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Water-Quality, Phytoplankton, and Trophic-Status Characteristics of Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004

Prepared in cooperation with
LITTLE ROCK AIR FORCE BASE

Scientific Investigations Report 2005-5068

U.S. Department of the Interior
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Abstract

Little Rock Air Force Base is the largest C-130 base in the Air Force and is the only C-130 training base in the Department of Defense. Little Rock Air Force Base is located in central Arkansas near the eastern edge of the Ouachita Mountains, near the Mississippi Alluvial Plain, and within the Arkansas Valley Ecoregion. Habitats include upland pine forests, upland deciduous forest, broad-leaved deciduous swamps, and two small freshwater lakes—Big Base Lake and Little Base Lake. Big Base and Little Base Lakes are used primarily for recreational fishing by base personnel and the civilian public. Under normal (rainfall) conditions, Big Base Lake has a surface area of approximately 39 acres while surface area of Little Base Lake is approximately 1 acre.

Little Rock Air Force Base personnel are responsible for managing the fishery in these two lakes and since 1999 have started a nutrient enhancement program that involves sporadically adding fertilizer to Big Base Lake. As a means of determining the relations between water quality and primary production, Little Rock Air Force Base personnel have a need for biological (phytoplankton density), chemical (dissolved-oxygen and nutrient concentrations), and physical (water temperature and light transparency) data. To address these monitoring needs, the U.S. Geological Survey in cooperation with Little Rock Air Force Base, conducted a study to collect and analyze biological, chemical, and physical data. The U.S. Geological Survey sampled water quality in Big Base Lake and Little Base Lake on nine occasions from July 2003 through June 2004. Because of the difference in size, two sampling sites were established on Big Base Lake, while only one site was established on Little Base Lake.

Lake profile data for Big Base Lake indicate that low dissolved-oxygen concentrations in the hypolimnion probably constrain most fish species to the upper 5-6 feet of depth during the summer stratification period. Dissolved-oxygen concentrations in Big Base Lake below a depth of 6 feet generally were less than 3 milligrams per liter for summer months that were sampled in 2003 and 2004.

Some evidence indicates that phosphorus was limiting primary production during the sampling period. Dissolved nitrogen constituents frequently were detected in water samples (indicating availability) but dissolved phosphorus constituents-orthophosphorus and dissolved phosphorus-were not detected in any samples collected at the two lakes. The absence of dissolved phosphorus constituents and presence of total phosphorus indicates that all phosphorus was bound to suspended material (sediment particles and living organisms). Nitrogen:phosphorus ratios on most sampling occasions tended to be slightly higher than 16:1, which can be interpreted as further indication that phosphorus could be limiting primary production to some extent.

An alkalinity of 20 milligrams per liter of calcium carbonate or higher is recommended to optimize nutrient availability and buffering capacity in recreational fishing lakes and ponds. Median values for water samples collected at the three sites ranged from 12-13 milligrams per liter of calcium carbonate. Alkalinities ranged from 9-60 milligrams per liter of calcium carbonate, but 13 of 17 samples collected at the deepest site had alkalinities less than 20 milligrams per liter of calcium carbonate.

Results of three trophic-state indices, and a general trophic classification, as well as abundant green algae and large growths of blue-green algae indicate that Big Base Lake may be eutrophic. Trophic-state index values calculated using total phosphorus, chlorophyll *a*, and Secchi disc measurements from both lakes generally exceeded criteria at which lakes are considered to be eutrophic. A second method of determining lake trophic status-the general trophic classification-categorized the three sampling sites as mesotrophic or eutrophic. Green algae were found to be in abundance throughout most of the study period with the lowest biovolume during April and May 2004. Many of the green algae, such as *Ankistrodesmus, Cryptomonas, Cyclotella,* and *Crucigenia,* that were identified are less than 20 microns making them an appropriate size zooplankton for grazing; however, the abundance of green algae also is evidence of eutrophy.

In addition to being of little use as a food source to filter feeding zooplankton, some blue-green algae such as *Anabaena* species identified in this study can produce algal toxins such as microcystin, a hepatotoxin that can cause serious illness to humans as well as other mammals. In some States, blue-green algal densities at Big and Little Base Lakes would trigger tests for algal toxins. Fertilization of the lakes could compound the

problem of algal toxicity. Introducing a fertilizer with less nitrogen than phosphorus (10:43:0) to the lakes could result in lake water being nitrogen limited. Nitrogen-limited lake water could favor blue-green algae (such as *Anabaena* or *Microcystis* spp.) that have the ability to fix atmospheric nitrogen as a nutrient source.

Introduction

Little Rock Air Force Base (LRAFB) is the largest C-130 base in the Air Force and is the only C-130 training base in the Department of Defense. Big Base and Little Base Lakes are located on LRAFB and are used primarily for recreational fishing by base personnel and the civilian public (fig. 1). LRAFB personnel are responsible for managing the fishery in these two lakes and since 1999 have started a nutrient enhancement program that involves sporadically adding fertilizer to Big Base Lake (U.S. Department of Defense, 1999). The purpose of fertilizing is to optimize primary (phytoplankton) production which is essential for rapid fish growth and survival in recreational fish ponds (Florida Cooperative Extension Service, 2002; Mississippi State University, 2003). As a means of determining the relations between water quality and primary production, LRAFB personnel have a need for biological (phytoplankton density), chemical water-quality data (such as dissolved oxygen and nutrient concentrations), and physical water-quality data (such as water temperature and light transparency). To address these monitoring needs, the U.S. Geological Survey (USGS) in cooperation with LRAFB, conducted a study to collect and analyze these biological, chemical, and physical data.

Purpose and Scope

The purpose of this report is to describe water-quality, phytoplankton, and trophic status characteristics at Big Base Lake and Little Base Lake from July 2003 through June 2004.Variables measured in this study can influence lake conditions (such as the extent and duration of thermal stratification and trophic status), which in turn have an influence on fish production. Data collected in this study will be used by LRAFB personnel to make informed decisions for managing water quality to optimize fish production.

Study Area Description

LRAFB is located in central Arkansas near the eastern edge of the Ouachita Mountains, near the Mississippi Alluvial Plain, and within the Arkansas Valley Ecoregion (Omernik, 1987). The area is dominated by pines and upland hardwoods and supports a wide array of plant wildlife species. Habitats include upland pine forests, upland deciduous forest, broad-leaved deciduous swamps, and two small freshwater lakes—Big Base Lake and Little Base Lake. These two lakes are connected beneath Arnold Drive by a 4-foot diameter culvert, and Big Base Lake is much larger and deeper than Little Base Lake. Under normal (rainfall) conditions, Big Base Lake has a surface area of approximately 39 acres while surface area of Little Base Lake is approximately 1 acre (U.S. Department of Defense, 1999).

Acknowledgments

Special thanks are extended to Dr. Russell Rhodes, Southwest Missouri State University, who identified phytoplankton, calculated phytoplankton density and biovolumes, and provided interpretation of phytoplankton data. Appreciation also is extended to USGS personnel Christine Barnett, Elizabeth Beavers, Dennis Evans, Charles Heavener, Jan Heavener, and Dwight Lasker for field and laboratory assistance.

Methods

The USGS sampled water quality in Big Base Lake and Little Base Lake on nine occasions from July 2003 through June 2004. Because of the difference in size, two sampling sites were established on Big Base Lake (referred to as Big Base East and Big Base West) while only one site was established on Little Base Lake (fig. 1, table 1). As sampling sites were selected, the latitude and longitude of each location was determined with a global positioning system. The two sites located on Big Base Lake are near the dam in the deepest part of the lake and are separated by approximately 0.1 mile. Lake depth at the western site (Big Lake West) averaged 20 feet throughout the study and at the eastern site (Big Lake East) depth averaged approximately 14 feet. The site established on Little Base Lake is located near the center and deepest part of the lake, where depth averaged approximately 3.5 feet.

Table 1. Site information for three lake sites sampled at Little Rock Air Force Base, Arkansas, 2003-2004.

Site name	Abbreviated name	Station identification number	Latitude[1]	Longitude[1]	Estimated size (acres)	Approximate depth (feet)
Big Base Lake East near Jacksonville, Arkansas	Big Base Lake East	07263923	34° 53’37”	92° 09’46"	39	14
Big Base Lake West near Jacksonville, Arkansas	Big Base Lake West	07263924	34° 53’38"	92° 09’57"	39	20
Little Base Lake near Jacksonville, Arkansas	Little Base Lake	07263922	34° 53’50”	92° 09’43"	1	3

[1]Latitude and longitude were referenced to the North American Datum of 1927 (NAD 27).

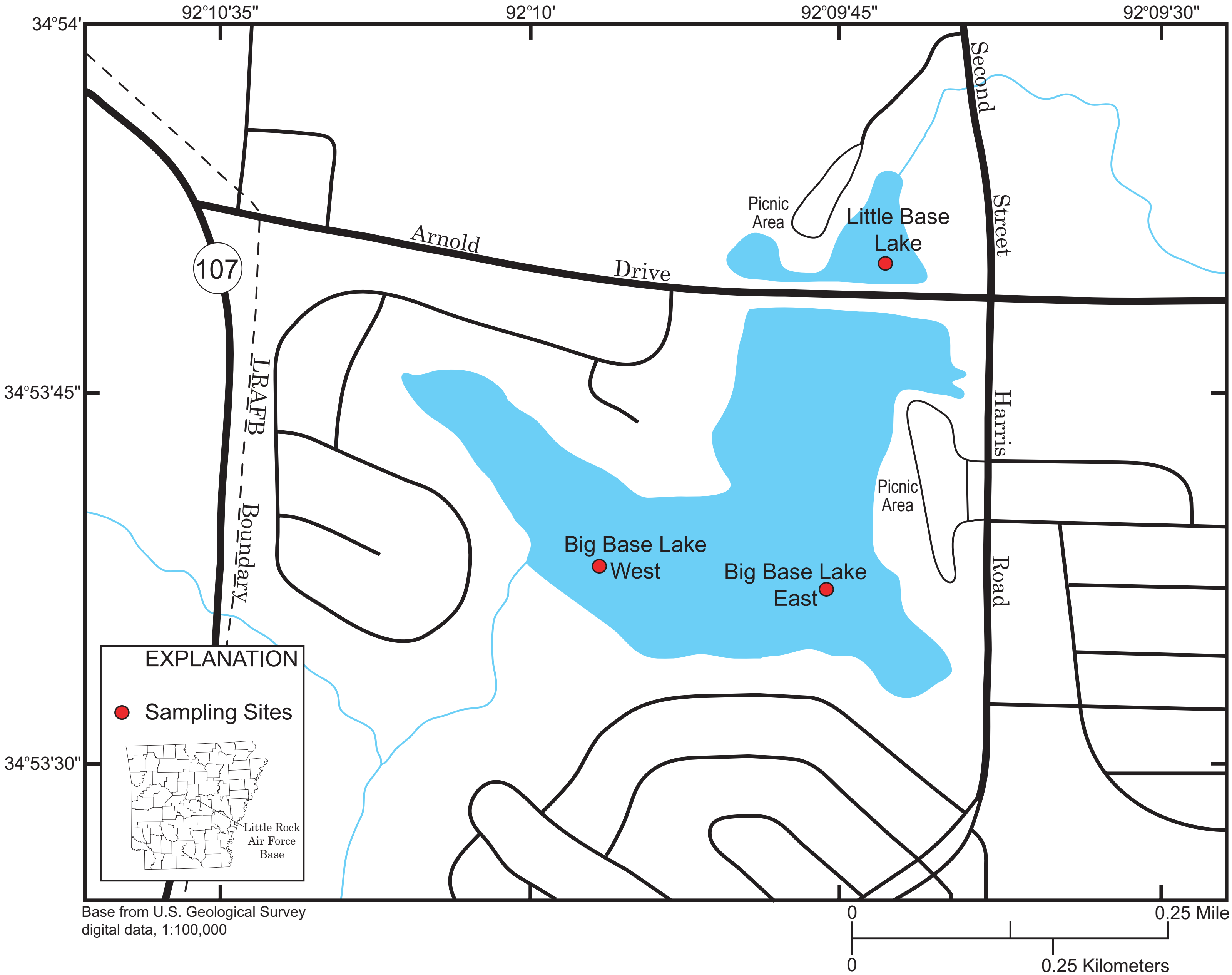

Figure 1. Location of water-quality sampling sites on Big Base Lake and Little Base Lake, Little Rock Air Force Base, Arkansas, 2003-2004.

Samples were collected monthly from July 2003 through June 2004, with the exception of three winter months (December, January, and February) when samples were not collected. Water was collected and processed using USGS protocols (Wilde and others 1999). Water was collected with a Van Dorn sampler or by pumping water to the surface with a peristaltic pump, but only one method was used to sample water for each sampling date.

Field methods associated with water sampling included conducting a water-quality profile and recording field observations on field forms. A water-quality field monitor was used to record water-column profiles for water temperature, dissolved oxygen, pH, and specific conductance at each site on every sampling occasion (Wilde and Radtke, 1998). The water-quality monitor was calibrated prior to collecting profile data on the day of sampling. Measurements were recorded at depth intervals where the change in water temperature was 1^{o} C or at 3-feet intervals, whichever occurred first. Water temperature and dissolved-oxygen data were entered into a contour mapping program (Golden Software, 1999), which was used to display these profile data for this report. Field observations included general routine observations for the appearance of the lake, weather characteristics, Secchi disc measurements (depth of light transparency), and atypical observations (the presence of waterfowl or other potential sources of impairment to water quality).

Thermal stratification characteristics observed as the water-column profile was conducted, generally determined the depth at which water samples were collected. When thermal stratification was apparent at a sampling site, a sample was collected at a depth approximately midway through the epilimnion (the uppermost thermal stratification layer) and a second sample was collected at a depth approximately midway through the hypolimnion (the lowermost thermal stratification layer). When no thermal stratification was apparent (isothermic conditions persisted), sites were sampled one time near mid-depth. One exception to this general rule pertained to the site at Big Base Lake West, which had the greatest depth of the three sampling sites and was sampled at two depths on all sampling occasions, at approximately one-third and two-thirds of total depth.

Water-quality constituents selected for analyses in this study were chosen based on the potential relations of the constituents to lake trophic status (an indication of the lake aging process) (Wetzel, 2001). Nutrients (total ammonia plus organic nitrogen, dissolved ammonia, dissolved nitrite plus nitrate, dissolved nitrite, total organic nitrogen, dissolved orthophosphorus, and total phosphorus) were the primary group of constituents analyzed, but some constituents analyzed were selected because of potential relations to phytoplankton density (chlorophyll *a*, turbidity, and total alkalinity, for example). All chemical analyses were conducted at USGS laboratories following USGS procedures and were subjected to internal quality assurance and quality-control procedures (Fishman, 1993). Organic nitrogen and total nitrogen are calculated from other nitrogen constituents (Organic nitrogen = Ammonia plus organic nitrogen - Ammonia; Total Nitrogen = Ammonia plus organic nitrogen + nitrite plus nitrate). In a few cases, constituent concentrations used in these calculations were below detection and one-half the detection level was substituted for the detection level in order that organic nitrogen and total nitrogen concentrations could be calculated.

USGS collected samples for identification and enumeration of phytoplankton as an indication of the influence that nutrient concentrations were having on primary production. Phytoplankton were identified and counted by Dr. Russell Rhodes, Southwest Missouri State University. Phytoplankton samples were counted at a magnification of 400X. Counting generally involved enumerating the phytoplankton for 30 fields in a Utermöhl chamber and conducting three replicate counts. Of the total volume (10 milliliter (mL) sample), 0.1 percent of the phytoplankton was counted for each replicate sample. As individual specimens were encountered and counted, measurements were made along with drawings. These measurements and drawings served as a source for biovolume calculations. Measurements were averaged for each species at each site and averages from all sites were used to calculate a mean average value. In cases where algal density was low, algal density and biomass were estimated by counting and measuring algae from a 25 millimeter (mm) $\times$ 0.128 mm rectangle and extrapolating those values to the approximate area of the Utermöhl chamber.

One method of classifying lake water quality is to compare Trophic-State Index (TSI) values calculated from total phosphorus, chlorophyll *a*, and Secchi-depth measurements. The TSI can be used to assess lake productivity and uses phytoplankton biomass as a basis for a continuum of trophic states (Carlson, 1977). The underlying assumption for this continuum is that in time there is a steady progression from oligotrophic lakes (lakes having a low nutrient input and low productivity) to eutrophic lakes (lakes that have a high nutrient input and high productivity) (Wetzel, 2001). Algal density increases in response to increased productivity, and total phosphorus, chlorophyll *a*, and Secchi-depth measurements often can be used to reflect algal density. TSI values calculated using total phosphorus, chlorophyll *a*, and Secchi-disc measurements were calculated using the following equations:

$$TSI\ (TP) = 14.42\ \ln(TP*1000) + 4.15$$
$$TSI\ (CHL) = 9.81\ \ln(CHL) + 30.6$$
$$TSI\ (SD) = 60 - 14.41\ \ln(SD)$$

where TP is total phosphorus concentrations (milligrams per liter), CHL is chlorophyll *a* pigment concentrations (micrograms per liter), and SD is Secchi depth (meters). TSI values of less than 30 are common for oligotrophic lakes and TSI values from 50-70 are typical of classical eutrophic lakes (Wetzel, 2001).

As a second method of determining how the lakes should be classified in terms of a continuum of trophic state, a general trophic classification (Wetzel, 2001) also was applied to total phosphorus, chlorophyll *a*, and Secchi disc data collected from the three sampling sites. This comparison involved comparing mean values for the three characteristics to mean values and ranges measured in international lakes that were classified as oligotrophic lakes, mesotrophic lakes, and eutrophic lakes by resident lake experts.

Water-Quality Characteristics

Physical and chemical data from the water-column profiles on the nine sampling dates provide insight into the stratification characteristics of Big Base and Little Base Lakes. Lake profile data indicate that Big Base Lake was stratified on five of the nine sampling occasions (July, August, September, and October 2003 and June 2004) but that isothermic conditions persisted at Little Base Lake on all sampling occasions (figs. 2-3; appendixes 1-3). When Big Base Lake was stratified, water temperature (fig. 2), dissolved oxygen (fig. 3), and pH tended to be higher in the epilimnion than in the hypolimnion and specific conductance tended to be lower in the epilimnion than in the hypolimnion (appendixes 1-3).

In addition to patterns of thermal stratification, physical and chemical data from the water-column profiles also reflect typical limnological patterns as well as patterns typical of seasonal variability (appendixes 1-3). Water temperature (fig. 2) and dissolved-oxygen concentrations (fig. 3) were higher at the surface on all sampling occasions. The pH also tended to be higher near the surface, but specific conductance tended to be lower at the surface. Water temperatures ranged from 9.8 to 31.7 ^{o}C. Warmest water temperatures were recorded in July 2003, and coolest water temperatures were recorded in March 2004. Dissolved oxygen ranged from 0.1 to 10.2 milligrams per liter (mg/L). At all three sites, dissolved-oxygen concentrations were at the lowest concentration throughout the water column in July 2003 and again in June 2004. The pH ranged from 5.8 to 8.4 and tended to be much higher in the summer than in the fall and spring. Specific conductance ranged from 37 to 377 microsiemens per centimeter (μS/cm). Specific conductance in the epilimnion ranged from 40 to 50 μS/cm for most sampling dates, but was usually at least three times higher in the hypolimnion.

Low dissolved-oxygen concentrations in the hypolimnion probably constrain most fish species to the upper 5-6 feet of depth during the summer stratification period. Dissolved-oxygen concentrations in Big Base Lake below a depth of 6 feet generally were less than 3 mg/L for summer months that were sampled in 2003 and 2004. Monomictic lakes near this latitude (34 degrees) generally are stratified from May through September and circulate from October to April (Reid and Wood, 1976). During extreme stratification, dissolved-oxygen concentrations in the hypolimnion often will be depleted, particularly if the lake is of small size and moderately productive (mesotrophic or eutrophic).

Observations made as samples were collected also may provide some insight for potential nutrient sources. Some waterfowl were present on most sampling occasions, and their feces almost always were apparent on the shoreline. In April 2004, a flock of approximately 120 ducks was present in Big Base Lake. In addition to being a source of nutrients, dabbling ducks could resuspend nutrients from bottom sediments.

The frequent detection of dissolved nitrogen constituents is possible indication that nitrogen may not be limiting primary production in Big Base Lake (appendix 4, figs. 4-5). Dissolved ammonia (as N) was detected in 27 of 32 samples collected from the two sites on Big Base Lake and was detected from 6 of 9 samples collected on Little Base Lake. Dissolved ammonia concentrations ranged from 0.01 to 1.3 mg/L. Nitrates and nitrites (also dissolved) were detected less frequently than ammonia and in low concentrations in about 25 percent of samples. Higher concentrations of most nitrogen species were detected in the hypolimnion compared to the epilimnion, a characteristic typical of stratified lakes (fig. 4; Reid and Wood, 1976).

Laboratory analyses indicate that phosphorus could be limiting primary production in Big Base Lake to some extent (appendix 4, fig. 6). Dissolved phosphorus constituents—orthophosphorus and dissolved phosphorus—were not detected in any samples collected at the two lakes and total phosphorus concentrations average about 0.03 mg/L (fig. 6). The absence of dissolved phosphorus constituents and presence of total phosphorus indicates that all phosphorus was bound to suspended material (sediment particles and living organisms). There were no apparent differences in total phosphorus concentrations in the epilimnion and hypolimnion of Big Base Lake.

One method of evaluating nutrient availability to phytoplankton involves comparing the ratio of total nitrogen to total phosphorus (the N:P ratio). A N:P ratio less than 16:1 generally is perceived to mean that a lake is nitrogen limited and a ratio greater than 16:1 generally is perceived to mean that a lake is phosphorus limited (Wetzel, 2001). N:P ratios on most sampling occasions tended to be slightly higher than 16:1 (table 2). N:P ratios slightly higher than 16:1 are further indication that phosphorus could be limiting primary production to some extent.

Alkalinity is of interest to fishery managers because it can influence the availability of nutrients and the buffering capacity of the water body being managed (Florida Cooperative Extension Service, 2002). Adding lime to lakes that have acid soils in the watershed tends to increase alkalinity and increase the availability of nutrients to phytoplankton. An alkalinity of 20 mg/L of calcium carbonate (mg/L of $CaCO_3$) or higher is recommended to optimize nutrient availability and buffering capacity in recreational fishing lakes and ponds (Florida Cooperative Extension Service, 2002; Mississippi State University, 2003). Median values for the three sites ranged from about 12 to 13 mg/L of $CaCO_3$. Alkalinities ranged from 9 to 60 mg/L of $CaCO_3$ (appendix 4) but 13 of 17 samples collected in Big Base Lake West had alkalinities less than 20 mg/L of $CaCO_3$. (fig. 7). Values were highest in July 2003, August 2003, and June 2004, and highest values were detected in the hypolimnion of Big Base Lake (both East and West) (appendix 4).

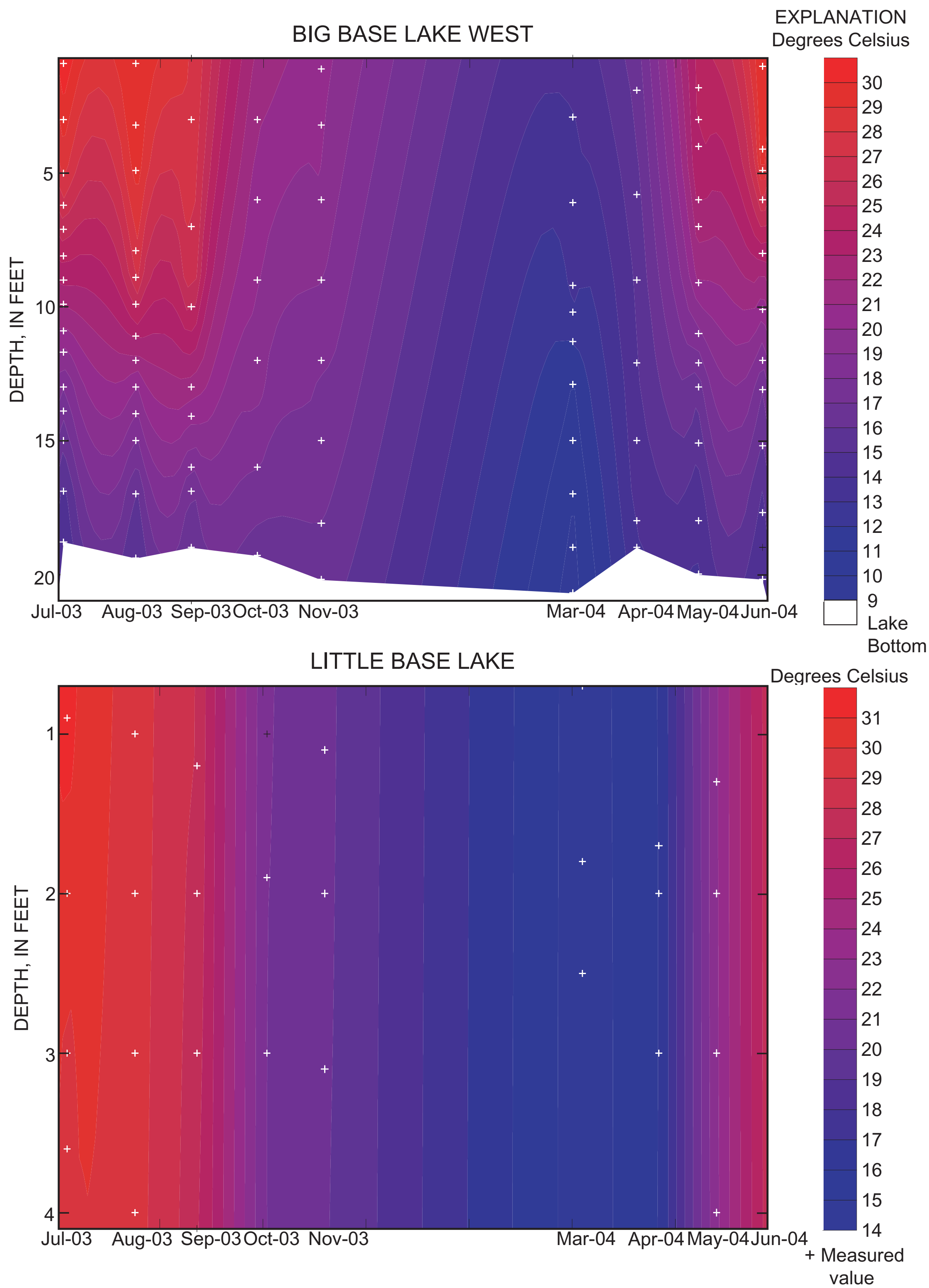

Figure 2. Distribution of water temperature with depth and time at Big and Little Base Lakes, Little Rock Air Force Base, Little Rock, Arkansas, July 2003-June 2004.

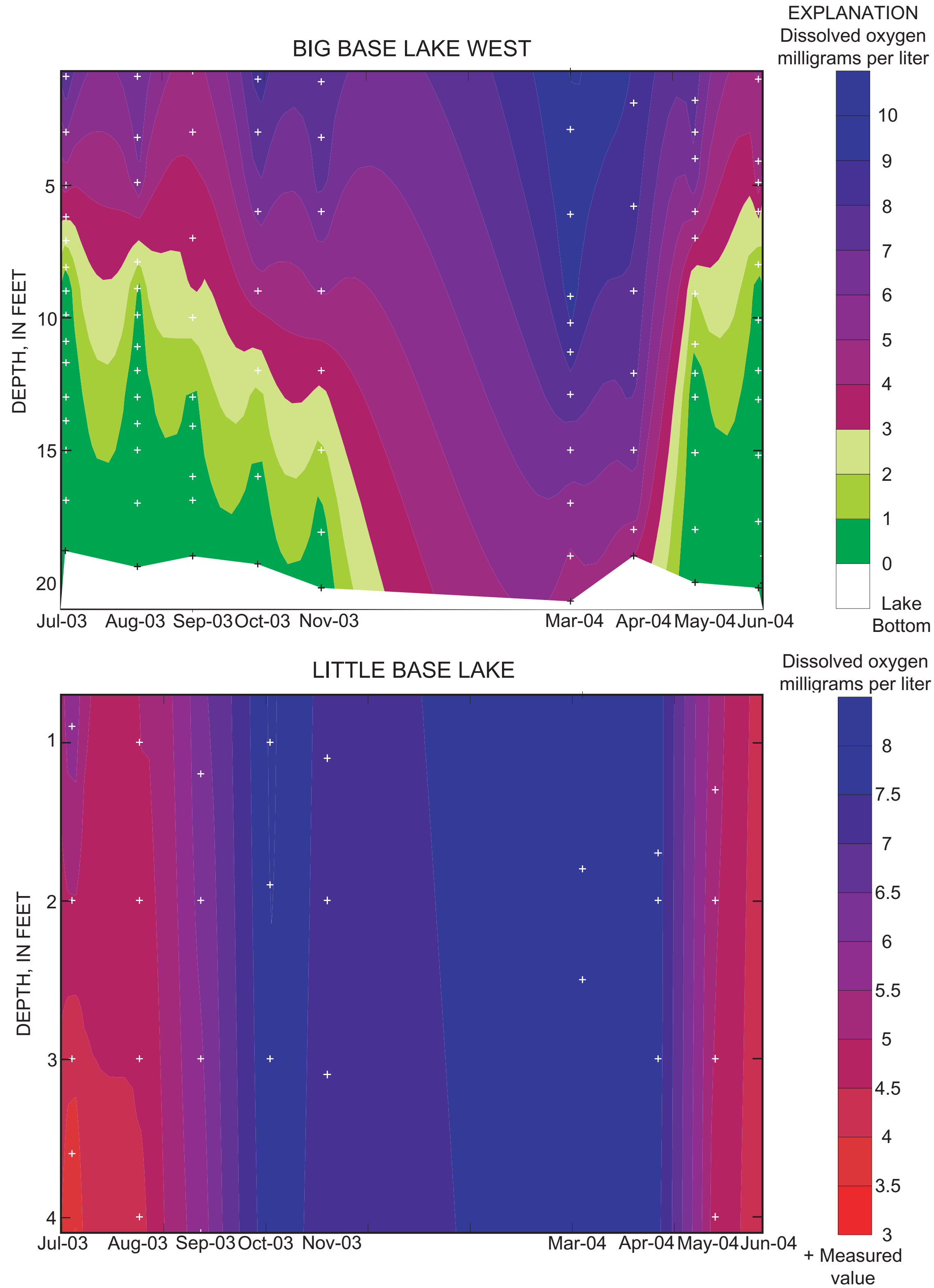

Figure 3. Distribution of dissolved-oxygen concentrations with depth and time at Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, July 2003-June 2004.

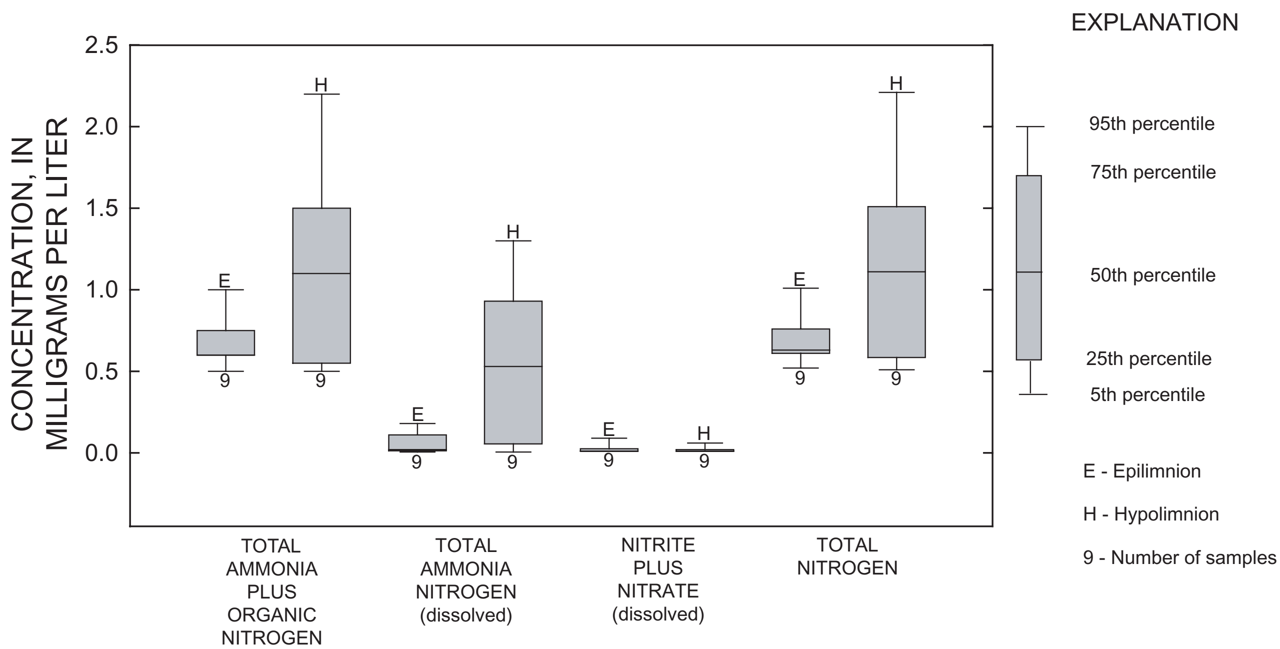

Figure 4. Distribution of four nitrogen constituents analyzed from water samples collected in the epilimnion and hypolimnion at Big Base Lake West, Little Rock Air Force Base, Arkansas, 2003-2004.

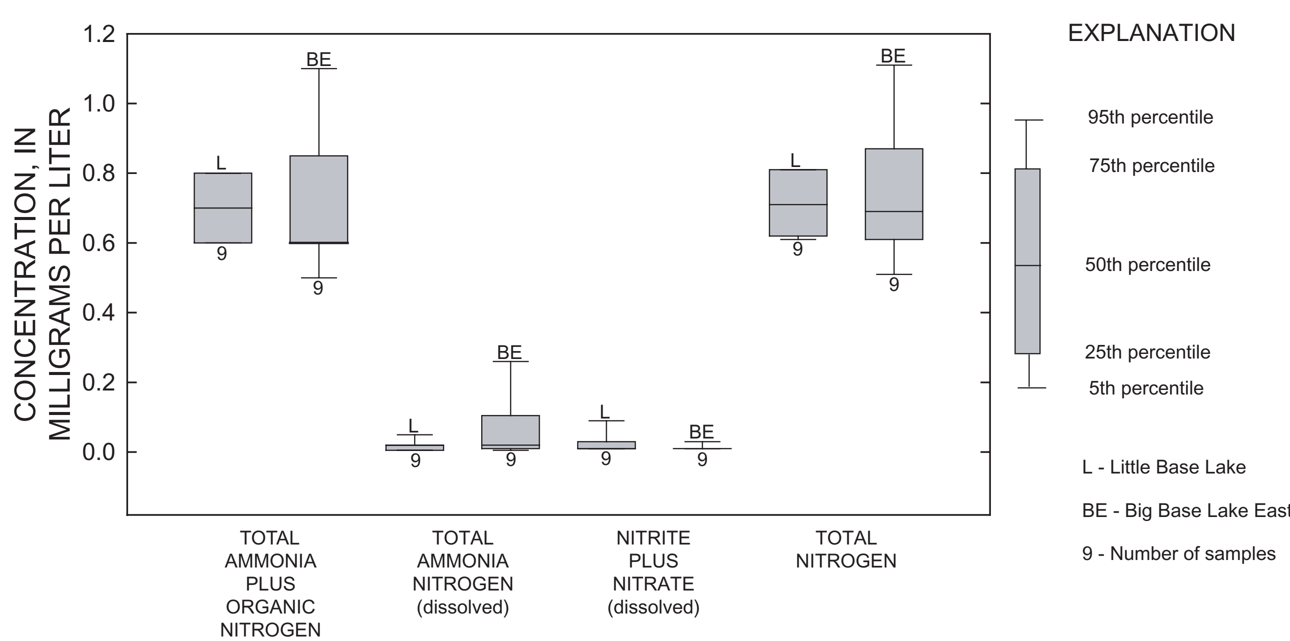

Figure 5. Distribution of four nitrogen constituents analyzed from water samples collected in the epilimnion at Big Base Lake East and Little Base Lake, Little Rock Air Force Base, Arkansas, 2003-2004.

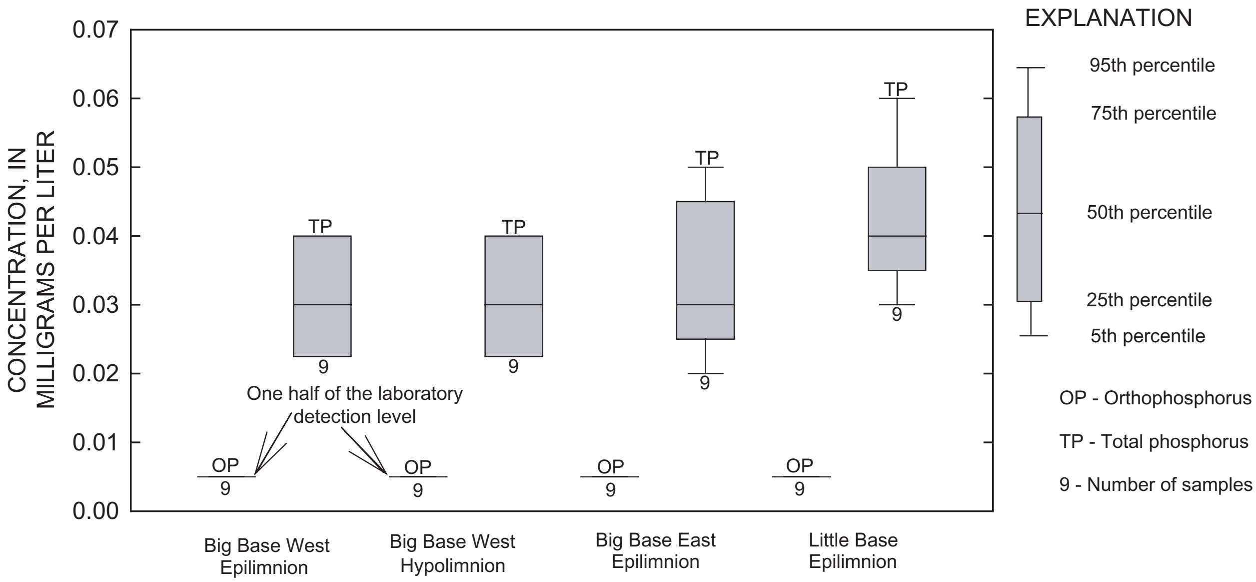

Figure 6. Distribution of orthophosphorus and total phosphorus in water samples collected from Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

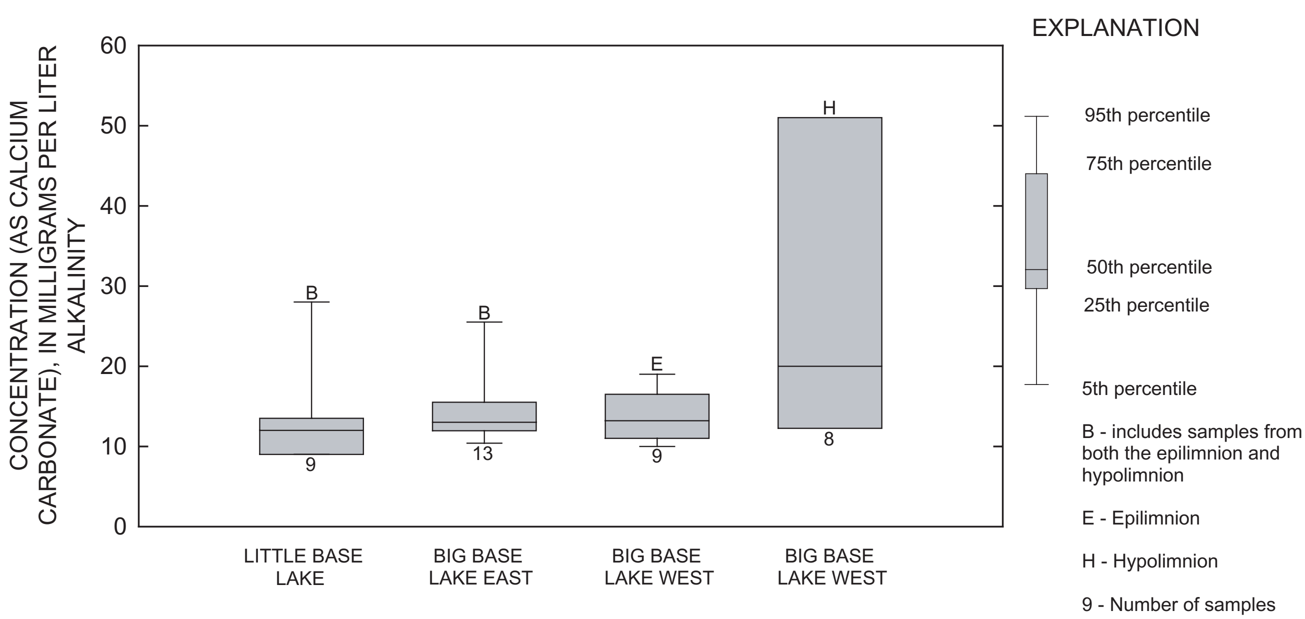

Figure 7. Distribution of alkalinity in water samples collected from Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

Table 2. Nitrogen:phosphorus ratios for four sampling sites on Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

[bold, value is equal to or greater than 16—a value of 16 or greater is a general indication that phosphorus could be limiting primary production (Wetzel, 2001)]

Sampling date	Little Base Lake	Big Base Lake East	Big Base Lake West - epilimnion	Big Base Lake West - hypolimnion
7/03/2003	14	**20**	**31**	**26**
8/05/2003	**24**	**36**	13	**40**
9/04/2003	15	**20**	**20**	**86**
10/08/2003	**20**	**20**	**27**	**28**
11/05/2003	**20**	**22**	**20**	**20**
3/09/2004	**20**	**37**	**24**	**74**
4/15/2004	13	**16**	**20**	**56**
5/13/2004	14	**17**	**32**	**16**
6/15/2004	14	**23**	**35**	**33**

Phytoplankton Characteristics

Chlorophyll *a* and turbidity data were collected as possible surrogates for phytoplankton biovolume. Differences in chlorophyll *a* in the epilimnion and the hypolimnion probably reflect differences in phytoplankton biovolume in the two stratification layers; a natural phenomena related to a difference in light availability in the two layers. Chlorophyll *a* values were slightly higher for samples collected in the epilimnion at Big Base Lake East, Big Base Lake West, and Little Base Lake than for samples collected in the hypolimnion (fig. 8) and phytoplankton biovolume was greater in the epilimnion compared to the hypolimnion (fig. 9). Turbidity was relatively low throughout the study ($\leq$ 15 nephelometric turbidity units for all but three samples) (fig. 10, appendix 4). Although the apparent relation between turbidity and phytoplankton biovolume was not as good as the relation between chlorophyll *a* and phytoplankton biovolume, clay turbidity was not noted in field observations and it is likely that suspended phytoplankton were responsible for the turbidity measured.

For purposes of analyses and reporting, each algal taxon was assigned to one of four algal groups (appendix 5). The four groups were: blue-green algae; diatoms; flagellates, including those from the classes Chlorophyceae, Dinophyceae, Chrysophyceae, Cryptophyceae, Euglenophyceae, and Prymnesiophyceae; and green algae, including algal taxa in the class Chlorophyceae.

Dense populations of blue-green algae collected at Big and Little Base Lakes may be of little if any value to fish production and are a potential health concern to resident aquatic organisms and terrestrial organisms that ingest the water. Blue-green algae exhibited pulses of total biovolume in Big Base Lake in August 2003 and in June 2004 (fig. 11). Because these blue-green algae occur as filaments, they are not a viable food source for many filter feeding zooplankton that often dominant the zooplankton community. As a consequence, blue-green algae may be of little benefit to the food chain (Reynolds, 1984).

Some blue-green algae including *Anabaena affinis,* which was dominant in June 2004 (table 3) can produce algal toxins such as microcystin, a hepatotoxin that can cause serious illness to humans as well as other mammals (World Health Organization, 1999). In some States, blue-green algal biovolumes observed at Big Base Lake in August 2003 and June 2004 would cause concern for direct water contact and would trigger tests for algal toxins (table 4; Nebraska Department of Environmental Quality, 2004; Oregon Department of Human Services, 2001). Fertilization of the lakes could compound the problem of algal toxicity. Introducing a fertilizer with more P than N (for example, 10:43:0 as N:P:K) to the lakes could result in lake water being nitrogen limited. Nitrogen-limited lake water could favor blue-green algae (such as *Anabaena* or *Microcystis* spp.) that have the ability to fix atmospheric nitrogen as a nutrient source (Wetzel, 2001).

Green algae were found to be in abundance throughout most of the study period with the lowest and highest biovolume occurring during the spring and fall seasons, respectively (figs. 11-12). Dominant taxa of green algae included *Ankistrodesmus* and *Selenastrum* (table 2). Many of the green algae such as *Ankistrodesmus, Cryptomonas, Cyclotella,* and *Crucigenia* that were identified are less than 20 microns making them a suitable size for zooplankton consumption; however, the combination of the large growths of blue-green alga filaments and abundant green algae provides further evidence that Big Base Lake may be eutrophic (Reynolds, 1984; Russell Rhodes, Southwest Missouri State University, written commun., September 2004).

Compared to the blue-green and green algae, diatoms and flagellates were not a major algal group in most of the study collections. Flagellates exhibited one large pulse in both lakes in August 2003 (figs. 11-12) that can be attributed to a dense population of a *Ceratium sp.*, a dinoflagellate.

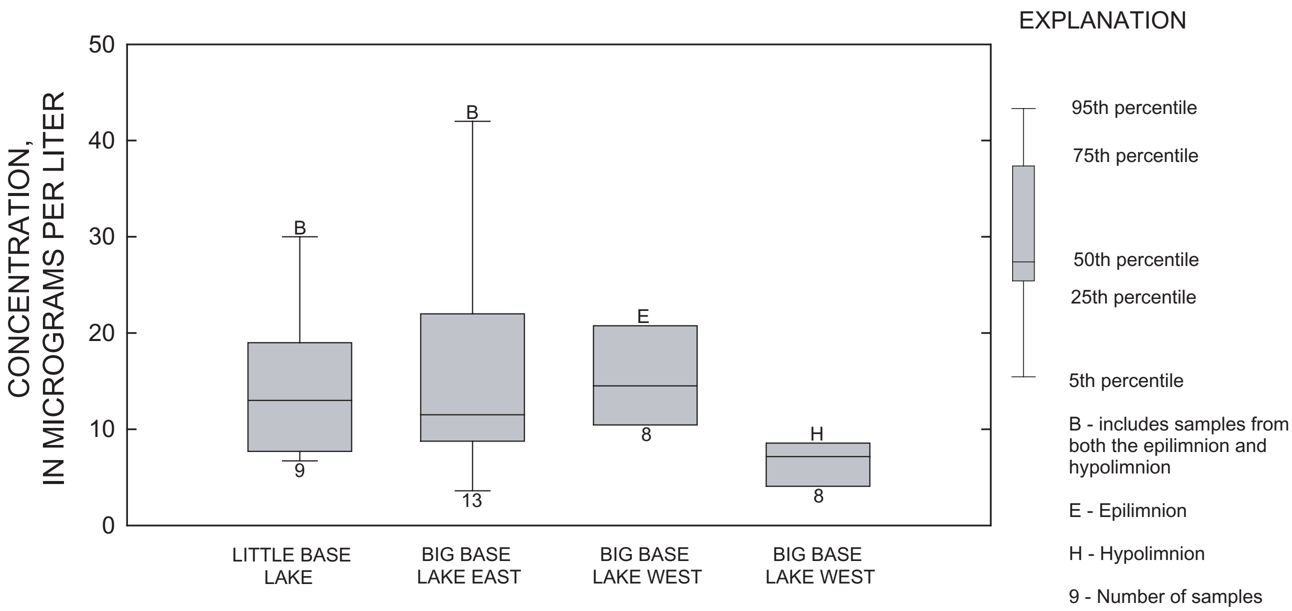

Figure 8. Distribution of chlorophyll *a* in water samples collected from Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

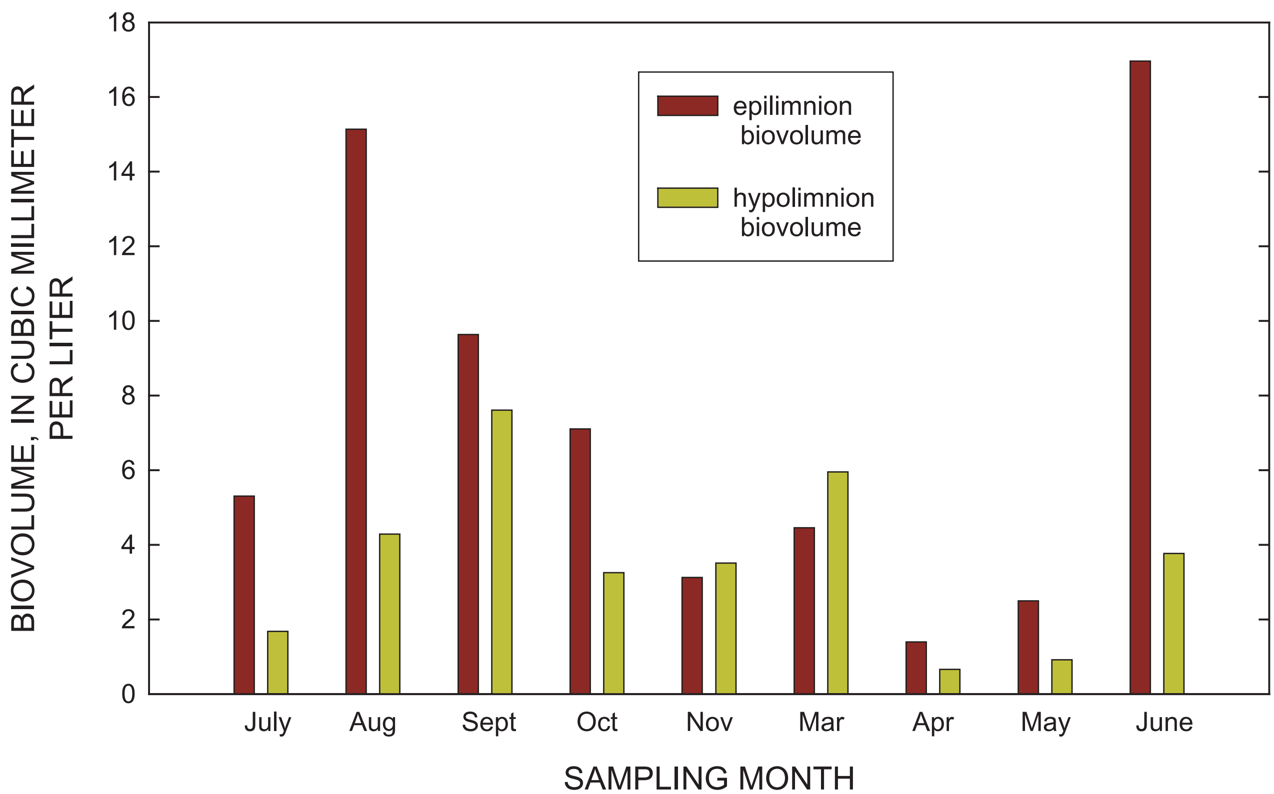

Figure 9. Biovolume of phytoplankton collected from Big Base Lake West, Little Rock Air Force Base, Arkansas, 2003-2004.

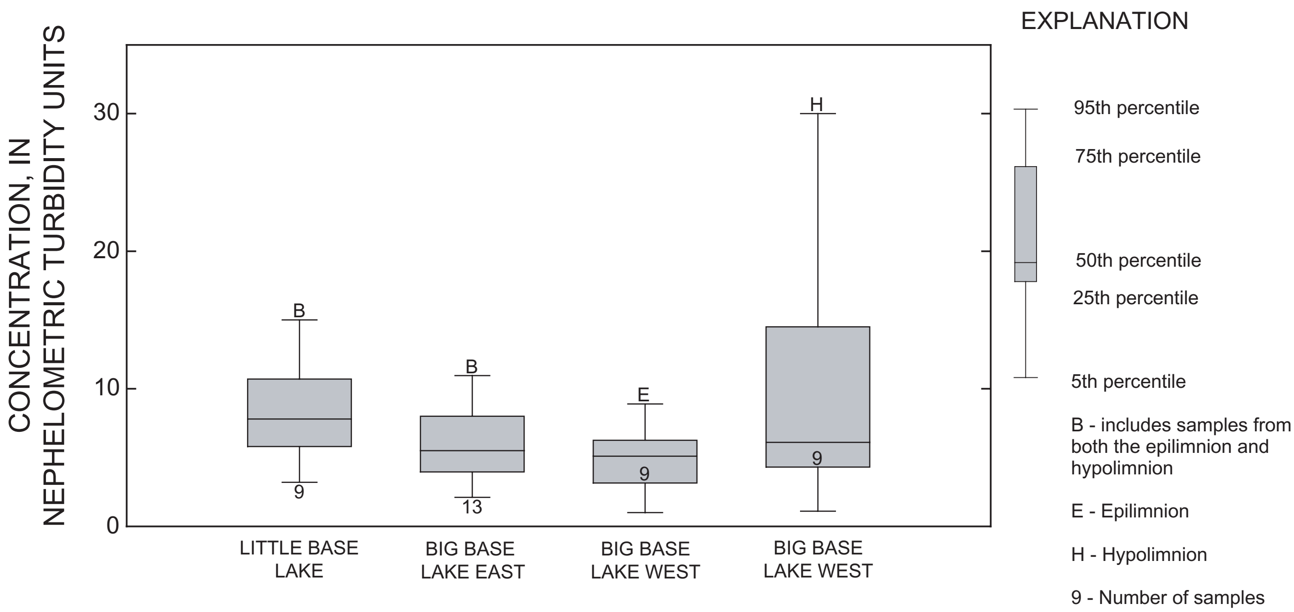

Figure 10. Distribution of turbidity in water samples collected from Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

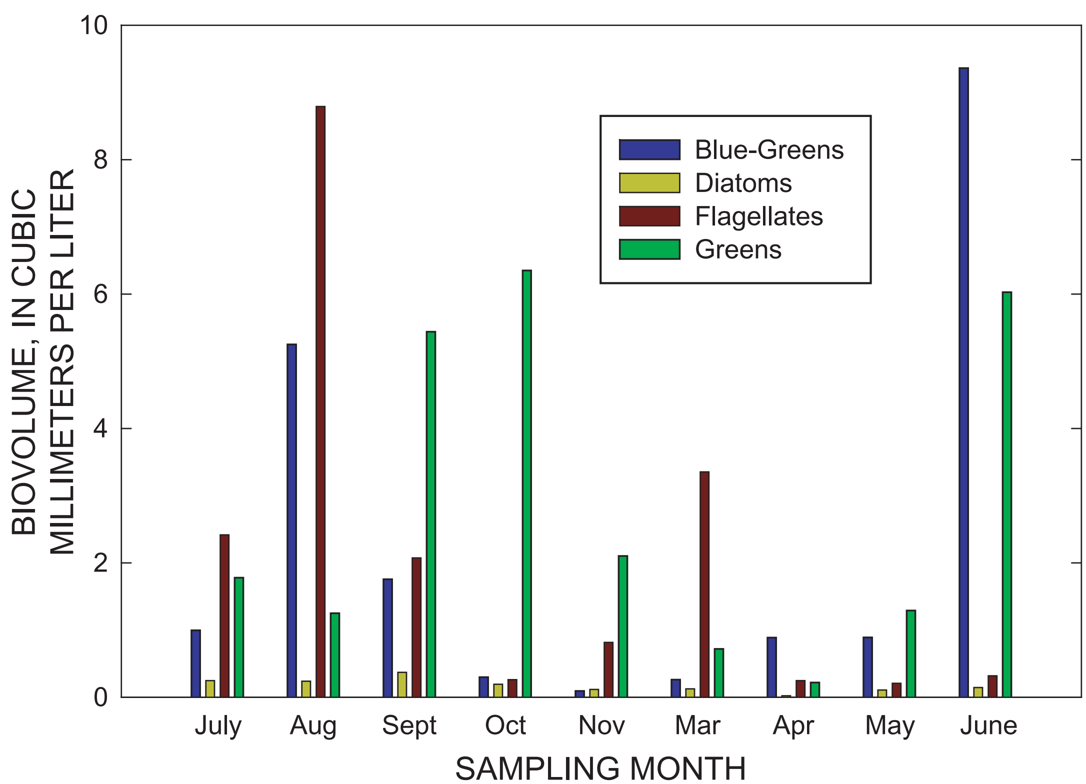

Figure 11. Algal biovolume for four groups of algae in Big Base Lake, Little Rock Air Force Base, Arkansas, July 2003-June 2004.

Table 3. Synopsis of dominant algae found in a study of Big Base Lake and Little Base Lake, Little Rock Air Force Base, Arkansas, 2003-2004.

Collection date	Dominant alga	Notes
	Big Base Lake	
7/03/2003	*Ankistrodesmus*	A small green unicell[1]
8/05/2003	*Phormidium*	A filamentous blue-green alga
9/04/2003	*Phormidium*	A filamentous blue-green alga
10/08/2003	*Scenedesmus*	A small species of colonial green alga
11/05/1002	*Merismopedia*	A colonial blue-green alga
3/09/2004	*Ankistrodesmus*	A small green unicell[1]
3/09/2004	*Selenastrum*	A small green unicell[1]
4/15/2004	*Merismopedia*	A colonial blue-green alga
4/15/2004	*Anabaena affinis*	A filamentous blue-green alga
5/13/2004	*Anabaena affinis*	A filamentous blue-green alga[2]
5/13/2004	*Microcystis*	A colonial blue-green alga[3]
6/15/2004	*Anabaena affinis*	A filamentous blue-green alga[2]
	Little Base Lake	
7/03/2003	*Asterionella*	A colonial diatom
7/03/2003	*Ankistrodesmus*	A small green unicell[1]
8/05/2003	*Cryptomonas*	A small flagellate species[4]
8/05/2003	*Cyclotella*	A small species of diatom[4]
10/8/2003	*Crucigenia*	A small green colonial species[4]
11/5/2003	*Crucigenia*	Continuation from October sample[4]
3/05/2004	*Cryptomonas*	A small flagellate species[4]
5/13/2004	*Melosira*	A filamentous diatom

[1]*Ankistrodesmus* remained abundant throughout the study period and is a good food source for zooplankton.

[2]A potential source of microcystin and antitoxin, respectively, a hepatotoxin and a neurotoxin.

[3]A potential source of microcystin, a hepatotoxin.

[4]Small size is less than 20 microns and good food source for zooplankton.

Table 4. A comparison of algal (*Anabaena* spp.) density and total algal biovolume in Big Base Lake to density and biovolume criteria for protection against harmful algae.

[mL, milliliter; mm^3/L, cubic millimeter per liter; WHO, World Health Organization guidelines; <, less than; >, greater than]

Source	Density (cell/mL)	Biovolume (mm^3/L)	WHO Criteria Notes
WHO criteria (low)	20,000	<2.5	Low risk of adverse health
WHO criteria (moderate)	20-100,000	2.5-12.5	Moderate risk of adverse health
WHO criteria (high)	>100,000	>12.5	High risk of adverse health
Big Base Lake, Arkansas (8/5/2003)	63,400	5.25	Moderate risk
Big Base Lake, Arkansas (6/15/2004)	270,600	9.36	Moderate-high risk

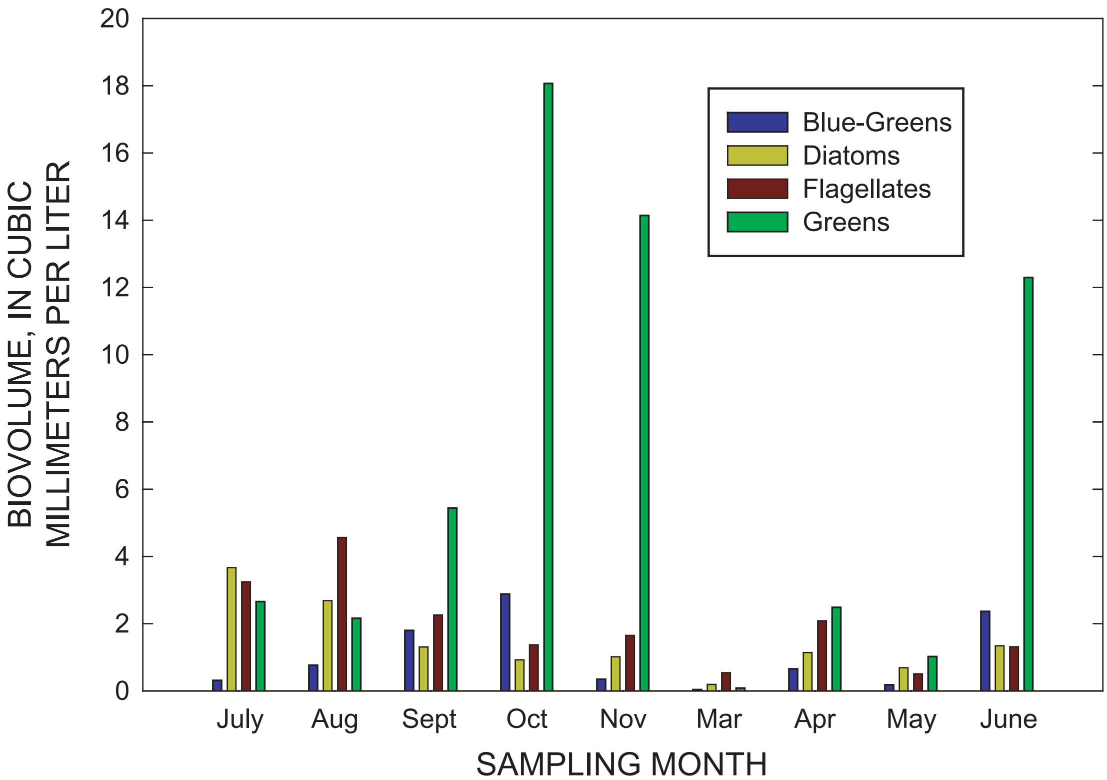

Figure 12. Algal biovolume for four groups of algae in Little Base Lake, Little Rock Air Force Base, Arkansas, July 2003-2004.

Trophic-State Characteristics

Trophic-state index values calculated using total phosphorus, chlorophyll *a*, and Secchi-depth measurements from both lakes generally exceeded a value of 50, which is a threshold above which lakes are considered to be eutrophic (table 5, figs. 13-15). TSI (TP) and TSI (CHL) values were greater than 50 in more than 75 percent of the samples and TSI (SD) values were greater than 50 for 100 percent of samples. A second method of determining lake trophic status—the general trophic classification (Wetzel, 2001)—categorized the three sampling sites as mesotrophic or eutrophic (table 6).

Table 5. Trophic-state indices (Carlson, 1977) based on total phosphorus, chlorophyll *a*, and Secchi-depth measurements for sampling sites on Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

[**bold,** exceeds criterion of 50 (at which lakes are considered euthrophic)]

Sampling date	Little Base Lake	Big Base Lake East	Big Base Lake West - epilimnion	Big Base Lake West - hypolimnion
	Trophic-status index (phosphorus)			
7/03/2003	**61**	**53**	**57**	**53**
8/05/2003	**53**	47	47	47
9/04/2003	**57**	**53**	**53**	47
10/08/2003	**57**	**61**	**53**	**57**
11/05/2003	**57**	**61**	**53**	**53**
3/09/2004	**53**	47	**53**	**53**
4/15/2004	**61**	**57**	**61**	37
5/13/2004	**61**	**53**	47	**57**
6/15/2004	**63**	**53**	47	**57**
	Trophic-status index (chlorophyll *a*)			
	Little Base Lake	**Big Base Lake East**	**Big Base Lake West - epilimnion**	**Big Base Lake West - hypolimnion**
7/03/2003	**52**	**54**	**63**	36
8/05/2003	**64**	**66**	**56**	**51**
9/04/2003	**60**	**59**	**61**	**50**
10/08/2003	**56**	**69**	**50**	**56**
11/05/2003	**53**	**53**	**58**	**50**
3/09/2004	49	**55**	**58**	**50**
4/15/2004	49	**57**	**53**	**52**
5/13/2004	**59**	**54**	**56**	43
6/15/2004	**56**	44		
	Trophic-status index (Secchi depth[1])			
	Little Base Lake	**Big Base Lake East**	**Big Base Lake West - epilimnion**	
7/03/2003	**67**	**64**	**59**	
8/05/2003	**68**	**60**	**65**	
9/04/2003	**63**	**63**	**63**	
10/08/2003	**67**	**65**	**62**	
11/05/2003	**68**	**59**	**62**	
3/09/2004	**76**	**65**	**59**	
4/15/2004	**65**	**59**	**63**	
5/13/2004	**64**	**61**	**64**	
6/15/2004	**68**	**58**	**58**	

[1]Secchi depth can be measured only at one depth and hypolimnion values for trophic state were not calculated.

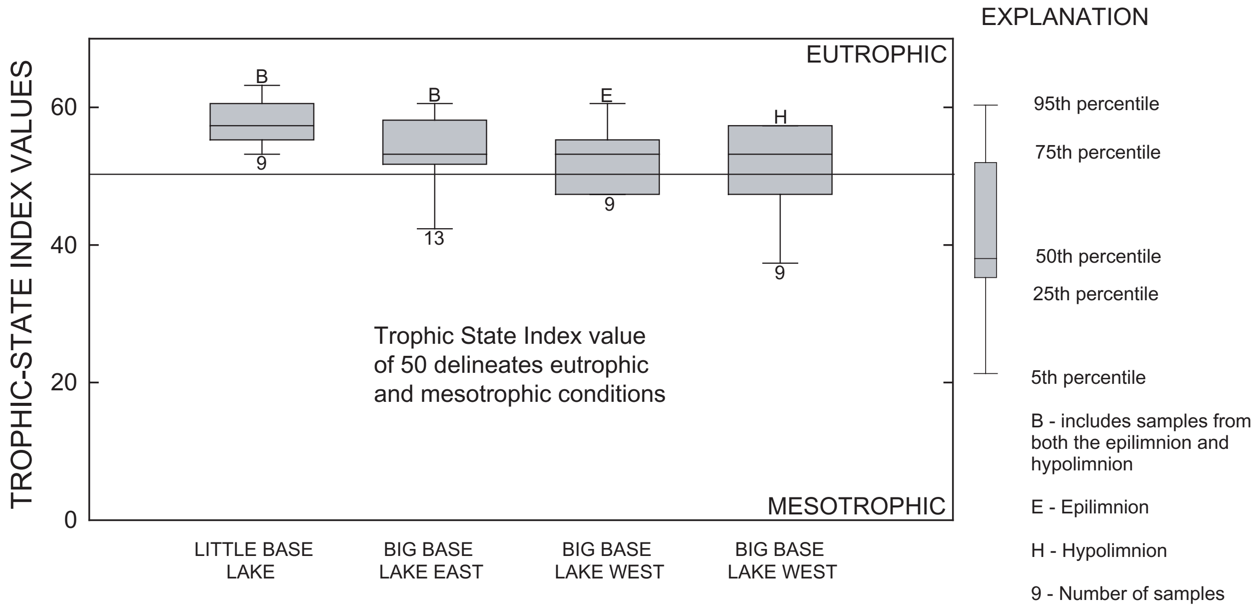

Figure 13. Distribution of a trophic-state index (Carlson, 1977) using total phosphorus data for water samples collected from Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

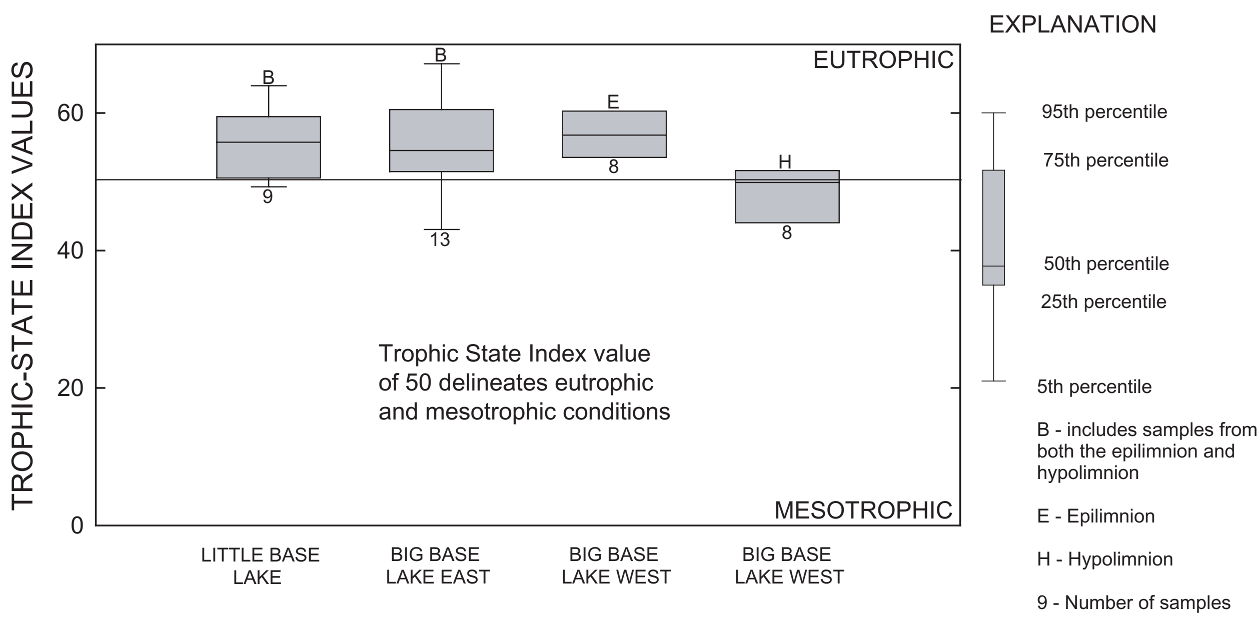

Figure 14. Distribution of a trophic-state index (Carlson, 1977) using chlorophyll *a* data for water samples collected from Little and Big Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

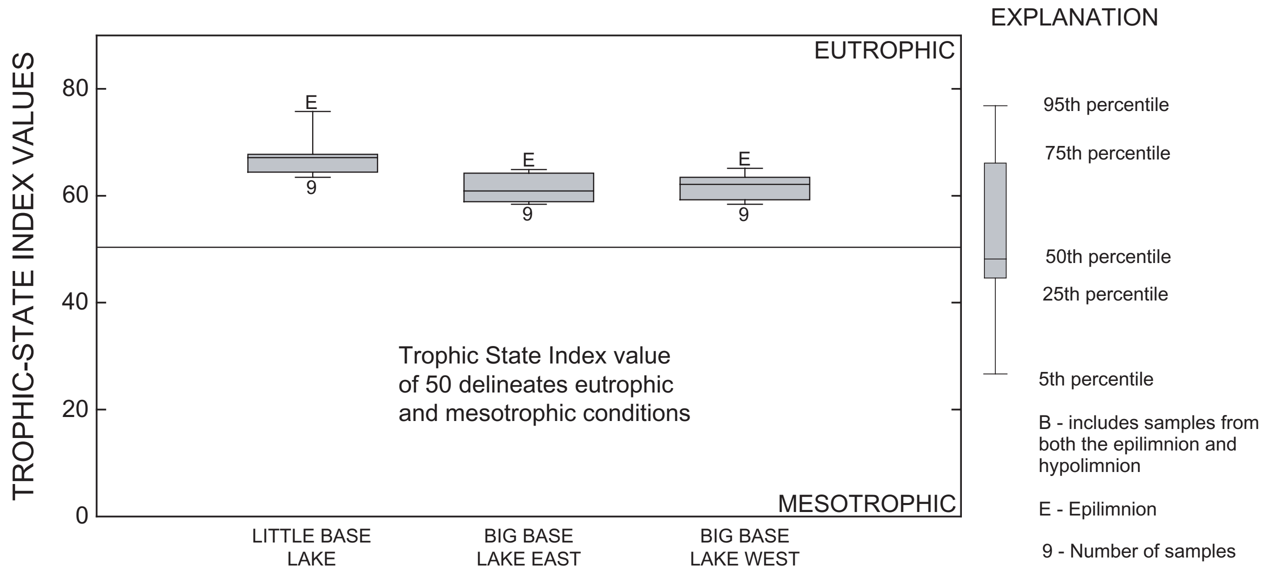

Figure 15. Distribution of a trophic-state index (Carlson, 1977) using Secchi-depth measurements at Big and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

Table 6. A comparison of a general trophic classification of lakes and reservoirs (modified from Wetzel, 2001) to total phosphorus, chlorophyll *a*, and Secchi-depth data collected on nine occasions at three lake sites on Big Base and Little Base Lakes, Little Rock Air Force Base, 2003-2004.

[mg/L, milligram per liter; µg/L, microgram per liter]

Trophic Classification	Oligotrophic	Mesotrophic	Eutrophic			
Test Lake				Big Lake Base East	Big Lake Base West	Little Base Lake
Total phosphorus (mg/L)						
Mean	0.01	0.03	0.08	0.04	0.03	0.04
Range	0.003-0.018	0.011 - 0.096	0.016 - 0.386			
Test lake classification				Mesotrophic	Mesotrophic	Mesotrophic
Chlorophyll *a* (µg/L)						
Mean	1.7	4.7	14.3	16.6	10.5	14.0
Range	0.3 - 4.5	3.0 - 11	3.0 - 78			
Test lake classification				Eutrophic	Mesotrophic/Eutrophic	Eutrophic
Secchi transparency (inches)						
Mean	390	165	96	34.6	35.4	24.4
Range	210-1,100	59-320	31-275			
Test lake classification				Eutrophic	Eutrophic	Eutrophic

Summary

LRAFB is the largest C-130 base in the Air Force and is the only C-130 training base in the Department of Defense. LRAFB is located in central Arkansas near the eastern edge of the Ouachita Mountains, near the Mississippi Alluvial Plain, and within the Arkansas Valley Ecoregion. Habitats include upland pine forests, upland deciduous forest, broad-leaved deciduous swamps, and two small freshwater lakes—Big Base Lake and Little Base Lake. Under normal (rainfall) conditions, Big Base Lake has a surface area of approximately 39 acres while surface area of Little Base Lake is approximately 1 acre.

Big Base and Little Base Lakes are used primarily for recreational fishing by base personnel and the civilian public. LRAFB personnel are responsible for managing the fishery in these two lakes and since 1999 have started a nutrient enhancement program that involves sporadically adding fertilizer to Big Base Lake. The purpose of fertilizing is to optimize primary (phytoplankton) production which is essential for rapid fish growth and survival in recreational fish ponds. As a means of determining the relations between water quality and primary production, LRAFB personnel have a need for biological (phytoplankton density), chemical (dissolved-oxygen and nutrient concentrations), and physical (water temperature and light transparency) data. To address these monitoring needs, the USGS in cooperation with LRAFB, conducted a study to collect and analyze biological, chemical, and physical data. The purpose of this report is to describe water-quality, phytoplankton, and trophic status characteristics at Big Base Lake and Little Base Lake from July 2003 through June 2004. Data collected in this study will be used by LRAFB personnel to make informed decisions for managing water quality to optimize fish production.

Samples were collected monthly from July 2003 through June 2004 with the exception of three winter months (December, January, and February). Two sites were sampled in Big Base Lake at two depths when the lake was stratified. One site was sampled in Little Base Lake near the center of the lake and at mid-depth. A water-quality field monitor was used to record water-column profiles for water temperature, dissolved oxygen, pH, and specific conductance at each site on every sampling occasion. Field observations included general routine observations for the appearance of the lake, weather characteristics, Secchi disc measurements (depth of light transparency), and atypical observations (the presence of waterfowl or other potential sources of impairment to water quality). Water-quality constituents selected for analyses in this study were chosen because of potential relations to lake trophic status. Nutrient constituents were the primary analyses, but some constituents analyzed were selected because of potential relations to phytoplankton density. USGS collected phytoplankton samples for identification and enumeration to increase understanding of relations between nutrient concentrations and primary production. A Trophic-State Index (TSI) that uses phytoplankton biomass as a basis for a continuum of trophic states was used to assess lake productivity. TSI values were calculated using total phosphorus, chlorophyll a, and Secchi disc measurements. As a second method of assessing lake trophic state, a general trophic classification also was applied to total phosphorus, chlorophyll a, and Secchi disc data collected from the three sampling sites.

Physical and chemical data from the water-column profiles on the nine sampling dates provide insight into the stratification characteristics of Big Base and Little Base Lakes. Lake profile data indicate that Big Base Lake was stratified on five of the nine sampling occasions (July, August, September, and October 2003 and June 2004), but that isothermic conditions persisted at Little Base Lake on all sampling occasions. Observations made as samples were collected also may provide some insight for potential nutrient sources. Some waterfowl were present on most sampling occasions, and their feces almost always were apparent on the shoreline. In April 2004, a flock of approximately 120 ducks was present in Big Base Lake. In addition to being a source of nutrients, dabbling ducks could resuspend nutrients from bottom sediments.

Frequent detections of dissolved nitrogen constituents and no detection of dissolved phosphorus constituents indicate that nitrogen is not limiting primary production in either of the lakes but that phosphorus could be limiting primary production in the two lakes. Dissolved ammonia (as N) was detected in 27 of 32 samples collected from the two sites on Big Base Lake and was detected from 6 of 9 samples collected on Little Base Lake. Dissolved ammonia concentrations ranged from 0.01 to 1.3 mg/L. Nitrates and nitrites (also dissolved) were detected less frequently and in low concentrations in about 25 percent of samples. Dissolved phosphorus constituents-orthophosphorus and dissolved phosphorus-were not detected in any samples collected at the two lakes and total phosphorus concentrations averaged about 0.03 mg/L. The absence of dissolved phosphorus constituents and presence of total phosphorus constituents indicate that all phosphorus was bound to suspended material (sediment particles and living organisms). Nitrogen:phosphorus ratios on most sampling occasions tended to be slightly higher than 16:1, which can be interpreted as further indication that phosphorus could be limiting primary production to some extent.

Alkalinity is of interest to fishery managers because it can influence the availability of nutrients and the buffering capacity of the water body being managed. Adding lime to lakes that have acid soils in the watershed tends to increase alkalinity and increase the availability of nutrients to phytoplankton. An alkalinity of 20 mg/L of calcium carbonate (mg/L of $CaCO_3$) or higher is recommended to optimize nutrient availability and buffering capacity in recreational fishing lakes and ponds. Median values for the three sites ranged from 12 to 13 mg/L of $CaCO_3$. Alkalinities ranged from 9-60 mg/L of $CaCO_3$ but 13 of 17 samples collected in Big Base Lake West had alkalinities less than 20 mg/L of $CaCO_3$.

Results of three trophic-state indices, and a general trophic classification, as well as abundant green algae and large growths of blue-green algae indicate that Big Base Lake may be eutrophic. Trophic-state index values calculated using total

phosphorus, chlorophyll *a*, and Secchi disc measurements from both lakes generally exceeded criteria at which lakes are considered to be eutrophic. A second method of determining lake trophic status-the general trophic classification-categorized the three sampling sites as mesotrophic or eutrophic. Green algae were found to be in abundance throughout most of the study period with the lowest biovolume during April and May 2004. Many of the green algae, such as *Ankistrodesmus, Cryptomonas, Cyclotella,* and *Crucigenia* that were identified are less than 20 microns making them an appropriate size for zooplankton grazing; however, the abundance of green algae also is evidence of eutrophy.

In addition to being of little use as a food source to filter feeding zooplankton, some blue-green algae such as *Anabaena* species, can produce algal toxins such as microcystin, a hepatotoxin that can cause serious illness to humans as well as other mammals. In some States, blue-green algal densities at Big and Little Base Lakes would trigger tests for algal toxins. Fertilization of the lakes could compound the problem of algal toxicity. Introducing a fertilizer with less nitrogen than phosphorus (for example, 10:43:0 as N:P:K) to the lakes could result in lake water being nitrogen limited. Nitrogen-limited lake water could favor blue-green algae (such as *Anabaena* or *Microcystis* spp.) that have the ability to fix atmospheric nitrogen as a nutrient source.

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APPENDIXES

Appendix 1. Physical and chemical field data collected at Big Base Lake East, Little Rock Air Force Base, Arkansas, 2003-2004.

[° C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microseimens per centimeter at 25 degrees Celsius; *, missing data]

Date	Time	Sampling depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Secchi disc (inches)
7/3/2003	1126	1	31.7	7.8	8.4	46	
	1128	3	29.8	7.2	7.3	46	30
	1129	5	28.2	4.3	6.5	44	
	1130	6	27.6	1.6	6.0	43	
	1131	7	26.4	0.2	6.0	47	
	1132	8	24.8	0.2	6.4	66	
	1133	9	23.3	0.2	6.5	78	
	1134	10	21.8	0.1	6.6	92	
	1135	11	20.1	0.1	6.7	110	
	1136	12	18.6	0.1	6.8	118	
	1137	13	17.3	0.1	6.9	128	
	1138	14	16.4	0.1	6.9	132	
8/5/2003	1116	1	29.8	7.5	8.2	43	
	1117	3	29.8	7.3	8.1	43	40
	1119	5	29.7	7.1	7.6	42	
	1120	8	28.6	2.2	6.3	44	
	1121	9	27.8	0.3	6.2	48	
	1123	10	25.8	0.2	6.4	86	
	1124	11	23.6	0.1	6.5	119	
	1125	12	22.1	0.1	6.7	139	
	1126	13	19.8	0.1	6.9	159	
	1127	14	18.3	0.1	7.0	175	
	1128	16	16.7	0.1	7.3	192	
9/4/2003	1110	1	27.7	4.4	6.6	47	
	1111	3	27.7	4.1	6.4	48	33
	1112	8	27.5	3.6	6.4	48	
	1113	11	26.2	0.3	6.5	90	
	1114	12	23.1	0.1	6.5	159	
	1115	13	21.0	0.1	6.6	174	
	1116	14	19.7	0.1	6.7	198	
	1117	15	18.3	0.1	6.8	218	
	1118	16	17.6	0.1	6.9	233	
10/8/2003	1014	1	21.5	8.7	7.8	51	
	1015	3	20.9	8.3	7.7	50	
	1016	6	20.3	6.4	7.4	52	28
	1017	9	20.1	5.3	7.3	52	
	1018	12	20	3.5	7.2	55	
	1019	13	19.9	2.4	7.2	56	

Appendix 1. Physical and chemical field data collected at Big Base Lake East, Little Rock Air Force Base, Arkansas, 2003-2004.—Continued

[° C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microseimens per centimeter at 25 degrees Celsius; *, missing data]

Date	Time	Sampling depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Secchi disc (inches)
11/5/2003	853	1	20.1	7.4	6.8	53	
	854	3	20	7.5	6.9	53	
	855	7	20	7.6	6.8	53	42
	856	9	18.6	3.6	6.4	56	
	857	11	18.1	1.7	6.3	60	
3/9/2004	1007	1	14.2	10.2	7.0	38	
	1008	3	14.2	10	7.0	38	
	1009	6	14.1	10	7.0	38	29
	1010	9	14.1	9.9	7.1	38	
	1011	11	14.1	9	7.0	38	
4/15/2004	*	1	*	*	*	*	
	854	3	16.2	8.7	7.0	44	
	855	6	15.5	8.1	6.8	43	43
	856	9	15.1	7.8	6.8	44	
	857	12	14.9	7.3	6.7	44	
	858	15	14.8	6.8	6.6	44	
5/13/2004	921	1	24.1	6.9	6.7	42	
	922	3	24.1	6.8	6.7	42	37
	923	6	23.9	5.3	6.5	43	
	925	8	21.7	1.6	6.1	44	
	926	9	21.3	1.2	6.0	45	
	927	10	20.5	0.7	6.0	47	
	928	11	18.6	0.2	6.0	55	
	929	12	17.4	0.2	6.1	60	
	930	13	16.1	0.1	6.1	65	
	931	14	15.6	0.1	6.2	69	
6/15/2004	1027	1	29.4	4.5	6.8	39	
	1028	4	29.4	4.4	6.8	39	44
	1029	5	29.4	4.2	6.8	39	
	1030	6	27.7	0.5	6.9	56	
	1031	7	25.5	0.2	7.2	70	
	1032	8	23.7	0.2	7.1	75	
	1033	9	21.2	0.3	6.9	77	
	1034	10	19.8	0.3	6.9	84	
	1035	12	17.9	0.3	6.8	92	
	1036	14	15.9	0.2	6.9	110	

Appendix 2. Physical and chemical field data collected at Big Base Lake West, Little Rock Air Force Base, Arkansas, 2003-2004.

[° C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microseimens per centimeter at 25 degrees Celsius]

Date	Time	Sampling depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Secchi disc (inches)
7/3/2003	1013	1	30.9	8.0	8.2	46	
	1014	3	29.7	7.4	7.5	45	32
	1015	5	28.3	4.2	6.6	44	
	1016	6	27.3	0.8	6.0	42	
	1017	7	26.2	0.3	6.1	50	
	1018	8	25.2	0.2	6.3	62	
	1019	9	23.1	0.2	6.5	80	
	1020	10	21.7	0.1	6.6	94	
	1021	11	20.1	0.1	6.7	105	
	1022	12	19.0	0.1	6.8	113	
	1023	13	18.1	0.1	6.8	116	
	1024	14	16.8	0.1	6.9	124	
	1026	15	15.6	0.1	7.0	137	
	1028	17	14.6	0.1	7.0	152	
	1029	19	14.1	0.1	7.1	160	
8/5/2003	1005	1	29.8	6.9	6.9	43	
	1008	3	29.8	6.9	6.8	43	35
	1010	5	29.6	6.3	6.6	43	
	1012	8	28.6	1.4	5.8	43	
	1013	9	27.6	0.3	5.8	53	
	1014	10	25.5	0.2	6.1	90	
	1016	11	23.5	0.2	6.2	119	
	1017	12	21.4	0.2	6.3	138	
	1018	13	19.8	0.2	6.5	138	
	1019	14	18.1	0.1	6.7	161	
	1020	15	16.7	0.1	7.0	180	
	1022	17	15.8	0.1	7.5	197	
	1024	19	14.9	0.1	8.0	220	
9/4/2003	1015	1	27.7	4.5	6.5	48	
	1018	3	27.7	4.1	6.4	48	34
	1020	7	27.5	3.6	6.3	48	
	1021	10	27.1	3.1	6.4	52	
	1023	13	21	0.2	6.6	174	
	1024	14	19.8	0.1	6.7	186	
	1026	16	17.6	0.1	6.9	217	

Appendix 2. Physical and chemical field data collected at Big Base Lake West, Little Rock Air Force Base, Arkansas, 2003-2004.—Continued

[° C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microseimens per centimeter at 25 degrees Celsius]

Date	Time	Sampling depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Secchi disc (inches)
	1028	17	16.5	0.1	7.1	237	
	1029	19	15.7	0.1	7.2	261	
	1030	21	15	0.1	7.3	285	
10/8/2003	915	1	21.3	8.5	7.2	50	
	916	3	21.1	8.0	7.1	50	
	917	6	20.4	6.4	6.9	51	30
	918	9	20.1	4.8	6.8	52	
	920	12	19.8	1.9	6.7	58	
	922	16	18.5	0.3	7.4	228	
	923	19	15.8	0.2	8.0	377	
11/5/2003	759	1	20.1	7.6	6.9	53	
	800	3	20.1	7.6	6.9	53	
	801	6	20.1	7.5	6.9	53	44
	802	9	19	4.9	6.5	54	
	803	12	18	3.3	6.4	56	
	804	15	17.5	1.6	6.3	59	
	805	18	17.2	0.3	6.3	68	
	806	20	16.5	0.2	7.1	238	
3/9/2004	910	1	14.0	10.0	7.0	37	
	911	3	14.0	9.9	7.0	38	28
	912	6	13.9	9.9	7.0	38	
	913	9	13.8	9.9	6.9	38	
	914	10	12.9	8.9	6.6	38	
	915	11	11.6	7.7	6.3	39	
	916	13	10.9	7.6	6.3	39	
	917	15	10.2	6.5	6.2	40	
	918	17	10.0	5.6	6.1	40	
	919	19	9.9	4.8	6.1	41	
	920	21	9.8	4.2	6.1	41	
4/15/2004	813	2	16.2	8.7	7.1	44	41
	814	6	15.7	8.4	7.1	44	
	815	9	15.1	7.7	7.0	44	
	816	12	14.9	7.2	6.9	44	

Appendix 2. Physical and chemical field data collected at Big Base Lake West, Little Rock Air Force Base, Arkansas, 2003-2004.—Continued

[° C, degrees Celsius; mg/L, milligrams per liter; µS/cm, microseimens per centimeter at 25 degrees Celsius]

Date	Time	Sampling depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Secchi disc (inches)
	817	15	14.7	6.9	6.8	45	
	818	18	14.4	5.6	6.6	47	
	819	19	13.7	2.5	6.4	57	
5/13/2004	828	2	24.1	7.2	6.5	42	
	829	3	24.1	7.1	6.6	42	42
	830	6	24.1	6.9	6.5	42	
	833	4	24.1	6.9	6.5	41	
	834	7	23.0	3.9	6.3	43	
	835	9	21.1	1.4	6.1	45	
	836	11	19.3	0.3	6.0	54	
	837	12	17.0	0.2	6.0	56	
	838	13	16.0	0.2	6.0	61	
	839	15	14.9	0.2	6.1	71	
	840	18	14.2	0.2	6.3	90	
	841	20	14.0	0.2	6.5	95	
6/15/2004	934	1	29.7	5.0	6.8	39	
	935	4	29.7	5.0	6.8	39	32
	937	5	29.6	4.5	6.8	39	
	938	6	27.8	0.7	6.8	56	
	939	8	22.9	0.5	6.9	69	
	940	10	20.2	0.5	6.8	76	
	941	12	17.9	0.4	6.7	86	
	942	13	17.0	0.3	6.8	91	
	943	15	15.7	0.1	6.8	103	
	944	18	14.6	0.1	6.9	123	
	945	19	14.4	0.1	6.9	131	
	946	20	14.2	0.1	7.0	137	

Appendix 3. Physical and chemical field data collected at Little Base Lake, Little Rock Air Force Base, Arkansas, 2003-2004.

[° C, degrees Celsius; mg/L, milligrams per liter; μS/cm, microseimens per centimeter at 25 degrees Celsius]

Date	Time	Sampling depth (feet)	Water temperature (° C)	Dissolved oxygen (mg/L)	pH	Specific conductance (μS/cm)	Secchi disc (inches)
7/3/2003	1304	1	32.4	6.5	6.5	44	
	1305	2	30.1	5.4	6.3	44	24
	1306	3	29.2	3.8	6.2	45	
	1307	4	29.0	2.8	6.1	46	
8/5/2003	1312	1	29.5	5.0	6.6	41	23
	1313	2	29.5	4.9	6.5	41	
	1314	3	29.5	4.8	6.4	41	
	1315	4	29.4	4.1	6.3	41	
9/4/2003	1238	1	28.0	6.5	6.7	44	
	1239	2	28.0	6.3	6.6	44	31
	1240	3	27.2	5.8	6.5	44	
	1241	4	27.0	5.5	6.4	43	
10/8/2003	1059	1	21.2	8.1	7.5	45	
	1100	2	21.1	8.1	7.4	46	24
	1101	3	20.9	7.8	7.3	46	
11/5/2003	938	1	20.3	7.3	6.8	50	
	939	2	20.3	7.2	6.8	50	23
	940	3	20.1	7.3	6.7	50	
3/9/2004	1057	1	14.5	7.8	6.3	34	
	1058	2	14.5	7.8	6.4	34	13
	1059	3	14.5	7.8	6.3	34	
4/15/2004	931	1	15.9	7.7	6.6	42	
	932	2	15.9	7.7	6.5	43	28
	933	3	15.9	7.7	6.5	42	
5/13/2004	1014	1	22.9	5.4	6.4	44	
	1015	2	22.9	5.0	6.4	44	30
	1016	3	22.9	4.9	6.3	44	
	1017	4	22.7	4.6	6.3	45	
6/15/2004	1200	1	28.9	4.1	6.6	39	
	1201	2	29.0	3.9	6.6	40	23
	1202	3	28.9	3.8	6.6	40	

Appendix 4. Laboratory results for water samples collected from three sampling sites in Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.

[mg/L, milligram per liter; N, nitrogen, P, phosphorus, NTU, nephelmetric turbidity units, $CaCO_3$, calcium carbonate; bold, value calculated using one-half of the detection limit for dissolved ammonia; *, missing data]

Sampling date	Sampling depth (feet)	Ammonia plus organic nitrogen dissolved (mg/L as N)	Ammonia plus organic nitrogen total (mg/L as N)	Ammonia dissolved (mg/L as N)	Nitrite plus nitrate dissolved (mg/L as N)	Nitrite dissolved (mg/L as N)	Organic nitrogen dissolved (mg/L)	Organic nitrogen total (mg/L)
Big Base Lake East								
7/03/2003	3	0.2	0.6	<0.01	<0.02	<0.01	**0.20**	**0.60**
7/03/2003	8	0.3	0.8	<0.01	<0.02	<0.01	**0.30**	**0.80**
8/05/2003	3	0.4	0.7	0.01	<0.02	<0.01	0.39	0.69
8/05/2003	10	0.4	0.6	0.02	<0.02	<0.01	0.38	0.58
9/04/2003	3	0.4	0.6	0.06	0.02	<0.01	0.34	0.54
9/04/2003	13	0.4	0.7	0.07	<0.02	<0.01	0.33	0.63
10/08/2003	6	0.5	0.7	0.07	0.03	<0.01	0.43	0.63
11/05/2003	7	0.5	0.6	0.14	0.09	<0.01	0.36	0.46
3/09/2004	6	0.3	0.5	0.01	<0.02	<0.01	0.29	0.49
4/15/2004	6	0.3	0.6	0.02	0.03	<0.01	0.28	0.58
5/13/2004	3	0.3	1.0	0.02	<0.02	<0.01	0.28	0.98
5/13/2004	12	0.3	0.7	0.04	<0.02	<0.01	0.26	0.66
6/15/2004	4	0.6	1.1	0.26	<0.02	<0.01	0.34	0.84
6/15/2004	10	0.9	1.0	0.62	<0.02	<0.01	0.28	0.38
Minimum	3	0.2	0.5	<0.01	<0.02	<0.01	**0.19**	0.38
Maximum	13	0.9	1.1	0.62	0.09	<0.01	0.43	0.98
Median	6	0.4	0.7	0.03	<0.02	<0.01	0.31	0.61
Big Base Lake West								
7/03/2003	3	0.4	0.6	<0.01	<0.02	<0.01	**0.40**	**0.60**
7/03/2003	13	1.7	1.7	1.2	<0.02	<0.01	0.50	0.50
8/05/2003	3	0.3	0.8	<0.01	<0.02	<0.01	**0.30**	**0.80**
8/05/2003	13	0.7	1.1	0.53	<0.02	<0.01	0.17	0.57
9/04/2003	3	0.4	0.6	0.07	<0.02	<0.01	0.33	0.53
9/04/2003	16	0.4	0.6	0.07	<0.02	<0.01	0.33	0.53
10/08/2003	6	0.4	0.6	0.07	0.03	<0.01	0.33	0.53
10/08/2003	16	1.8	2.2	1.3	<0.02	<0.01	0.50	0.90
11/05/2003	6	0.5	0.6	0.15	0.09	<0.01	0.35	0.45
11/05/2003	18	1.1	1.3	0.64	<0.02	<0.01	0.46	0.66
3/09/2004	3	0.3	0.6	0.02	<0.02	<0.01	0.28	0.58
3/09/2004	17	0.3	0.5	0.04	0.06	<0.01	0.26	0.46
4/15/2004	2	0.3	0.5	0.02	0.02	<0.01	0.28	0.48

Appendix 4. Laboratory results for water samples collected from three sampling sites in Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2003-2004.—Continued

[mg/L, milligram per liter; N, nitrogen, P, phosphorus, NTU, nephelmetric turbidity units, $CaCO_3$, calcium carbonate; bold, value calculated using one-half of the detection limit for dissolved ammonia; *, missing data]

Sampling date	Sampling depth (feet)	Ammonia plus organic nitrogen dissolved (mg/L as N)	Ammonia plus organic nitrogen total (mg/L as N)	Ammonia dissolved (mg/L as N)	Nitrite plus nitrate dissolved (mg/L as N)	Nitrite dissolved (mg/L as N)	Organic nitrogen dissolved (mg/L)	Organic nitrogen total (mg/L)
Big Base Lake West (continued)								
4/15/2004	18	0.5	0.6	0.13	0.03	<0.01	0.37	0.47
5/13/2004	3	0.4	0.7	0.02	<0.02	<0.01	0.38	0.68
5/13/2004	12	0.3	0.5	<0.01	<0.02	<0.01	0.30	0.50
6/15/2004	4	0.6	1	0.18	<0.02	<0.01	0.42	0.82
6/15/2004	12	0.9	1.2	0.66	<0.02	<0.01	0.24	0.54
Minimum	2	0.3	0.5	<0.01	<0.02	<0.01	0.17	0.45
Maximum	18	1.8	2.2	1.3	0.09	<0.01	0.50	0.90
Median	9.0	0.4	0.6	0.07	<0.2	<0.01	0.33	0.54
Little Base Lake								
7/03/2003	2	0.3	0.7	<0.01	<0.02	<0.010	**0.30**	**0.70**
8/05/2003	3	0.4	0.7	<0.01	<0.02	<0.010	**0.40**	**0.70**
9/04/2003	2	0.3	0.6	0.02	<0.02	<0.010	0.28	0.58
10/08/2003	2	0.3	0.8	<0.01	<0.02	<0.010	**0.30**	**0.80**
11/05/2003	2	0.5	0.8	0.02	<0.02	<0.010	0.48	0.78
3/09/2004	2	0.4	0.6	0.02	<0.02	<0.010	0.38	0.58
4/15/2004	2	0.4	0.6	0.02	0.03	<0.010	0.38	0.58
5/13/2004	2	0.4	0.7	0.05	<0.02	<0.010	0.35	0.65
6/15/2004	2	0.4	0.8	0.01	<0.02	<0.010	0.39	0.79
Minimum	2	0.3	0.6	<0.01	<0.02	<0.01	0.28	0.58
Maximum	3	0.5	0.8	0.05	0.03	<0.01	0.48	0.80
Median	2	0.4	0.7	0.02	<0.02	<0.01	0.38	0.70

Appendix 4. Laboratory results for water samples collected from the three sampling sites in two lakes on Little Rock Air Force Base, Arkansas, 2003-2004.—Continued

[mg/L, milligram per liter; N, nitrogen, P, phosphorus, NTU, nephelmetric turbidity units, $CaCO_3$, calcium carbonate; bold, value calculated using one-half of the detection limit; *, missing data]

Sampling date	Sampling depth (feet)	Ortho-phosphate dissolved (mg/L as P)	Phos-phorus dissolved (mg/L)	Phos-phorus total (mg/L)	Total nitrogen dissolved (mg/L)	Total nitrogen total (mg/L)	Chloro-phyll *a* fluoro-metric, (µg/L)	Turbidity (NTU)	Alkalinity as $CaCO_3$ (mg/L)
Big Base Lake East									
7/03/2003	3	<0.01	<0.02	0.03	0.21	0.61	11.0	6	23
7/03/2003	8	<0.01	<0.02	0.05	0.31	0.81	5.0	12	15
8/05/2003	3	<0.01	<0.02	0.02	0.41	0.71	36.0	4	11
8/05/2003	10	<0.01	<0.02	<0.02	0.41	0.61	11.0	5	12
9/04/2003	3	<0.01	<0.02	0.03	0.41	0.61	18.0	4	13
9/04/2003	13	<0.01	<0.02	0.03	0.41	0.71	15.0	4	12
10/08/2003	6	<0.01	<0.02	0.02	0.53	0.73	12.0	7	14
11/05/2003	7	<0.01	<0.02	0.03	0.59	0.69	4.1	4	17
3/09/2004	6	<0.01	<0.02	0.03	0.31	0.51	11.0	1	12
4/15/2004	6	<0.01	<0.02	0.04	0.33	0.63	15.0	5	10
5/13/2004	3	<0.01	<0.02	0.05	0.31	1.01	48.0	6	15
5/13/2004	12	<0.01	<0.02	0.04	0.31	0.71	34.0	9	13
6/15/2004	4	<0.01	<0.02	0.05	0.61	1.11	10.0	9	12
6/15/2004	10	<0.01	<0.02	0.03	0.91	1.01	3.1	6	28
Minimum	3	<0.01	<0.02	<0.02	0.21	0.51	3.1	1	10
Maximum	13	<0.01	<0.02	0.05	0.91	1.11	48.0	12	28
Median	7	<0.01	<0.02	0.03	0.41	0.71	11.5	5	13
Big Base Lake West									
7/03/2003	3	<0.01	<0.02	0.03	0.41	0.61	22	6	16
7/03/2003	13	<0.01	<0.02	0.02	1.71	1.71	7.0	1	57
8/05/2003	3	<0.01	<0.02	0.03	0.31	0.81	6.9	3	12
8/05/2003	13	<0.01	<0.02	0.04	0.71	1.11	*	14	60
9/04/2003	3	<0.01	<0.02	0.03	0.41	0.61	17	4	13
9/04/2003	16	<0.01	<0.02	0.03	0.41	0.61	13	4	13
10/08/2003	6	<0.01	<0.02	0.02	0.43	0.63	13	7	13
10/08/2003	16	<0.01	<0.02	0.03	1.81	2.21	7.3	30	*
11/05/2003	6	<0.01	<0.02	0.02	0.59	0.69	*	4	19
11/05/2003	18	<0.01	<0.02	0.04	1.11	1.31	3.4	15	23
3/09/2004	3	<0.01	<0.02	0.02	0.31	0.61	13	1	17
3/09/2004	17	<0.01	<0.02	<0.02	0.36	0.56	6.1	1	12
4/15/2004	2	<0.01	<0.02	0.04	0.32	0.52	26	5	10

Appendix 4. Laboratory results for water samples collected from the three sampling sites in two lakes on Little Rock Air Force Base, Arkansas, 2003-2004.—Continued

[mg/L, milligram per liter; N, nitrogen, P, phosphorus, NTU, nephelmetric turbidity units, $CaCO_3$, calcium carbonate; bold, value calculated using one-half of the detection limit; *, missing data]

Sampling date	Sampling depth (feet)	Ortho-phosphate dissolved (mg/L as P)	Phos-phorus dissolved (mg/L)	Phos-phorus total (mg/L)	Total nitrogen dissolved (mg/L)	Total nitrogen total (mg/L)	Chloro-phyll *a* fluoro-metric, (µg/L)	Turbidity (NTU)	Alkalinity as $CaCO_3$ (mg/L)
Big Base Lake West (continued)									
4/15/2004	18	<0.01	<0.02	0.04	0.53	0.63	8.8	7	10
5/13/2004	3	<0.01	<0.02	0.03	0.41	0.71	16	5	10
5/13/2004	12	<0.01	<0.02	0.02	0.31	0.51	7.8	5	17
6/15/2004	4	<0.01	<0.02	0.05	0.61	1.01	9.6	9	13
6/15/2004	12	<0.01	<0.02	0.03	0.91	1.21	1.7	5	33
Minimum	1.9	<0.01	<0.02	<0.02	0.31	0.51	1.7	1	10
Maximum	18.1	<0.01	<0.02	0.05	1.81	2.21	26	30	60
Median	9.0	<0.01	<0.02	0.03	0.42	0.66	9.2	5.2	13.4
Little Base Lake									
7/03/2003	2	<0.01	<0.02	0.05	0.31	0.71	8.6	12	28
8/05/2003	3	<0.01	<0.02	0.03	0.41	0.71	30.0	7	12
9/04/2003	2	<0.01	<0.02	0.04	0.31	0.61	20.0	5	12
10/8/2003	2	<0.01	<0.02	0.04	0.31	0.81	13.0	9	9
11/5/2003	2	<0.01	<0.02	0.04	0.51	0.81	9.7	6	14
3/09/2004	2	<0.01	<0.02	0.03	0.41	0.61	6.7	3	9
4/15/2004	2	<0.01	<0.02	0.05	0.43	0.63	6.8	8	9
5/13/2004	2	<0.01	<0.02	0.05	0.41	0.71	18.0	9	10
6/15/2004	2	<0.01	<0.02	0.06	0.41	0.81	13.0	15	13
Minimum	2	<0.01	<0.02	0.03	0.31	0.61	6.7	3	9
Maximum	3	<0.01	<0.02	0.06	0.51	0.81	30	15	28
Median	2	<0.01	<0.02	0.04	0.41	0.71	13.0	8	12

Appendix 5. Taxonomic list and biovolume for algae identified from water samples collected at Big Base and Little Base Lakes, Little Rock Air Force Base, 2003-2004.

[μm^3, cubic micrometer; B, blue-green algae; D, diatoms; G, green algae; flagellates (Chl, Chlorophyceae; Chrypto, Cryptophyceae; Crys, Chrysophyceae; Dino, Dinophyceae; E, Euglenphyceae; Pr, Prymnesiophyceae)]

Taxon	Cell biovolume (μm^3)	Group
Achnanthes	36	D
Actinastrum gracilimum	523	G
Amphora	36	D
Anabaena	603	B
Anabaena planktonica	2,194	B
Anabaena affinis	1,256	B
Anabaenopsis	120	B
Ankistrodesmus falcatus	100	G
Ankyra	100	G
Aphanotheca	400	B
Aphanizomenon flos-aquae	1,337	B
Asterionella formosa	480	D
Attheya zachariasi	800	D
Botryococcus braunii	3,000	G
Carteria sp.	696	Chl
Centritractus dubius	208	G
Ceratium hirundinella	9,000	Dino
Ceratium cornutum	720	Dino
Characium ambiguum	50	G
Chlamydomonas sp.	65	Chl
Chlorella sp.	33	G
Chlorococcus sp.	50	G
Chlorogonium euchlorum	100	Chl
Chodatella longiseta	100	G
Chroococcus prescotti	288	B
Chroomonas sp.	113	Chrypto
Chrysochromulina sp.	28	Crys
Chrysococcus sp.	33	Crys
Closterium sp. A	334	G
Closterium sp. B	1,030	G
Closteriopsis longissima	168	G
Coelastrum microporum	904	G
Coelastrum proboscideum	675	G
Cosmarium sp. A	108	G
Cosmarium sp. B	1,808	G
Crucigenia rectangularis	432	G
Crucigenia truncata	128	G
Cruciginia tetrapedia	112	G

Taxon	Cell biovolume (μm^3)	Group
Cyanarcus hamiformis	20	B
Cryptomonas sp. A	30	Chrypto
Cryptomonas sp. B	112	Chrypto
Cyclotella sp. A	452	D
Cyclotella sp. B	56	D
Cymatopleura sp.	5,137	D
Cymbella sp.	50	D
Diatoma vulgare	4,452	D
Dictyosphaerium pulchellum	7,238	G
Dinobryon sp. A	42	Cryso
Dinobryon sp. B	235	Crys
Dinobryon sp. C	3,142	Crys
Dysmorphococcus globosus	904	Chl
Euastrum ciastontii	720	G
Euglena sp. A	753	E
Euglena sp. B	2,220	E
Euglena sanguineria	4,536	E
Eunotia	36	D
Fragilaria crotonensis	7,200	D
Fragilaria sp.	384	D
Franceia ovalis	56	G
Glenodinium sp.	140	Dino
Gloeotheca sp.	12	B
Golenkinia radiata	14	G
Gomphonema sp. A	35	D
Gomphonema sp. B	720	D
Gomphosphaeria lacustris	1,296	D
Gonium sp	3,267	G
Gymnodinium sp. A	720	Dino
Gymnodinium sp. B	3,448	Dino
Hormidium klebsii	393	G
Hymenomonas sp.	48	Pr
Kirchneriella elongata	1,25	G
Lagynion sp.	20	Crys
Mallomonas sp. A	381	Crys
Mallomonas sp. B	3,534	Crys
Melosira sp. A	3,506	D
Melosira sp. B	303	D

Appendix 5. Taxonomic list and biovolume for algae identified from water samples collected at Big Base and Little Base Lakes, Little Rock Air Force Base, 2003-2004.—Continued

[μm^3, cubic micrometer; B, blue-green algae; D, diatoms; G, green algae; flagellates (Chl, Chlorophyceae; Chrypto, Cryptophyceae; Crys, Chrysophyceae; Dino, Dinophyceae; E, Euglenphyceae; Pr, Prymnesiophyceae)]

Taxon	Cell biovolume (μm^3)	Group
Meridion sp.	548	D
Merismopedia tenuissima	64	B
Merismopedia convulta	588	B
Micratanium pusillum	155	G
Microcystis sp.	1,155	B
Mougeotia sp.	510	G
Nannochloris sp.	19	G
Navicula sp. A	432	D
Navicula sp. B	141	D
Nitzschia sp.	141	D
Nitzschia hungarica	904	D
Ochromonas sp.	14	Crys
Oocystis sp.	388	G
Ophiocytium capitatum	650	G
Oscillatoria sp.	282	B
Oscillatoria tenuis	785	B
Oscillatoria rubescens	263	B
Paulschulzia sp.	72	G
Pediastrum tetra	288	G
Pediastrum sp.	1,809	G
Peridinium sp. A	24,480	Dino
Peridinium sp. B	6,682	Dino
Peridinium sp. C	1,017	Dino
Phacotus sp.	72	Chl
Phacus longicauda	6,082	E
Phacus lemmermania	508	E
Phormidium tenue	263	B
Pleurosigma sp.	480	D
Pseudokephyrion sp.	34	Crys
Pteromonas sp.	20	G
Quadrigula lacustris	226	G
Raphidiopsis sp.	12	B
Rhabdoderma sp.	36	B
Rhizosolenium sp.	3,015	D
Rhoicosphenia sp.	509	D
Scenedesmus sp.	32	G
Scenedesmus abundans	300	G
Scenedesmus armatus	576	G
Schroderia sp.	79	G
Selenastrum sp.	37	G
Sphaerocystis sp.	24,429	G
Staurastrum sp. A	675	G
Staurastrum sp. B	1,296	G
Stephanodiscus sp.	371	D
Suriella linearis	2,064	D
Suriella sp. A	989	D
Suriella sp. B	4,500	D
Synedra sp. A	94	D
Synedra sp. B	2,827	D
Synura sp.	7,238	Crys
Tetraedron minimum	50	G
Tetraedron regulare	200	G
Tetraedron gracile	576	G
Tetraedron regulare	65	G
Trachelomonas sp. A	268	E
Trachelomonas sp. B	904	E
Trachelomonas sp. C	2,035	E
Trachelomonas sp. D	6,107	E
Trachelomonas sp. E	8,482	E
Trebaria sp.	65	G