# An Assessment of the Biological Health and Water Quality of Four Coastal Dune Lakes in Walton and Bay Counties

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2001

**TITLE:** An Assessment of the Biological Health and Water Quality of Four Coastal Dune Lakes in Walton and Bay Counties.

**ABSTRACT:** Biological and physicochemical assessments were performed on four coastal dune lakes in the panhandle during late winter 2000. The macrobenthic community was selected as the primary biological monitor of the health of these lakes. Chlorophyll *a* and the phytoplankton communities were also included in the biological assessment. A suite of chemical parameters was analyzed from each lake to determine the level of nutrients and possible pollutants in the water. While the overall water quality and health of these lakes is reasonably good, there were indicators that signal a level concern. Early signs of nutrient increase in most of these lakes suggest the possible effects of expanding population and development may already be showing up in these water bodies.

## Acknowledgments

We would like to express gratitude to Kenny Ferguson who helped with the fieldwork, collecting biology and water samples. He also untiringly spent many days at the microscope sorting the macroinvertebrates from the sediments for subsequent identification and enumeration. We also express appreciation to Barbara Ruth for critically reviewing this report.

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# INTRODUCTION

The Florida panhandle is one of the fastest growing regions in Florida. It is due to this rapid rate of growth that the integrity of many natural resources in the panhandle is being threatened. Among the most threatened resources: Water, especially coastal waters and lakes. The many social and aesthetic qualities associated with waterfront living often result in high-density development around these fragile systems.

Florida's karst topography, abundant rainfall and ever-changing coastline provide an ideal landscape for the formation of lakes. The state has been divided into 47 lake regions based on physiography, hydrology and geology (Griffith, et al. 1997).

A unique system in Florida is the Coastal Dune Lakes found in the lake region known as the Gulf Coastal Lowlands (lake region 75-01) (Griffith, et al. 1997) (Figure 1). Coastal dune lakes typically are within two miles of the coast and lie in an elliptical shape that is oriented perpendicular to the coast; however, a few are irregular and lie parallel to the coast. These lakes lie in depressions that are protected to varying degrees by sand dunes.

The water in most of these systems is dark, stained by tannic acids. Water input is primarily from lateral movement of subsurface flow; some also have small streams that discharge into them. There are a few exceptions to this water quality and Campbell Lake in Topsail Hill State Preserve is one of them. This lake is clear and is probably spring-fed. Natural connections to the Gulf of Mexico are typically ephemeral and occur when the basin fills with water to the point where pressure opens a shallow outlet. These connections provide intermittent saline tidal waters to enter the lakes.

Many coastal lakes have their water level manipulated to accommodate development that has encroached too close to shore. Since these systems naturally have fluctuating water levels and lie in low elevation settings, development may occur when water levels are low and do not take into account this variability. Thus, artificial water drawdowns of these lakes exact a greater marine influence on many of these systems today. Often, the public desires the marine influence for inshore fishing opportunities and a connection to the Gulf of Mexico.

There are a few examples of lakes that have been left in a nearly natural state (e.g., Deer, Morris and Campbell). These systems do exhibit a freshwater community, based on the macrobenthos and aquatic plants. Archeological evidence indicates that Lake Powell has primarily been a freshwater lake with sporadic occurrences of marine tidal flush through the inlet (DEP, 1997). However, for most of the last 100 years, the outlet to the gulf, Phillips Inlet, has been dredged and the connection maintained. Recently, the Division of Parks has limited the frequency of dredging the outlet. The dynamic environmental influence of an intermittent connection to the Gulf defines a coastal dune lake.

## Materials and Methods

### Water Quality

Some physicochemical parameters were measured in situ with a Hydrolab® multiparameter probe. Those parameters included: dissolved oxygen (DO) (mg/L); pH (standard units (SU)); temperature (°C) and conductivity (µmho/cm). A profile of these parameters was recorded by taking surface, mid- and bottom depth readings in each lake. These measurements were taken near the center of each lake or, if the lake was subdivided, near the center of each subdivision. A physical parameter in assessing water quality in lakes is transparency. This is measured using a Secchi disk; it is lowered into the water column to the point where the alternating black-white divisions are just visible.

Grab samples of certain water quality indicators were taken approximately 30 cm below surface at locations where the Hydrolab® measurements were taken. If the lake was subdivided and sampled for macroinvertebrates in multiple divisions (i.e., Western Lake) grab samples were collected for water quality parameters in each subdivision. Samples for nutrients (ammonia, nitrite-nitrate, total phosphorus, total Kjeldahl nitrogen (TKN) and total organic carbon (TOC)) were collected in 500 mL plastic bottles and preserved with sulfuric acid to pH <2 SU. Water samples for turbidity, alkalinity, color and total suspended solids (TSS) were collected in 1 L plastic bottles. Water was filtered through a 0.45 µm pore Whatman® filter for orthophosphate determination and collected into 250 mL plastic bottles.

**Phytoplankton**

Phytoplankton were collected in 1 L brown Nalgene® bottles for identification to the generic level and determination of relative densities. Water for algal growth potential test (AGPT) was collected in 500 mL plastic bottles for analyses while chlorophyll *a* samples were obtained using 1 L brown Nalgene® bottles. These water quality indicators were collected near the lake center. Chlorophyll *a* and AGPT samples were placed on ice and phytoplankton were preserved using Lugol's solution. All of these samples were shipped via FedEx® to the Central Biology Laboratory in Tallahassee for analyses.

**Sediments**

Sediment composition was determined qualitatively in conjunction with sampling for benthic macroinvertebrates. Relative percents of lakebed substrate types were determined and recorded at the 12 macroinvertebrate sample locations. These locations were in the sublittoral zone. This zone is defined by the Department of Environmental Protection (DEP) protocol as that area of lake that is between 2 m-4 m deep. These analyses determined the sediment composition as defined by five classifications: sand; silt/clay; coarse particulate organic matter (>1 mm in diameter) (CPOM); muck; and submerged aquatic vegetation (SAV). The presence or absence of hydrogen sulfide odor (indicative of anaerobic conditions) was noted at each sample station. Once the sediment composition at these 12 sample locations had been determined, a sediment sample was collected from a location that represented the typical composition in the sublittoral zone. The sediment sample was collected at each lake using a petite ponar, placed in a galvanized tub then spooned into a 250 mL glass jar. These samples were placed on ice and shipped to the Central Chemistry Laboratory in Tallahassee along with other samples.

**Macroinvertebrates**

Each lake lobe was divided into twelfths for sampling the benthos; however, Western Lake was subdivided into three sections. A composite of all 12 grabs was made at each lake except Western Lake. At Western Lake, each of the three subdivisions had four composite sample locations and those composite samples were kept exclusive to each subdivision. A petite ponar was employed for quantitative sampling. The 12 sampling locations were established in the sublittoral zone. This zone is defined as that portion near the shore that is between 2 m to 4 m deep. While this zone is defined as free of rooted macrophytes, this often is not the case in Florida lakes. Many of them have an extensive zone of rooted macrophytes.

Most organisms comprising the benthic community are sedentary; thus, not capable of easily fleeing pollutants as fish often do. These organisms are good biological monitors that incorporate deleterious effects into the benthic community structure over time.

Each ponar grab per location (12 total) was placed in a galvanized steel tub then washed through an U. S. number 30 mesh net (600 $\mu m$). Composite samples of the sediments and benthos remaining on the mesh from each sample location were placed into a 2 L Nalgene® container and fixed with buffered formalin. Within 5-10 days, the formalin was replaced with 70% ethyl alcohol.

In the laboratory, each composite sample was evenly spread out in a shallow tray that had the bottom divided in 5 $cm^2$ divisions. Squares were randomly chosen, than picked using a dissecting microscope until a minimum of 100 organisms were obtained.

Identifications of macroinvertebrates were made using a Wild M3Z dissecting microscope at 6.5X-40X and a Nikon Labophot-Z compound microscope at 4X-1000X. Various state and regional keys were used for identifications, these included: Aquatic insects of North America (Merritt and Cummins, 1996); Identification manual for the larval Chironomidae (Diptera) of Florida, (Epler, 1995); Florida dragonflies (Anisoptera): a species key to the aquatic larval stages (Daigle, 1992); Florida damselflies (Zygoptera): a species key to the aquatic larval stages (Daigle, 1991); Guide to the freshwater aquatic microdrile oligochaetes of North America (Brinkhurst, 1986); Fresh-water invertebrates of the United States (Pennak, 1978); and Identification manual for the aquatic Oligochaeta of Florida, volume 1, freshwater oligochaetes (Milligan, 1997). Identifications were made to the lowest practical level possible, often to species or type.

**Multimetric Lake Condition Index**

In the freshwater environment of Deer Lake, the Lake Condition Index (LCI) was employed to determine the overall health of the lake (Gerritsen, et al. 2000). Hulbert's Index (HI) is incorporated into this multimetric index (Table 1). The HI is a modification of the Hulbert Lake Condition Index (Hulbert, 1990). The modified HI incorporates sensitive benthic macroinvertebrates. Two groups of macroinvertebrates (Class A and Class B) found to be sensitive to pollution received a numerical value. Class A taxa (most sensitive) received two points each while Class B taxa received one point each (Table 1). The index is calculated by the following formula: HI= 2(Class A taxa) + Class B taxa. This number is then incorporated into the Lake Condition Index (LCI). This index incorporates six metrics: total taxa; EOT (Ephemoroptera, Odonata, Trichoptera); percent EOT; HI; Shannon-Wiener diversity; and percent Diptera. The score from this index is then used to rank the overall condition of the water body as very good, good, poor or very poor.

## RESULTS

Lake Powell (sampled on 8 March 2000)

Samples for nutrient analyses were collected at a depth of approximately 30 cm. The nutrients were low in Lake Powell as nitrite-nitrate was below detection of 4 µg/L, total Kjeldahl-nitrogen (TKN) (organic nitrogen) was 0.34 mg/L and ammonia was below detection of 10 µg/L; thus, total nitrogen was <0.344 mg/L (Table 2; Figure 2). Total phosphorus was below detection of 15 µg/L and orthophosphate was below 6 µg/L (Table 2; Figure 3).

Chlorophyll *a* was below detection of 1.0 µg/L and AGPT was low at 0.209 mg dry wt/L (Table 2; Figure 4). Total organic carbon (TOC) was low in this lake with a concentration of 2.5 mg/L (Table 2; Figure 3). The phytoplankton community had 13 taxa and a density of 129 individuals/mL (Table 3).

Water color was 15 PCU (platinum cobalt units) (little water color) and the Secchi transparency was to 3.1 m (Table 2). Related to Secchi transparency, turbidity was 0.50 NTU (Table 2). Water temperature was 21.43° C near the surface (Table 2), but increased to 24.84 near the bottom (3.3 m). The salinity was 19.60 ppt near the surface (Table 2) and was 23.10 ppt near the bottom at 3.3 m. Alkalinity was 58 mg $CaCO_3$/L and pH was 7.47 (Table 2). The dissolved oxygen (DO) ranged from 7.92 mg/L near the surface to 6.71 mg/L near the bottom (Table 2).

The benthic community collected had 27 taxa with a relative density of 4915 individuals/m$^2$ (Table 4). The community had a Shannon-Wiener diversity of 2.48 and evenness of 0.5. The lakebed consisted primarily of medium sand (0.25-0.5) (60.8%) with 0.63% organic matter (Table 5).

Deer Lake (sampled on 13 March 2000)

Samples for nutrients were collected and analyzed from Deer Lake. Nitrite-nitrate was below detection of 4 µg/L, TKN was 0.46 mg/L and ammonia was below detection of 10 µg/L (Table 2; Figure 2); thus, total nitrogen was <0.464 mg/L. Total phosphorus was 60 µg/L and orthophosphate was below detection of 4 µg/L (Table 2; Figure 3). TOC was approximately 6.9 mg/L (Table 2; Figure 3).

Chlorophyll *a* was below detection of 1.0 µg/L and the AGPT was 0.202 mg dry wt/L (Table 2; Figure 4). The phytoplankton community had 23 taxa with a density of 228 individuals/mL (Table 3).

Secchi disk visibility was 1.6 m deep, water color was 80 PCU and turbidity was 0.85 NTU (Table 2). Water temperature was 20.04° C near the surface and 18.56 near bottom; DO ranged from 8.71 mg/L at surface to 8.14 mg/L near bottom (3 m) (Table 2). The salinity was 0.10 ppt and conductivity ranged from 205 µmho/cm near the surface (Table 2) to 207 µmho/cm at 3 m deep. Alkalinity was 5 mg $CaCO_3$/L and pH was 6.40 SU (Table 2).

The benthic community collected had 23 taxa and a relative density of 24,644/$m^2$ (Table 6). The community had a Shannon-Wiener diversity of 2.9 and evenness of 0.7. The lakebed substrate consisted primarily of coarse/very coarse and medium sand (70.3%) with 0.7% organic content (Table 5).

<u>Western Lake-Northeast Arm (sampled on 28 February 2000)</u>

Nitrite-nitrate was below detection of 4 µg/L, TKN was approximately 0.46 mg/L and ammonia was below detection of 10 µg/L (Table 2; Figure 2); total nitrogen was <0.464 mg/L. Total phosphorus was approximately 16 µg/L and orthophosphate was below detection of 20 µg/L (Table 2; Figure 3). The TOC was approximately 6.4 mg/L (Table 2; Figure 3).

Chlorophyll *a* was 11.9 µg/L and AGPT was <0.100 mg dry wt/L (Table 2; Figure 4). Secchi disk visibility was 0.9 m; water color was 40 PCU and turbidity 3 NTU (Table 2). Water temperature was 20.02° C and DO ranged from 9.21 mg/L (0.3 m deep) to 8.85 mg/L near the bottom (2.2 m) (Table 2). Salinity was 5.80 ppt with the conductivity at 10,280 µmho/cm (Table 2), near the surface (0.3 m). Salinity and conductivity varied little near the bottom (2.2 m). The pH ranged from 6.93 SU near the surface to 7.07 SU near the bottom (Table 2).

The benthic community collected had 10 taxa and a relative density of 1,312 individuals/$m^2$ (Table 7). Shannon-Wiener diversity of the benthic community was 2.37 and evenness of 0.7. The lakebed substrate was composed primarily of medium to coarse/very coarse sand (63.6%) with 1.1% organic content (Table 5).

Western Lake-North Arm (sampled on 28 February 2000)

Nitrite-nitrate and ammonia were below detection limits of 4 µg/L, 20 mg/L and 10 µg/L, respectively; TKN was 0.53 mg/L (Table 2; Figure 3). Total phosphorus was approximately 16 µg/L and orthophosphate was below detection of 20 µg/L (Table 2; Figure 3). TOC was approximately 8.0 mg/L (Table 2; Figure 3).

Chlorophyll *a* was 15.4 µg/L and AGPT was below detection of 0.100 mg dry wt/L (Table 2; Figure 4). Secchi disk visibility was 0.85 m; water color was 60 PCU and turbidity of 2 NTU (Table 2). Water temperature ranged from 19.89° C at 0.3 m deep to 18.00° C at 1.9 m and DO ranged 8.51 mg/L at 0.3 m to 6.08 mg/L near the bottom (1.9 m) (Table 2). Salinity was 5.50 ppt and conductivity of 9,720 µmho/cm at 0.3 m deep (Table 2). Salinity was 6.20 ppt and conductivity was 10,960 µmho/cm near the bottom (1.9 m). The pH ranged from 6.62 SU (surface) (Table 2) to 6.72 SU near the bottom.

The benthic community consisted of 21 taxa. The Shannon-Wiener diversity was 2.7 and evenness 0.6. This community had 2,208 individuals/cm$^2$ (Table 8). The lakebed substrate was composed primarily of silt/clay (55.8%) and had 7.1% organic content (Table 5).

Western Lake-Southern Lobe (sampled on 28 February 2000)

The nitrite-nitrate and ammonia concentrations were below detection of 4 and 10 µg/L, respectively (Table 2; Figure 2). TKN was approximately 0.46 mg/L (Table 2; Figure 2). Total phosphorus was approximately 18 µg/L and orthophosphate was below detection limit of 20 µg/L; TOC was approximately 5.9 mg/L (Table 2; Figure 3). Chlorophyll *a* concentration was 7.3 µg/L and AGPT was 0.100 mg dry wt/L (Table 2; Figure 4). The Secchi visibility was to 0.85 m, turbidity was 4 NTU and water color was 40 PCU (Table 2). Water temperature was 18.83° C at 0.3 m; DO ranged from 8.41 mg/L near the surface to 8.01 mg/L at 2.6 m (Table 2). Salinity was 6.20 ppt at 0.3 m and conductivity 10,970 µmho/cm (Table 2). Salinity remained the same throughout the water column. The pH was 6.68 SU at 0.3 m (Table 2); pH was 7.02 SU at 2.6 m.

The benthic community had 21 taxa with a density of 836 individuals/m$^2$ (Table 9). The Shannon-Wiener diversity was 2.75 and community evenness 0.6. The substrate of the lakebed was composed primarily of silt/clay (65%) and an organic content of 6.2% (Table 5).

Camp Creek Lake (sampled on 15 March 2000)

Total phosphorus and orthophosphate were below minimum detection limits of 15 and 4 µg/L, respectively; TOC was approximately 5.0 mg/L (Table 2; Figure 3). Nitrite-nitrate was 21 µg/L, TKN approximately 0.56 mg/L and ammonia was below laboratory detection of 10 µg/L (Table 2; Figure 2).

Chlorophyll *a* and AGPT were below laboratory detection limits of 1.0 µg/L and 0.100 mg dry wt/L, respectively (Table 2; Figure 4). The phytoplankton community had 18 taxa and a relative density of 371 individuals/mL (Table 3).

Secchi disk visibility was to 1.4 m; turbidity was 1.5 NTU (Table 2). Water color was determined as 30 PCU (Table 2). The salinity was 5.00 ppt at 0.3 m and conductivity was 8,800 µmho/cm; pH was 7.18 SU at 0.3 m (Table 2). Water temperature was 20.12° C at 0.3 m and 20.21° C near bottom (1.6 m) and DO ranged from 8.86 mg/L to 7.31 mg/L near the bottom at 1.6 m (Table 2).

The benthic community had 17 taxa with a density of 1,527 individuals/m$^2$ (Table 10). The Shannon-Wiener diversity was 1.68 and community evenness of 0.4. The lakebed substrate was composed primarily of silt/clay (66.2%) and had an organic content of 18% (Table 5).

## Discussion

Lake Powell

At time of this assessment, Lake Powell had little development along the shoreline (Figure 1). About 20% of the area had been developed; most of this development was along the eastern arm.

Water quality in Lake Powell was good and indicative of an oligotrophic state. The Secchi transparency was greater than the maximum listed (2.9 m) for lakes in Lake Region 75-01 (Gulf Coast Lowlands) (Griffith, et al. 1997) (Table 2). Transparency is also related to water color and turbidity. Water color may influence the benthic community structure, either directly or indirectly. Lake Powell water color was 15 PCU. There is evidence that dark water (>60 or 80 PCU) limits diversity. This may limit the photic zone to such an extent that the food web is limited in such environments (e.g., phytoplankton/zooplankton communities which are the foundation of lentic food webs).

Turbidity was low; this, along with water color and Secchi transparency indicate the photic zone was extensive in the lake. Turbidity is a measure of the suspended material in the water column. These materials are organic debris, inorganic matter, silt and clay.

The salinity of the water reflected the connection the lake has to the Gulf of Mexico. Historically, entities have artificially maintained a connection of the lake to the Gulf through Phillips Inlet (Keppner and Keppner, 2000). Tesar (1996) determined that the freshwater marsh clam (*Rangia cuneata*) dominated archaeological locations through time with but one exception, the period of ca. A. D. 1000-1250. This time was coincident with higher sea level. Thus, archeological evidence support that Lake Powell was a predominantly freshwater system with limited saline influence.

The dissolved oxygen was good throughout the water column with a surface measurement of 7.92 mg/L and a bottom measurement of 6.71 mg/L (Table 2). Dissolved oxygen is an important determinant of the types of organisms an environment can support. The State water quality standard is 5.0

mg/L (freshwater) or 4.0 mg/L for marine water. As DO concentration begins to slip below 5.0 mg/L a limited number of aerobic organisms can be supported. Once this concentration goes below 2.0 mg/L most aerobic organisms are eliminated from those habitats. In lakes that stratify, usually a result of temperature gradients and little or no mixing of the water column (salinity gradients can also result in stratification), seasonal periods of low DO concentrations may be natural, especially in systems like Lake Powell that have significant organic inputs (i.e., littoral vegetation) entering the lake. Since this assessment was conducted in late winter, this phenomenon was not observed.

The pH was slightly alkaline and reflective of the marine influence on the lake. Background freshwater environments in the area are acidic (pH 4.5-5.5 SU). The pH is a measure of hydrogen ions in solution. Typically, basic (alkaline) waters have greater biological diversity than acidic ones. This is primarily because calcium is limited in acidic water; thus excluding mollusks from the system. Those systems that have good buffer capacity typically have chemically stable environments.

Measurement of nutrients in a water body is of great importance when determining the ecological condition and health of aquatic systems. In lakes, knowing the level of nutrients in the watershed is critical since there is usually a long residence time for the water. Unlike streams in the 1$^{st}$ to 4$^{th}$ order that are heterotrophic, driven by allochthonous matter, lakes are lentic and the food web is driven by autotrophs. Excess nutrients result in over production of phytoplankton that may increase diversity and have other short-term positives, but ultimately result in a senescent environment. Lake Powell had low nutrient concentrations, measured as nitrite-nitrate, ammonia, total phosphorus, orthophosphate, TKN and TOC (Table 2; Figures 2 and 3). Total nitrogen (nitrite-nitrate plus TKN) was below the 25$^{th}$ percentile and total phosphorus was below the median value (Griffith, et al. 1997). Total organic carbon, a measure that indicates the level of organic contaminants (insecticides, herbicides, agricultural chemicals and natural substances) in water bodies, is a good screening tool to determine if carbon-containing substances are above background levels. As these substances increase, an increase in aerobic respiration can result in over-consumption of available oxygen and lead to decreases in benthos diversity and ultimately loss of fish species. The level of TOC was low in this lake, another indication of an oligotrophic state.

Related to nutrient concentrations is the algae pigment chlorophyll *a*. This measurement is an indirect indicator of the level of phytoplankton present. As this level increases to about 15 µg/L, a bloom is reached and this level is usually considered a nuisance. High concentrations of these plankton may result in a high level of DO during the day; at night, and particularly early morning, a DO deficit may occur as they use oxygen for respiration. This condition may result in fish stress and kills. Algae blooms are usually viewed by the public as undesirable aesthetically (i.e., “pea-green soup”) and may produce allergic reactions when some toxins are released to the atmosphere. Chlorophyll *a* was undetectable (below 1.0 µg/L) during this assessment. The phytoplankton community was sampled and identified to generic level and relative abundance calculated. There were 13 taxa and 129 individuals per mL (Table 3). The blue-green algae were low in numbers and taxa. These community determinations add an increased level of discretion to the chlorophyll *a* assay. An abundance of bluegreens is an indication of organically polluted water bodies.

All benthic macroinvertebrates recovered from Lake Powell were estuarine forms common in brackish waters and tide pools. A total of 27 taxa were found during this study. The community structure consisted of 1,495 individuals, 4,914 organisms per meter squared of substrate, and a Shannon-Wiener diversity of 2.48. The dominant organisms were the common clam *Anomalocardia auberiana* (769 individuals), the amphipod *Ampelisca abdita* (216 individuals), and the marine annelid *Streblospio benedicti* (198 individuals) (Table 4).

*Anomalocardia* spp., are small hard-shelled white clams that are often abundant in sandy, medium to high salinity embayments. Bivalve communities are important constituents of the benthic macrofauna because they filter impurities out of the water and serve as a primary food source for many marsh animals. Five bivalve species consisting of 842 individuals were recovered from

Lake Powell during this study. Bivalves accounted for 56% of the total species found in Lake Powell.

*Ampelisca* spp., are common gammaridean amphipods found in sand and silt in protected embayments. They have a wide salinity regime from brackish to marine. This organism is often used in marine water toxicity testing. Four amphipod species were found in the study comprised of 245 individuals. Amphipods comprised 16% of the total benthic community structure. Gammaridean amphipods are considered clean water indicators, as are most other motile epifaunal forms. Amphipods are the primary food source for many important juvenile estuarine fishes.

The polychaetous annelid *Streblospio* spp., are common estuarine species preferring organic/muddy substrata. They tolerate salinities ranging from 5 to 25 parts per thousand. These burrowing infaunal worms are considered pollution tolerant and may serve as indicators of organic enrichment. Ten polychaete species were recovered and accounted for 361 individuals. Marine annelids accounted for 24% of the benthic assemblage.

The polychaete/bivalve fraction of the total community was 80%, which suggests a skewed community structure. The three taxa discussed above comprised 79% of the total assemblage, which leaves the remaining 24 organisms accounting for 21% of the total. Coastal estuarine systems are considered some of the most productive ecosystems in the world. The dominance associated with bivalve clams in Lake Powell confirms a productive lake bottom. High numbers of the marine annelids *Streblospio* spp., and *Capitella capitella* (86 individuals) suggest organically enriched productive substrata. An organic substratum is natural in coastal salt marshes and estuaries. This highly productive ecosystem is fueled by the decomposition of marsh grass (*Spartina* spp., and *Juncus* spp.,) into detritus. This food web supports high numbers of filter-feeding detritivores, in this case *Anomalocardia* spp., *Ampelisca* spp., and *Streblospio* spp. According to Heard (1982), less than 10% of the vascular plant material produced in the marsh is consumed directly by detritivorus animals. This means that over 90% of the marsh grass is converted into nutrients and detritus by microbial decomposition prior to consumption by detritivores. Additional nutrients into this system could upset the natural balance.

Deer Lake

Deer Lake is located in southeast Walton County and lies between Eastern and Camp Creek lakes along SR 30A (Figure 1). This lake lies entirely within the proclamation boundary of Deer Lake State Park (2,006 acres). Deer Lake is a typical Coastal Dune Lake lying perpendicular to the coast. This lake covers approximately 50 acres. It is surrounded east, west and to the north by scrub and mesic flatwoods; the south shores of the lake are surrounded by beach-dune community. The topography on the south side of the lake is dramatic due to these dunes. The only infringement on this natural system is SR 30A that cuts across the north end of the lake. Because of the relative protection of the lake and limited development in the immediate area (a small lake and adjoining wetland has homes and apartment buildings several 100 meters west of Deer Lake), this lake was selected as a reference for Coastal Dune Lakes in the area.

Secchi transparency is related to water color, turbidity and algal production. It is a quick and inexpensive method often employed in volunteer monitoring programs. The Secchi transparency was slightly above the 75$^{th}$ percentile for lakes in this lake region (Griffith, et al. 1997). The water color was 80 PCU, which is between the 25$^{th}$ percentile and median for similar lakes in the region (Table 2). This relatively dark water is due to the tannic acids that naturally leach into the water from the surrounding woody vegetation. Some data suggest dark colored water lakes have reduced benthic community diversity. This may also affect the phytoplankton/zooplankton communities that form the basis for food webs in lakes. Deer Lake receives inflow from a 1$^{st}$ order stream that flows southwesterly through forested uplands. According to maps, this stream is entirely within the proclamation boundary of Deer Lake State Park.

Turbidity was low in Deer Lake, near the 10$^{th}$ percentile for all Florida lakes (DEP, 1990-95). The lack of turbidity was reflected in the Secchi transparency. Turbidity is a measure of the suspended material in the water column. These materials are organic debris, inorganic matter, silt and clay.

Unlike other coastal dune lakes in this report, Deer Lake was a freshwater system. Conductivity was 205 µmho/cm and salinity was 0.10 ppt (Table 2). Since development is some distance from this lake and it is buffered by inclusion in a state park, this lake can function relatively naturally. At the time of this sampling event the outlet to the Gulf was closed. The littoral vegetation was indicative of a long residence of freshwater environment. Some examples of these plants were: *Juncus effusus*; *Spartina bakeri*; *Nymphaea odorata*; *Sagittaria lancifolia* and *Typha*. *Typha* (cattail) was also found in small patches in the upper end of the lake.

DO in Deer Lake was good from surface to near bottom (above 8.0 mg/L). DO is an important determinant of the types of organisms that can inhabit an environment. The State water quality standard is 5.0 mg/L for freshwater. As DO concentration decreases below 5.0 mg/L, a limited number of aerobic organisms can be supported. Once this concentration falls below 2.0 mg/L, most aerobic organisms are eliminated from those habitats. In lakes that stratify, usually a result of temperature gradients and little or no mixing of the water column (salinity gradients can also result in stratification), seasonal periods of low DO concentrations may be natural. Given the time of year (winter), this phenomenon was not observed.

The pH of the water was slightly acidic (6.40 SU). Background freshwater systems in this region typically have a pH of 4.5-5.5 SU. The pH is a measure of hydrogen ions in solution. Typically, basic (alkaline) waters have greater biological diversity than acidic ones. This is primarily because calcium is limited in acidic water and this excludes mollusks from the system. Those systems that have good buffer capacity tend to have chemically stable environments. Related to pH, alkalinity was low in this lake. This is typical of water bodies in the western panhandle. Alkalinity is a measure of the buffering capacity of water and is expressed as $CaCO_3$/L.

Nutrients were measured in this assessment. These chemical constituents are important when determining the ecological condition and health of aquatic systems. In lakes, knowing the level of nutrients in the watershed is critical since there is usually a long residence time for the water. Unlike streams in the 1st to 4th order that are heterotrophic (the food web driven by allochthonous matter), the food web in lakes is driven by autotrophs. An excess of nutrients can result in over production of phytoplankton that may increase diversity and have other short-term positives, but ultimately result in a senescent lake. The total nitrogen was 0.464 mg/L; this is below the 25th percentile for lakes in this region (Griffith, et al. 1997). Total phosphorus was elevated above the 75th percentile for lakes in Lake Region 75-01 (Griffith, et al. 1997). However, orthophosphate was below detection of 4 µg/L (Table 2; Figure 3). This parameter is a measure of the bioavailable phosphorus in the water column. Phosphorus is typically the limited nutrient in these lakes.

Concerned about the high total phosphorus level, a return trip was made in early May 2000 to once again measure this nutrient. A grab sample was taken from Deer Lake and the nearby lake to the west was sampled in an attempt to determine the possible source of phosphorus. The lake to the west "Lakewood Pond" was thought to be a potential source given the development along a significant percentage of its shore and quasi connection via wetlands to Deer Lake. Results from samples taken from "Lakewood Pond" (one from the NW and one from the SE sides of the pond) found total phosphorus below minimum detection limit (MDL) of 5 µg/L; it was 7 µg/L (which was between the MDL and practical quantitation limit) at Deer Lake.

With bioavailable phosphorus and adequate nitrogen, algal populations grow and may result in annoying blooms. Large populations of phytoplankton may increase DO during the day, but by early morning their consumption of oxygen will result in low DO levels, often approaching zero mg/L. If these conditions persist, a depauperate benthic fauna and stressed fish populations are likely to occur. Ultimately this condition can lead to fish kills and may result in toxins in the air that cause people to have an allergic reaction that may include burning, watery eyes and sneezing. An indirect measure of algal production is determination of chlorophyll *a*. This pigment was below minimum detection limit of 1.0 μg/L (Table 2; Figure 4). The phytoplankton community was sampled and generic level determinations made. There were 23 taxa and a population density of 228 individuals/mL (Table 3). This was a low population and no taxon was a member of the blue-green group.

The benthic community consisted of 18 taxa; all were freshwater organisms (Table 6). The greatest proportion (88%) of this community was composed of true flies (Diptera). Two taxa, *Polypedilum halterale* group and *P. scalaenum* group accounted for over 60% of the community population. These taxa have a variety of feeding strategies, e.g., collector-gatherers, shredders and filterers. One of these, *P. scalaenum* group, has been reported to commonly occur in areas with poor water quality (Epler, 1995). The number of individuals per meter squared was high for coastal lakes that have been assessed to date: 24,644 and over 15,000 of that number was contributed by the two previously mentioned chironomids. Three taxa from the EOT (Emphemeroptera, Odonata, Trichoptera) group were identified in this sample; two taxa were *Oecetis* spp. These caddisflies are predators and found commonly in sediments of sandy lakes in the panhandle. The mayfly genus *Caenis* is typically found in sediments of silt where they are scavengers. The EOT group is usually indicative of good water quality in Florida lakes (Gerritsen, et al. 2000).

The Lake Condition Index (LCI) ranked Deer Lake in the good category, out of a possible very good, good, poor and very poor ranking. This score was on the low end of that category. The high percentage of Diptera and low percentage of EOT were two of the six metrics that scored the minimum in the multimetric index. While Deer Lake is in relatively good health, there are some early indicators of perturbation to the system. The presence of cattails indicates some organic enrichment. The density of cattails was small so these should be monitored for increased coverage as an indication of excess nutrients entering the lake.

Western Lake

Western Lake is located in south Walton County just west of the community of Seaside (Figure 1). This lake is bisected by SR 30A creating two sections that are connected via culvert/bridge, the two north arms and the relatively large southern lobe. The southern lobe is connected to a southwest arm via a channel that often prevents boat navigation between the two. There were few developments on the two north arms and southern lobe at time of this assessment. However, the southwest arm had considerable single-family housing around its western shore. Construction of a high-density community and associated commercial development on the northeast arm had just started. Since this bioassessment was conducted to determine a baseline for biology and physicochemical parameters prior to the development of the northeast arm, the southwest arm was not considered in this endeavor. All but the southwest arm of the lake has been in a relatively undeveloped condition. The bisection of the lake by the construction of SR 30A, which resulted in considerable fill material in order to eliminate as much bridge construction as possible, has been the greatest change to all the lake but the southwest arm. Therefore, the area considered in this assessment was thought to represent a relatively natural state.

Overall water quality in the two arms and below SR 30A was similar. In the three lake divisions, the Secchi transparency was in the median for lakes in Lake Region 75-01 (Griffith, et al. 1997). Secchi transparency is related to water color, turbidity and algae production. It is a quick and inexpensive method often employed in volunteer monitoring programs. The water color was below the 25$^{th}$ percentile for lakes in this lake region (Griffith, et al. 1997). The north lobe had the highest color at 60 PCU. The water color in the other two divisions was 40 PCU (Table 2). Some data indicate that dark colored water negatively affects the diversity of the benthic community. This may also have an adverse affect on the phytoplankton/zooplankton communities that form the basis of the food web in many lakes. A small 1$^{st}$ order coastal stream drains into the lake from the east. This stream had impacts associated with urbanization. Habitat was restricted to one type (undercut banks/roots) and much of the habitat was smothered with silt and, to a lesser degree, sand.

Turbidity was higher at Western Lake than the other three coastal lakes assessed during this period. Those values ranged in the 30th to 50th percentile of all lakes in the state for turbidity (DEP, 1990-95). Rain occurred on the day prior to this assessment and may have contributed to the slightly elevated turbidity. Visually, there appeared to be slight turbidity when transparency was measured with the Secchi disk. Turbidity is the measure of suspended material in the water column. These materials are organic debris, inorganic matter, silt and clay.

Salinity in these divisions of Western Lake ranged from 5.50 ppt in the north arm to 6.20 ppt in the portion south of SR 30A (Table 2). The outlet to the Gulf is manipulated by the county to lower lake levels to accommodate lakeside development, particularly on the southwestern lobe of the system. These salinity levels created an almost exclusive estuarine environment, excluding all freshwater taxa with the exception of a few dipterans and oligochaetes.

DO was good throughout the water column with the lowest concentration occurring in the north arm (6.08 mg/L) (Table 2). DO is an important determinant of the types of organisms that can inhabit an environment. The state water quality standard is 5.0 mg/L for freshwater and 4.0 mg/L for marine water. As DO concentration begins to fall below 5.0 mg/L, a limited number of aerobic organisms can be supported. Once this concentration falls below 2.0 mg/L most aerobic organisms are eliminated from those habitats. In lakes that stratify, usually a result of temperature gradients and little or no mixing of the water column (salinity gradients can also result in stratification) seasonal periods of low DO concentrations may be natural, especially in systems like Western Lake that have significant organic inputs (i.e., littoral vegetation) entering the lake. Since this assessment was conducted in late winter, this phenomenon was not observed.

The pH was near neutral in Western Lake and reflected the marine influence on the system. Background freshwater systems in this region are acidic (pH 4.5-5.5 SU). Western Creek, which empties into the northeastern arm of Western Lake, had a pH of 5.57 SU. The pH is a measure of hydrogen ions in solution. Typically, basic (alkaline) waters have greater biological diversity than acidic ones. This is primarily because calcium is limited in acidic water to the exclusions of mollusks from the system. Those systems that have good buffer capacity tend to have chemically stable environments. Salinity in this stream was 0.10 ppt compared to 5.80 ppt in the northeast arm.

A suite of nutrients was measured in this lake at time of benthic collection. In lake assessments, knowing the level of nutrients in the watershed is critical since there is usually a long residence time for the water. Unlike streams in the 1$^{st}$ to 4$^{th}$ order that are heterotrophic, driven by allochthonous matter, lakes are lentic and the food web is driven by autotrophs. An excess of nutrients result in over production of phytoplankton that may increase diversity and have other short-term positives, but ultimately result in a senescent environment. All three divisions of the lake were low in total nitrogen, below the median for lakes in the 75-01 Lake Region (Griffith, et al. 1997); however, total phosphorus was detected and reported as being between the detection limit and lab practical quantitation limit. These total phosphate levels (16-18 µg/L) (Table 2; Figure 3) are much higher than levels typical of lakes in the southern panhandle and are slightly above the median for lakes in this region statewide (Griffith, et al. 1997). Orthophosphate was not detected; however, the minimum detection limit was too high (20 µg/L) to dismiss this nutrient as being below a threshold of concern. TOC, a parameter that indicates the level of organic contaminants (insecticides, herbicides, agricultural chemicals and natural substances) in water bodies, is a good screening tool to determine if carbon-containing substances are above background levels. As these levels increase, an increase in aerobic respiration may result in over-consumption of available oxygen and lead to decreases in benthos diversity and ultimately, loss of fish species. The concentrations provided by the laboratory for the three divisions were all estimated values (Table 2; Figure 3). Those values fell between the median and 60$^{th}$ percentile for all Florida lakes (DEP, 1990-95).

Related to nutrient levels in lakes is the concentration of chlorophyll *a* in the water column. This measurement is an indirect indicator of the level of phytoplankton present. As this level increases to about 15 µg/L, a bloom is reached and this level is usually considered a nuisance. High concentrations of phytoplankton may result in a high level of DO during the day, although at night and early morning the DO often drops below 2.0 mg/L. At night, these plants respire using great quantities of DO; this condition may lead to loss of benthos diversity, fish stress and ultimately fish kills. Algal blooms are usually considered by the public as aesthetically undesirable (i.e., "pea-green soup"). These blooms may produce allergic reactions when some toxins are released to the atmosphere. This assessment found elevated chlorophyll *a* concentrations, especially in the north and northeast arms. The north arm had a chlorophyll *a* concentration of 15.4 µg/L. This level is indicative of algal bloom conditions. The northeast arm was 11.9 µg/L and those waters south of SR 30A had 7.3 µg/L chlorophyll *a* (Table 2; Figure 4). These unusually high chlorophyll *a* levels appear to indicate nutrients, especially phosphorus, were elevated in Western Lake. Total phosphorus concentrations of 8 µg/L or less are typical of background lakes in the coastal region of the western panhandle.

Estuarine forms dominated the benthic macrofauna recovered from Western Lake. The common aorid amphipod *Grandidierella bonnieroides* dominated the sample from each lobe of Western Lake. This organism represented about 50% of the total taxa recovered in this study (Tables 7-9). *Grandidierella* spp., are euryhaline organisms found in a wide range of salinity from 1 ppt to over 40 ppt. It is widely distributed in coastal lagoons, tidal rivers, bayous and tide pools in temperate to subtropical areas of the United States. In general, amphipods are swimming epifaunal organisms recognized as clean water indicators. They are also important in the diets of many estuarine fishes.

The faunal assemblage found in the north arm consisted of 21 taxa, 224 individuals, and a Shannon-Wiener diversity of 2.7. Fifty-nine percent of the benthic macrofauna recovered consisted of free-swimming epifaunal organisms. The amphipod *Grandidierella* comprised 51% of the total benthic assemblage.

Bottom dwelling infaunal forms comprised 41% of the total, of these only 26% are considered freshwater forms. The freshwater fraction of the north arm fauna consisted of nine taxa, mostly chironomid midges, however the phantom midge *Chaoborus punctipennis* comprised 15.6% of the total. These dipterans are commonly found in the profundal zone of organically enriched lakes and are tolerant of low DO. The pollution tolerant midge *Chironomus* was present (1.8% of fauna). The midges *Procladius* spp., and *Polypedilum scaleaenum* group are also found in water bodies of poor water quality (Epler, 1995). While the overall benthic community had some estuarine forms that suggest a healthy environment, some chemical data and certain benthos indicate early signs of degradation.

The northeast arm yielded only 10 taxa, significantly the lowest recovered in the three divisions of Western Lake. *Grandidierella* was the dominant form at 46% of the total faunal assemblage. The total taxa were reduced by 47.6% in this lobe when compared to the other two lobes. Since method of sampling and water column physicochemical data were similar, the reduction in taxa in the northeast arm is puzzling. The sediment analyses data indicated a higher percentage of larger grain size and less percentage of organic matter compared to the north arm and south of SR 30A (Table 5). This only suggests better substrate availability for most clean water taxa. Perhaps this community difference is an artifact of random sampling.

The south lobe contained 21 taxa, 256 individuals, and a Shannon-Wiener diversity of 2.75. The amphipod *Grandidierella bonnieroides* was the dominant taxon comprising 51% of the community. The south lobe had 10 species in common with the north lobe; therefore, a similarity index (S) between these samples was 0.47. The similarity index was calculated as follows:

[S= 2 C/ A+B, where A= number of species in sample 1, B= number in sample 2, and C= number of species common to both samples].

The theoretical limit for this index is 1.0 (both samples are identical), a condition not likely found in nature, thus the similarity value of 0.47 may suggest a slight faunal dissimilarity between these lobes. The swimming epifaunal (59%) fraction of both lobes was identical in percentage and very close in species composition. The freshwater taxa were fewer and contributed a smaller proportion of individuals to the community composition. The macrobenthic community found in the south lobe is indicative of a healthy environment.

Camp Creek Lake

Camp Creek Lake is located in an area of rapid development. At the time of this assessment, the lake had low-density residential development along about 40% of the shoreline. The upper lake is buffered by Point Washington State Forest.

Overall, water quality in Camp Creek Lake was relatively good. The Secchi disk transparency was slightly above the 75$^{th}$ percentile for lakes in this region (Griffith, et al. 1997). Secchi transparency is related to water color, turbidity and algae production. It is a quick and inexpensive method often employed in volunteer monitoring programs. The water color was 30 PCU, slightly colored. There is evidence that lakes of high color have limited benthos diversity. This may be a result of a limited photic zone. Dark water color may adversely affect the phytoplankton/zooplankton communities that form the basis for food webs in lakes. Camp Creek Lake receives drainage from the surrounding uplands via Camp Creek, a 2$^{nd}$ order coastal stream. At the time of this assessment, the panhandle had been in a severe drought, thus limiting the tannic acids one would expect to add significantly to the water color. This stream lies primarily within the proclamation boundary of Point Washington State Forest.

Turbidity was relatively low, visually there appeared to be slight turbidity when transparency was recorded with the Secchi disk. This slight turbidity may be attributed to easterly winds of about 15 mph that were stirring the water column. Turbidity is a measure of the suspended material in the water column. These materials are organic debris, inorganic matter, silt and clay.

Salinity was low in this lake, yet still reflecting its connection to the Gulf. Over a period of a month, the outlet was observed to be open to the Gulf; the complete time of this direct connection was not known. The outlet is likely maintained for boat access. Salinity creates an environment that begins to eliminate freshwater organisms that cannot physiologically function in hypertonic solutions.

The DO was good throughout the water column with a surface concentration of 8.86 mg/L and a bottom measurement of 7.31 mg/L (Table 2). DO is an important determinant of the types of organism that can inhabit an environment. The State water quality standard is 5.0 mg/L for freshwater and 4.0 mg/L for marine water. As DO concentration begins to fall below 5.0 mg/L, a limited number of aerobic organisms can be supported. Once this concentration falls below 2.0 mg/L most aerobic organisms are eliminated from those habitats. In lakes that stratify, usually a result of temperature gradients and little or no mixing of the water column (salinity gradients can also result in stratification) seasonal periods of low DO concentrations may be natural, especially in systems like Camp Creek Lake that have significant organic inputs (i.e., littoral vegetation) entering the lake. Since this assessment was conducted in late winter, this phenomenon was not observed.

The pH was slightly alkaline and reflective of the marine influence on the lake. Background freshwater systems in this region are acidic (pH 4.5-5.5 SU). The pH is a measure of the hydrogen ions in solution. Typically, basic (alkaline) waters have greater biological diversity than acidic ones. This is primarily because calcium is limited in acidic water; thus, excluding mollusks from the system. Those systems that have good buffer capacity tend to have chemically stable environments. During this assessment, Camp Creek was accessed as far as possible via boat, several hundred meters, and the pH had dropped to 6.81 SU (from 7.18 SU) and salinity was zero (compared to 5.00 ppt).

Measurement of nutrients in a water body is of great importance when determining the ecological condition and health of aquatic systems. In lakes, knowing the level of nutrients in the watershed is critical since there is usually a long residence time for the water. Unlike streams in the 1$^{st}$ to 4$^{th}$ order that are heterotrophic, driven by allochthonous matter, lakes are lentic and the food web is driven by autotrophs. Excess nutrients result in over production of phytoplankton that may increase diversity and have other short-term positives, but ultimately result in a senescent environment. Camp Creek Lake had elevated total nitrogen levels (581 µg/L) compared to other coastal lakes in the vicinity. However, compared on a regional basis, it was just below the median (648 µg/L) (Griffith, et al. 1997). Total phosphorus was below the median value of lakes in Lake Region 75-01 and orthophosphate was below detection of 4 µg/L. Orthophosphate is the fraction of phosphorus that is dissolved in the water column and therefore bioavailable. This nutrient is essential for plant growth (algal) when present in adequate concentration of nitrogen. These nutrients help fuel primary production in the food web. However, in high concentrations it is a pollutant since it stimulates over production of algal growth. Total organic carbon, a parameter that indicates the level of organic contaminants (insecticides, herbicides, agricultural chemicals and natural substances) in water bodies, is a good screening tool to determine if carbon-containing substances are above background levels. As these substances increase, an increase in aerobic respiration may result in over-consumption of available oxygen and lead to decreases in benthos diversity and ultimately loss of fish species. The level of TOC was relatively low; it was in the 20$^{th}$ percentile for all Florida Lakes (DEP, 1990-95).

Related to nutrient concentrations is the algae pigment chlorophyll *a*. This measurement is an indirect indicator of the level of phytoplankton present. As this level increases to about 15 µg/L, a bloom is reached and this level is usually considered a nuisance. High concentrations of phytoplankton may result in a high level of DO during the day, although at night and early morning the DO often drops below 2 mg/L. At night, these plants respire using great quantities of DO; this condition often leads to loss of benthos diversity, fish stress and ultimately fish kills. Algae blooms are usually viewed by the public as undesirable aesthetically (i.e., “pea-green soup”) and may produce allergic reactions when some toxins are released to the atmosphere. During this assessment, chlorophyll *a* was undetected, the threshold being 1.0 µg/L (Table 2). The phytoplankton community was sampled, enumerated and identified to generic level. Of the three coastal lakes where those data were obtained, this lake had the greatest density (371 individuals per mL). While this is a low density, most of the individuals were members of the blue-green phylum Cyanophycota (Table 3). An abundance of bluegreens is an indication of organic pollution.

The benthic macroinvertebrate fauna from Camp Creek Lake was dominated by the spionid polychaete *Streblospio spp.*, and the aorid amphipod *Grandidierella bonneroides*. These two organisms comprised 89.7% of the total community structure. Seventeen taxa were present represented by 467 individuals (Table 10). Since this was a highly skewed community, the Shannon-Wiener diversity of 1.68 reflected the dominance of these two species. The first six species in rank order were estuarine forms comprising 95% of the faunal composition. The dominance by the spionid polychaete *Streblospio spp.*, (56.7%) suggests the bottom substrata in Camp Creek Lake sublittoral zone are mud/silt. Spionids are characteristic of, and often dominate, soft-bottom habitats in euryhaline embayments. *Grandidierella bonneroides*, the co-dominant, is a common gammaridean amphipod often occurring in high numbers in coastal environments. The remaining 15 species in the faunal assemblage comprised 10.3% of the total. Only 3% of these forms were swimming epifaunal organisms. Burrowing infaunal organisms dominated the sublittoral zone, as expected.

While the benthic community was dominated by estuarine organisms, other arthropods were present that are typically associated with freshwater environments. Five of the seven freshwater taxa were members of the order Diptera (true flies). Most of these insects have relatively short generations and can quickly adapt to a wide range of ecological conditions. Most of these fly larvae feed on bacteria and plankton while one taxon in particular is a nocturnal predator of zooplankton (*Chaoborus punctipennis*). *Chaoborus puncipennis* are tolerant of low DO and have air sacs that increase respiratory capability in these environments. At night, they migrate through the water column feeding on zooplankton. This taxon is typical of sediments that have a high percentage of organic matter, conditions found in eutrophic lakes (Cole, 1983). Sediment analyses indicated the high organic fraction exists in this lake, 18%. The silt/clay grain size was the most prevalent constituent of the primarily inorganic fraction comprising over 65% of the sediment composition (Table 5). The benthic macroinvertebrate data recovered from Camp Creek Lake suggests a skewed community structure, which usually indicates sediment perturbation.

## Summary

Deer Lake was the only freshwater lake in the group; therefore, this lake was the only one where the Lake Condition Index (LCI) could be used to determine the overall health of the water body. This multimetric index rated the lake as good. However, some early signals in the composition of the benthos and nutrient level suggest a system that has incurred some perturbations. The protection given this lake by the surrounding state parkland should provide a buffer to this water body. However, any future increased building of housing units and associated increased population density to adjoining land to the west should be a signal for more water quality monitoring.

Western Lake was estuarine from a biological and water quality perspective. During this assessment, ground had just been broken near the northeast arm of the lake for development. Baseline data was needed to determine any possible degradation of the lake in the future. Water quality in the three divisions indicated early signs of possible phosphorus levels higher than expected. Chlorophyll *a* concentrations verified nutrient enrichment at time of assessment. Overall, the benthic community was indicative of a healthy estuarine environment. With the development pressures only increasing in this watershed, regular water quality monitoring is prudent. Potential source(s) of phosphorus need to be identified.

Lake Powell had salinity levels high enough to be representative of conditions in the Gulf of Mexico. The overall water quality in this lake was good and indicative of oligotrophic conditions. These low nutrient levels were reflected in low chlorophyll *a* concentration. The benthic community indicated a healthy, organically productive estuarine system. However, due to the high level of productivity from littoral marsh grass (*Spartina* and *Juncus*), common in this type of system, any additional levels of nutrients could easily upset the delicate balance in Lake Powell. If proposed development occurs, regular monitoring of water quality will be necessary for early abatement of potential pollutants.

Camp Creek Lake salinity levels were similar to those found in Western Lake. The water quality in this lake was good. Nutrient levels were low, with the exception of nitrite-nitrate. The fact that phosphorus was low probably prevented an algal bloom. The benthic community indicated some level of stress to the environment. This community was dominated by organisms that interstitially inhabit organically enriched substrata. The small percent of freshwater organisms in this lake was typical given the relatively high salinity. Periodic monitoring of water quality in this lake is suggested.

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**Tables and Figures**

Table 1. Class A and B taxa as identified in Hulbert's Index (HI) (Hulbert, 1990).

| Class A Organisms | Class B Organisms |
|---|---|
| *Hexagenia orlando* | *Caenis diminuta* |
| *Cernotina truncona* | *Gammarus* spp. |
| *Orthotrichia* spp. | *Hyallela azteca* |
| *Aphylla williamsoni* | *Oxeythira* spp.[a] |
| *Pachydiplax longipennis*[a] | *Oecetis* spp. |
| *Nectopsyche* spp.[a] | *Palaemonetes paludosus* |
| *Byssanodonta cubensis* | *Pagastiella spp.* |
| *Paralauterboniella nigrohalteralis* | *Pseudochironomus* spp. |
| *Corbicula fluminea* | Unionidae |
| *Djalmabatista pulcher* | *Campeloma floridense* |
| *Nilothauma* spp. | *Procladius bellus* |
| *Clinotanypus pinguis* | *Polypedilum halterale* |
| *Stictochironomus devinctus* | *Polypedilum illinoense* |
| *Cryptotendipes* sp. | *Nimbocera pinderi* |
| *Ablabesmyia*[b] | *Einfeldia* spp. |
| | *Gomphus* spp. |

[a]Mainly associated with vegetation
[b]Probably all species but *annulata* in particular

Table 2. Physicochemical and selected biological parameters from four coastal dune lakes in Walton and Bay counties. Parameters measured, or water collected, from near center of water body. All reported values were obtained at a depth of 0.3 m unless otherwise noted.

| Lake: / Parameter | Deer | Western NE Lobe | Western N Lobe | Western S Lobe | Camp Creek | Powell |
|---|---|---|---|---|---|---|
| Water depth (m) | 3.15 | 2.2 | 1.9 | 2.6 | 1.9 | 3.9 |
| Secchi transparency (m) | 1.6 | 0.9 | 0.85 | 0.85 | 1.4 | 3.1 |
| Color (PCU) | 80 | 40 | 60 | 40[d] | 30[d] | 15 |
| Turbidity (NTU) | 0.85 | 3 | 2 | 4[d] | 1.5 | 0.50 |
| Conductivity (μmho/cm) | 205 | 10,280 | 9,720 | 10,970 | 8,880 | 31,400 |
| Salinity (ppt) | 0.10 | 5.80 | 5.50 | 6.20 | 5.00 | 19.60 |
| Temperature (°C) | 20.04 | 20.02 | 19.89 | 18.83 | 20.12 | 21.43 |
| pH (standard units) | 6.40 | 6.93 | 6.62 | 6.68 | 7.18 | 7.47 |
| Alkalinity (mg $CaCO_3$/L) | 5 | --- | --- | --- | 30 | 58 |
| Dissolved oxygen (mg/L) (depth m) | | | | | | |
| Surface (0.3 m) | 8.71 | 9.21 | 8.51 | 8.41 | 8.86 | 7.92 |
| Mid-depth | 8.66 | 9.16 | 7.95 | 8.32 | 8.79 | 7.58 |
| Bottom | 8.14 | 8.85 | 6.08 | 8.01 | 7.31 | 6.71 |
| Nutrients (μg/L) | | | | | | |
| Ammonia | 10[a] | 10[a] | 10[a] | 10[a] | 10[a] | 10[a] |
| Nitrite-Nitrate | 4[a] | 4[a] | 4[a] | 4[a] | 21 | 4[a] |
| Total P | 60 | 16[b] | 16[b] | 18[b] | 15[a] | 15[a] |
| Orthophosphate | 4[a] | 20[a] | 20[a] | 20[a] | 4[a] | 6[a] |
| Total Kjeldahl-nitrogen (mg/L) | 0.46 | 0.46[c] | 0.53[c] | 0.46[c] | 0.56[c] | 0.34[c] |
| Total organic carbon (mg/L) | 6.9[c] | 6.4[c] | 8.0[c] | 5.9[c] | 5.0[b] | 2.5[b] |
| Chlorophyll *a* (μg/L) | 1.0[a] | 11.9 | 15.4 | 7.3 | 1.0[a] | 1.0[a] |
| Algal growth potential test (mg dry wt/L) | 0.202 | 0.100[a] | 0.100[a,d] | 0.100[a] | 0.100[a] | 0.209[b,d] |

[a]Material was analyzed for but not detected; the value reported is the minimum detection limit.
[b]Value reported is between the laboratory method detection limit and the laboratory practical quantitation limit.
[c]Estimated value.
[d]Value reported is the mean of two or more determinations.

# Figure 1. Locations of the four lakes considered in this report.

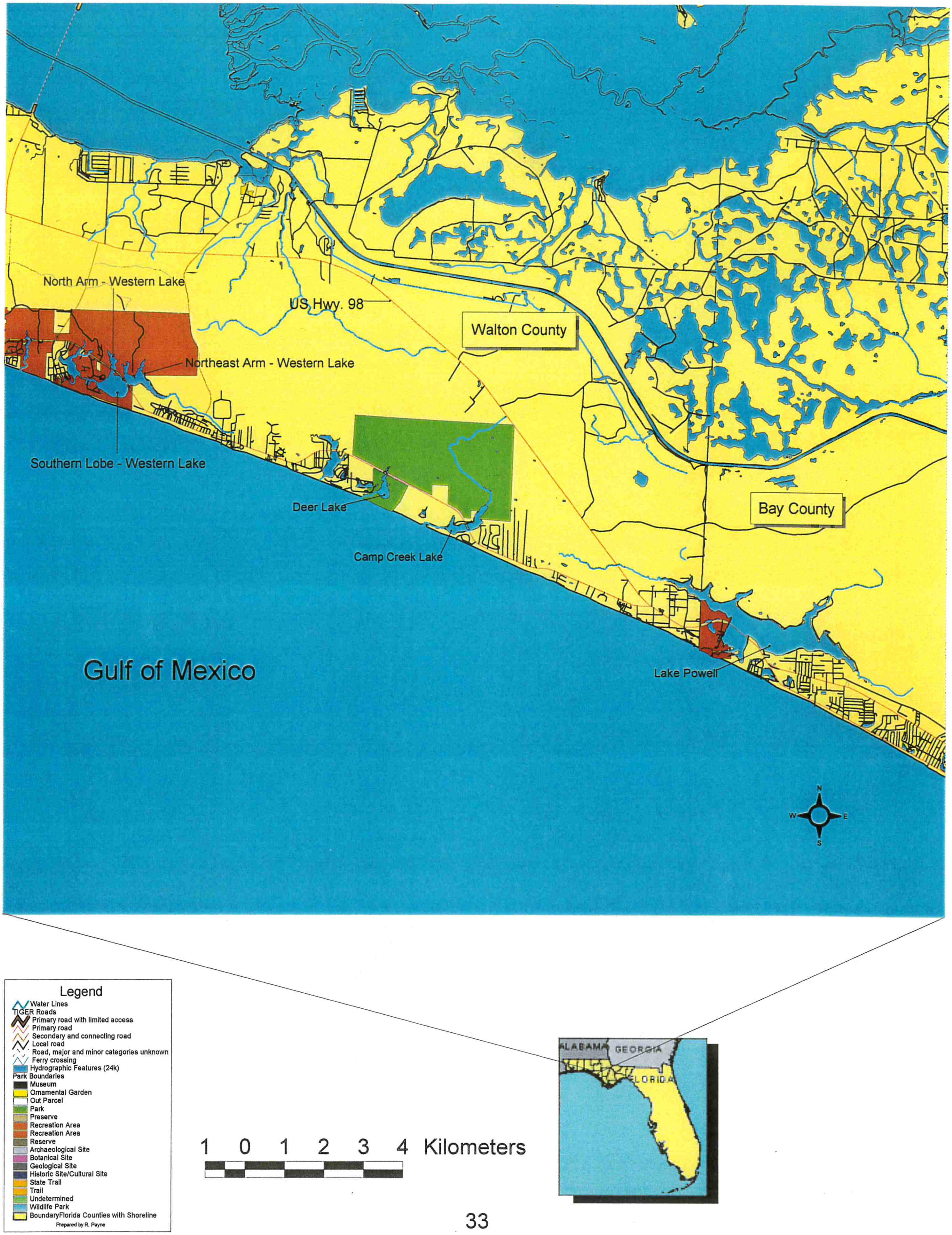


Figure 2. Total Kjeldahl-nitrogen, nitrite-nitrate and ammonia values obtained form near-center of each lake and those subdivisions of Western Lake.

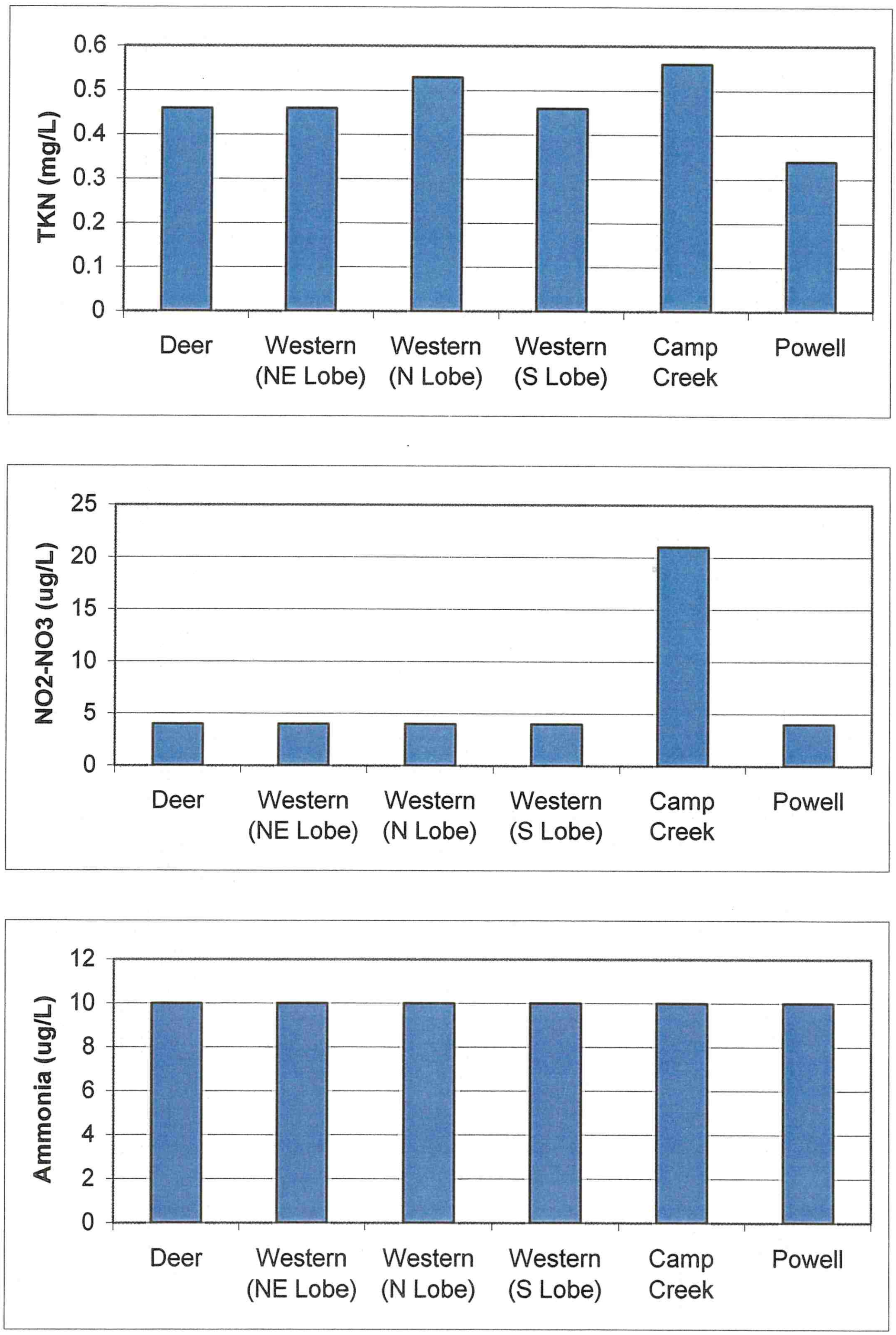
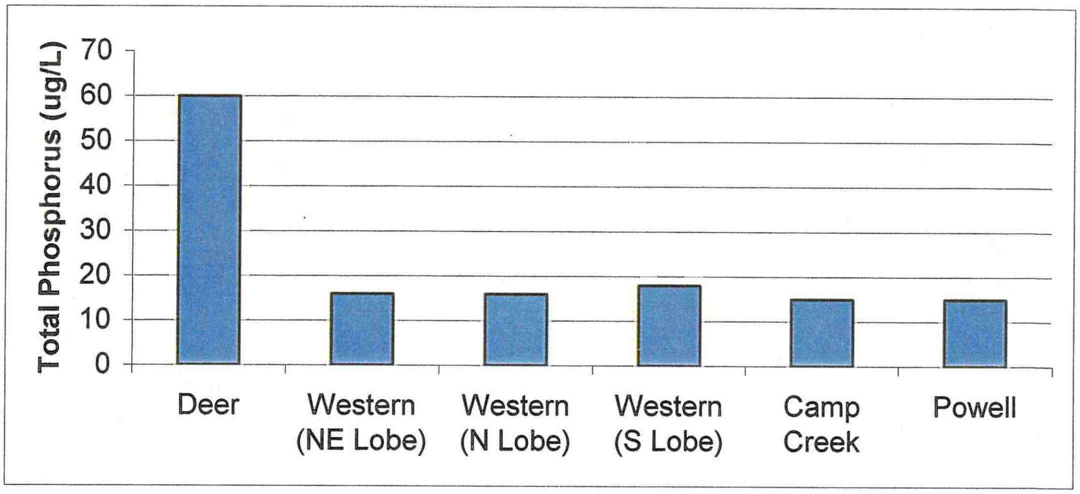
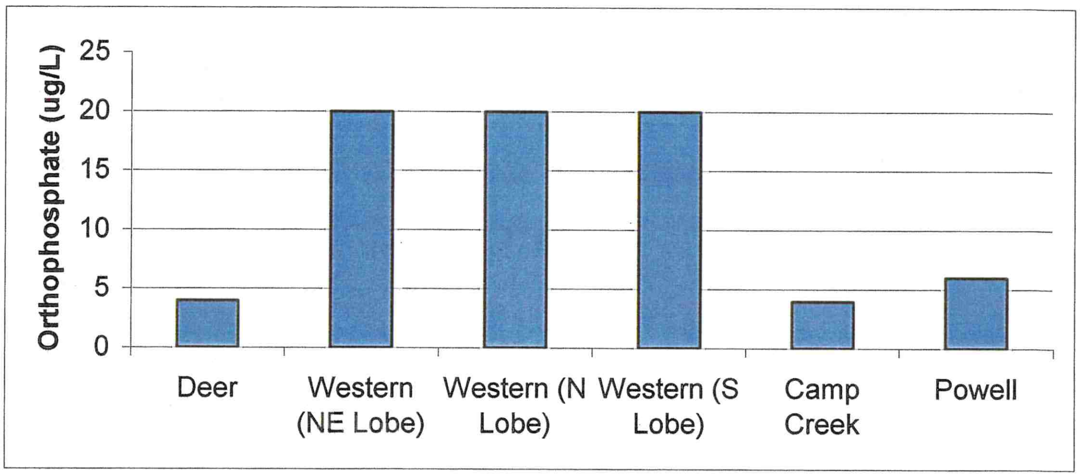


Figure 3. Total phosphorus, orthophosphate and total organic carbon values obtained from near-center of each lake and those subdivisions of Western Lake.



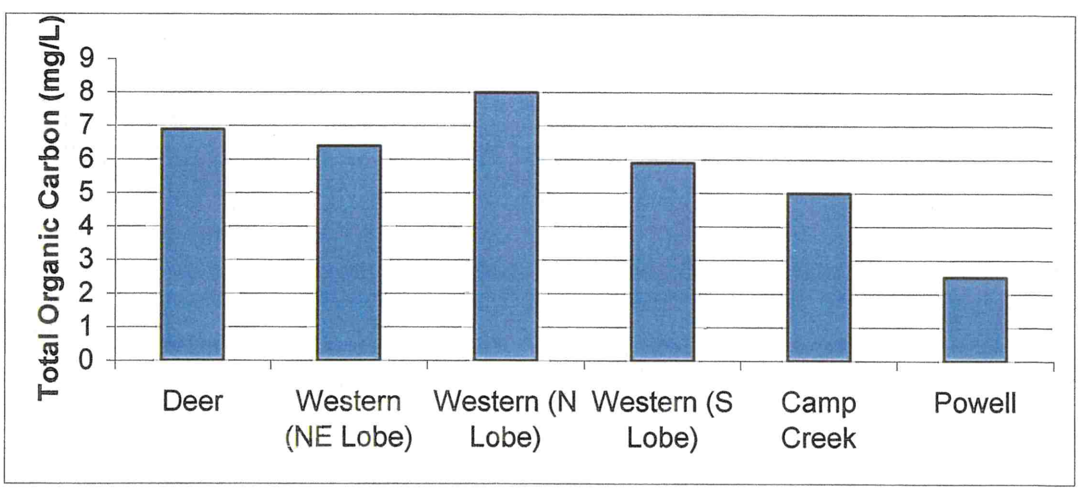
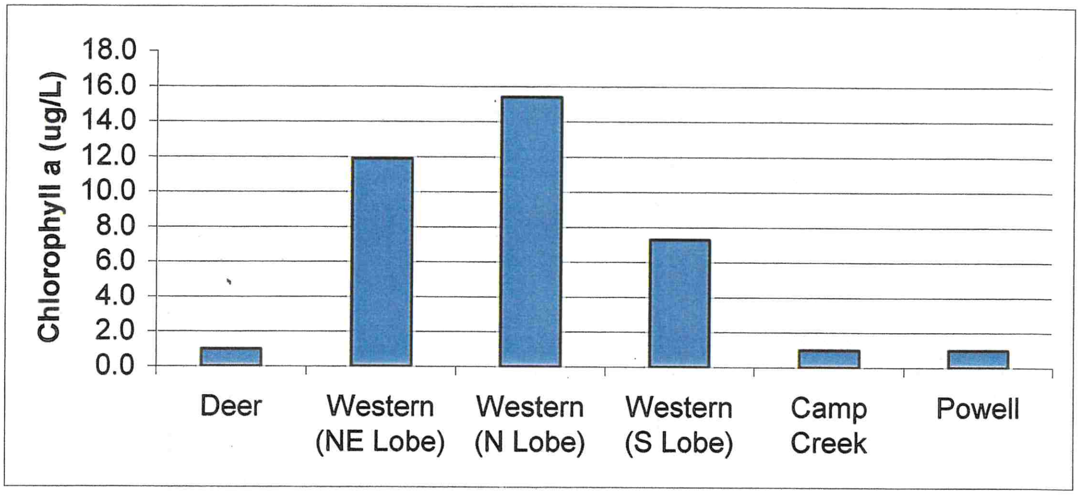



Figure 4. Chlorophyll *a* and algal growth potential test results obtained from near-center of each lake and subdivisions of Western Lake.



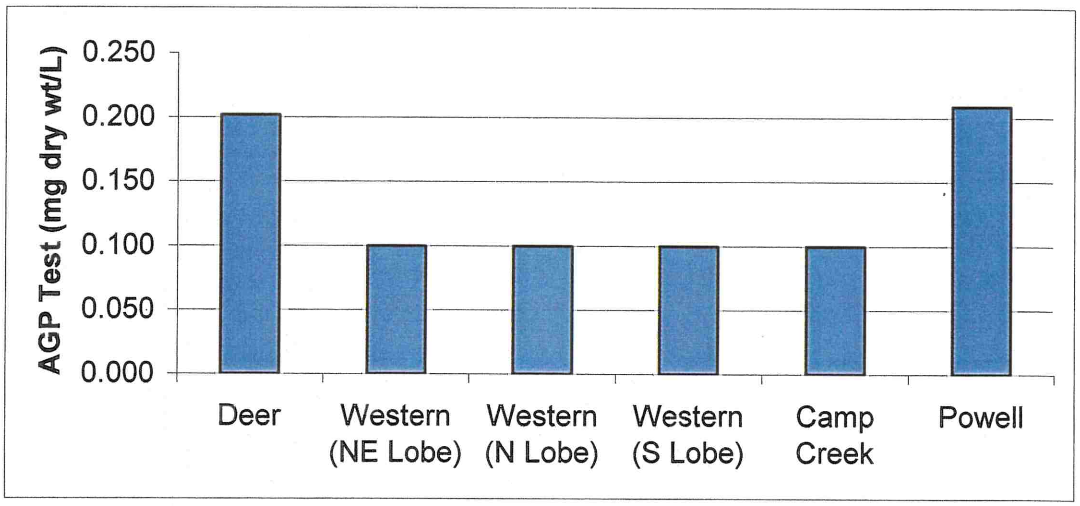



Table 3. Phytoplankton taxa and relative densities (number/mL) collected from three of the four lakes sampled winter 2000. Samples for phytoplankton determination were collected at a depth of approximately 30 cm.

| Lake:<br>Taxon | Deer | Powell | Camp Creek |
|---|---|---|---|
| **Bacillariophyta** | | | |
| *Cyclotella* spp. | 11 | 1 | 9 |
| Cymbellaceae | 2 | --- | --- |
| Diatomaceae | 2 | --- | 1 |
| *Nitzschia* spp. | 3 | --- | 1 |
| *Pennales* spp. | 3 | 1 | 3 |
| *Rhizosolenia* spp. | 5 | --- | --- |
| *Tabellaria spp.* | 4 | --- | --- |
| Thalassiosiraceae | --- | --- | 106 |
| **Chlorophycota** | | | |
| *Ankistrodesmus* falcatus | 1 | --- | --- |
| *Ankistrodesmus* spp. | 111 | --- | --- |
| *Chlamydomonas* spp. | 6 | --- | --- |
| *Chlorella* spp. | 1 | 1 | 10 |
| Chlorophyceae | 14 | 11 | 24 |
| *Crucigenia* spp. | --- | --- | 15 |
| *Characium* spp. | 1 | --- | --- |
| *Franceia* spp. | 1 | --- | --- |
| *Selenastrum* spp. | 14 | --- | 4 |
| *Staurastrum* spp. | 1 | --- | --- |
| *Tetraedron minimum* | 2 | --- | --- |
| **Chrysophyta** | | | |
| *Dinobryon bavaricum* | 36 | --- | --- |
| *Kephyrion* spp. | 1 | --- | --- |
| Chrysophyceae | --- | 3 | --- |
| **Cryptophycota** | | | |
| *Chroomonas* spp. | --- | 3 | 3 |
| *Cryptomonas* spp. | 1 | 49 | 18 |
| Cryptophyceae | 6 | 47 | 13 |
| **Cyanophycota** | | | |
| *Anabaena* spp. | --- | 1 | --- |
| Chroococcaceae | --- | --- | 124 |
| *Chroococcus* spp. | --- | --- | 10 |
| *Merismopedia* spp. | --- | --- | 9 |
| *Microcystis* spp. | --- | --- | 1 |
| *Oscillatoria* spp. | --- | --- | --- |
| *Synechococcus* spp. | --- | 7 | 18 |

Continued next page.

Table 3. Continued.

| Lake: | Deer | Powell | Camp Creek |
|---|---|---|---|
| Taxon | | | |
| **Euglenophycota** | | | |
| *Lepocinclis* spp. | 1 | --- | 1 |
| | | | |
| **Pyrrophycophyta** | | | |
| *Gymnodinium* | 1 | 2 | 1 |
| *Glenodinium* spp. | --- | 1 | --- |
| *Prorocentrum* spp. | --- | 2 | --- |
| | | | |
| Total Number Of Taxa: | 23 | 13 | 18 |
| Total Density (Number/mL): | 228 | 129 | 371 |

Table 4. Taxa rank and percent of community contribution at Lake Powell, Bay County. Benthos collected on 8 March 2000 in sublittoral zone (2 m–4 m deep).

| Rank | Taxon | No. | Percent of Community | Cumulative Percent | No./$m^2$ |
|---|---|---|---|---|---|
| 1 | *Anomalocardia auberiana* | 769 | 51.4 | 51.4 | 2528 |
| 2 | *Ampelisca abdita* | 216 | 14.4 | 65.8 | 710 |
| 3 | *Streblospio benedicti* | 198 | 13.2 | 79.0 | 651 |
| 4 | *Capitella capitata* | 86 | 5.8 | 84.8 | 283 |
| 5 | *Tagelus plebeius* | 55 | 3.7 | 88.5 | 181 |
| 6 | *Ampelisca vadorum* | 27 | 1.8 | 90.3 | 89 |
| 7 | *Hobsonia florida* | 21 | 1.4 | 91.7 | 69 |
| 7 | *Leitoscoloplos fragilis* | 21 | 1.4 | 93.1 | 69 |
| 9 | *Almyracuma* spp. | 18 | 1.2 | 94.3 | 59 |
| 10 | *Amygdalum papyrium* | 16 | 1.1 | 95.4 | 53 |
| 10 | *Tetrastemma candidum* | 16 | 1.1 | 96.5 | 53 |
| 12 | *Mediomastus ambiseta* | 13 | 0.9 | 97.4 | 43 |
| 13 | *Sigambra tentaculata* | 11 | 0.7 | 98.1 | 36 |
| 14 | *Pectinaria gouldi* | 7 | 0.5 | 98.6 | 23 |
| 15 | *Edotea montosa* | 3 | 0.2 | 98.8 | 10 |
| 15 | Nemertea | 3 | 0.2 | 99.0 | 10 |
| 15 | *Oxyurostylis smithi* | 3 | 0.2 | 99.2 | 10 |
| 18 | *Bowmaniella floridana* | 2 | 0.1 | 99.3 | 7 |
| 18 | *Neanthes succinea* | 2 | 0.1 | 99.4 | 7 |
| 20 | *Eteone heteropoda* | 1 | 0.1 | 99.5 | 3 |
| 20 | *Grandidierella bonnieroides* | 1 | 0.1 | 99.6 | 3 |
| 20 | *Hargeria rapax* | 1 | 0.1 | 99.7 | 3 |
| 20 | *Haustorius* spp. | 1 | 0.1 | 99.8 | 3 |
| 20 | *Mysidopsis almyra* | 1 | 0.1 | 99.9 | 3 |
| 20 | *Parandalia americana* | 1 | 0.1 | 100.0 | 3 |
| 20 | *Rangia cuneata* | 1 | 0.1 | 100.1 | 3 |
| 20 | *Solen viridis* | 1 | 0.1 | 100.2 | 3 |

Table 5. Percent sediment grain size and organic matter obtained from the sublittoral zone (2 m–4 m deep) of each lake and those subdivisions of Western Lake.

| **Lake:** | **Deer** | **Western NE Lobe** | **Western N Lobe** | **Western S Lobe** | **Camp Creek** | **Powell** |
|---|---|---|---|---|---|---|
| **Percent organic:** | 0.7 | 1.1 | 7.1 | 6.2 | 18 | 0.63 |
| **Percent grain size (mm):** | | | | | | |
| >2.0 | 0.42 | 0.71 | 0.5 | 0.3 | 0.43 | 0.48 |
| 0.5-2.0 | 21.7 | 20.5 | 2.99 | 1.1 | 1.22 | 10.9 |
| 0.25-0.5 | 48.6 | 43.1 | 11.4 | 11 | 9.82 | 60.8 |
| 0.125-0.25 | 17.0 | 18.9 | 15.3 | 13 | 11.8 | 19.6 |
| 0.063-0.125 | 2.26 | 1.54 | 14.5 | 9.7 | 11.0 | 1.06 |
| <0.063 | 10.5 | 16.0 | 55.8 | 65 | 66.2 | 7.64 |

>2.0= Gravel
0.5-2.0= Coarse to very coarse sand
0.25-0.5= Medium sand
0.125-0.25= Fine sand
0.063-0.125= Very fine sand
<0.063= silt/clay

Table 6. Taxa rank and percent of community contribution at Deer Lake, Walton County. Benthos collected on 13 March 2000 in sublittoral zone (2 m–4 m deep).

| Rank | Taxon | No. | Percent of Community | Cumulative Percent | No./$m^2$ |
|---|---|---|---|---|---|
| 1 | *Polypedilum halterale* grp. | 33 | 34.7 | 34.7 | 8,562 |
| 2 | *Polypedilum scalaenum* grp. | 25 | 26.3 | 61.0 | 6,486 |
| 3 | *Cladopelma* spp. | 10 | 10.5 | 71.5 | 2,594 |
| 4 | *Cryptochironomus* spp. | 4 | 4.2 | 75.7 | 1,038 |
| 4 | *Oecetis porteri* | 4 | 4.2 | 79.9 | 1,038 |
| 6 | *Zavreliella marmorata* | 3 | 3.2 | 83.1 | 778 |
| 7 | *Aulodrilus pigueti* | 2 | 2.1 | 85.2 | 519 |
| 7 | *Hyalella azteca* | 2 | 2.1 | 87.3 | 519 |
| 7 | *Palpomyia/Bezzia* grp. | 2 | 2.1 | 89.4 | 519 |
| 7 | *Procladius* spp. | 2 | 2.1 | 91.5 | 519 |
| 11 | *Ablabesmyia mallochi* | 1 | 1.1 | 92.6 | 259 |
| 11 | *Caenis* sp. | 1 | 1.1 | 93.7 | 259 |
| 11 | Chironomidae | 1 | 1.1 | 94.8 | 259 |
| 11 | *Oecetis* sp. | 1 | 1.1 | 95.9 | 259 |
| 11 | *Planaria* sp. | 1 | 1.1 | 97.0 | 259 |
| 11 | *Polypedilum* sp. | 1 | 1.1 | 98.1 | 259 |
| 11 | *Tanytarsus* sp. I – Epler | 1 | 1.1 | 99.2 | 259 |
| 11 | *Tanytarsus* sp. | 1 | 1.1 | 100.3 | 259 |

Table 8. Taxa rank and percent of community contribution at Western Lake (north arm), Walton County. Benthos collected on 28 February 2000 in sublittoral zone (2 m–4 m deep).

| Rank | Taxon | No. | Percent of Community | Cumulative Percent | No./$m^2$ |
|---|---|---|---|---|---|
| 1 | *Grandidierella bonnieroides* | 114 | 50.9 | 50.9 | 1,124 |
| 2 | *Chaoborus punctipennis* | 35 | 15.6 | 66.5 | 345 |
| 3 | *Hobsonia florida* | 12 | 5.4 | 71.9 | 118 |
| 4 | *Hargeria rapax* | 11 | 4.9 | 76.8 | 108 |
| 5 | *Corophium louisianum* | 6 | 2.7 | 79.5 | 59 |
| 5 | *Polymesoda caroliniana* | 6 | 2.7 | 82.2 | 59 |
| 5 | *Tanypus clavatus* | 6 | 2.7 | 84.9 | 59 |
| 8 | *Parandalia americana* | 5 | 2.7 | 87.6 | 49 |
| 9 | *Chironomus* spp. | 4 | 1.8 | 89.4 | 39 |
| 9 | *Laeonereis culveri* | 4 | 1.8 | 91.2 | 39 |
| 9 | *Tanytarsus* spp. | 4 | 1.8 | 93.0 | 39 |
| 12 | *Coelotanypus* spp. | 3 | 1.3 | 94.3 | 30 |
| 12 | *Tellina texana* | 3 | 1.3 | 95.6 | 30 |
| 14 | Ceratopogonidae | 2 | 0.9 | 96.5 | 20 |
| 14 | *Procladius* spp. | 2 | 0.9 | 97.4 | 20 |
| 14 | Spionidae | 2 | 0.9 | 98.3 | 20 |
| 17 | *Almyracuma* sp. | 1 | 0.4 | 98.7 | 20 |
| 17 | *Dicrotendipes lobus* | 1 | 0.4 | 99.1 | 20 |
| 17 | *Edotea montosa* | 1 | 0.4 | 99.5 | 20 |
| 17 | *Lembos* sp. | 1 | 0.4 | 99.9 | 20 |
| 17 | *Polypedilum scalaenum* grp. | 1 | 0.4 | 100.3 | 20 |

Table 9. Taxa rank and percent of community contribution at Western Lake (southern lobe), Walton County. Benthos collected on 28 February 2000 in sublittoral zone (2 m–4 m deep).

| Rank | Taxon | No. | Percent of Community | Cumulative Percent | No./$m^2$ |
|---|---|---|---|---|---|
| 1 | *Grandidierella bonnieroides* | 131 | 51.2 | 51.2 | 429 |
| 2 | *Hargeria rapax* | 27 | 10.5 | 61.7 | 88 |
| 3 | *Corbula* spp. | 19 | 7.4 | 69.1 | 62 |
| 4 | *Gammarus muctonatus* | 15 | 5.9 | 75.0 | 49 |
| 5 | *Leitoscoloplos* spp. | 10 | 3.9 | 78.9 | 33 |
| 6 | *Parandalia* spp. | 9 | 3.5 | 82.4 | 29 |
| 6 | *Tellina* spp. | 9 | 3.5 | 85.9 | 29 |
| 8 | *Chironomus* spp. | 8 | 3.1 | 89.0 | 26 |
| 9 | Tubificidae | 6 | 2.3 | 91.3 | 20 |
| 10 | *Almyracuma* spp. | 5 | 2.0 | 93.3 | 16 |
| 11 | *Cyathura polita* | 3 | 1.2 | 94.5 | 10 |
| 11 | Hydrobiidae | 3 | 1.2 | 95.7 | 10 |
| 13 | *Bowmaniella floridana* | 2 | 0.8 | 96.5 | 7 |
| 13 | Ceratopogonidae | 2 | 0.8 | 97.3 | 7 |
| 14 | *Actiniaria* spp. | 1 | 0.4 | 97.7 | 3 |
| 14 | *Amphicteis* sp. | 1 | 0.4 | 98.1 | 3 |
| 14 | *Chaoborus punctipennis* | 1 | 0.4 | 98.5 | 3 |
| 14 | *Edotea tiloba* | 1 | 0.4 | 98.9 | 3 |
| 14 | *Eteone heteropoda* | 1 | 0.4 | 99.3 | 3 |
| 14 | *Polypedilum scalaenum* | 1 | 0.4 | 99.7 | 3 |
| 14 | *Cryptochironomus* sp. | 1 | 0.4 | 100.1 | 3 |

Table 10. Taxa rank and percent of community contribution at Camp Creek Lake, Walton County. Benthos collected on 15 March 2000 in sublittoral zone (2 m–4 m deep).

| Rank | Taxon | No. | Percent of Community | Cumulative Percent | No./$m^2$ |
|---|---|---|---|---|---|
| 1 | *Streblospio* spp. | 265 | 56.7 | 56.7 | 868 |
| 2 | *Grandidierella bonnieroides* | 154 | 33.0 | 89.7 | 504 |
| 3 | *Laeonereis culveri* | 9 | 1.9 | 91.6 | 29 |
| 4 | *Apocorophium* spp. | 8 | 1.7 | 93.3 | 26 |
| 5 | Nemertea | 5 | 1.1 | 94.4 | 16 |
| 6 | *Americamysis* spp. | 4 | 0.9 | 95.3 | 13 |
| 6 | Ceratopogonidae | 4 | 0.9 | 96.2 | 13 |
| 6 | *Chironomus* spp. | 4 | 0.9 | 97.1 | 13 |
| 6 | Hydrobiidae | 4 | 0.9 | 98.0 | 13 |
| 10 | *Chaoborus punctipennis* | 2 | 0.4 | 98.4 | 7 |
| 10 | *Tanytarsus* sp. J – Epler | 2 | 0.4 | 98.8 | 7 |
| 12 | *Capitella capitata* | 1 | 0.2 | 99.0 | 3 |
| 12 | Corophiidae | 1 | 0.2 | 99.2 | 3 |
| 12 | *Dubiraphia* spp. | 1 | 0.2 | 99.4 | 3 |
| 12 | *Hyalella azteca* | 1 | 0.2 | 99.6 | 3 |
| 12 | *Polypedilum trigonum* | 1 | 0.2 | 99.8 | 3 |
| 12 | Veneridae | 1 | 0.2 | 100.0 | 3 |