	Section	Section Miles	Section Feet	Miles per Hour	Feet per Minute	Trip Time	Gallons to Spread	Gallons per Foot	Gallons per Minute	Check
30-Jul	1	9.5	50160	6	528	95	1113	0.02219298	11.72	1113
30-Jul	2	22.6	119328	6	528	226	784	0.00657264	3.47	784
30-Jul	3	9.2	48576	6	528	92	352	0.00724432	3.83	352
6-Aug	1	9.5	50160	6	528	95	1113	0.02219298	11.72	1113
6-Aug	2	22.6	119328	6	528	226	784	0.00657264	3.47	784
6-Aug	3	9.2	48576	6	528	92	352	0.00724432	3.83	352
13-Aug	1	9.5	50160	6	528	95	1329	0.02650319	13.99	1329
13-Aug	2	22.6	119328	6	528	226	934	0.00782549	4.13	934
13-Aug	3	9.2	48576	6	528	92	345	0.00710227	3.75	345
20-Aug	1	9.5	50160	6	528	95	1329	0.02650319	13.99	1329
20-Aug	2	22.6	119328	6	528	226	934	0.00782549	4.13	934
20-Aug	3	9.2	48576	6	528	92	345	0.00710227	3.75	345
27-Aug	1	9.5	50160	6	528	95	1329	0.02650319	13.99	1329
27-Aug	2	22.6	119328	6	528	226	934	0.00782549	4.13	934
27-Aug	3	9.2	48576	6	528	92	345	0.00710227	3.75	345
3-Sep	1	9.5	50160	6	528	95	1329	0.02650319	13.99	1329
3-Sep	2	22.6	119328	6	528	226	934	0.00782549	4.13	934
3-Sep	3	9.2	48576	6	528	92	345	0.00710227	3.75	345
10-Sep	1	9.5	50160	6	528	95	1233	0.02457735	12.98	1233
10-Sep	2	22.6	119328	6	528	226	863	0.00722798	3.82	863
10-Sep	3	9.2	48576	6	528	92	274	0.00563447	2.98	274
17-Sep	1	9.5	50160	6	528	95	1233	0.02457735	12.98	1233
17-Sep	2	22.6	119328	6	528	226	863	0.00722798	3.82	863
17-Sep	3	9.2	48576	6	528	92	274	0.00563447	2.98	274
24-Sep	1	9.5	50160	6	528	95	1233	0.02457735	12.98	1233
24-Sep	2	22.6	119328	6	528	226	863	0.00722798	3.82	863
24-Sep	3	9.2	48576	6	528	92	274	0.00563447	2.98	274
1-Oct	4	13.467	71104	6	528	135	1233	0.01733798	9.15	1233
1-Oct	5	13.317	70312	6	528	133	863	0.01226675	6.48	863
1-Oct	6	13.167	69520	6	528	132	274	0.003937	2.08	274
8-Oct	7	13.017	68728	6	528	130	1233	0.01793738	9.47	1233
8-Oct	8	12.867	67936	6	528	129	863	0.01269577	6.70	863
8-Oct	9	12.717	67144	6	528	127	274	0.00407631	2.15	274

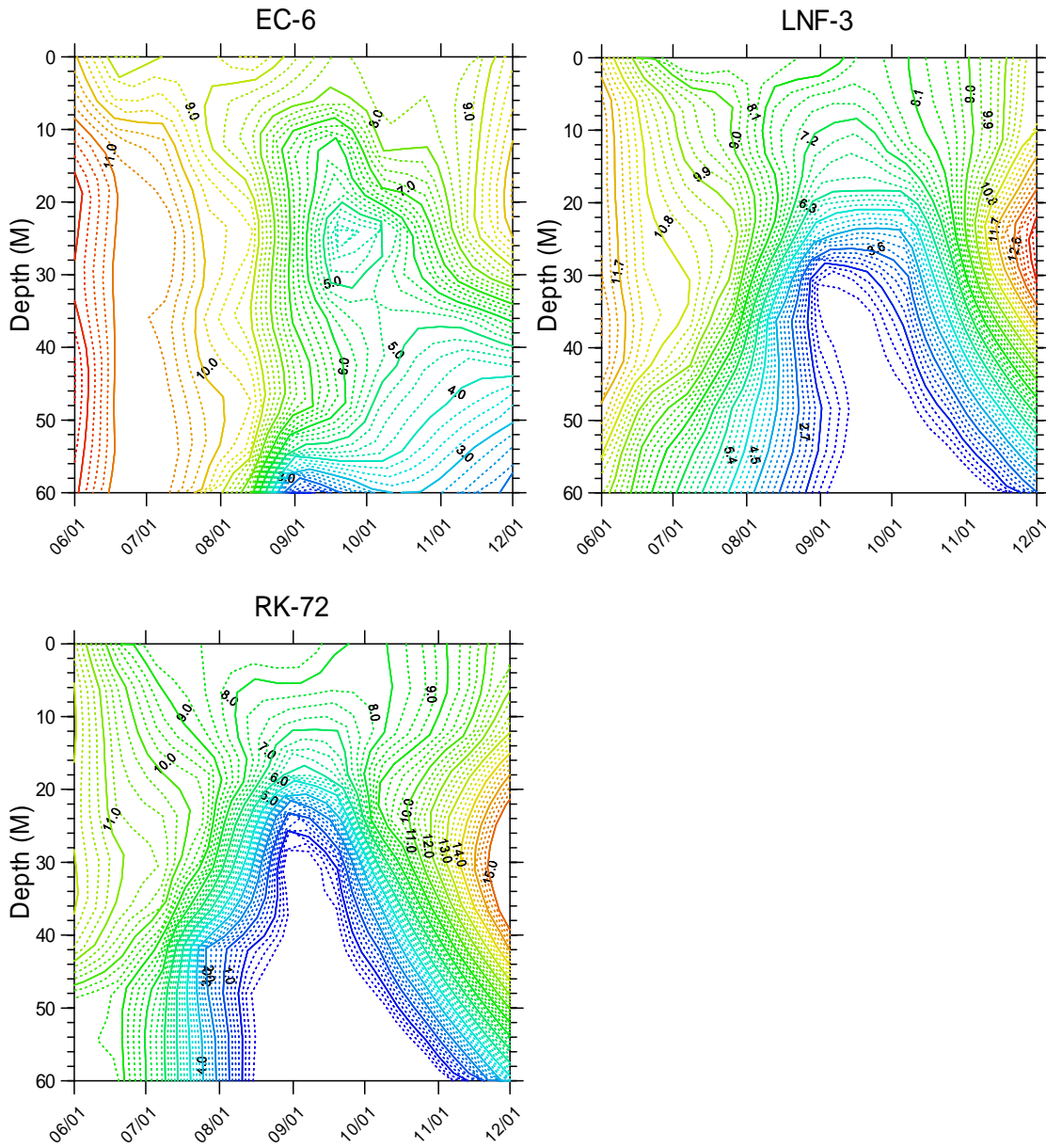
## **Appendix B**

Supplemental Figures of Limnological Data

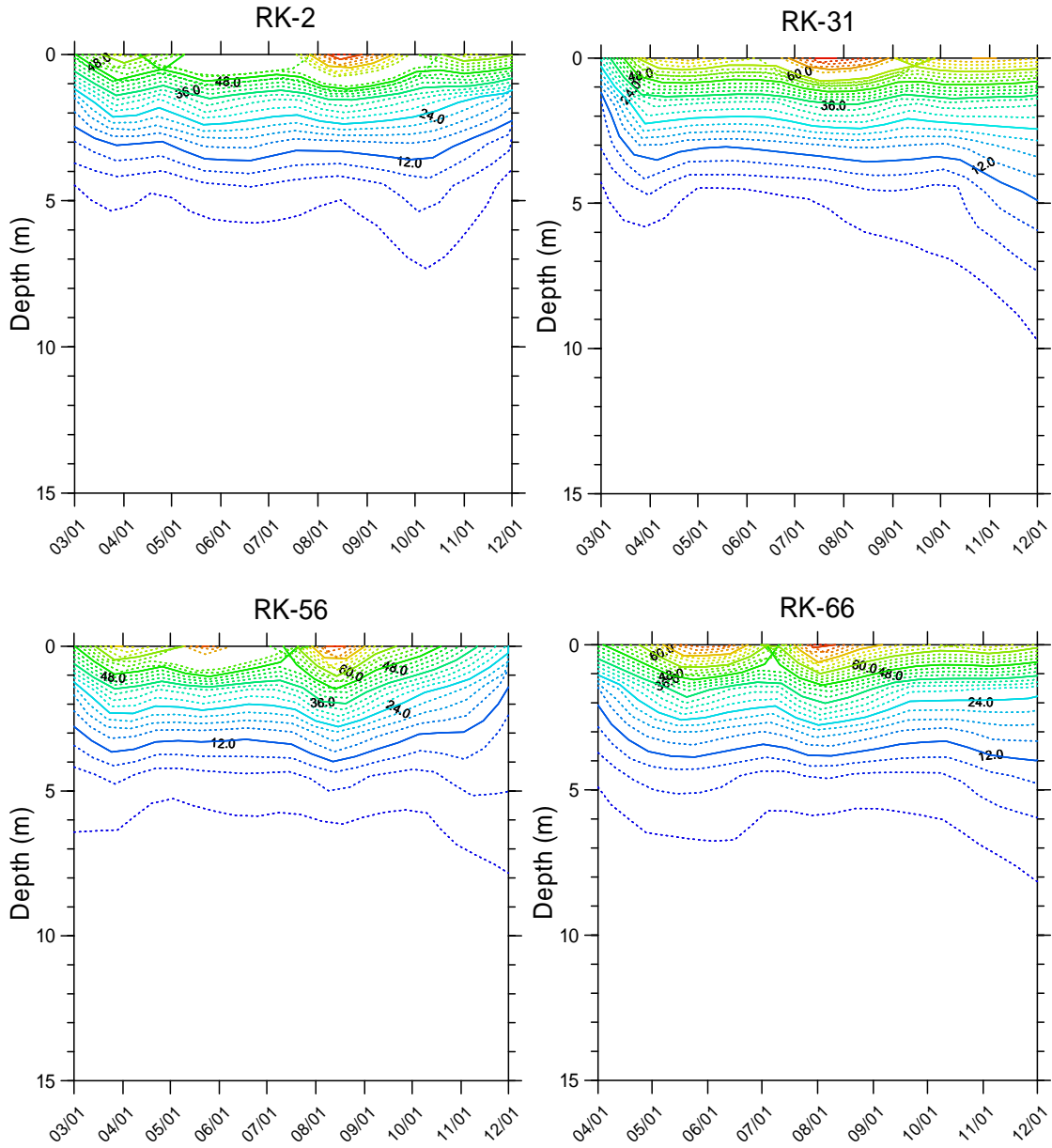
Dissolved oxygen (mg/L) isopleths from Dworshak Reservoir 2009. The x-axis indicates date in the MM:DD format.



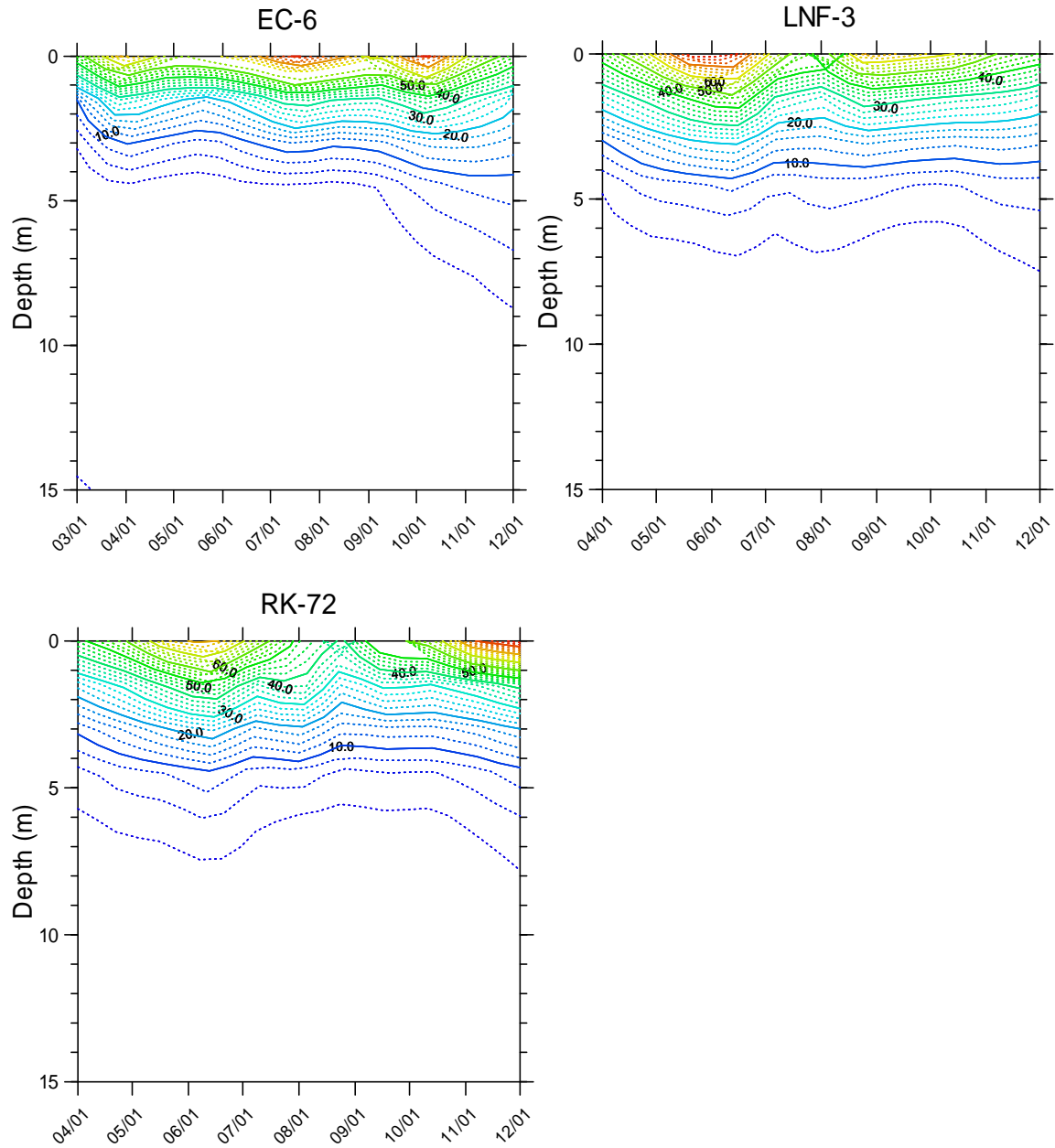
Dissolved oxygen (mg/L) isopleths from Dworshak Reservoir 2009 (continued). The x-axis indicates date in the MM:DD format.



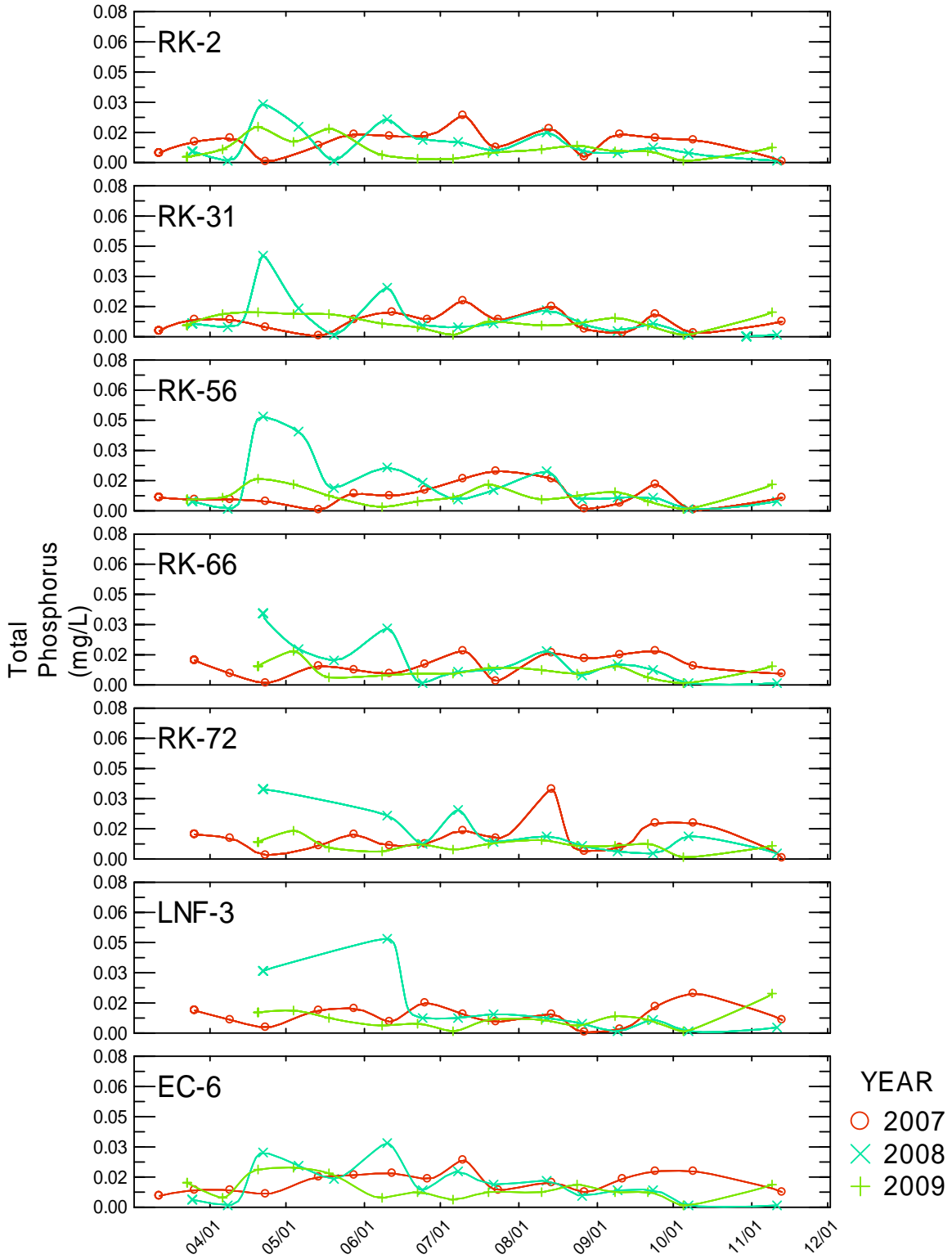
Isopleths for percent light transmission from surface at Dworshak Reservoir in 2009. The x-axis indicates date in the MM:DD format.



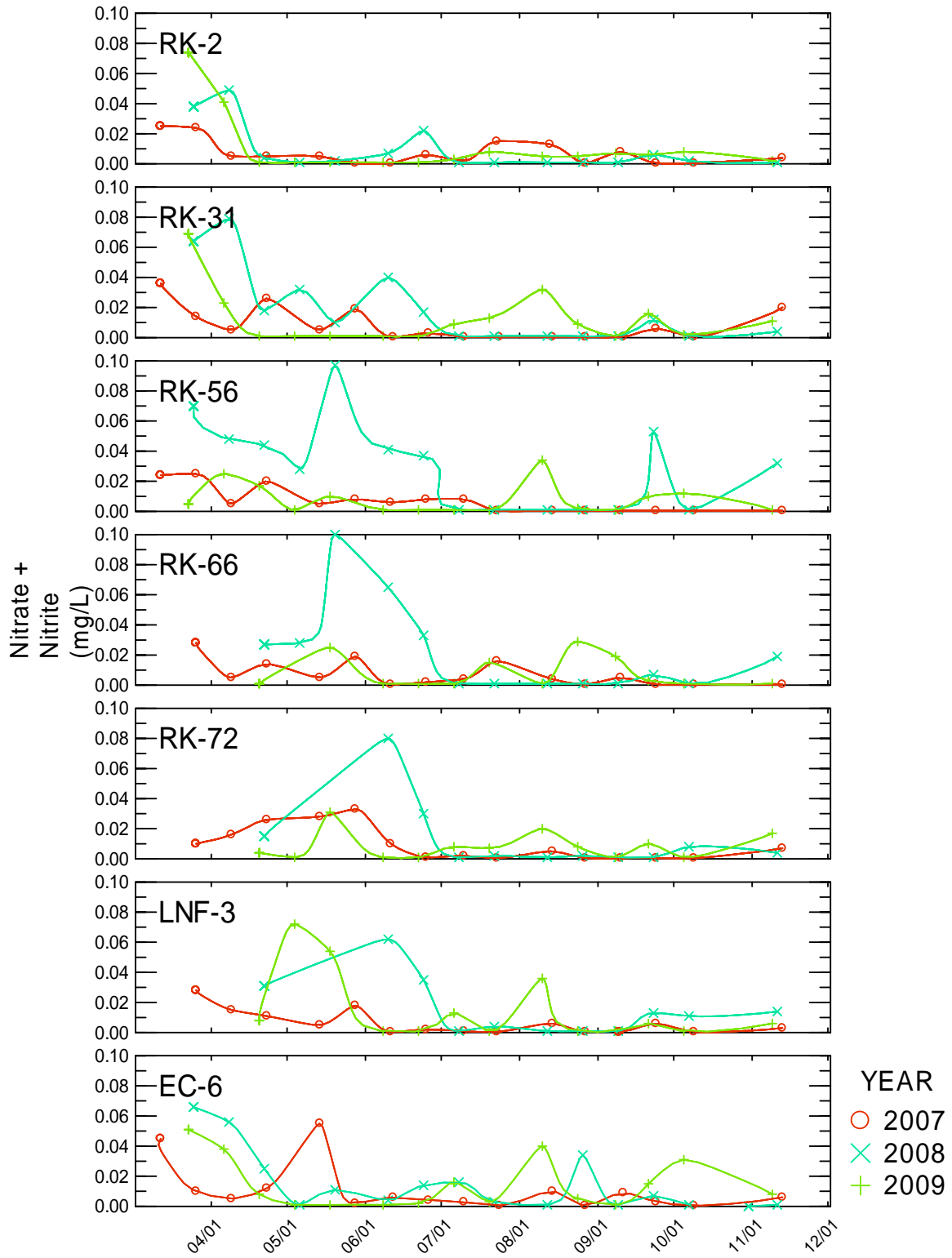
Isopleths for percent light transmission from surface at Dworshak Reservoir in 2009 (continued). The x-axis indicates date in the MM:DD format.



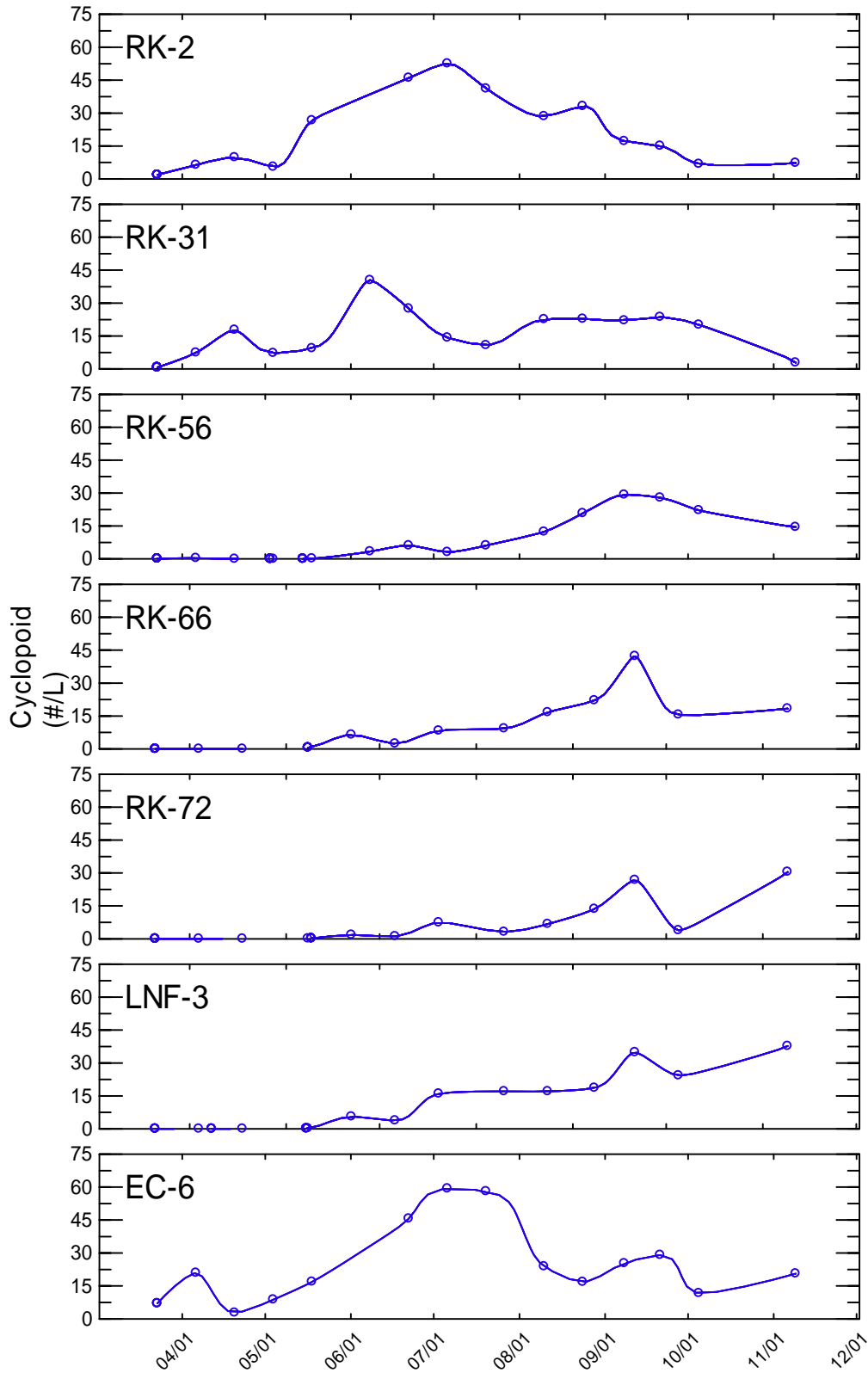
Total phosphorus concentrations by station and year. The x-axis indicates date in the MM:DD format.



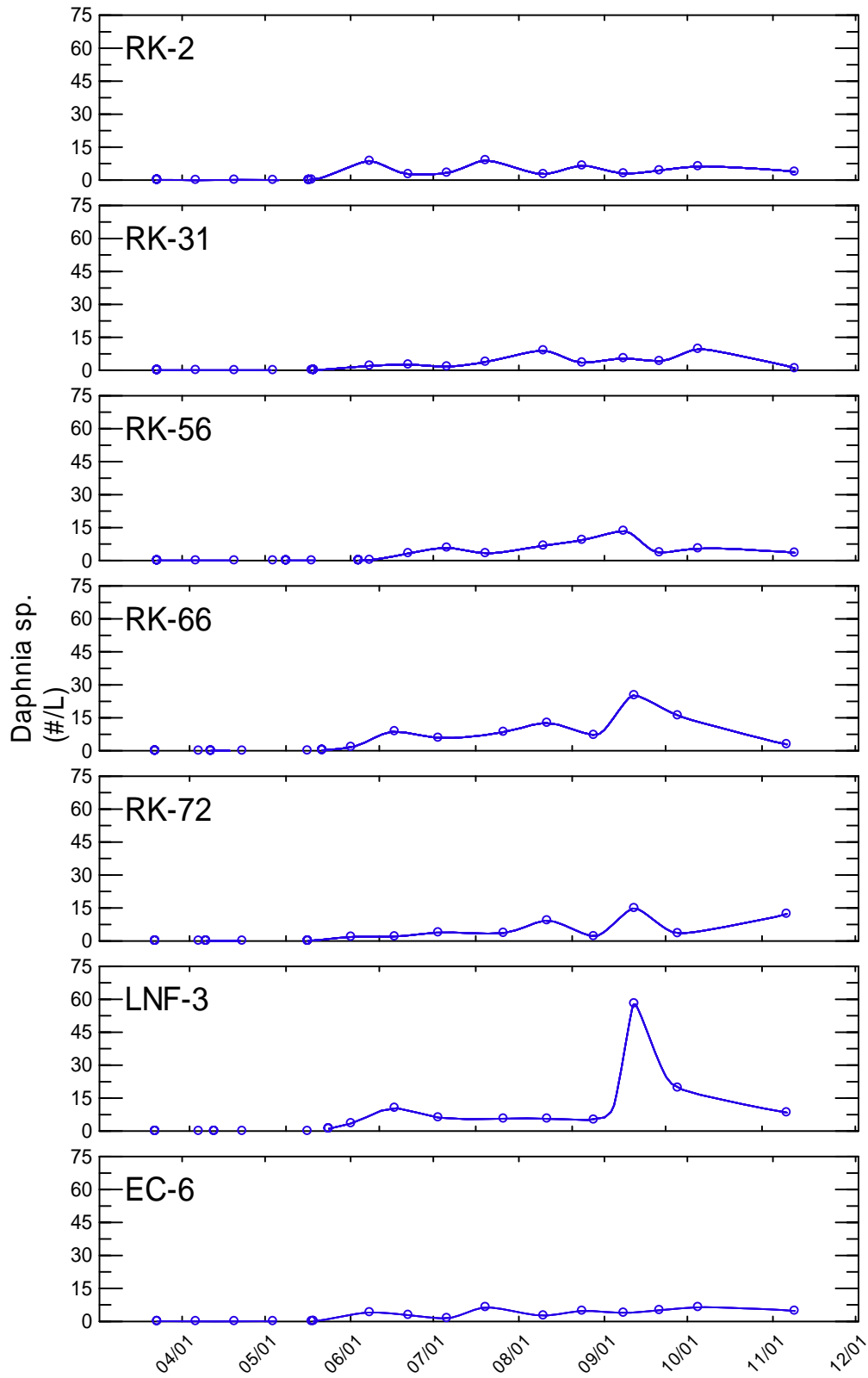
Nitrate + nitrite concentrations by station and year. The x-axis indicates date in the MM:DD format.



Cyclopoid density by station and year. The x-axis indicates date in the MM:DD format.



*Daphnia* sp. density by station and year. The x-axis indicates date in the MM:DD format.



## **Appendix C**

### Summary Tables of Limnological Data

Water temperature, dissolved oxygen, and Secchi disk summary statistics by station in 2009.

		Water Temperature (C°)	Dissolved Oxygen (mg/L)	Secchi Disk (m)
EC-6	N of Cases	438	438	15
	Minimum	3.0	0.5	1.4
	Maximum	25.3	12.1	5.8
	Median	7.5	8.5	2.4
	Arithmetic Mean	9.0	8.6	2.7
	Standard Dev	5.2	2.3	1.2
RK-2	N of Cases	480	480	15
	Minimum	3.8	3.6	2.1
	Maximum	24.1	12.1	8.5
	Median	7.0	9.8	3.4
	Arithmetic Mean	8.8	9.2	3.7
	Standard Dev	5.3	2.2	1.6
RK-31	N of Cases	480	480	15
	Minimum	3.4	2.5	2.0
	Maximum	25.7	13.7	7.3
	Median	6.8	9.8	3.0
	Arithmetic Mean	8.5	9.5	3.5
	Standard Dev	5.2	2.5	1.4
RK56	N of Cases	480	480	15
	Minimum	2.0	1.9	1.8
	Maximum	23.5	12.6	6.4
	Median	6.9	9.0	3.0
	Arithmetic Mean	8.5	8.6	3.3
	Standard Dev	5.0	2.5	1.1
LNF-3	N of Cases	234	234	13
	Minimum	4.5	1.2	2.4
	Maximum	23.5	12.7	5.8
	Median	9.9	9.3	2.9
	Arithmetic Mean	11.4	9.0	3.3
	Standard Dev	5.1	2.5	1.1
RK-66	N of Cases	313	313	13
	Minimum	4.6	0.1	2.1
	Maximum	24.9	12.4	6.4
	Median	9.0	9.3	2.7
	Arithmetic Mean	10.6	8.8	3.5
	Standard Dev	4.8	2.7	1.5
RK-72	N of Cases	236	236	12
	Minimum	5.3	0.1	2.4
	Maximum	24.7	12.1	6.1
	Median	9.7	9.2	3.1
	Arithmetic Mean	11.6	9.0	3.6
	Standard Dev	5.1	2.1	1.3

Water temperature, dissolved oxygen, and Secchi disk summary statistics by sampling event.

Sampling Event		Water Temperature (C°)	Dissolved Oxygen (mg/L)	Secchi Disk (m)
3/22/2009	N of Cases	128	128	4
	Minimum	2.0	3.8	2.4
	Maximum	4.9	12.6	4.6
	Median	3.4	7.5	4.3
	Arithmetic Mean	3.5	7.3	3.9
	Standard Deviation	0.7	1.7	1.0
4/5/2009	N of Cases	126	126	4
	Minimum	3.2	3.9	3.0
	Maximum	7.8	12.5	3.8
	Median	3.8	7.3	3.4
	Arithmetic Mean	4.1	7.2	3.4
	Standard Deviation	0.8	2.2	0.4
4/19/2009	N of Cases	169	169	7
	Minimum	3.8	3.3	1.8
	Maximum	9.6	11.8	5.5
	Median	4.9	8.1	3.0
	Arithmetic Mean	5.4	7.7	3.7
	Standard Deviation	1.5	2.1	1.5
5/3/2009	N of Cases	171	171	7
	Minimum	3.8	1.9	2.1
	Maximum	12.0	11.6	6.1
	Median	5.7	7.6	3.4
	Arithmetic Mean	6.1	6.9	3.9
	Standard Deviation	1.8	2.3	1.6
5/17/2009	N of Cases	211	211	7
	Minimum	4.0	1.2	1.4
	Maximum	17.5	12.7	3.4
	Median	6.4	11.5	2.4
	Arithmetic Mean	7.1	10.8	2.4
	Standard Deviation	2.4	2.5	0.7

Water temperature, dissolved oxygen, and Secchi disk summary statistics by sampling event for epilimnion (continued 2).

Sampling Event		Water Temperature (C°)	Dissolved Oxygen (mg/L)	Secchi Disk (m)
6/7/2009	N of Cases	214	214	7
	Minimum	4.3	8.7	2.4
	Maximum	19.7	12.7	3.2
	Median	8.2	11.6	2.9
	Arithmetic Mean	8.9	11.4	2.8
	Standard Deviation	3.4	0.8	0.3
6/21/2009	N of Cases	208	208	7
	Minimum	4.5	8.1	2.6
	Maximum	20.5	11.6	3.4
	Median	8.6	10.7	2.7
	Arithmetic Mean	9.5	10.5	2.9
	Standard Deviation	4.0	0.8	0.3
7/5/2009	N of Cases	206	206	7
	Minimum	4.7	7.3	1.8
	Maximum	23.5	13.5	3.4
	Median	8.4	10.8	2.1
	Arithmetic Mean	10.1	10.6	2.4
	Standard Deviation	5.2	1.3	0.6
7/19/2009	N of Cases	202	202	7
	Minimum	4.6	4.7	1.6
	Maximum	25.7	12.1	2.9
	Median	8.6	10.4	2.6
	Arithmetic Mean	11.0	10.3	2.4
	Standard Deviation	5.9	1.2	0.5
8/9/2009	N of Cases	189	189	7
	Minimum	4.9	5.0	1.9
	Maximum	24.9	13.7	3.0
	Median	9.7	9.5	2.4
	Arithmetic Mean	12.2	9.4	2.5
	Standard Deviation	6.1	1.9	0.4

Water temperature, dissolved oxygen, and Secchi disk summary statistics by sampling event for epilimnion (continued 3).

Sampling Event		Water Temperature (C°)	Dissolved Oxygen (mg/L)	Secchi Disk (m)
8/23/2009	N of Cases	179	179	7
	Minimum	4.6	0.1	2.0
	Maximum	23.7	12.1	3.0
	Median	10.8	8.8	2.4
	Arithmetic Mean	12.9	8.7	2.5
	Standard Deviation	6.0	2.2	0.3
9/7/2009	N of Cases	166	166	6
	Minimum	4.4	0.1	2.4
	Maximum	21.8	10.7	4.3
	Median	12.4	7.5	3.0
	Arithmetic Mean	13.2	7.4	3.2
	Standard Deviation	5.7	2.1	0.6
9/20/2009	N of Cases	164	164	7
	Minimum	3.9	0.3	3.4
	Maximum	20.3	10.6	4.9
	Median	13.9	7.5	3.8
	Arithmetic Mean	13.2	7.2	3.9
	Standard Deviation	5.7	2.2	0.5
10/4/2009	N of Cases	165	165	7
	Minimum	4.4	0.1	3.2
	Maximum	17.2	10.4	5.0
	Median	12.4	7.5	3.7
	Arithmetic Mean	11.9	7.3	4.0
	Standard Deviation	4.3	2.0	0.8
11/8/2009	N of Cases	163	163	7
	Minimum	4.4	4.1	5.5
	Maximum	12.0	11.5	8.5
	Median	10.5	9.1	6.4
	Arithmetic Mean	9.5	8.8	6.5
	Standard Deviation	2.4	1.3	1.1

Water chemistry and picoplankton summary statistics by station and depth in 2009.

<b>Epilimnion</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>	<b>Total Dissolved Solids (mg/L)</b>	<b>Chlorophyll <i>a</i> (µg/L)</b>	<b>Heterotrophic Bacteria (cells/mL)</b>	<b>Pico-cyano Bacteria (cells/mL)</b>
EC-6	N of Cases	15	15	15	9	15	15	15
	Minimum	0.001	0.001	0.001	17.0	0.35	225,091	265
	Maximum	0.021	0.012	0.051	26.0	5.14	2,576,464	490,028
	Median	0.008	0.006	0.008	20.0	2.13	1,312,394	88,171
	Arithmetic Mean	0.010	0.006	0.015	20.3	2.26	1,258,121	113,009
	Standard Dev	0.006	0.003	0.017	3.4	1.30	679,127	137,356
RK-2	N of Cases	15	15	15	9	15	15	15
	Minimum	0.001	0.001	0.001	19.0	0.86	180,581	8,319
	Maximum	0.019	0.007	0.074	21.0	5.15	1,869,399	349,294
	Median	0.006	0.003	0.005	20.0	2.14	1,292,047	165,745
	Arithmetic Mean	0.007	0.003	0.011	19.9	2.29	1,282,114	151,710
	Standard Dev	0.005	0.002	0.020	0.8	1.07	428,216	117,275
RK-31	N of Cases	15	15	15	9	15	15	15
	Minimum	0.001	0.001	0.001	17.0	0.82	446,155	1,802
	Maximum	0.013	0.011	0.069	25.0	5.44	2,027,090	351,837
	Median	0.007	0.004	0.009	21.0	2.71	1,279,330	113,817
	Arithmetic Mean	0.008	0.004	0.013	20.7	2.74	1,271,940	119,965
	Standard Dev	0.004	0.003	0.018	2.6	1.62	402,837	121,638
RK-56	N of Cases	15	15	15	9	15	15	15
	Minimum	0.001	0.001	0.001	16.0	0.20	164,049	1,007
	Maximum	0.017	0.019	0.034	22.0	4.62	1,699,839	300,121
	Median	0.007	0.003	0.002	20.0	1.97	1,154,704	64,221
	Arithmetic Mean	0.008	0.004	0.008	19.6	1.98	1,040,138	86,046
	Standard Dev	0.005	0.005	0.010	2.3	1.27	483,882	93,233
LNF-3	N of Cases	13	13	13	7	13	13	13
	Minimum	0.001	0.001	0.001	14.0	0.35	209,195	530
	Maximum	0.021	0.007	0.072	25.0	5.69	1,856,682	328,099
	Median	0.007	0.004	0.006	21.0	2.04	1,164,877	103,644
	Arithmetic Mean	0.007	0.004	0.015	19.6	2.24	1,041,588	96,238
	Standard Dev	0.005	0.002	0.023	4.0	1.35	532,537	97,303
RK-66	N of Cases	13	13	13	7	13	13	13
	Minimum	0.001	0.001	0.001	16.0	0.27	252,433	371
	Maximum	0.018	0.007	0.170	25.0	3.47	1,767,663	238,232
	Median	0.006	0.003	0.001	22.0	1.38	1,045,337	75,030
	Arithmetic Mean	0.007	0.003	0.021	21.1	1.49	1,008,719	78,543
	Standard Dev	0.004	0.002	0.046	3.2	1.01	468,064	70,336
RK-72	N of Cases	13	13	13	7	13	13	13
	Minimum	0.001	0.001	0.001	16.0	0.36	153,876	795
	Maximum	0.015	0.007	0.031	25.0	4.75	2,301,777	193,298
	Median	0.007	0.003	0.007	24.0	1.43	1,045,337	62,525
	Arithmetic Mean	0.007	0.003	0.008	21.3	1.75	1,018,387	65,586
	Standard Dev	0.003	0.002	0.009	4.1	1.37	633,354	62,710

Water chemistry and picoplankton summary statistics by station and depth in 2009  
(continued 2).

<b>Hypolimnion</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>
EC-6	N of Cases	9	9	9
	Minimum	0.002	0.001	0.001
	Maximum	0.014	0.010	0.087
	Median	0.011	0.005	0.027
	Arithmetic Mean	0.009	0.005	0.038
	Standard Dev	0.005	0.004	0.035
RK-2	N of Cases	9	9	9
	Minimum	0.001	0.001	0.001
	Maximum	0.018	0.007	0.075
	Median	0.004	0.003	0.004
	Arithmetic Mean	0.006	0.004	0.020
	Standard Dev	0.005	0.002	0.031
RK-31	N of Cases	9	9	9
	Minimum	0.001	0.001	0.001
	Maximum	0.017	0.006	0.059
	Median	0.005	0.004	0.015
	Arithmetic Mean	0.006	0.003	0.025
	Standard Dev	0.005	0.002	0.024
RK56	N of Cases	9	9	9
	Minimum	0.001	0.001	0.001
	Maximum	0.012	0.006	0.083
	Median	0.007	0.004	0.038
	Arithmetic Mean	0.007	0.004	0.031
	Standard Dev	0.004	0.002	0.025
LNF-3	N of Cases	7	7	7
	Minimum	0.001	0.001	0.001
	Maximum	0.015	0.008	0.043
	Median	0.013	0.006	0.001
	Arithmetic Mean	0.010	0.005	0.010
	Standard Dev	0.005	0.003	0.015
RK-66	N of Cases	7	7	7
	Minimum	0.003	0.001	0.001
	Maximum	0.015	0.007	0.079
	Median	0.009	0.003	0.020
	Arithmetic Mean	0.009	0.004	0.031
	Standard Dev	0.005	0.002	0.030
RK-72	N of Cases	7	7	7
	Minimum	0.002	0.001	0.001
	Maximum	0.027	0.013	0.056
	Median	0.010	0.005	0.013
	Arithmetic Mean	0.010	0.005	0.020
	Standard Dev	0.009	0.005	0.021

Water chemistry and picoplankton summary statistics by station and depth in 2009 (continued 3).

<b>Below Dworshak Reservoir</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>	<b>Total Dissolved Solids (mg/L)</b>	<b>Chlorophyll <i>a</i> (µg/L)</b>
NFC	N of Cases	14	14	14	9	15
	Minimum	0.001	0.001	0.003	14.0	0.04
	Maximum	0.013	0.008	0.069	25.0	1.44
	Median	0.006	0.003	0.031	18.0	0.39
	Arithmetic Mean	0.007	0.003	0.031	19.4	0.45
	Standard Dev	0.004	0.002	0.023	4.2	0.43

NFC raw water chemistry and picoplankton data by sampling event.

	<b>Sampling Event</b>	<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>	<b>Total Dissolved Solids (mg/L)</b>	<b>Chlorophyll <i>a</i> (µg/L)</b>
NFC	3/23/2009	0.004	0.004	0.069	18.0	1.33
	4/6/2009	0.006	0.002	0.068	18.0	0.52
	4/20/2009	0.011	0.008	0.008		0.39
	5/4/2009	0.012	0.005	0.006	22.0	0.60
	5/18/2009	0.006	0.001	0.009		1.44
	6/8/2009	0.003	0.001	0.006	25.0	0.41
	6/22/2009	0.006	0.003	0.036		0.22
	7/6/2009	0.009	0.001	0.003	22.0	0.45
	7/20/2009					0.08
	8/10/2009	0.013	0.004	0.032	25.0	0.12
	8/24/2009	0.003	0.007	0.054		0.08
	9/8/2009	0.011	0.003	0.041	15.0	0.04
	9/21/2009	0.005	0.002	0.053		0.06
	10/5/2009	0.001	0.001	0.030	14.0	0.32
	11/9/2009	0.013	0.005	0.018	16.0	0.62

Water chemistry and picoplankton summary statistics by sampling event for epilimnion.

<b>Epilimnion</b>								
<b>Sampling Event</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>	<b>Total Dissolved Solids (mg/L)</b>	<b>Chlorophyll <i>a</i> (µg/L)</b>	<b>Heterotrophic Bacteria (cells/mL)</b>	<b>Pico-cyano Bacteria (cells/mL)</b>
3/22/2009	N of Cases	4	4	4	4	4	4	4
	Minimum	0.003	0.003	0.005	19.0	0.23	691,805	3,126
	Maximum	0.013	0.006	0.074	20.0	1.94	1,162,334	8,319
	Median	0.006	0.005	0.060	19.0	0.63	1,016,088	5,007
	Arithmetic Mean	0.007	0.005	0.050	19.3	0.86	971,579	5,365
	Standard Deviation	0.004	0.002	0.031	0.5	0.78	198,852	2,169
4/5/2009	N of Cases	4	4	4	4	4	4	4
	Minimum	0.005	0.005	0.023	17.0	0.20	709,609	1,537
	Maximum	0.012	0.011	0.041	20.0	5.44	1,597,255	9,379
	Median	0.007	0.007	0.032	17.5	2.58	1,014,817	3,391
	Arithmetic Mean	0.008	0.007	0.032	18.0	2.70	1,084,124	4,424
	Standard Deviation	0.003	0.003	0.009	1.4	2.16	376,654	3,444
4/19/2009	N of Cases	7	7	7	0	7	7	7
	Minimum	0.009	0.001	0.001	.	0.36	225,091	265
	Maximum	0.020	0.012	0.017	.	5.42	1,292,047	16,638
	Median	0.013	0.006	0.004	.	0.81	318,561	848
	Arithmetic Mean	0.014	0.005	0.006	.	1.99	531,207	3,558
	Standard Deviation	0.004	0.004	0.006	.	2.26	439,056	5,869
5/3/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.011	0.004	0.001	16.0	0.27	153,876	530
	Maximum	0.021	0.009	0.170	21.0	4.93	1,241,179	20,135
	Median	0.014	0.004	0.001	18.0	1.60	252,433	1,272
	Arithmetic Mean	0.015	0.005	0.035	18.6	1.91	577,897	3,944
	Standard Deviation	0.004	0.002	0.065	1.8	1.74	492,750	7,171
5/17/2009	N of Cases	7	7	7	0	7	7	7
	Minimum	0.004	0.001	0.001	.	0.74	300,757	371
	Maximum	0.018	0.006	0.054	.	4.16	1,439,564	231,279
	Median	0.008	0.002	0.010	.	1.96	750,303	2,067
	Arithmetic Mean	0.011	0.002	0.018	.	2.28	759,114	35,984
	Standard Deviation	0.006	0.002	0.020	.	1.28	368,011	86,189

Water chemistry and picoplankton summary statistics by sampling event for epilimnion  
(continued 2).

<b>Epilimnion</b>								
<b>Sampling Event</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>	<b>Total Dissolved Solids (mg/L)</b>	<b>Chlorophyll <i>a</i> (µg/L)</b>	<b>Heterotrophic Bacteria (cells/mL)</b>	<b>Pico-cyano Bacteria (cells/mL)</b>
6/7/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.002	0.001	0.001	17.0	0.51	281,682	3,073
	Maximum	0.007	0.004	0.001	25.0	0.93	1,241,179	179,946
	Median	0.004	0.001	0.001	22.0	0.82	501,050	64,221
	Arithmetic Mean	0.004	0.002	0.001	22.0	0.75	645,933	71,700
	Standard Deviation	0.002	0.001	0.000	2.8	0.15	346,450	64,869
6/21/2009	N of Cases	7	7	7	0	7	7	7
	Minimum	0.002	0.002	0.001	.	1.00	872,386	70,579
	Maximum	0.008	0.004	0.002	.	2.99	1,541,300	253,492
	Median	0.005	0.003	0.001	.	2.53	1,368,349	128,018
	Arithmetic Mean	0.006	0.003	0.001	.	2.18	1,269,157	134,376
	Standard Deviation	0.002	0.001	0.000	.	0.77	277,786	58,324
7/5/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.001	0.001	0.001	14.0	0.56	905,450	193,298
	Maximum	0.007	0.002	0.016	21.0	3.66	2,052,524	328,099
	Median	0.004	0.001	0.008	17.0	2.58	1,175,051	300,121
	Arithmetic Mean	0.004	0.001	0.007	16.9	2.30	1,409,407	281,227
	Standard Deviation	0.002	0.000	0.006	2.1	0.97	442,492	48,346
7/19/2009	N of Cases	7	7	7	0	7	7	7
	Minimum	0.005	0.002	0.001	.	0.82	778,280	62,525
	Maximum	0.014	0.006	0.015	.	3.52	2,027,090	490,028
	Median	0.008	0.004	0.007	.	1.71	1,462,455	189,907
	Arithmetic Mean	0.008	0.004	0.007	.	1.72	1,391,603	231,661
	Standard Deviation	0.003	0.001	0.006	.	0.89	375,395	136,968
8/9/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.006	0.003	0.001	16.0	1.38	839,322	90,079
	Maximum	0.010	0.006	0.040	26.0	3.14	1,437,021	213,646
	Median	0.007	0.004	0.032	23.0	2.33	1,233,549	112,969
	Arithmetic Mean	0.007	0.005	0.024	22.3	2.35	1,169,601	146,791
	Standard Deviation	0.001	0.001	0.016	3.5	0.64	213,794	55,495

Water chemistry and picoplankton summary statistics by sampling event for epilimnion  
(continued 3).

<b>Epilimnion</b>								
<b>Sampling Event</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>	<b>Total Dissolved Solids (mg/L)</b>	<b>Chlorophyll <i>a</i> (µg/L)</b>	<b>Heterotrophic Bacteria (cells/mL)</b>	<b>Pico-cyano Bacteria (cells/mL)</b>
8/23/2009	N of Cases	7	7	7	0	7	7	7
	Minimum	0.004	0.004	0.001	.	1.71	971,579	70,155
	Maximum	0.012	0.008	0.029	.	4.62	1,877,029	185,032
	Median	0.007	0.007	0.005	.	2.21	1,236,092	113,817
	Arithmetic Mean	0.008	0.006	0.008	.	2.65	1,368,713	120,055
	Standard Deviation	0.003	0.001	0.010	.	0.99	336,128	43,164
9/7/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.006	0.003	0.001	17.0	1.06	446,155	24,480
	Maximum	0.010	0.005	0.019	25.0	2.01	2,301,777	59,452
	Median	0.009	0.004	0.001	22.0	1.43	1,699,839	41,569
	Arithmetic Mean	0.009	0.004	0.004	21.7	1.51	1,481,531	41,330
	Standard Deviation	0.002	0.001	0.007	2.9	0.36	674,728	11,772
9/20/2009	N of Cases	7	7	7	0	7	7	7
	Minimum	0.004	0.001	0.003	.	1.24	1,594,712	111,274
	Maximum	0.008	0.006	0.016	.	2.50	2,576,464	351,837
	Median	0.006	0.001	0.010	.	1.79	1,833,791	211,738
	Arithmetic Mean	0.006	0.002	0.009	.	1.83	1,872,306	219,822
	Standard Deviation	0.001	0.002	0.005	.	0.49	330,591	97,174
10/4/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.001	0.001	0.001	19.0	1.01	180,581	83,932
	Maximum	0.001	0.001	0.031	24.0	3.52	1,655,753	165,745
	Median	0.001	0.001	0.002	21.0	3.04	1,281,874	104,915
	Arithmetic Mean	0.001	0.001	0.008	20.9	2.64	1,216,109	119,388
	Standard Deviation	0.000	0.000	0.011	1.6	0.95	501,270	32,603
11/8/2009	N of Cases	7	7	7	7	7	7	7
	Minimum	0.007	0.003	0.001	19.0	1.51	1,019,903	15,967
	Maximum	0.021	0.019	0.017	25.0	5.69	1,383,610	58,710
	Median	0.012	0.006	0.006	22.0	3.84	1,279,330	43,238
	Arithmetic Mean	0.012	0.008	0.007	21.9	3.89	1,229,552	39,675
	Standard Deviation	0.005	0.005	0.006	1.8	1.44	129,446	14,060

Water chemistry and picoplankton summary statistics by sampling event for hypolimnion.

<b>Hypolimnion</b>				
<b>Sampling Event</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>
3/22/2009	N of Cases	4	4	4
	Minimum	0.004	0.002	0.040
	Maximum	0.007	0.006	0.075
	Median	0.005	0.005	0.049
	Arithmetic Mean	0.005	0.004	0.053
	Standard Deviation	0.001	0.002	0.015
4/5/2009	N of Cases	4	4	4
	Minimum	0.007	0.004	0.003
	Maximum	0.017	0.010	0.073
	Median	0.012	0.007	0.063
	Arithmetic Mean	0.012	0.007	0.051
	Standard Deviation	0.004	0.003	0.032
5/3/2009	N of Cases	7	7	7
	Minimum	0.007	0.004	0.001
	Maximum	0.018	0.010	0.056
	Median	0.012	0.006	0.001
	Arithmetic Mean	0.012	0.006	0.014
	Standard Deviation	0.004	0.002	0.023
6/7/2009	N of Cases	7	7	7
	Minimum	0.002	0.001	0.001
	Maximum	0.013	0.007	0.038
	Median	0.003	0.001	0.014
	Arithmetic Mean	0.004	0.002	0.019
	Standard Deviation	0.004	0.002	0.016
7/5/2009	N of Cases	7	7	7
	Minimum	0.001	0.001	0.001
	Maximum	0.005	0.001	0.057
	Median	0.003	0.001	0.022
	Arithmetic Mean	0.003	0.001	0.022
	Standard Deviation	0.001	0.000	0.021

Water chemistry and picoplankton summary statistics by sampling event for hypolimnion (continued 2).

<b>Hypolimnion</b>				
<b>Sampling Event</b>		<b>Total Phosphorus (mg/L)</b>	<b>Total Dissolved Phosphorus (mg/L)</b>	<b>Nitrate + Nitrite (mg/L)</b>
8/9/2009	N of Cases	7	7	7
	Minimum	0.004	0.003	0.001
	Maximum	0.014	0.009	0.027
	Median	0.010	0.006	0.003
	Arithmetic Mean	0.009	0.006	0.010
	Standard Deviation	0.004	0.002	0.011
9/7/2009	N of Cases	7	7	7
	Minimum	0.003	0.002	0.001
	Maximum	0.027	0.007	0.085
	Median	0.014	0.006	0.038
	Arithmetic Mean	0.013	0.005	0.038
	Standard Deviation	0.008	0.002	0.034
10/4/2009	N of Cases	7	7	7
	Minimum	0.001	0.001	0.001
	Maximum	0.009	0.003	0.087
	Median	0.002	0.001	0.015
	Arithmetic Mean	0.004	0.001	0.039
	Standard Deviation	0.004	0.001	0.037
11/8/2009	N of Cases	7	7	7
	Minimum	0.006	0.002	0.001
	Maximum	0.015	0.013	0.016
	Median	0.011	0.005	0.004
	Arithmetic Mean	0.011	0.006	0.005
	Standard Deviation	0.003	0.003	0.005

Percent relative abundance (RA) of phytoplankton observed in 2008 and 2009 based on density in natural counting units.

Major Taxonomic Group	Species Name	RA% 08	RA% 09	
<b>Blue-greens</b>	<i>Anabaena circinalis</i>	0.668	0.000	
	<i>Anabaena sp.</i>	0.688	0.465	
	<i>Anabaenopsis sp.</i>	0.457	0.000	
	<i>Aphanothecae sp.</i>	0.023	0.000	
	<i>Chroococcus sp.</i>	1.414	5.928	
	<i>Coelosphaeria sp.</i>	1.094	0.023	
	<i>Lyngbya sp.</i>	0.000	0.002	
	<i>Merismopedia sp.</i>	0.000	0.176	
	<i>Microcystis sp.</i>	8.990	1.680	
	<i>Planktothrix agardhii</i>	0.008	0.109	
	<i>Pseudoanabaena sp.</i>	0.586	0.166	
	<i>Synechococcus sp. (coccoid)</i>	9.623	2.809	
	<i>Synechococcus sp. (rod)</i>	8.687	6.588	
	<i>Synechocystis sp.</i>	1.086	0.334	
	<b>Blue-green Total</b>		<b>33.323</b>	<b>18.281</b>
<b>Cocoid Greens, Desmids, etc.</b>	<i>Acanthosphaera sp.</i>	0.000	0.006	
	<i>Ankistrodesmus sp.</i>	0.372	0.029	
	<i>Ankyra sp.</i>	0.019	0.009	
	<i>Botryococcus sp.</i>	0.000	0.209	
	<i>Carteria sp.</i>	0.000	0.015	
	<i>Chlorella sp.</i>	0.489	0.077	
	<i>Clamydocapsa sp.</i>	0.120	0.025	
	<i>Coccomyxa sp.</i>	0.000	0.025	
	<i>Coelastrum sp.</i>	0.870	1.357	
	<i>Cosmarium sp.</i>	0.728	0.066	
	<i>Crucigenia sp.</i>	0.047	0.105	
	<i>Dichtyosphaerium sp.</i>	0.004	0.102	
	<i>Distigma sp.</i>	0.000	0.009	
	<i>Elakatothrix sp.</i>	0.574	0.055	
	<i>Eudorina elegans</i>	0.000	0.022	
	<i>Euglena sp.</i>	0.000	0.005	
	<i>Geminella sp.</i>	0.000	0.014	
	<i>Gloeococcus sp.</i>	0.000	0.008	
	<i>Golenkinia sp.</i>	0.012	0.020	
	<i>Hemitoma meandrocystis</i>	0.000	0.002	
	<i>Monomastix sp.</i>	0.000	0.291	
	<i>Monoraphidium sp.</i>	0.344	0.057	
	<i>Nephroselmis sp.</i>	0.000	0.618	
	<i>Oocystis sp.</i>	0.517	0.300	
	<i>Pandorina sp.</i>	0.000	0.009	
	<i>Paulschultzia sp.</i>	0.000	0.002	
	<i>Pediastrum sp.</i>	0.004	0.000	
	<i>Phacus sp.</i>	0.015	0.069	
	<i>Planctonema sp.</i>	0.010	0.017	
	<i>Planctosphaeria sp.</i>	0.217	0.732	
	<i>Pseudosphaerocystis sp.</i>	0.000	0.006	
	<i>Scenedesmus sp.</i>	0.000	0.026	
	<i>Scourfieldia sp.</i>	0.000	0.122	
	<i>Sphaerocystis sp.</i>	0.000	0.120	
	<i>Spondylosium sp.</i>	0.096	0.092	
	<i>Stichococcus minutissimus</i>	0.000	24.872	
	<i>Tetraedron sp.</i>	0.007	0.011	
	<i>Volvox sp.</i>	0.000	0.002	
	<b>Cocoid Greens, Desmids, etc. Total</b>		<b>4.443</b>	<b>29.505</b>

Percent relative abundance (RA) of phytoplankton observed in 2008 and 2009 based on density in natural counting units (continued).

Major Taxonomic Group	Lowest Practical Taxon	RA % 2008	RA % 2009
Diatoms	<i>Achnantheidium sp.</i>	0.621	0.035
	<i>Asterionella formosa var1</i>	1.277	0.970
	<i>Aulacoseira granulata</i>	0.152	0.000
	<i>Aulacoseira italica</i>	0.083	0.052
	<i>Aulicoseira distans</i>	0.010	0.000
	<i>Ceratoneis sp.</i>	0.078	0.000
	<i>Cocconeis sp.</i>	0.014	0.000
	<i>Cyclotella comta</i>	0.083	0.022
	<i>Cyclotella glomerata</i>	1.209	0.009
	<i>Cyclotella stelligera</i>	0.010	0.003
	<i>Cymbella sp.</i>	0.163	0.022
	<i>Diatoma sp.</i>	0.032	0.000
	<i>Fragilaria capucina</i>	0.633	0.117
	<i>Fragilaria construens</i>	0.088	0.022
	<i>Fragilaria crotonensis</i>	1.811	2.196
	<i>Fragilaria intermedia</i>	0.000	0.045
	<i>Frustulia sp.</i>	0.000	0.002
	<i>Gomphonema sp.</i>	0.013	0.002
	<i>Hannea arcus</i>	0.032	0.009
	<i>Meridion sp.</i>	0.000	0.003
	<i>Navicula sp.</i>	0.329	0.045
	<i>Neidium sp.</i>	0.000	0.002
	<i>Nitzschia sp.</i>	0.006	0.020
	<i>Pinnularia sp.</i>	0.013	0.000
	<i>Rhizosolenia sp.</i>	0.004	0.023
	<i>Rhicospheria curvata</i>	0.000	0.002
	<i>Stephanodiscus sp.</i>	0.305	0.011
	<i>Synedra sp.</i>	0.234	0.430
	<i>Synedra acus</i>	0.364	0.049
	<i>Synedra acus var. angustissima</i>	0.324	0.008
	<i>Synedra nana</i>	0.000	0.310
	<i>Synedra ulna</i>	0.040	0.011
	<i>Tabellaria fenestrata</i>	0.000	0.005
	<b>Diatom Total</b>	<b>7.929</b>	<b>4.422</b>
Dinoflagellates	<i>Ceratium sp.</i>	0.008	0.003
	<i>Glenodinium sp.</i>	0.016	0.005
	<i>Gloeodinium sp.</i>	0.000	0.002
	<i>Gymnodinium sp. 1</i>	0.358	0.131
	<i>Gymnodinium sp. 2</i>	0.102	0.055
	<i>Peridinium spp.</i>	0.227	0.011
		<b>Dinoflagellate Total</b>	<b>0.711</b>
Flagellates	<i>Bitrichia sp.</i>	0.016	0.018
	<i>Chromulina sp.</i>	0.972	0.578
	<i>Chrysidiastrum sp.</i>	0.012	0.000
	<i>Chrysochromulina sp.</i>	2.341	0.139
	<i>Chrysococcus sp.</i>	0.000	0.670
	<i>Cryptomonas sp.</i>	2.236	1.029
	<i>Dinobryon sp.</i>	0.529	0.250
	<i>Eusphaerella sp.</i>	0.000	0.002
	<i>Gyromitus sp.</i>	0.000	0.002
	<i>Kephyrion sp.</i>	0.506	0.097
	<i>Komma sp.</i>	10.211	3.409
	<i>Mallomonas sp. 1</i>	0.000	0.003
	<i>Mallomonas sp. 2</i>	0.107	0.026
	<i>Ochromonas sp.</i>	0.254	0.698
	<i>Paranema sp.</i>	0.003	0.000
	<i>Phaeaster sp.</i>	0.000	0.005
	<i>Pseudokephrion sp.</i>	0.197	0.000
	Nanoflagellates	36.061	40.583
	<i>Synura sp.</i>	0.125	0.062
	<i>Trachelomonas sp.</i>	0.025	0.015
<i>Uroglena sp.</i>	0.000	0.002	
	<b>Flagellate Total</b>	<b>53.593</b>	<b>47.585</b>

Zooplankton net efficiencies (%) from 2009.

Date	EC-6	LNF-3	RK-2	RK-31	RK-56	RK-66	RK-72	Event Means
3/23/2009	13.9		14.1	14.1	12.0			13.5
4/6/2009	19.9		18.6	17.4	18.5			18.6
4/20/2009			17.3					17.3
5/4/2009	18.1	14.3	20.4	12.7	22.0	12.5	13.0	16.2
5/18/2009	13.7	14.6	11.7	12.3	12.8	14.8	6.1	12.3
6/8/2009	6.2	20.0	7.4	6.8	17.3	13.8	22.5	13.4
6/22/2009	16.6	22.4	7.4	6.2	10.3	11.9	12.2	12.4
7/6/2009	10.3	16.2	18.0	11.2	12.7	11.2	12.8	13.2
7/20/2009	6.3	5.8	12.0	6.7	7.1	9.3	10.7	8.3
8/10/2009		6.1				12.2	12.9	10.4
8/24/2009	12.0	14.4	18.4		13.9	16.4	13.9	14.8
9/8/2009	10.3	10.5	11.5	12.3	10.0	11.3	18.9	12.1
9/21/2009	8.7	9.0	11.7	9.7	9.7	13.7	10.1	10.4
10/5/2009	20.0	15.5	11.5	18.6	11.0	12.2	15.0	14.8
11/9/2009		25.6	14.2	18.0	22.0	21.9	19.1	20.1
<b>Station Means</b>	<b>13.0</b>	<b>14.5</b>	<b>13.9</b>	<b>12.2</b>	<b>13.8</b>	<b>13.4</b>	<b>13.9</b>	<b>13.5</b>

Mean zooplankton density by station in 2009.

0-10 m tows (# / L)							
Taxa	EC-6	LNF-3	RK-2	RK-31	RK-56	RK-66	RK-72
<i>Bosmina</i>	3.259	0.662	2.556	0.946	0.611	0.633	0.532
<i>Chydorid</i>	0.000	0.007	0.000	0.005	0.005	0.000	0.000
<i>Daphnia</i>	2.835	9.459	3.374	2.858	3.655	6.835	4.093
<i>Diaphnosoma</i>	0.390	1.611	0.421	1.400	1.973	2.082	3.286
<i>Holopedium</i>	0.427	0.680	1.196	1.460	0.581	0.579	0.369
<i>Leptodora</i>	0.053	0.087	0.031	0.018	0.017	0.018	0.006
<i>Macrothrix</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<i>Scapholeberis</i>	0.000	0.003	0.027	0.000	0.003	0.000	0.000
<b>Total Cladoceran</b>	<b>6.964</b>	<b>12.509</b>	<b>7.605</b>	<b>6.686</b>	<b>6.845</b>	<b>10.147</b>	<b>8.286</b>
Calanoid	2.260	3.029	7.164	1.909	1.586	2.316	2.259
Cyclopoid	29.357	13.479	25.307	16.639	9.767	10.930	7.323
<i>Ergasilus</i>	3.364	1.209	1.186	1.319	0.632	0.652	0.404
Harpactoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<b>Total Copepods</b>	<b>34.981</b>	<b>17.717</b>	<b>33.657</b>	<b>19.866</b>	<b>11.986</b>	<b>13.898</b>	<b>9.987</b>
<b>Total Zooplankton</b>	<b>41.945</b>	<b>30.226</b>	<b>41.262</b>	<b>26.553</b>	<b>18.830</b>	<b>24.045</b>	<b>18.272</b>

Mean zooplankton density by month in 2009.

0-10 m tows (# / L)									
Taxa	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
<i>Bosmina</i>	0.057	0.173	1.541	6.083	0.442	0.093	0.115	0.329	2.005
<i>Chydorid</i>	0.000	0.000	0.000	0.000	0.005	0.005	0.000	0.013	0.000
<i>Daphnia</i>	0.040	0.018	0.026	2.394	5.136	6.469	11.110	9.578	5.225
<i>Diaphnosoma</i>	0.000	0.000	0.000	0.740	9.416	0.302	0.406	0.136	0.061
<i>Holopedium</i>	0.020	0.085	0.139	3.187	1.335	0.156	0.236	0.563	0.057
<i>Leptodora</i>	0.000	0.000	0.003	0.055	0.050	0.041	0.039	0.087	0.000
<i>Macrothrix</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<i>Scapholeberis</i>	0.000	0.000	0.000	0.007	0.007	0.022	0.000	0.000	0.000
<b>Total Cladoceran</b>	<b>0.117</b>	<b>0.278</b>	<b>1.708</b>	<b>12.466</b>	<b>16.391</b>	<b>7.087</b>	<b>11.906</b>	<b>10.706</b>	<b>7.348</b>
Calanoid	0.000	0.023	0.032	0.181	0.943	5.553	8.859	5.981	4.655
Cyclopoid	2.448	5.947	5.326	25.673	20.319	17.919	24.834	14.937	18.829
<i>Ergasilus</i>	0.290	0.606	1.184	1.125	1.673	1.512	1.853	1.381	0.946
Harpactoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<b>Total Copepods</b>	<b>2.738</b>	<b>6.577</b>	<b>6.543</b>	<b>26.978</b>	<b>22.935</b>	<b>24.984</b>	<b>35.546</b>	<b>22.298</b>	<b>24.429</b>
<b>Total Zooplankton</b>	<b>2.854</b>	<b>6.854</b>	<b>8.251</b>	<b>39.445</b>	<b>39.326</b>	<b>32.071</b>	<b>47.452</b>	<b>33.004</b>	<b>31.777</b>