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LAKE WEIR EUTROPHICATION STUDY

Final Report for Phases I and II

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TABLE OF CONTENTS

FOREWORD

Water quality in Lake Weir has been deteriorating progressively since the early 1970's. Based on nutrient loading models and water column concentrations, water quality in 1969 was deemed to be in the excellent range (oligotrophic) but close to slipping into the middle range (mesotrophic) of the water quality scale. By 1974, however, the lake was definitely in the mesotrophic range and dangerously close to slipping into the lake category of worst water quality (eutrophic). This cultural eutrophication has continued to progress to the point that lake residents have noticed a marked degradation in water quality in the past five years.

The demise of Lake Weir is unquestionably the result of human activity. Between 1970 and 1980 over 350 houses were built in the watershed. Unfortunately, the area lacks a central sewer system, and relies on septic tanks for waste treatment. Other potential contributors to the nutrient levels of the lake are citrus agriculture and runoff from the extensive road system completed since 1970.

The biotic response of Lake Weir to increased nutrient loading has been complex. Between 1970 and 1980 algal abundance increased 40% in response to a progressive enhancement of water column phosphorus concentrations. Since 1980, however, both algal and phosphorus levels in the open water of the lake have declined markedly as aquatic weed populations have expanded in shallow water. These plants trap phosphorus released from the watershed before it can reach the open areas of the lake. Nutrient loading has continued to increase during the last six years but the potential biological problem has shifted from algae to weeds.

Our research is designed to assess the history of cultural eutrophication in Lake Weir, the important causes responsible for deterioration of water quality, the current status of the lake, and using these data, to prepare a strong management plan designed to maintain/restore water quality in the lake. Of immediate concern today is the manner in which aquatic weeds are controlled or eliminated from Lake Weir. If the aquatic weeds were to be controlled too quickly, the nutrients released from this decomposing material would be available for algal uptake thus driving the system towards a eutrophic state exemplified by Lake Apopka.

EXECUTIVE SUMMARY

Lake Weir, a seepage lake isolated from the Floridan aquifer, was historically an oligotrophic system which received most of its nutrients from precipitation. Watershed soils are composed of well-drained, acidic sands. Historically, annual rainfall is typical of central Florida, varying from 40 to 70 inches. Lake surface levels have closely reflected the previous year's rainfall since 1943. Originally, the watershed was dominated by upland pine forests, with strips of wetland hammock vegetation near the lake.

Changes in land clearance, citrus agriculture and urban development over the past century within Lake Weir's watershed were documented from historical records, maps and aerial photographs (Figure 2-6). Specific natural and manmade events which may have made short-term or lasting impacts on the lake's water quality were outlined (Table 2-2). Watershed population and nutrient yield coefficients for specific land use practices were used to estimate total loading of nitrogen and phosphorus to the lake at specific time intervals (Figure 2-11). Increased watershed population and urbanization are clearly responsible for the observed degradation in water quality since 1969.

Statistical analysis of 1300 Secchi disk readings made from 1985 to 1986 by lake residents revealed lower water clarity in areas of higher shoreline population (Figure 3-6). Secchi depths in Lake Weir were influenced mainly by algal concentrations, and hence nutrient loading. After excluding two Secchi stations which were subjected to other sources of nutrient loading, water clarity at the remaining nearshore stations showed a high negative correlation (R^2 = 0.88) with the number of houses immediately onshore (Figure 3-11). The use of Septic systems in the watershed reduces water clarity when shoreline housing density exceeds one house per hectare.

After a full year of limnological monitoring, comparisons between current and historical conditions in Lake Weir proper reveal that nutrient concentrations, chlorophyll a and Secchi depth have not changed significantly since 1970. While trophic state indices calculated from these parameters have increased slightly, Lake Weir is still classified as mesotrophic. The macrophyte community appears to be stable in both extent and species composition, and is typical of moderately productive Florida lakes. Zooplankton biomass in Lake Weir is low compared to other mesotrophic lakes in the state, but only minor changes in community structure have occurred since 1979. Specifically, scuticociliate protozoans and rotifers have markedly increased in abundance indicating a shift toward greater lake productivity. So few phytoplankton or benthic macroinvertebrate data are available from past studies that no real comparisons are possible for these parameters. Overall, Lake Weir appears to be a typical mesotrophic Florida lake that is responding as expected to increased human use and watershed development.

Sediment core samples from six sites in the Lake Weir system were collected to measure historical trends in trophic state and water quality. Sediment parameters to be studied include: water content, organic and inorganic fractions, phosphorus levels, photosynthetic pigments, and invertebrate species composition. Lead-210 isotopic dating of the sediment will pinpoint the timing of major changes in the lake and will quantify sedimentation rates over time. Accumulation rates of phosphorus, pigments and subfossils at various dated core intervals should reflect the relative impact of concomitant land use practices on Lake Weir. This will provide a more complete picture of historical changes in water quality caused by watershed activities, allowing predictions of future changes with development.

ACKNOWLEDGMENTS

This final report reflects the efforts of many persons who contributed their time and energies to its completion. Funding was provided by St. Johns River Water Management District, Marion County, and the Save Lake Weir Association.

We are indebted to the residents of Lake Weir for their enthusiastic support of the project. We applaud the efforts of Del Wood who supervised the Secchi disk monitoring program. We would especially like to thank Nancy MacCarter, Shirley Little, and Ed Anderson, whose energetic involvement in the Save Lake Weir Association has made a real difference.

The staff of University of Florida's Archives Library was of great assistance in locating historical maps and references. The historical photographs were provided by Jay Dopkin of the University of South Florida's Special Collections. We thank Dr. Armstrong of U.F.'s map library who graciously made aerial photographs of the Florida Citrus Surveys available to us. In addition, the Marion County Tax Assessment Office contributed the aerial photographs for the 1980 and 1985 land use study.

Finally, we are indebted to David Billett and Chris Taylor who assisted with this investigation in the library and in the laboratory, and to Dan Peterson for his help with the captions. We are particularly grateful to Uli Crisman for her laboratory expertise and assistance in the preparation of this document.

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: PHYSICAL AND BIOLOGICAL SETTING OF LAKE WEIR

Physical Setting

Located 57 feet above sea level at 21° 01' N--081° 55' W, Lake Weir falls within the intermediate zone between warm temperate and subtropical climates (Beaver et al 1981). This 2100 hectare lake system is comprised of three distinct basins: Little Lake Weir, Sunset Harbor, and Lake Weir proper. Lake Weir proper is nearly circular with a diameter of approximately seven kilometers. The lake has a relatively small vegetated littoral zone; the sides of the lake basin drop off quickly to a flat bottom ranging from six to eight meters in depth.

Lake Weir is a seepage lake with no permanent tributaries. It receives water and nutrients through groundwater seepage, surface runoff, and precipitation (Messer 1975). There is intermittent outflow to the Oklawaha River over a weir structure located on the north shore.

The Lake Weir watershed, defined on the basis of topographic highs surrounding the lake, was determined to be 4500 hectares in area (Figure 1-1). Several small enclosed wetlands occupy topographic lows in the upper watershed. Messer (1975) did not include these in his calculations, and hence arrived at a smaller watershed area. Because of the low nutrient affinity of the soils (Messer 1975), nutrient loading from the entire 4500 hectare watershed may impact the lake.

Figure 1-1. Map of Lake Weir's watershed, as defined by topographic highs surrounding the lake. Wetland areas are denoted.

Soils in the Lake Weir region are well-drained, being comprised of thick layers of acid sands (Brezonik and Messer 1975). These highly permeable soils are well-drained, and erosion is not generally a problem throughout this gently sloping watershed (Brezonik and Messer 1975). Two distinct aquifers are present: the deep Floridan aquifer and a shallow, unconfined aquifer (Figure 1-2).

The lake is thought to be historically an oligotrophic system, being isolated from the phosphate-rich Floridan aquifer by impermeable clays in the Hawthorn Formation (Messer 1975). Lake Weir was originally a sandbottom lake, but much of the basin is now covered by up to a meter of flocculent organic sediment. The lake's trophic state has likely been in the mesotrophic range for the past several decades, but a few indicators have recently slipped closer to the eutrophic range.

Rainfall data have been compiled for Ocala (30 Km NW of Lake Weir) since 1892. Annual precipitation varied from 40 to 75 inches over the past century, showing a cyclical pattern of three to six year intervals (Figure 1-3). Lake surface levels, monitored since 1943 at Oklawaha by the USGS, showed similar fluctuations (Figure 1-4). The lake water elevation reached its lowest recorded levels in 1956 to 1958, being under 54 feet above sea level. Lake water level rebounded to a recorded high of over 59 feet in 1961. On a year by year comparison of variance, trends in lake water levels closely reflected rainfall for the previous year (Figure 1-5). This lag time was probably due to the absence of overland runoff into the lake.

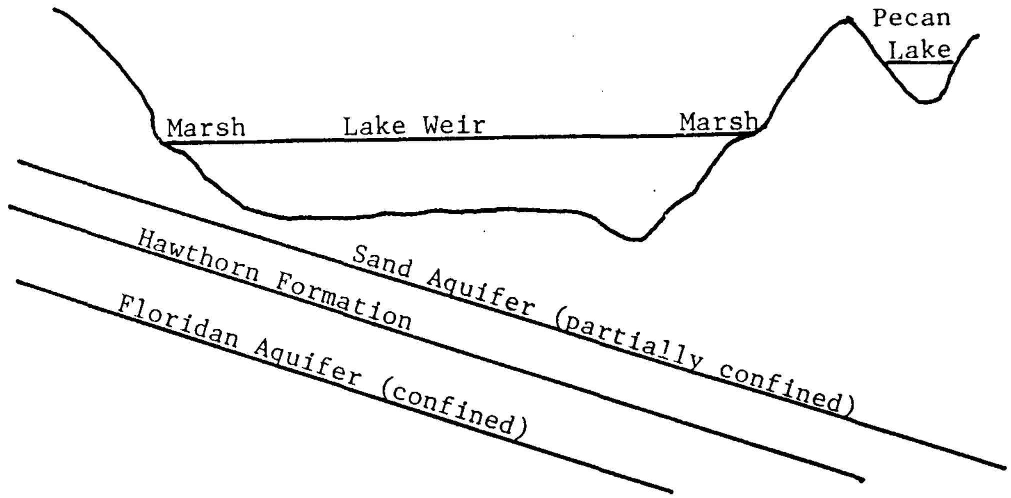

Figure 1-2. Geologic map of Lake Weir watershed showing the Floridan aquifer and an unconfined sand aquifer (adapted from Messer, 1975).

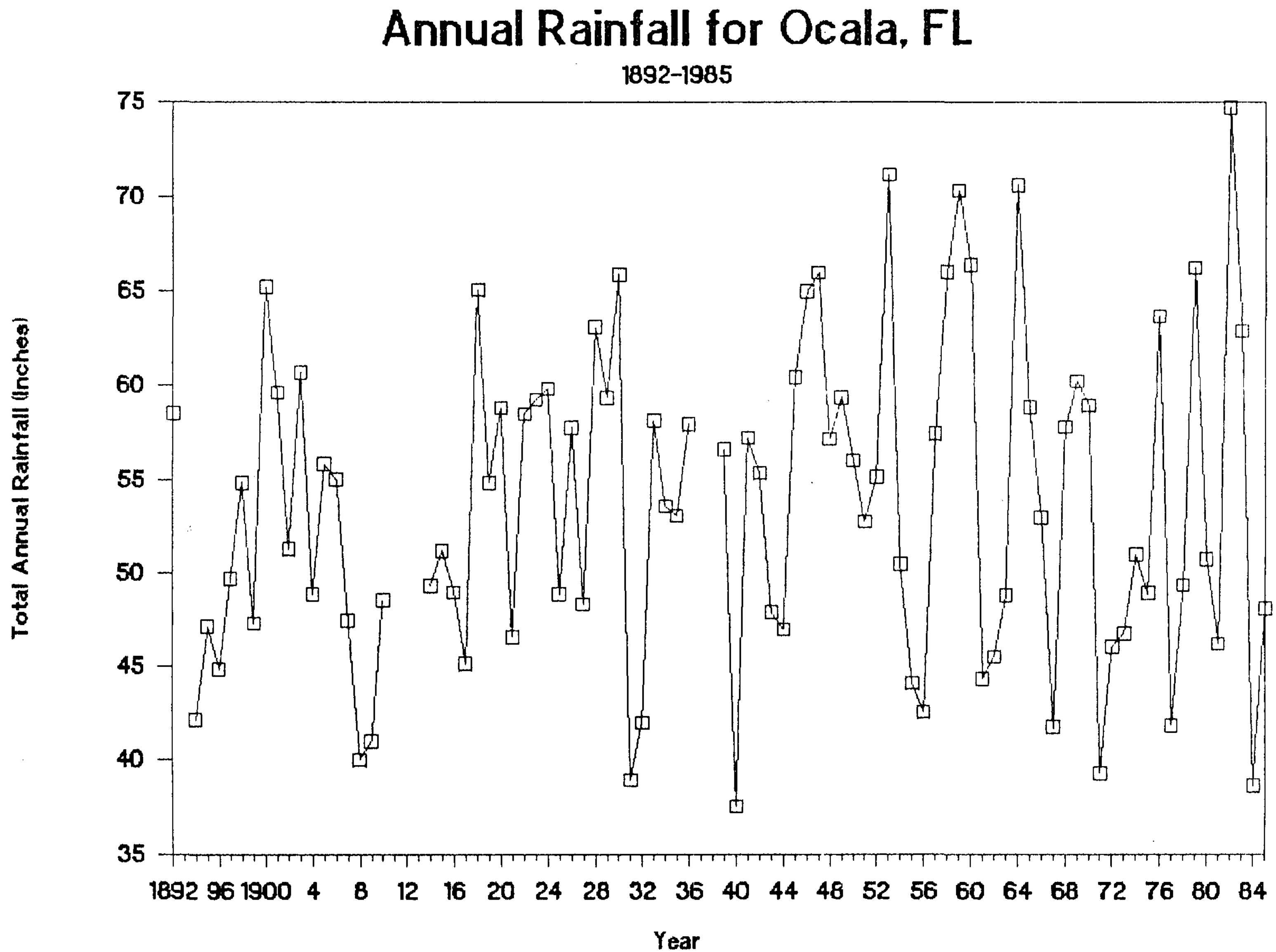

Figure 1-3. USGS annual rainfall data for Ocala, Fl. Note cyclical pattern.

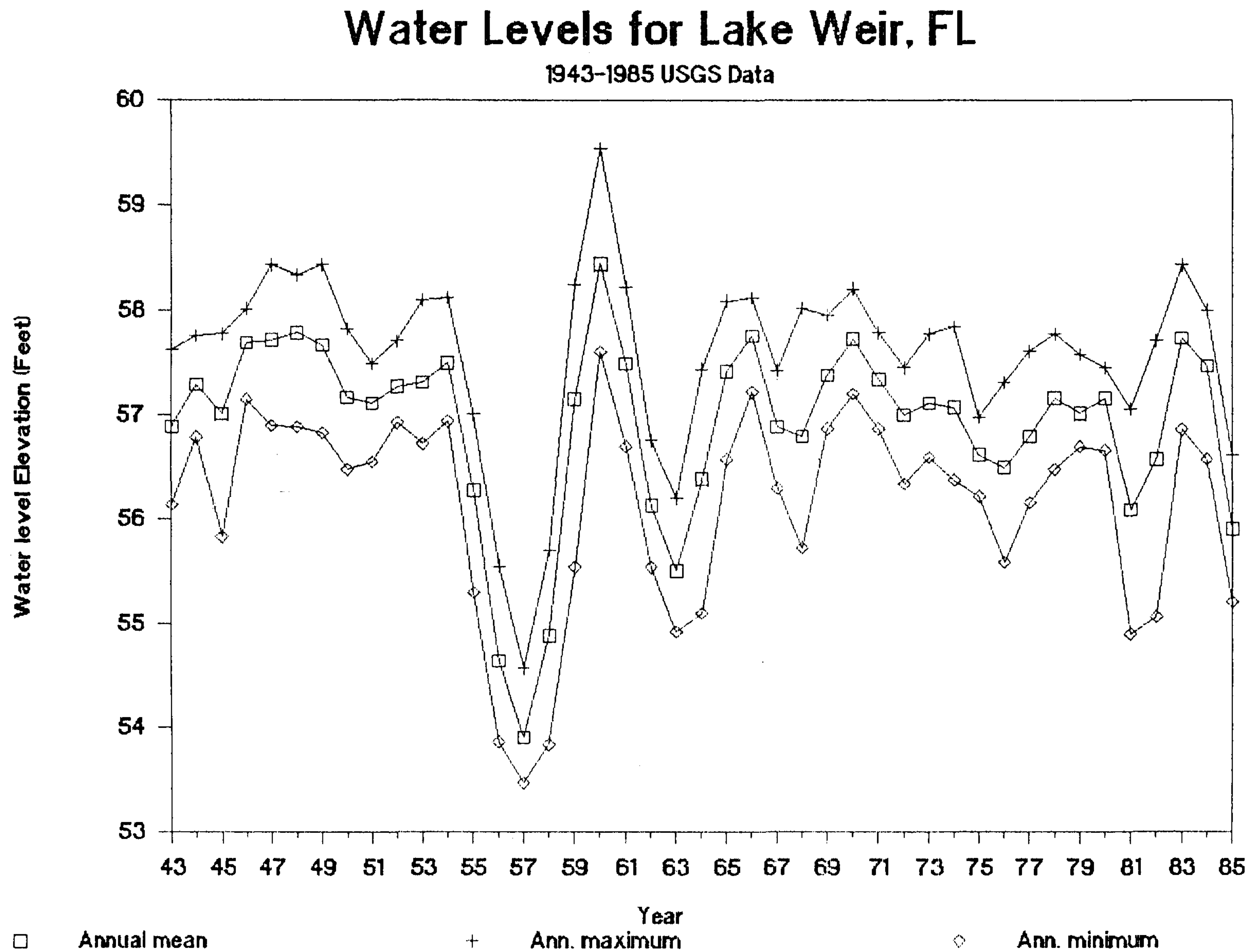

Figure 1-4. Lake Weir water surface levels by year, monitored by USGS at Oklawaha. The lowest recorded level occurred in 1957; the highest in 1961. Water levels have been falling since 1983.

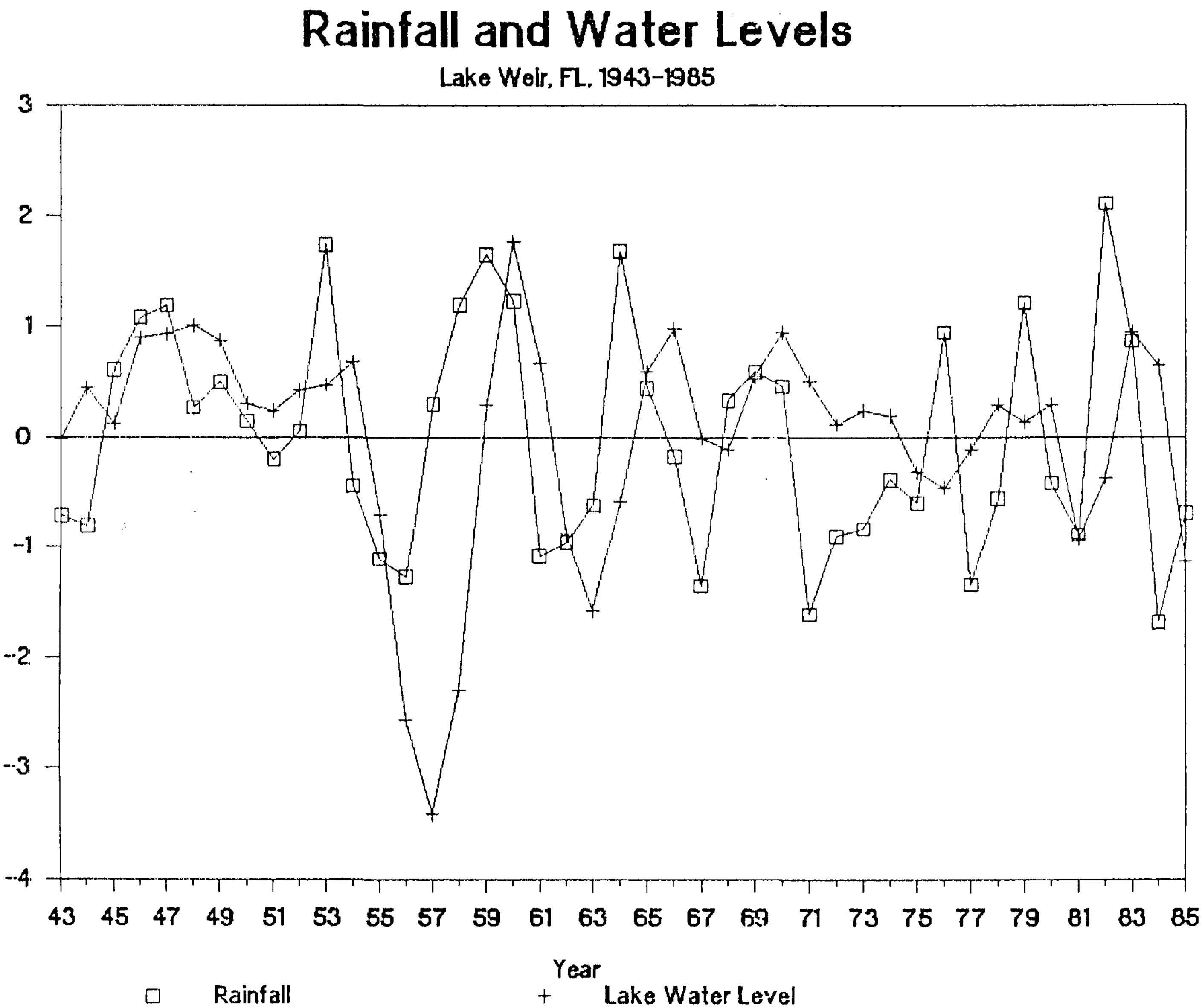

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Figure 1-5. Annual rainfall and mean water levels for Lake Weir, expressed as standard deviations from their mean values since 1943. Note that water levels closely echo rainfall, after a lag time of one year.

As lake water level has fluctuated through time, the shoreline has been significantly altered. Comparison of the shoreline in Shackleford's map of 1883 to a recent topographic map showed that the water level had been as high as 61 feet, higher than any level recorded since 1943. Little Lake Weir was directly connected to Lake Weir proper, isolating four islands which now are part of the peninsula. Shackleford noted that US government maps prior to 1883 depicted lower water levels.

Lake level has been dropping since 1983, and is now at one of the lowest recorded levels. Periods of low water can exert a significant short-term nutrient impact on the lake. Because most exchange with the shallow aquifer occurs in the littoral area of the lake, there is less dilution of nutrients by groundwater flushing during low water stage. Further, the shallower water levels are more conducive to sediment mixing and concomitant nutrient recycling. Finally, lower water level temporarily reduces the extent of wetlands and shallow littoral zones, which act as filters to mitigate nutrient loading.

Episodes of low water level may also have long-term beneficial effects on lake water quality. These periods may serve to consolidate littoral sediment, sealing the nutrients from future recycling into the lake water column. Low lake stage also allows the rejuvenation of shoreline vegetation, which ameliorates future nutrient loading from the watershed. Nevertheless, low lake water levels exert a short-term nutrient impact, and current water quality of Lake Weir may be partially attributable to recent lower water levels.

Biological Setting

The native vegetation around Lake Weir was dominated by pine forests (Shackleford 1883). Yellow pine was reported to be a valuable timber resource throughout that region (Marion County Surveyor's Map of 1888). Hammock associations of live oak, water oak, magnolia, sweetgum, hickory, bay and holly occurred on the peninsula, islands, and in strips along the lake's margin (Shackleford 1883). The Marion County map of 1888 showed wetlands consisting of hammock, bay, cypress, saw grass, and "scrub" north of the lake (Figure 2-4). A photograph taken circa 1900 of Lake Weir's southeastern shoreline shows a dense strip of natural hardwood hammock vegetation (Figure 1-6). Also, stumps of dead cypress trees were present in the shallow littoral area. The Vegetation and Land Use Map (SJRWMD 1973) showed very little mesic hammock or sand pine scrub remaining (Figure 1-7).

Lake Weir's fertile hardwood hammocks were highly regarded for their rich organic soils and great suitability for citrus (Shackleford 1883). Wild oranges found on these lands were were not indigenous, as believed by settlers of the late 1800's, but rather had been introduced to Florida by the Spanish. While the hammock forests provided the best soils for citrus, pine lands could also support citrus agriculture with additional fertilization.

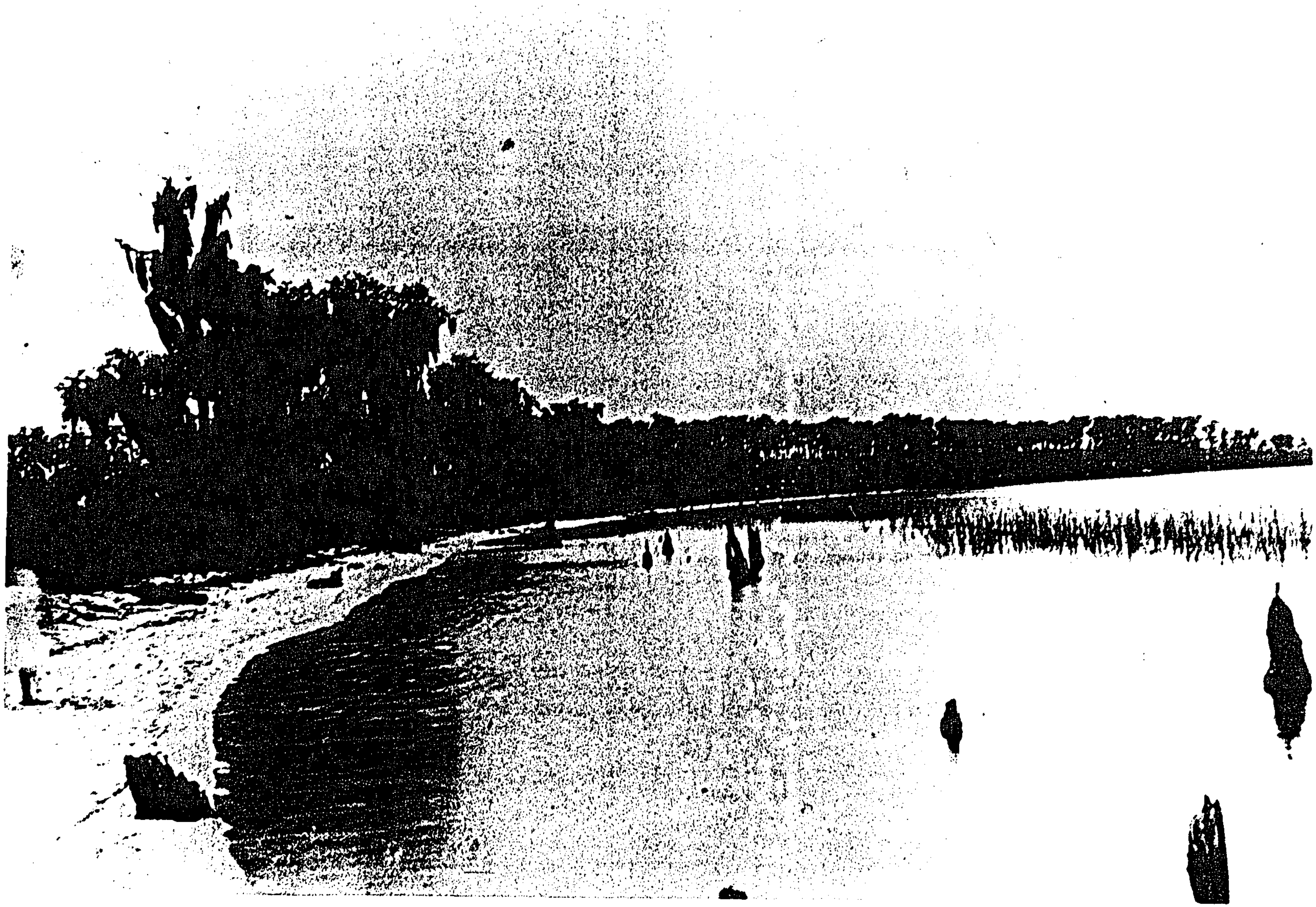
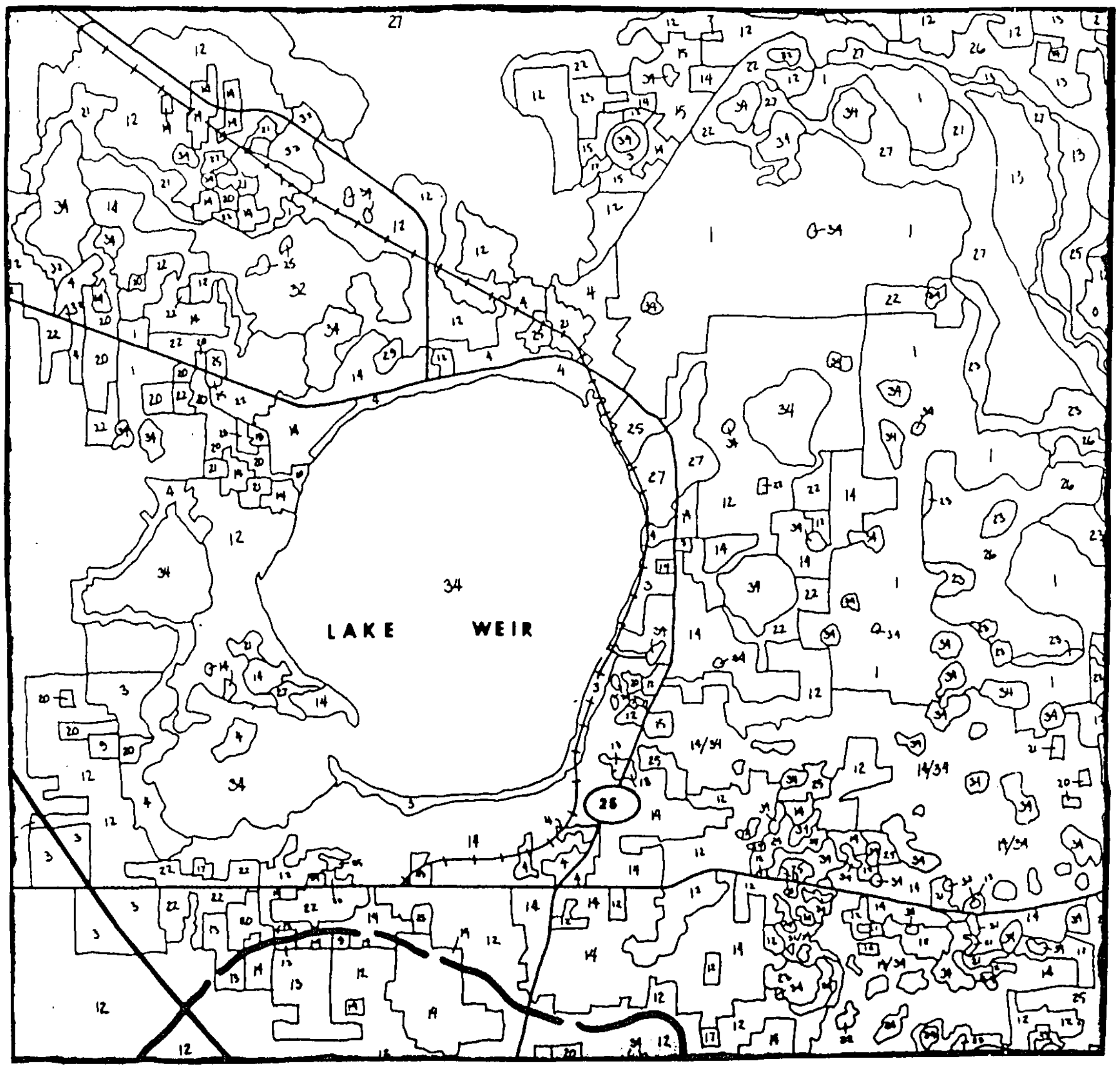


Figure 1-6. Photograph (ca. 1900) of Lake Weir's southeastern shoreline showing dense hardwood hammock vegetation. Note cypress stumps in the foreground.



Legend

1	Open land
3	Residential, low density
4	Residential, high density
12	Improved pasture
13	Crop lands
14	Citrus groves
21	Sand pipes scrub
22	Sandfill community
25	Mesic Hammock
27	Hardwood swamp
32	Freshwater marsh
34	Lakes and ponds

Figure 1-7. Vegetation and Land Use Map of 1973 by St. Johns River Water Management District. Scale: 1"= 2 mi (1:80,000).

Concerning fish populations, Shackleford (1883) described Lake Weir as being "well stocked with fish, consisting of trout [largemouth bass], bream, perch [crappie], pike, cat, and freshwater mullet." Sportfish populations today are similar, with the notable exception of the loss of crappie. Whether the "freshwater mullet" was indeed mullet remains uncertain, but if resolved would provide evidence for a natural connection to the Oklawaha River.

CHAPTER TWO:
HISTORICAL DEVELOPMENT OF LAKE WEIR'S WATERSHED AND ASSOCIATED NUTRIENT INPUTS TO THE LAKE

In order to assess the historical impact of various land use practices on the water quality of Lake Weir, watershed history must be delineated. With such a database, it becomes possible to correlate water quality to the type and degree of development around the lake for a given time period. This information can then be used to establish future land management policies to preserve Lake Weir from further eutrophication.

Eutrophication is an additive process whereby increased nutrient yields due to changes in watershed land use practices will increase nutrient concentrations in a lake. Any practices which introduce nutrients or increase erosion will contribute to nutrient loading. Common disturbances include land clearance, agricultural practices, and urbanization. The amount of rainfall and water level also affect the concentration of nutrients in a lake.

Lake Weir's watershed development over the past century was documented from old maps, aerial photographs, government records, and published reports. We were especially interested in changes in land clearance, citrus agriculture (areal extent and management practices), and urbanization (residential area, human population, dredging, and road construction) as well as historical trends in rainfall and water level. With such an approach we were able to establish a detailed chronology of potential nutrient sources from Lake Weir's watershed.

Settlement of Lake Weir

Lake Weir may have been home to a number of past Indian cultures. Today, at least four prehistoric archaeological sites, including two lithic scatter type sites, are known around Lake Weir (Archaeological Consultants, Inc. 1987). Shackleford (1883) claimed that it was not uncommon to find pottery fragments, arrow heads, spear heads, and other Indian relics.

Spanish missionaries began to frequent this region around 1600. Groups of Timucuan Indians known as the Ocale and Potono Tribes occupied Marion County at that time (Milanich and Fairbanks 1980). The agricultural Timuqua were decimated about 1630 by diseases introduced by Europeans.

Around 1700, the British forced the Creek Indians out of Alabama and Georgia. These peoples relocated into north central Florida and became known as the Seminoles. Some settled around Lake Weir, raising cattle and farming the fertile hammocks. They named the lake Amaskohegan, meaning Bright Moon Lake (Shackleford 1883).

Early maps of the Oklawaha River region were made by the US Army Corps of Engineers during the Seminole Indian Wars of 1818 and 1835-1842. These maps are now preserved in the National Archives. An undated early map (Figure 2-1) described the unnamed lake: "a lake 3 1/2 miles in diameter" with "a bay gall extending [north] from lake to the [Oklawaha] river hammock." The term "gall" probably refers to a forested wetland. An 1836 map (Figure 2-2) showed a stream connecting

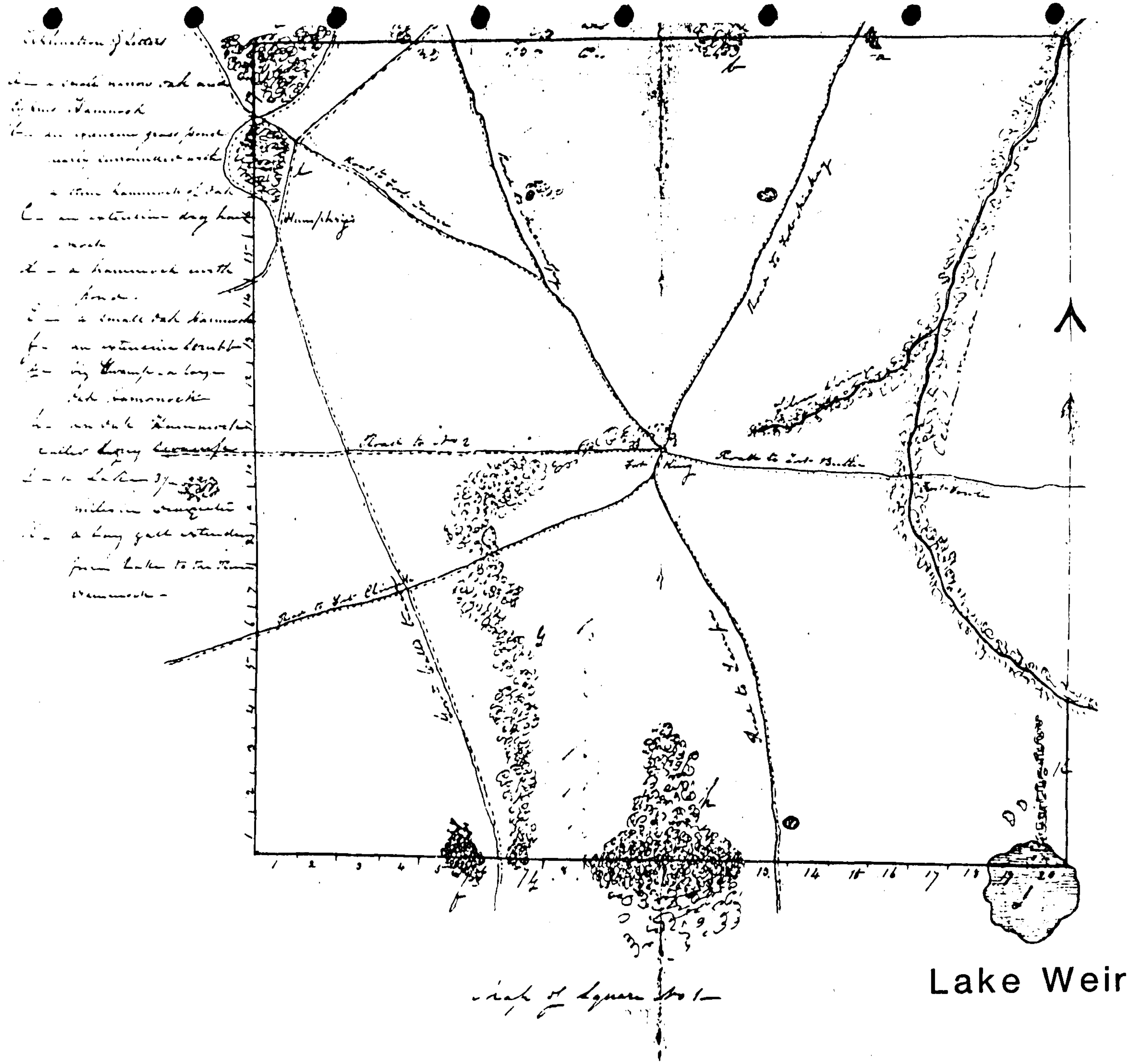


Figure 2-1. Map (circa 1835) of the Oklawaha River region of Central Florida by the U.S. Army Corps of Engineers. Lake Weir, in the lower right corner, was described as "a lake 3 1/2 miles in diameter" and the area to the north was labelled "a bay gall extending from the lake to the river hammock."

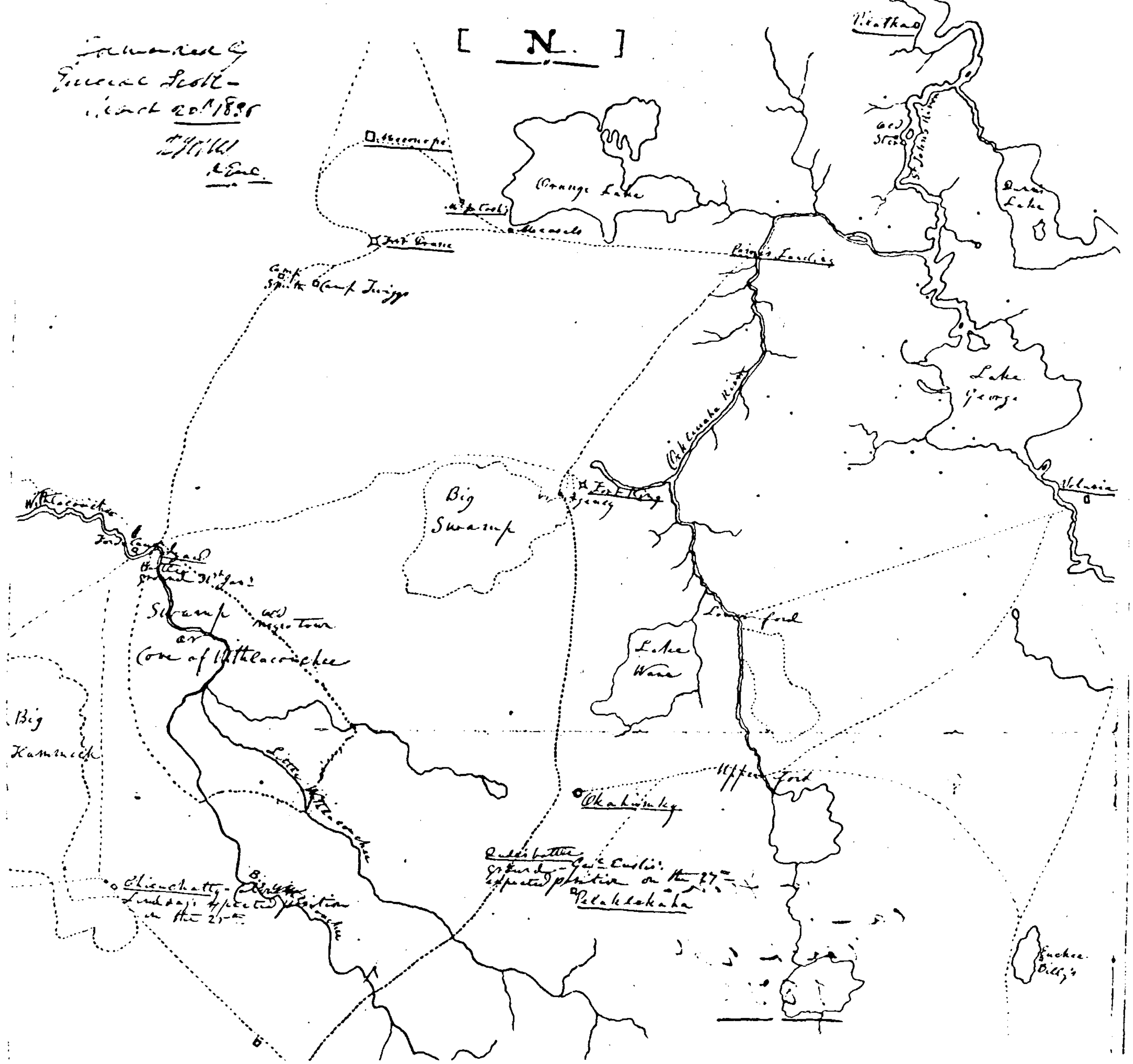


Figure 2-2. 1836 map of the Oklawaha River region of Central Florida by the U.S. Army Corps of engineers. Note the river connecting "Lake Ware" to the Oklawaha River.

"Lake Ware" north to the Oklawaha River. This suggests that there may have been at least an intermittent stream predating the weir structure and canal of 1938.

Shackleford (1883) stated that the lake was named "in honor of Lieutenant Weir of the US Army who was killed near its borders by the Seminoles during one of their wars with the United States." Like the 1836 map, a Florida map of 1834 in Marion County's Regional Library depicted "Ware's Lake." This indicates that the lieutenant was killed before the Second Seminole Indian War, and that his name may have been "Ware." If this was the case, "Weir" was probably a corruption of "Ware".

The U.S. Army registry listed two men for whom the lake may have been named. The most likely candidate is William F. Ware of Georgia, who was honorably discharged as a Captain on January 15, 1815. He may have come out of retirement in 1818 to join Jackson's Tennessee Volunteers during the First Seminole War. Lake Weir may also be the namesake of Second Lieutenant Lewis Weir of Tennessee who died on November 14, 1809. However, the location of his death was not specified, and his death predates the Seminole Indian wars.

Shackleford (1883) provided a detailed account of Lake Weir's early plantation owners. In 1843, under the "Armed Occupation Act," Col. S.F. Halladay became the first European settler on Lake Weir. The few early settlers experimented unsuccessfully with different forms of agriculture, particularly cotton and various vegetables. By 1870, Lake Weir was still virtually uninhabited due to its distance from all means of transportation. The nearest steamboat landing and railroad station were in Silver Springs, and the post office was in Ocala.

Captain John L. Carney became the first citrus grower at Lake Weir in 1874 when he purchased 400 acres on Hammock Peninsula and Orange and Lemon Islands (now part of the peninsula dividing Lake Weir from Little Lake Weir). Lake Weir's great suitability for citrus was not appreciated for a few more years, until news of Carney's success brought a rush of entrepreneurs starting in 1880.

The Lake Weir watershed developed rapidly in the 1880's as a number of families purchased and cleared plots of land around the lake, as depicted on the map from Shackleford's book (1883) (Figure 2-3). By 1888, a number of small towns had been incorporated within the watershed (Figure 2-4). Photographs taken circa 1900 show a number of fine houses, stores, and community buildings (Figure 2-5).

Watershed Development

Shackleford (1883) and the 1890's photographs provided baseline hectarage of citrus and land clearance. Subsequent changes in land use within Lake Weir's watershed were measured from aerial photographs using a Micro-plan II digitizing computer. Florida Citrus Survey photos (1:20,000) were used for 1940, 1957, and 1964. More detailed aerial photos (1:7920)

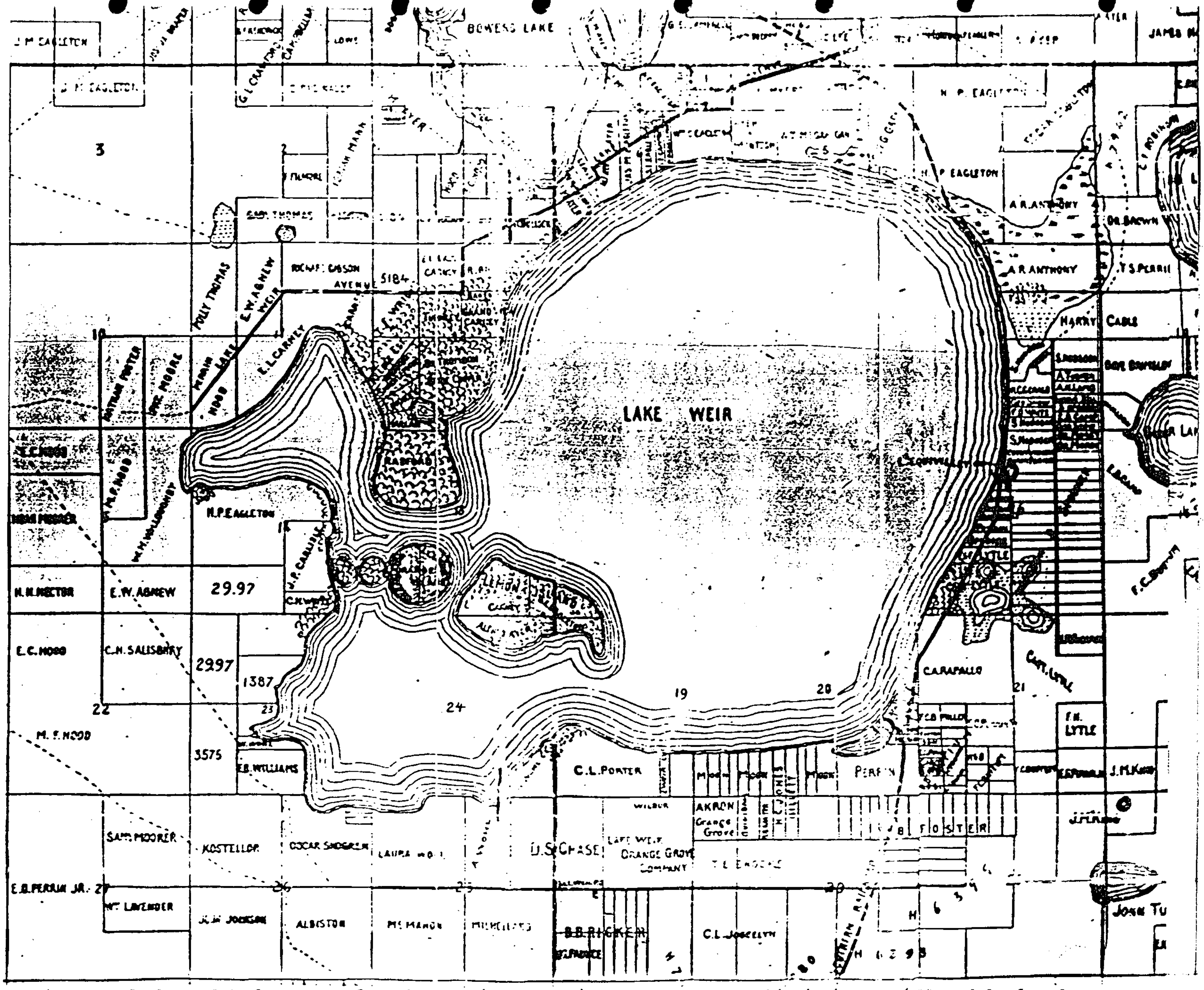


Figure 2-3. 1883 map of Lake Weir showing property divisions (Shackleford, 1883). A plot typically contained one house, a citrus grove, forest, and some cleared land. Note the high water level which divided the peninsula into islands.

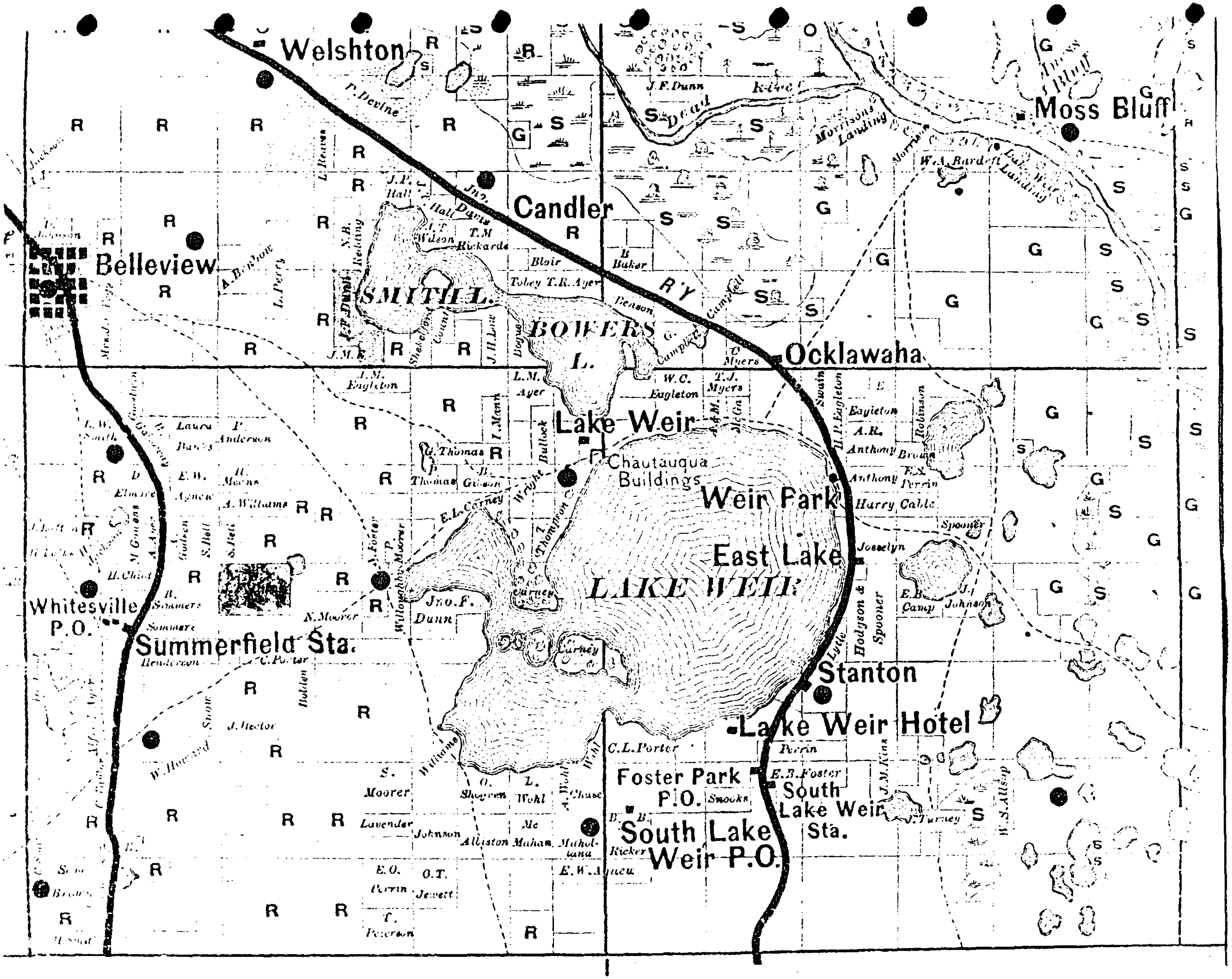


Figure 2-4. Portion of Marion County map of 1888 showing Lake Weir and numerous small towns which had been established within its watershed.

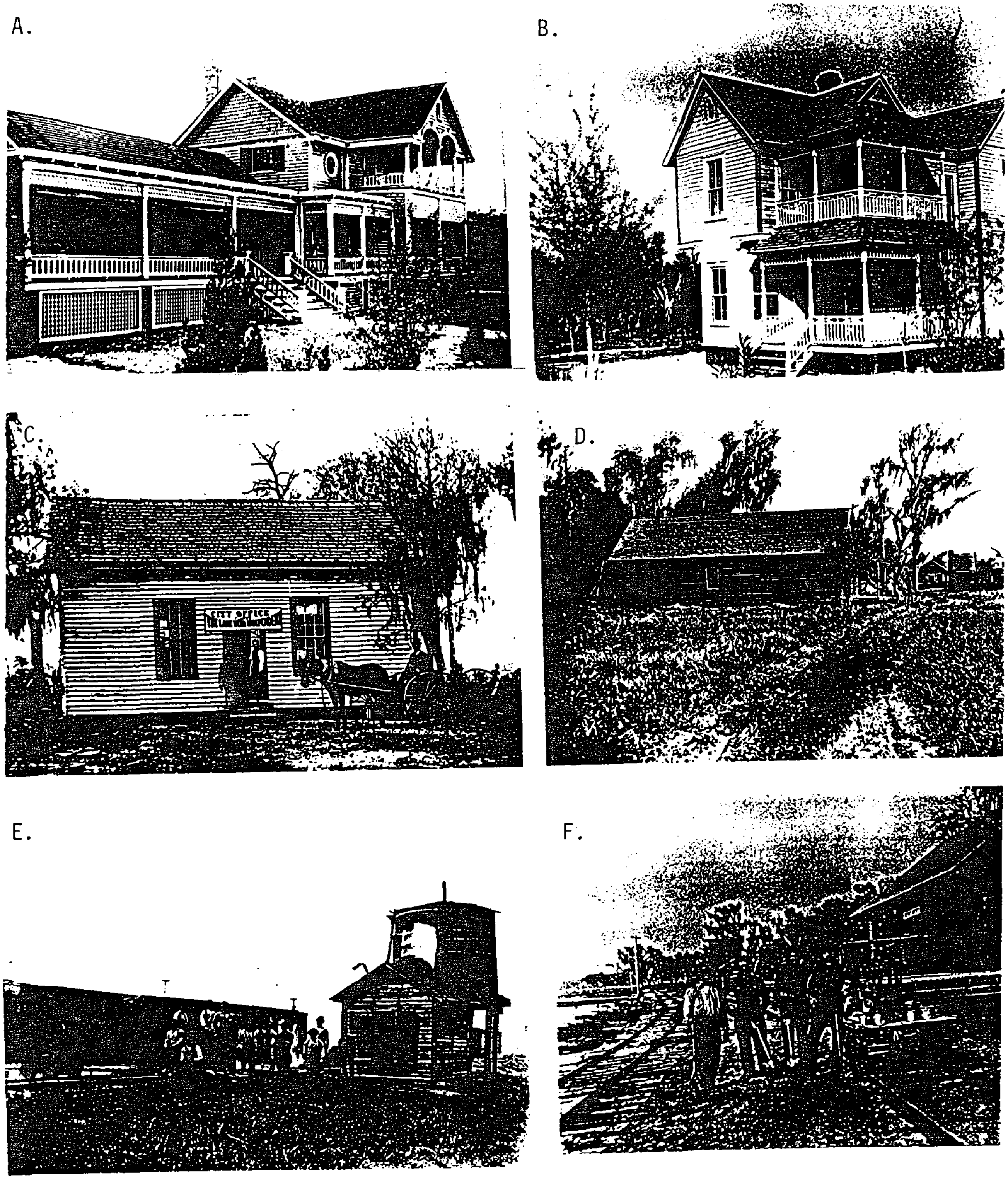


Figure 2-5. Photographs taken circa 1900 showing nice houses, buildings, and the new railroad near Lake Weir.
A. Buffum's house in Stanton (Weirsdale)
B. Dr. Henry's residence in Eastlake Weir
C. Lake Weir Printing Office
D. First old railroad depot in Eastlake Weir
E. First pumping station at Eastlake Weir
F. First Eastlake Station (before it burned)

were available for 1980 and 1985, courtesy of Marion County's Tax Assessors Office.

Multiple measurements of Lake Weir's total watershed area (excluding lake surface) averaged 4500 hectares. Variation was less than two percent for the 1980 and 1985 photos, with values ranging from 4481 to 4557 hectares. Error due to measurement was greater in the smaller scale photos, and total watershed area varied from 4000 to 5000 hectares.

Five land use categories were defined for the watershed:

Residential	clusters of four or more houses or buildings, including lawns.
Citrus	plots of viable citrus trees, not stumps or seedlings.
Pasture	all open land: grazing pastures, prairies, miscellaneous borders, some non-citrus agriculture.
Forest	clusters of trees over one hectare, including forested wetlands and a few commercial pine plots.
Wetlands	marshes and small ponds.

Pasture area, which was fragmented and difficult to measure, was calculated by subtracting the other land use areas from the mean watershed size of 4500 hectares. This simplified measurement and compensated for differences in watershed size estimates, permitting direct comparison between years.

The results revealed several trends and a few dramatic changes in watershed land use (Figure 2-6). A severe pulse of deforestation occurred after 1883. Forest area continued to decrease from 1940 to 1957, then rebounded slightly to date. Pasture area peaked in 1957 and again in 1985. Citrus was well

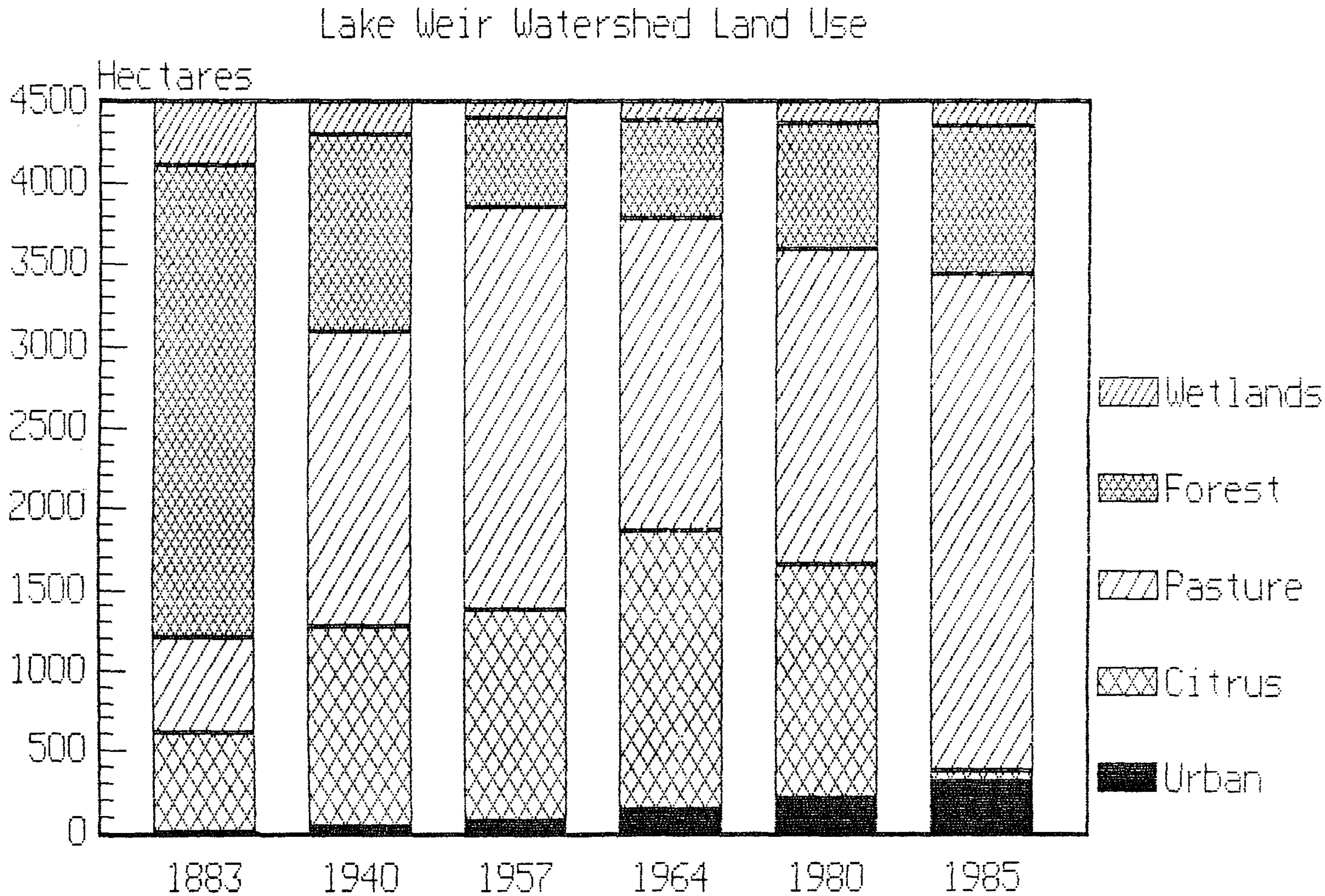


Figure 2-6. Historical watershed land use practices for Lake Weir. Pasture area, including all open lands and misc. land uses, was adjusted slightly to bring each year's watershed size to the mean value of 4500 hectares. Land use areas for 1883 were estimated from Shackleford's book. Values for 1940, 1957, and 1964 were computer digitized from Florida Citrus Survey aerial photographs (scale 1:20000). Land uses for 1980 and 1985 were digitized from Marion County tax assessment aerial photos (scale 1:7920).

established by 1883, increased in area through 1964, and was decimated between 1980 and 1985. Residential area increased tenfold from 1940 to 1985, with most of that expansion after 1964. These trends will be discussed in detail in the following sections.

Land use areas smaller than three hectares could not be measured on the small scale photographs. Smaller plots of trees and houses were easier to identify and measure on the larger scale photos of 1980 and 1985. This may account in part for the increase in forest and residential areas (and the relative decrease in citrus) from 1964 to 1980.

A. Land Clearance

Early descriptions of Lake Weir (Shackleford 1883) and Marion County (Surveyor's map of 1888) characterize the region as being covered by pineland and hammock forest, with little natural upland pasture. Two saw mills were in full time operation by the 1880's and 1890's, clearing land for pasture and citrus groves while providing wood for construction of houses. Photographs taken around the turn of the century showed large tracts of cleared land with only a few solitary pine trees surviving (Figure 2-7).

The late 1800's marked the most rapid pulse of deforestation in Lake Weir's history; forest area was reduced to perhaps half of its original area. Forest area declined from 1200 to under 600 hectares between 1940 and 1957 (Figure 2-6).

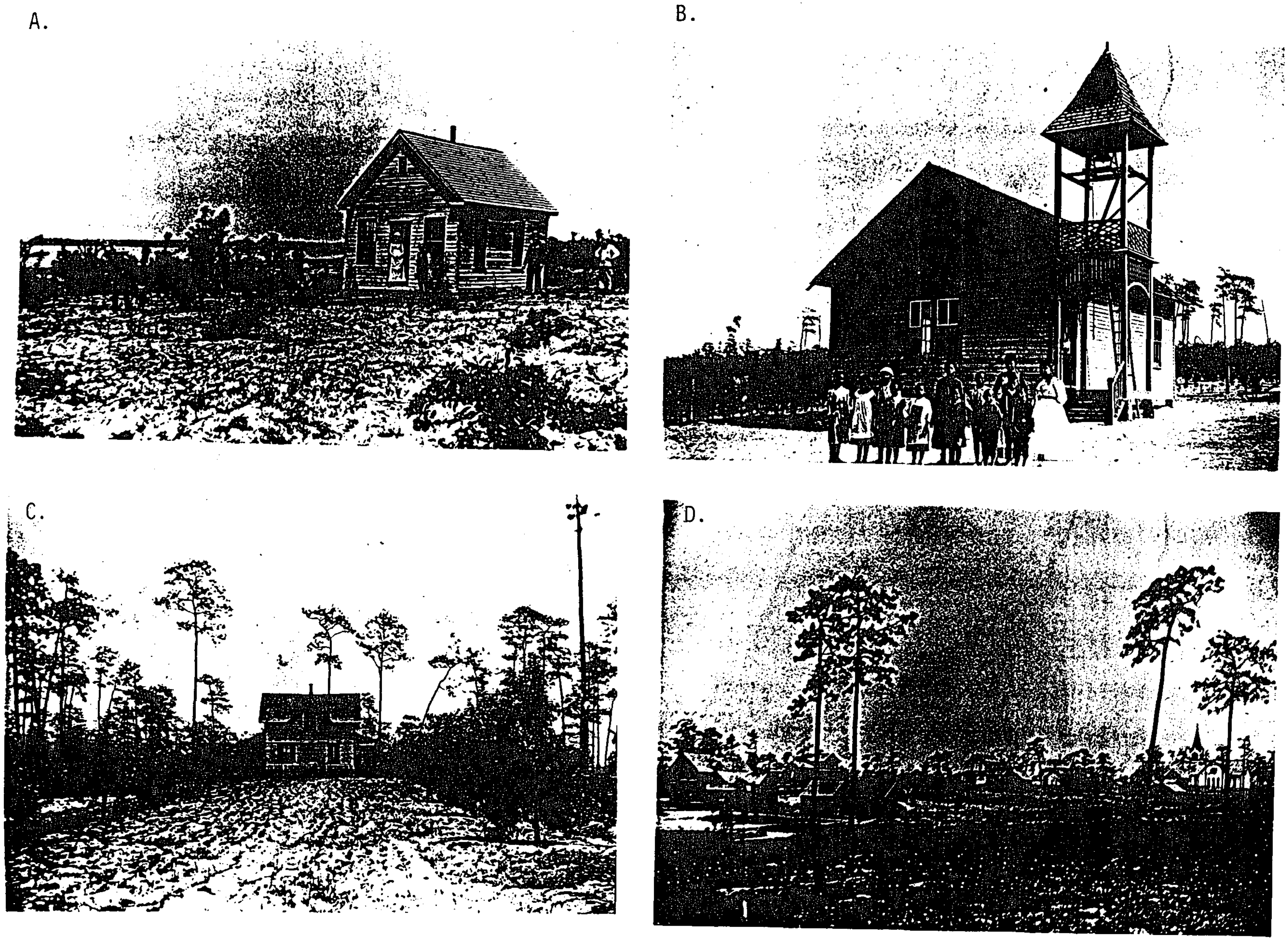


Figure 2-7. Photographs taken circa 1900 showing extensive amount of deforestation around Lake Weir. Note solitary pine trees where pine forest originally stood.
A. House in Eastlake Weir (lake in background)
B. School/Church in Weirsdale
C. House in South Weir
D. View of Weirsdale (Mr. Douglas' store on left)

After 1957, the areal extent of forest increased slightly with a few commercial tracts of pine.

Pasture acted as a transitional land use between forest and citrus. Pasture area peaked following deforestation activities of the 1940's and was partially replaced by citrus by 1964. Pasture dominated the watershed following the citrus crash in 1983.

B. Citrus Industry

In order to assess the impact of nutrient loading from citrus agriculture on the lake, two factors need to be considered: the total amount of citrus in the watershed at a given time (Figure 2-6) and contemporary citrus management practices (Table 2-1).

The citrus industry was firmly established by 1883, comprising 150,000 orange and lemon trees in 600 hectares of groves surrounding the lake, with many more groves soon to be started. Citrus groves were decimated by the freezes of 1894, but were reestablished by the turn of the century. By 1940, citrus groves covered a quarter of the watershed (Figure 2-6). Citrus expanded and remained a prominent part of the watershed until the freezes of 1983 and 1984. By 1985, less than two percent of the watershed contained viable citrus.

Various methods of land clearance, citrus planting, fertilization, and pest control may have different effects on erosion and nutrient loading to the lake. Shackleford's 1883 book contained an entire chapter describing the best ways to

Table 2-1. Historical changes in citrus management practices within the lake Weir watershed.

1600's	Spanish introduced sour oranges which were later thought to be indigenous or "wild".
1874	Captain John Carney established Lake Weir's first commercial orange grove.
1880-1890	Many more orange groves were started, totaling 600 hectares of citrus by 1883. Methods of clearing land and planting groves varied with land type. Pineland areas to the south and east of Lake Weir were burned off and young trees were set in large holes. Hammock areas on the islands and peninsula were cleared by hand and sweet orange scions were grafted onto existing wild orange trunks. Highly nitrogenous fertilizers such as manure were most commonly applied; commercial fertilizers were rarely imported to the area. Rows of beans were planted then plowed under to provide nitrogen for young groves. Insects may have been controlled by the spraying of heavy metals (Cu, Cd, As), as was the practice in that era.
1894	Freezes obliterated the citrus trees around Lake Weir. Nutrients were possibly released to the lake from the dead trees and soil.
1895-1900	All groves were restarted. Heavy nitrogenous fertilization presumably occurred.
1940	Citrus groves covered 1200 hectares. Commercial fertilizers containing N and P became common.
1945	Commercial herbicides and pesticides containing organo-phosphorus were introduced. Episodes of massive fertilization occurred in Florida.
1964	Citrus groves exceeded 1700 hectares.
1984	Freezes decimated Lake Weir's citrus to 68 hectares of viable trees. Nutrient release from dead trees and soil may have had a significant impact on the lake.
1980's	Many citrus owners have switched to fertilizers containing no phosphorus.

plant and manage an orange grove. Comparison of these methods to modern practices may account for changes in the impact of citrus on Lake Weir.

Shackleford (1883) prescribed two different methods for land clearance for citrus groves. In the fertile hammock areas, cleared vegetation was stacked to decompose and release nutrients. The more acidic pineland areas were burned off, creating a much more rapid pulse of nutrients following clearance.

Techniques of planting citrus groves also varied around the lake. Sweet orange scions were often grafted onto the "wild" orange trees which grew in the hammock areas. Many groves were started with young trees from nurseries. Prior to planting, holes seven feet wide would be left exposed for a week to equilibrate so that the trees would all be the same height. This practice would have left large areas subject to erosion in the event of heavy rainfall.

Changing fertilizer types and application rates could have influenced nutrient loading to the lake. Cattle manure and other nitrogenous fertilizers were most commonly used in the 1800's. Manure was applied particularly heavily on pineland groves. Also at that time it was common to plant rows of beans between rows of young citrus trees. The beans, nitrogen fixers, would be plowed under to fertilize the ground.

Phosphorus rich commercial fertilizers were rarely used around Lake Weir during the 1800's, due to the expense and difficulty in transporting them to the lake. Heavy application of commercial fertilizers became more widespread after World War II. Therefore, current citrus management practices yield more nutrients and provide a higher ratio of phosphorus to nitrogen.

In the 1800's, a common method to control insect damage was to spray heavy metals (such as copper, arsenic or cadmium) as insecticides. It is reasonable to assume that this practice may have been conducted at Lake Weir, though Shackleford (1883) made no mention of it. Commercial pesticides and herbicides were introduced at the end of World War II. These contained organo-phosphorus, which would have increased nutrient loading to the lake.

One other potential source of nutrient loading to the lake occurs after citrus killing freezes as the rotting trees release significant amounts of nutrients. The freeze of 1894 killed over ninety percent of the citrus in central Florida, but there is no detailed record of tree mortality within the Lake Weir watershed. More recently, the freezes of 1983 and 1984 may have made such an impact.

C. Urbanization

Urban growth is another factor which may have affected the lake's water quality. Changes in residential area, human population, road construction, and dredging activities were examined.

At the time of Shackleford's book (1883), Lake Weir's watershed hosted three stores, two saw mills, and two post offices. By 1888, the Lake Weir watershed had ten stores, seven post offices, three hotels, two railroad stations, the Chautauqua Buildings, a bank, and a seminary.

Residential area was absent in 1883 and grew to less than one percent of the total watershed by 1940. Residential area doubled by 1957, doubled again by 1964, and more than doubled again by 1985 (Figure 2-6). The residential areas were concentrated in the vicinity of Oklawaha, Weirsdale, and Sunset Harbor.

Shackleford (1883) reported: "Ten years ago there were no citizens. . .on Lake Weir. Now over one thousand people dwell upon its shores or in its immediate vicinity." His figure included Belleview, which lies just outside the watershed. Judging by the relative growth rates of Belleview and the Weir watershed, it is reasonable to estimate that 300 people lived in the watershed at that time.

Decennial census data were available for Lake Weir starting in 1900. From 1900 to 1940, precinct number nine was the town of Lake Weir (now part of Oklawaha). Precinct nineteen was Stanton, which was later renamed Weirsdale.

In 1950 and 1960, Marion County was divided into five sections, so population data could not be derived separately for the Weir watershed. The increase in population for this time was probably proportional to the increase in residential area (Figure 2-6).

In 1970 and 1980, Enumeration Districts (E.D.) were initiated, showing Lake Weir's watershed population. Data from 1970 were not available at UF's library. The 1980 E.D. tract included a few areas of low population outside the watershed, so the population was estimated at 4600, instead of 4721.

The population growth rate has accelerated in recent years (Figure 2-8). Such population expansion could have exerted a significant effect on the lake's nutrient loading, especially because there is no central sewage treatment facility. Septic tanks, even if operated properly, release nutrients into the lake. Septic tank contributions were estimated to have an average daily effluent of 475 liters, having concentrations of 36 mg/l N and 8 mg/l P (Messer 1975, Brezonik and Shannon 1971). Messer (1975) assumed that 25% of the N and 10% of the P was transported from shoreline septic tanks to the lake.

Aerial photos showed that increased road construction roughly paralleled the expansion of residential area until 1971 to 1972 when a huge network of roads was built in the northeast corner of the watershed. Road lengths were digitized on the topographic maps of 1970 and 1977. Whereas the length of roads in the entire watershed increased by 45% during this time, there was a 200% increase within the northeast corner (Figure 2-9).

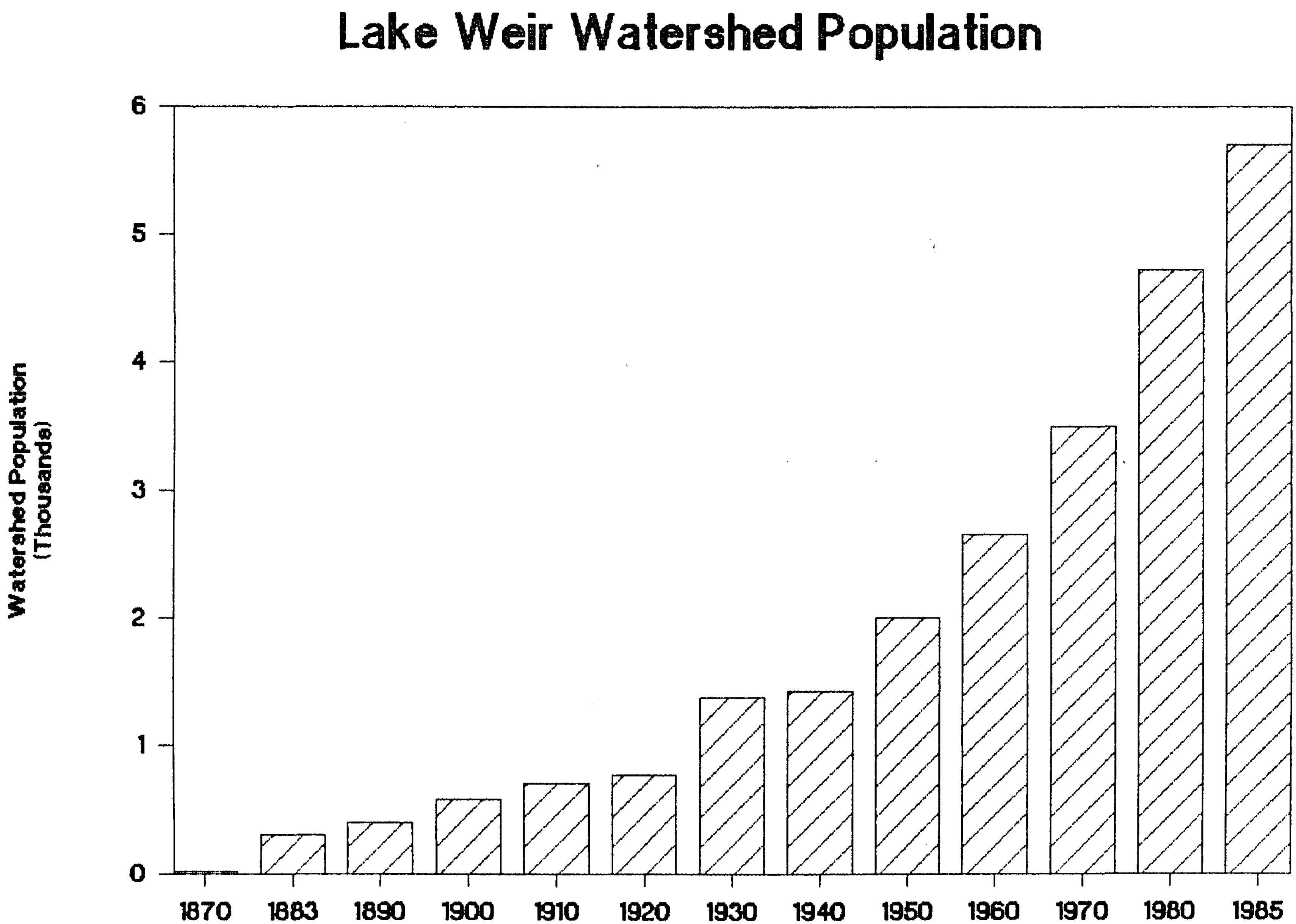


Figure 2-8. Human population within the Lake Weir watershed from 1870 to 1985. Figures for 1870 and 1883 were from Shackleford's book. Decennial census data were availiable for 1900 through 1940, and 1980. All other values were estimated as a function of residential area, as depicted in Figure 2-6.

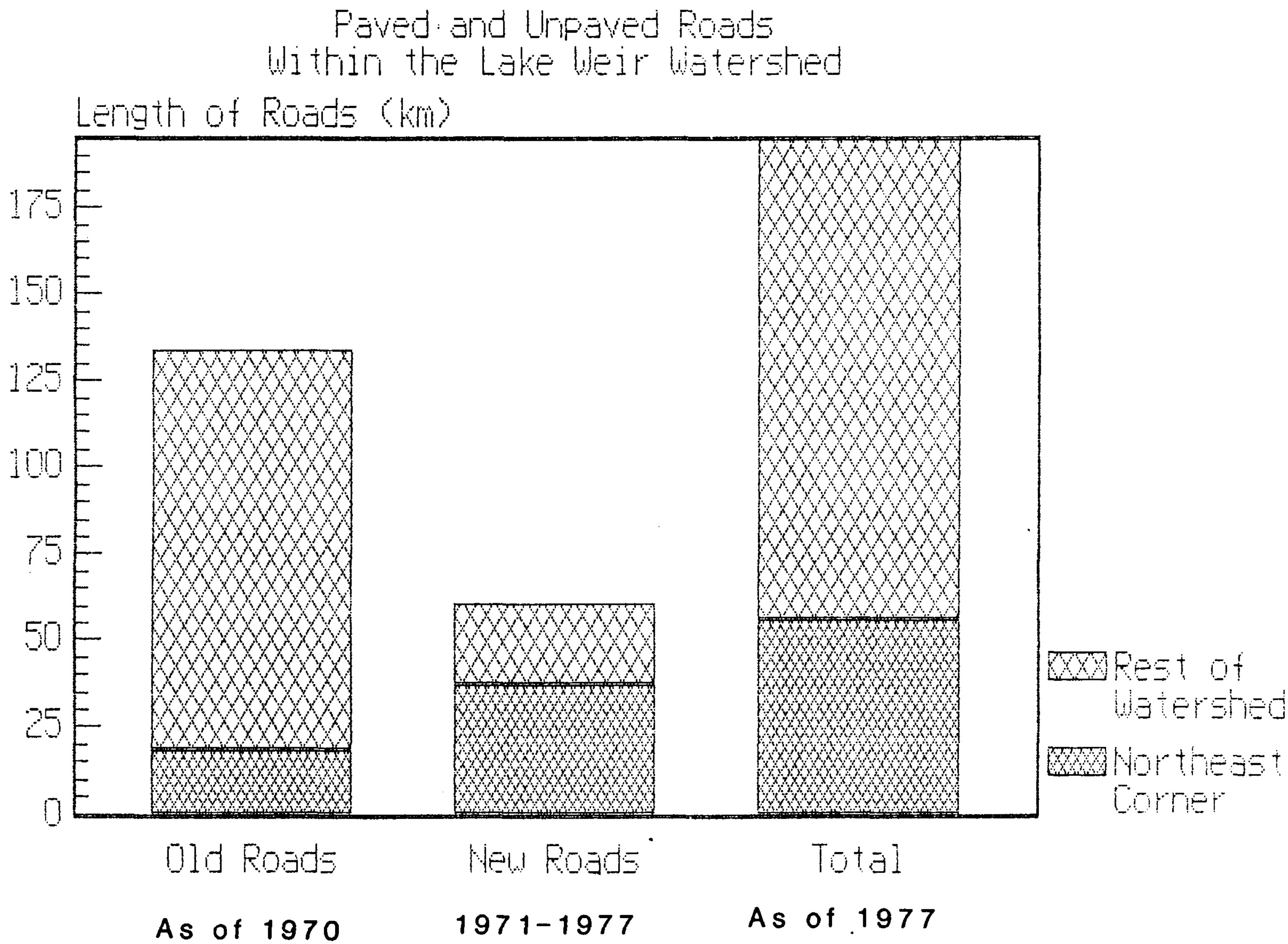


Figure 2-9. Length of paved and unpaved roads in the Lake Weir watershed, in km. Distances were computer digitized from 1970 USCS topographic map (photorevised 1980, with 1977 photos). Note the extreme degree of road development which occurred in the northwest watershed between 1970 and 1977.

Phosphate-rich clays from the Hawthorn Formation are commonly used for road beds in Central Florida, and road construction often leads to increased erosion. Therefore, this episode of development may have impacted the northeast section of the lake.

Dredging is another developmental activity which could affect the lake's water quality (Figure 2-10). Aerial photos showed that the canal between Little Lake Weir and Sunset Harbor was first dredged between 1949 and 1957. This canal was widened and lengthened by 1964. The bridge and canals on Bird Island were also made between 1957 and 1960. By 1972, more cross channels were dredged in the Little Lake Weir canal, and the canal west of Sunset Harbor was dredged. The weir structure and its canal were constructed on the northern shore in April of 1938.

In summary, the history of Lake Weir's watershed has been punctuated by several distinct periods of potential increases in nutrient loading to the lake (Table 2-2). Commencement of citrus agriculture in the 1880's, the citrus-killing freeze of 1894, and rapid deforestation during the 1890's may have significantly increased erosion and nutrient loading. Extremely low lake water level in 1957 may have increased lake nutrient concentrations. Dredging activities in the early 1960's and extensive road construction around 1972 also may be marked by pulses of nutrient loading. Rapid population growth and concomitant urban expansion highlight the 1980's potential sources of nutrients.

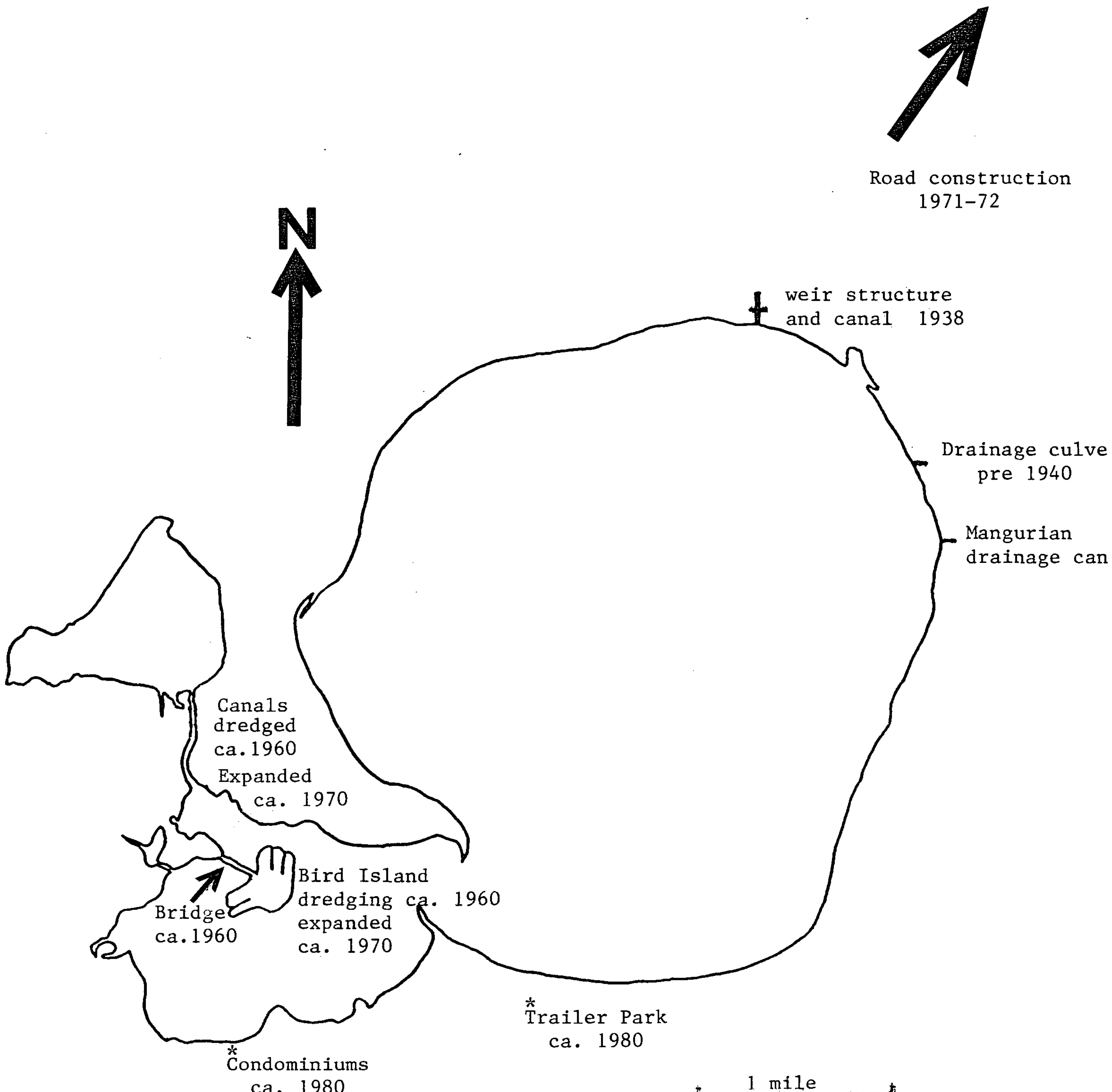


Figure 2-10. Map of Lake Weir showing dates of dredging and construction around Lake Weir.

Table 2-2. Summary of historical events in Lake Weir watershed potentially affecting nutrient loading to the lake.

1880's	Citrus management practices (land clearance, planting, fertilization, insect control).
1894	Citrus freeze.
1890-1910	Massive deforestation.
1938	Construction of broad-crested weir structure and canal.
1940's	Massive application of commercial fertilizers containing nitrogen and phosphorus.
1945	Introduction of orthophosphate-based herbicides and pesticides.
1956-1958	Extremely low lake water levels.
1960-1961	Extremely high lake water levels.
1962	Dredging of canals on peninsula and bird island. Bridge built.
1972	Extensive road construction in northeastern watershed.
1975-1988	Population boom! Condominiums, trailer parks, housing developments. Significant increase in population and residential area.
1983-1984	Citrus freeze.
1985-1988	Lake water level falling.

Nutrient Budget

Loading rates of N and P for the Lake Weir watershed were calculated using Brezonik and Messer's (1975) areal yield coefficients (Table 2-3). Their estimates were based on a number of assumptions, but these values are the best available, and provide a basis for comparison between periods in the watershed's development. Brezonik and Messer used a much smaller watershed area and hence arrived at much lower nutrient loading rates.

Human septic input was calculated using Vollenweider's (1968) human nutrient yields of 12 g N and 2.25 g P per person per day. It was assumed that 25 percent of the nitrogen and 10 percent of the phosphorus were transported to the lake.

Annual nitrogen loading to Lake Weir from the watershed doubled from 3×10^7 g in 1883 to 6×10^7 g in 1964, paralleling the increase in citrus area (Figure 2-11). Nitrogen loading decreased after the citrus freezes of 1984, but remained higher than the 1883 value due to the higher watershed population.

Annual phosphorus input from the watershed remained fairly constant at around 2.4×10^6 g from 1883 to 1964, then increased in 1980 and again in 1985 to 3.3×10^6 g (Figure 2-12). These figures are conservative, as only ten percent of the phosphorus in human waste was assumed to reach the lake.

Rates of nutrient removal by wetlands adjacent to the lake were not estimated. Brezonik and Messer (1975) speculated that these wetlands acted as nutrient sinks during the growing

Table 2-3. Nitrogen and phosphorus loading coefficients for watershed land use practices and human population at Lake Weir. Land use nutrient loading values were based on Messer 1975. Human septic input was estimated by Brezonik and Shannon (1971), assuming that only 25% of the nitrogen and 10% of the phosphorus was transported to the lake (Messer 1975).

	ANNUAL YIELD	
NUTRIENT SOURCE	NITROGEN	PHOSPHORUS
+ Residential	0.88 g/m2	0.110 g/m2
+ Citrus	2.24 g/m2	0.018 g/m2
+ Pasture	0.75 g/m2	0.065 g/m2
+ Forest	0.37 g/m2	0.060 g/m2
* Total produced	4380. g/person	821. g/person
* Amount reaching lake	1095. g/person	82.1 g/person

+ Land use
* Human waste

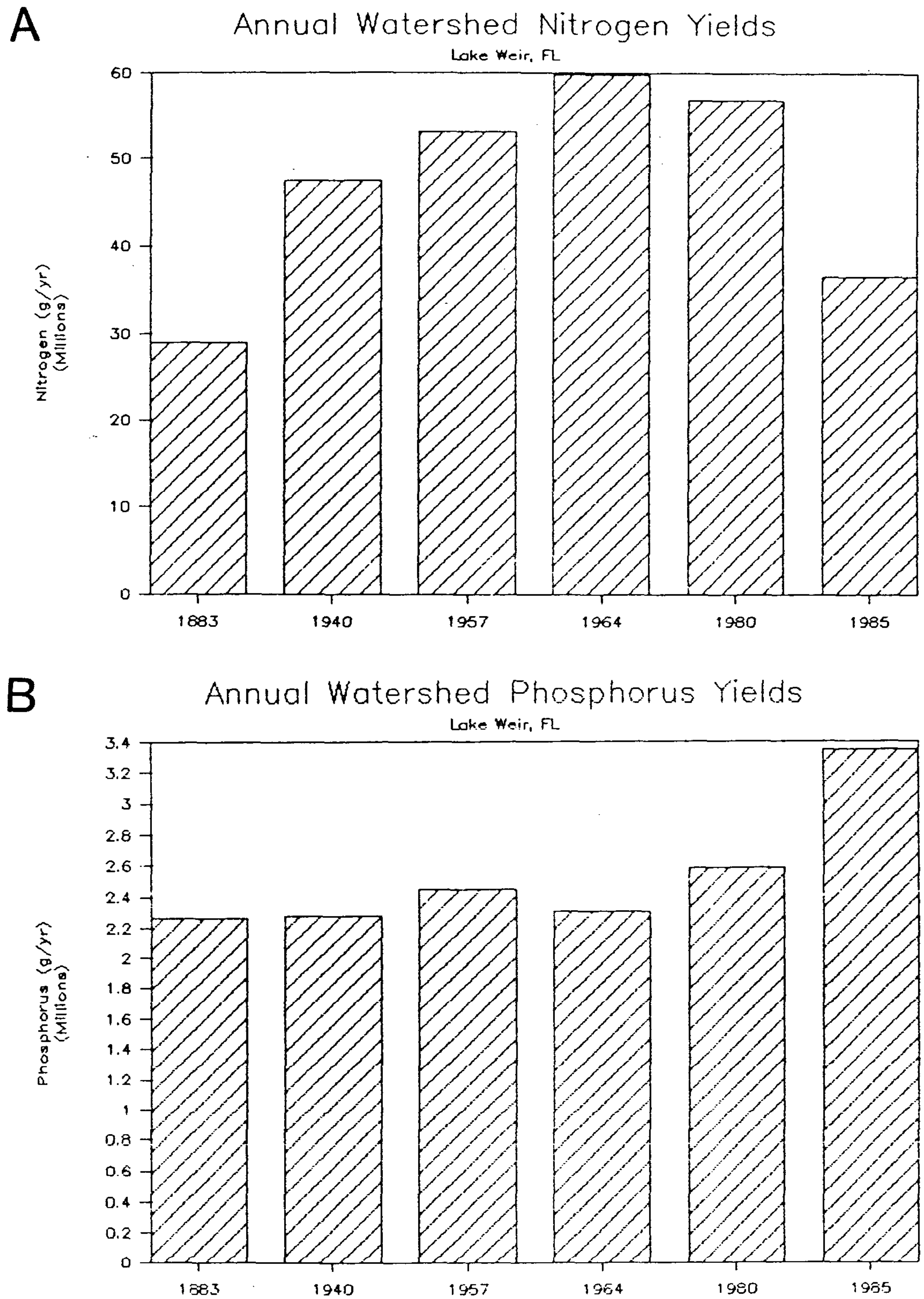


Figure 2-11. Historical annual loading of nitrogen (A) and phosphorus (B) into Lake Weir from the watershed. Nutrient loading coefficients for land use practices and human population are listed in Table 2-3. These values do not include aerial or groundwater nutrient contributions, and do not quantify the nutrient uptake by wetland areas surrounding the lake.

season and nutrient sources during the winter. Later studies have shown that wetland systems in subtropical environments act as nutrient sinks throughout the year. Therefore, the reduction in wetland area around Lake Weir since 1883 would have increased nutrient loading to the lake.

These loading values of N and P do not include input from precipitation or water fowl. Several residents have noted that herring gull populations have increased substantially in recent years, especially during winter. This may also have had a significant nutrient impact.

CHAPTER THREE:
SECCHI DISK SURVEY

Much of the public's perception of Lake Weir's cultural eutrophication over recent years has been attributed to increased algal turbidity. This reduction in water clarity has been associated with poorer water quality, given the recreational water use objectives of the lake residents.

Nutrient loading at Lake Weir is largely from non-point sources including various watershed land use practices. It is difficult to separate the impacts of these practices, especially since nutrients can enter the lake through groundwater seepage. Studies of nutrient contributions from non-point sources are expensive and time consuming, often involving construction of a lake's complete nutrient budget. Secchi disk surveys may provide a fast, low cost alternative for ranking the relative importance of non-point sources. This chapter reviews a citizen-based Secchi disk survey of Lake Weir.

Secchi disks are used to measure water clarity, which is a function of light penetration through the water column and is often related to water quality (A.P.H.A. 1971). Three factors influence water clarity: dissolved color, sediment turbidity, and algal biomass. Water color and turbidity were not significant variables in Lake Weir. Dissolved water color was low and uniform throughout the lake, and all of the stations were in areas deep enough to minimize resuspension of bottom sediments. Therefore, water clarity was closely related to algal biomass and hence nutrient concentrations in Lake Weir.

Other experimental variables alter the intensity of light impinging on the lake surface, and thus may affect Secchi depth. Weather, sea state, and time of day were recorded for each observation. In addition, instruction sheets were distributed to the participants in order to minimize systematic error which could result from differences between observers' techniques.

Because algal biomass in Lake Weir closely reflected proximal loading of limiting nutrients, Secchi disk depths at different sections of the lake basin could be compared to assess the intensity of nutrient contributions by various land uses practices. Agricultural activities such as citrus groves and grazing pastures have dominated Lake Weir's watershed for almost a century. Residential development around the lake has increased four-fold over the past thirty years, yet all houses in the watershed remain on septic tanks; there is no central sewage treatment facility. Lake Weir is considered to be phosphorus-limited (Messer 1975), and there has been a shift toward higher P:N loading with recent urbanization.

Materials & Methods

Secchi disk depths were monitored weekly for an entire year at 32 stations throughout Lake Weir system (Figure 3-1). Over 1400 Secchi disk readings were recorded from 20 July 1985 to 5 July 1986. This extensive effort was coordinated by Mr. Del Wood. Several teams of residents shared the responsibility of monitoring the stations, which were marked by buoys. The

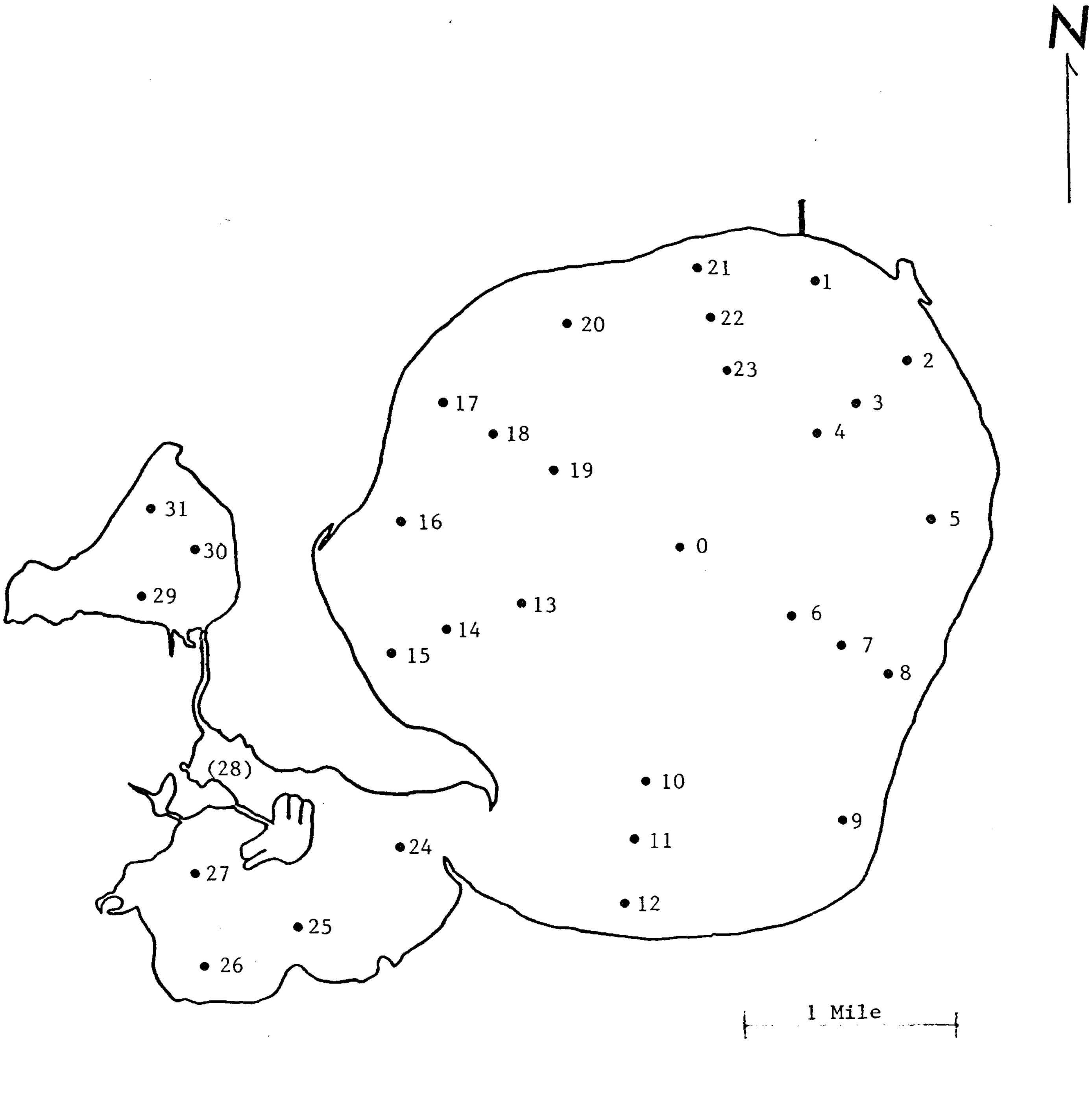


Figure 3-1. Map of Lake Weir showing the radial pattern of Secchi disk stations by numbers. Station #28 was not included in the data analyses.

stations were set up in a radial pattern to identify "hot spots" of water quality degradation and to isolate their non-point sources.

Residents participating in the study were given a list of specific instructions to keep the readings uniform (Figure 3-2). Readings were to be made each Saturday, close to noon, while standing on the sunny side of the boat and not wearing sunglasses.

On at least ten occasions, Mr. Wood personally replicated readings made by the investigators and found almost all of their observations to be within two inches of his own. Although Mr. Wood did not record these observations, he acknowledged that there was no difference between the groups of observers. Therefore, error was assumed to be randomly distributed across the stations.

For each observation, investigators recorded three experimental variables which may have influenced the degree of light penetration into the water column: weather condition, sea state, and time of day (Figure 3-3). Weather was recorded as a code of 1 to 4, with 1 representing a bright sunny day and 4 being heavily overcast. Sea state was a measure of wave amplitude, recorded in inches. Time of day was related to the angle of the sunlight's incidence on the lake surface.

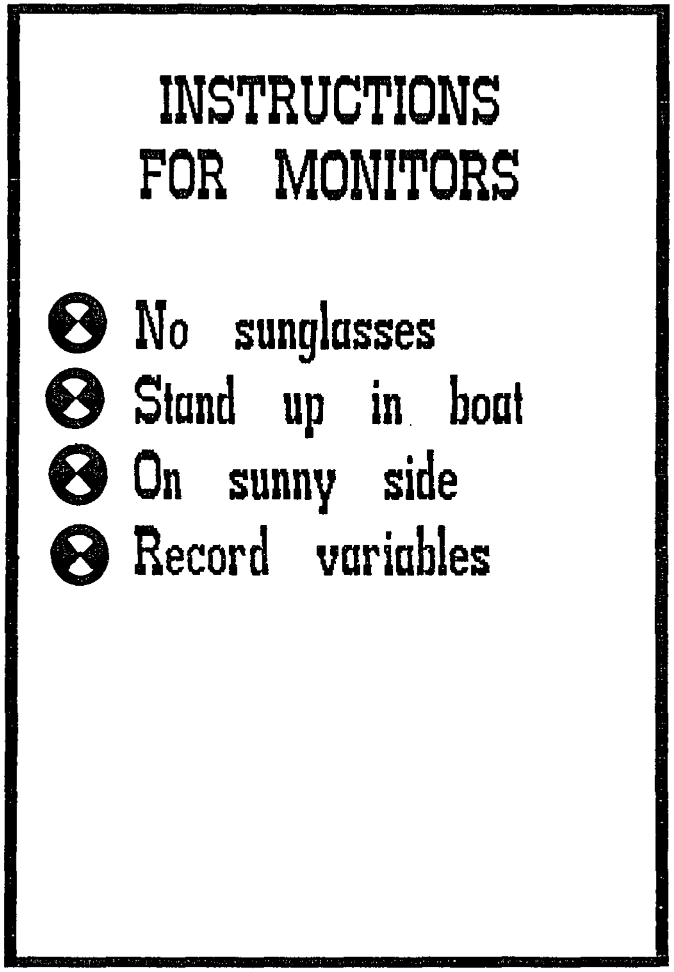


Figure 3-2. Instructions given to Secchi disk monitoring teams.

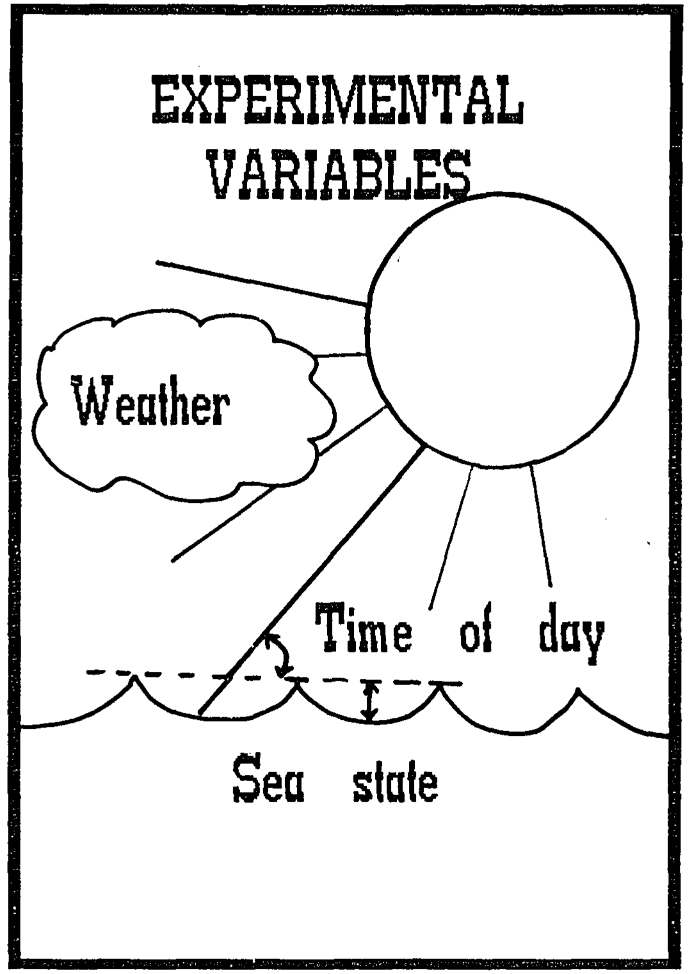


Figure 3-3. Three variables influencing the penetration of light through the water column (and hence, Secchi disk depth).

Data Analyses and Results

The objective of this study was to statistically identify groups of stations having significantly lower Secchi disk depths. In order to accomplish this, experimental variables had to be factored out, then groups of stations having significantly lower water clarity could be related to the type and degree of watershed development immediately onshore.

Four readings which were made after 6:00 p.m. on a single sampling day were omitted, as they were anomalously low. Also, station #28 was eliminated from the study because over half of the readings at this shallow site were on the lake bottom. All other stations were in at least three meters of water (Figure 3-4). In all, 1349 observations were included in the study. These data were entered onto Lotus 123 and were transferred to SAS for statistical analyses.

Analyses of variance were performed to determine whether weather, sea state, or time of day significantly influenced Secchi disk depth. Weather code showed a negative correlation with Secchi depth which proved to be highly significant at all levels (Table 3-1). Sea state analyses showed only calm waters to have significantly greater Secchi depths (Table 3-2). Time of day showed that a highly significant difference existed between the time intervals as a collective group (Table 3-3).

Regression analyses of Secchi disk depth versus the independent variables were run (Table 3-4). Variation due to regression of Secchi depths with time of day and with sea state was not significant at alpha of five percent. However,

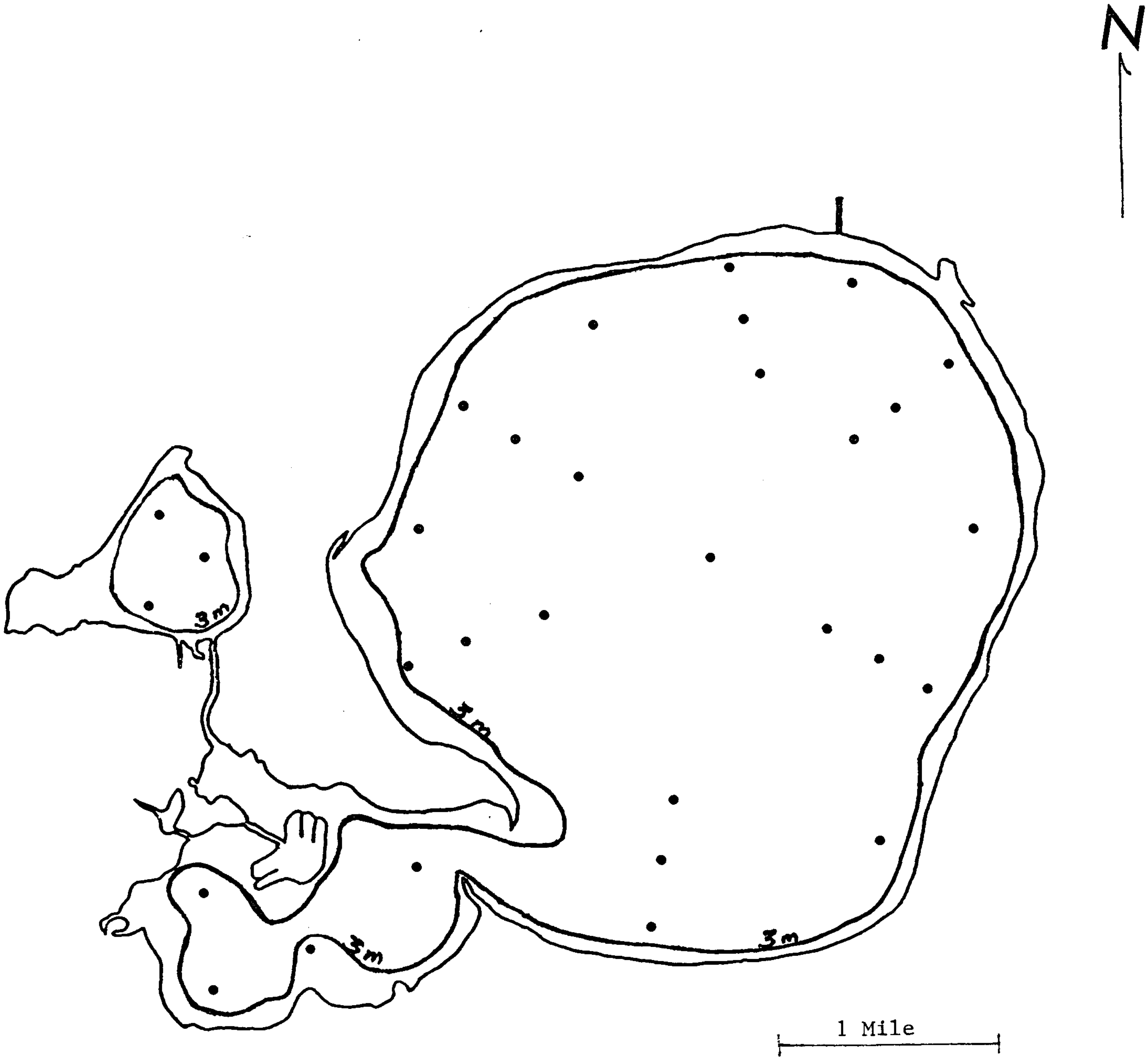


Figure 3-4. Map of Lake Weir Secchi disk stations and 3 meter bathymetric contour. Only stations 28 and 25 were in less than 3 m of water.

Table 3-1. ANOVA between Secchi depths for Weather Codes in Lake Weir proper and Lake Weir.

Weather Code 1 = clear, sunny
Weather Code 2 = partly overcast
Weather Code 3 = overcast; no sun
Weather Code 4 = rain

Secchi depth vs. weather code for Lake Weir proper (m)

Group	# observ	mean	std devn
Weather Code 1	548	1.946	0.2092
Weather Code 2	349	1.909	0.1819
Weather Code 3	104	1.822	0.1481
Weather Code 4	1	1.830	------

Comparison	F value	alpha
Weather Code 1 vs 2	45.97	0.0001 **
Weather Code 1 vs 3	41.34	0.0001 **
Weather Code 2 vs 3	19.79	0.0001 **

Secchi depth vs. weather code for entire Lake Weir (m)

Group	# observ	mean	std devn
Weather Code 1	751	1.971	0.2591
Weather Code 2	420	1.899	0.2188
Weather Code 3	173	1.818	0.1999
Weather Code 4	5	1.708	0.1291

Comparison	F value	alpha
Weath 1 vs 2 vs 3 vs 4	23.66	0.0001 **

** significant at alpha = .01

Table 3-2. ANOVA between Secchi depths for groups of Sea States in Lake Weir proper and Lake Weir.

Secchi depth vs. sea state for Lake Weir proper (m)

Group	# observ	mean	std devn
0-1 inches (A)	428	1.976	0.2148
2-5 inches (B)	184	1.903	0.2206
6-11 inches (C)	178	1.922	0.1744
12-17 inches (D)	157	1.958	0.1816
18+ inches (E)	55	1.930	0.1486

Comparison	F value	alpha	
A vs B vs C vs D vs E	5.404	0.0003	**
A vs B	14.790	0.0001	**
A vs C	8.957	0.0029	**
A vs D	0.836	0.3608	
A vs E	2.382	0.1234	
B vs C	0.812	0.3682	
B vs D	6.350	0.0122	*
B vs E	0.736	0.3918	
C vs D	3.576	0.0595	
C vs E	0.099	0.7538	
D vs E	1.093	0.2971	

Secchi depth vs. sea state for entire Lake Weir (m)

Group	# observ	mean	std devn
0-1 inches (A)	566	1.969	0.2705
2-5 inches (B)	363	1.861	0.2482
6-11 inches (C)	200	1.917	0.2021
12-17 inches (D)	165	1.945	0.1884
18+ inches (E)	55	1.930	0.1486

Comparison	F value	alpha	
A vs B vs C vs D vs E	11.240	0.0001	**

* significant at alpha = .05
** significant at alpha = .01

Table 3-3. ANOVA between Secchi depths for specified Time-of-Day intervals in Lake Weir proper and Lake Weir.

Secchi depth vs. time of day for Lake Weir proper (m)

Group	# observ	mean	std devn
845-959	73	2.009	0.1552
1000-1059	161	1.992	0.2115
1100-1159	250	1.963	0.2000
1200-1259	243	1.952	0.1892
1300-1359	145	1.914	0.2058
1400-1559	106	1.860	0.2065
1600-1759	24	1.857	0.2373

Comparison	F value	alpha
Betw. all 7 intervals	7.675	0.0001 **

Secchi depth vs. time of day for entire Lake Weir (m)

Group	# observ	mean	std devn
845-959	136	1.870	0.2831
1000-1059	398	1.950	0.2945
1100-1159	289	1.950	0.2140
1200-1259	244	1.950	0.1896
1300-1359	152	1.900	0.2121
1400-1559	106	1.860	0.2065
1600-1759	24	1.857	0.2373

Comparison	F value	alpha
Betw. all 7 intervals	4.653	0.0001 **

** significant at alpha = .01

Table 3-4 . Multiple regressions of Secchi depth by independent variables Weather Code, Sea State, and Time of Day for Lake Weir.

(m)
Regression of Secchi depth by Weather Code

Intercept	2.0478	Regr Coeff	-0.0760
Std Err Y Estim	0.2396	Std Er Rgr Coef	0.0090
R-Squared	0.0500	Corr X vs. Y	-0.2236

ANOVA for regression

Source of Error	DF	SS	MS	F	Alpha
Due to R.	1	4.0702	4.0702	70.8909	0.0001 **
Devn fr R.	1347	77.3380	0.0574		
Total	1348	81.4082			

(m)
Regression of Secchi depth by Sea State

Intercept	1.9329	Regr Coeff	-0.0012
Std Err Y Estim	0.2458	Std Er Rgr Coef	-0.0012
R-Squared	0.0007	Corr X vs. Y	-0.0255

ANOVA for regression

Source of Error	DF	SS	MS	F	Alpha
Due to R.	1	0.0530	0.0530	0.8772	0.3491
Devn fr R.	1347	81.3550	0.0604		
Total	1348	81.4080			

(m)
Regression of Secchi depth by Time of Day

Intercept	2.0102	Regr Coeff	-0.0001
Std Err Y Estim	0.2456	Std Er Rgr Coef	0.0000
R-Squared	0.0023	Corr X vs. Y	-0.0477

ANOVA for regression

Source of Error	DF	SS	MS	F	Alpha
Due to R.	1	0.1856	0.1856	3:0777	0.0796
Devn fr R.	1347	81.2220	0.0603		
Total	1348	81.4076			

** significant at alpha = .01

regression of Secchi depths by weather code showed a high degree of variation attributable to regression, with an alpha of less than 0.0001. Because weather codes were evenly distributed across all stations, remaining analyses were performed on the raw data.

The annual means were calculated for each station (Figure 3-5). Sixteen stations had a mean Secchi depth less than the overall lakewide average of 1.928 meters. These stations were clustered near the areas of greatest shoreline population (Figure 3-6). All seven stations in the highly populated Little Lake Weir and Sunset Harbor basins were below the lakewide mean. Eight of the nine below-average stations in Lake Weir proper were clustered along the northeastern shore of the lake, adjacent to the town of Oklawaha. The single exception, station #15, was barely below the lakewide mean and was located immediately offshore of the highest concentration of citrus near the lake.

Next, mean Secchi depths of the three lake basins were compared throughout the year (Figure 3-7). Sunset Harbor had a significantly lower Secchi depth throughout the year than Lake Weir proper. Little Lake Weir displayed a high degree of seasonality, unlike the other two basins. Analysis of variance tests confirmed that these lakes were statistically different (Table 3-5).

During summer, Little Lake Weir exhibited the lowest water clarity of the entire system. This may have been due to the higher watershed to lake surface ratio and the shallower water

Lake Weir Annual Mean Secchi Depths

20 July 1985 - 5 July 1986

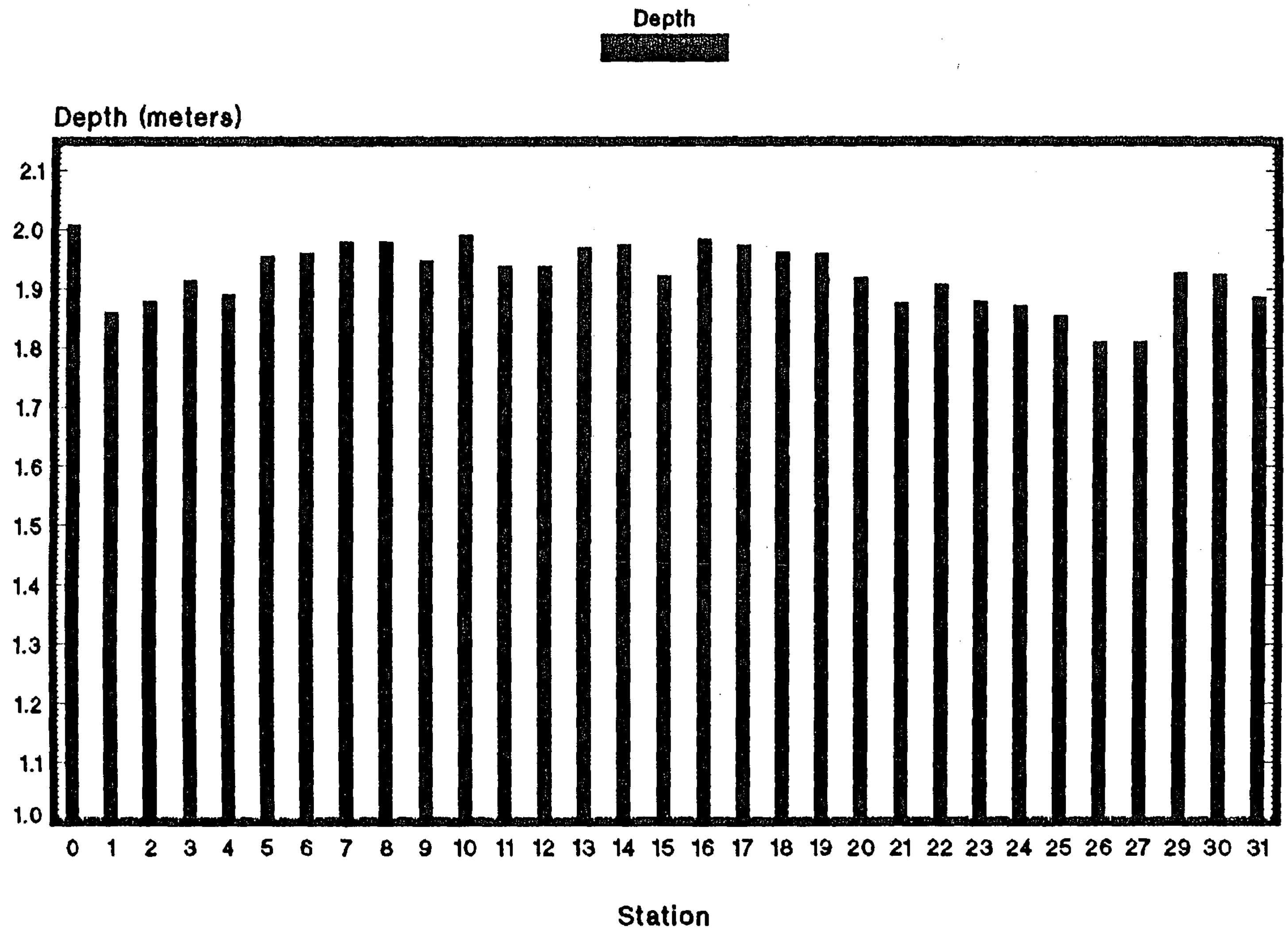


Figure 3-5. Annual mean Secchi disk depths by station. Each bar represents up to 50 observations. Lakewide mean Secchi depth was 1.93 m.

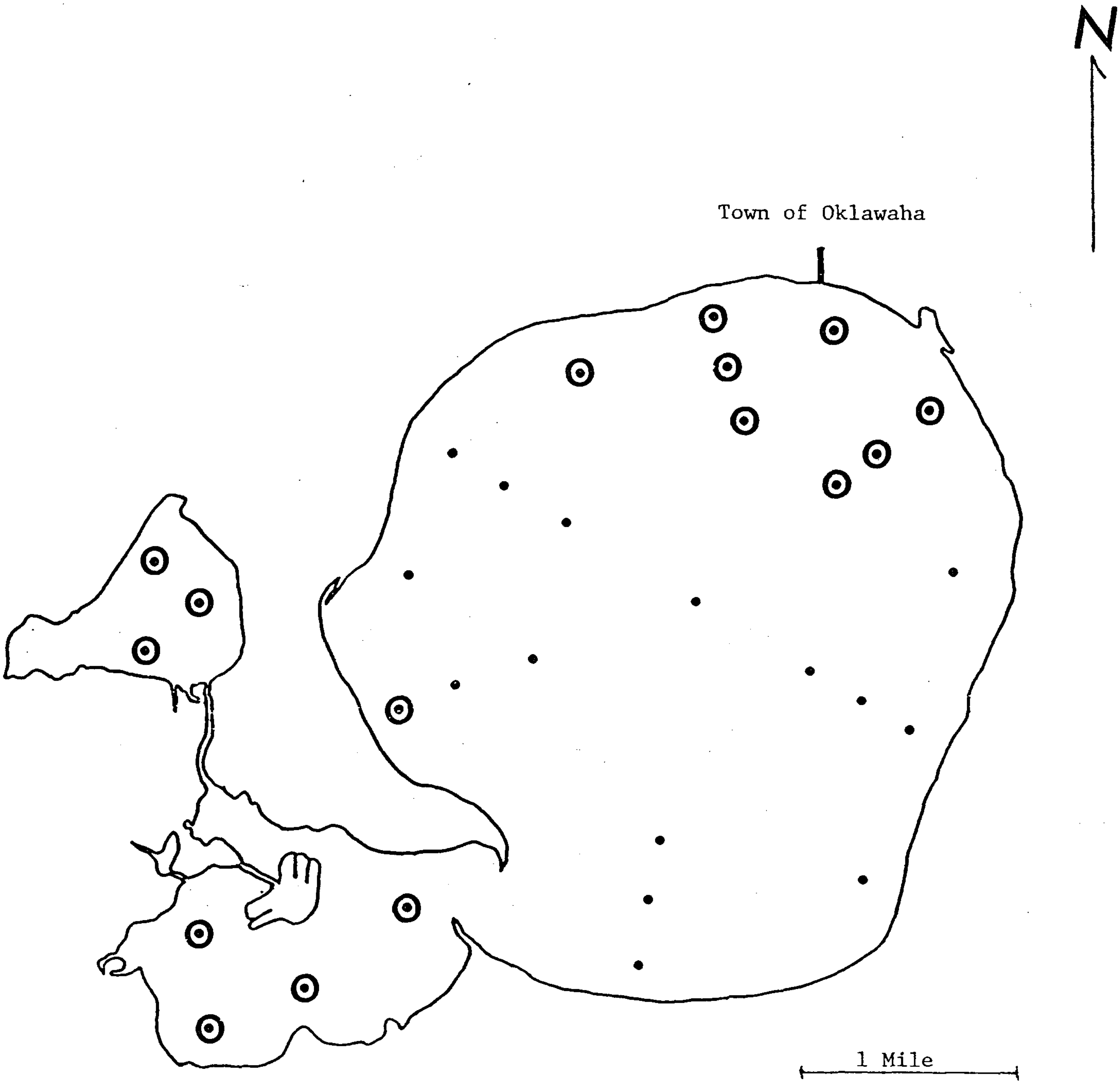


Figure 3-6. Map of Lake Weir Secchi disk stations showing location of stations with a mean annual Secchi depth less than the lakewide mean of 1.93 m.

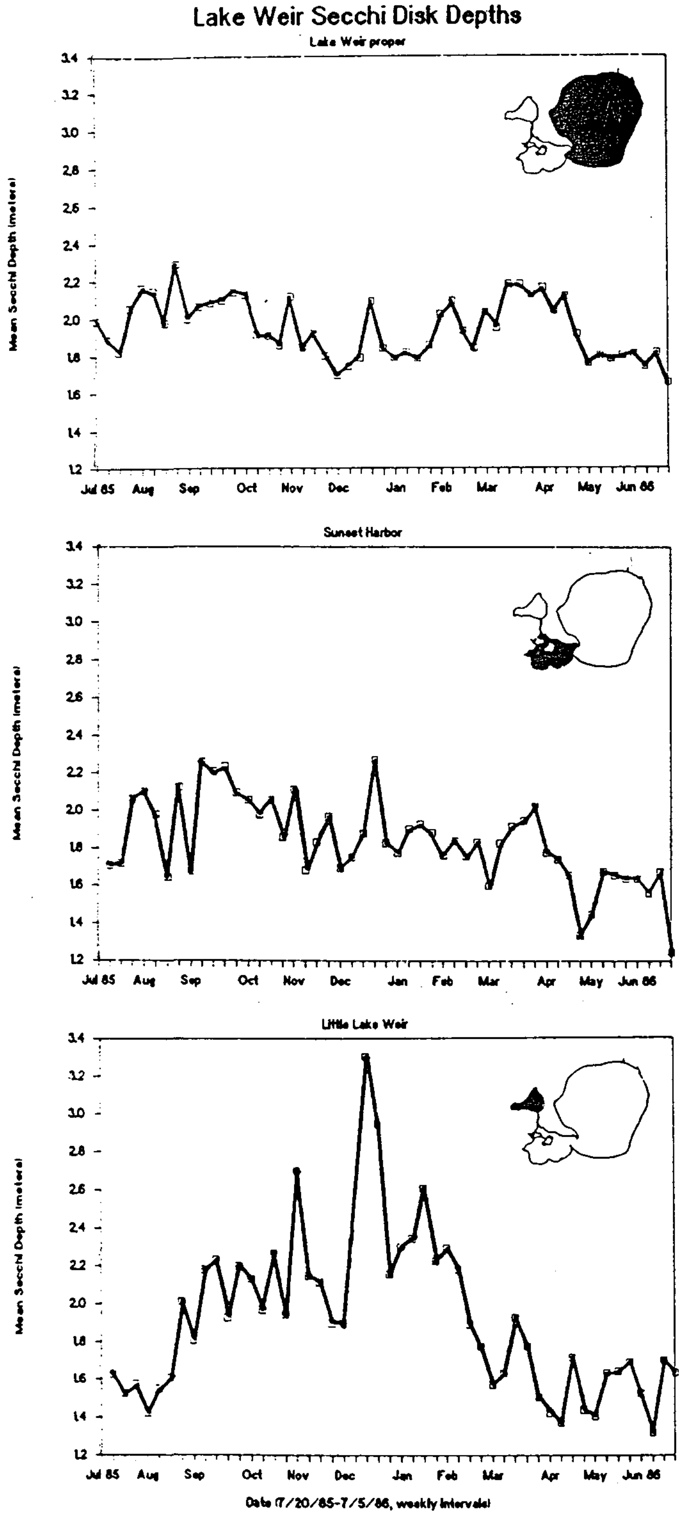


Figure 3-7. Mean Secchi disk depths for each of Lake Weir's three basins at weekly intervals throughout the year.

Table 3-5. ANOVA between secchi depths at Lake Weir proper, Sunset Harbor, and Little Lake Weir.

Secchi depth vs. lake division
(m)

Group	# observ	mean	std dev
Overall	1349	1.928	0.246
Lake Weir proper	1002	1.948	0.204
Sunset Harbor	200	1.838	0.242
Little Lake Weir	147	1.913	0.424

ANOVA Lake Weir proper vs. Sunset Harbor

Source of Error	DF	SS	MS	F	Alpha
Between	1	1.9930	1.9930	45.1075	0.0001 **
Within	1200	53.0200	0.0442		
Total	1201	55.0130			

ANOVA Lake Weir proper vs. Little Lake Weir

Source of Error	DF	SS	MS	F	Alpha
Between	1	0.1484	0.1484	2.5150	0.1130
Within	1147	67.6800	0.0590		
Total	1148	67.8284			

ANOVA Little Lake Weir vs. Sunset Harbor

Source of Error	DF	SS	MS	F	Alpha
Between	1	0.4788	0.4788	4.3265	0.0383 *
Within	345	38.1800	0.1107		
Total	346	38.6588			

* significant at alpha = .05
** significant at alpha = .01

depth. Thus, nutrients from a proportionately larger watershed would be delivered to a smaller volume of water, yielding higher nutrient concentrations and hence greater algal biomass. During winter, Little Lake Weir showed the greatest water clarity, with Secchi depths greater than three meters on 28 December 1985. Several lake residents have noted the presence of a spring in Little Lake Weir, which could account for a higher degree of groundwater flushing during the winter, and hence greater water clarity.

Because Little Lake Weir, Sunset Harbor, and Lake Weir proper appeared to behave as separate systems, comparisons of stations across the entire system may not be valid. The remaining statistical analyses were performed only on Lake Weir proper.

Duncan's Multiple Range Test was used to identify stations in Lake Weir proper having significantly different water clarity. At an alpha value of five percent, the stations near Oklawaha were significantly lower than the other stations (Table 3-6).

Owing to Lake Weir's nearly circular shape, small littoral area, and uniform station depth around the lake, there is no reason to believe that morphometric factors would exert a bias on Secchi depth from one side of the lake to the other. To determine the influence of proximity to shoreline, stations in Lake Weir were grouped into three concentric rings (Figure 3-8). ANOVA tests revealed no significant differences between these rings (Table 3-7). The middle of the lake (Station #0)

Table 3-6. Duncan's Multiple Range Test for differences between annual Secchi disk means for stations in Lake Weir proper.

Alpha = .05

Stations underscored by the same line are not significantly different.

Station:

```
 0 10 16  8  7 17 14 13 18 19  6  5  9 12 11 15 20  3 22  4  2 23 21  1
 ______________________________________
    _________________________________________
                                      _________________________________
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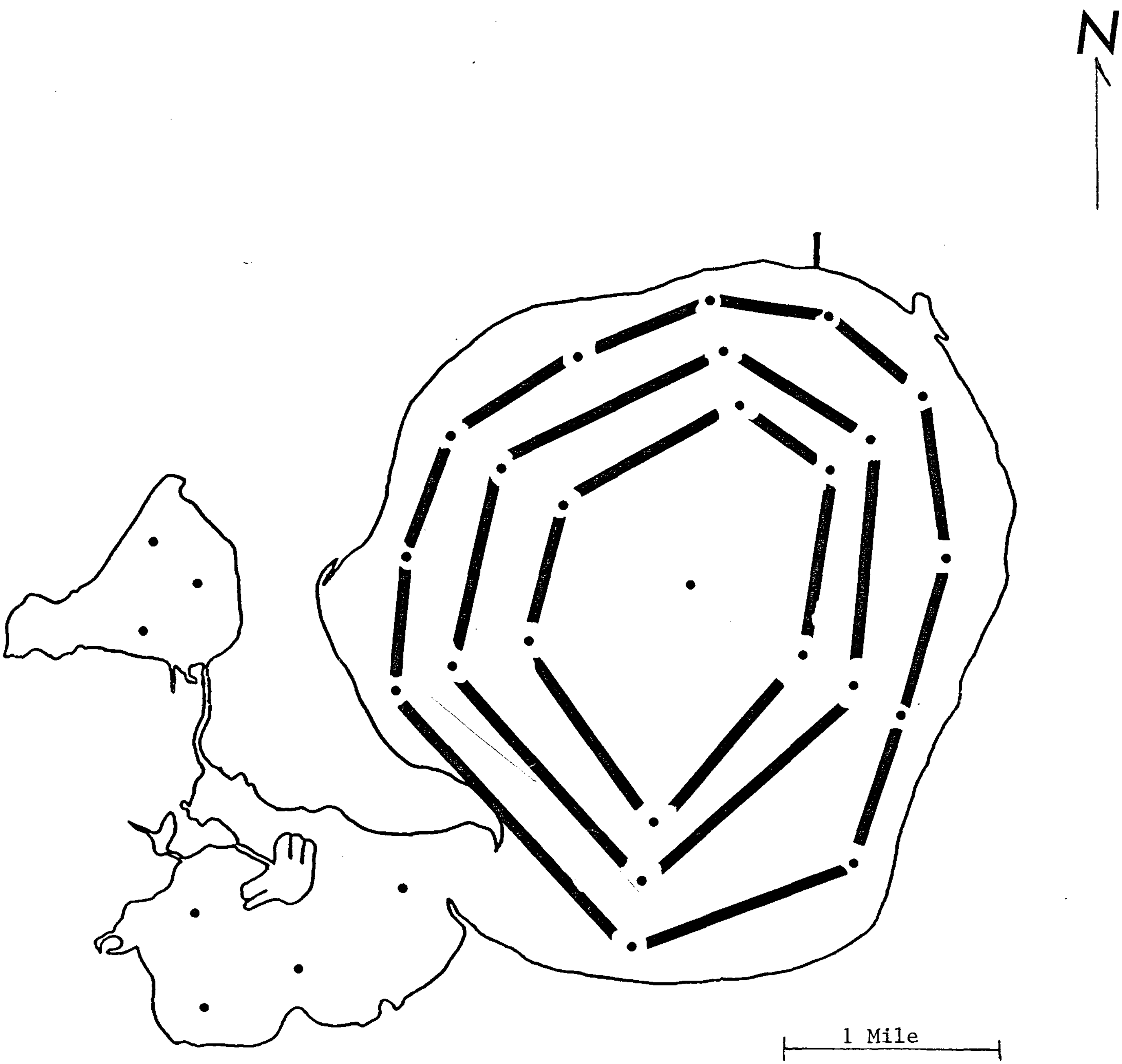


Figure 3-8. Map of Lake Weir Secchi disk stations grouped in three concentric rings to test the effect of proximity to shoreline.

Table 3-7. ANOVA between Secchi depths for concentric rings of stations at different distances from shoreline.

Secchi depth vs. shoreline proximity for Lake Weir proper (m)

Group	# observ	mean	std devn
Outer Ring (OR)	457	1.937	0.2072
Middle Ring (MR)	249	1.952	0.2011
Inner Ring (IR)	248	1.951	0.2000
Lake Center (C)	48	2.009	0.1779

Comparison	F value	alpha
C vs IR	3.4790	0.0632
C vs MR	3.3140	0.0679
C vs OR	5.2490	0.0224 *
IR vs MR	0.0000	1.0000
IR vs OR	0.6876	0.4073
MR vs OR	0.7897	0.3745

* significant at alpha = .05

demonstrated greater water clarity than the three rings, but it was only significantly greater than the outer ring. Therefore, direct comparisons could be made between stations regardless of distance from shore.

Thus, it was possible to compare the effects of shoreline development by partitioning the lake into sectors. The stations which had statistically lower water clarity in Duncan's multiple range test were grouped into the north sector near Oklawaha. Two control sectors of similar but less populated areas were arbitrarily defined. Secchi disk depths in the Oklawaha sector appeared to show higher variance, being generally lower but periodically having greater water clarity (Figure 3-9). The two control sectors showed nearly identical mean Secchi depths throughout the year, with no strong seasonal trends. Analysis of variance confirmed that the Oklawaha sector had significantly lower mean Secchi depths (Table 3-8).

To quantify this relationship between water clarity and human population, mean Secchi disk depths of the outer ring of stations were compared to the number of houses in the proximity. Houses within 1/4 mile of the lake and 3/8 of a mile to either side of a point immediately onshore of each station were counted on the 1985 tax assessment map (Figure 3-10). This shoreline distance was less than the average distance between stations, but these bands slightly overlapped in three areas.

The plot of all eleven stations nearest to shore showed a distinct relationship of decreased water clarity with

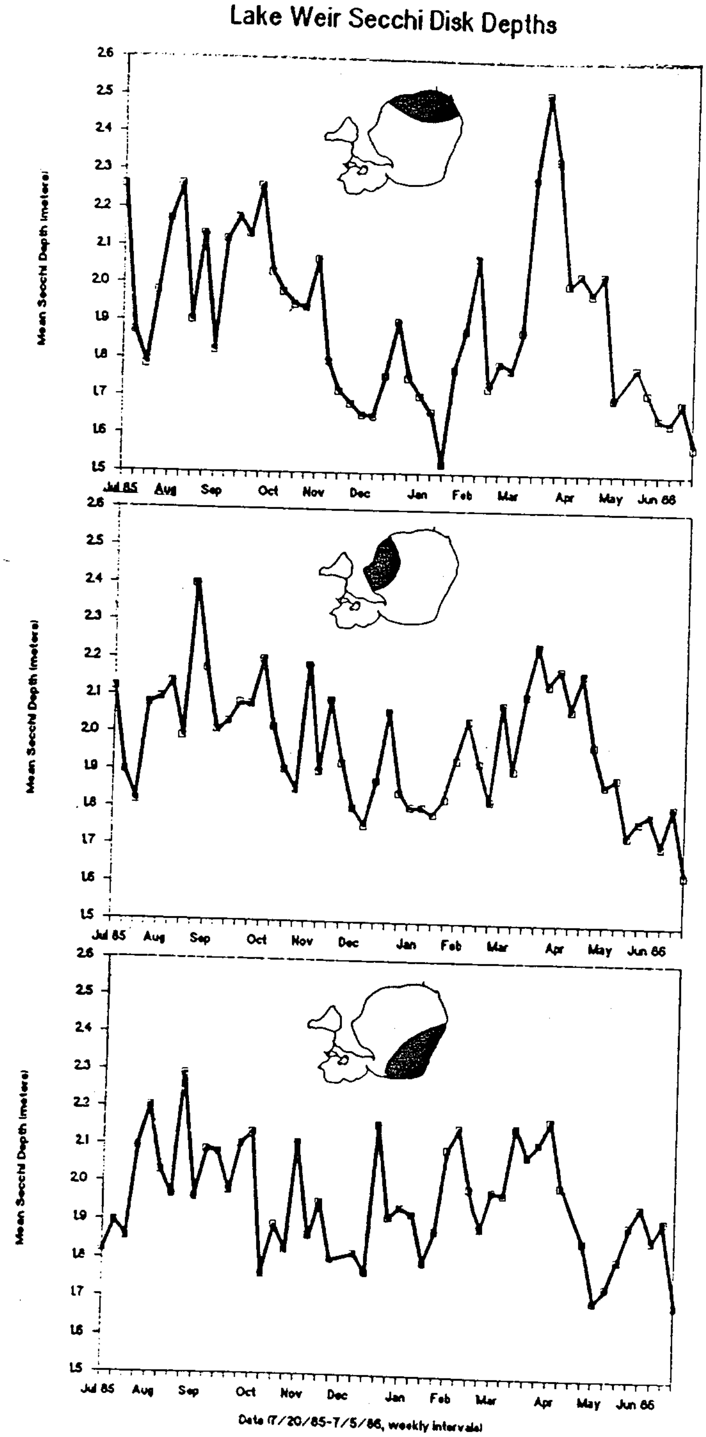


Figure 3-9. Mean Secchi disk depths for three sectors of Lake Weir proper at weekly intervals throughout the year. The north sector was defined by the stations which had statistically lower water clarity. The west and south sectors were controls.

Table 3-8. ANOVA of Secchi depths (m) between three sectors in Lake Weir proper.

Group	# observ	mean	std dev
North Sector	257	1.894	0.234
South Sector	361	1.962	0.180
West Sector	336	1.965	0.197

ANOVA North Sector vs. South Sector

Source of Error	DF	SS	MS	F	Alpha
Between	1	0.7080	0.7080	17.0097	0.0001 **
Within	616	25.6400	0.0416		
Total	617	26.3480			

ANOVA North Sector vs. West Sector

Source of Error	DF	SS	MS	F	Alpha
Between	1	0.7358	0.7358	16.1417	0.0001 **
Within	591	26.9400	0.0456		
Total	592	27.6758			

ANOVA South Sector vs. West Sector

Source of Error	DF	SS	MS	F	Alpha
Between	1	0.0010	0.0010	0.0275	0.8683
Within	695	24.6600	0.0355		
Total	696	24.6610			

* significant at alpha = .05
** significant at alpha = .01

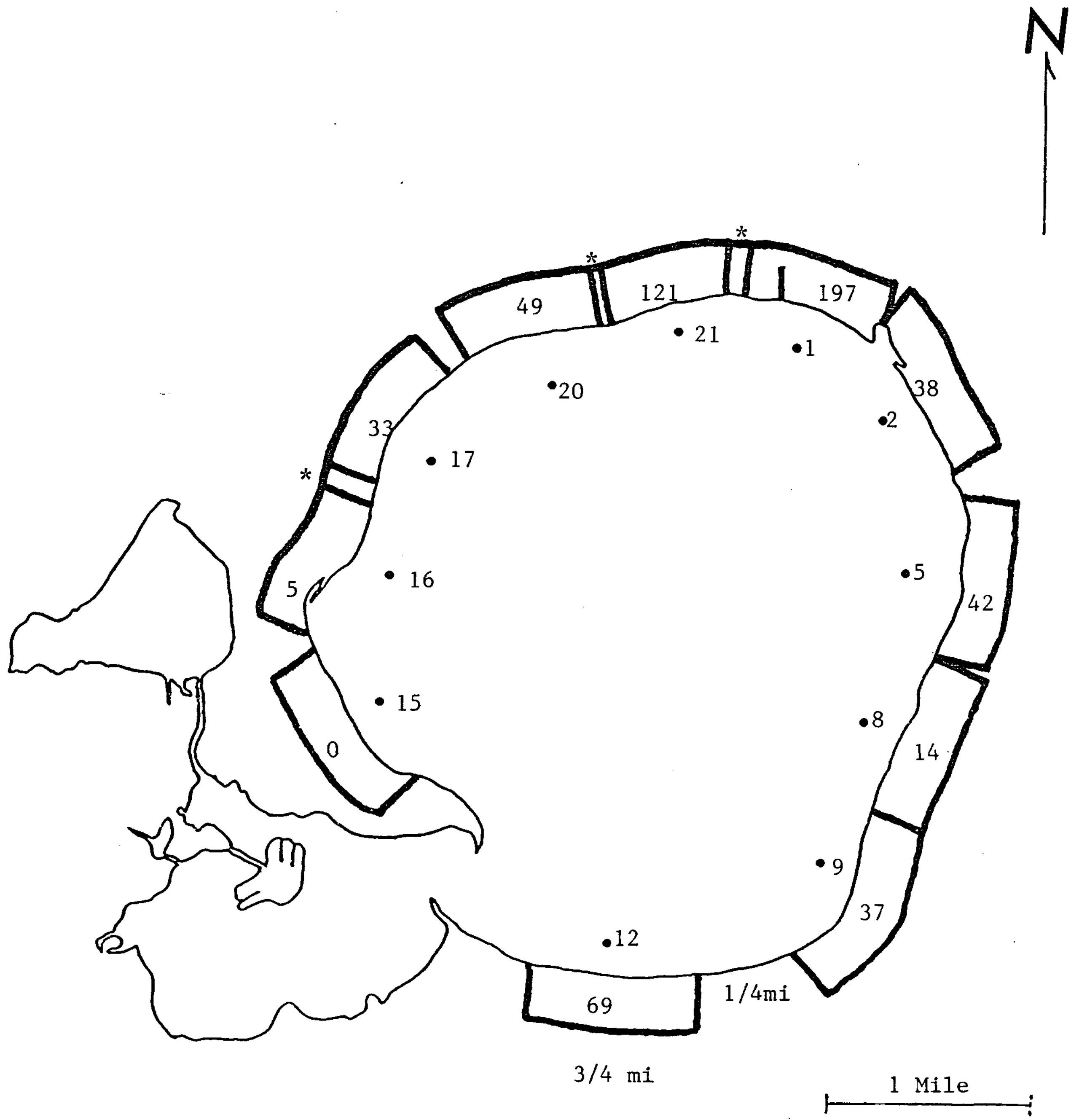


Figure 3-10. Outer rings of Secchi disk stations and annual mean depth (m) and corresponding shoreline area 3/4 mile by 1/4 mile with number of houses contained in each. Houses in areas of overlap ("*") were counted for both stations.

increasing shoreline population (Figure 3-11 A). However, linear regression of these points yielded an R squared value of only 0.53 due to two outliers (stations #2 and #15).

These stations have lower water clarity than other stations with similar numbers of houses. They appear to be picking up signals of nutrient sources not related to septic input. Station #15, as mentioned earlier, was just offshore of a major citrus grove. Station #2 was subjected to increased urban runoff from the northeastern watershed, where a major network of roads had been paved a few years earlier. It is important to note that this curve represents the maximum water clarity in Lake Weir for a given shoreline population; other factors can independently reduce water clarity.

After removing the two outlying points, the correlation was much stronger, having a linear regression R squared value of 0.88 (Figure 3-11 B). Water clarity appears to become less satisfactory for recreational purposes when house density exceeds 40 houses per 3/4 by 1/4 mile band. This density might be considered an acceptable limit for houses with septic tanks.

Summary

Secchi disk depths measure water clarity, which is a composite of dissolved water color, inorganic turbidity and algal biomass. The latter reflects nutrient loading into the lake system. All of the stations in this survey were in areas deep enough to minimize turbidity due to resuspension of bottom sediments by boating or wave action. Therefore, Secchi disk

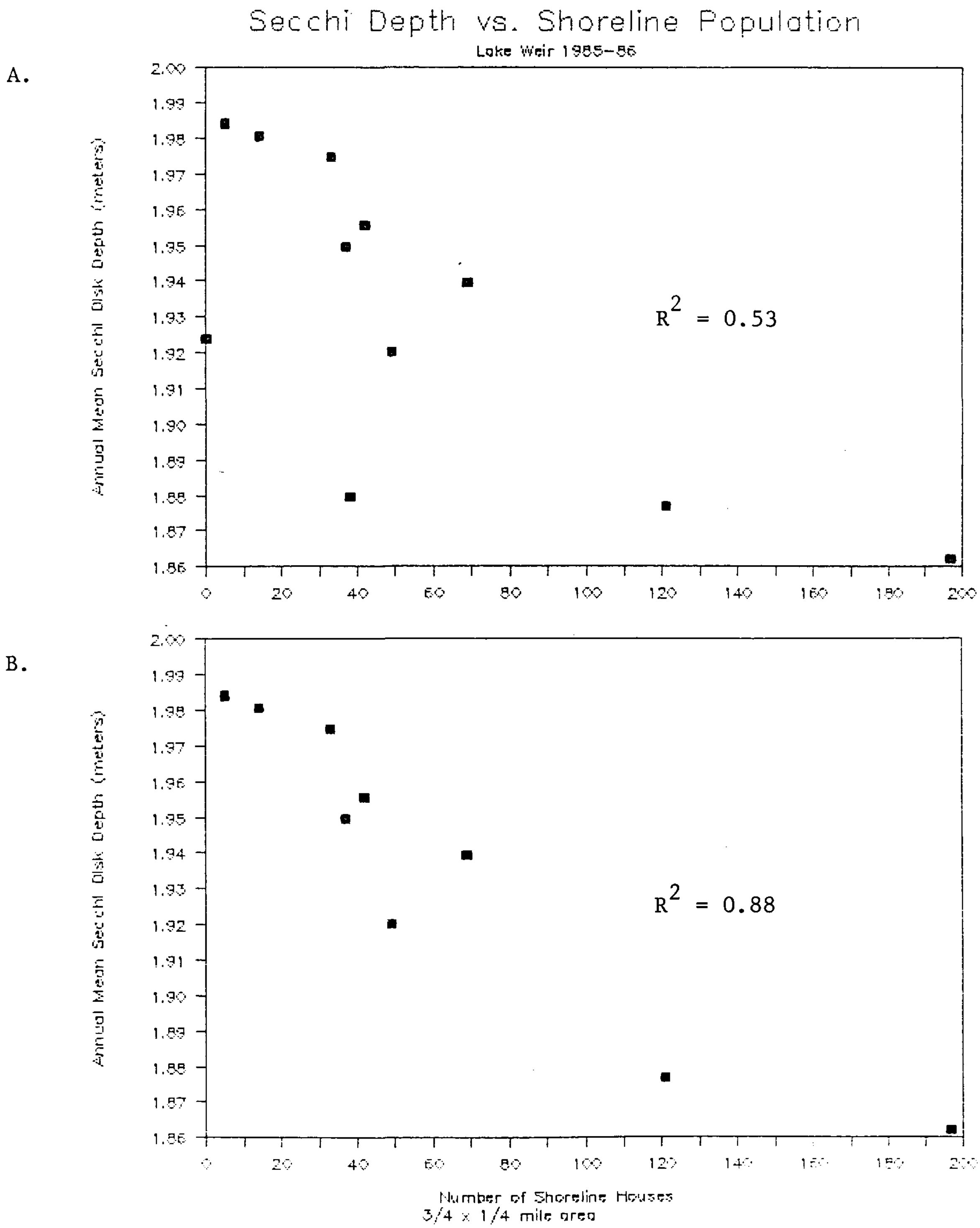


Figure 3-11. Mean annual Secchi disk depths versus number of houses along proximal shoreline.
A. Includes all eleven stations in outer rings.
B. Excluded stations #2 and #15.

depths in this survey were assumed to indicate relative amounts of nutrient loadings to Lake Weir.

Sunset Harbor, Little Lake Weir, and the Oklawaha area of Lake Weir exhibited significant reductions in water clarity. These areas coincided with areas of higher population along the shoreline. Different baseline conditions existed between the lake divisions. Duncan's multiple range test for stations in Lake Weir proper confirmed that the stations near Oklawaha had significantly lower water clarity.

Little Lake Weir and Sunset Harbor appeared to behave as isolated systems. Both had much higher shoreline to surface area ratios and were shallower than Lake Weir proper. Therefore, nutrients would be more concentrated than in the big lake. Little Lake Weir exhibited much greater seasonal changes in water clarity than Lake Weir. Little Lake Weir had many of the lake system's most turbid readings during the spring and summer; yet had by far the highest water clarity during the winter. There may have been increased flushing by groundwater during the winter months.

Reduction in water clarity was closely correlated to shoreline population, with an R-squared value of 0.88 after excluding stations #2 and #15, which were subject to other sources of nutrient loading. Septic tank input seems to have been responsible for this effect. Weirsdale appeared to have no significant impact on water clarity. Distance of development from the lake may have been a major factor governing the nutrient impact.

CHAPTER FOUR: LIMNOLOGICAL MONITORING OF LAKE WEIR, FLORIDA-- CURRENT CONDITIONS AND HISTORICAL PERSPECTIVES

MATERIALS AND METHODS

Field Sampling Methods

Monthly water samples for chemical analyses and plankton counts, and sediment samples for macroinvertebrate counts were collected at 7 stations (Figure 4-1). Five stations were established in Lake Weir, and a midlake station was used in both Sunset Harbor and Little Lake Weir. Dissolved oxygen and water temperature were measured at 1 m intervals at each station. Secchi disk transparency and bottom depth were recorded at each station.

Water chemistry samples were taken from 0.5 m depth in acid-washed nalgene bottles, acid-preserved (Total Phosphorus, Total Kjeldhal Nitrogen) or not (Orthophosphate, alkalinity, pH, conductivity) as required for the various analyses and put on ice. Plankton samples were taken from water column composites of Kemmerer bottle samplings at 1 m intervals and were stored in 80 ml glass bottles. Zooplankton and phytoplankton were preserved with Lugol's solution. Bacterial samples were preserved with 4 ml of formalin (in 80 ml sample). Water samples to be used for protozoan counts were preserved with bromothymol blue and $HgCl_2$. Macroinvertebrate samples were taken in triplicate at each station with a petit ponar grab (0.02 m^2), sieved in the field (600 um mesh) and preserved

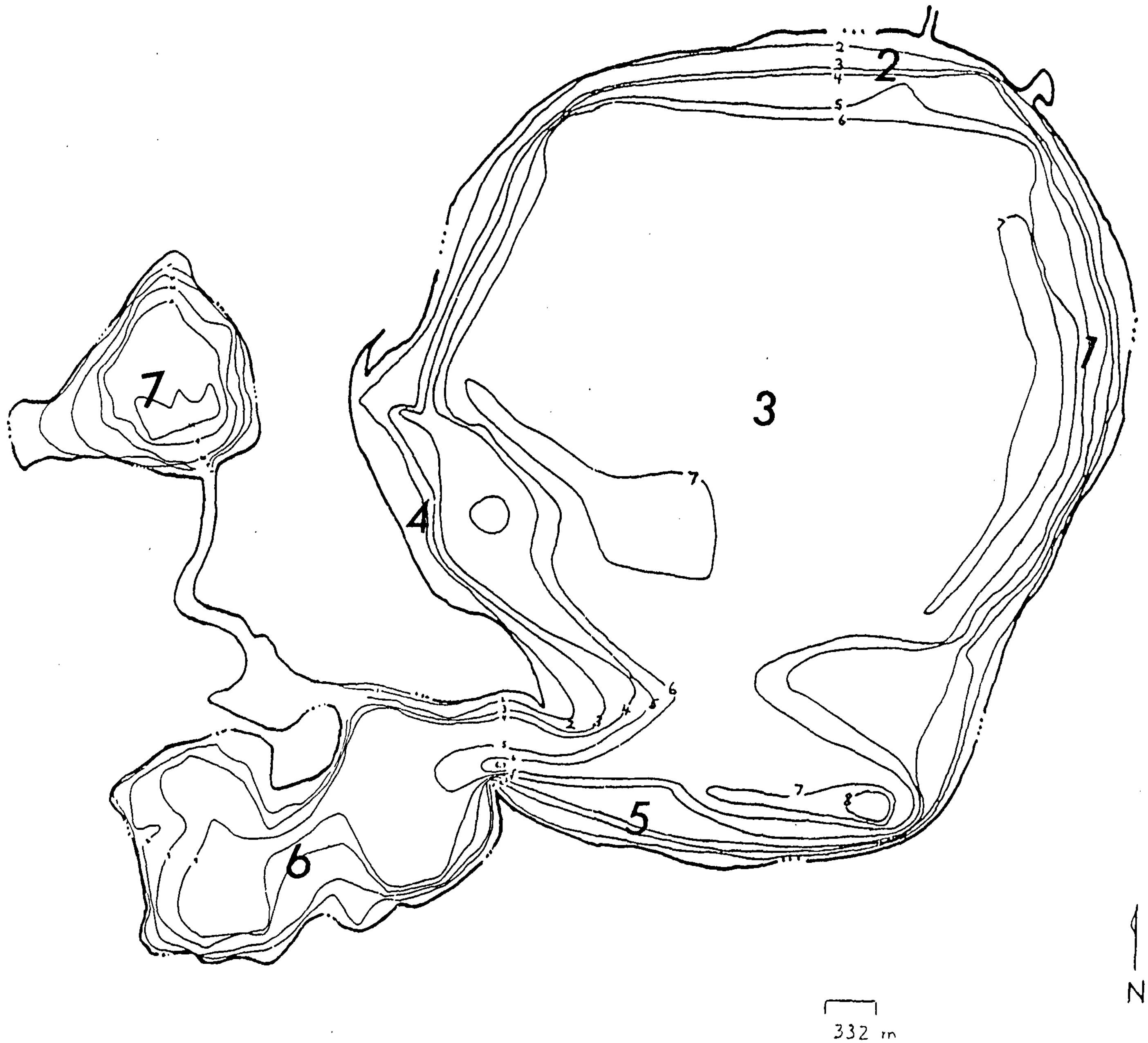


Figure 4-1. Bathymetric map of Lake Weir developed from fathometric tracings, 1988. Seven stations for monthly limnological monitoring are marked.

in 70% ethanol containing Rose bengal. Upon returning to the laboratory, chemistry and plankton samples were stored at 4 C until analyzed.

Submersed Macrophyte Mapping

Fathometric tracings were made along nine transects in Lake Weir, twelve transects in Sunset Harbor and ten transects in Little Lake Weir (Figure 4-2) to estimate the percent of the water column infested by submersed macrophytes (Maceina and Shireman 1980). Biovolume (Maceina and Shireman 1980), is the percent of the water column occupied by submersed plants. It provides data on the presence and location of submersed macrophytes. Along with water chemistry, biovolume measurements help to identify factors controlling the spread of macrophytes in a lake. For example, if plants are absent below a particular depth, it may be due to a physical limit on littoral zone expansion based on basin morphometry. Such a physical limitation is likely in lakes where low to moderate water column chlorophyll a (0-10 ug/L) concentrations are measured. When high levels of chlorophyll a are present, the growth of submersed plants may be limited solely by algal shading. The extent of the littoral zone may also have an impact on the accuracy of lake trophic state indicators based on water column chlorophyll a levels or nutrient concentrations (Canfield et al. 1984). A current bathymetric map of each basin was drafted depicting the extent of the littoral zone (Figure 4-3).

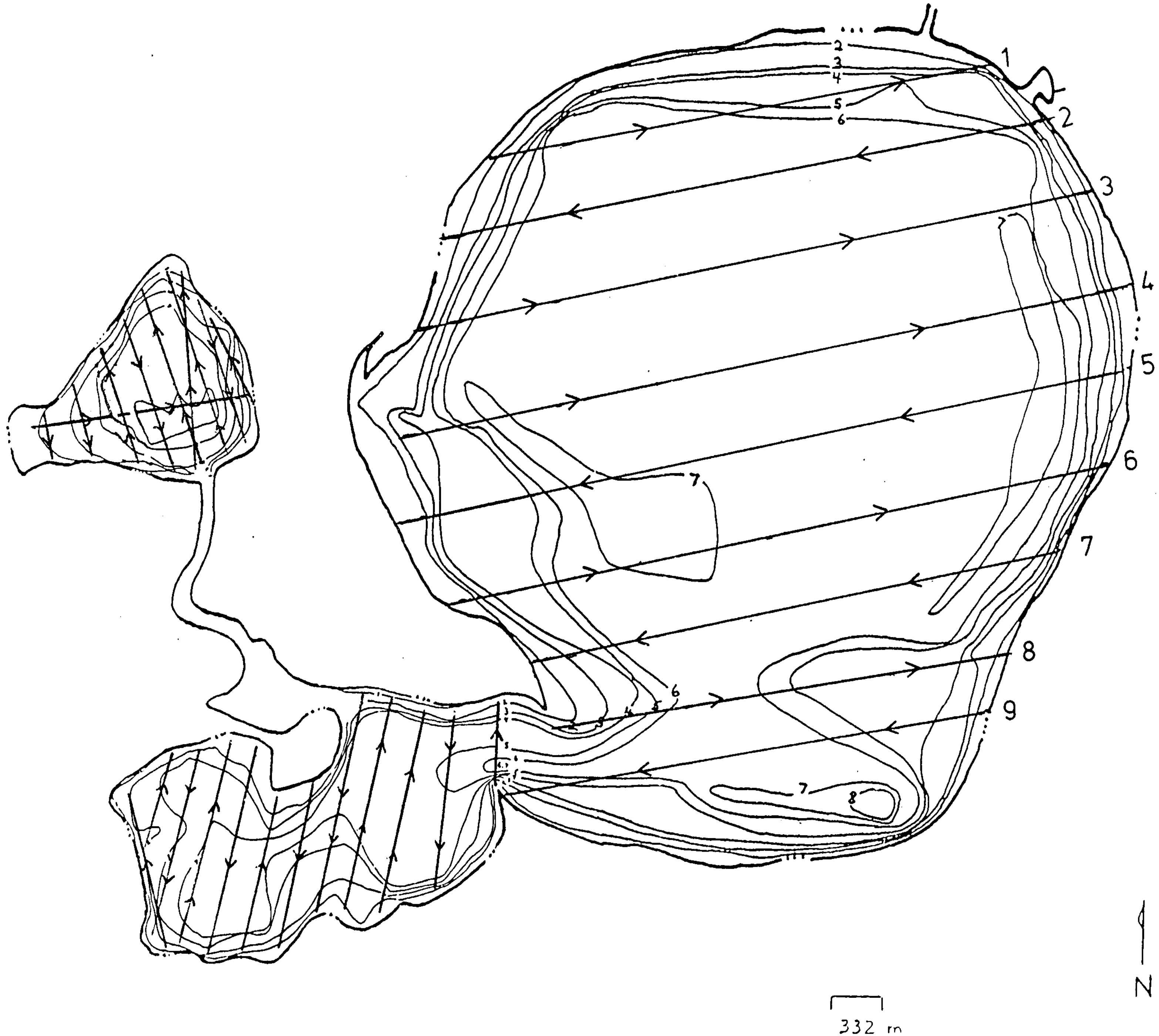


Figure 4-2 Transects used for bathymetric tracing's Lake Weir, Sunset Harbor and Little Lake Weir, Summer 1987.

Figure 4-3 Current bathymetric map of Lake Weir, Florida showing extent of littoral zone defined by rooted aquatic vegtation (shaded area).

Water Chemistry Analyses

Water samples were analyzed for total phosphorus (EPA method 365.2), ortho-phosphate (EPA method 362.2), total Kjeldahl nitrogen (EPA 351.2), nitrate (EPA method 353.2), Chlorophyll a concentration (A.P.H.A. method 1002G), alkalinity (EPA method 310.1), and pH (A.P.H.A. method 423).

Standards were run before and after each analysis (where applicable). Samples were run in duplicate. Reference standards obtained from EPA were also run with samples for TKN, TP and nitrate analyses. Values determined for these reference standards all fell within the 95% confidence intervals established by EPA. Chemistry data were analyzed for significant differences between stations and months using ANOVA and Duncan's multiple range test.

Bacteria

Water was prepared for bacteria counts by filtering samples through 0.2 um Nuclepore filters stained with Irgalan black. Counts were made on duplicate 1 ml subsamples for February, March, May, June, July and August 1987, and on triplicate subsamples for all other months, using direct-count epifluorescence (Hobbie et al. 1977). At least five fields and 200 cells were counted per filter. Acridine orange (0.01% final concentration) was the fluorescing agent. ANOVA and Duncan's multiple range tests were performed on station and monthly means of bacteria densities to determine if any were significantly different from the rest.

Zooplankton

Zooplankton communities were sampled approximately monthly at the seven lake stations. Water samples were taken at 1 m intervals from the surface to the bottom of the water column (exclusive of the sediments) with a 2.2 liter Kemmerer bottle and pooled.

Rotifer and crustacean populations were determined by passing 3 liter portions from this composite through an 80 um mesh Wisconsin plankton net and the concentrate was preserved with 2 ml of Lugol's solution. One ml aliquots from this concentrate were enumerated in a Sedgwick-Rafter chamber at 100x. If the total tally was less than 150 organisms, an additional aliquot was counted. Identification followed the keys of Ruttner-Kolisko (1974), Edmondson (1959), and Deevey and Deevey (1971). Dry weight biomass of rotifers and crustaceans was assigned by using published conversion factors (Dumont et al. 1975, Maslin 1969) as well as values empirically determined in this laboratory (Bays 1983).

Subsamples (76 ml) for ciliated protozoa were also taken from this composite, stained with several drops of bromothymol blue and preserved with 2 ml saturated $HgCl_2$. Appropriate aliquots were settled into Utermohl chambers and enumerated. The volume examined varied seasonally but was always between 3 ml and 10 ml, with each count representing at least 150 individual ciliates.

Biomass values were obtained using previously published volumes for individual taxa (Beaver & Crisman 1982) or direct measurement, and then the volumes were converted to dry weight biomass using a .279 pg d.w. um^3 conversion factor (Gates et al. 1982). Ciliate taxonomy was based on Kahl (1930-1935), Maeda (1986), and Maede and Carey (1985). Prior to analyses, plankton counts and chemical variables were normalized by a LOG (n+1) transformation.

Benthic Invertebrates

Macroinvertebrate samples were taken in triplicate at each station with a petit ponar grab (0.02 m^2), sieved in the field (600 um mesh) and preserved in 70% ethanol containing Rose bengal. Upon returning to the laboratory, samples were stored at 4°C until analyzed.

In the laboratory, macroinvertebrate samples were sorted in white enamel pans under a magnifying glass with fluorescent lighting. Picked specimens were kept in glass vials with 70% ethanol. Specimens were enumerated and identified to the generic level using keys of Pennak (1978), Parrish (1968), Merritt and Cummins (1984) and Brigham et al. (1982).

The mean number of organisms of the three grab samples collected at each station each month was recorded. The collected invertebrates were also categorized into functional groups based on their mode of food acquisition (Merritt and Cummins, 1984). Data were transformed (log) prior to analysis to conform to the assumption of ANOVA that the variances be homogeneous (Sokal and Rohlf, 1969). Statistical analyses of proportions used arcsine transformed data.

RESULTS AND DISCUSSION

Physical Parameters

Dissolved oxygen levels in the water column remained above 5 mg/L at all seven stations except during March, September and November (Figure 4-4). In the latter months, oxygen concentrations declined to 3-4 mg/L in water deeper than two meters at stations 2, 3, 6 and 7. Periods of oxygen stratification were brief, probably being limited by wind mixing action.

Lake water temperatures ranged from a low of 14°C in January to a high of 30°C in June, and were essentially uniform throughout the water column during the entire year (Figure 4-5). Neither dissolved oxygen levels nor temperature would be considered limiting factors as far as fish reproduction or survival are concerned.

During the past year, Secchi depths were lowest during May (1.00-1.31 m) and September (1.18-1.40 m) at all sampling stations (Figure 4-6). Station 6 (Sunset Harbor) had a Secchi depth of 1.10 m in May, the lowest value for all stations and months. The greater relative impacts of boating, septic tank input and erosion in this smaller basin than are evident in Lake Weir itself may explain the poor Secchi transparency. The highest reading (2.20 m) was taken in March at station 7 (Little Lake Weir). While this basin is the smallest of the Lake Weir system and might be expected to respond to human impacts more dramatically than the other two basins, lake

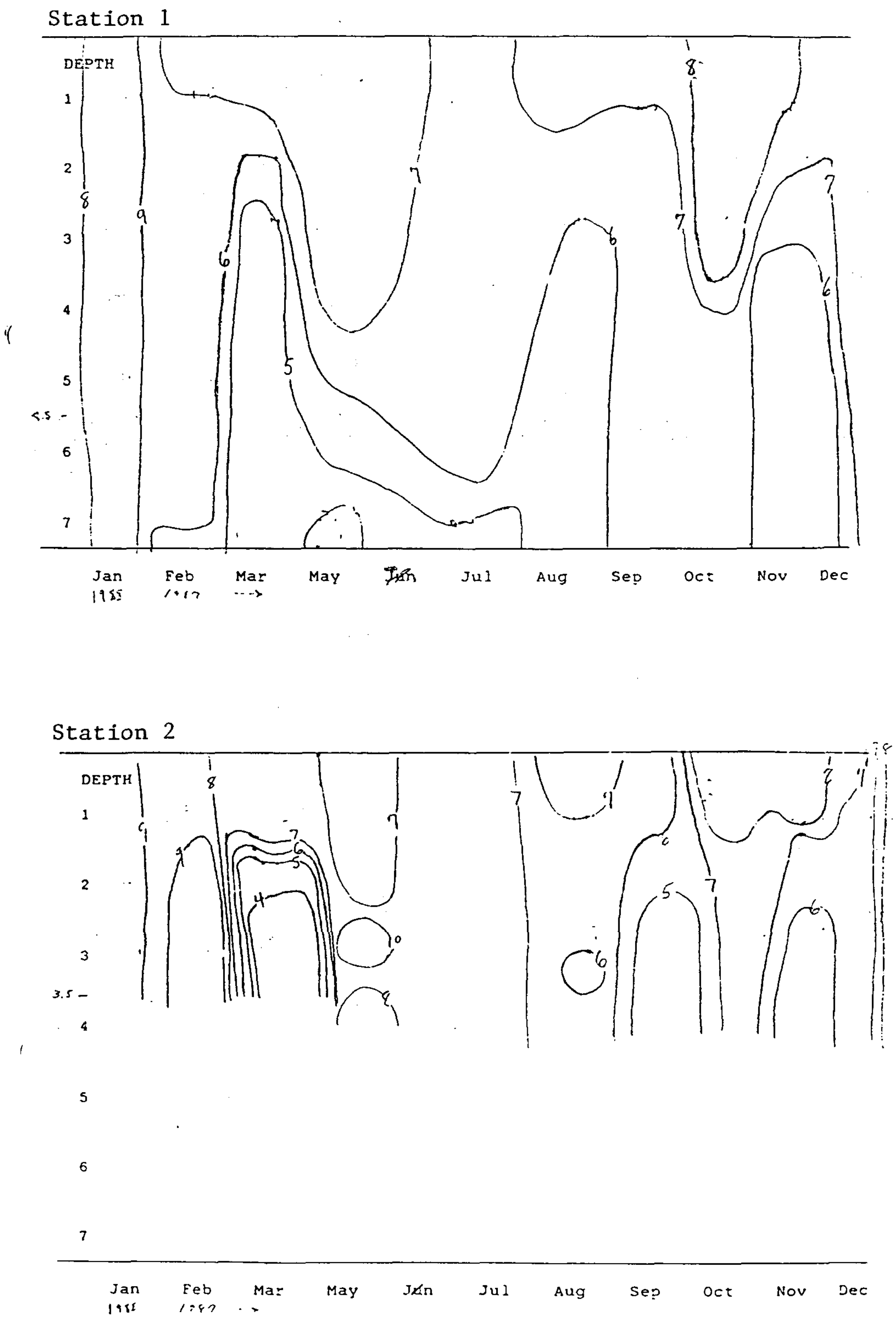
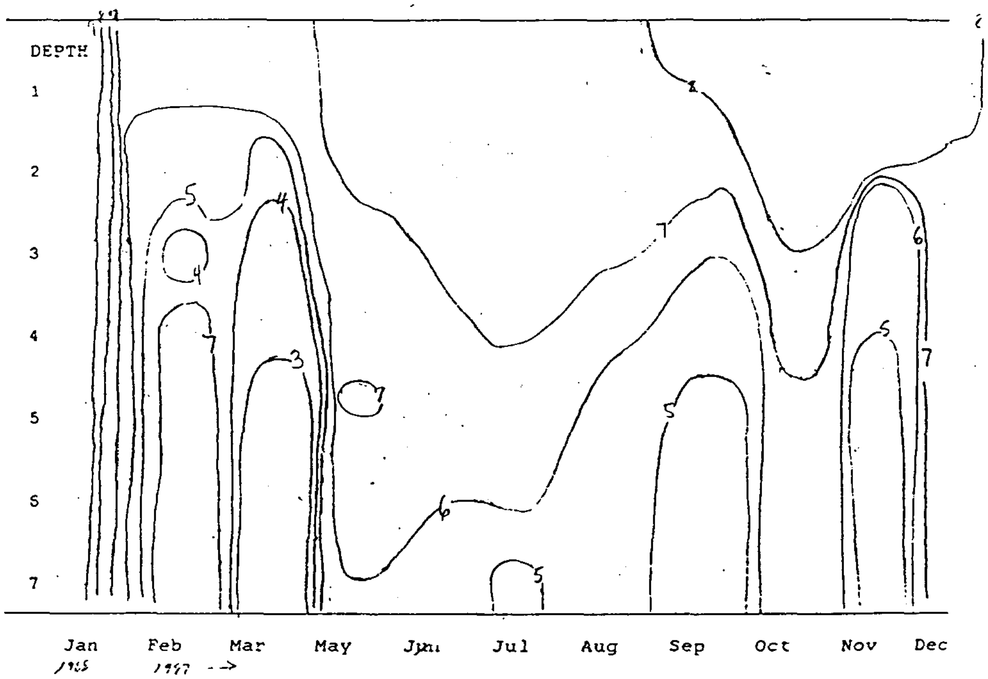


Figure 4-4 Water column dissolved oxygen (mg/L) isopleths for Lake Weir, Florida, 1987-1988.

Station 3



Station 4

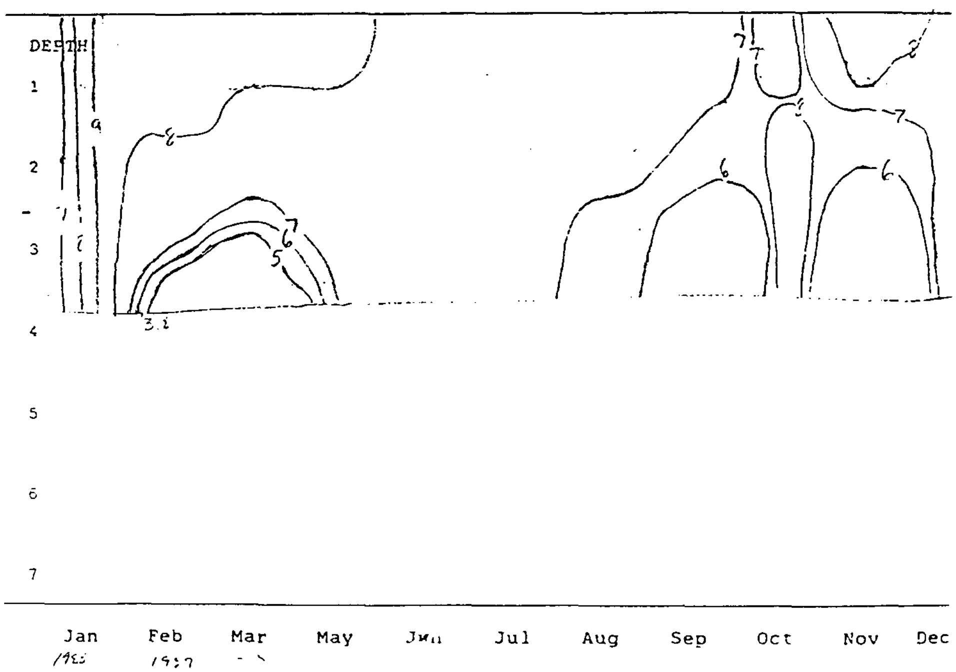
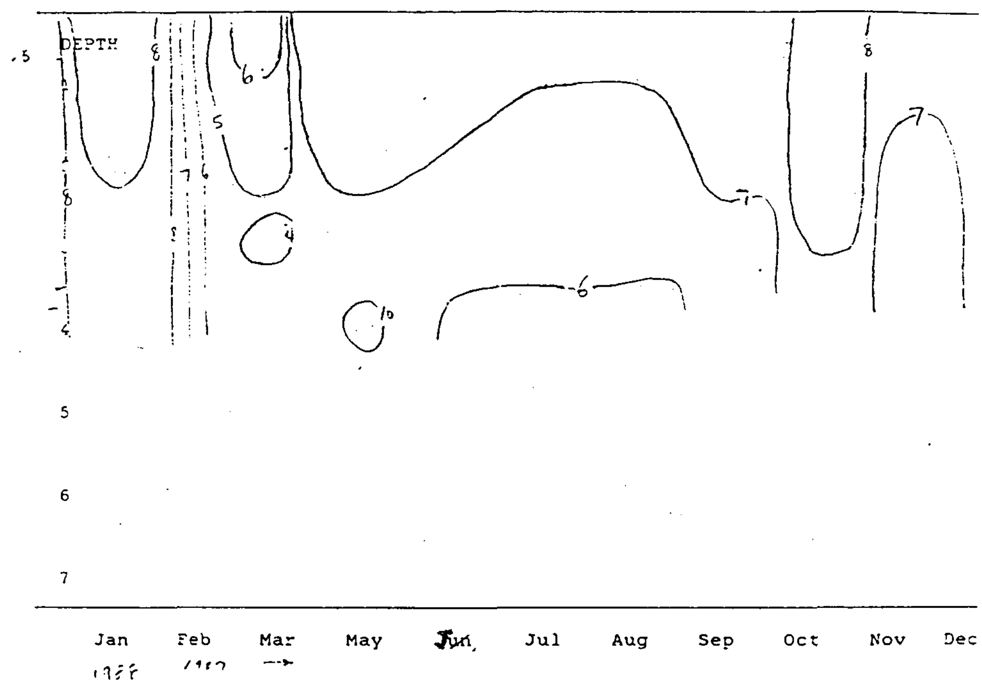


Figure 4-4 Continued.

Station 5



Station 6

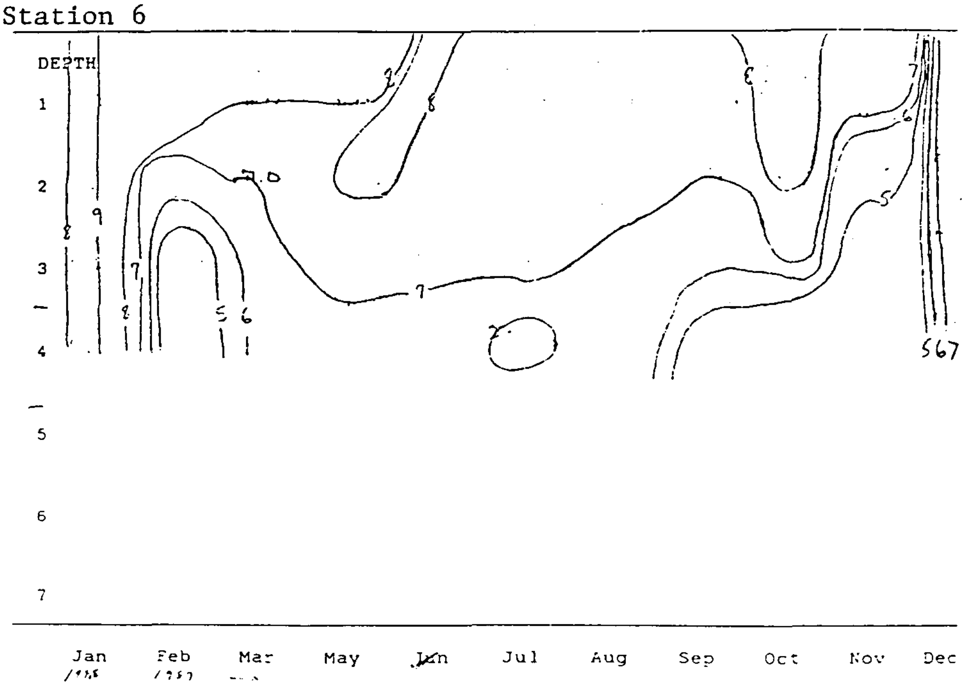


Figure 4-4 Continued.

Station 7

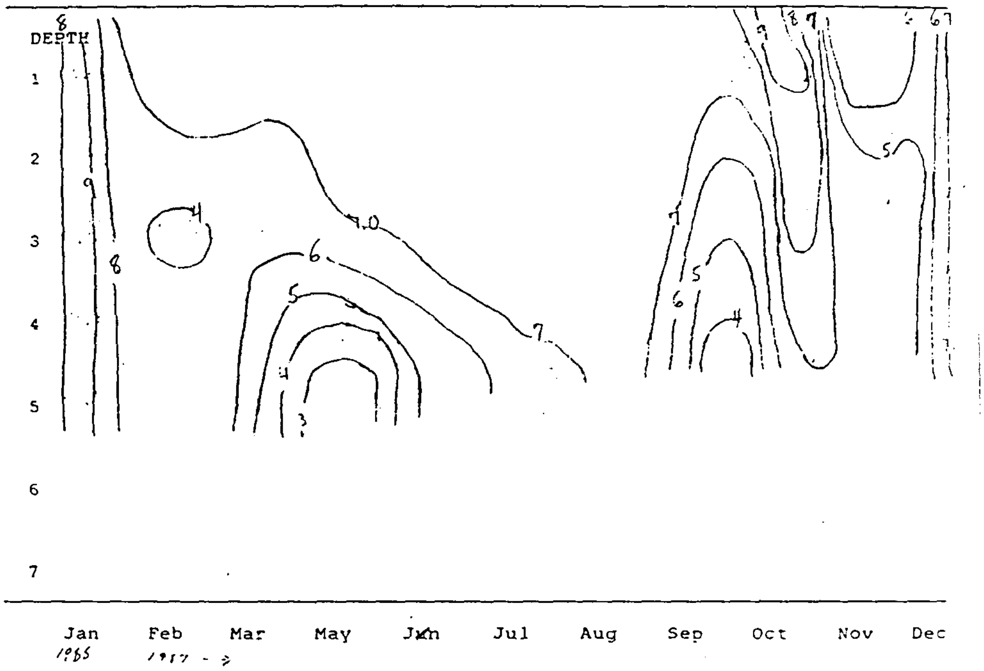
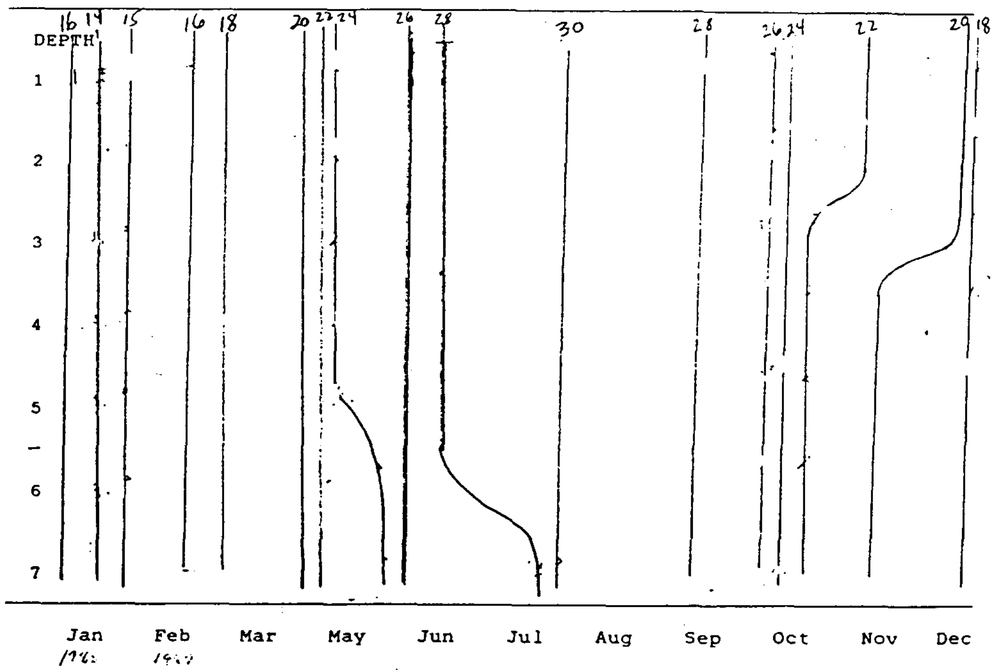


Figure 4-4 Continued.

Station 1.



Station 2.

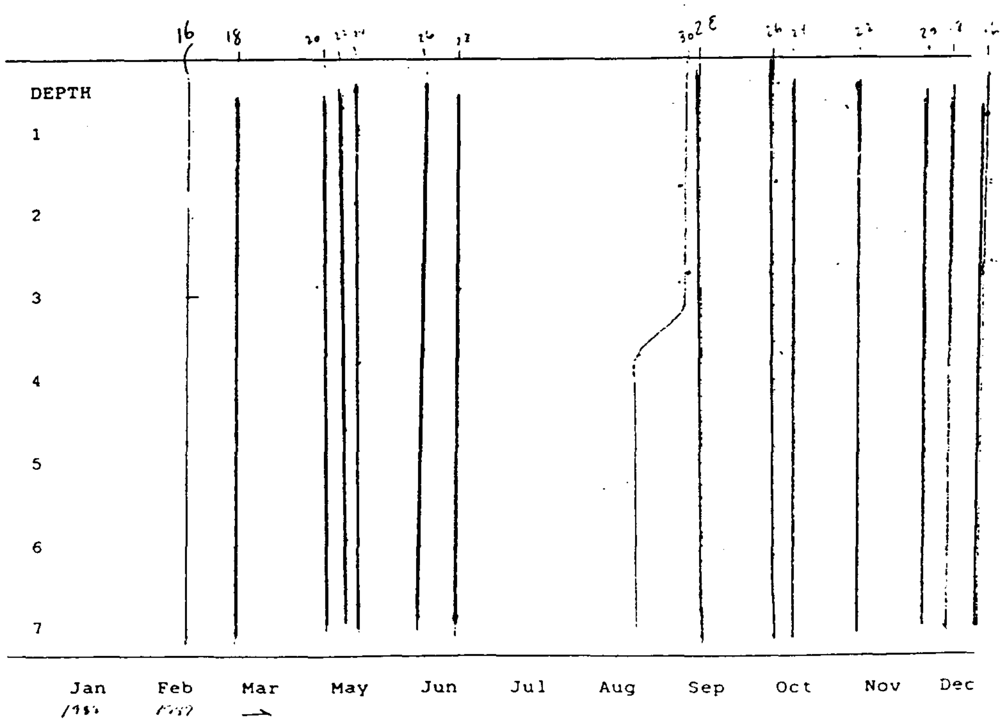
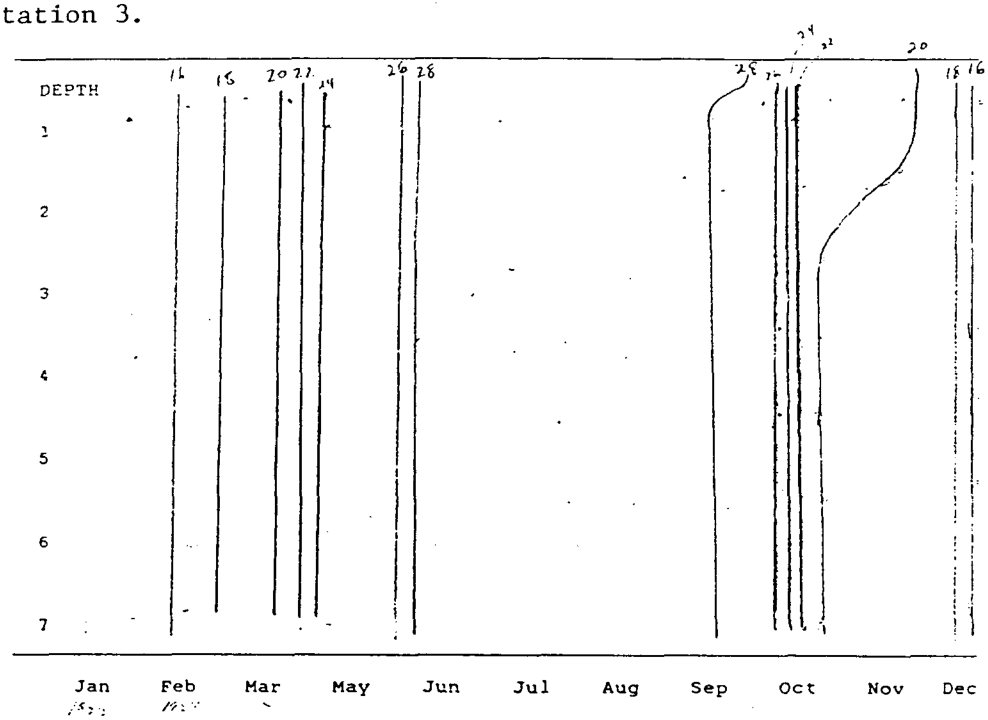


Figure 4-5. Water temperature (C) isopleths for Lake Weir, FL, 1987-1988.

Station 3.



Station 4.

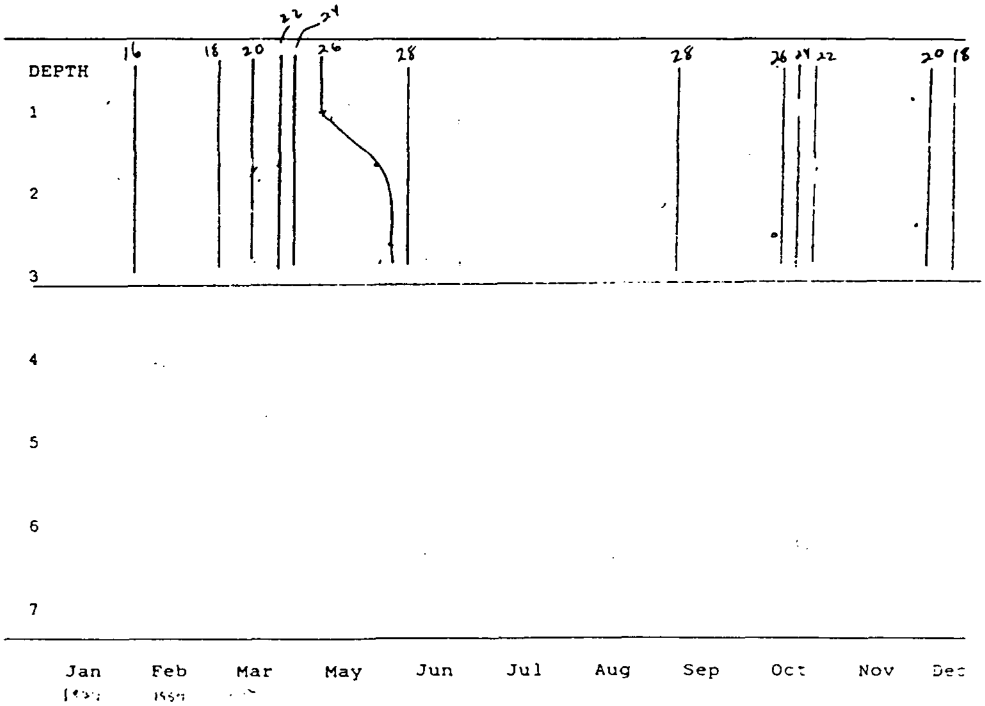
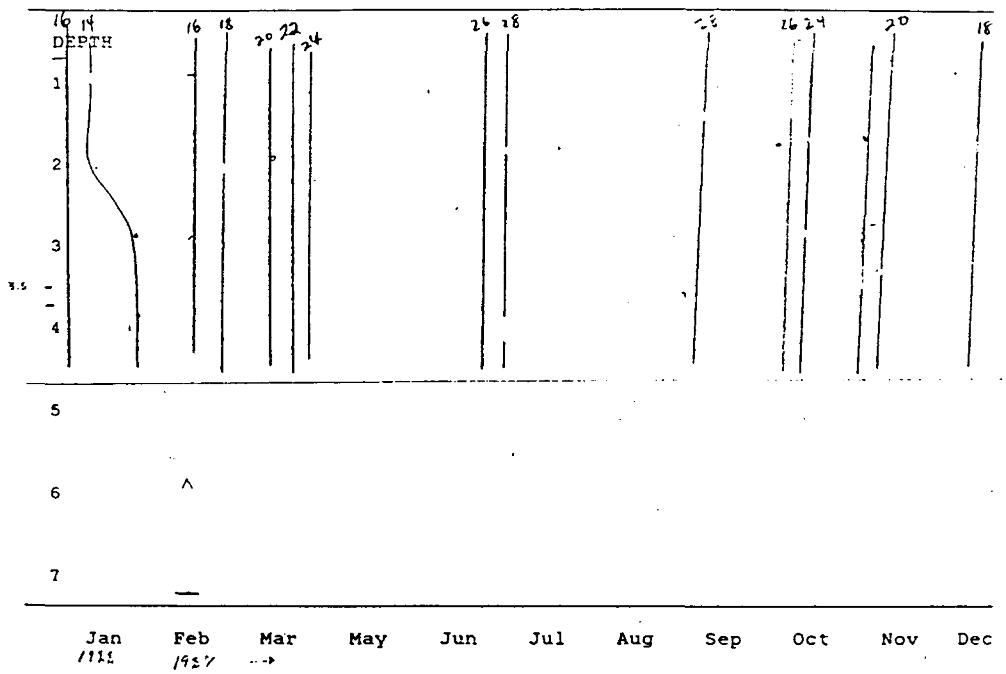


Figure 4-5. Continued.

Station 5.



Station 6.

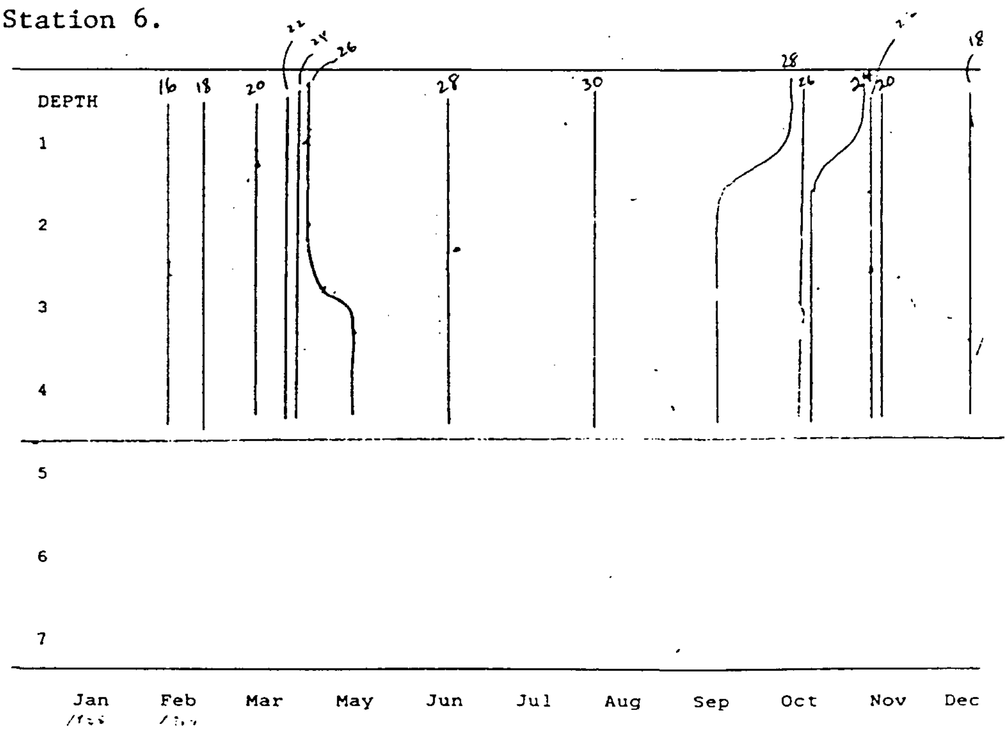


Figure 4-5 Continued.

Station 7.

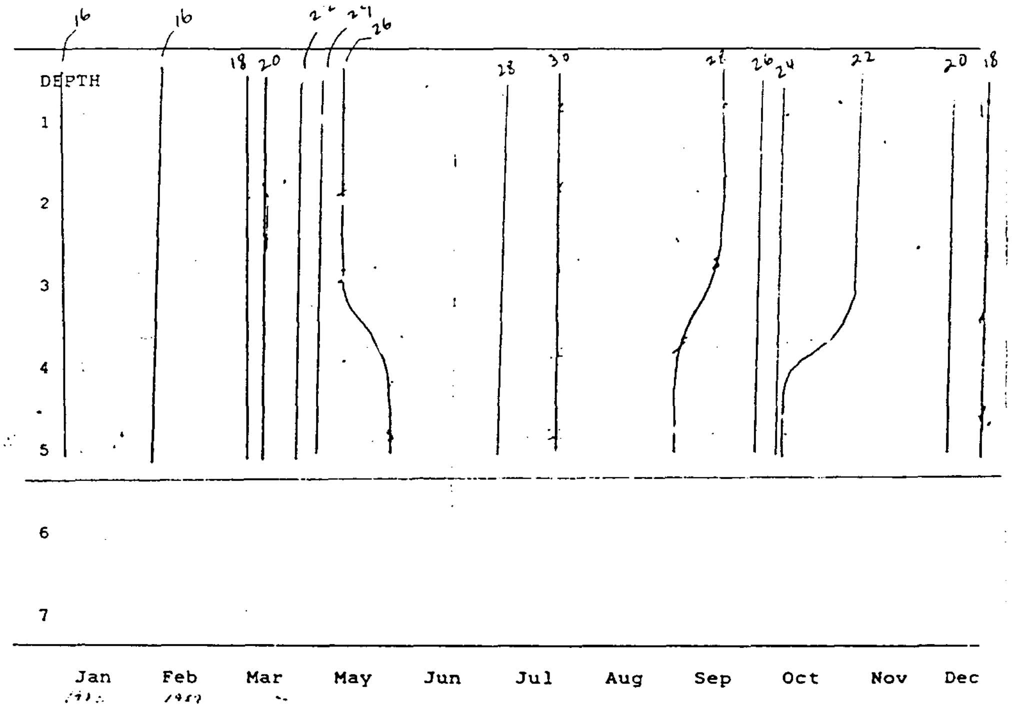


Figure 4-5 Continued.

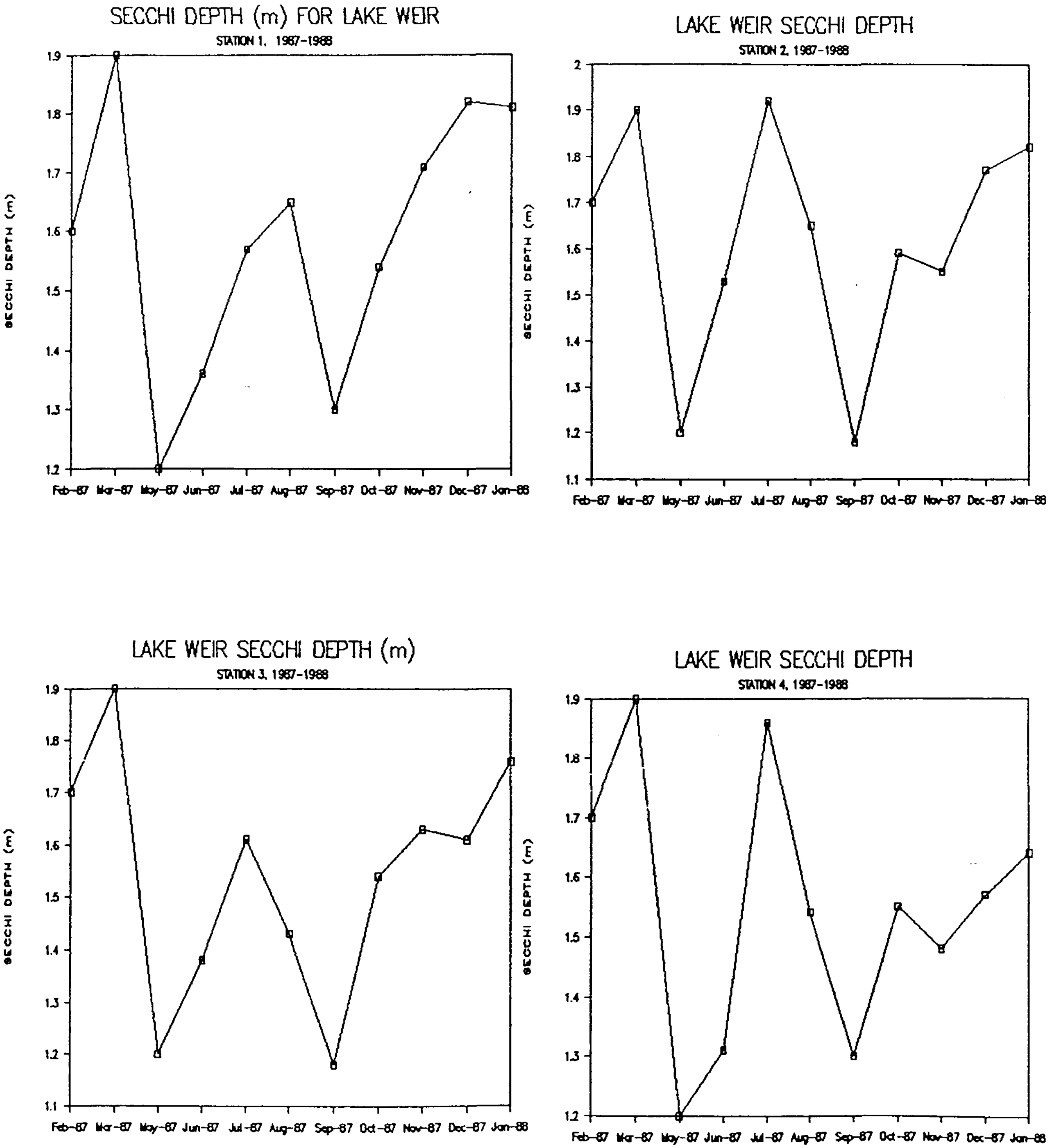
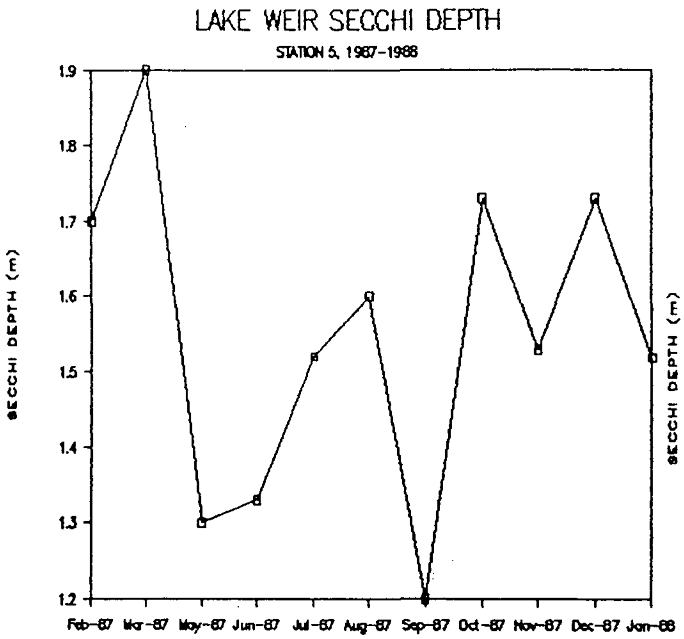
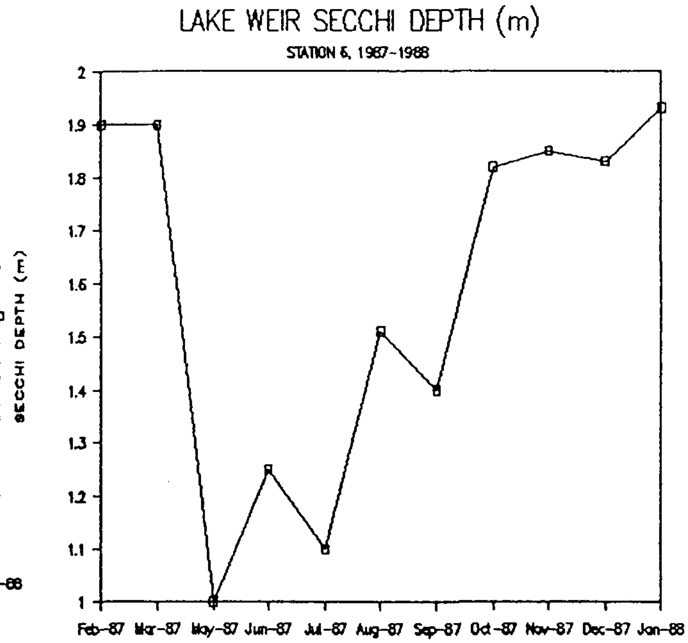


Figure 4-6. Seasonal Secchi depths (m) for the seven sampling stations in Lake Weir, Florida, 1987-1988.





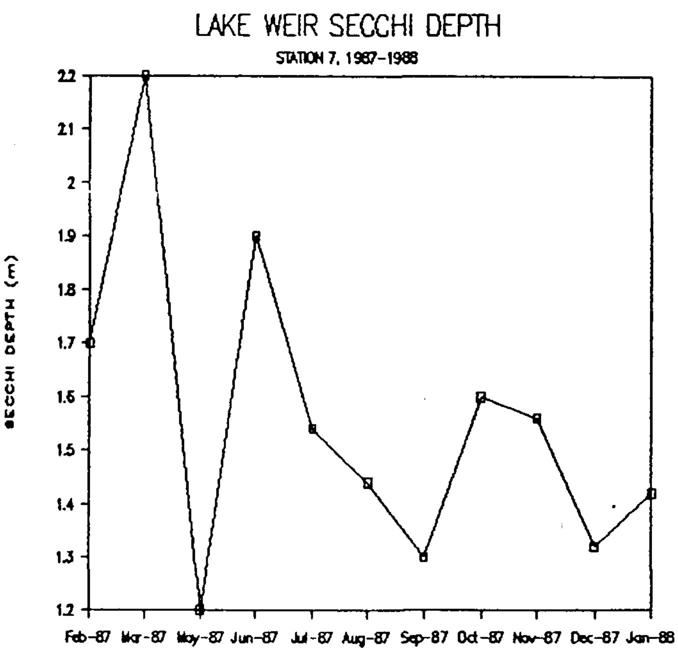


Figure 4-6. Continued.

residents have noted the presence of several springs in Little Lake Weir which they feel have pronounced flows during some periods. This may account for the high Secchi depth in March.

Secchi depths measured by lake residents as part of the Secchi Disk Program of 1985-1986 revealed that water clarity in northeastern Lake Weir (our Station 2) was significantly lower than it was in the rest of the lake (Stations 1, 3-5). During 1987-1988 there were no significant differences in Secchi depths among stations. The lack of agreement among data from these 3 years is probably due to the large number of Secchi depth measurements taken at each station during the earlier 2 years. Citizens took over 1300 Secchi depths at 31 stations in 1985 and 1986, while our monitoring data included only one measurement per month at each of seven stations. A larger sample number provides more degrees of freedom in statistical analyses and thereby resolution of smaller differences.

Water Chemistry

Seasonal fluctuations in water chemistry are depicted in Figures 4-7 through 4-10. All seven stations exhibited peaks of total phosphorus in August, while fall and winter values were generally lower. At stations 6 (Sunset Harbor) and 7 (Little Lake Weir), the August values for TP were 72 and 140 ug/L, respectively, while January had the lowest level of TP (10.3 ug/L) at station 6 and February had the lowest TP at station 7 (22 ug/L). For Lake Weir (station 3), TP was measurable for all months except January 1988 (Figure 4-7). During

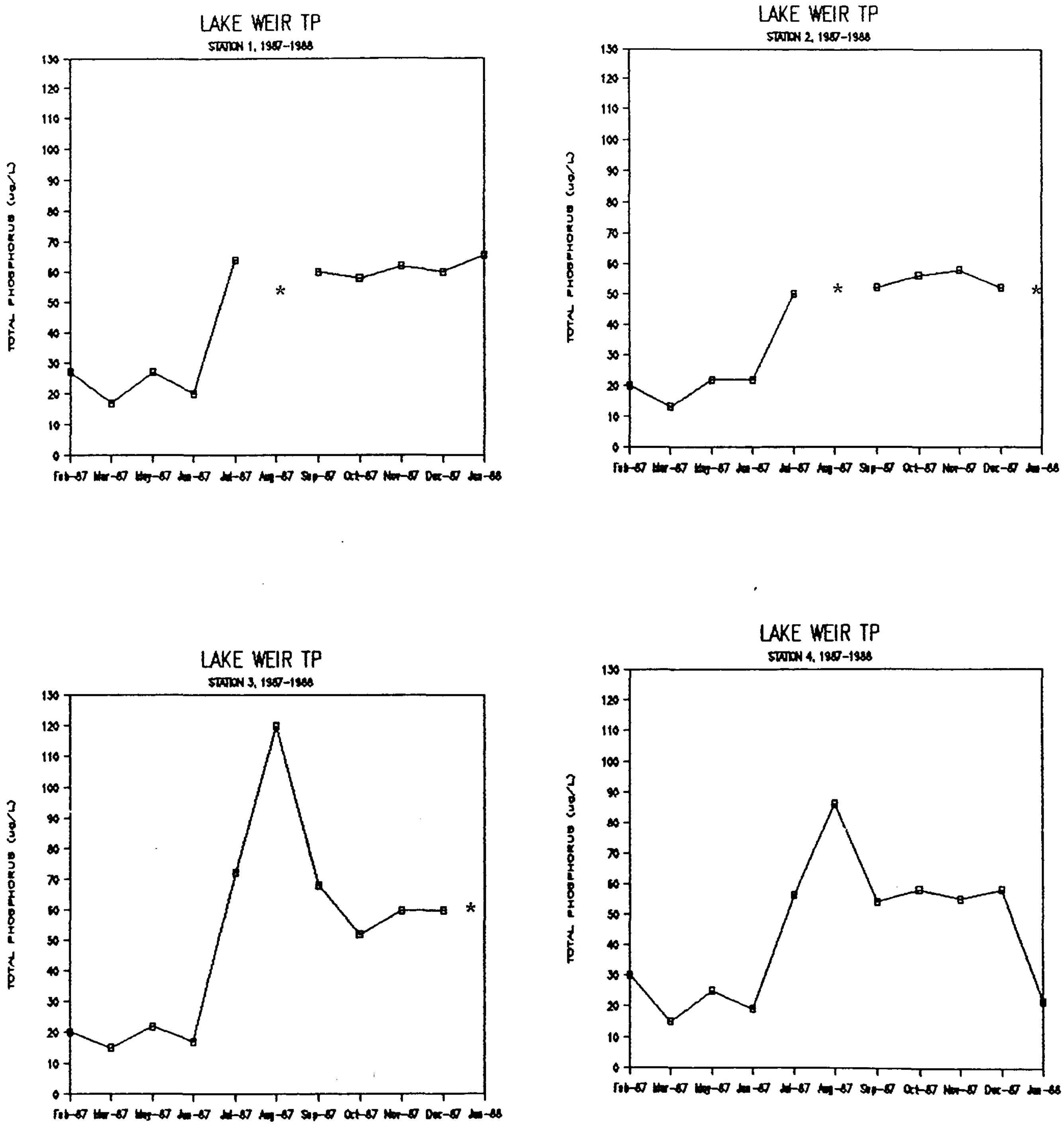
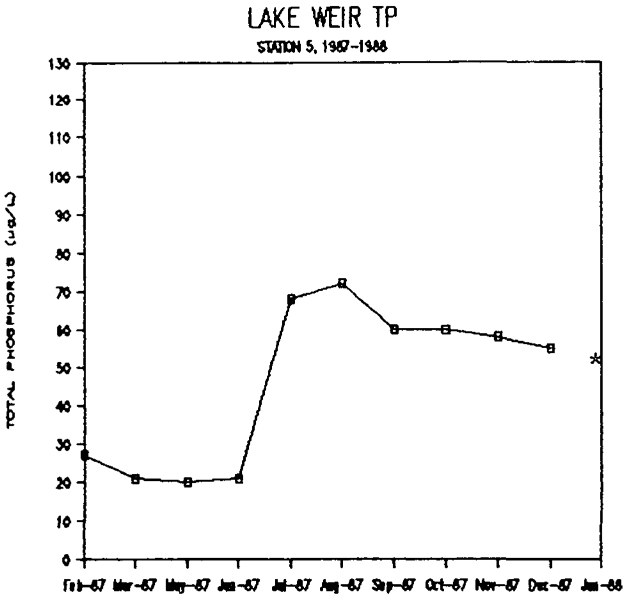
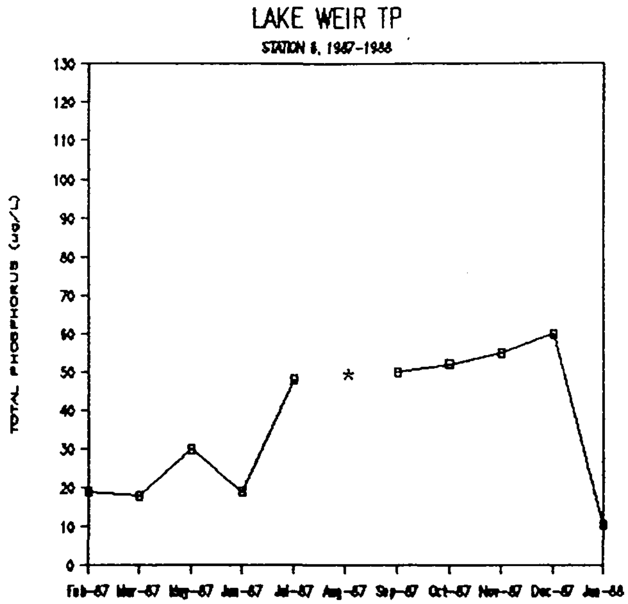


Figure 4-7. Seasonal levels of Total Phsophorus in Lake Weir, Florida, February 1987-Janaury 1988. (Asterisk indicates value below detection limits -- 0.01 mg/L.)





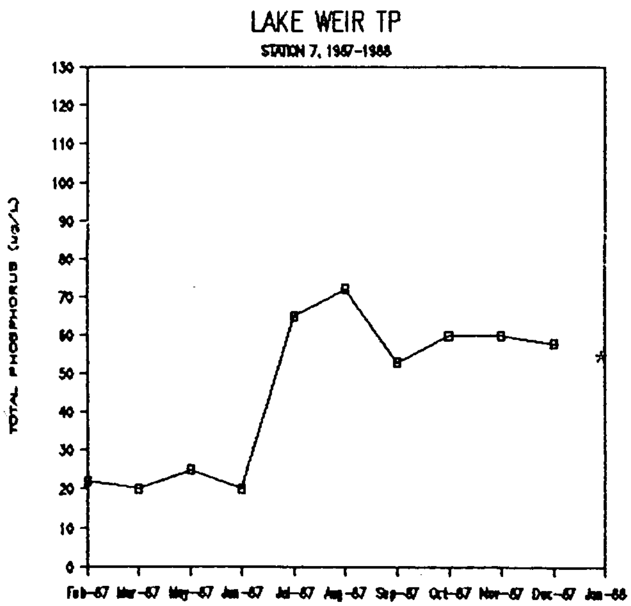


Figure 4-7. Continued. (Asterisk indicates value below detection limits--0.01 mg/L.)

late winter and spring, TP was at its lowest measured levels (15-22 ug/L) at station 3. Regarding the Lake Weir perimeter stations (1,2,4 and 5), August TP values were highest (72-740 ug/L), as in the center lake station, and spring and fall were lower (10-70 ug/L). There were no significant differences between stations (Table 4-1). However, results of ANOVA and Duncan's multiple range test indicated that there were statistically significant differences between months (Tables 4-2, 4-3). These differences supported the observations (Figure 4-7) that levels of total phosphorus were higher in summer and winter than during the rest of the year.

Total Kjeldahl nitrogen (TKN) levels (Figure 4-8) exhibited no obvious patterns among the mid-lake stations (3, 6 and 7). Station 3, in the middle of Lake Weir, was highest in January and February (840-900 ug/L), perhaps due to inputs from migrating waterfowl which were abundant in the middle of Lake Weir during that time. In Little Lake Weir and Sunset Harbor (stations 6 and 7) TKN levels were generally highest during spring and fall, but overall were more variable than those measured at station 3. For all three mid-lake stations, TKN levels fluctuated around low points during summer (680-810 ug/L) and increased in late fall.

At stations 1, 2, 4 and 5 in Lake Weir, TKN decreased in late spring (690-850 ug/L) and remained low until October. Total nitrogen was generally highest in spring and fall at these four stations. There were no significant differences in TKN between stations, but ANOVA and Duncan's multiple range

Table 4-1. Results of analyses of differences between sampling stations for current chemistry data in Lake Weir, FL by ANOVA and Duncan's procedure.

Parameter	N	F	Significance
Secchi depth	77	0.13	n.s.
Chlorophyll *a*	77	0.51	n.s.
Conductivity	77	0.97	n.s.
Total Kjeldahl nitrogen	77	0.93	n.s.
Total phosphate	71	0.19	n.s.
Orthophosphate	66	0.07	n.s.
Total alkalinity	77	106.92	**
pH	76	7.11	**

n.s.=not significant.
*=significant at $p \leq 0.05$.
**=significant at $p \leq 0.01$.

Table 4-2. Results of ANOVA for monthly comparisons of water chemistry at the seven sampling stations in Lake Weir, Florida.

Parameter	N	F	Significance
Secchi	11	13.37	**
Chlorophyll a	11	10.82	**
Specific conductivity	11	104.87	**
Total Kjeldhal nitrogen	9	3.24	*
Total phosphorus	11	33.21	**
Orthophosphate	10	88.46	**
Total alkalinity	11	0.54	n.s.

** $p \leq 0.01$; * $p \leq 0.05$; n.s.= not significant.

Table 4-3. Results of Duncan's multiple range test for chemistry by month. Months connected by underlines were not significantly different.

Secchi depth

```
3  2  1  12  10  11  7  8  6  9  5
   ----------------------
                     -------
                                ----
```

Chlorophyll *a*

```
6  8  12  1  5  7  9  11  10  3  2
--------------------
          -------------
             ---------------
                          -----
                              ----
```

Specific conductivity

```
7  8  6  9  11  10  5  1  12  3  2
-------
      ----
            ---------
                       -----
```

Total Kjeldhal nitrogen

```
5  11  12  3  6  1  9  10  2
---------------
       ----------------
           ------------------
```

Total phosphorus

```
8  7  11  12  9  10  1  5  2  6  3
   ----------------
                     ----------
                        ----------
```

Orthophosphate

```
11  12  5  7  6  9  10  3  2  8
------
        ----------------
              ---------------
```

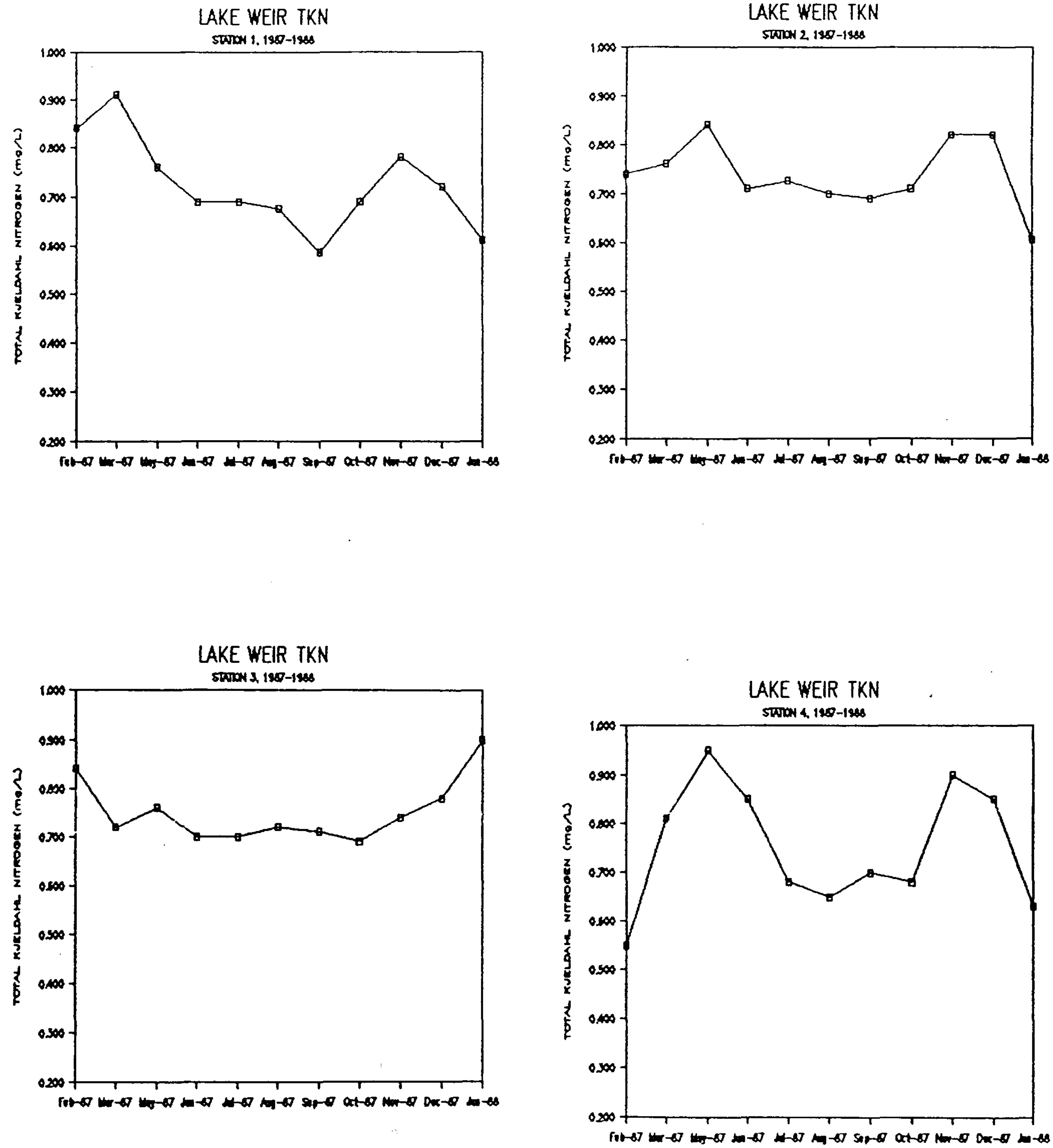
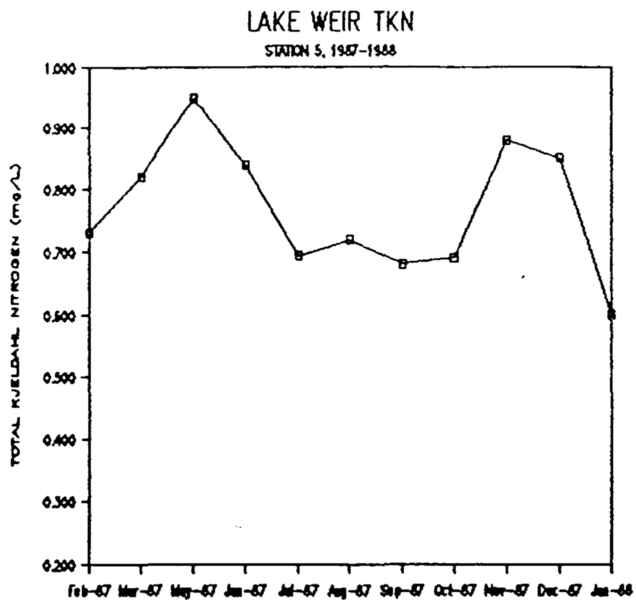
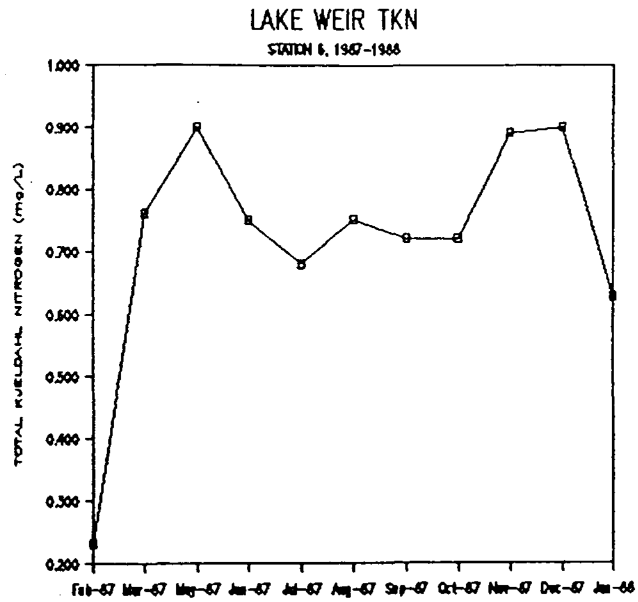


Figure 4-8 . Seasonal levels of Total Kjeldahl Nitrogen in Lake Weir, Florida, February 1987-January 1988.





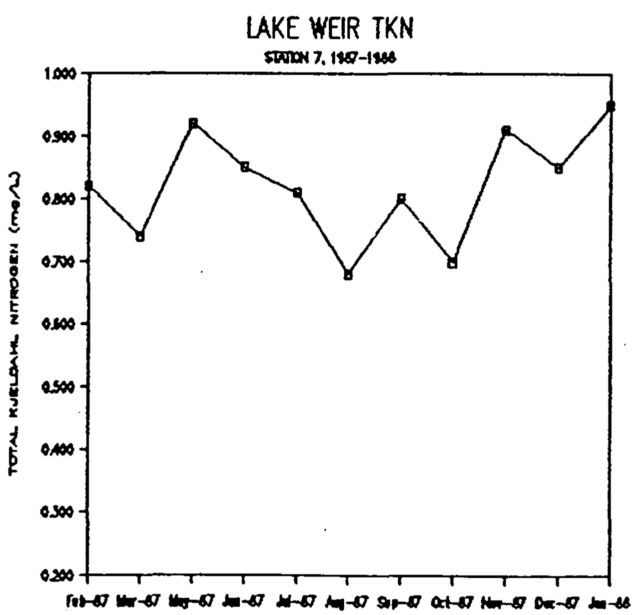


Figure 4-8. Continued.

test identified some significant monthly differences (Table 4-3). However, these do not follow any pattern.

Station 3 had chlorophyll a peaks (Figure 4-9) during May (10.2 ug/L), August (9.34 ug/L) and January (8.79 ug/L). Chlorophyll a (Chla) levels peaked in June (7.4-12.2 ug/L), July (9.04-10.42 ug/L) and again in December (8.35-9.40 ug/L) at stations 6 and 7. High summer Chla values reflect the summer production peak which is common in Florida lakes, as ideal conditions for phytoplankton growth occur then. At stations 1, 2, 4 and 5, chlorophyll a concentrations generally peaked in June (9.00-10.30) and were lowest in February (3.10-4.20). The effect of higher Chla concentrations is seen in decreased Secchi depths during May and September at most stations.

As with other chemistry parameters, there were no significant differences between chlorophyll a levels at the seven stations. However, Duncan's multiple range test identified monthly differences (Table 4-3). Chlorophyll a was highest during summer months, December, and January.

Specific conductivity was highest from June to September (155-173 ug/L) for all seven sampling stations (Figure 4-10). Conductivity is affected by dissolved solids contained in rain-water or run-off from the watershed. Since Florida lakes usually receive considerable rainfall during frequent summer thunderstorms, it is not surprising that conductivity was highest in the summer at all three mid-lake stations. Perimeter Lake Weir stations (1, 2, 4 and 5) followed the same trend

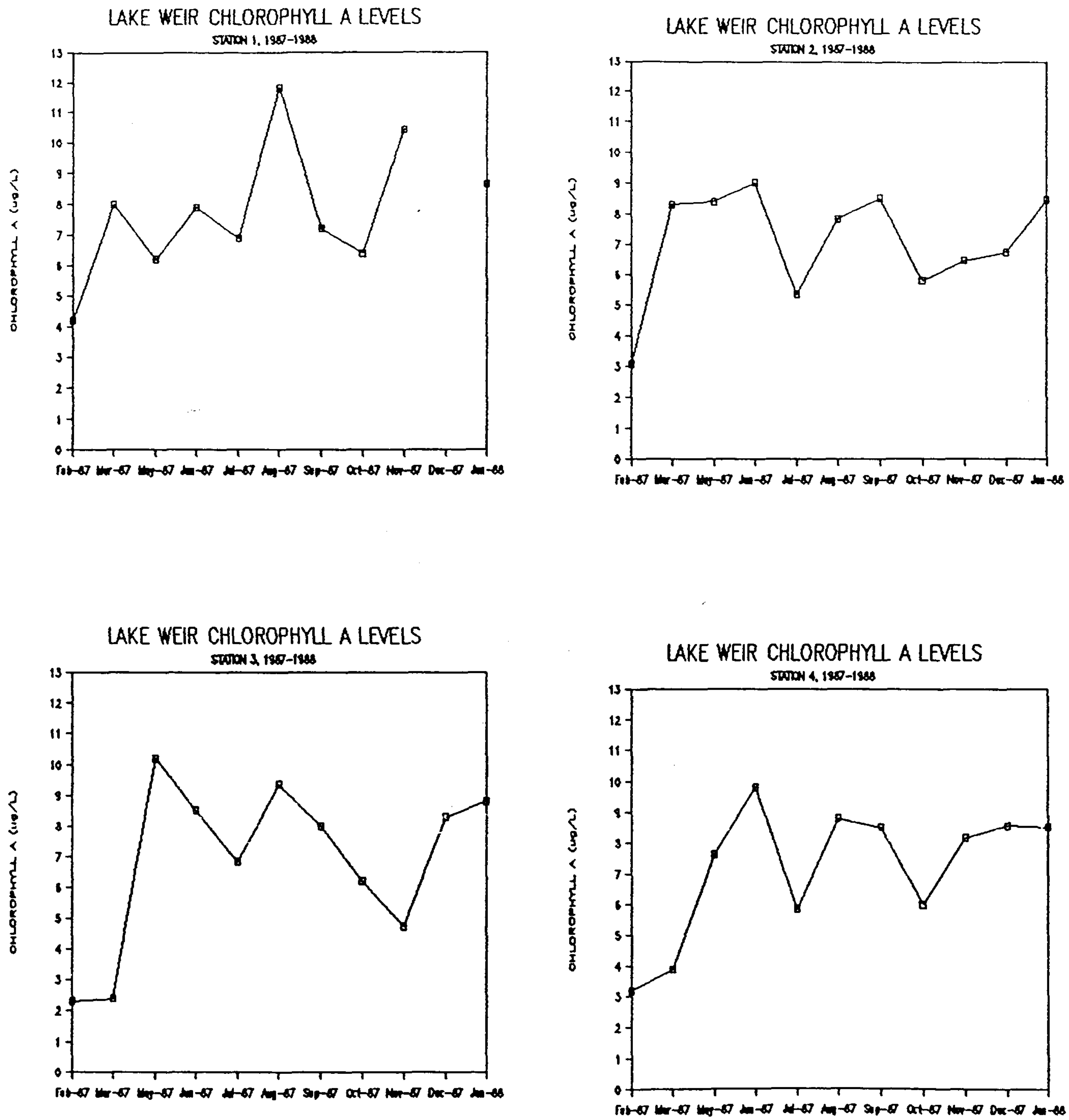
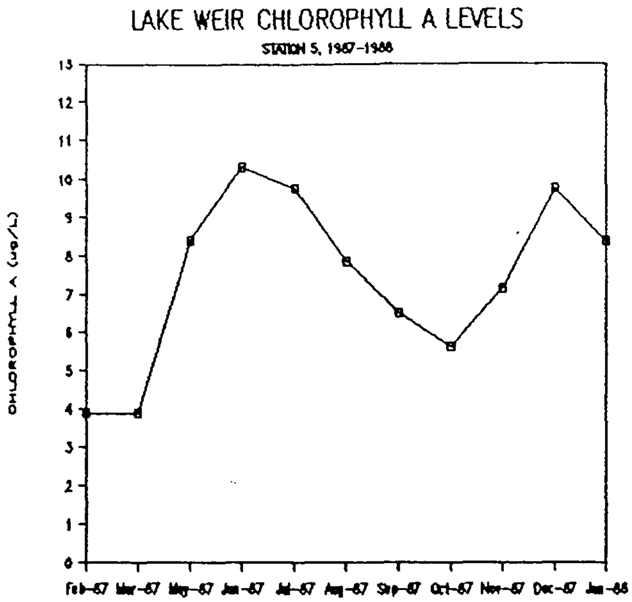
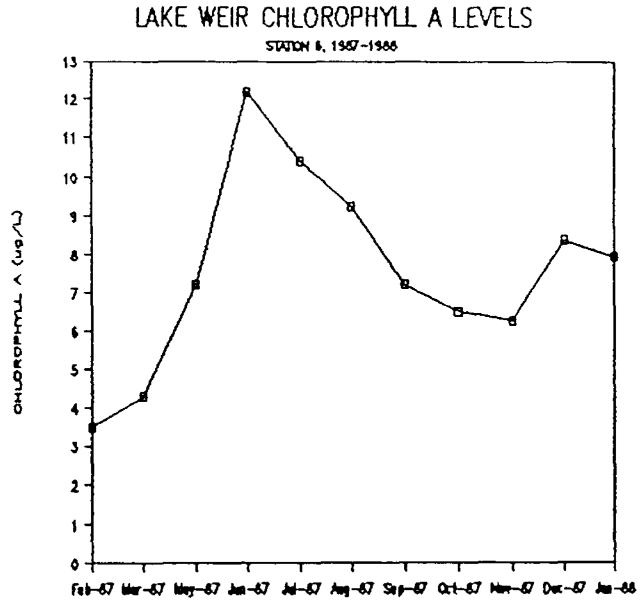


Figure 4-9. Seasonal levels of Chlorophyll a in Lake Weir, Florida, February 1987-January 1988.





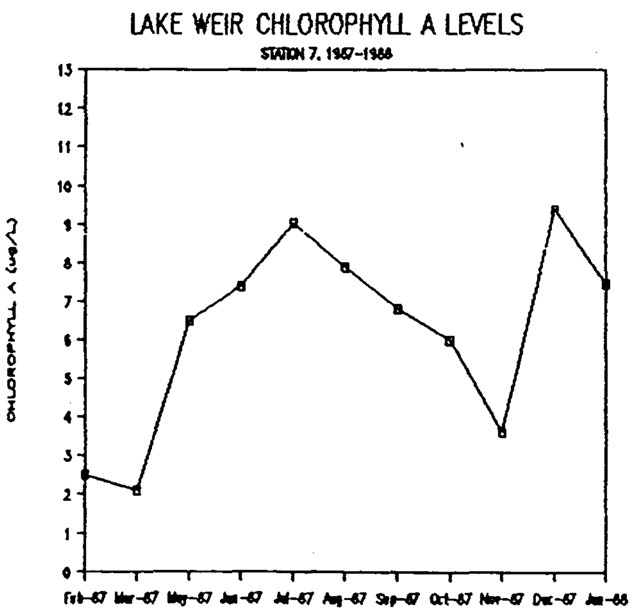


Figure 4-9. Continued.

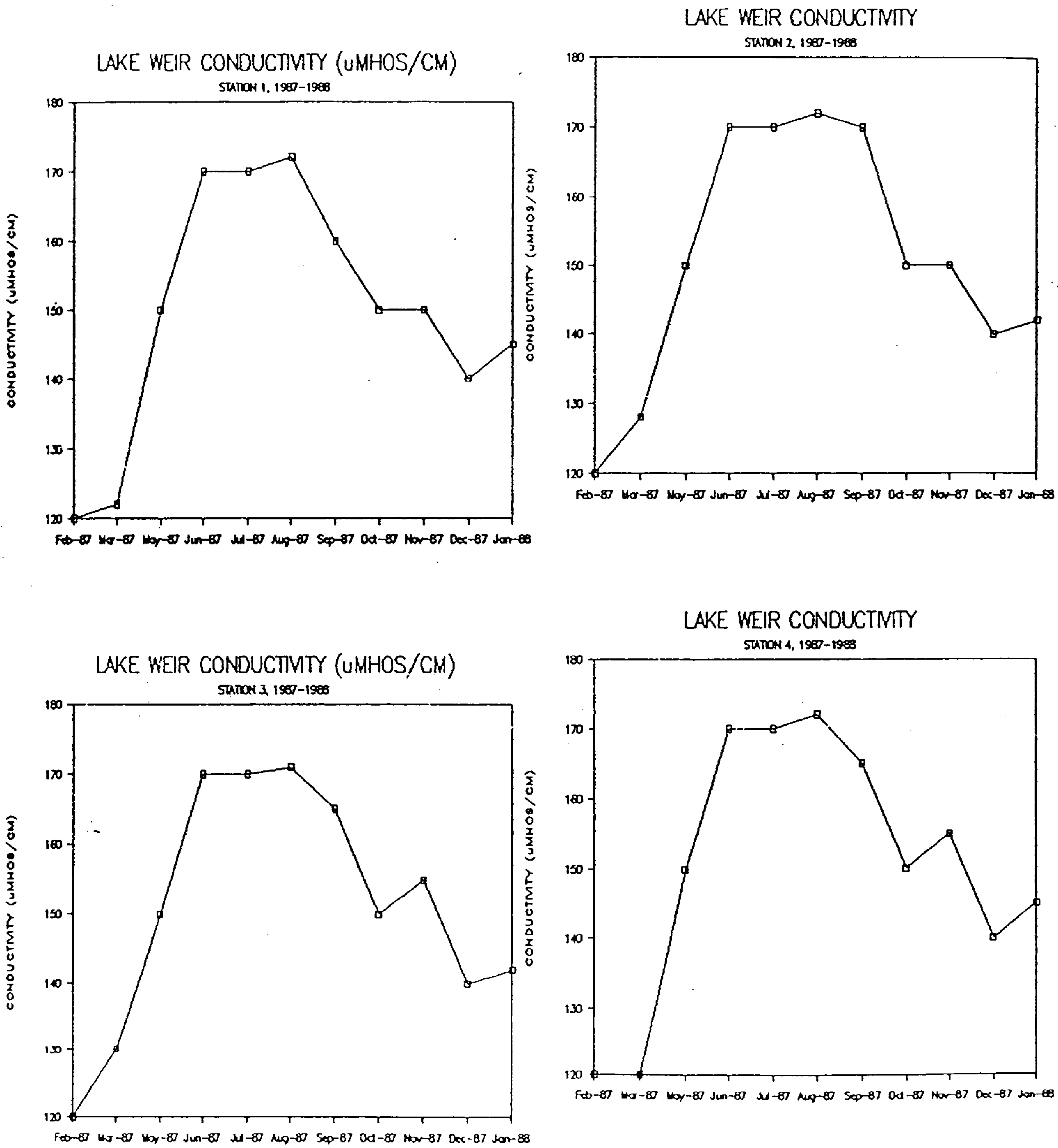
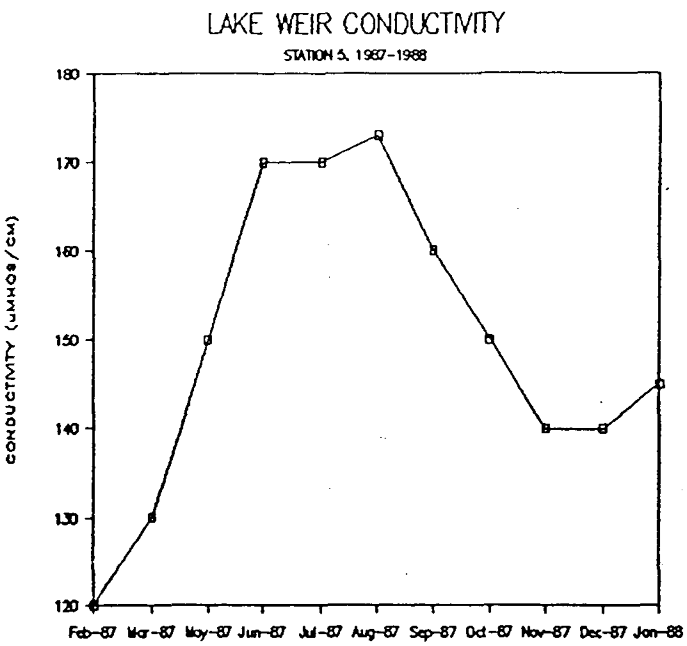
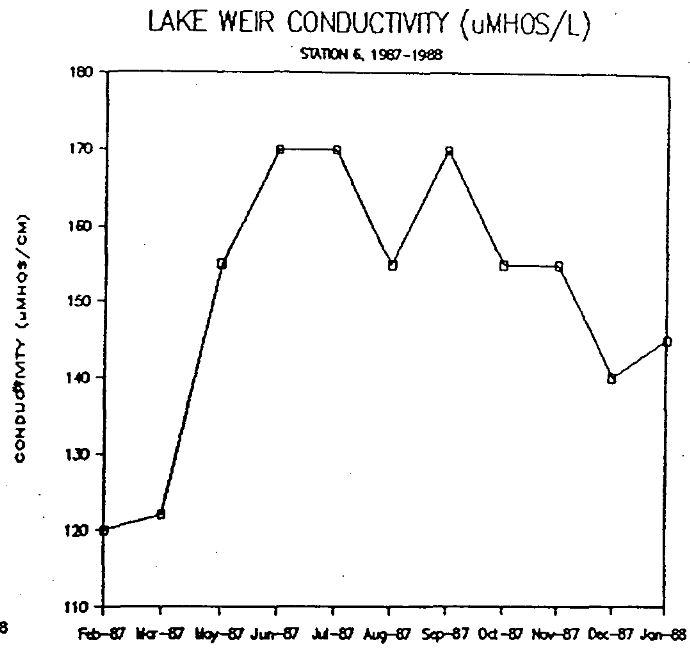


Figure 4-10 Seasonal fluctuations in specific conductivity (umhos/cm) at the seven sampling stations in Lake Weir, Florida, 1987-1988.





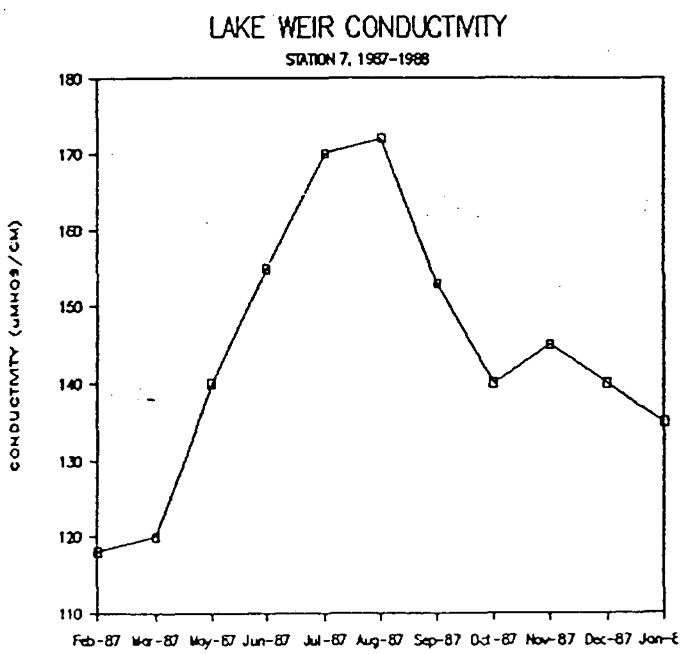


Figure 4-10 Continued.

as the mid-lake stations, with highest conductivity levels measured from May through September. ANOVA and Duncan's multiple range test supported these observations.

Total alkalinity was lowest in May at stations 1-6 (Figure 4-11) increasing from a low of 13-14 mg/L $CaCO_3$ to a high in January of 17.5-18.0 mg/L $CaCO_3$. The total alkalinity of Little Lake Weir (station 7) was significantly lower than that of the other basins, with a low of 3.5 mg/L in May and a high of 7.0 in January. There were no significant differences in total alkalinity when compared on a monthly basis (Tables 4-2, 4-3).

The pH varied from a low of 5.74 in Little Lake Weir (Station 7) during May, to a high of 7.59 at Station 3 in June. Overall, pH was highest between June and October at all seven stations, with Station 7 being significantly lower than the other six (Table 4-4).

Annual means for water chemistry parameters were analyzed by ANOVA and Duncan's multiple range test to determine whether there were station or monthly differences. Total phosphorus (TP), orthophosphate (OP), total Kjeldahl nitrogen (TKN), nitrate (NIT), chlorophyll a (Chla), conductivity (Cond.) and total alkalinity (Totalk) by station (Tables 4-2, 4-3) were included. Nitrate measurements for 75% of the samples were below detection limits (BDL). Orthophosphate levels were also too low to detect for 75-80% of the samples.

Inter-station comparisons showed that only Station 7 (Little Lake Weir) was significantly different from the others, as the mid-lake stations, with highest conductivity levels measured from May through September. ANOVA and Duncan's multiple range test supported these observations.

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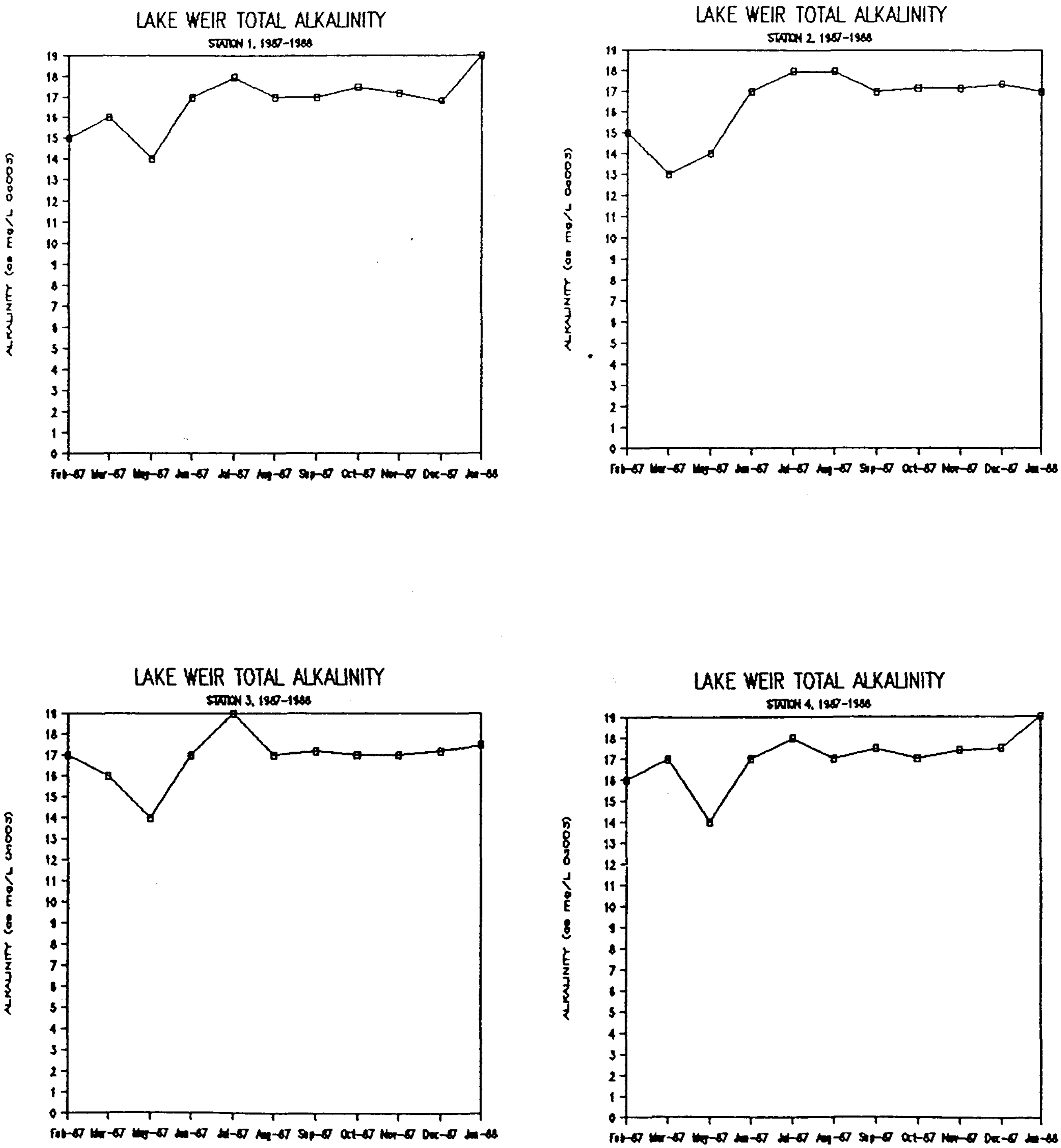
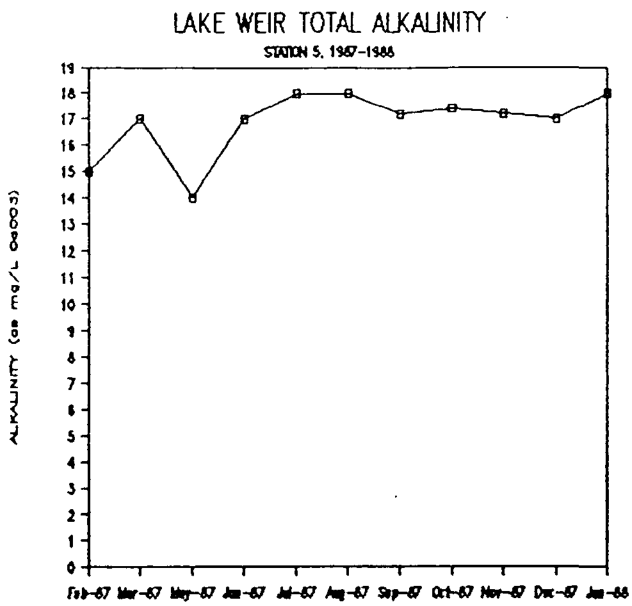
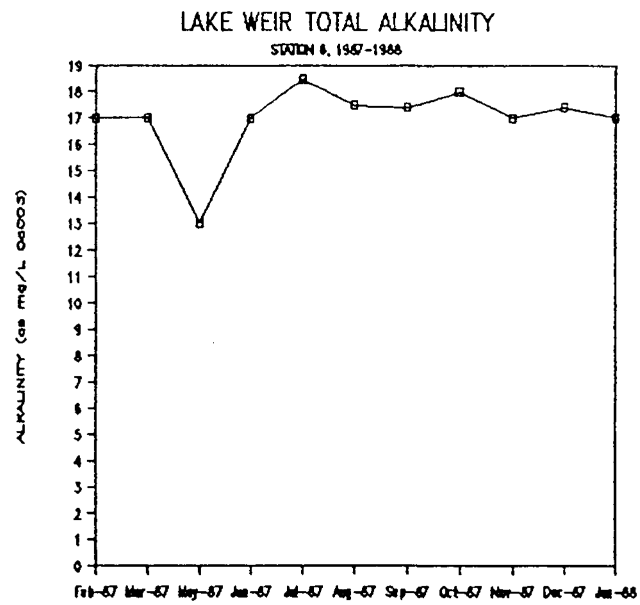


Figure 4-11 Seasonal levels of Total Alkalinity in Lake Weir, Florida, February 1987-January 1988.





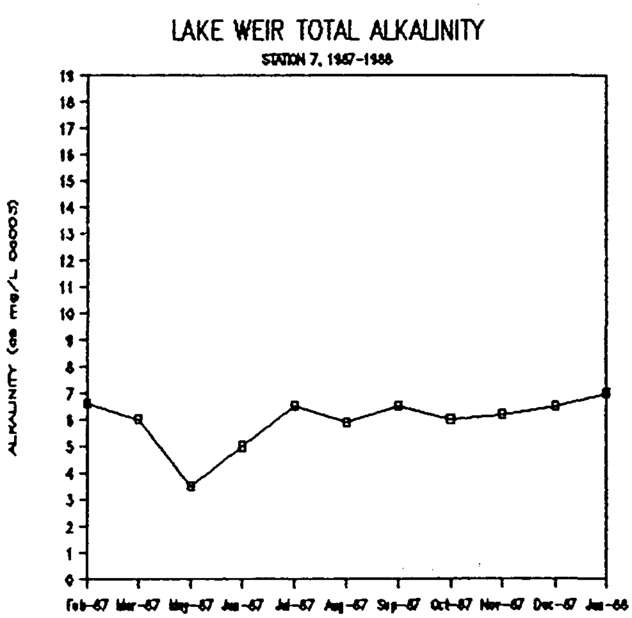


Figure 4-11 Continued.

Table 4-4. Results of Duncan's multiple range test for significant differences between water chemistry data at the seven sampling stations in Lake Weir, FL. (Stations that are connected by the same underline are not significantly different).

Total Alkalinity

Station

```
4    6    3    5    1    2      7
__________________________     _
```

pH

Station

```
5    1    4    3    6    2      7
__________________________     _
```

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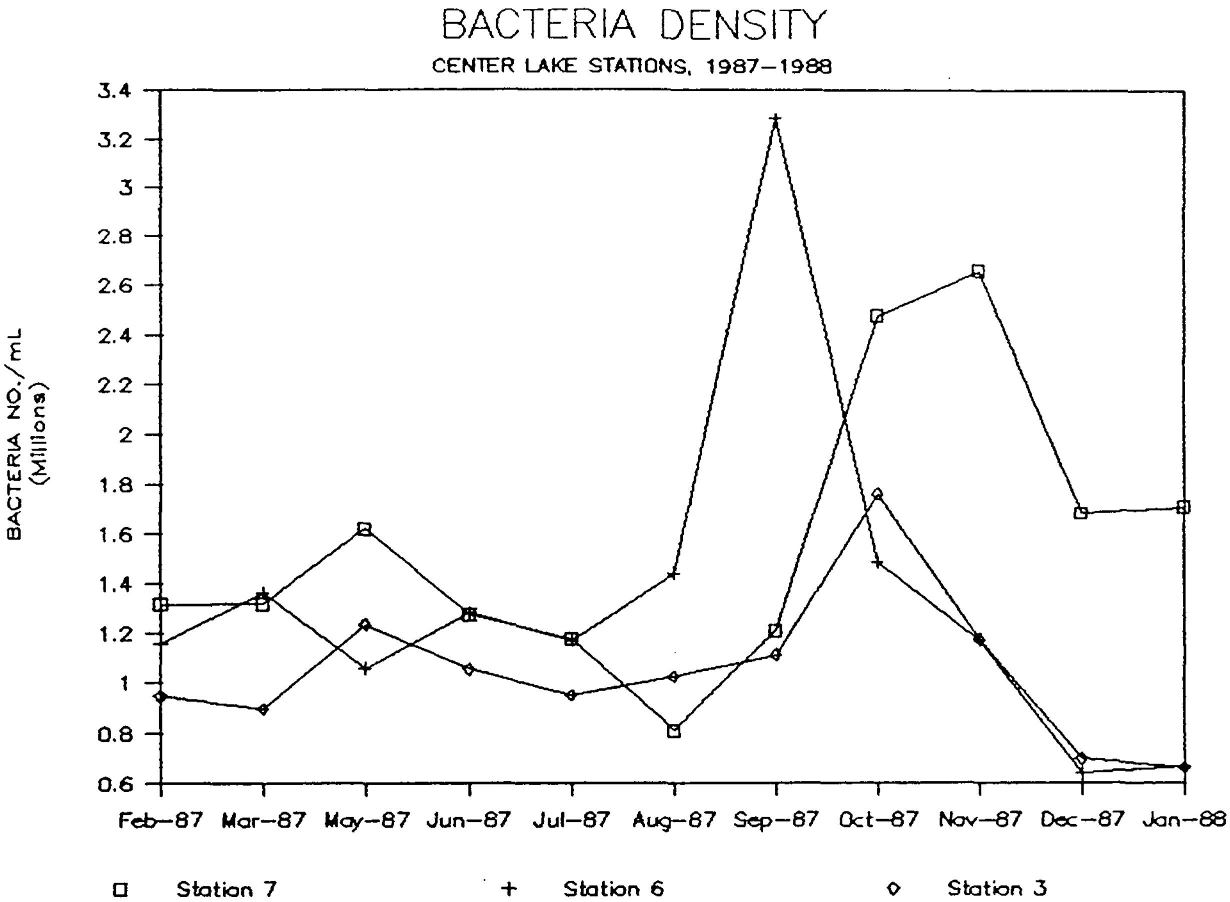
and only for total alkalinity and pH (Table 4-4). Values for TP, TKN, Chla and Totalk were similar to data reported for 1986-1987 by the St. Johns River Water Management District.

Bacteria

Water column bacterial densities (Figure 4-12; Tables 4-5, 4-6) were generally highest in spring and fall (1.19-1.50 X 10^6/mL) with the lowest values in summer and winter (0.83-1.09 X 10^6/mL). Results of ANOVA and Duncan's procedure indicated that bacterial densities at stations 1-5 in Lake Weir were not significantly different from each other, but were significantly lower than both the Sunset Harbor (6) and Little Lake Weir (7) stations (Table 4-7). This may be the result of increased nutrient availability in the smaller basins due to greater human activities along their immediate shorelines. An analysis of the impact of season on mean bacteria density lakewide did not show any clear trends (Table 4-7). However, on a station-by-station basis, there was a relationship between lake temperature and bacterial densities (Figure 4-13). With increasing water temperature, bacteria levels increased until water reached about 24-25 C. Above that temperature, bacterial density decreased until late summer or fall when the water temperature dropped again to 24-25 C. A similar pattern was observed in other Florida lakes (Crisman et al. 1984). Whether this decline in bacterial density at temperatures above 25 C is a direct result of water temperature, increased microzooplankton grazing or some other factor is unknown.



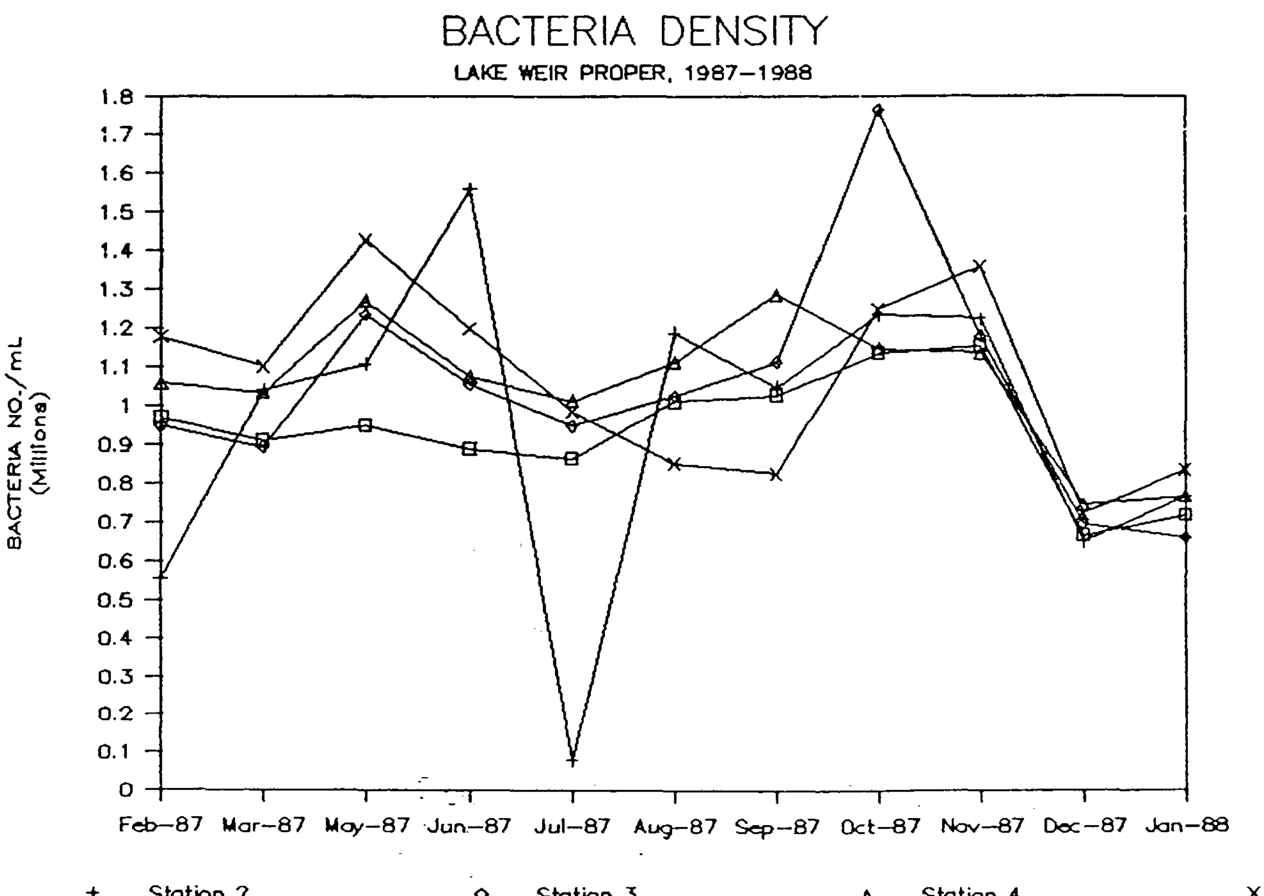


Figure 4-12 Monthly water column bacteria densities (no.cells/ml x 10^6) at the seven sampling stations in Lake Weir, Florida, 1987-1988.

Table 4-5. Mean (S.D.) bacterial density (No./mL) by station in Lake Weir, FL 1987-1988.

Station	N	Mean $\times 10^6$	S.D.
1	27	0.94	0.20
2	27	1.06	0.30
3	27	1.05	0.33
4	27	1.05	0.25
5	27	1.05	0.33
6	27	1.36	0.89
7	27	1.64	0.58

Table 4-6. Lakewide mean (s.d.) bacterial density (No./mL) by month in Lake Weir, FL 1987-1988.

Month	N	Mean $\times 10^6$	TEMP C
February	14	1.03(0.26)	19.0
March	14	1.09(0.26)	25.5
May	14	1.24(0.25)	25.0
June	14	1.19(0.24)	27.0
July	14	0.99(0.16)	29.5
August	14	1.05(0.28)	29.5
September	21	1.40(0.95)	27.6
October	21	1.50(0.54)	20.0
November	21	1.41(0.55)	21.3
December	21	0.83(0.37)	17.9
January	21	0.87(0.37)	14.5

Table 4-7. Results of inter-station and inter-month comparisons of bacterial density (No./mL) in Lake Weir, FL by ANOVA and Duncan's procedure. Numbers connected by the same line are not significantly different.

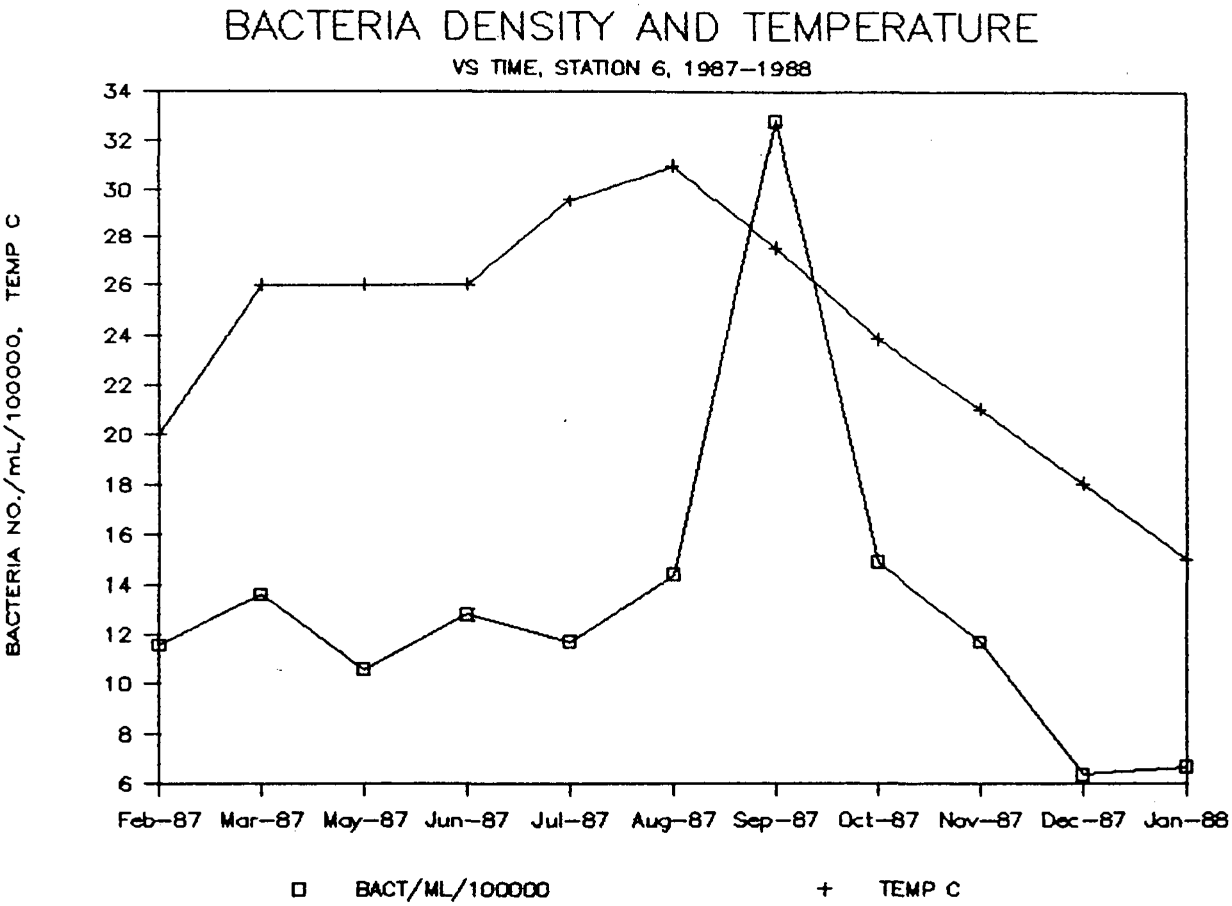
Parameter	N	F	Significance
Station	189	7.64	0.01
Month	27	11.54	0.01

Station ranking (X marks numbers connected by the same line):

Station	7	6	5	3	4	2	1
			X	X	X	X	X

Month ranking (X marks numbers connected by the same line):

Month	10	9	11	5	6	3	8	2	7	1	12
	X	X	X								
		X	X	X							
				X	X	X	X	X			
					X	X	X	X	X		
						X	X	X	X	X	
									X	X	X



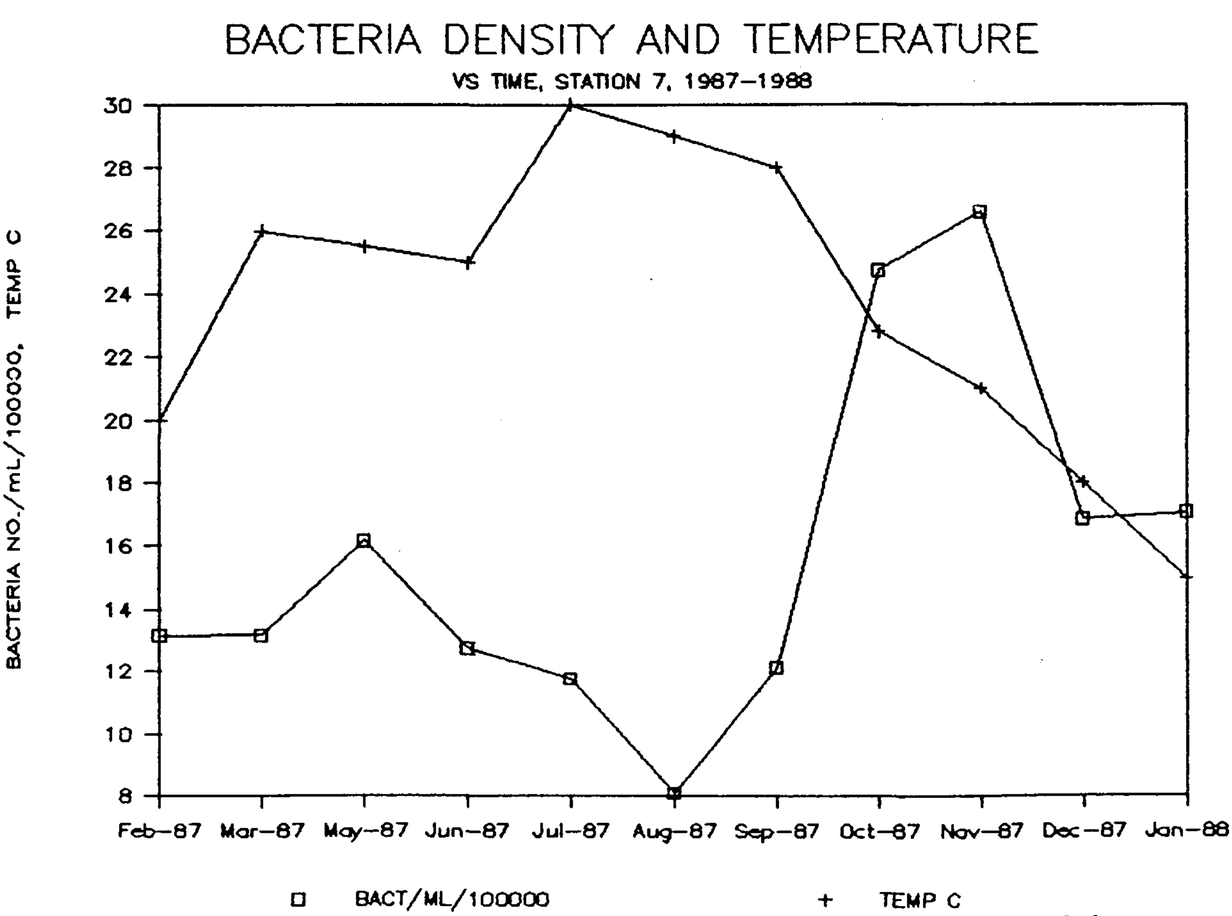


Figure 4-13 Bacteria density vs. water temperature at the center lake stations in Lake Weir, Florida, 1987-1988.

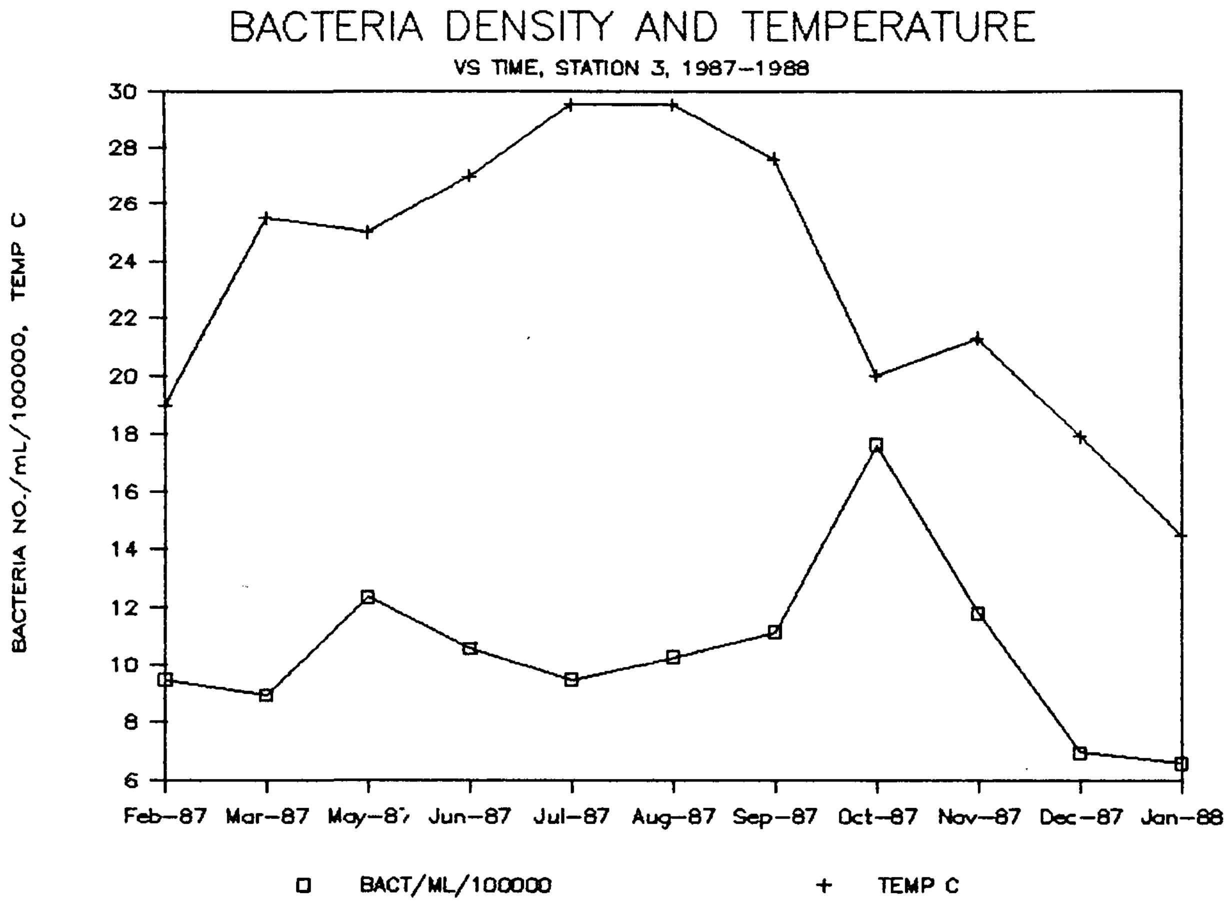


Figure 4-13 Continued.

Fathometric Determination of Submergent Plant Biomass

Biovolume, the percent of submersed plant infestation of the water column, was low in all three lake basins (Figure 4-3). Macrophytes occupied 8% of the water column in Lake Weir, 14% in Sunset Harbor and 15.5% in Little Lake Weir. Plants were essentially absent below 3.5 m (Table 4-8). Only 16% of Lake Weir was shallower than 3.5 m, while 51% of Sunset Harbor and 56% of Little Lake Weir were that shallow. These data suggest that basin morphometry is limiting the extent of the littoral zone in the big lake, and that algal shading is likely to prevent the movement of macrophytes into deeper water in Sunset Harbor and Little Lake Weir.

In lakes with a high biovolume (percent vertical plant infestation), trophic state indices based on water column nutrient or chlorophyll _a_ concentrations may be inaccurate because they do not account for nutrient levels in plant tissue (Canfield _et al_. 1984). Since percent vertical plant infestation is low in all three basins, water column chlorophyll _a_ concentrations can be used as accurate indicators of trophic state.

The distributions of individual submersed macrophyte species were not mapped but appeared to be generally the same as in recent FGFWFC surveys. There was a relatively dense growth of _Websteria_ near the east side of Bird Island, and _Potamogeton_ and _Chara_ were noted along much of the shoreline in Sunset Harbor. _Potamogeton_ and _Bacopa_ were prevalent on the shallower north and south shores of Lake Weir.

Table 4-8. Summary of morphometric characteristics, mean annual water quality data and biovolume (percent vertical plant infestation) values for Lake Weir, Sunset Harbor and Little Lake Weir, FL.

Parameter	Lake Weir	Sunset Harbor	Little Lake Weir
Secchi depth (m)	1.54	1.59	1.56
TP[a] (ug/L)	51.0	45.5	45.5
TKN[b] (ug/L)	760	722	838
Chlorophyll *a* (ug/L)	6.9	7.55	6.23
Surface area (hectares)	2,086	350	151
Maximum depth (m)	8.4	6.7	5.5
Mean depth (m)	4.27	2.13	1.95
Lake volume ($m^3 \times 10^6$)	89	7.45	2.95
Biovolume (%)	8	14	15.4

In contrast to the two larger basins, Little Lake Weir contained not only Potamogeton and Bacopa, but was infested with Utricularia from the shoreline to 3.5 m depth. Whether the presence of the latter species in Little Lake Weir reflects a nitrogen imbalance in the lake or just that the species is able to survive in the more sheltered environment of Little Lake Weir is not clear. However, there was no significant difference in nitrogen or phosphorus levels among the three lakes (Table 4-1).

Zooplankton

Numerous investigations of temperate and subtropical lakes have documented changes in zooplankton community structure associated with increasing eutrophication. Typically, total zooplankton biomass increases with lake productivity and is accompanied by species replacements within the Cladocera and Copepoda (O'Brien & de Noyelles 1974, Hall et al. 1970). The importance of macrozooplankton decreases and the community shifts to dominance by microzooplankton, especially rotifers and ciliated protozoa (Gannon & Stemberger 1978, Bays & Crisman 1983). Within the macrozooplankton, calanoid copepods decrease in proportional abundance (McNaught 1975, Gliwicz 1969) while small-bodied cladocerans and cyclopoid copepods dominate the zooplankton communities of eutrophic lakes (Brooks 1969).

Compositional shifts in zooplankton community structure associated with eutrophication are believed to be controlled by increasing predation pressure (Brooks 1969). Since planktivorous fish abundance increases with lake productivity (Larkin & Northcote 1969), large-bodied zooplankton are often eliminated due to their higher susceptibility to vertebrate predation.

Invertebrate predators such as Chaoborus and cyclopoid copepods also increase with eutrophication and may alter zooplankton community size structure through selective predation (Zaret 1980).

In addition to the observed shifts in zooplankton community structure associated with eutrophication, ciliated protozoan populations have been shown to be altered by lake productivity changes. Oligotrophic lakes are usually dominated by large-bodied oligotrichs which graze both bacteria and nannoplankton but are replaced by small-bodied scuticociliates which are specialized on bacteria (Beaver & Crisman 1982, Beaver & Crisman 1988a).

This aspect of this report examines the zooplankton and protozooplankton community of Lake Weir, and contrasts the present community with historical measures of these communities. In addition, the zooplankton population of Lake Weir will be compared with other mesotrophic Florida lakes as well as other Florida lakes of different trophic states.

A. Annual Mean Biomass Values of Zooplankton Components

The average biomass of zooplankton components are given in Table 4-9. Total biomass ranged from 126 ug d.w. 1^{-1} at Station 2 to 156.7 ug d.w. 1^{-1} at Station 4. ANOVA indicated no significant differences between stations and the lake average for total zooplankton biomass was 145.0 ug 1^{-1}.

Table 4-9. Annual mean biomass values ($\mu g\ l^{-1}$) of zooplankton components in Lake Weir.

COMPONENT	STATION 1	2	3	4	5	6	7	Lake mean	% Composition
Total zooplankton	138.2	126.9	147.6	156.7	146.3	144.7	154.8	145.0	----
Macrozooplankton	27.3	25.4	24.5	39.1	42.7	36.9	43.2	34.2	23.6
Microzooplankton	110.9	101.5	123.1	117.6	103.6	107.8	111.5	110.8	76.4
Cladocera	6.1	3.2	1.9	10.2	8.7	6.1	1.7	5.4	3.7
Calanoida	15.2	16.8	13.0	18.8	22.9	17.8	19.2	17.7	12.2
Cyclopoda	6.0	5.5	9.6	10.1	11.2	12.9	22.4 *	11.1	7.7
Nauplii	10.3	8.5	9.2	9.8	11.3	9.5	11.0	9.9	6.8
Rotifera	38.6	42.0	47.2	52.0	39.8	46.6	37.0	43.3	29.9
Ciliata	62.1	50.9	66.7	55.8	52.5	51.7	63.4	57.6	39.7
Oligotrichida	21.0	18.7	24.8	18.5	20.0	18.5	34.1 *	22.2	15.3
Scuticociliatida	13.6	12.7	15.7	14.1	11.5	8.9	9.5	12.3	8.5
Haptorida	5.0	5.1	6.0	4.9	5.4	3.7	8.1	5.5	3.8

* significantly different (ANOVA, $p < 0.05$) from other stations

Macrozooplankton (adult copepods, copepodites, cladocerans) biomass ranged from 24.5 ug d.w. l^{-1} at Station 3 to 43.2 ug d.w. l^{-1} at Station 7. In general, macrozooplankton biomass decreased in Lake weir from south to north but no significant differences were noted between stations.

Microzooplankton (nauplii, rotifers, ciliates) biomass displayed very little variation between stations (range 101.9 - 123.1, $\bar{x}$ = 110.8 ug d.w. l^{-1}), with the highest biomass found at the midlake station. The contribution of microzooplankton biomass to total zooplankton biomass averaged 76.4% for the lake.

Cladocerans were relatively rare in Lake Weir and had the smallest mean biomass of any zooplankton component. No intra-lake distribution patterns were evident although cladoceran biomass was exceptionally low at Stations 3 and 7.

Likewise, calanoid copepods did not display much variation by station (range 13.0 - 22.9, $\bar{x}$ = 17.7 ug d.w. l^{-1}). They were, however, the dominant crustacean group comprising 12.2% of the total zooplankton biomass. The only calanoid copepod found in Lake Weir was _Diaptomus dorsalis_.

Cyclopoid copepods tended to be the least abundant at the north end of the lake and most abundant at the south end of the lake. Station 7 displayed significantly higher cyclopoid biomass (22.4 ug d.w. l^{-1}) when compared to the remaining stations. The dominant cyclopoid found in Lake Weir was _Tropocyclops prasinus_, a relatively small-bodied copepod.

Copepod nauplii were frequently abundant but because of their small size contributed only negligibly to total zooplankton biomass (6.8%). No distribution patterns were evident for this component.

Rotifers were a co-dominant with ciliated protozoa in the Lake Weir zooplankton community. They comprised 29.9% of the total zooplankton biomass. Average values ranged from 37.0 ug d.w. l^{-1} at Station 7 to 52.0 ug d.w. l^{-1} at Station 4. The lake wide average was 43.3 ug d.w. l^{-1} and no significant differences were noted between stations.

Total ciliate biomass varied little between stations. This taxonomic group was the major contributor to biomass in the lake with a mean value of 57.6 ug d.w. l^{-1}. The three dominant orders of ciliates - Oligotrichida, Scuticociliatida, and Haptorida - generally differed little between stations. One exception to this trend was oligotrich biomass at Station 7 which was significantly higher when contrasted with other stations.

B. Comparison of the Present Lake Weir Zooplankton Assemblage with Historical Data

Fortunately, the zooplankton analysis made for this report can be directly compared with the community in 1979. Bays (1983) and Beaver (1980) monitored Station 3 monthly in Lake Weir during that calendar year, and the methodology they employed was almost identical to that used in the present study.

The annual mean biomass values for major zooplankton components at Station 3 in 1979 and 1987 are presented in Table 4-10. Total zooplankton biomass was only slightly higher in

Table 4-10. Historical comparison of the mean annual biomass of various components of the Lake Weir zooplankton community at Station 3. Data for 1979 taken from Bays (1983) and Beaver (1980). Biomass values in ug/L (±SE).

COMPONENT	1979	1987	% CHANGE
Total zooplankton	135.9 ± 15.9	147.6 ± 23.2	+ 8.6
Macrozooplankton	33.8 ± 5.9	24.5 ± 7.6	- 27.5
Microzooplankton	102.1 ± 14.0	123.1 ± 18.2	+ 20.6
Cladocera	** 6.8 ± 2.4	** 1.9 ± 0.8	- 72.1
Calanoida	6.5 ± 1.7	13.0 ± 5.0	+100.0
Cyclopoda	** 20.5 ± 5.3	** 9.6 ± 3.5	- 53.2
Nauplii	* 24.8 ± 4.5	* 9.2 ± 1.3	- 62.9
Rotifera	** 23.2 ± 6.3	** 47.2 ± 13.3	+103.4
Ciliata Biomass	54.0 ± 8.1	66.7 ± 25.9	+ 23.5
Ciliata Abundance	25.3 ± 4.5	36.5 ± 4.7	+ 44.3
Oligotrichida	23.0 ± 5.6	24.8 ± 3.9	+ 7.8
Scuticociliatida	* 7.3 ± 1.7	* 15.7 ± 2.6	+115.1
Haptorida	10.8 ± 3.6	6.0 ± 1.6	- 44.4

* significantly different (t-test, $p < 0.05$)
** significantly different (t-test, $p < 0.10$)

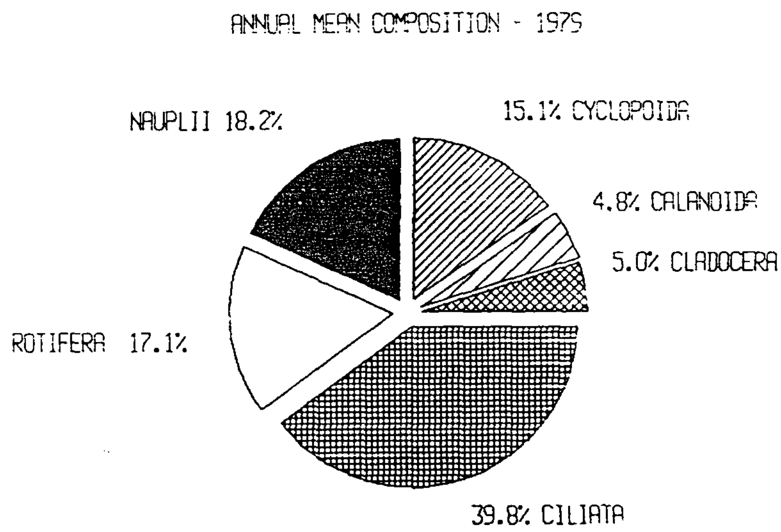
1987 than in 1979. Macrozooplankton biomass, however, was 27.5% lower in the present study and microzooplankton 20.6% higher. Cladoceran biomass was reduced by 72.1%, but since April values are missing and this season is traditionally high in Cladocera, this conclusion should be considered provisional. Calanoid biomass increased 100% between the two years while cyclopoids and nauplii were down 53.2% and 62.9%, respectively.

Rotifer biomass was 103.4% higher in 1987 while ciliate biomass increased a modest 23.5%. Within the Ciliata, oligotrichs increased 7.8% and the scuticociliates were up 115.1%. Haptorid ciliates were down 44.4%.

Expressing these changes on a percentage basis reveals that microzooplankton (nauplii, rotifers, ciliates) constituted 75.1% of the zooplankton community in 1979 and 83.4% of the population in 1987 (Figure 4-14). The major contributor to this compositional shift in biomass appears to be rotifers which increased from 17.1% to 32.0% of total zooplankton biomass. Although cladocerans and copepods appear to be less important in 1987, it is important to note that the missing April sample probably substantially underestimates their significance. Nauplii were considerably reduced in their contribution to total zooplankton biomass in 1987 compared to 1979.

C. Comparison of Zooplankton Community Structure in Lake Weir with Comparable Mesotrophic Florida Systems

Seven mesotrophic lakes were selected for a detailed comparison of Lake Weir with Florida lakes of similar trophy. These lakes were chosen because of their complete data bases of



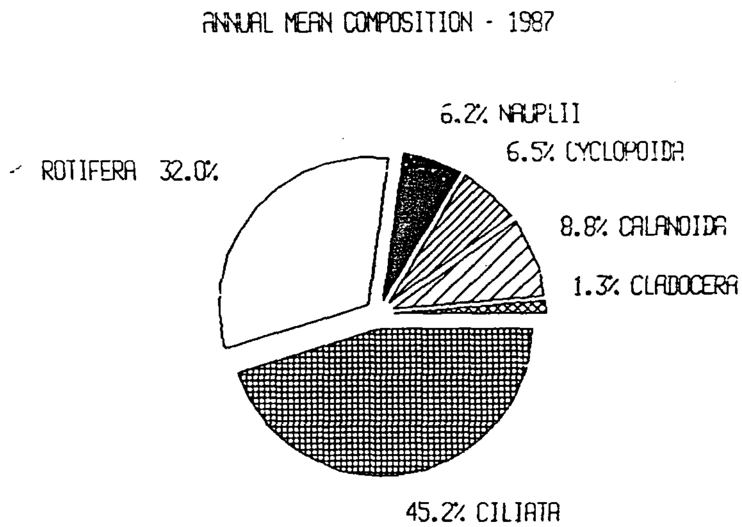


Figure 4-14. Partitioning of the Zooplankton biomass in Lake Weir in 1979 and 1987.

all zooplankton components, as well as their similarity in sampling and analytical regimes to the present study (Bays 1983, Beaver 1980).

Comparison of the values calculated for other mesotrophic systems in Table 4-11 with Lake Weir values from Table 4-9 indicates that in general Lake Weir possesses a relatively depauperate zooplankton assemblage. The alke averages for the major zooplankton components in Lake Weir were lower than means calculated for the other mesotrophic lakes in 11 of the 13 comparisons. Lake Weir did have substantially more scuticociliate biomass than most mesotrophic Florida systems and slightly above average rotifer compliment.

The relative absence of cladocerans, calanoid copepods, and nauplii greatly contribute to the reduced total zooplankton biomass. Expressed on a percentage composition basis, rotifers are proportionally more important to the Lake Weir zooplankton community than most mesotrophic Florida lakes.

Of the seven lakes used for comparison, Lake Weir most closely resembles Lake Placid in several respects. This Highlands County lake had similar nutrient concentrations, color, pH, and was morphometrically like Lake Weir - relatively large and deep for a Florida lake. The zooplankton populations of both systems appear to be impoverished compared to other mesotrophic lakes.

D. <u>Estimates of Zooplankton Biomass from Equations Derived for Florida Lakes</u>

Beaver & Crisman (1988a) and Bays & Crisman (1983) have derived predictive equations for estimating ciliate, rotifer,

Table4-11 Annual biomass distribution of major zooplankton components in 7 mesotrophic Florida lakes. Data calculated from Bays (1983) and Beaver (1980). Location of lakes given in Beaver & Crisman (1982).

	LAKE							
COMPONENT	A	B	C	D	E	F	G	MEAN
Total zooplankton	505.7	308.7	184.0	212.5	279.8	248.6	98.0	262.5
Macrozooplankton	269.6	157.7	64.8	89.9	62.6	23.7	17.8	98.0
Microzooplankton	236.1	151.0	119.2	122.6	217.8	225.0	80.2	164.5
Cladocera	130.6	34.0	18.3	57.3	21.9	7.6	4.5	39.2
Calanoida	74.1	108.1	31.2	17.3	18.9	4.2	65.7	45.6
Cyclopoda	64.9	15.6	15.2	15.2	21.8	11.9	9.5	22.0
Nauplii	77.5	37.5	26.6	21.0	33.0	20.8	9.8	32.3
Rotifera	56.9	45.4	31.7	27.4	56.8	59.4	6.0	40.5
Ciliata	101.7	68.1	60.9	74.2	127.5	144.8	64.4	91.7
Oligotrichida	23.8	14.1	22.4	23.8	56.8	55.7	17.8	30.6
Scuticociliatida	8.9	3.7	2.5	7.8	2.6	4.1	3.4	4.7
Haptorida	4.7	39.3	9.6	23.8	30.3	22.5	13.3	20.5

Lake code:

A = Francis
B = Ocean Pond
C = Placid
D = Sampson
E = Santa Fe
F = East Lake Tohopelagika
G = Washington

crustacean, microzooplankton, macrozooplankton, and total zooplankton biomasses. These equations, which are based on annual mean chlorophyll a concentrations, were developed from a 39 lake data base ranging from softwater oligotrophic to hypereutrophic, and allow an assessment of the response of the major zooplankton components in Lake Weir to trophic conditions relative to other Florida lakes.

The lake means for the various zooplankton components and chlorophyll a concentrations in Lake Weir were used for analysis (Table 4-12). The equation for total zooplankton biomass over-predicted the actual biomass by 51.6%. Similarly, macrozooplankton was overestimated by 170.9% while microzooplankton was much more accurate with only a 18.6% underestimation.

All crustacean components, especially calanoid copepods, are underestimated by the equations although predicted nauplii biomass was very close to the actual value. Rotifer biomass was underpredicted by 151.3%. As a whole, observed ciliate concentrations were reasonably close to those predicted by the equations although total ciliate abundance was underestimated by 52.2% and scuticociliate biomass were overestimated by 52.2% and 86.4%, respectively.

These results are in agreement with the trends previously established in this report - Lake Weir exhibits a low zooplankton biomass for its trophic state primarily due to a greatly reduced macrozooplankton population.

Table 4-12. Comparison of the observed biomass of zooplankton components in Lake Weir with those predicted by equations empirically derived for Florida lakes.

COMPONENT	OBSERVED VALUE	PREDICTED VALUE	EQUATION SOURCE *
Total zooplankton	53.9	81.7	Bays & Crisman (1983)
Macrozooplankton	15.1	40.9	"
Microzooplankton	38.9	31.6	"
Cladocera	2.4	9.1	"
Calanoida	7.8	59.1	"
Cyclopoida	4.9	10.2	"
Nauplii	4.4	5.3	"
Rotifera	19.1	7.6	"
Ciliata Biomass	57.6	65.9	Beaver & Crisman 1988a
Ciliata Abundance	31.8	20.9	"
Oligotrichida	22.2	17.8	"
Scuticociliatida	12.3	6.6	"
Haptorida	5.5	5.8	"

* for Bays & Crisman (1983) equations express biomass in ug C l^{-1}

for Beaver & Crisman (1988a) equations express biomass in ug d.w l^{-1}

E. Ciliate Indicator Taxa

Beaver & Crisman (1988a) have developed a statistical relationship between the annual mean abundance of select ciliate species with lake trophic state. In this scheme, the average abundance of these taxa increased predictably with increasing lake productivity as measured by mean chlorophyll a concentrations. Multilinear regression analysis indicated that 92% of the variation in chlorophyll a densities in Florida lakes could be explained by the mean abundances of *Vorticella microstoma* and *Mesodinium pulex*.

Application of this index to the mean abundance of these species in Lake Weir indicated that this system would be characterized as mesotrophic (Table 4-13). The abundances of *V. microstoma* ranged from 48 cells l^{-1} at Station 7 to 1263 cells l^{-1} at Station 2. The lake wide average was 893 cells l^{-1}. All of the values with the exception of Station 7 were well within the range recommended for mesotrophic lakes.

The results produced for *M. pulex* were similar, with all stations characterized as mesotrophic except Station 7 whose abundances classify as eutrophic. Concentrations for *M. pulex* ranged from 3154 cells l^{-1} at Station 6 to 5999 cells l^{-1} at Station 7 with a lake average of 4191 cells l^{-1}.

F. Seasonality of Major Zooplankton Components Lake Weir in 1987

Total zooplankton biomass in Lake Weir generally peaked in July (Figure 4-15). Values at that time ranged from 235.2 ug d.w. l^{-1} (Station 2) to 347.0 ug d.w. l^{-1} (Station 6). Most stations recorded their highest biomass in July with the

Table 4-13. Trophic conditions associated with the mean annual abundance of select ciliate species in Lake Weir (O = oligotrophic, M = mesotrophic, E = eutrophic).

	STATION						
Ciliate species	1	2	3	4	5	6	7
Vorticella microstoma	M	M	M	M	M	M	O
Mesodinium pulex	M	M	M	M	M	M	E

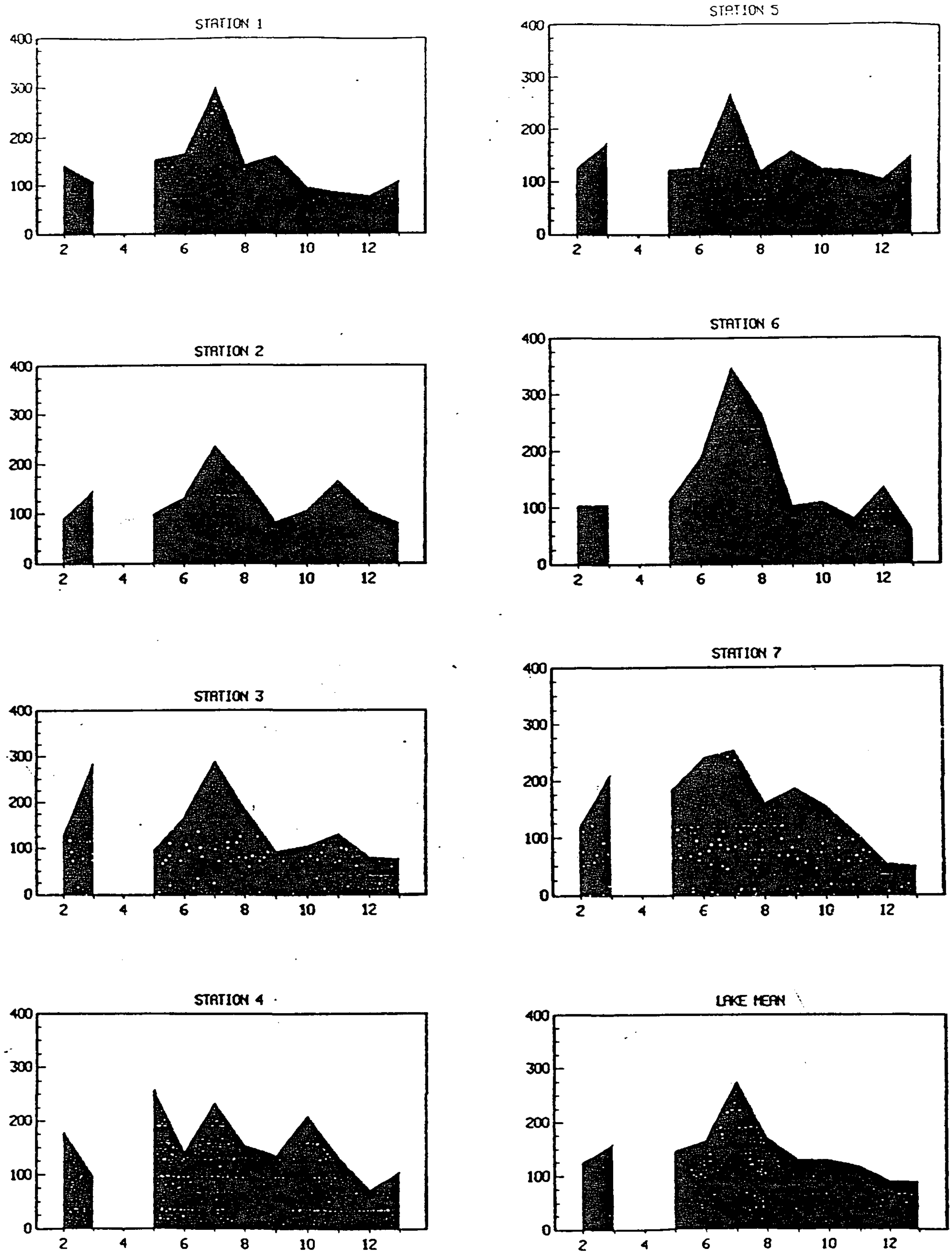


Figure 4-15. Monthly biomass (ug d.w./l) of total zooplankton in Lake Weir in 1987.

exception of the midlake station, which had a biomass peak in March equal to that in July, and Station 4 which had a higher total zooplankton biomass in May.

The temporal distribution of macrozooplankton biomass was extremely variable on a station to station basis (Figure 4-16). Most stations did have peak abundance during spring (March, May) while others recorded pulses during the fall or midsummer. The highest macrozooplankton biomass (115.0 ug d.w. 1^{-1}) was recorded at Station 7 in March.

Microzooplankton biomass showed a clear seasonality when compared to macrozooplankton. Each station consistently recorded biomass peaks during the summer, usually during July (Figure 4-17). Station 3 also had a secondary microzooplankton peak in March. Populations tended to be relatively depressed at other seasons. The highest microzooplankton biomass observed was 273.6 ug d.w. 1^{-1} at Station 1.

Cladocerans were usually the most abundant during the spring months and occasionally displayed secondary peaks during the fall (Figure 4-18). Unfortunately, April samples were not take and, therefore, interpretation of the seasonal trends for this taxonomic group is hampered. The largest cladoceran biomass encountered was 71.9 ug d.w. 1^{-1} at Station 4 in May. The cladoceran community was invariably dominated by Eubosmina tubicen.

Calanoid copepods generally began to increase in spring and maintained high levels until the fall decline (Figure 4-19). The timing of the biomass peaks for this group were quite

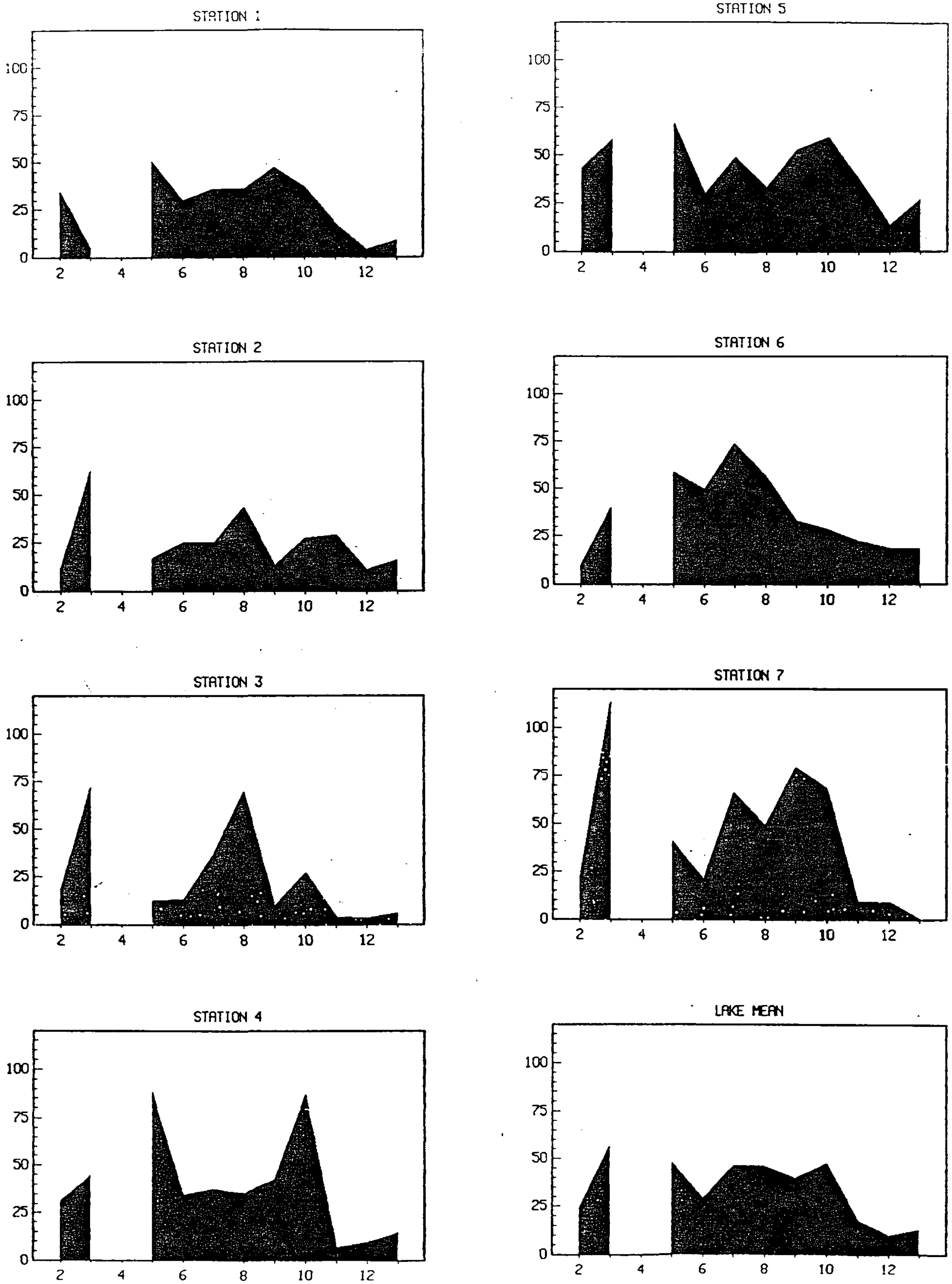


Figure 4-16. Monthly biomass (ug d.w. l^{-1}) of macrozooplankton in Lake Weir in 1987.

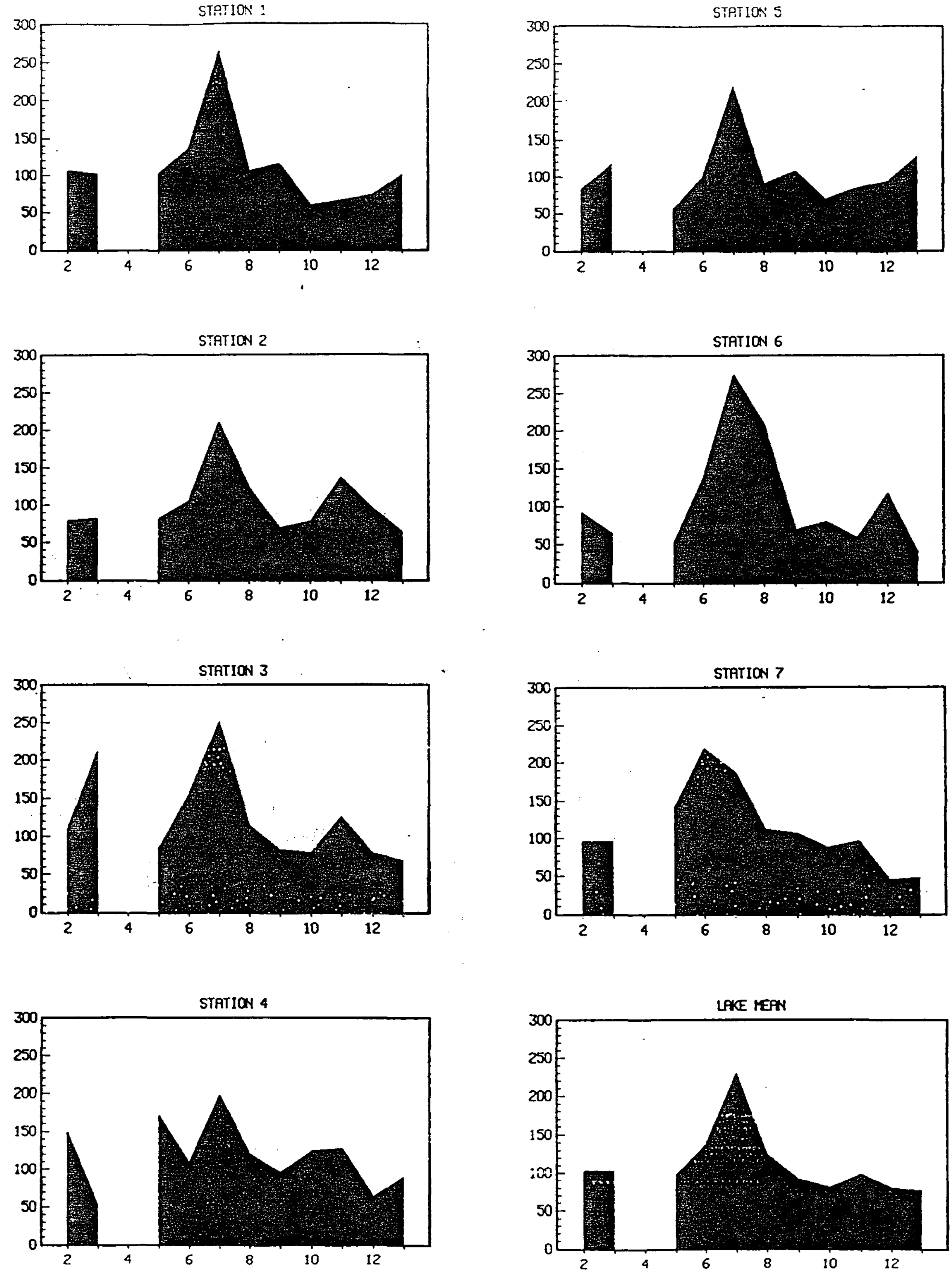


Figure 4-17. Monthly biomass (ug d.w. l^{-1}) of microzooplankton in Lake Weir in 1987.

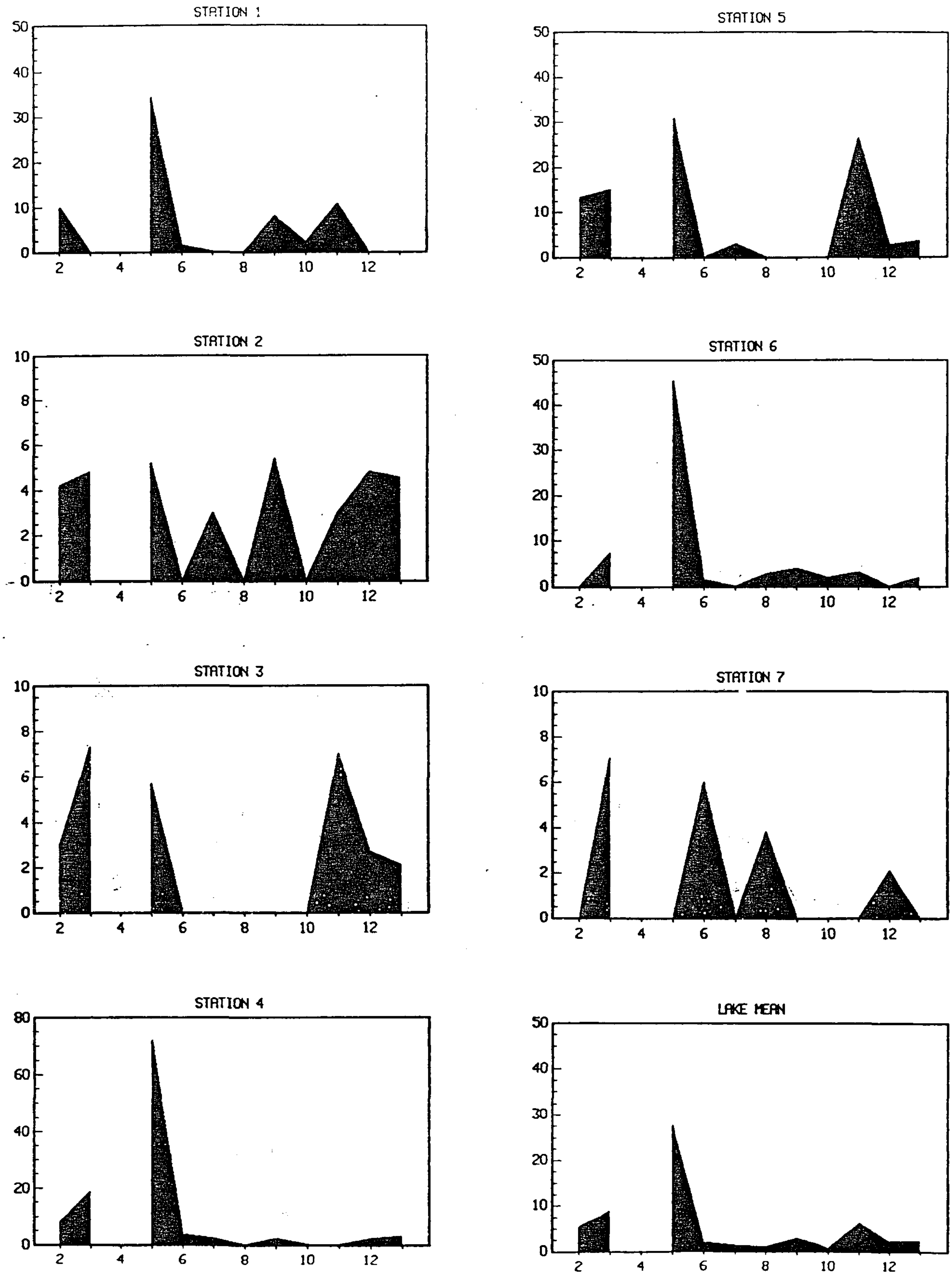


Figure 4-18 Monthly biomass (ug d.w. l^{-1}) of cladocerans in Lake Weir in 1987. Note variable scale.

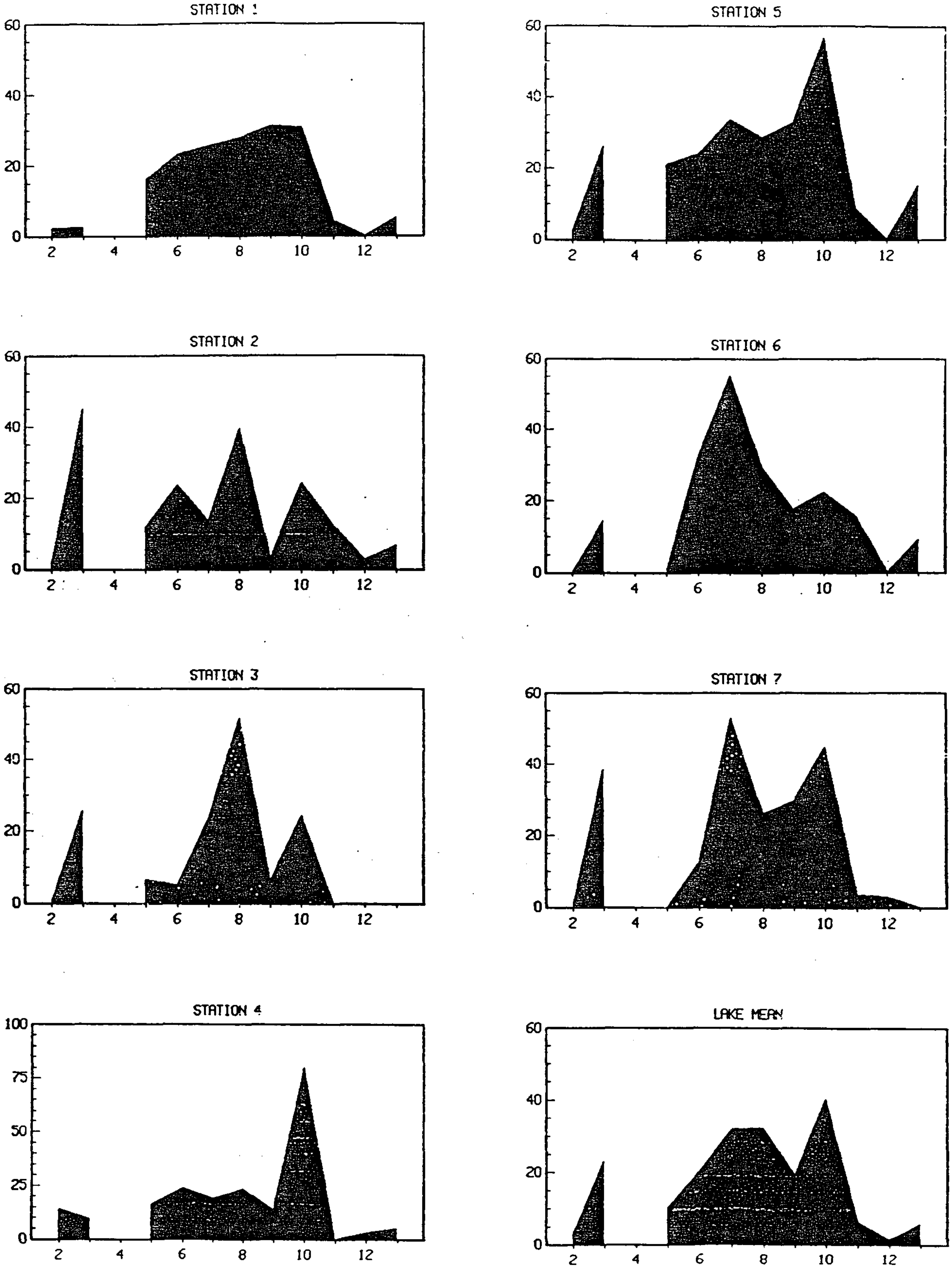


Figure 4-19 Monthly biomass (ug d.w. l^{-1}) of calanoid copepods in Lake Weir in 1987. Note larger scale for station 4.

variable. The highest biomass detected for this group was 80.0 ug d.w. l^{-1} in October at Station 4.

Cyclopoid copepods usually peaked in March and sometime late summer or early fall (Figure 4-20). Since April data is missing interpretation is once again meaningless.

Nauplii populations displayed a consistent seasonality regardless of station (Figure 4-21). Populations increased during spring and then declined during summer. A large November biomass pulse was noted at most stations. The highest biomass attained by nauplii was 38.6 ug d.w. l^{-1} at Station 6 in May.

Rotifer populations displayed a clear seasonality with midsummer pulses occurring at all station (Figure 4-22). These periods of high rotifer biomass were characterized by surges in all rotifer species with their populations dominated by *Hexarthra mira* and *Colletheca libera*. The highest rotifer biomass (141.2 ug d.w. l^{-1}) recorded in Lake Weir, however, was in March at Station 3 and was attributable to a bloom of *H. mira*.

Total ciliate biomass usually tracked rotifers with peaks recorded during July (Figure 4-23). Populations remained depressed at other times of the year. the highest ciliate biomass observed in Lake Weir was 167.5 ug d.w. l^{-1} in July at Station 1. Midsummer ciliate communities were characterized by elevated densities of most species. Myxotrophic ciliates (those with endosymbiotic zoochlorellae) peaked in July and composed an average of 30.0% of total ciliate biomass. Two myxotrophic ciliate species, *Coleps hirtus* and *Strobilidium* cf

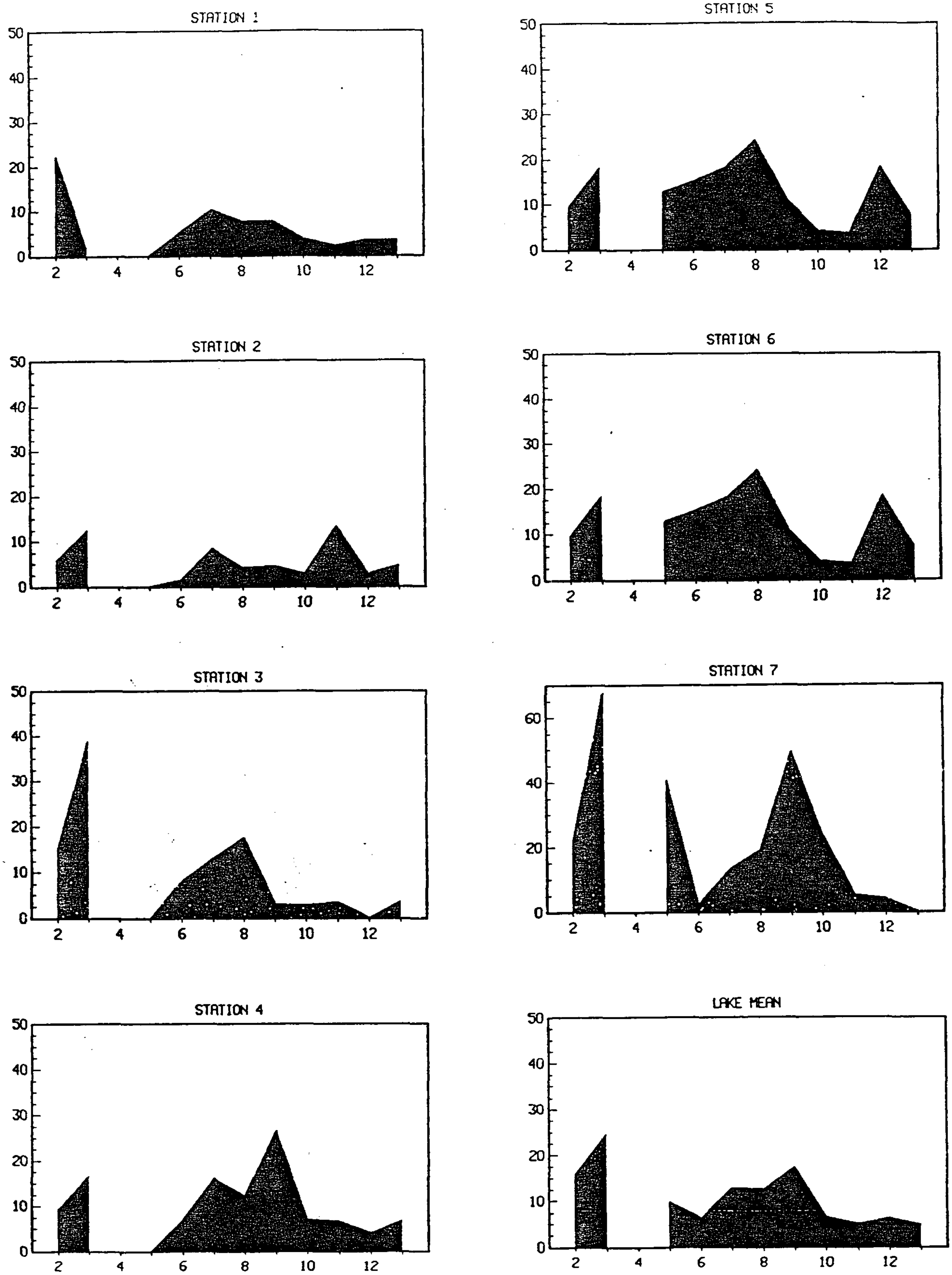


Figure 4-20. Monthly biomass (ug d.w. l^{-1}) of cyclopoid copepods in Lake Weir in 1987. Note larger scale for Station 7.

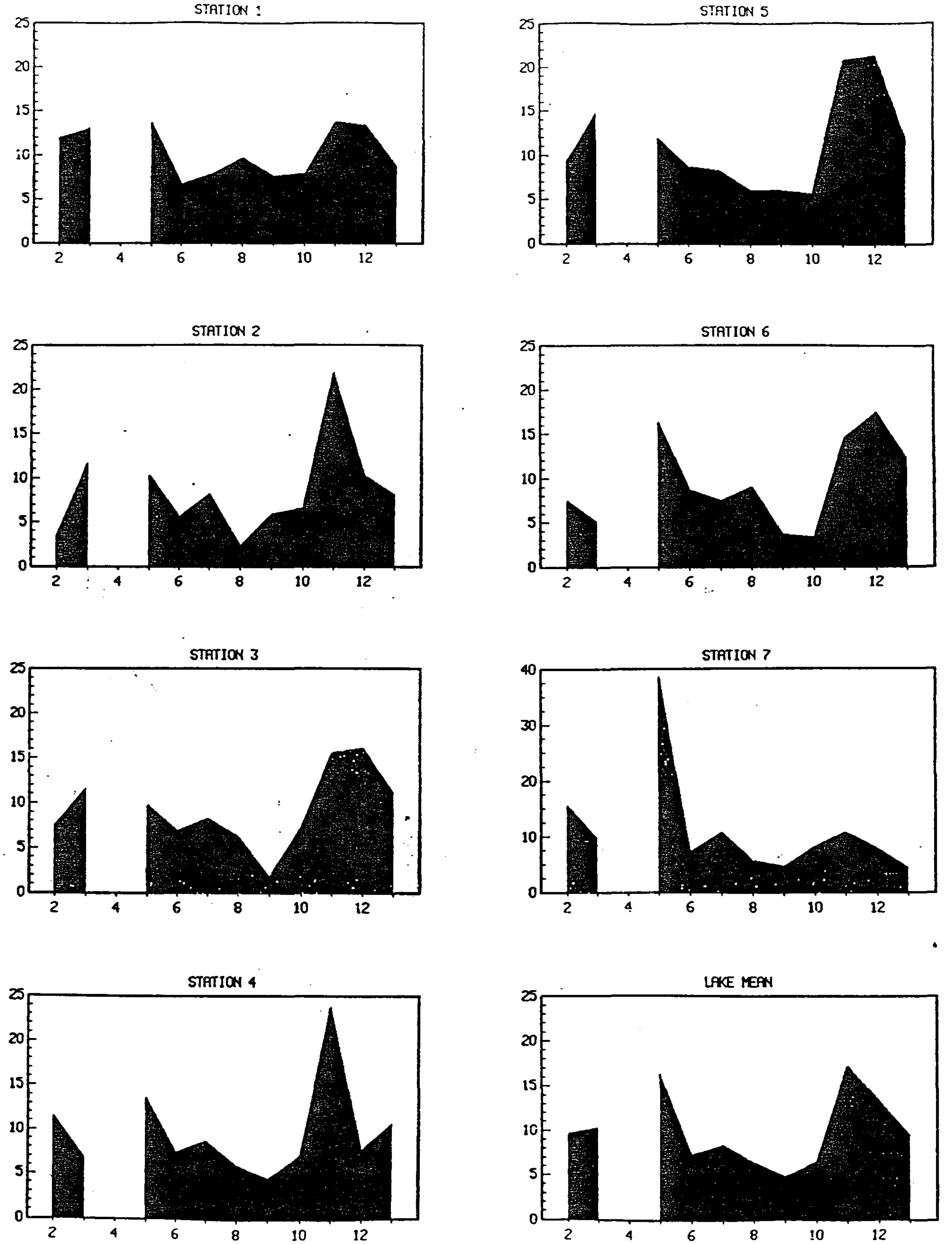


Figure 4-21. Monthly biomass (ug d.w. 1^{-1}) of copepod nauplii in Lake Weir in 1987. Note larger scale for station 7.

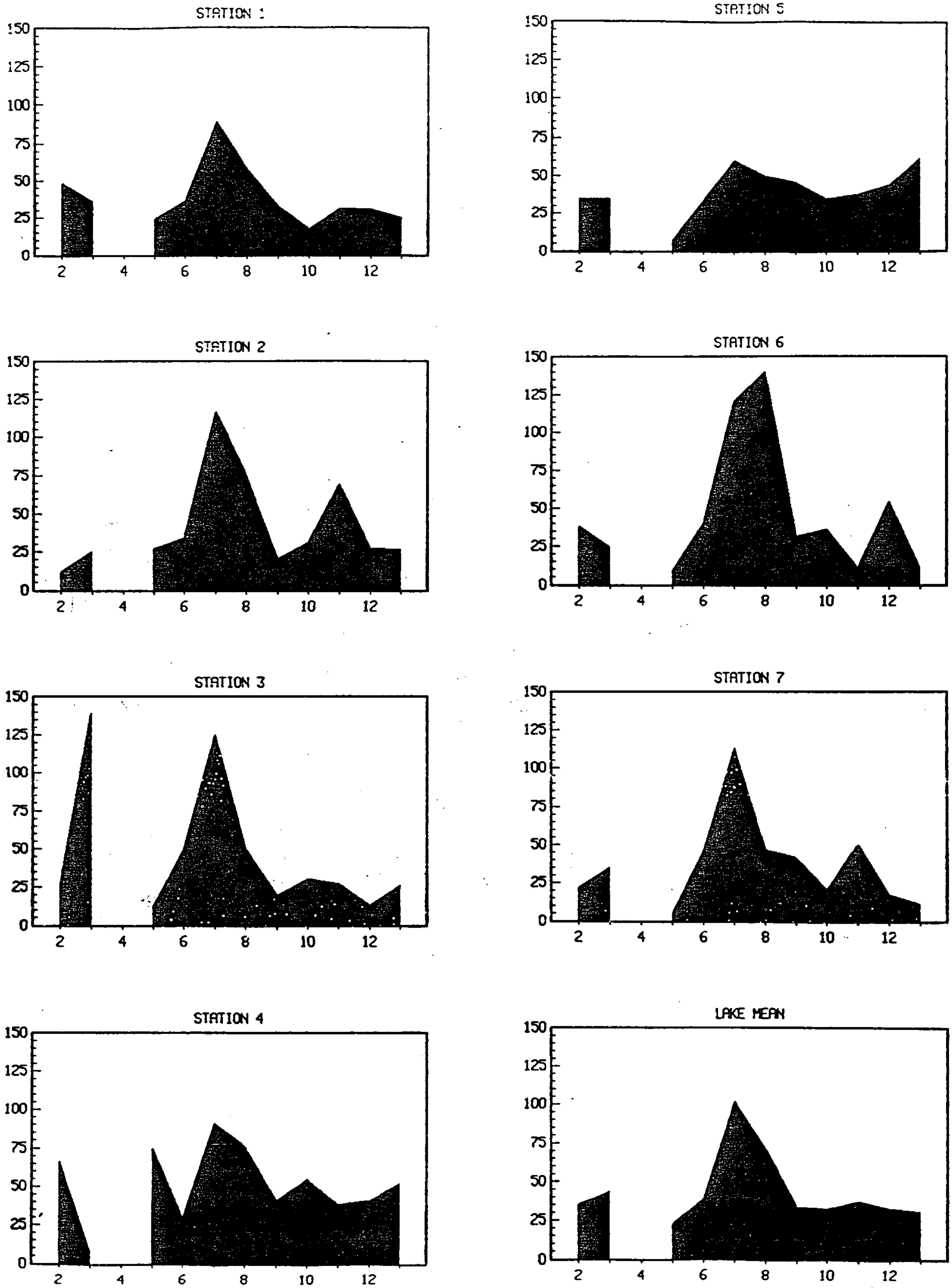


Figure 4-22. Monthly biomass (ug d.w. l^{-1}) of rotifers in Lake Weir in 1987.

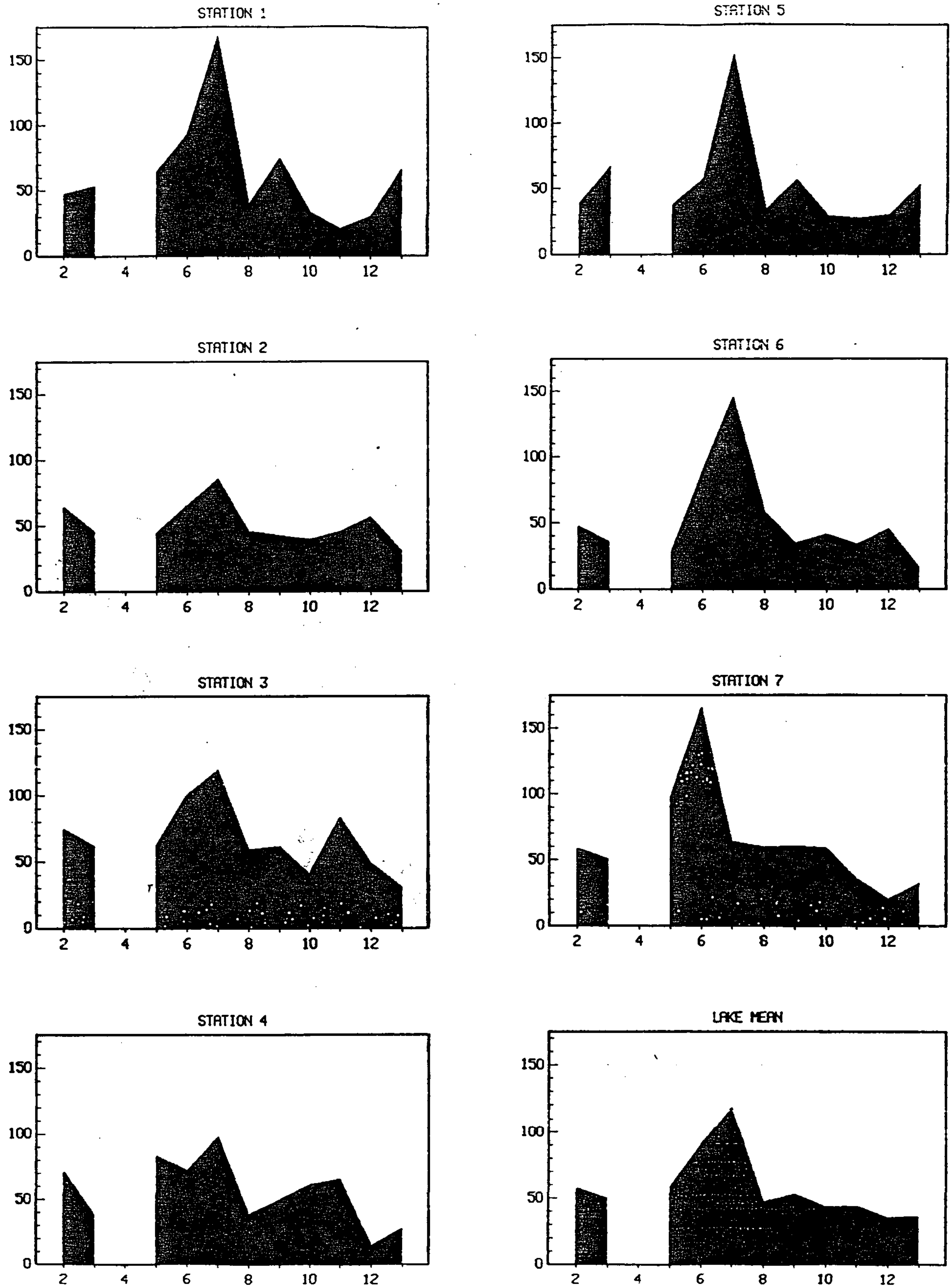


Figure 4-23. Monthly biomass (ug d.w. l^{-1}) of total ciliates in Lake Weir in 1987.

oculatum, were the most abundant. These ciliates are known to inhabit the metalimnion and hypolimnion, respectively. A similar midsummer maxima of myxotrophic ciliates has been noted for highly colored Florida systems, and has been ascribed to the development of thermal stratification and nutrient limiting conditions in the water column (Beaver et al. 1988).

Oligotrich ciliates were frequently abundant during the first part of the year and occasionally increased until the midsummer biomass peak (Figure 4-24). Scuticociliate populations tended to peak in June prior to total zooplankton, microzooplankton, rotifers, and total ciliate biomass (Figure 4-25). Populations of this order then declined to varying extents during summer and often a secondary peak was noted in fall. Haptorid ciliates tended to peak in the early summer but peaks were also seen during the fall at Stations 2 and 3 (Figure 4-26).

G. Relationship between Major Zooplankton Components and Environmental Variables in Lake Weir

Pearson product-moment correlations of major zooplankton components with limnological variables are presented in Table 4-14. Chlorophyll *a* was positively correlated only with scuticociliate biomass (r=0.37) and negatively correlated with cyclopoids (r= -0.33) and oligotrichs (r= -0.21). Total phosphorus concentrations were positively related to rotifers (r=0.33) and negatively correlated with cladocerans (r= -0.35) and oligotrichs (r= -0.42).

Temperature displayed the strongest and best relationship with zooplankton components. Total zooplankton biomass

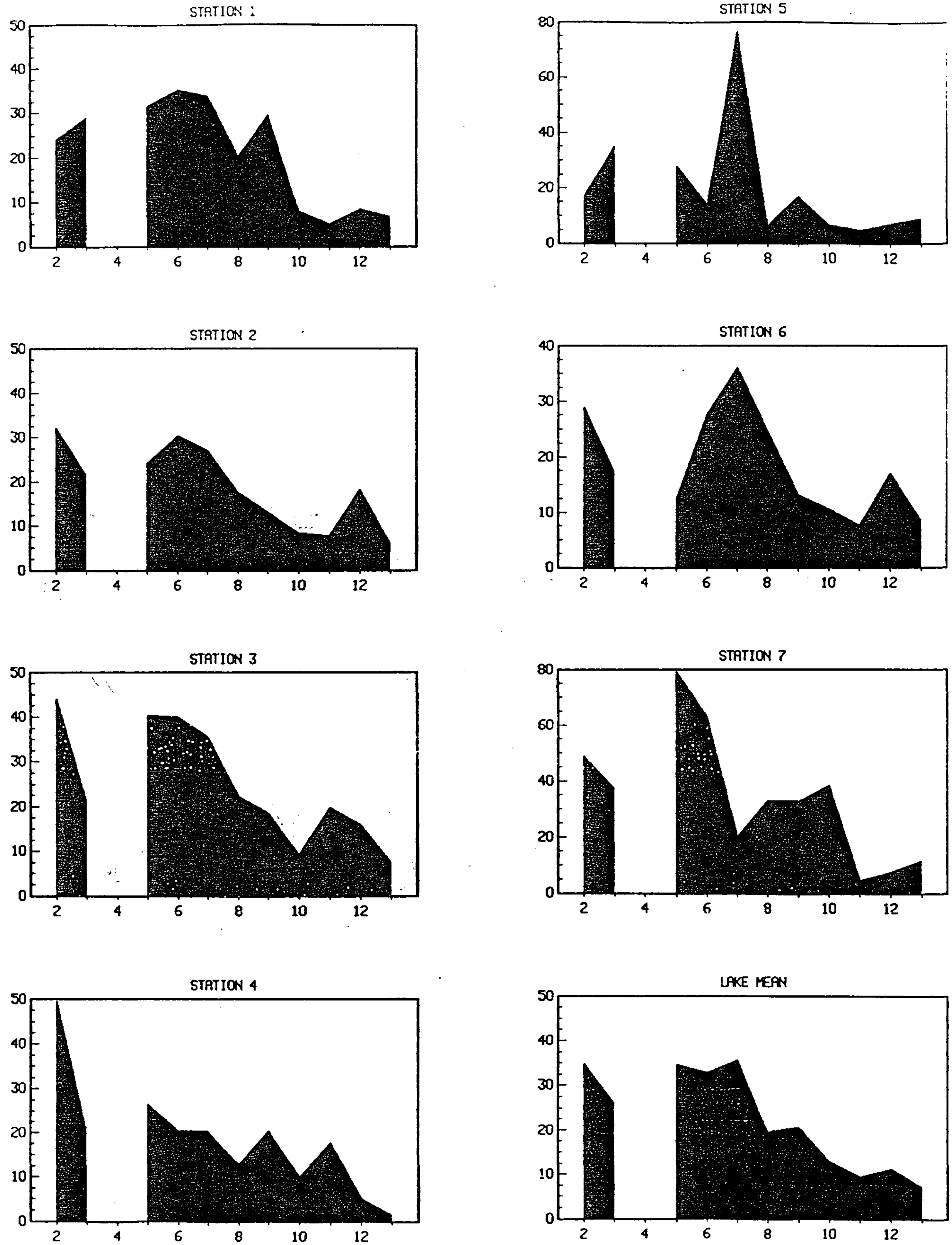


Figure 4-24. Monthly biomass (ug d.w. l^{-1}) of oligotrich ciliates in Lake Weir in 1987. Note larger scale for Stations 3 and 7.

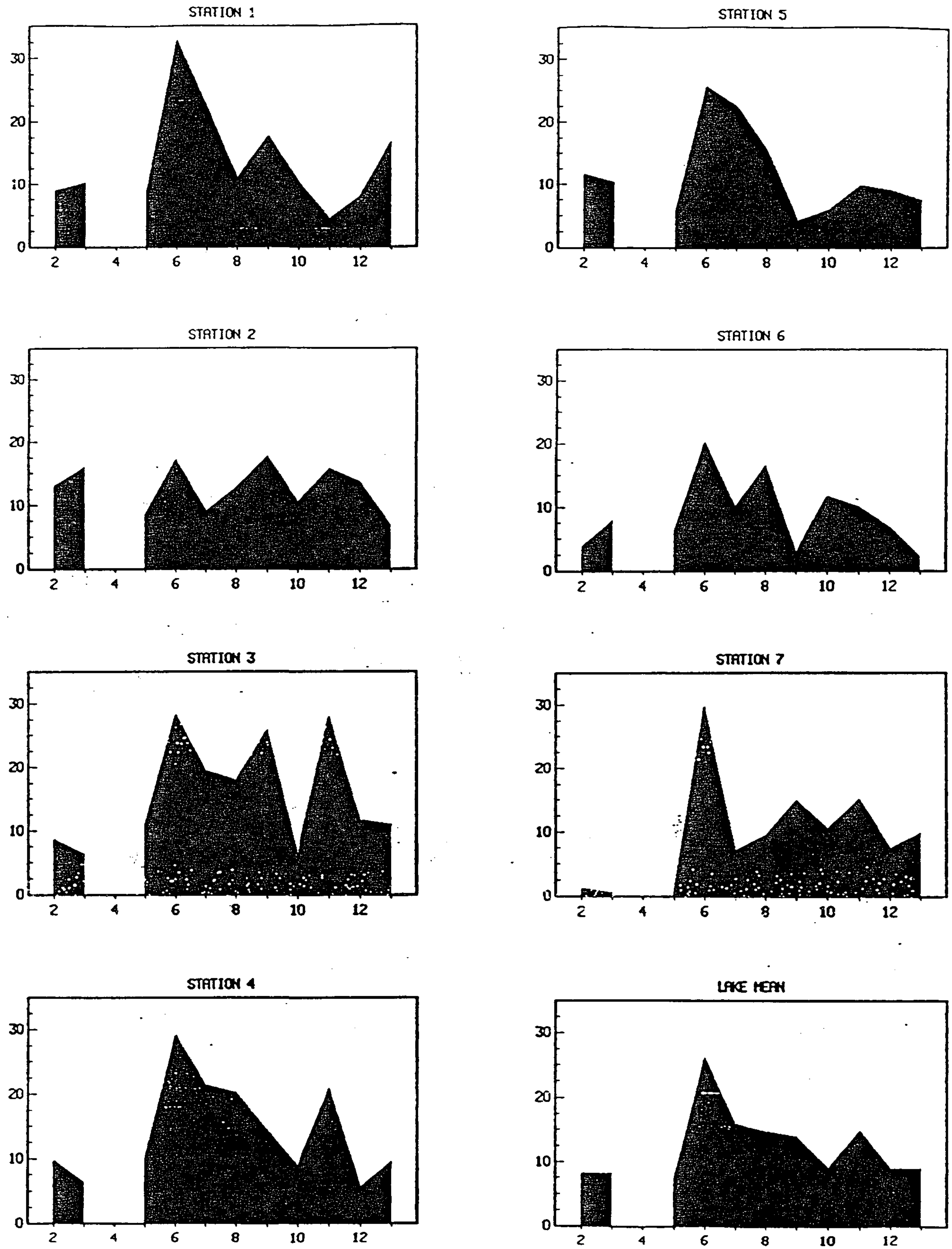


Figure 4-25. Monthly biomass (ug d.w. l^{-1}) of scuticociliate ciliates in Lake Weir in 1987.

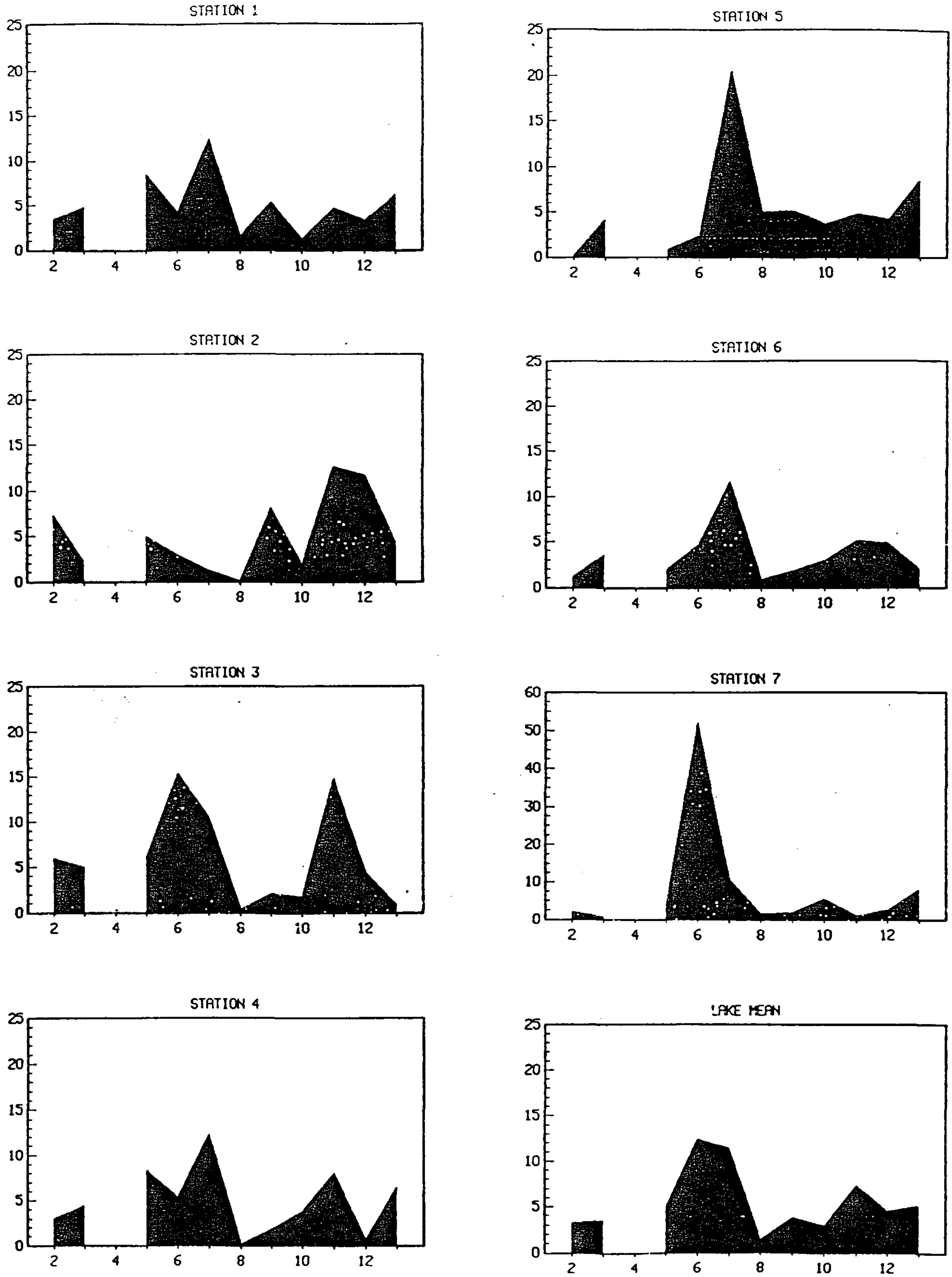


Figure 4-26. Monthly biomass (ug d.w. l^{-1}) of haptorid ciliates in Lake Weir in 1987. Note larger scale for station 7.

Table 4-14. Significant correlations ($p < 0.05$) between major zooplankton components in Lake Weir with selected limnological variables. Coefficients are Pearson product-moment type.

COMPONENT	Chl.a (n=76)	TP (n=68)	Temperature (n=77)	Secchi disk (n=77)	pH (n=76)	Bacteria (n=77)
Total zooplankton	NS	NS	0.52	NS	NS	NS
Macrozooplankton	NS	NS	0.45	NS	NS	NS
Microzooplankton	NS	NS	0.43	NS	NS	NS
Cladocera	NS	-0.35	NS	NS	-0.32	NS
Calanioda	NS	NS	0.58	NS	NS	NS
Cyclopoda	-0.33	NS	NS	NS	NS	NS
Nauplii	NS	NS	-0.30	NS	-0.34	NS
Rotifera	NS	0.33	NS	NS	0.39	NS
Ciliata	NS	NS	0.42	NS	NS	NS
Oligotrichida	-0.21	-0.42	0.32	NS	NS	NS
Scuticociliatida	0.37	NS	0.36	NS	0.41	NS
Haptorida	NS	NS	NS	NS	NS	NS

(r=0.52) as well as the two major size classes, macrozooplankton (r=0.45) and microzooplankton (r=0.43), were moderately related to increasing water temperature.

Although pH was positively related to rotifers (r=0.39) and scuticociliate biomass (r=0.41), it was negatively correlated with cladocerans (r= -0.32) and nauplii (-0.34). No significant relationship was demonstrated between either secchi disk transparency or bacterial abundances and major zooplankton components.

H. Comparison of Seasonality in 1987 with Historical Data

Total zooplankton biomass at Station 3 peaked in September during 1979 whereas it peaked in March and July in 1987 (Figure 4-27). Macrozooplankton biomass displayed a bimodal seasonality in both years with peaks occurring in March and September in 1979 and March and August in 1987. Microzooplankton also displayed a bimodal seasonality with highest values recorded at approximately the same periods as macrozooplankton.

It is unclear whether seasonality in the cladocerans differed between years because of the missing April point. However, it appears that the major pulse during both years occurred during the spring with a much reduced secondary peak in fall. Messer (1975) found this bimodal pattern in cladoceran abundance in 1974 in Lake Weir.

Calanoid copepods exhibited only a fall peak in 1979 but had biomass maxima in both spring and late summer in 1987. Cyclopoid copepods displayed similar population peaks during spring and late summer and fall in both years, but the

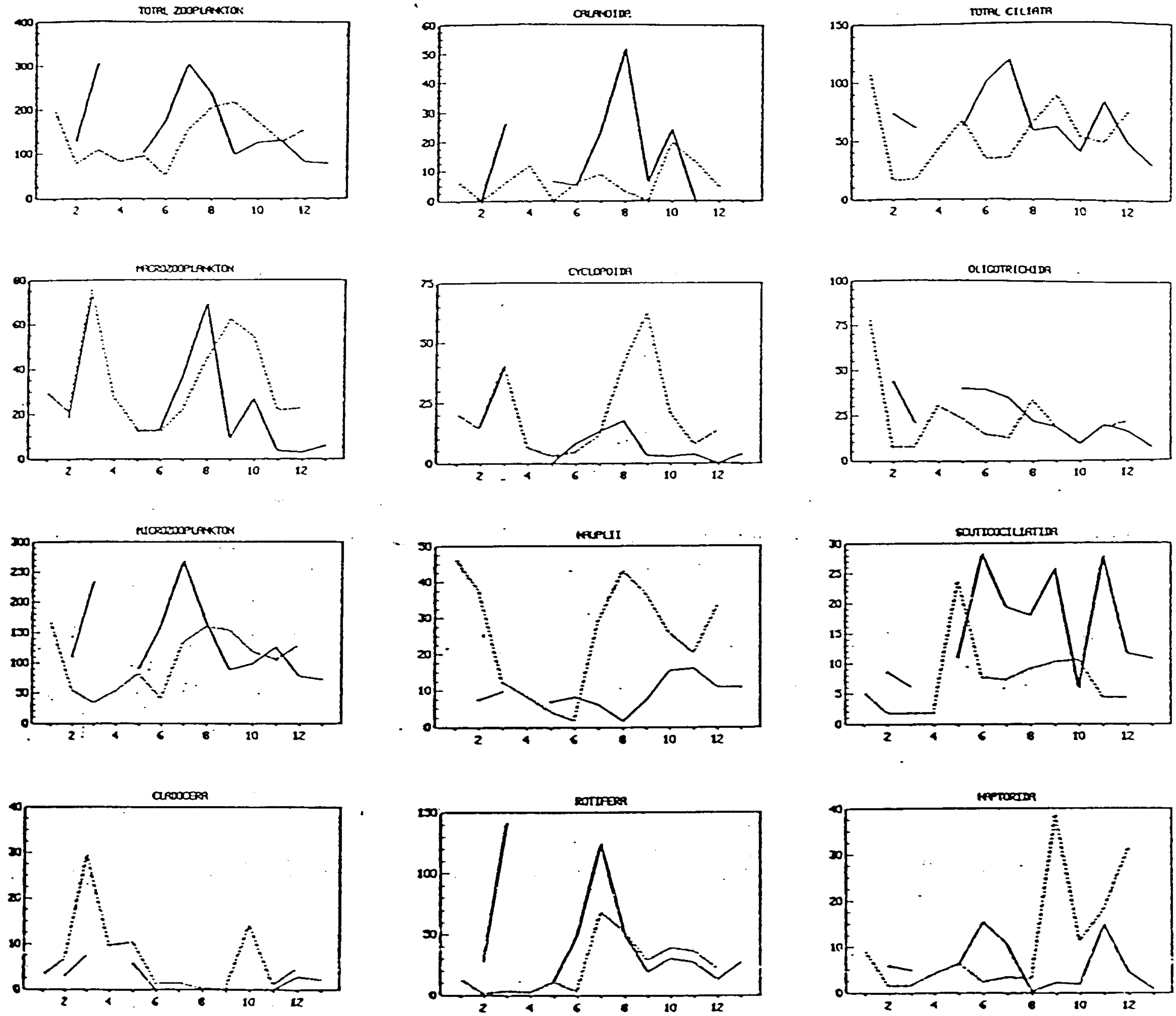


Figure 4-27. Comparison of seasonality of the major zooplankton components in Lake Weir at station 3 in 1979 (dashed line) and 1987 (solid line). Biomass in ug d.w. l^{-1}

magnitude was much greater in 1987. During 1974, Messer (1975) noted a similar pattern for total copepod abundance. Nauplii displayed a clear bimodality in 1979 with two major peaks in January and August. this trend was not observed during 1987 with only a moderate elevation noted in fall.

Rotifers showed only one peak in July 1979 but during 1987 had a major peak in July as well as in March. Similarly, Messer (1975) reported midsummer maxima in rotifer abundance during 1974 at three stations in Lake Weir. Total ciliate biomass was highest in January and September of 1979 but the peaks occurred in July and November in 1987.

Oligotrich seasonality appears much the same between years with higher values recorded in the first half of the year followed by declining populations through summer and fall. Scuticociliate populations exhibited a major pulse in June and a smaller peak in October of 1979. During the present study, their populations increased in spring but were maintained at higher levels during summer with other major peaks in September and November. Haptorid ciliates peaked in September and December of 1979 but peaked in June and November of 1987.

I. Comparison of Seasonality in Lake Weir with other Mesotrophic Florida Systems

Comparison of the seasonality of major zooplankton groups in Lake Weir with other Florida systems was accomplished by computing monthly mean values for each component in seven mesotrophic lakes discussed earlier (Figure 4-28).

Total zooplankton biomass in mesotrophic Florida lakes usually peaked in spring, summer, and fall. In Lake Weir,

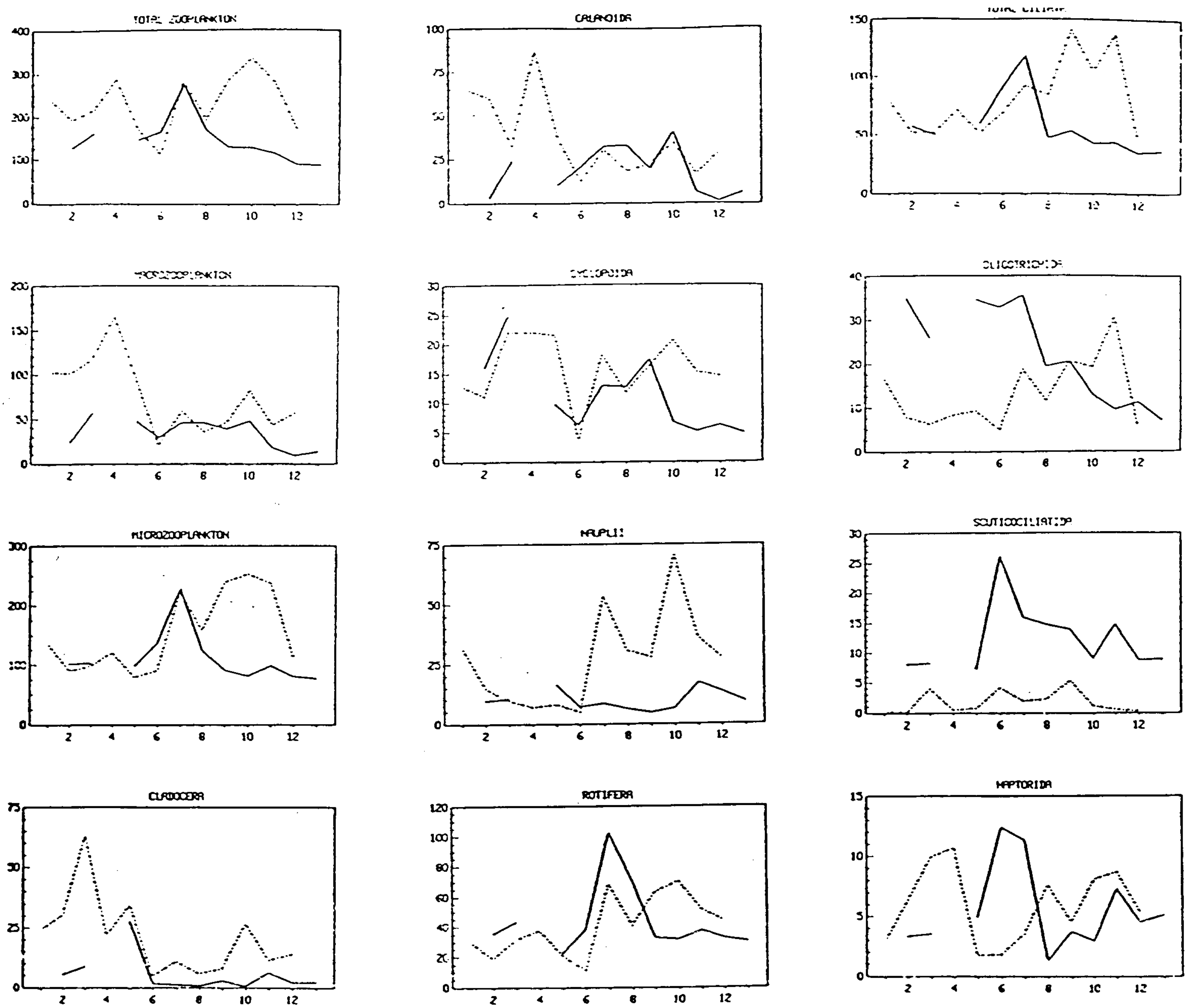


Figure 4-28. Seasonality of the major zooplankton components in Lake Weir in 1987 (solid line) and the monthly mean of seven comparable mesotrophic Florida systems (dashed line). Biomass in ug d.w. l^{-1}. Lake Weir values are the lake means.

however, a midsummer peak was noted. Macrozooplankton biomass in mesotrophic Florida systems showed one pronounced spring maxima with populations beginning to increase during winter. No clear trend was apparent for macrozooplankton in Lake Weir, but the missing April point confounds complete interpretation. Microzooplankton peaked in July in both Lake Weir and other mesotrophic lakes, but the fall maxima in other mesotrophic systems was not seen in Lake Weir.

Cladoceran seasonality showed a clear seasonality in mesotrophic lakes with the largest biomasses encountered during spring and a small peak in fall. This pattern is consistent with those described for other mesotrophic Florida systems (Shireman & Martin 1978, Blancher 1984, Elmore et al. 1984), and was also true for Lake Weir but the missing April sample prohibits firm conclusions.

Calanoid copepods tended to peak during the end of winter and spring in mesotrophic Florida lakes (Shireman & Martin 1978, Blancher 1984, Elmore et al. 1984) but no pattern is evident in Lake Weir for this taxa. Cyclopoid copepods peaked throughout spring and again in fall in the mesotrophic subset and other mesotrophic systems (Shireman & Martin 1978, Elmore et al. 1984). This trend was observed in Lake weir. Nauplii displayed peaks during July and October in the generalized cycle but exhibited comparatively little variation in Lake Weir. Other mesotrophic Florida lakes often show elevated nauplii populations in late summer or early fall (Shireman & Martin 1978, blancher, 1984, Elmore et al. 1984).

Rotifers generally peaked in both July and throughout fall in mesotrophic Florida lakes. Lake Weir experienced rotifer maxima in July but the peak was shortlived and populations quickly declined and did not surge in the fall. The July pulse in Lake Weir was approximately 50% higher than the average midsummer peak for the comparison systems. Rotifer maxima in other Florida systems frequently occurs during the summer months but have been noted during other seasons (Shireman & Martin 1978, Blancher 1984, Elmore et al. 1984).

The generalized pattern for total ciliate biomass indicates that these lakes experienced prolonged maxima during fall. In contrast, Lake Weir had only a single brief biomass peak during July. The generalized oligotrich cycle for mesotrophic lakes is inverse to the pattern observed in Lake Weir. Most mesotrophic systems have depressed populations during the first half of the year and then gradually increase from July until November. Lake Weir had elevated oligotrich densities in the first half of the year with a decrease beginning in August and continuing down.

The scuticociliates in Lake Weir peaked in July and then gradually declined until fall. In the mesotrophic lakes, scuticociliate populations peaked in March, June, and September and were usually 4 to 5 times less than the biomass maxima in Lake Weir. The pattern described for Lake Weir for scuticociliate biomass and total ciliate biomass is most similar to that described for eutrophic/hypereutrophic Florida lakes, however, in the latter lake group, the biomass values were usually an order of magnitude greater than that found in Lake Weir (Beaver & Crisman 1988b).

The haptorid biomass cycle is in basic agreement with that noted for Lake Weir. In the generalized pattern, the primary pulse came during spring with some systems having a secondary maxima in fall while in Lake Weir it occurred only in July.

J. <u>Correlations between Major Zooplankton Components and Limnological Variables in Other Florida Lakes</u>

A comparable correlation matrix developed for the seven comparison mesotrophic systems indicates that, as in Lake Weir, few strong relationships exist between environmental variables and the biomass of zooplankton groups (Table 4-15).

Both correlation analyses share a weak but significant relationship between scuticociliate biomass and chlorophyll <u>a</u>. Total phosphorus was negatively correlated with microzooplankton, nauplii, rotifers, and oligotrichs and weakly correlated with cladocerans. Temperature was also weakly to moderately related to several zooplankton components in mesotrophic systems. pH was negatively correlated with total zooplankton, macrozooplankton, cladocerans and calanoids.

Comparison of the above correlation matrices with one developed from a 20 lake data set spanning the entire trophic gradient (Table 4-16), indicates that periods of high productivity (as measured by chlorophyll <u>a</u>, total phosphorus, total nitrogen, and pH) are frequently associated with increases in most zooplankton compartments. This pattern is inversely related to the size of the zooplankton group, suggesting that high productivity may have a more direct and detectable effect

Table 4-15. Significant correlations (p <0.05) between major zooplankton components in seven mesotrophic Florida lakes with selected limnological variables. Coefficients are Pearson product-moment type. Data for correlation analysis taken from Bays (1983) and Beaver (1980).

COMPONENT	Chl. a (n=84)	TP (n=80)	Temperature (n=84)	Secchi disk	pH (n=81)	Bacteria
Total zooplankton	NS	NS	NS	ND	-0.26	ND
Macrozooplankton	NS	NS	-0.25	ND	-0.40	ND
Microzooplankton	NS	-0.32	0.25	ND	NS	ND
Cladocera	NS	0.23	-0.26	ND	-0.31	ND
Calanoida	NS	NS	NS	ND	-0.42	ND
Cyclopoda	0.24	NS	NS	ND	NS	ND
Nauplii	NS	-0.45	NS	ND	NS	ND
Rotifera	NS	-0.31	NS	ND	NS	ND
Ciliata	NS	NS	0.32	ND	NS	ND
Oligotrichida	NS	-0.22	0.30	ND	NS	ND
Scuticociliatida	0.24	NS	0.54	ND	NS	ND
Haptorida	NS	NS	NS	ND	NS	ND

Table 4-16. Significant correlations ($p < 0.05$) of major zooplankton components in Florida lakes with limnological variables. Coefficients are Pearson product-moment type (n=238).

COMPONENT	Chl. a	TP	TN	Temp.	pH
Total zooplankton	0.63	0.42	0.25	NS	0.28
Macrozooplankton	NS	NS	NS	-0.23	-0.12
Microzooplankton	0.70	0.44	0.35	0.17	0.35
Cladocera	-0.13	NS	-0.28	-0.35	-0.24
Calanoida	NS	NS	NS	-0.15	-0.14
Cyclopoda	0.17	0.14	NS	NS	NS
Nauplii	0.41	NS	0.20	NS	0.21
Rotifera	0.45	NS	0.21	0.15	0.13
Ciliata	0.71	0.53	0.42	0.20	0.37
Oligotrichida	0.47	0.46	0.22	0.23	0.24
Scuticociliatida	0.72	0.56	0.54	0.29	0.53
Haptorida	0.28	0.21	NS	-0.13	NS

on small-bodied opportunistic plankters with high reproductive capacity. In contrast to the mesotrophic trend, temperature has only a weak effect when Florida systems are considered as a whole.

It has been inferred from field studies in Florida lakes that many interrelated limnological factors control the abundance and composition of zooplankton communities. Included among these factors are predation (Bays & Crisman 1983, blancher 1984, Elmore 1983, Elmore et al. 1983), competition (Elmore 1983, Elmore et al. 1983, Foran 1986a, 1986b), food availability (Beaver & Crisman 1981, 1982, 1988b, Elmore et al. 1984, Brezonik et al. 1984) and temperature (Blancher 1984, Foran 1986a, 1986b).

It is clear from this study that temperature exerts a variable but significant influence on zooplankton communities in Florida lakes. Foran (1986a, 1986b) concluded that the absence of large-bodied cladocerans in subtropical lakes is due to the competitive advantage accrued to smaller species at elevated temperatures typical of these systems. The spring cladoceran maxima observed in Lake Weir and other Florida lakes coincides with increasing water temperature and is believed to be a response to increased reproductive and growth rates, and their rapid early summer decline has been ascribed to intense predation from young-of-the-year fish (Bays & Crisman 1983).

Among the copepods, Diaptomus dorsalis usually dominates the copepod communities of eutrophic lakes due to its reduced susceptibility to vertebrate predation (Elmore et al. 1983), and excluded from less productive systems by superior competition from D. mississippiensis and D. floridanus (Elmore 1983).

Finally, food quality and quantity likely influences the temporal and spatial distribution of zooplankton species in Florida lakes (Beaver & Crisman 1981, 1982, 1988b, Bays & Crisman 1983, Brezonik et al. 1984). The results of the correlation analysis suggest that food is the primary factor regulating zooplankton populations when Florida lakes are considered as a whole.

K. Conclusions of Zooplankton Study

Based on the data accumulated to date, the zooplankton community of Lake Weir would be classified as a mesotrophic assemblage. The biomass of most major zooplankton components were relatively depressed when contrasted with lakes of similar trophy. This trend was most notable within the macrozooplankton since cladoceran and copepod adult biomass were very low compared to other mesotrophic Florida lakes.

Historical comparison with the zooplankton community in 1979 indicates only minor taxonomic changes have occurred. It is important to note, however, that scuticociliate ciliates and rotifers have markedly increased since 1979, and the elevated abundance of these taxa is strongly associated with increased eutrophication in Florida lakes (Beaver & Crisman 1982, 1988a, Bays & Crisman 1983).

Benthic Invertebrates

Benthic macroinvertebrate communities in seven profundal bottom areas (i.e., areas without rooted vegetation) in Lake Weir were sampled at approximately monthly intervals for a year. Benthic invertebrate community abundance and distribution were analyzed to evaluate the water quality of Lake Weir.

Substrate type at the stations fell into three main groups:

A. Fine sand - Stations 1, 2, 5, and 6.

B. Coarse sand - Station 4.

C. Organic "muck" (no sand) - Stations 3 and 7.

Fine sand passed through the 600 um mesh; coarse sand was retained by the sieve bucket.

Thirty-three samples were collected at each station from February, 1987 to January, 1988; making a total of 231 samples collected and analyzed for Lake Weir, Sunset Harbor and Little Lake Weir.

Annual mean densities and taxa obtained at each of the seven stations are summarized in Table 4-17, and presented in full in Appendix B. Annual mean abundance of macroinvertebrates was greatest at station 6 (4,072/m^2) and least at station 1 (1,280/m^2). With the exception of station 1, all the sand bottom stations had significantly greater mean densities than the stations (3 and 7) with organic "muck" substrate stations (Table 4-18).

Table 4-17. Annual mean densities (number per m^2) of benthic macroinvertebrates at seven stations in Lake Weir.

Station	1	2	3	4	5	6	7
Insecta							
Diptera							
Chironomidae							
Chironomus sp.	35	37	798	159	56	1175	80
Cryptochironomus sp.	3	7	6	68	32	69	27
Tanytarsus sp.	44	37	41	54	37	119	132
Cladotanytarsus sp.	44	127	32	245	227	113	28
Coelotanpus sp.	98	71	19	77	219	156	65
Procladius sp.	41	68	51	47	63	95	66
Harnischia sp.	36	35	2	10	15	37	24
Polypedilum sp.	3	0	2	8	0	53	65
Pseudochironomus sp.	3	23	0	53	12	80	0
Total Chironomidae	307	405	951	721	661	1897	487
Chaoboridae							
Chaoborus sp.	441	513	360	23	86	340	534
Ceratopogonidae							
Palpomyia sp.	3	12	5	15	10	168	10
Ephemeroptera							
Hexagenia sp.	19	9	0	16	146	242	104
Misc. Insects[1]	1	3	0	7	7	3	2
Amphipoda							
Hyalella sp.	286	1356	780	1942	2239	786	71
Oligochaeta[2]	177	237	195	331	275	349	153
Mollusca[3]	10	100	1	95	63	109	7
Hirudinea	6	48	43	36	92	74	15
Nematoda	30	129	64	82	112	104	30
Total Organisms	1280	2812	2399	3268	3691	4072	1413
Mean No. of sp.	8.6	10.7	7.1	11.4	12.8	13.6	8.1

1. Miscellaneous Insecta : Decetis sp.; Aphylla sp.
2. Oligochaeta: Tubificidae; Lumbriculidae; Branchiobdella.
3. Mollusca: Viviparus sp.; Elliptio sp.; Physa sp.

Table 4-18. Macroinvertebrate Annual Mean Abundance at each station over all dates[1].

	Annual Mean Abundance at each station						
	6	5	4	2	3	7	1
Mean density (no./m2)	4.072	3.691	3.268	2.812	2.399	1.413	1.280
	————	————		————	————	————	————
		————	————				
	6	5	4	2	1	7	3
Mean No. of species	13.6	12.8	11.4	10.7	8.6	8.1	7.1
	————	————	————	————	————	————	
						————	————

[1] Means underscored by the same line are not significantly different using Duncan's Multiple Range Test (ANOVA; $p = 0.05$).

Similarly, the mean number of species were significantly greater at sand bottom stations than at the organic substrate stations (Table 4-18). The highest mean number of species (13.6) was recorded for station 6 while the lowest mean number (7.1) was recorded for station 3.

The most abundant groups of organisms found in Lake Weir were the amphipods, chironomids, chaoborids and oligochaetes, comprising 39.4%, 28.7%, 12.1% and 9.1% of total macro-invertebrate abundance, respectively. The mayfly, Hexagenia sp. was abundant at only stations 5, 6, and 7, with annual mean densities of 146, 242 and 104 individuals/m^2, respectively (Table 4-17). No Hexagenia individuals were found at station 3 throughout the sampling period. The amphipod, Hyalella sp. was abundant throughout the lake system, with highest mean densities at stations 4 and 5, having 1,942 and 2,239 individuals/m^2.

The ceratopogonid Palpomyia sp. was abundant only at station 6 with a mean density of 168 individuals/m^2. A total of nine chironomid genera were recorded for the sample period. All nine genera were found at all 7 stations with the exception of Polypedilum sp. and Pseudochironomus sp., which were absent from stations 2, 6, and 3, 7, respectively. Overall the most abundant chironomid taxa were Chironomus sp., Cladotanytarsus sp., and Coelotanypus sp., comprising 43%, 15%, and 13%, respectively, of total chironomid populations.

Stations 7, 2, and 1 had lower midge abundance than the other stations (Table 4-17). The greatest midge abundance was obtained at station 6 with an annual mean of 1,897 individuals per m^2. The lowest abundance of 307 individuals per m^2 occurred at station 1. Different midge taxa were numerically dominant at different stations. Chironomus sp. was the dominant taxon at stations 3 (83.9%) and 6 (62.9%), and Cladotanytarsus sp. was the dominant taxon at stations 2 (31.4%), 4 (35%) and 5 (34%). Coelotanypus sp. was dominant at stations 1 (32%) and 5 (37%) while Tanytarsus was dominant at station 7 (27%).

Chaoborus sp. was generally abundant at all stations except at stations 4 and 5. Mean density ranged from 23 individuals per m^2 at station 4 to a maximum of 534 individuals per m^2 at station 7 (Table 4-17).

The oligochaetes were fairly abundant at all stations but were more so at stations 4 and 6 with mean annual densities of 331 and 334 individuals per m^2.

The most common mollusks found in Lake Weir were the bivalve Elliptio sp. and the snail Viviparus sp. Physa sp. was encountered occasionally. Not surprisingly, the "mucky" substrate of stations 3 and 7 had the lowest mean abundance of mollusks with 1 and 7 individuals per m^2, respectively. The sand bottom stations, with the exception of station 1, had greater mollusk abundances with stations 2, 4, and 6 showing similar mean abundances of 100, 95, and 109 individuals per m^2.

Looking at the proportions (percent) of the major groups of organisms collected at each of the seven stations, two groups of stations emerge. The first group comprising stations

2, 4, and 5 were dominated by the amphipod Hyalella sp. with 48.2%, 59.4%, and 60.6% of total station macroinvertebrate abundance respectively (Figure 4-29). The second group of stations -- 1, 3, 6, and 7 -- was dominated by the Class Insecta with total insect compositions of 60.1, 54.8, 65.0 and 80.0% (Figure 4-30).

The insect-dominated stations (1, 3, 6, and 7) can be further divided into two subgroups. Chironomids were dominant at stations 3 and 6, representing 39.6% and 46.6% of the total benthic invertebrate population. Chaoborus sp. was dominant at stations 1 and 7, comprising 34.4% and 37.7% of the population.

Macroinvertebrate community structure based on functional feeding groups showed that the collector-gatherer group was the most dominant followed by the predators, filterers and scrapers (Table 4-19). Not surprisingly, no shredders were found at any of the stations since the profundal areas all lacked vegetation. the collector-gatherers were most dominant at stations 1 and 7, ranging in percent abundance from 84.7% at station 4 to 27.9% at station 7. Conversely, the predators were most dominant at stations 1 and 7 and least dominant at station 4, with percent composition ranging from 69.8% at station 7 to 9.6% at station 4 (Table 4-19). The filterers were numerically more dominant at stations 6, 2, and 4 than at the other stations. A maximum of 7.8 percent composition was found at stations 6 and 2, with none at station 3. Again, scrapers were most dominant at station 2 (3.7%) and least dominant at station 3 (0.05%). The stations dominated by the collector-gatherer

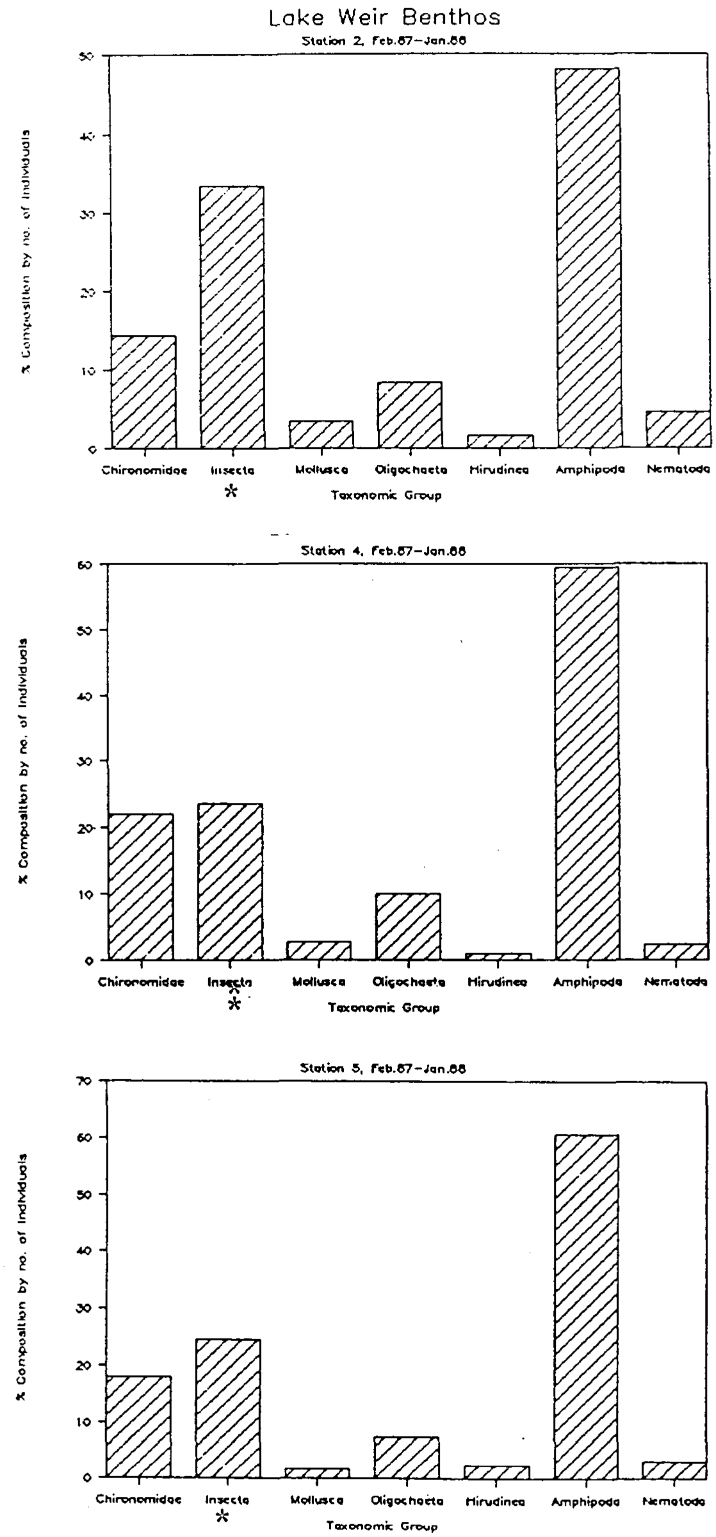


Figure 4-29. Macroinvertebrate group abundance in Lake Weir at stations 2, 4 and 5.

*Total Insecta, including Chironomidae.

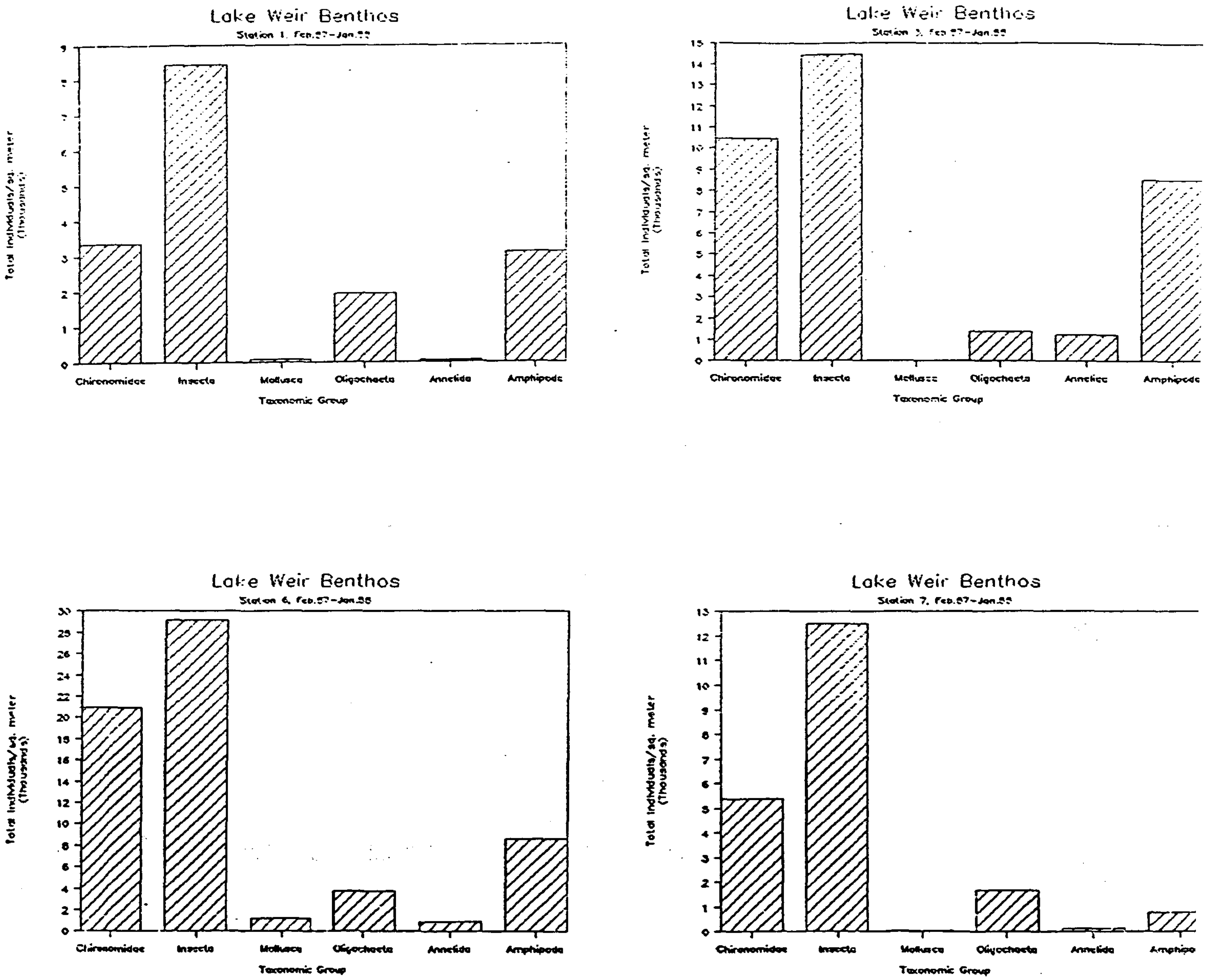


Figure 4-30. Macroinvertebrate group abundance in Lake Weir at stations 1, 3, 6 and 7.

Table 4-19. Macroinvertebrate functional group mean density as a percent of total density (no. m-2) at each station over all dates.1

Functional Group	Percent by density (no. m^{-2}) at each station						
	4	5	2	3	6	1	7
Collector-gatherers	84.7	72.7	70.2	61.5	60.5	44.6	27.9
	----	----	----	----	----	----	----
					----	----	
	7	1	3	6	5	2	4
Predators	69.8	54.2	34.0	33.6	25.2	22.3	9.6
	----	----	----	----	----	----	----
	6	2	4	5	7	1	3
Filterers	3.8	3.8	3.0	1.4	0.05	0.04	0.0
	----	----	----	----	----	----	----
	2	5	4	1	6	7	3
Scrapers	3.7	1.2	1.2	0.9	0.7	0.3	0.05
	----	----	----	----	----	----	----

1Means underscored by the same line are not significantly different using Duncan's Multiple Range Test (ANOVA; $p = 0.05$).

feeding group (i.e., stations 2, 4, and 5) were the stations with the highest proportions of the amphipod, Hyalella sp. Also, the stations dominated by the predator feeding group (i.e., stations 7 and 1) were the stations with the highest proportions of Chaoborus sp. The filterers were represented by the pelecypod Elliptio sp. and the scrapers by the snail Viviparus sp.

Total monthly abundances of the major taxa per station show a trend of lowest yearly values from July to December at stations 1-6 (Figures 4-31, 4-32). At station 7, the trend showed a decline in May with values remaining low through January (Figure 4-32). Seasonal patterns in the abundance of individual taxa were not discernible due to high variability in mean monthly numbers.

In a comparison among the mid-lake stations -- 3 (Lake Weir, mucky substrate), 6 (Sunset Harbor, sandy substrate) and 7 (Little Lake Weir, mucky substrate) -- similarities and differences emerge. Station 6 was significantly more productive than stations 3 and 7, having the greatest number of organisms as well as number of taxa (Table 4-18). Whereas stations 3 and 6 were dominated by the midge Chironomus sp., station 7 was dominated by Chaoborus sp.

The chironomid Pseudochironomus sp. was absent from stations 3 and 7. The dominant midge at station 7 was Tanytarsus sp. Overall, station 6 (mid station of Sunset Harbor) was the most productive of all seven stations sampled.

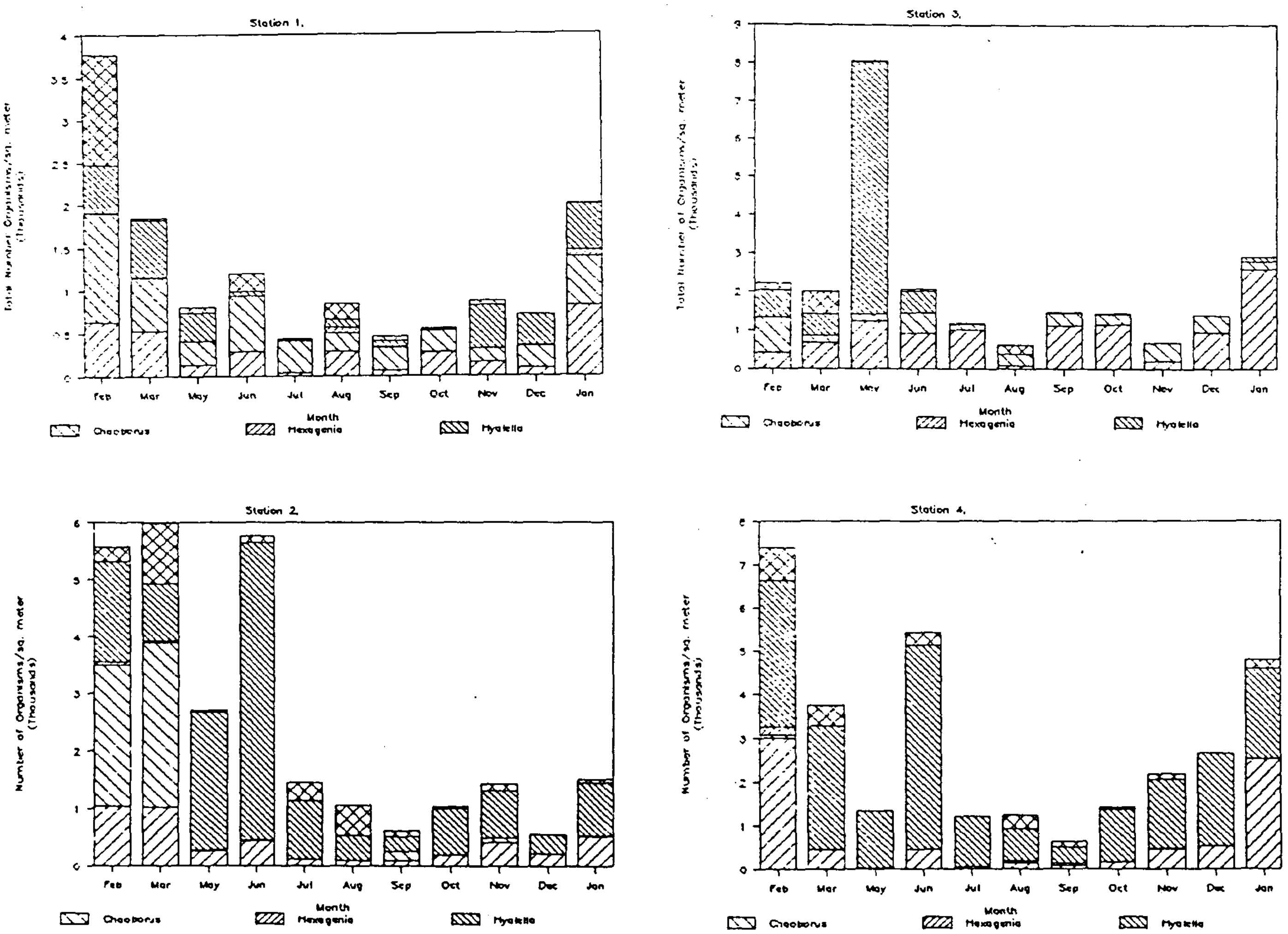
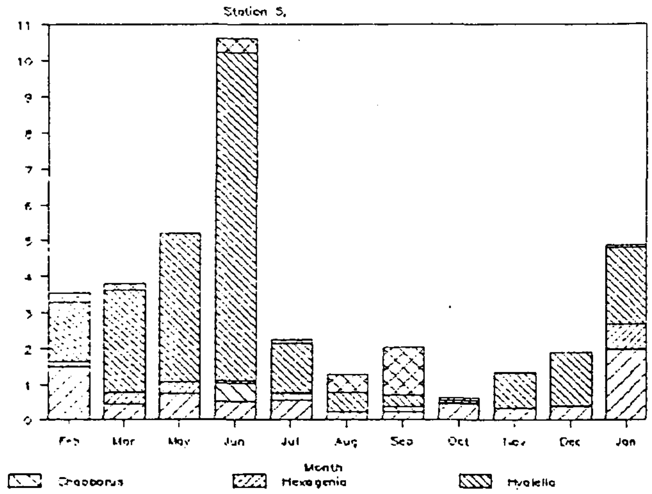
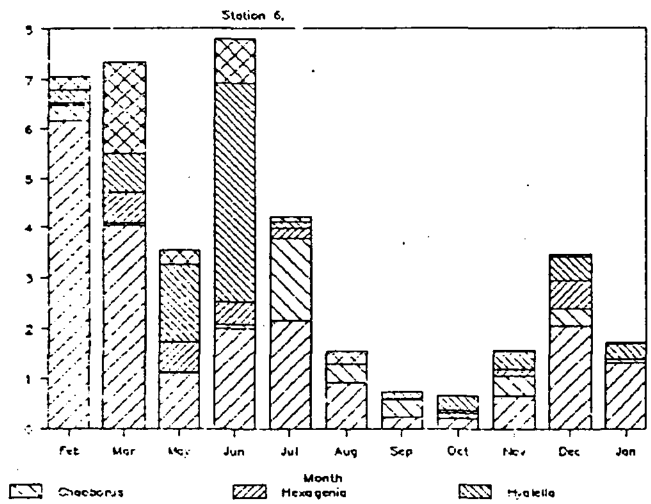


Figure 4-31. Total monthly abundances of major taxa in Lake Weir stations 1, 2, 3 and 4.





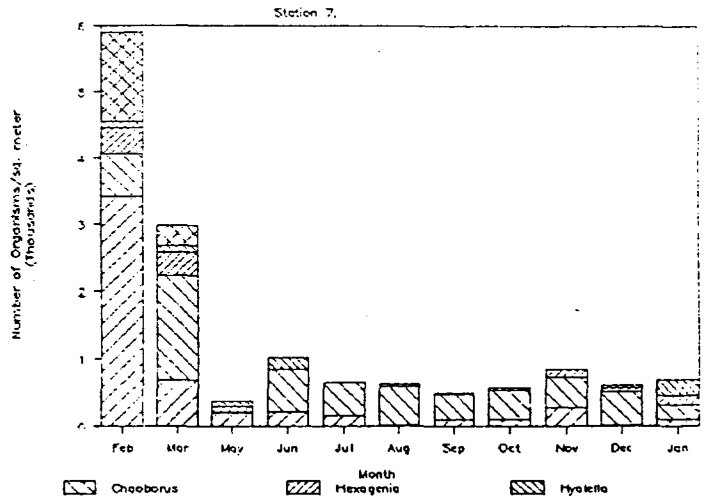


Figure 4-32. Total monthly abundances of major taxa in Lake Weir at stations 5, 6 and 7.

Large-scale distribution and abundance patterns of benthic macroinvertebrate communities have been shown to be influenced by factors related to the trophic state of lakes (Vodopich 1980, Cowell and Vodopich 1981, Saether 1985, Hunt 1953). Profundal chironomid and oligochaete communities have been used as indicators of trophic state and/or pollution (Wiederholm 1980, Warwick 1980). The structure of these communities is thought to be determined by differences in tolerance to low oxygen concentration, especially in eutrophic lakes.

Macroinvertebrate community structure at the stations sampled showed two main community types: (a) an amphipod-dominated group and (b) an insect-dominated group. Oligochaetes were relatively unimportant at all stations. The relative abundance of amphipods and insects compared to oligochaetes generally indicated good water quality. The greater number of *Chironomus* at stations 3 and 6 may indicate the presence of a type of organic matter which allows this species to out-compete other chironomids. Similar reasoning may apply to *Hyalella*. Both *Chironomus* and *Hyalella* are considered to collect fine particulate organic matter from the sediments.

Amphipods are sensitive to a wide variety of pollutants and are usually more sensitive to chronic life-cycle toxicants than fish (Macek et al. 1976a, 1976b). *Hyalella azteca* has been found to be extremely sensitive to Diquat and more sensitive to dichlobenil (herbicides) than any insect larvae tested.

The mayfly, _Hexagenia_ was more abundant at stations 5, 6, and 7 than at the other stations. Since these stations include the sandy and organic "muck" substrates, the relatively impoverished populations of _Hexagenia_ nymphs at stations 1, 2, 3, and 4 (i.e., northern half of Lake Weir) could be due to fish predation and/or distribution of ovipositing adult females. _Hexagenia_ nymphs burrow into soft bottom sediments by digging u-shaped respiratory tubes. Their distribution is generally determined by sediment type and dissolved oxygen concentration of the sediment/water interface.

Hexagenia could be used as an indicator species of the water quality in Lake Weir. Any change that would cause an increase in the oxygen demand of the water and sediments for prolonged periods may drastically deplete dissolved oxygen concentrations, especially during periods of calm weather. This situation would decimate the populations of _Hexagenia_ sp. in Lake Weir. As a result of oxygen depletion, _Hexagenia_ populations have been replaced by worms, midges, and other more tolerant organisms (Wood 1973; Cook and Johnson, 1974).

The taxa found in Lake Weir are very similar to those found in similar Florida lakes (e.g. Kingsley Lake). Factors that may influence seasonal abundances and taxa richness of macroinvertebrate communities include:

1. Biotic interactions of competition and predation
2. Food quality and abundance (e.g., phytoplankton species and abundance)
3. Tolerance of variations in chemical and physical parameters.

Florida Benthos

Interpretation of benthic invertebrate data for Florida lakes is hindered by the lack of a detailed calibration model for the state. As part of an unfunded research project, we have begun to collect all benthos data available from the files of state agencies and universities. We are now in the preliminary analysis phase of this project.

The relationship between total benthos abundance (minus mollusks) and chlorophyll a in Florida lakes is not clear (Figure 4-33). We feel that the apparent lack of a clear relationship reflects the fact that extremely macrophyte-infested lakes have been included in the database, and no attempt has yet been made to account for either substrate organic content and degree of flocculation or differences in sampling methodologies. We are now incorporating these factors into our model construction.

We have also examined the relationship between total chironomid abundance and chlorophyll a for our Florida lake database (Figure 4-34). As mentioned previously for total benthos, we are now incorporating additional environmental and substrate factors with the hope of delineating relationships that may be of value for predicting water quality in Florida lakes.

Our laboratory has collected over four years of benthos data on the Oklawaha lakes. As sampling methodologies were similar between this study and the current investigation at Lake Weir, we can use the former database to predict how the

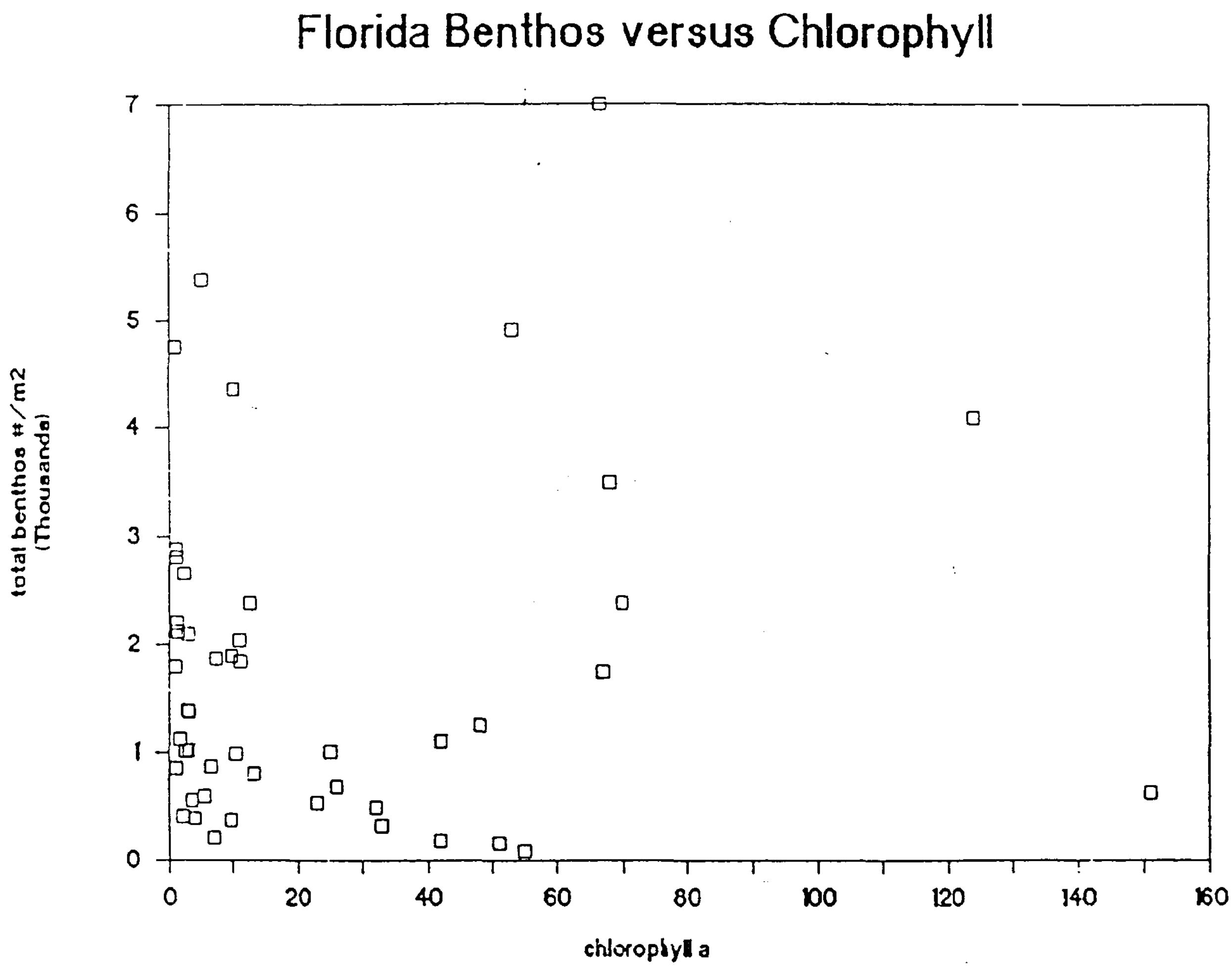


Figure 4-33. Relationship between total benthic invertebrates (minus molluscs) and chlorophyll for Florida lakes.

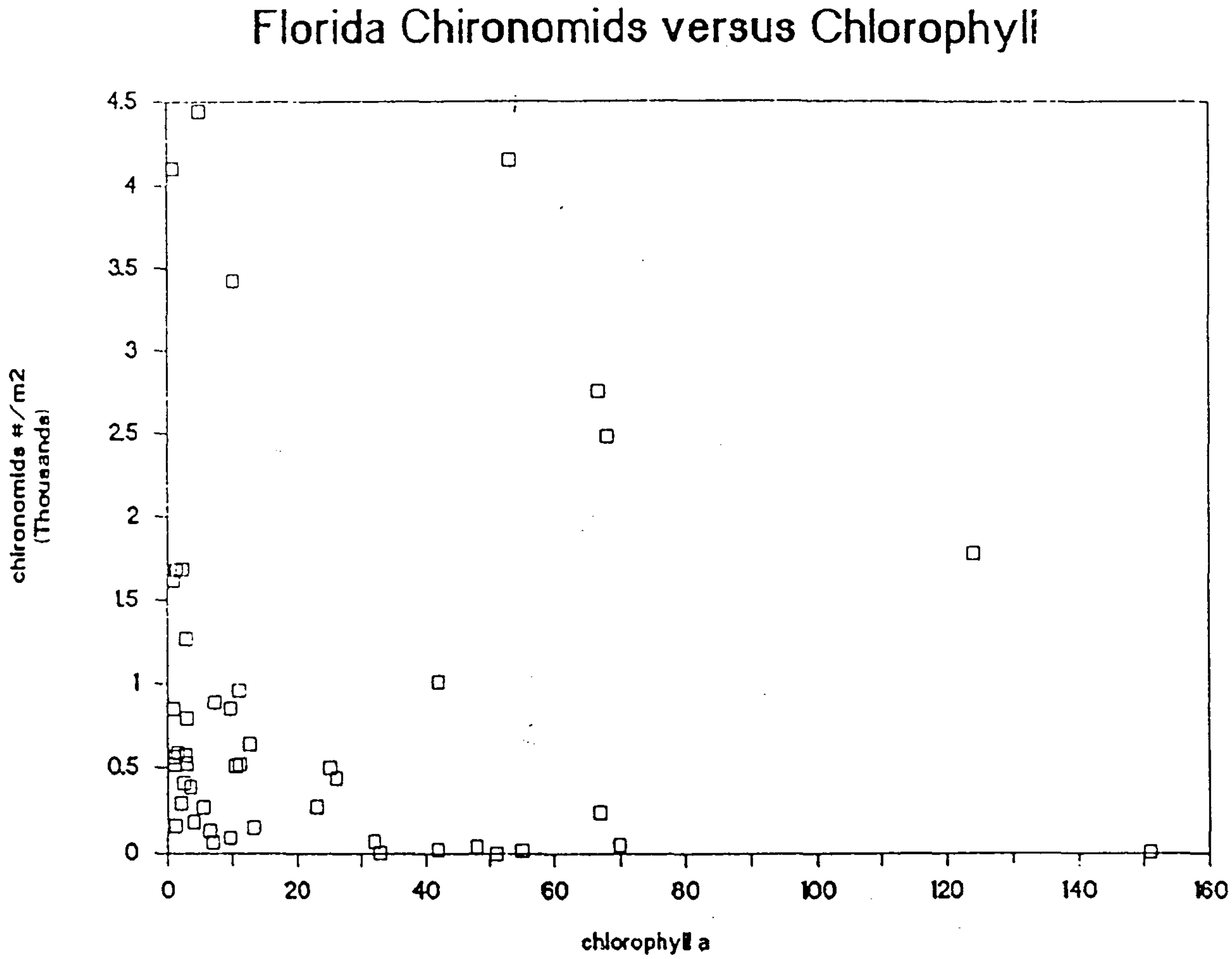


Figure 4-34. Relationship between total chironomid abundance and chlorophyll for Florida lakes.

benthic invertebrate community of the Lake Weir system may respond to further cultural eutrophication.

Total benthos abundances (minus mollusks) in the three basins of the Lake Weir system were similar to those of the more eutrophic Oklawaha lakes (Figure 4-35). The notable exceptions were Lakes Eustis and Apopka, which displayed the lowest values of both investigations. Oligochaete abundance in the Lake Weir system (Figure 4-36) was comparable to that of the three least productive Oklawaha lakes (Eustis, Griffin, Apopka) and more than five times lower than the most productive lakes (Dora and Beauclair). It appears that annual mean chlorophyll concentrations in the Lake Weir system would have to increase 500% before oligochaetes would be expected to be significantly more abundant.

Finally, chironomid abundance in the three basins of the Lake Weir system approximated that of Lakes Griffin and Dora but was higher than that of the other three lakes (Figure 4-37). Of the three latter lakes, Apopka and Beauclair displayed the most flocculent sediments.

On the basis of our preliminary analysis of benthos in Florida lakes, it appears that the abundance of total benthos, chironomids, and oligochaetes in the Lake Weir system should not change markedly if a moderate rate of cultural eutrophication continues. However, if sediments become flocculent, regardless of a change in annual mean chlorophyll, major changes in chironomid abundance could occur. These observations are considered preliminary and will be tested further as

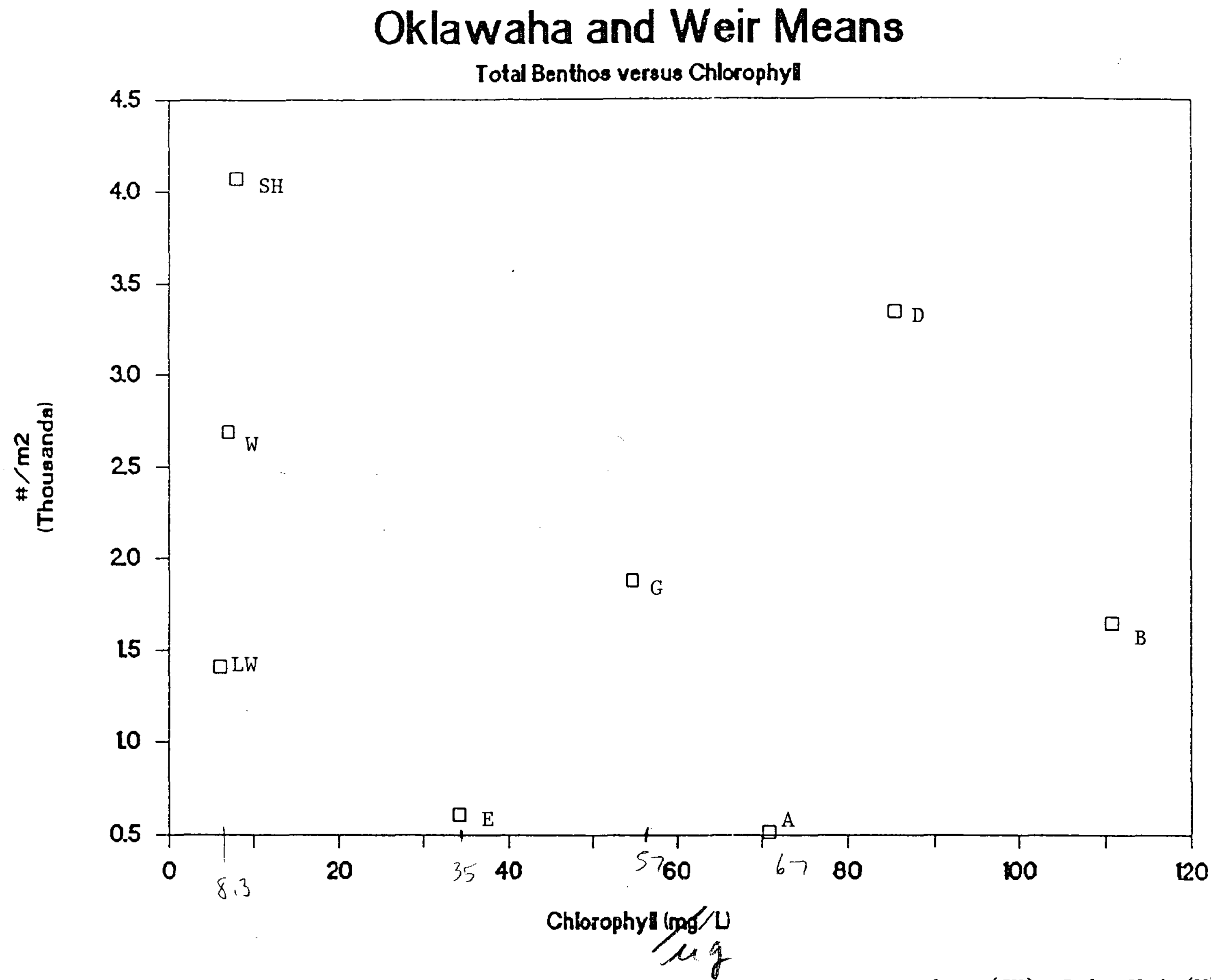


Figure 4-35. Mean abundance of total benthos for Sunset Habor (SH), Lake Weir(W), Little Lake Weir (LW), and lakes Eustis (E), Griffin (G), Apopka (A), Dora (D), and Beauclair (B).

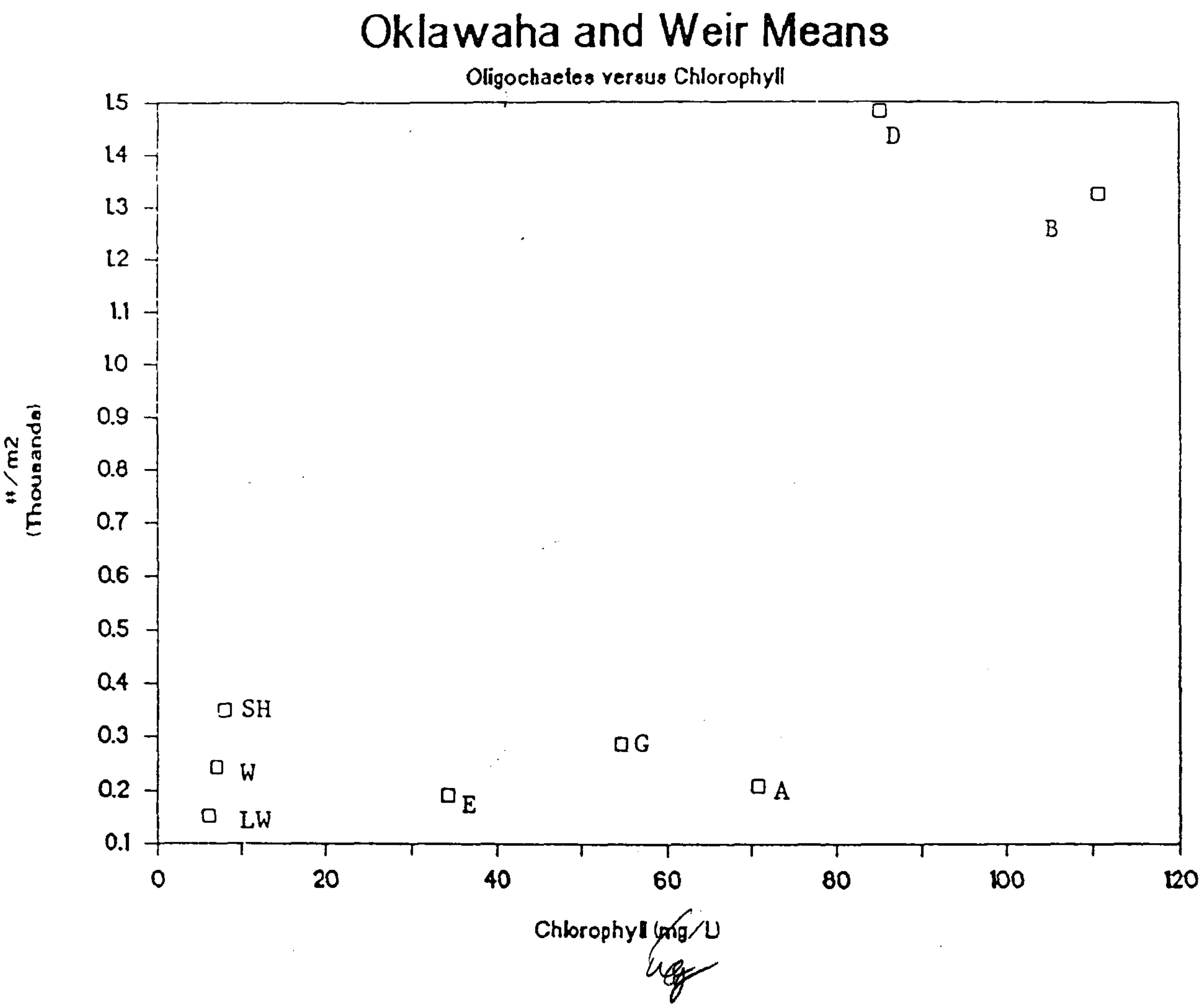


Figure 4-36. Mean abundance of Oligochaetes for Sunset Harbor (SH), Lake Weir (W), Little Lake Weir (LW), and lakes Eustis (E), Griffin (G), Apopka (A), Dora (D), and Beauclair (B).

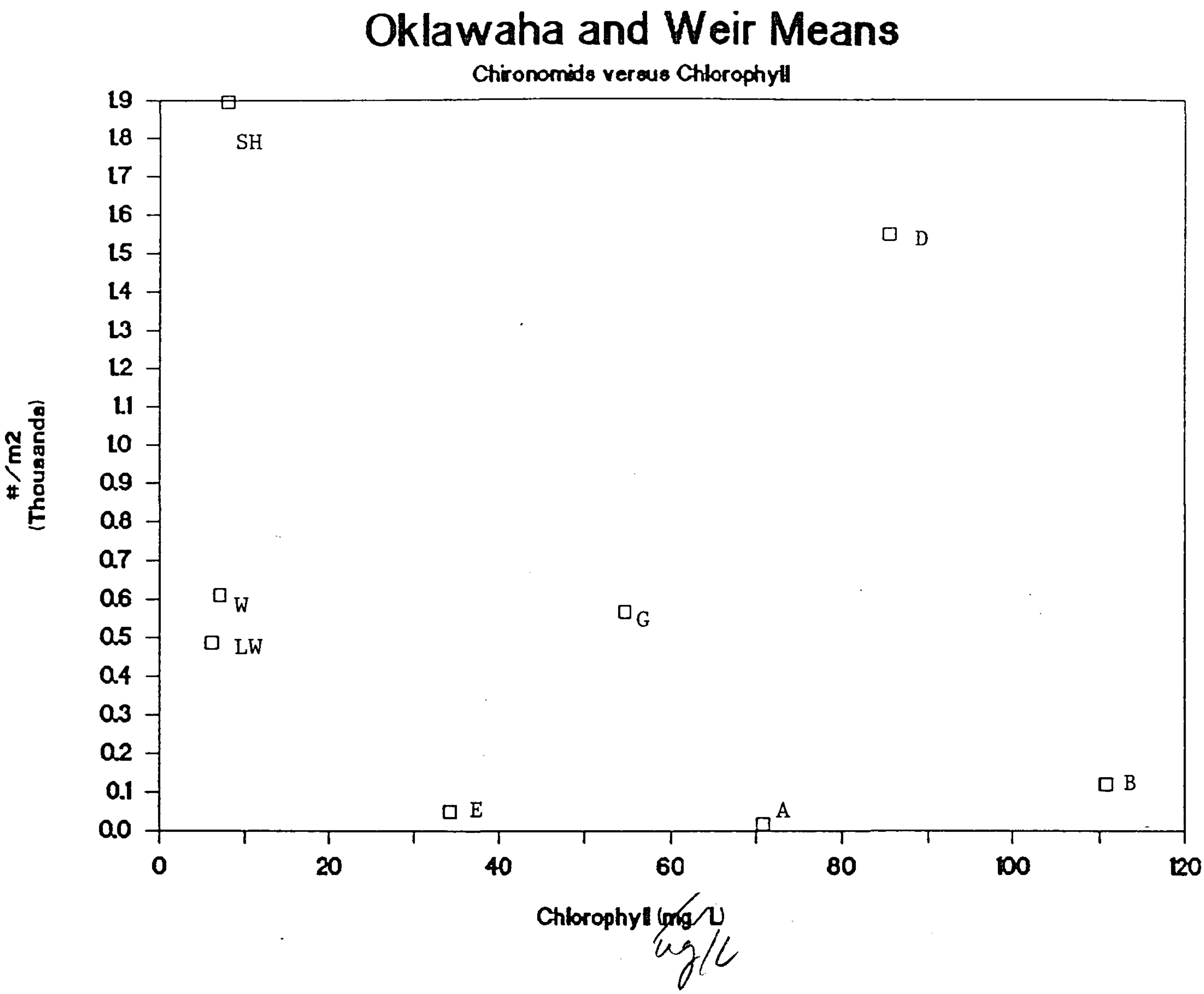


Figure 4-37. Mean abundance of chironomids for Sunset Harbor (SH), Lake Weir (W), Little Lake Weir (LW), and lakes Eustis (E), Griffin (G), Apopka (A), Dora (D), and Beauclair (B).

our work on analysis of the Florida benthos database continues during the coming year.

Fish

Lake Weir's fish assemblage is typical of many mesotrophic Florida lakes (Keller 1984, FGFWFC 1975-1986). Centrarchids such as bluegill, redear sunfish, black crappie and largemouth bass have been the dominant gamefish species historically (Table 4-20). Forage fish include threadfin shad, brook silversides, mosquitofish, Seminole killifish and golden shiners, while rough fish are represented by gar and mudfish (FGFWFC 1985). In all, 19 species of fish have been identified in Lake Weir. This value corresponds to the predicted number of species for a lake with a pH of 7.15 and a surface area of 2,086 hectares based on regression models (Table 4-21) for Florida lakes (Keller 1984).

Historical records of year class strength and the abundance of particular species are lacking because little routine monitoring of fish occurred prior to 1983 (FGFWFC 1985). At that time, the FGFWFC initiated a fish population survey in response to public concern over the onset of algal blooms and a declining black crappie fishery. This monitoring was continued in 1985 and 1986.

Survey results (Figure 4-38) indicate that the Lake Weir (only the main basin) largemouth bass population has fluctuated somewhat (from 20,722 in 1983 to 13,493 in 1987), as have those of the bluegill and redear sunfish. Such changes are normal

Table 4-20. Lake Weir fish species list*.

SCIENTIFIC NAME	COMMON NAME
Micropterus salmoides floridanus	Largemouth bass
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear sunfish
Lepomis gulosus	Warmouth
Lepomis marginatus	Dollar sunfish
Pomoxis nigromaculatus	Black crappie
Enneacanthus gloriosus	Bluespotted sunfish
Esox niger	Chain pickerel
Erimyzon succetta	Lake chubsucker
Notemigonus crysoleucas	Golden shiner
Fundulus seminolis	Seminole killifish
Gambusia affinis	Mosquitofish
Labidesthes sicculus	Brook silverside
Amia calva	Bowfin
Etheostoma fusiforme	Swamp darter
Lepisosteus platyrhincus	Florida gar
Dorosoma petenense	Threadfin shad
Ictalurus nebulosus	Brown bullhead
Ictalurus natalis	Yellow bullhead

*FGFWFC 1985.

Table 4-21. Predicted number of fish species in Lake Weir using two regression models[a] based on lake pH and lake surface area.

Model[b]	Predicted No. Species
Y = 0.42 (pH) + 1.34	18.8
Y = 0.75 (SA) + 3.55	20.8

[a]From: Keller (1984). [b]Y represents the square root of the (number of fish species + 0.05).

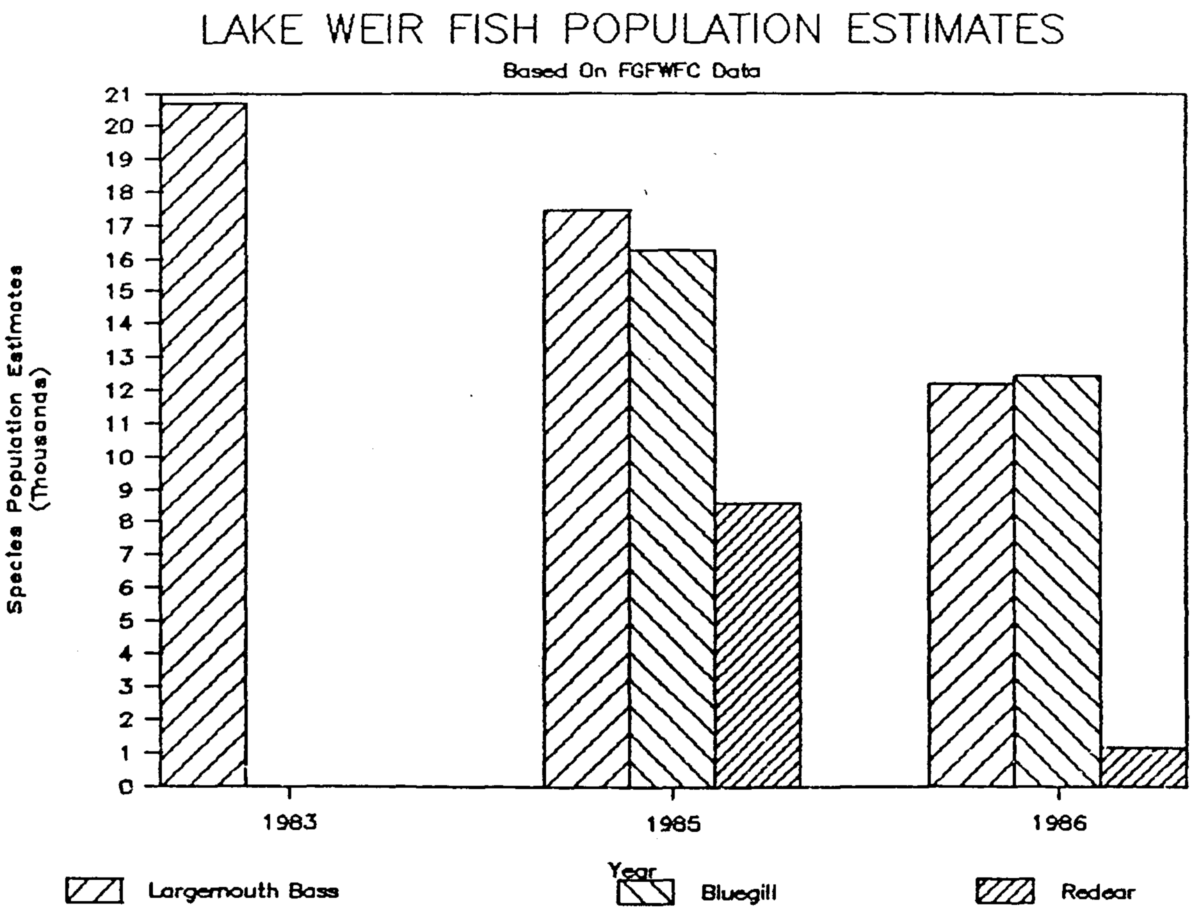


Figure 4-38. Population estimates of largemouth bass, bluegill and redear sunfish in Lake Weir (proper), Florida, 1983-1986.

responses to food availability, climatic cycles and mortality due to disease or fishing pressure. However, the complete loss of black crappie between 1982 and 1984 is not so easily explained.

Crappie Loss

Interviews with fishermen and data from creel reports indicate that in 1981-1982 almost all of the black crappie caught were large, i.e. older adults. By 1983-1984, the catch had declined dramatically and in the following year there were virtually no crappie at all. Extensive sampling by the FGFWFC with a variety of methods resulted in the capture of only eight crappie individuals between 1983 and 1988. Several hypotheses have been proposed to explain this dramatic loss. They include changes in habitat quality due to eutrophication, the colder than normal winters of 1982 and 1983, food limitations or losses, an influx of heavy metals or pesticides from the citrus groves killed by recent winter freezes, and a species-specific viral or bacterial agent (Table 4-22).

While each sunfish species exhibits some degree of food preference, they are all considered generalists (Werner 1977). That is, their diets overlap considerably. If one food type becomes limited, such fish can switch to another food source. Macroinvertebrates, forage fish and plankton appear to be abundant in recent Lake Weir samples (FGFWFC 1985 and 1986, current study). Thus, since only normal fluctuations in other sunfish generalists (i.e., bluegill and redear sunfish)

Table 4-22. Some possible causes of the loss of black crappie from Lake Weir, FL and results of analyses of each parameter.

Possible Cause	Finding	Conclusions	Reference
Fish pathogens	*Aeromonas*, white grubs	Not significant	Bitton *et al.* (1982); Goldsby and Plumb (1987).
Food limitations	abundant forage, plankton, fish, macroinvertebrates	Not a factor	FGFWFC (1983-1986); Current work.
Habitat changes	Good mixture of littoral/pelagic, sandy and soft sediments	Should not affect reproductive success	Current work.
Winter temperatures	Much colder than usual (1983-84)	Did not affect other crappie populations	FGFWFC*
Pesticides/ heavy/metals	DDE found in several fish samples, but very low. No other pesticides identified. Metals low.	Measured levels not high, but other pesticides may be present. More work suggested.	FDER (1987)

* Personal communication from Sam McKinney, Ocala office of the FGFWFC.

occurred between 1983-86 in Lake Weir, it is not likely that crappie were lost because of food limitations.

The habitat requirements for successful recruitment of sunfish species commonly found in Lake Weir are similar (Carlander 1977). Sunfish build nests in sandy areas along the border between open water and vegetation. They prefer fairly compact sediments which are common along the shoreline of Lake Weir. The open water/plant interface is an important boundary for large size classes of crappie, bluegill and redear sunfish. Black crappie become more pelagic as they mature, while the bluegill and redear sunfish remain in the littoral zone. Since both pelagic and littoral zones are present in Lake Weir, loss of habitat cannot explain the extinction of crappie.

Statistical comparisons between current and historical estimates of Lake Weir's trophic state indicate that while there has been no significant change during the past 20 years (See Tables 4-24, 4-25), recent phosphorus levels are higher and Secchi depth is lower than the annual means of past data. While Lake Weir is still oligo-mesotrophic, there may be a trend toward increasing lake productivity. Data from five Florida lakes (Apopka, Dora, Griffin, Newnan's and Ocean Pond) collected by the Florida Game and Fresh Water Fish Commission demonstrate the adaptability of black crappie to increasing trophic state (Figure 4-39). As chlorophyll a concentration increases so does the biomass of crappie. Therefore, Lake Weir crappie harvest should have increased with any increase in trophic state.

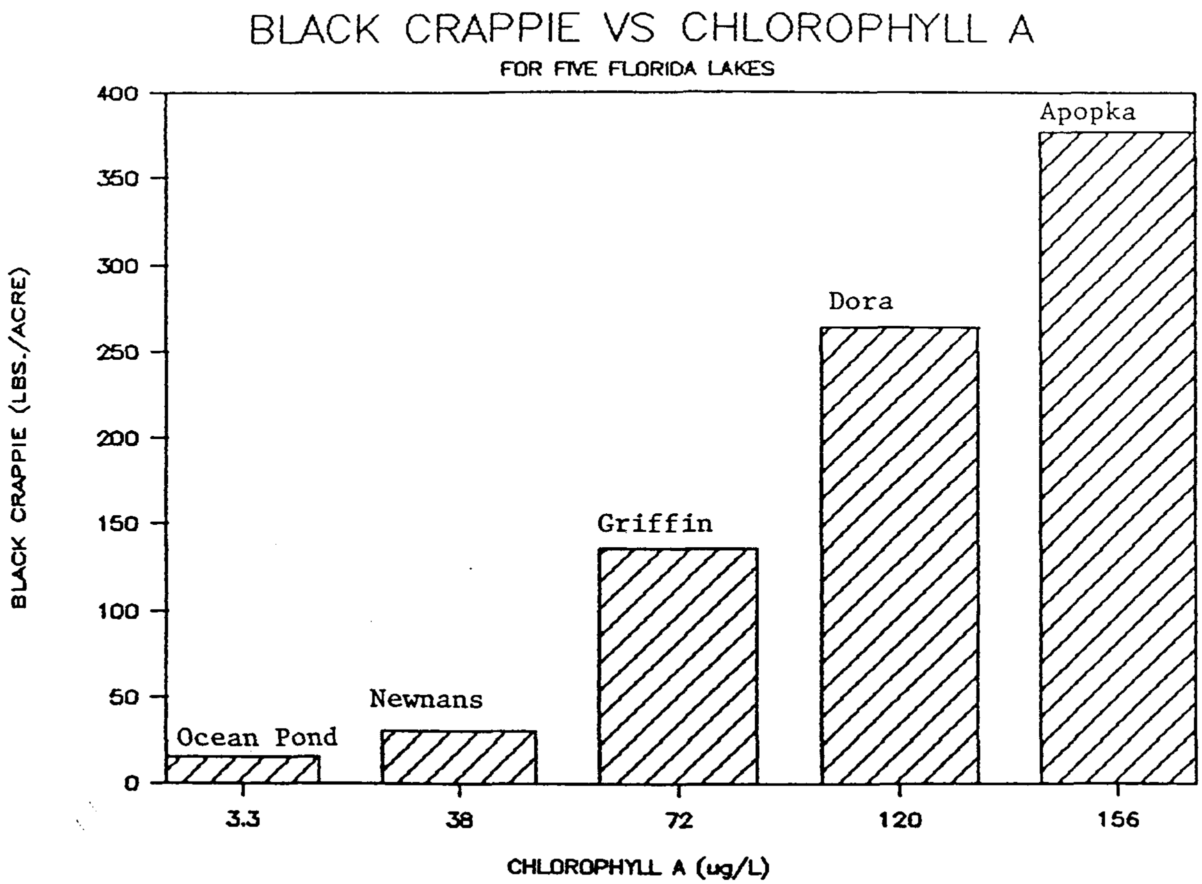


Figure 4-39.Biomass of black crappie relative to lake chlorophyll a levels (Data from FGFWFC Annual Reports).

Extremely cold winters can lead to recruitment failure in fish populations for several reasons. Adults can be killed, the forage base may decline and/or eggs or fry may be adversely affected in early spawning species. Small, shallow lakes are more likely to experience fish losses due to extreme weather than are deeper lakes. In 1983 and 1984, the winters were inordinately cold. Since black crappie spawn in late winter or early spring, it is possible that their recruitment failed in those years due to the cold. Indeed, some decline in other sunfish including largemouth bass and bluegill was detected in population surveys conducted in 1985 and 1986 (FGFWFC 1986). However, crappie populations in nearby shallower lakes were not lost (FGFWFC). It does not appear that cold weather killed the crappies.

A substantial citrus industry has flourished within the Lake Weir watershed since the late 1800's (Shackleford 1883). In the decades since World War II, the use of agricultural pesticides has increased steadily for all crops. Citrus growers have used a variety of these chemicals to boost crop production and minimize harvest effort. Pesticides have included organics such as DDT, aldrin and chlordane as well as compounds containing copper. With continual use, such chemicals accumulate in the trees and soils, and eventually they can begin to leach into lakes with runoff from rain.

Lake sediment, water and fish tissue samples were collected in 1986 by the FGFWFC for analysis of heavy metal and pesticide content. Results of analyses by the FGFWFC, Florida

Department of Health and Rehabilitative Services, and Florida Department of Environmental Regulation (Table 4-23) detected virtually no heavy metals or pesticides in the samples (FGFWFC 1986). Copper ranged from 0.3-0.6 mg/kg wet weight, mercury from 0.09-0.85 mg/kg, zinc from 4.5-10.9 mg/kg and lead from 0.37-0.61 mg/kg. A few samples of largemouth bass had low but detectable amounts of DDE, a degradation product of DDT. The levels encountered, however, were not considered to be hazardous to fish (FGFWFC 1986).

There is nothing to suggest that black crappie are more vulnerable to pesticides than are largemouth bass. Consequently, it seems unlikely that influxes of pesticides from decaying citrus trees or grove soils eliminated the crappie. However, further examination of fish tissue herbicide burdens and levels of previously unmeasured organic compounds may be performed in 1988.

Finally, Auburn University researchers Terry Goldsby and Dr. John Plumb have taken blood, muscle and organ samples from largemouth bass and bluegills to screen for pathological agents. Their findings indicate that parasite burdens may be a factor in the fish deaths occurring in Lake Weir. However, there is no indication of an unusual disease vector, and there was no largescale die-off of crappie.

Both white grubs and bacterial pathogens are common among natural fish populations (Hoffman 1967). It still remains unknown whether a species-specific agent killed the crappie population. We cannot test such a theory without an extant

Table 4-23. Heavy metal concentrations in fish and hydrosoil samples from Lake Weir (1986).*

Fish Species	Total Length (mm)	Cd	Cu	Hg	Pb	Zn
		(mg/kg wet weight)				
Largemouth bass	538	0.05	0.6	0.45	0.46	5.4
Largemouth bass	463	BDL**	0.4	0.62	0.46	6.1
Largemouth bass	1320	BDL	0.5	0.85	0.61	4.5
Bluegill	91	BDL	0.4	0.10	0.37	9.5
Bluegill	66	BDL	0.3	0.10	0.40	10.9
Bluegill	79	BDL	0.6	0.09	0.40	9.1
				(MDL = 0.03)		

Soil	Cd	Cu	Hg	Pb	Zn
	(mg/kg dry weight)				
#1	0.07	3.4	0.04	2.31	11.7
#2	0.05	2.2	0.04	2.31	9.0
#3	0.03	1.1	BDL	1.59	3.7
			(MDL = 0.04)		

* Analyses performed by FGFWFC.
** BDL = Below Detection Limits; MDL = Minimum Detection Limits.

population and proposed disease-causing agent. Black crappie were stocked in Lake Weir in 1986 and 1987 (FGFWFC) but have not been detected to date after extensive population sampling efforts. No further stocking or fish sampling is scheduled for 1988.

After examining the possible causes for the dramatic loss of the black crappie fishery, no obvious explanation exists. Extreme fishing pressure, inappropriate use of herbicides or other factors can contribute to fish population changes. But even these suggestions can be ruled out for Lake Weir since neither has occurred (FDNR and FGFWFC, personal communication). Perhaps a combination of factors led to the loss. If crappie can be re-established by stocking, the problem will be solved although an explanation for their current demise may be lacking. If not, further efforts to identify the factor or factors that killed the crappie will probably continue.

Historical Limnological Data

Data were extracted from various University of Florida theses, and reports unpublished data from the Department of Environmental Regulation, Florida Game and Fresh Water Fish Commission, United States Geological Survey and St. Johns River Water Management District for analysis of trends in water quality changes over the past 30 years (Table 4-24). Means were calculated by year, and station numbers were assigned to correspond to our current sampling stations. Statistical analyses were performed using SAS (1986).

Table 4-24. List of studies containing water chemistry data from Lake Weir from 1968-1987.

Reference[a]	Study Date	No. Sample Dates	Sample[b] Station
FGFWFC 1968	1967-1968	26	2,4,6
Shannon 1971	1969-1970	6	3[c]
FGFWFC 1973	1972-1973	2	3
Messer 1975	1974-1975	12	3[c]
Beaver 1980	1979	12	3[c]
Canfield 1981	1979-1980	3	3[c]
Garren 1982	1981	1	3
FDER 1987	1975-1986	46	3,5,6[c]
USGS 1987	1956-1983	40	2

[a] Complete citation in Literature Cited. [b] Stations designated to correspond to current sampling stations in Lake Weir. [c] Data used for comparison between historical and current water chemistry parameters.

Comparisons between current and past records of phytoplankton (Messer 1975), and macrophyte abundance and species lists (Garren 1982, FGFWFC 1985 and 1986) were made using data from several University of Florida theses, and reports by the Florida Game and Fresh Water Fish Commission.

Comparisons of Historical vs Current Data

A. Water Quality

Records of water quality parameters in Lake Weir have been maintained by various agencies since 1956 (Appendix C). However, virtually no measurements of chlorophyll a are available for years prior to 1969, and other parameters were only intermittently recorded over the years (e.g. Secchi depth, turbidity and alkalinity). Numerous samples were taken at multiple stations in some years, while for others only 1 midlake sample was analyzed. Therefore, comparisons between these past data and current conditions in Lake Weir were based on means calculated for 1969, 1975, 1979, 1981, and 1984-1985 from the midlake station, and those from our first year's sampling effort. Data were most abundant for that station, and it is more indicative of overall conditions in Lake Weir due to its location and depth.

Analyses of past and current annual means of chlorophyll a, TKN, TP, and Secchi depth in Lake Weir by ANOVA and Duncan's procedure indicate that there are no significant differences among the years except for Secchi depth (Tables 4-25, 4-26, Figure 4-40). However, the decline in Secchi depth transpar-

Table 4-25. Summary of historical and current values for four water quality indicators at Station 3 in Lake Weir, FL.

Parameter	Historical Value* Mean ± S.D (N)	Current Value Mean ± S.D (N)
Chlorophyll *a* (ug/L)	8.01 ± 1.30 (32)	6.78 ± 2.69 (11)
Total phosphorus (ug/L)	28.08 ± 16.29 (34)	50.60 ± 33.18(10)
Total Kjeldahl nitrogen (ug/L)	854.17 ± 180.44 (32)	760 ± 145.70 (9)
Secchi depth (m)	1.94 ± 0.34 (35)	1.54 ± 0.22 (11)

*Historical values based on data from 1969, 1975, 1979, 1980, 1984-85.

Table 4-26. Results of comparisons of indicators of historical and current trophic state in Lake Weir by ANOVA and Duncan's procedure. Years connected by the same underline are not significantly different.

Parameter	N	F	Significance
Chlorophyll *a*	43	1.44	n.s.
Total Kjeldahl nitrogen	41	1.65	n.s.
Total phosphorus	44	3.07	n.s.
Secchi depth	46	4.60	*

Year	80	79	85	69	75	87	84
	—	—	—	—	—		
		—	—	—	—	—	
					—	—	—

n.s.=not significant; * Significant at $p \leq 0.05$.

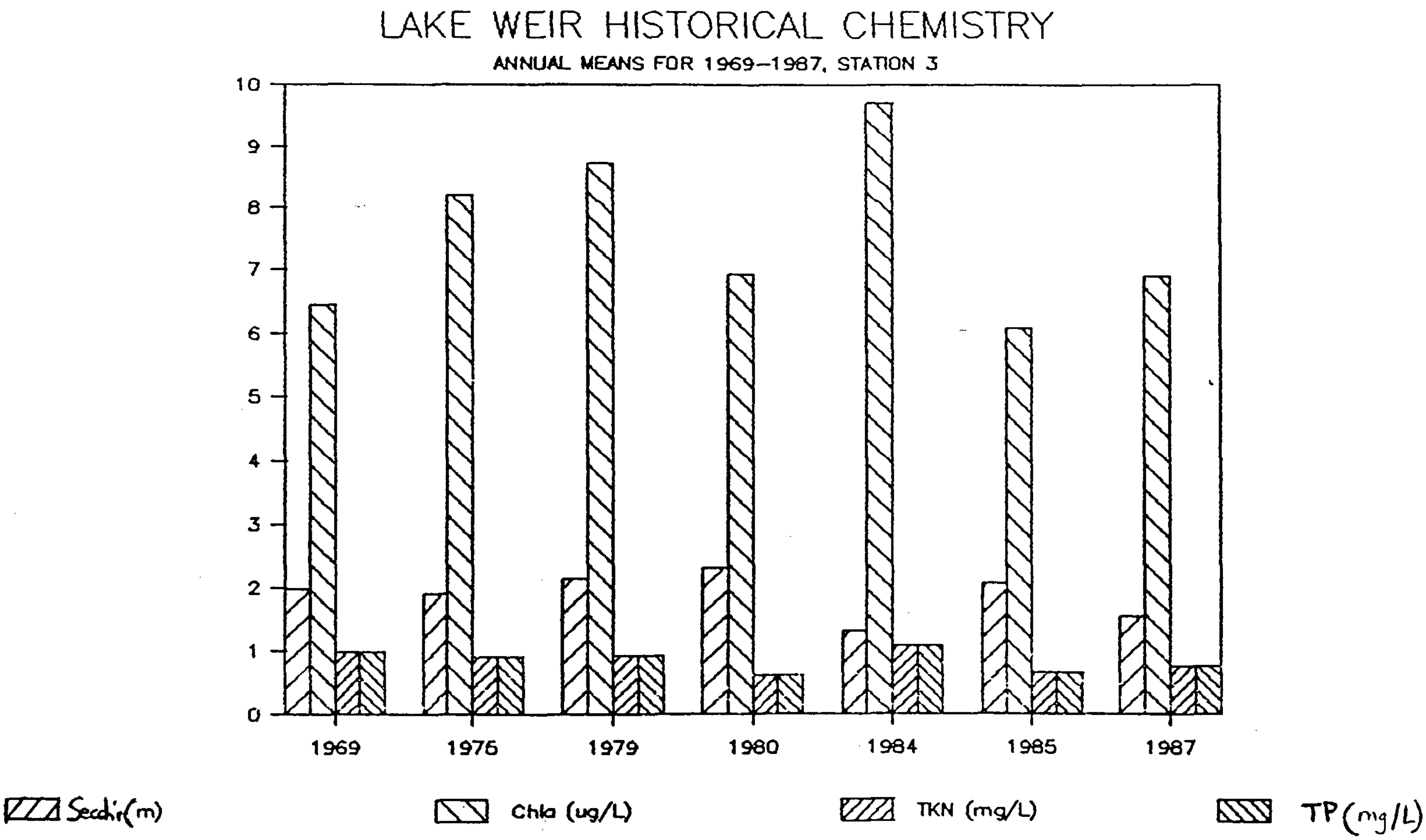


Figure 4-40. Annual means of Secchi depth (m), chlorophyll a (ug/l), total Kjeldahl nitrogen (mg/L) and total phosphorus (mg/L) for 1969-1987.

ency has not been continuous over the years. Since the human population around Lake Weir has risen continuously, climatic changes such as rain and drought may be as much a factor in determining water clarity as development, septic input, or other human impacts. Sampling frequency, station locations, and analytical methodologies used by various agencies and researchers whose historical data we used may also have dampened our ability to see statistical differences.

Trophic state indices (TSI) were calculated from both historical and current means of Secchi depth, chlorophyll a concentration, total nitrogen and total phosphorus (Table 4-27). These indices take into account the relationship between lake primary production and nutrient concentrations, chlorophyll a levels, and water clarity (Huber et al. 1982). As lake production increases, the TSI rises. Comparisons of these values enabled us to evaluate changes in the overall trophic level of Lake Weir based on several parameters.

Little difference existed between the indices based on past data and those calculated from current measurements. All values placed Lake Weir in the mesotrophic category. However, as with the water chemistry data, the historical TSI for chlorophyll a was slightly lower than the TSI based on current data, while the other TSI rose. The TSI calculated from Secchi depth increased the most.

Table 4-27. Trophic state indices (Huber *et al.* 1982) calculated from historical and current values for Lake Weir water quality at Station 3.

TSI	Historical Value	Current Value	Trophic* State
Chlorophyll *a*	46.76	44.55	O-M
Total phosphorus	43.63	51.56	M
Total Kjeldahl nitrogen	52.87	50.77	M
Secchi depth (m)	40.05	47.00	M

* O=oligotrophic, M=mesotrophic;

B. Bacteria

No historical water column bacteria data for Lake Weir have been located to date. Thus, no comparisons between current and past bacteria data are possible.

C. Phytoplankton

A species list for the current sampling period is not available at this time. Messer (1975) collected monthly samples at a midlake station in Lake Weir during 1974-1975. The dominant algal species at that time were the cyanophytes *Chroococcus rufescens*, *Lyngbya digueti*, *L. contorta*, *L. putealis*, and *Microcystis aeruginosa*, and the dinoflagellate *Glenodinium quadriens* (Table 4-28). There was little relationship between chlorophyll *a* levels and phytoplankton cell densities (Figure 4-41).

D. Macrophytes

Macrophytes were identified during four surveys conducted on Lake Weir (Messer 1975, Garren 1982, FGFWFC 1985 and 1986). Seventeen species were encountered in 1975, nine in 1982, 15 in 1985, and 17 in 1986. The change in number of species recorded in 1982 (9 species) compared to the other years (15-17 species) is probably the result of less complete sampling and identification during 1982 (Table 4-29). Compared to 14 Florida lakes studied by Garren (1982), the macrophyte community of Lake Weir is similar to that of other neutral pH lakes.

While no detailed survey of macrophyte species has been undertaken at Lake Weir during this study, we have noted the presence of most of the listed species. The emergent plants,

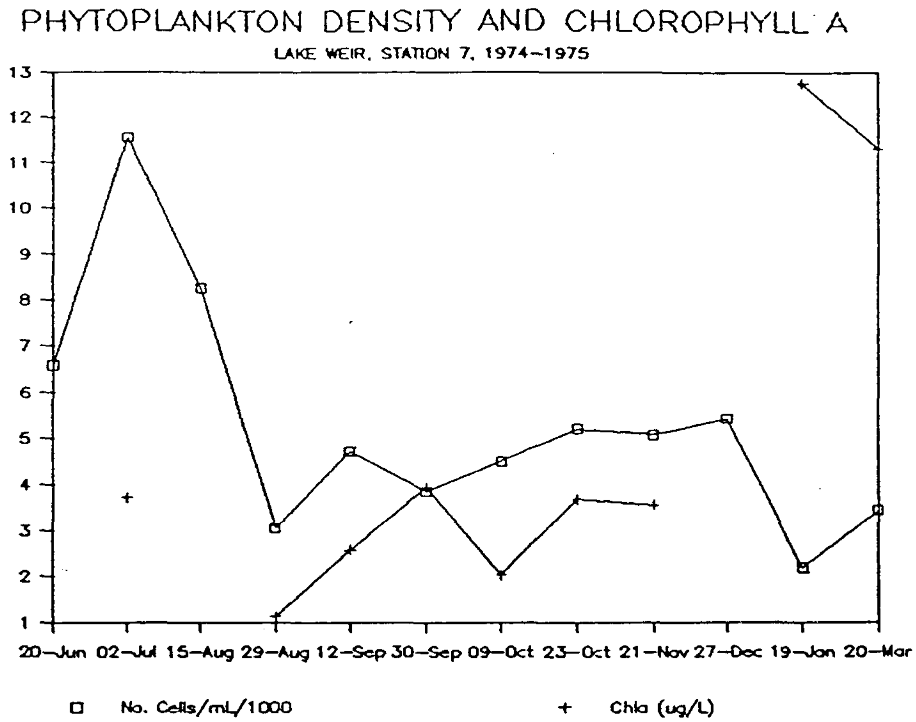
Table 4-28. Historical phytoplankton abundance and chlorophyll a data for Lake Weir, Florida.*

Date	Station [a]	Mean No. Cells/mL	Dominant Species [b]	Chlorophyll a Concentration [c]
6-20-74	3	8,022	L	-
	6	9,541	L	-
	7	6,573	L	-
7-2-74	3	5,175	L	5.57
	6	3,680	L	8.25
	7	11,563	L	3.71
7-26-74	3	8,518	L,C	5.40
8-15-74	3	8,265	L,C	1.61
	6	3,174	L,C	-
	7	8,268	L,C	-
8-29-74	3	8,364	L,C	5.92
	7	3,048	L,C	1.14
9-12-74	3	6,187	L,C,L',L"	4.33
	7	4,710	C,L	2.57
9-30-74	3	8,223	L,C	4.77
	6	4,562	L,C	4.06
	7	3,834	L,C	3.92
10-9-74	3	11,088	L,C	4.57
	6	9,452	L,M,C	1.51
	7	4,494	L,C	2.03
10-23-74	3	10,169	L,C,M	4.65
	7	5,203	L,S,C,M	3.66
11-21-74	3	7,843	L,C	4.33
	6	5,458	L,C,M	3.55
	7	5,063	L,C,D	3.54
12-27-74	3	6,320	M,L	27.26
	6	3,625	M,L,G	-
	7	5,422	C,G,L	-

Table 4-28. Continued

Date	Station [a]	Mean No. Cells/mL	Dominant Species [b]	Chlorophyll a Concentration [c]
1-19-75	3	8,809	M,L,G,C	7.56
	6	6,650	M,G,L	5.49
	7	2,184	M,L,G,Q	12.76
3-20-75	3	10,946	M,G,L	22.54
	6	8,855	M,G,L	17.57
	7	3,427	M,G	11.31

*From: Messer 1975. [a] Station numbers were reassigned here to coincide with current monitoring stations.
[b] C = _Chroococcus rufescens_, D = Pennate Diatom, G = Coccoid Green Alga, L = _Lyngbya diqueti_, L' = _L. contorta_, L" = _L. putealis_, M = _Microcystis aeruginosa_, Q = _Glenodinium quadriens_, S = _Synedra ulna_. [c] ug/l. Samples are from water column composites at 0, 1, 3, and 5 m (7 m included for station 3).



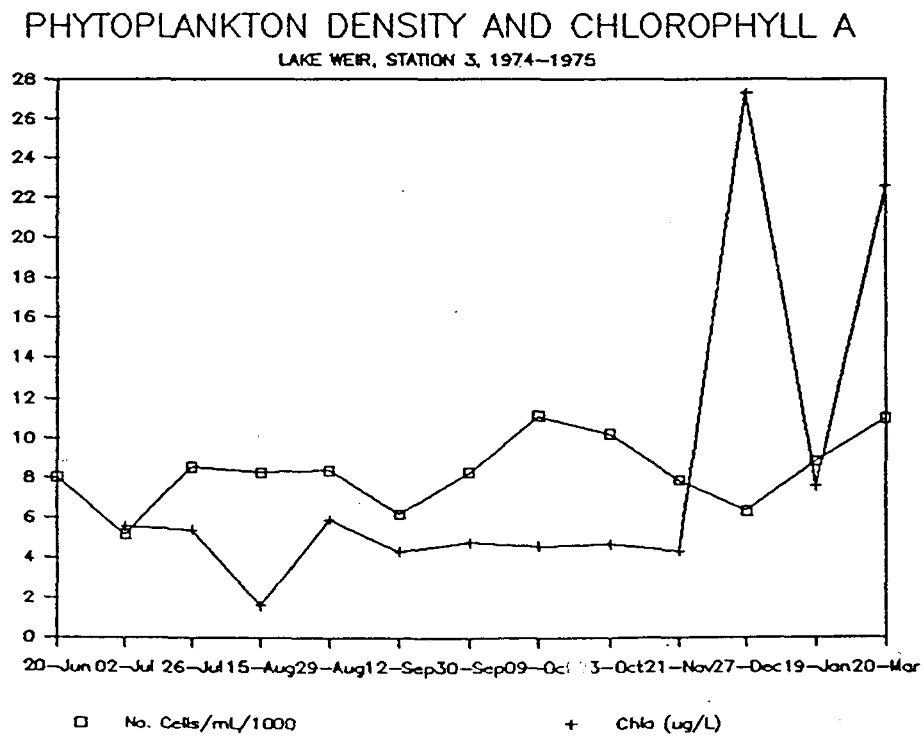


Figure 4-41. Seasonal fluctuations in phytoplankton cell densities and chlorophyll *a* levels at stations 3, 6 and 7 in Lake Weir, Florida (From: Messer 1975).

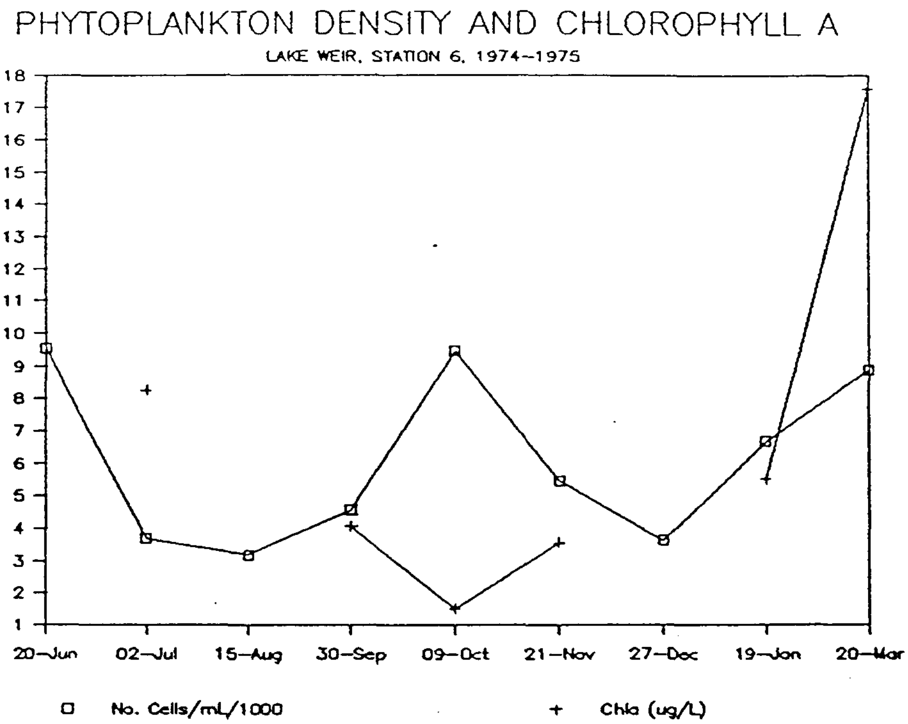


Figure 4-41. Continued.

Table 4-29. Macrophyte composite species list from various studies of Lake Weir.

	SURVEY YEAR*			
	1974	1982	1985	1986
EMERGENT SPECIES				
Panicum hemitomon	X			
Panicum sp.			X	X
Cyperus lecontei		X		
Cladium jamaicensis	X		X	X
Fuirena scirpoidea	X			
Juncus effusus	X			
Saururus cernus		X		
Scirpus sp.	X			
Eleocharis elongata	X	X	X	X
Peltandra virginica	X			
Pontederia lanceolata	X		X	X
Sagittaria lancifolia	X	X	X	X
Typha latifolia	X			
Typha sp.			X	X
SUBMERGENT SPECIES				
Hydrilla verticillata	X		X	
Ludwigia sp.	X			
Potamogeton illinoensis	X	X	X	X
Utricularia floridana	X			
Utricularia sp.		X	X	X
Eleocharis baldwinii				X
Bacopa caroliniana		X	X	X
Vallisneria americana			X	
Najas guadalupensis			X	
Sagittaria subulata			X	X
Nitella sp.			X	X
Chara sp.			X	X
FLOATING-LEAVED SPECIES				
Nymphoides aquaticum	X	X		
Nuphar luteum		X	X	X
Nymphaea odorata	X		X	X
FLOATING SPECIES				
Eichhornia crassipes	X			

* Messer (1975); Garren (1982); FGFWFC (1985); FGFWFC (1986).

e.g. Panicum sp., Juncus sp., Cladium sp., Peltandra sp., Pontederia sp. and Typha sp., dominate the narrow littoral zone and the channel connecting Sunset Harbor with Little Lake Weir. Submergent plants have been found in conjunction with the emergents and are apparent in the canal, as well as in areas of Sunset Harbor. Water lilies (Nymphaea odorata, Nuphar luteum and Nymphoides aquaticum) have colonized the shoreline in patches, most significantly near Bird Island, in the canal to Little Lake Weir and in various areas of Lake Weir itself. Water hyacinth (Eichhornia crassipes) has infested protected waters connected to the Sunset Harbor-Little Lake Weir canal.

CONCLUSIONS

With the completion of a full year of monitoring, we can now make comparisons between current and historical conditions in Lake Weir. Water quality in the main lake has not changed significantly over the last 20 years, based on nutrient concentrations, chlorophyll a and Secchi depth. While trophic state indices calculated from these parameters have increased slightly, Lake Weir is still classified as mesotrophic. The macrophyte community appears to be stable in both extent and species composition, and is typical of moderately productive Florida lakes. Zooplankton biomass in Lake Weir is low compared to other mesotrophic lakes in the state, but only minor changes in community structure have occurred since 1979. Specifically, scuticociliate protozoans and rotifers have markedly increased in abundance indicating a shift toward greater lake productivity. So few phytoplankton or benthic macroinvertebrate data are available from past studies that no real comparisons are possible for these parameters.

Overall, Lake Weir appears to be a typical mesotrophic Florida lake that is responding as expected to increased human use and watershed development. Further work on the paleolimnological samples will shed new light on the changes in nutrient input from the watershed. This will provide a more complete picture of what has already occurred in the lake, and allow predictions of changes to come.

CHAPTER FIVE:
PALEOLIMNOLOGY OF LAKE WEIR

This project employs paleolimnology, the reconstruction of past water quality from lake sediment cores. By correlating historical trends in water quality to concomitant development within the watershed, we may be able to pinpoint the activities which have contributed most heavily to observed changes in water clarity. With such insight, we could determine whether restoration efforts would even be appropriate, and what the most effective management strategies would be.

Other paleolimnological work has been conducted at Lake Weir, chiefly by Thompson (1981), Flannery (1982) and Deevey et al (1986). Additional unpublished data exist in Deevey's laboratory. In addition to estimating accumulation rates of organic and inorganic sediment, chlorophyll a, nutrients and metals, these studies also examined diatom and pollen stratigraphies. The current investigation examines stratigraphic changes in water, organic, and inorganic content of sediment, phosphorus concentrations, ratios of various photosynthetic pigments, and subfossil remains of chydorids, chironomids, and select green algae. Core intervals will be dated by measuring lead-210 isotopic decay with the hope that annual accumulation rates of each of the above parameters can be estimated.

Core Collection

Sediment cores for paleolimnological analyses were collected from six sites in Lake Weir, Sunset Harbor and Little Lake Weir in 1987 and 1988 (Figure 5-1, Table 5-1). Cores were collected using a modified Livingstone piston coring apparatus equipped with 4.1 cm ID cellulose buterate tubes. Appropriate caution was exercised to ensure preservation of the sediment-water interface. Visual observations of the cores were made in the field and again during sectioning in the lab in order to detect changes in sediment color or texture which might provide insight on the depositional environment.

Each core was sectioned into 0.5 cm intervals to a depth of 30 cm, and into 1.0 cm intervals below that. The upper intervals contained roughly 6 cc while the lower intervals had over 12 cc of sediment. Because the amount of sediment was limited, small portions of alternating intervals were allotted for each analysis in order to conserve material for lead-210 dating. Each core was carefully mapped out for this purpose (Table 5-2).

Physical Sediment Parameters

In order to measure the accumulation rates of nutrients, pigments, or subfossil remains, it is necessary to factor out changing sedimentation rates. This is accomplished by coupling lead-210 isotopic dating with Loss-On-Ignition (LOI) data. LOI procedures, used here to quantify water, organic and inorganic content of the sediment, will be performed on all six cores.

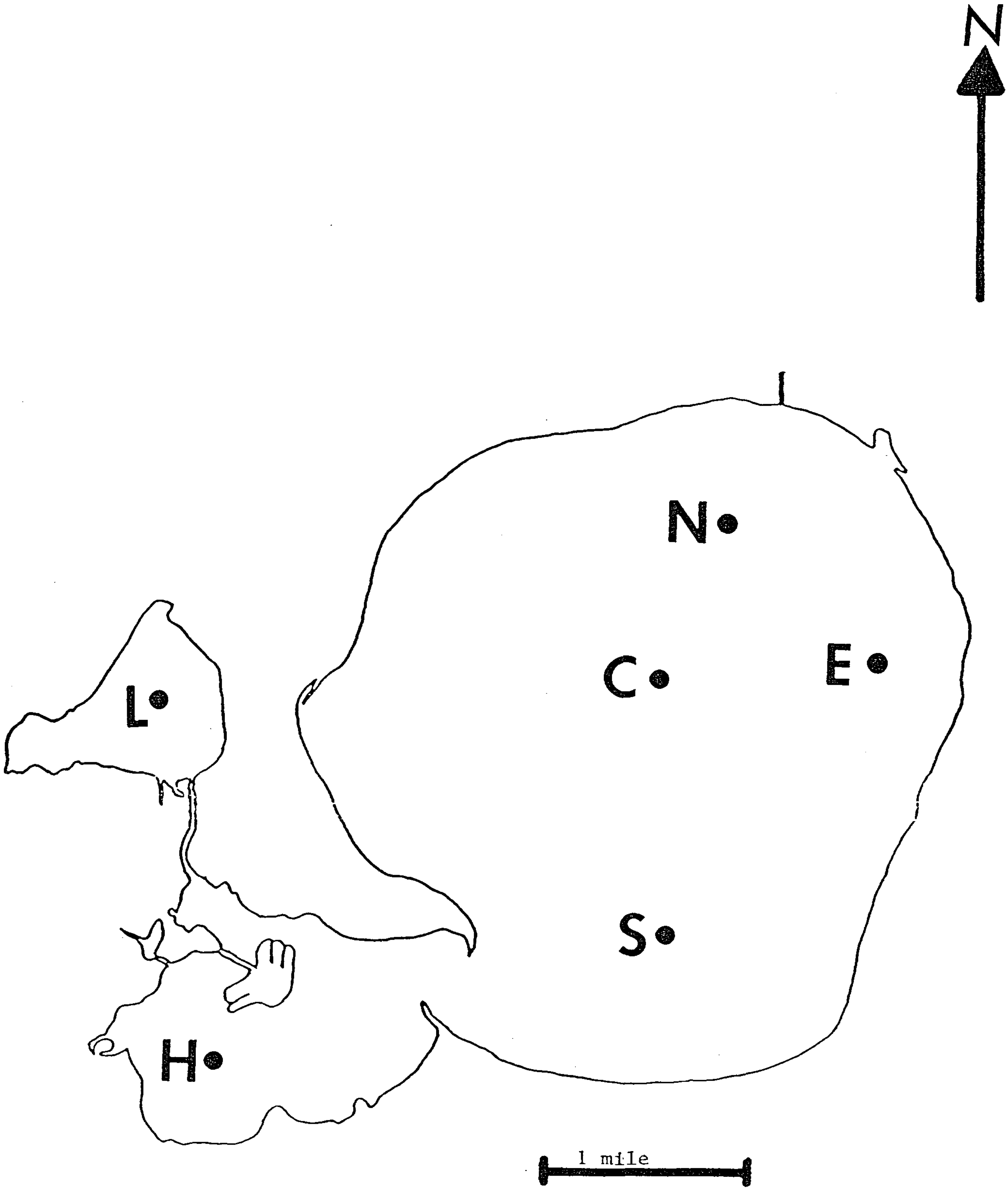


Figure 5-1. Map of Lake Weir, Florida showing six core sites.

Table 5-1. Sediment core collection data for Lake Weir, FL.

Core Name	Location	Date	Number of Cores	Lengths(cm)
E	East Lake Weir	26 Feb 87	1	109
C	Center Lake Weir	26 Feb 87	1	120
N	North Lake Weir	14 Dec 87	2	111, 162
S	South Lake Weir	14 Dec 87	1	119
H	Sunset Harbor	14 Dec 87	2	110, 117
L	Little Lake Weir	6 Mar 88	2	132, 124

Table 5-2. Outline of paleolimnological analyses to be run on the sediment core from north Lake Weir. Analyses were run on alternating intervals to conserve sediment.

Top of Interval (cm)	Water & Organics (cc)	Fossils (cc)	Phosphate (cc)	Pigments (cc)	Lead-210 Dating (cc)	Sedimen Remaini (cc)
0.0					Top	6
0.5					interval	6
1.0		1.0			taken from	5
1.5			1.0		backup	5
2.0	1.0				core	5
2.5				5.0		1
3.0		1.0		5.0		0
3.5			1.0			5
4.0	1.0					5
4.5						6
5.0		1.0				5
5.5			1.0			5
6.0	1.0			5.0		0
6.5				5.0		1
7.0		1.0				5
7.5			1.0			5
8.0	1.0					5
8.5						6
9.0		1.0				5
9.5			1.0	5.0		0
10.0	1.0			5.0		0
10.5					5.0	1
11.0		1.0			5.0	0
11.5			1.0		5.0	0
12.0	1.0				5.0	0
12.5					5.0	1
13.0		1.0			5.0	0
13.5			1.0		5.0	0
14.0	1.0				5.0	0
14.5				5.0		1
15.0		1.0		5.0		0
15.5			1.0			5
16.0	1.0					5
16.5						6
17.0		1.0				5
17.5			1.0			5
18.0	1.0			5.0		0
18.5				5.0		1
19.0		1.0				5
19.5			1.0			5
20.0	1.0					5
20.5						6
21.0		1.0				5
21.5			1.0	5.0		0
22.0	1.0			5.0		0
22.5					5.0	1
23.0		1.0			5.0	0
23.5			1.0		5.0	0
24.0	2.0				4.0	0
24.5					6.0	0
25.0		1.0			5.0	0
25.5			1.0		5.0	0

Table 5-2. (Continued).

Top of Interval (cm)	Water & Organics (cc)	Fossils (cc)	Phosphate (cc)	Pigments (cc)	Lead-210 Dating (cc)	Sedimen Remaini (cc)
26.0	1.0				5.0	0
26.5				5.0		1
27.0		1.0		5.0		0
27.5			1.0			5
28.0	1.0					5
28.5						6
29.0		1.0				5
29.5			1.0			5
30	1.0					11
31		1.0		10.0		1
32			1.0			11
33						12
34						12
35	1.0					11
36		1.0				11
37			1.0		10.0	1
38					10.0	2
39					10.0	2
40	1.0				10.0	1
41		1.0		10.0		1
42			1.0			11
43						12
44						12
45	1.0					11
46		1.0				11
47			1.0			11
48						12
49						12
50	2.0					10
51		1.0		10.0		1
52			1.0			11
53						12
54						12
55	1.0					11
56		1.0				11
57			1.0		10.0	1
58					10.0	2
59					10.0	2
60	1.0				10.0	1
61		1.0		10.0		1
62			1.0			11
63						12
64						12
65	1.0					11
66		1.0				11
67			1.0			11
68						12
69						12
70	1.0					11
71		1.0		10.0		1
72			1.0		10.0	1

Table 5-2. (Continued).

Top of Interval (cm)	Water & Organics (cc)	Fossils (cc)	Phosphate (cc)	Pigments (cc)	Lead-210 Dating (cc)	Sedimen Remaini (cc)
73					10.0	2
74					10.0	2
75	1.0				10.0	1
76		1.0				11
77			1.0			11
78						12
79						12
80	1.0					11
81		1.0		10.0		1
82			1.0			11
83						12
84						12
85	1.0				10.0	1
86	1.0	1.0			10.0	0
87			1.0		10.0	1
88	1.0				10.0	1
89						12
90	1.0					11
91		1.0		10.0		1
92	1.0		1.0		10.0	0
93					10.0	2
94	1.0				10.0	1
95	1.0				10.0	1
96		1.0				11
97	1.0		1.0			10
98						12
99						12
100	2.0					10
101		1.0		10.0		1
102	1.0		1.0		10.0	0
103					10.0	2
104	1.0				10.0	1
105	1.0				10.0	1
106	1.0	1.0				10
107			1.0			11
108	1.0					11
109						12
110	1.0					11

The following discussion deals with the North Core; the others are currently in progress.

Thirty-one samples consisting of 1.0 cc of sediment were removed at 2 cm intervals down to a core depth of 30 cm, and at 5 cm intervals below that. Thirty additional samples were run from alternating intervals throughout the core for LOI and subsequent total phosphorus analysis. Nine additional samples were run at lower intervals to further delineate two inorganic peaks. In all, 70 samples were included in the core's physical profile.

Samples were placed in small porcelain crucibles of known dry weight, and wet weight was measured using a Mettler analytical balance. Water loss was measured after drying the samples at 100°C for 24 hours. The inorganic and organic fractions were determined by weight loss on ignition at 550°C for one hour. Samples were allowed to cool to room temperature in a dessicator before weighing. Replicate samples were run on three select levels, and several samples were reweighed in each step to ensure precision.

While much of the core showed little variation in sediment water, inorganic and organic content, several distinct periods of change were evident (Figure 5-2). These transitional periods may correspond to dates of known watershed disturbances. Lead-210 dating will be necessary to establish this, but for now we may guess the dates of these episodes by assuming the sedimentation rate of 0.5 cm per year. This was

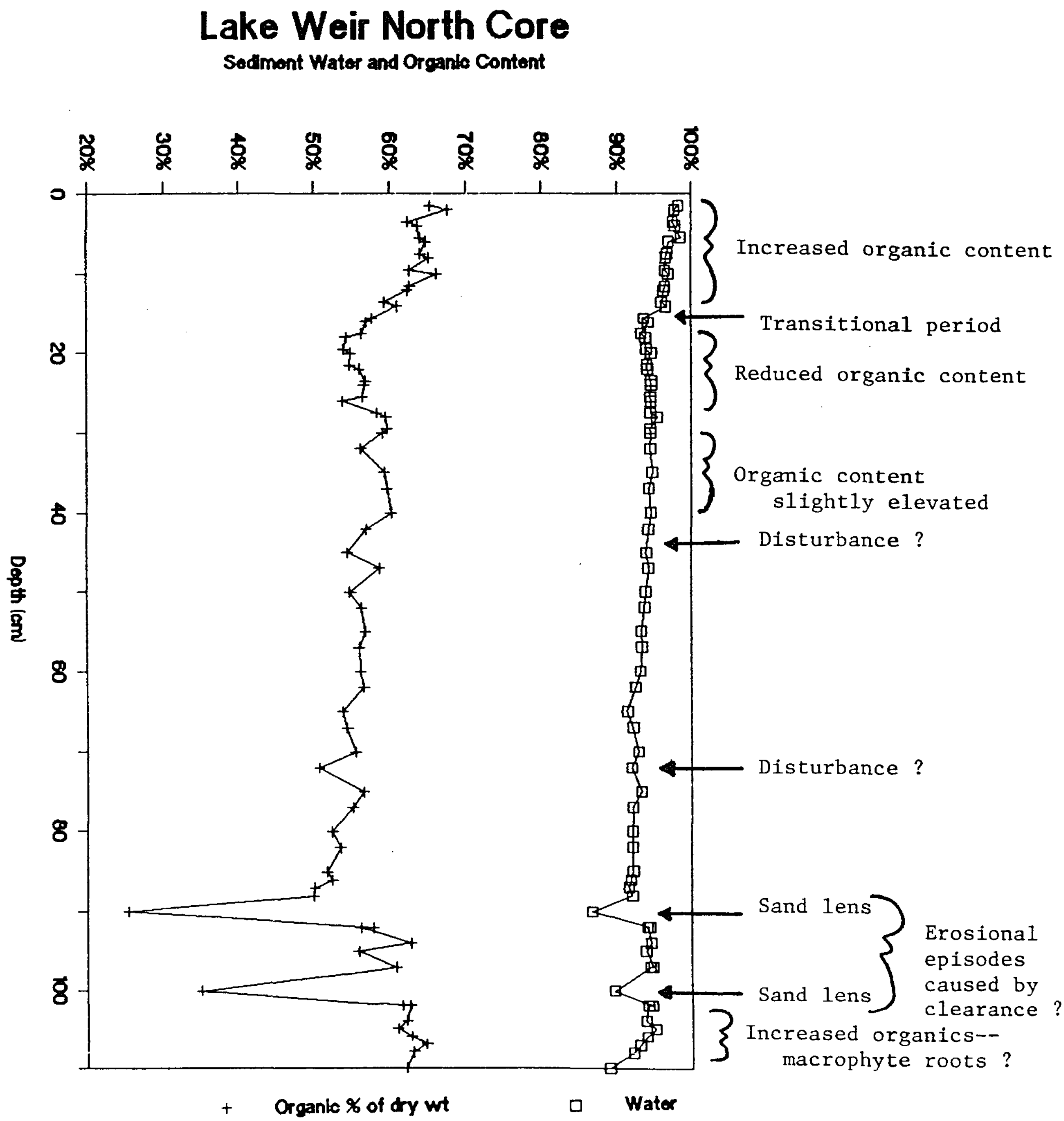


Figure 5-2. Lake Weir sediment water and organic content, determined by Loss-On-Ignition at 100° C for 24 hours and 550° C for 1 hour.

the sedimentation rate determined by lead-210 dating of a Lake Weir core used for a chemistry profile (Deevey unpublished).

Above approximately 15 cm (1958?) there was a 3% increase in water content to 97%. Organic content steadily increased from 54% at 18 cm (1950?) to 65% at 1.5 cm (1985?). This increase in organic sedimentation seems to coincide with the period of greatest population growth within the watershed (Figure 2-8).

Organic fraction was slightly elevated between 42 and 28 cm. Otherwise, water and organic concentrations remained fairly constant down to 88 cm. Below 88 cm these parameters exhibited a higher degree of variation, with two inorganic spikes at 90 and 100 cm. A high degree of clastic material at these levels was confirmed by visual observations of the core.

These intervals may have corresponded to episodes of increased erosion within the watershed, such as periods of deforestation, citrus planting, or railroad building. Because it becomes increasingly more difficult to predict the age of events at lower core levels, lead-210 dating will be necessary to establish any correlation to watershed activity.

The organic fraction was slightly higher below 100 cm. This probably represents the presence of root material from aquatic macrophytes which may have covered the lake bottom during this presumably oligotrophic period. Fibrous plant material was observed in lower intervals of cores S, H, and L (Figure 5-1).

It is important to note that the above observations reflect only the concentrations of water and organic matter, and that the rates of accumulation can be determined only after lead-210 dating has been completed. That is, periods of lower organic concentrations may represent either decreased system productivity or erosional episodes within the watershed.

Phosphorus Levels

Determination of total phosphorus for the core intervals was determined using Anderson's (1976) ignition method. Inorganic residue from the LOI analysis was washed into a 200 ml beaker using 25 ml of 1N HCl and boiled for 15 minutes on a hot plate. Each sample was diluted to exactly 100 ml, and orthophosphate was measured by the perchloric acid method (A.P.H.A. 1971).

This analysis is currently being run on all six cores, and results will be included in the next report. Phosphorus concentrations will be converted to accumulation rates after lead-210 dating has been completed.

Subfossil Assemblages

For subfossil analyses, 1.0 cc of sediment was extracted from the specified core intervals (Table 5-2). This sediment was boiled gently in 30-40 ml of 10% KOH for 30 minutes, while agitating the clumps of material with a glass stirring rod. The sample was then diluted to over 100 ml with distilled water and poured through a 40 um sieve. Water was flushed through the mesh for nearly a minute. The residue was rinsed with tertiary butyl alcohol (TBA) then was carefully concentrated and backwashed with TBA into a small beaker, and final volume was measured (generally 3-4 ml).

Glass microscope slides were placed on a warm hotplate and a drop of silicon oil (Dow-Corning 200 fluid) was added. A 100 um Eppendorf pipette with a wide aperture disposable tip was used to extract a random sample from the TBA slurry. This was slowly added to the silicon oil, drop by drop as the TBA volatilized. Generally two aliquots (0.2 ml) were added to the slide, but occasionally one was sufficient to achieve the desired density. Dilution factor (percent of total sample) was recorded on the slide to allow quantification of results. Slides were removed from the hotplate, allowed to cool, and coverslips were added. After several hours, clear fingernail polish was used to seal the coverslip.

In order for the sample to yield a statistically significant taxonomic composition, generally at least 100 recognizable fragments are necessary. Often two or three slides from an interval are necessary to produce enough cladoceran remains. When remains are far too scarce for a good distribution of species (as in some of the lower core intervals), it was occasionally necessary to sieve the sample through 80 um mesh to concentrate the larger species for semi-quantitative analysis. The 40 um fraction was always retained for future reference.

Chironomid head capsules were picked from the entire remaining sample on a counting wheel under a dissecting scope with an Eppendorf pipette. When necessary the sample was filtered through 80 um mesh as above. Midges were mounted and identified on glass microscope slides. Midges found on the chydorid slides were also identified and counted.

Slide preparation and species counts are currently underway. Preliminary findings show a scarcity of cladocerans and chironomids below 55 cm, suggesting that Lake Weir was historically an oligotrophic system. Two head capsules of Tanytarsus, a midge indicative of oligotrophy, were spotted at 71 cm depth during preliminary analyses. Virtually no planktonic cladocerans were present, thus providing further evidence of the low system productivity.

At 51 cm, the number of chydorids and chironomids increases sharply, showing a mixture of oligotrophic and eutrophic species. Rhynchatalona, an oligotrophic species (Crisman 1980), is the dominant chydorid. Yet several species associated with higher productivity such as Chironomus sp., Leydigia acanthercercoides, Alona affinis, and Chydorus sphaericus start to appear. There were many Bosmina remains, yet no Daphnia.

The dominant algae, Botryococcus (a colonial green) is far more abundant at 51 cm than in the lower intervals. Both Peridinium, a dinoflagellate associated with oligotrophic conditions and Pediastrum boryanum, which is associated with hard water mesotrophic to eutrophic systems (Crisman 1978), are found in abundance at 51 cm.

Hence, it appears that 51 cm marks a period of transition from lower to higher trophic conditions. Further analysis of the upper core intervals will be necessary to delineate shifts in the benthic invertebrate and algal community structures which may be indicative of changing productivity.

Subfossil analyses will be performed only on the North Core. Select intervals from other cores may be examined to elucidate specific transitional episodes. Paleoecological data and interpretations will be presented in the final project report.

Photosynthetic Pigments

Another measure of trophic state is the rate of accumulation of photosynthetic pigments such as chlorophyll a and carotenoids. Chlorophyll a can be estimated by the presence of pheopigments, its degradation products. Also, the relative proportion of chlorophyll derivatives to total carotenoids can identify the dominant algal groups. Because blue-green algae often become more dominant with increasing productivity, this can provide information about a system's trophic state.

Pigments were extracted from 10 g sediment (wet weight) by shaking and centrifuging in 20 ml measures of 90% acetone four consecutive times. The combined extract was brought up to 100 ml with 90% acetone. This 100 ml sample was divided into three aliquots: 10 ml for chlorophyll derivatives, 20 ml for total carotenoids, and 70 ml for blue-green algal pigments.

Chlorophyll derivatives were measured by absorbance at 665 nm and recorded in standard chlorophyll units (Vallentyne 1955). Absorbance at 665 nm was measured again after acidification of the sample to determine the proportion of native chlorophyll, that which has not been degraded.

Total carotenoids were extracted from the 20 ml aliquot in the same procedure described by Swain (1985). Absorbance of the resulting solution was measured at 448 nm.

Absolute determination of the blue-green algal pigments oscillaxanthin and myxoxanthophyll involves lengthy and detailed chromatographic analyses, but useful results can be obtained quickly from the trichromatic method used by Swain (1985). In this procedure, 40 ml petroleum ether is added to the 70 ml aliquot in a separatory funnel and is swirled. The highly polar pigments remain in the acetone-water hypophase (Swain 1985), which is removed and dried. The pigments are re-dissolved in ethanol to a known volume of 5 or 10 ml, and absorbance is measured at 412, 504, and 529 nm. The concentration of each pigment and of the contaminating phorbin can then be calculated by Swain's (1985) equations.

Pigment analyses will be run only on the North Core, as historical algal composition should reflect all of Lake Weir proper. Analyses are currently underway, and results will be published in the final project report.

Lead-210 Isotopic Dating

Lead-210 concentrations will be measured on the department's new low-energy, high-purity Germanium gamma-ray spectroscope. This unit allows direct determination of supported and unsupported lead-210 in lake-bottom sediments (Nagy 1988). The samples have had to wait several months while the system has been calibrated.

Nine horizons of the core were selected for lead-210 dating. These intervals immediately followed episodes marked by changes in the core's physical parameters (Figure 5-2). After sediment samples had been extracted for the other four paleolimnological analyses (Table 5-2), all of the remaining sediment from the selected intervals was used for lead-210 dating. The uppermost sediment sample (0-4 cm) was taken from the backup core from North Lake Weir.

Each of the nine horizons spanned 4.0 cm of the core and was equally represented by its component intervals, so as not to bias the age determination. Each sample was comprised of 40 to 50 cc of sediment (wet volume).

After weighing the wet samples, they were dried at 100°C for 24 hours, broken apart, and dried for 24 additional hours. The dried sediment was carefully hammered then pulverized by mortar and pestle, then weighed. Most of the lower samples contained 2-4 g of dried material, but the top two intervals contained less than 1.0 g and may require additional days to count.

Table sugar was ground with mortar and pestle until it no longer shined, and was mixed with the sediment samples. The small plastic petri dishes were filled with the sediment and sugar mixture and sealed with Duco glue. A blank containing only ground sugar was treated similarly.

Historical sedimentation rates will be determined for the North Core by lead-210 dating techniques. Specific intervals in other cores can be dated by stratigraphic correlation to the dated North Core. This can be accomplished by comparing physical sediment profiles and subfossil transition zones.

Core samples were prepared on 2 September 1988 and were sealed for two weeks to allow equilibration of radon gas. Radiometric counting has begun, and will require two days per sample. Results will be reported in the final project report.

Summary of Paleolimnological Investigation

Sediment core samples from six sites in the Lake Weir system were collected for paleolimnological analyses. Historical trends in trophic state and water quality will be reconstructed by physical, chemical and biological parameters of the sediment. These parameters include water content, organic and inorganic fractions, phosphorus, photosynthetic pigments, and subfossil composition.

Physical sediment parameters and phosphorus levels will be run for all six cores. In addition, pigment and subfossil stratigraphy will be delineated on the North Core. Intervals of major ecologic shifts may be cross-examined in other cores.

Lead-210 isotopic dating of the sediment will pinpoint the timing of major changes in the lake and will quantify sedimentation rates over time. Thereby, accumulation rates of phosphorus, pigments and subfossils can be estimated from their concentrations in the sediment.

These accumulation rates should be indicative of trophic state, and hence nutrient loading to the lake. Correlation of trophic conditions within a given core interval to contemporary land use practices may provide insight into the relative impacts of these practices.

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APPENDICES

A: Monthly water chemistry data for February 1987–January 1988 at the seven sampling stations in Lake Weir, Florida.

B: Monthly macroinvertebrate data for February 1987–January 1988 at the seven sampling stations in Lake Weir, Florida.

C: Historical data for Station 3 in Lake Weir, Florida, from the USGS, SJRWMD, FDER, and several University of Florida theses.

APPENDIX A

Monthly water chemistry data for February 1987–January 1988 at the seven sampling stations in Lake Weir, Florida.

OBS	YEAR	MONTH	DAY	SECCHI	CHLA	COND	PH	TKN	NIT	TP	OP	TOTALK	STATION	RPH
1	87	2	24	1.60	4.20	120	7.25	840	.	27.0	9	15.0	1	5.62341E-08
2	87	3	23	1.90	8.00	122	7.37	910	.	17.0	12	16.0	1	4.26580E-08
3	87	5	18	1.20	6.20	150	6.30	760	.	27.0	13	14.0	1	5.01187E-07
4	87	6	16	1.36	7.90	170	7.56	690	.	20.0	11	17.0	1	2.75423E-08
5	87	7	15	1.57	6.88	170	7.54	.	.	64.0	14	18.0	1	2.88403E-08
6	87	8	13	1.65	11.82	172	7.60	.	.	.	.	17.0	1	2.51189E-08
7	87	9	24	1.30	7.20	160	7.50	585	.	60.0	11	17.0	1	3.16228E-08
8	87	10	21	1.54	6.40	150	7.46	690	.	58.0	12	17.5	1	3.46737E-08
9	87	11	20	1.71	10.42	150	7.20	780	.	62.0	25	17.2	1	6.30957E-08
10	87	12	16	1.82	.	140	7.50	720	.	60.0	25	16.8	1	3.16228E-08
11	88	1	19	1.81	8.65	145	7.12	610	.	65.5	.	19.0	1	7.58578E-08
12	87	2	24	1.70	3.10	120	7.26	740	.	20.0	12	15.0	2	5.49541E-08
13	87	3	23	1.90	8.30	128	.	760	.	13.0	9	13.0	2	.
14	87	5	18	1.20	8.40	150	6.26	840	.	22.0	9	14.0	2	5.49541E-07
15	87	6	16	1.53	9.00	170	7.57	710	.	22.0	11	17.0	2	2.69153E-08
16	87	7	15	1.92	5.36	170	7.53	.	11	50.0	12	18.0	2	2.95121E-08
17	87	8	13	1.65	7.84	171	7.52	.	.	.	.	18.0	2	3.01995E-08
18	87	9	24	1.18	8.50	170	7.48	690	.	52.0	10	17.0	2	3.31131E-08
19	87	10	21	1.59	5.80	150	7.50	710	.	56.0	10	17.2	2	3.16228E-08
20	87	11	20	1.55	6.48	150	7.25	820	.	58.0	28	17.2	2	5.62341E-08
21	87	12	16	1.77	6.75	140	7.26	820	.	52.0	20	17.4	2	5.49541E-08
22	88	1	19	1.82	8.44	142	7.25	605	.	.	.	17.0	2	5.62341E-08
23	87	2	24	1.70	2.30	120	7.21	840	.	20.0	10	17.0	3	6.16595E-08
24	87	3	23	1.90	2.40	130	7.08	720	.	15.0	10	16.0	3	8.31764E-08
25	87	5	18	1.20	10.20	150	6.45	760	.	22.0	12	14.0	3	3.54813E-07
26	87	6	16	1.38	8.50	170	7.59	700	.	17.0	11	17.0	3	2.57040E-08
27	87	7	15	1.61	6.82	170	7.50	.	11	72.0	10	19.0	3	3.16228E-08
28	87	8	13	1.43	9.34	172	7.52	.	.	120.0	3	17.0	3	3.01995E-08
29	87	9	24	1.18	8.00	165	7.50	710	.	68.0	12	17.2	3	3.16228E-08
30	87	10	21	1.54	6.20	150	7.48	690	.	52.0	.	17.0	3	3.31131E-08
31	87	11	20	1.63	4.75	155	7.30	740	.	60.0	30	17.0	3	5.01187E-08
32	87	12	16	1.61	8.29	140	7.34	780	.	60.0	25	17.2	3	4.57088E-08
33	88	1	19	1.76	8.79	142	7.31	900	.	.	.	17.5	3	4.89779E-08
34	87	2	24	1.70	3.20	120	7.33	550	.	30.0	8	16.0	4	4.67735E-08
35	87	3	23	1.90	3.90	120	7.30	810	.	15.0	11	17.0	4	5.01187E-08
36	87	5	18	1.20	7.60	150	6.26	950	.	25.0	14	14.0	4	5.49541E-07
37	87	6	16	1.31	9.80	170	7.46	850	.	19.0	15	17.0	4	3.46737E-08
38	87	7	15	1.86	5.82	170	7.49	.	.	56.0	12	18.0	4	3.23594E-08
39	87	8	13	1.54	8.78	172	7.51	.	.	86.0	3	17.0	4	3.09030E-08
40	87	9	24	1.30	8.50	165	7.52	700	.	54.0	12	17.5	4	3.01995E-08
41	87	10	21	1.55	6.00	150	7.52	680	.	58.0	.	17.0	4	3.01995E-08
42	87	11	20	1.48	8.16	155	7.30	900	.	55.0	25	17.4	4	5.01187E-08
43	87	12	16	1.57	8.55	140	7.40	850	.	58.0	25	17.5	4	3.98107E-08
44	88	1	19	1.64	8.50	145	7.23	630	.	21.6	.	19.0	4	5.88844E-08
45	87	2	24	1.70	3.90	120	7.32	730	16	27.0	11	15.0	5	4.78630E-08
46	87	3	23	1.90	3.90	130	7.27	820	.	21.0	11	17.0	5	5.37032E-08
47	87	5	18	1.30	8.40	150	6.35	950	.	20.0	14	14.0	5	4.46684E-07
48	87	6	16	1.33	10.30	170	7.53	840	12	21.0	11	17.0	5	2.95121E-08
49	87	7	15	1.52	9.72	170	7.51	.	.	68.0	13	18.0	5	3.09030E-08
50	87	8	13	1.60	7.84	173	7.49	.	10	72.0	3	18.0	5	3.23594E-08
51	87	9	24	1.20	6.50	160	7.50	680	.	60.0	10	17.2	5	3.16228E-08
52	87	10	21	1.73	5.60	150	7.54	690	.	60.0	10	17.4	5	2.88403E-08
53	87	11	20	1.53	7.14	140	7.35	880	.	58.0	22	17.2	5	4.46684E-08
54	87	12	16	1.73	9.71	140	7.30	850	.	55.0	22	17.0	5	5.01187E-08
55	88	1	19	1.52	8.35	145	7.26	600	.	.	.	18.0	5	5.49541E-08
56	87	2	24	1.90	3.50	120	7.14	230	10	19.0	9	17.0	6	7.24436E-08
57	87	3	23	1.90	4.30	122	7.26	760	12	18.0	10	17.0	6	5.49541E-08
58	87	5	18	1.00	7.20	155	6.41	900	.	30.0	15	13.0	6	3.89045E-07
59	87	6	16	1.25	12.20	170	7.46	750	15	19.0	11	17.0	6	3.46737E-08
60	87	7	15	1.10	10.42	170	7.44	.	.	48.0	11	18.5	6	3.63078E-08
61	87	8	13	1.51	9.24	155	7.49	.	.	140.0	3	17.5	6	3.23594E-08
62	87	9	24	1.40	7.20	170	7.50	720	.	50.0	12	17.4	6	3.16228E-08
63	87	10	21	1.82	6.50	155	7.50	720	.	52.0	12	18.0	6	3.16228E-08
64	87	11	20	1.85	6.25	155	7.28	890	.	55.0	27	17.0	6	5.24807E-08
65	87	12	16	1.83	8.35	140	7.50	900	.	60.0	26	17.4	6	3.16228E-08
66	88	1	19	1.93	7.92	145	7.26	630	.	10.3	.	17.0	6	5.49541E-08
67	87	2	24	1.70	2.50	118	6.74	820	20	22.0	8	6.6	7	1.81970E-07
68	87	3	23	2.20	2.10	120	6.65	740	15	20.0	12	6.0	7	2.23872E-07
69	87	5	18	1.20	6.50	140	5.74	920	.	25.0	10	3.5	7	0.0000018197
70	87	6	16	1.90	7.40	155	6.77	850	31	20.0	11	5.0	7	1.69824E-07
71	87	7	15	1.54	9.04	170	6.84	.	11	65.0	14	6.5	7	1.44544E-07
72	87	8	13	1.44	7.80	172	6.78	.	.	72.0	3	5.9	7	1.65959E-07
73	87	9	24	1.30	6.80	153	6.70	800	.	53.0	14	6.5	7	1.99526E-07
74	87	10	21	1.60	6.00	140	6.68	700	.	60.0	10	6.0	7	2.08930E-07
75	87	11	20	1.56	3.63	145	6.35	910	.	60.0	30	6.2	7	4 46684E-07
76	87	12	16	1.32	9.40	140	6.30	850	.	58	30	6.5	7	5.01187E-07
77	88	1	19	1.42	7.46	135	6.67	950	.	.	.	7.0	7	2.13796E-07

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
STATION=1									
SECCHI	11	1.58727273	0.22525945	1.20000000	1.90000000	0.06791828	17.4600000	0.050742	14.192
CHLA	10	7.76700000	2.17237223	4.20000000	11.82000000	0.68696442	77.6700000	4.719201	27.969
COND	11	149.90909091	17.86871313	120.00000000	172.00000000	5.38761972	1649.0000000	319.290909	11.920
PH	11	7.30909091	0.37009335	6.30000000	7.60000000	0.11158734	80.4000000	0.136969	5.063
TKN	9	731.66666667	104.04326023	585.00000000	910.00000000	34.68108674	6585.0000000	10825.000000	14.220
TP	10	46.05000000	20.37216238	17.00000000	65.50000000	6.44224340	460.5000000	415.025000	44.239
TOTALK	11	16.77272727	1.36973786	14.00000000	19.00000000	0.41299151	184.5000000	1.876182	8.166
STATION=2									
SECCHI	11	1.61909091	0.24941750	1.18000000	1.92000000	0.07520221	17.8100000	0.0622091	15.405
CHLA	11	7.08818182	1.79627848	3.10000000	9.00000000	0.54159834	77.9700000	3.2266164	25.342
COND	11	151.00000000	17.82694590	120.00000000	171.00000000	5.37502643	1661.0000000	317.8000000	11.806
PH	10	7.28800000	0.38513490	6.26000000	7.57000000	0.12179035	72.8800000	0.1483289	5.285
TKN	9	743.88888889	75.48914565	605.00000000	840.00000000	25.16304855	6695.0000000	5698.6111111	10.148
TP	9	38.33333333	18.43908891	13.00000000	58.00000000	6.14636297	345.0000000	340.0000000	48.102
TOTALK	11	16.43636364	1.66569669	13.00000000	18.00000000	0.50222645	180.8000000	2.7745455	10.134
STATION=3									
SECCHI	11	1.54000000	0.22458851	1.18000000	1.90000000	0.06771598	16.9400000	0.0504400	14.584
CHLA	11	6.87181818	2.69514311	2.30000000	10.20000000	0.81261622	75.5900000	7.2637964	39.220
COND	11	151.27272727	17.26320312	120.00000000	172.00000000	5.20505158	1664.0000000	298.0181818	11.412
PH	11	7.29818182	0.32024422	6.45000000	7.59000000	0.09655727	80.2800000	0.1025564	4.388
TKN	9	760.00000000	70.17834424	690.00000000	900.00000000	23.39278141	6840.0000000	4925.0000000	9.234
TP	10	50.60000000	33.17696657	15.00000000	120.00000000	10.49147802	506.0000000	1100.7111111	65.567
TOTALK	11	16.90000000	1.19247641	14.00000000	19.00000000	0.35954517	185.9000000	1.4220000	7.056
STATION=4									
SECCHI	11	1.55000000	0.22297982	1.20000000	1.90000000	0.06723095	17.0500000	0.049720	14.386
CHLA	11	7.16454545	2.13918379	3.20000000	9.80000000	0.64498818	78.8100000	4.576107	29.858
COND	11	150.63636364	18.58640755	120.00000000	172.00000000	5.60401273	1657.0000000	345.454545	12.339
PH	11	7.30181818	0.36055008	6.26000000	7.52000000	0.10870994	80.3200000	0.129996	4.938
TKN	9	768.88888889	134.48461292	550.00000000	950.00000000	44.82820431	6920.0000000	18086.111111	17.491
TP	11	43.41818182	22.45447920	15.00000000	86.00000000	6.77028022	477.6000000	504.203636	51.717
TOTALK	11	17.03636364	1.25081791	14.00000000	19.00000000	0.37713579	187.4000000	1.564545	7.342
STATION=5									
SECCHI	11	1.55090909	0.21163433	1.20000000	1.90000000	0.06381015	17.0600000	0.044789	13.646
CHLA	11	7.39636364	2.23253342	3.90000000	10.30000000	0.67313415	81.3600000	4.984205	30.184
COND	11	149.81818182	17.18614664	120.00000000	173.00000000	5.18181818	1648.0000000	295.363636	11.471
PH	11	7.31090909	0.33723744	6.35000000	7.54000000	0.10168091	80.4200000	0.113729	4.613
TKN	9	782.22222222	112.89129481	600.00000000	950.00000000	37.63043160	7040.0000000	12744.444444	14.432
TP	10	46.20000000	21.24879082	20.00000000	72.00000000	6.71945765	462.0000000	451.511111	45.993
TOTALK	11	16.89090909	1.26921594	14.00000000	18.00000000	0.38268300	185.8000000	1.610909	7.514
STATION=6									
SECCHI	11	1.59000000	0.35102706	1.00000000	1.93000000	0.10583864	17.4900000	0.123220	22.077
CHLA	11	7.55272727	2.51981781	3.50000000	12.20000000	0.75975366	83.0800000	6.349482	33.363
COND	11	150.63636364	17.61972036	120.00000000	170.00000000	5.31254558	1657.0000000	310.454545	11.697
PH	11	7.29454545	0.31973000	6.41000000	7.50000000	0.09640222	80.2400000	0.102227	4.383
TKN	9	722.22222222	207.47155093	230.00000000	900.00000000	69.15718364	6500.0000000	43044.444444	28.727
TP	11	45.57272727	35.97149124	10.30000000	140.00000000	10.84581269	501.3000000	1293.948182	78.932
TOTALK	11	16.98181818	1.40770606	13.00000000	18.50000000	0.42443935	186.8000000	1.981636	8.289
STATION=7									
SECCHI	11	1.56181818	0.28906118	1.20000000	2.20000000	0.08715522	17.1800000	0.0835564	18.508
CHLA	11	6.23909091	2.47934045	2.10000000	9.40000000	0.74754927	68.6300000	6.1471291	39.739
COND	11	144.36363636	17.44289384	118.00000000	172.00000000	5.25923037	1588.0000000	304.2545455	12.083
PH	11	6.56545455	0.32268758	5.74000000	6.84000000	0.09729397	72.2200000	0.1041273	4.915
TKN	9	837.77777778	83.03279138	700.00000000	950.00000000	27.67759713	7540.0000000	6894.4444444	9.911
TP	10	45.50000000	21.05152409	20.00000000	72.00000000	6.65707644	455.0000000	443.1666667	46.267
TOTALK	11	5.97272727	0.96962973	3.50000000	7.00000000	0.29235436	65.7000000	0.9401818	16.234

MONTH=1

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
YEAR	7	88.00000000	0.00000000	88.00000000	88.00000000	0.00000000	616.0000000	0.000000
DAY	7	19.00000000	0.00000000	19.00000000	19.00000000	0.00000000	133.0000000	0.000000
SECCHI	7	1.70000000	0.18138357	1.42000000	1.93000000	0.06855655	11.9000000	0.032900
CHLA	7	8.30142857	0.46092040	7.46000000	8.79000000	0.17421154	58.1100000	0.212448
COND	7	142.71428571	3.68394199	135.00000000	145.00000000	1.39239919	999.0000000	13.571429
PH	7	7.15714286	0.22253946	6.67000000	7.31000000	0.08411201	50.1000000	0.049524
TKN	7	703.57142857	152.38969469	600.00000000	950.00000000	57.59789065	4925.0000000	23222.619048
NIT	0							
TP	3	32.46666667	29.16030407	10.30000000	65.50000000	16.83570940	97.4000000	850.323333
OP	0							
TOTALK	7	16.35714286	4.21024827	7.00000000	19.00000000	1.59132427	114.5000000	17.726190
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.666667
RPH	7	0.00000008	0.00000006	0.00000005	0.00000021	0.00000002	0.0000006	0.000000

MONTH=2

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.000000
DAY	7	24.00000000	0.00000000	24.00000000	24.00000000	0.00000000	168.0000000	0.000000
SECCHI	7	1.71428571	0.08997354	1.60000000	1.90000000	0.03400680	12.0000000	0.008095
CHLA	7	3.24285714	0.69247658	2.30000000	4.20000000	0.26173154	22.7000000	0.479524
COND	7	119.71428571	0.75592895	118.00000000	120.00000000	0.28571429	838.0000000	0.571429
PH	7	7.17857143	0.20391408	6.74000000	7.33000000	0.07707228	50.2500000	0.041581
TKN	7	678.57142857	222.21825393	230.00000000	840.00000000	83.99060524	4750.0000000	49380.952381
NIT	3	15.33333333	5.03322296	10.00000000	20.00000000	2.90593263	46.0000000	25.333333
TP	7	23.57142857	4.35343324	19.00000000	30.00000000	1.64544310	165.0000000	18.952381
OP	7	9.57142857	1.51185789	8.00000000	12.00000000	0.57142857	67.0000000	2.285714
TOTALK	7	14.51428571	3.60343751	6.60000000	17.00000000	1.36197136	101.6000000	12.984762
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.666667
RPH	7	0.00000007	0.00000005	0.00000005	0.00000018	0.00000002	0.0000005	0.000000

MONTH=3

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.0000000
DAY	7	23.00000000	0.00000000	23.00000000	23.00000000	0.00000000	161.0000000	0.0000000
SECCHI	7	1.94285714	0.11338934	1.90000000	2.20000000	0.04285714	13.6000000	0.0128571
CHLA	7	4.70000000	2.49466097	2.10000000	8.30000000	0.94289322	32.9000000	6.2233333
COND	7	124.57142857	4.57737708	120.00000000	130.00000000	1.73008592	872.0000000	20.9523810
PH	6	7.15500000	0.26538651	6.65000000	7.37000000	0.10834359	42.9300000	0.0704300
TKN	7	788.57142857	64.40201121	720.00000000	910.00000000	24.34167223	5520.0000000	4147.6190476
NIT	2	13.50000000	2.12132034	12.00000000	15.00000000	1.50000000	27.0000000	4.5000000
TP	7	17.00000000	2.88675135	13.00000000	21.00000000	1.09108945	119.0000000	8.3333333
OP	7	10.71428571	1.11269728	9.00000000	12.00000000	0.42056004	75.0000000	1.2380952
TOTALK	7	14.57142857	4.03555625	6.00000000	17.00000000	1.52529689	102.0000000	16.2857143
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.6666667
RPH	6	0.00000008	0.00000007	0.00000004	0.00000022	0.00000003	0.0000005	0.0000000

MONTH=5

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.0000000
DAY	7	18.00000000	0.00000000	18.00000000	18.00000000	0.00000000	126.0000000	0.0000000
SECCHI	7	1.18571429	0.08997354	1.00000000	1.30000000	0.03400680	8.3000000	0.0080952
CHLA	7	7.78571429	1.36189644	6.20000000	10.20000000	0.51474847	54.5000000	1.8547619
COND	7	149.28571429	4.49867705	140.00000000	155.00000000	1.70034010	1045.0000000	20.2380952
PH	7	6.25285714	0.23746679	5.74000000	6.45000000	0.08975401	43.7700000	0.0563905
TKN	7	868.57142857	82.95150620	760.00000000	950.00000000	31.35272233	6080.0000000	6880.9523810
NIT	0							
TP	7	24.42857143	3.40867241	20.00000000	30.00000000	1.28835707	171.0000000	11.6190476
OP	7	12.42857143	2.22539456	9.00000000	15.00000000	0.84112008	87.0000000	4.9523810
TOTALK	7	12.35714286	3.92337318	3.50000000	14.00000000	1.48289568	86.5000000	15.3928571
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.6666667
RPH	7	0.00000066	0.00000052	0.00000035	0.00000182	0.00000020	0.0000046	0.0000000

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE
MONTH=6								
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.0000000
DAY	7	16.00000000	0.00000000	16.00000000	16.00000000	0.00000000	112.0000000	0.0000000
SECCHI	7	1.43714286	0.22163892	1.25000000	1.90000000	0.08377164	10.0600000	0.0491238
CHLA	7	9.30000000	1.63095064	7.40000000	12.20000000	0.61644140	65.1000000	2.6600000
COND	7	167.85714286	5.66946710	155.00000000	170.00000000	2.14285714	1175.0000000	32.1428571
PH	7	7.42000000	0.29120440	6.77000000	7.59000000	0.11006492	51.9400000	0.0848000
TKN	7	770.00000000	74.16198487	690.00000000	850.00000000	28.03059553	5390.0000000	5500.0000000
NIT	3	19.33333333	10.21436896	12.00000000	31.00000000	5.89726867	58.0000000	104.3333333
TP	7	19.71428571	1.60356745	17.00000000	22.00000000	0.60609153	138.0000000	2.5714286
OP	7	11.57142857	1.51185789	11.00000000	15.00000000	0.57142857	81.0000000	2.2857143
TOTALK	7	15.28571429	4.53557368	5.00000000	17.00000000	1.71428571	107.0000000	20.5714286
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.6666667
RPH	7	0.00000005	0.00000005	0.00000003	0.00000017	0.00000002	0.0000003	0.0000000
MONTH=7								
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.00000000
DAY	7	15.00000000	0.00000000	15.00000000	15.00000000	0.00000000	105.0000000	0.00000000
SECCHI	7	1.58857143	0.26773299	1.10000000	1.92000000	0.10119356	11.1200000	0.07168095
CHLA	7	7.72285714	1.98861522	5.36000000	10.42000000	0.75162590	54.0600000	3.95459048
COND	7	170.00000000	0.00000000	170.00000000	170.00000000	0.00000000	1190.0000000	0.00000000
PH	7	7.40714286	0.25217152	6.84000000	7.54000000	0.09531188	51.8500000	0.06359048
TKN	0	.	.	.	.	.	.	.
NIT	3	11.00000000	0.00000000	11.00000000	11.00000000	0.00000000	33.0000000	0.00000000
TP	7	60.42857143	9.19886121	48.00000000	72.00000000	3.47684273	423.0000000	84.61904762
OP	7	12.28571429	1.49602648	10.00000000	14.00000000	0.56544486	86.0000000	2.23809524
TOTALK	7	16.57142857	4.45747099	6.50000000	19.00000000	1.68476567	116.0000000	19.86904762
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.66666667
RPH	7	0.00000005	0.00000004	0.00000003	0.00000014	0.00000002	0.0000003	0.00000000
MONTH=8								
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.00000000
DAY	7	13.00000000	0.00000000	13.00000000	13.00000000	0.00000000	91.0000000	0.00000000
SECCHI	7	1.54571429	0.09180725	1.43000000	1.65000000	0.03469988	10.8200000	0.00842857
CHLA	7	8.95142857	1.43112343	7.80000000	11.82000000	0.54091381	62.6600000	2.04811429
COND	7	169.57142857	6.45128263	155.00000000	173.00000000	2.43835564	1187.0000000	41.61904762
PH	7	7.41571429	0.28277536	6.78000000	7.60000000	0.10687904	51.9100000	0.07996190
TKN	0	.	.	.	.	.	.	.
NIT	1	10.00000000	.	10.00000000	10.00000000	.	10.0000000	.
TP	5	98.00000000	30.59411708	72.00000000	140.00000000	13.68210510	490.0000000	936.00000000
OP	5	3.00000000	0.00000000	3.00000000	3.00000000	0.00000000	15.0000000	0.00000000
TOTALK	7	15.77142857	4.37596248	5.90000000	18.00000000	1.65395835	110.4000000	19.14904762
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.66666667
RPH	7	0.00000005	0.00000005	0.00000003	0.00000017	0.00000002	0.0000003	0.00000000
MONTH=9								
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.0000000
DAY	7	24.00000000	0.00000000	24.00000000	24.00000000	0.00000000	168.0000000	0.0000000
SECCHI	7	1.26571429	0.08223080	1.18000000	1.40000000	0.03108032	8.8600000	0.0067619
CHLA	7	7.52857143	0.80770103	6.50000000	8.50000000	0.30528229	52.7000000	0.6523810
COND	7	163.28571429	6.10230245	153.00000000	170.00000000	2.30645353	1143.0000000	37.2380952
PH	7	7.38571429	0.30259198	6.70000000	7.52000000	0.11436902	51.7000000	0.0915619
TKN	7	697.85714286	63.49915635	585.00000000	800.00000000	24.00042517	4885.0000000	4032.1428571
NIT	0	.	.	.	.	.	.	.
TP	7	56.71428571	6.29058253	50.00000000	68.00000000	2.37761671	397.0000000	39.5714286
OP	7	11.57142857	1.39727626	10.00000000	14.00000000	0.52812079	81.0000000	1.9523810
TOTALK	7	15.68571429	4.05480315	6.50000000	17.50000000	1.53257154	109.8000000	16.4414286
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.6666667
RPH	7	0.00000006	0.00000006	0.00000003	0.00000020	0.00000002	0.0000004	0.0000000

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	
MONTH=10									
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.00000000	
DAY	7	21.00000000	0.00000000	21.00000000	21.00000000	0.00000000	147.0000000	0.00000000	
SECCHI	7	1.62428571	0.10875924	1.54000000	1.82000000	0.04110713	11.3700000	0.01182857	
CHLA	7	6.07142857	0.31997024	5.60000000	6.50000000	0.12093738	42.5000000	0.10238095	
COND	7	149.28571429	4.49867705	140.00000000	155.00000000	1.70034010	1045.0000000	20.23809524	
PH	7	7.38285714	0.31100452	6.68000000	7.54000000	0.11754866	51.6800000	0.09672381	
TKN	7	697.14285714	13.80131119	680.00000000	720.00000000	5.21640531	4880.0000000	190.47619048	
NIT	0	.	.	.	.	.	.	.	
TP	7	56.57142857	3.40867241	52.00000000	60.00000000	1.28835707	396.0000000	11.61904762	
OP	5	10.80000000	1.09544512	10.00000000	12.00000000	0.48989795	54.0000000	1.20000000	
TOTALK	7	15.72857143	4.30376358	6.00000000	18.00000000	1.62666973	110.1000000	18.52238095	
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.66666667	
RPH	7	0.00000006	0.00000007	0.00000003	0.00000021	0.00000003	0.0000004	0.00000000	1
MONTH=11									
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.0000000	
DAY	7	20.00000000	0.00000000	20.00000000	20.00000000	0.00000000	140.0000000	0.0000000	
SECCHI	7	1.61571429	0.12726051	1.48000000	1.85000000	0.04809995	11.3100000	0.0161952	
CHLA	7	6.69000000	2.22265607	3.63000000	10.42000000	0.84008503	46.8300000	4.9402000	
COND	7	150.00000000	5.77350269	140.00000000	155.00000000	2.18217890	1050.0000000	33.3333333	
PH	7	7.14714286	0.35457553	6.35000000	7.35000000	0.13401695	50.0300000	0.1257238	
TKN	7	845.71428571	66.29659188	740.00000000	910.00000000	25.05775641	5920.0000000	4395.2380952	
NIT	0	.	.	.	.	.	.	.	
TP	7	58.28571429	2.62769136	55.00000000	62.00000000	0.99317398	408.0000000	6.9047619	
OP	7	26.71428571	2.92770022	22.00000000	30.00000000	1.10656667	187.0000000	8.5714286	
TOTALK	7	15.60000000	4.14728827	6.20000000	17.40000000	1.56752763	109.2000000	17.2000000	
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.6666667	
RPH	7	0.00000011	0.00000015	0.00000004	0.00000045	0.00000006	0.0000008	0.0000000	1
MONTH=12									
YEAR	7	87.00000000	0.00000000	87.00000000	87.00000000	0.00000000	609.0000000	0.0000000	
DAY	7	16.00000000	0.00000000	16.00000000	16.00000000	0.00000000	112.0000000	0.0000000	
SECCHI	7	1.66428571	0.18146231	1.32000000	1.83000000	0.06858631	11.6500000	0.0329286	
CHLA	6	8.50833333	1.03973875	6.75000000	9.71000000	0.42447157	51.0500000	1.0810567	
COND	7	140.00000000	0.00000000	140.00000000	140.00000000	0.00000000	980.0000000	0.0000000	
PH	7	7.22857143	0.41981855	6.30000000	7.50000000	0.15867650	50.6000000	0.1762476	
TKN	7	824.28571429	58.55400438	720.00000000	900.00000000	22.13133341	5770.0000000	3428.5714286	
NIT	0	.	.	.	.	.	.	.	
TP	7	57.57142857	3.04724700	52.00000000	60.00000000	1.15175111	403.0000000	9.2857143	
OP	7	24.71428571	3.14718317	20.00000000	30.00000000	1.18952343	173.0000000	9.9047619	
TOTALK	7	15.68571429	4.05809010	6.50000000	17.50000000	1.53381389	109.8000000	16.4680952	
STATION	7	4.00000000	2.16024690	1.00000000	7.00000000	0.81649658	28.0000000	4.6666667	
RPH	7	0.00000011	0.00000017	0.00000003	0.00000050	0.00000007	0.0000008	0.0000000	1

APPENDIX B

Monthly macroinvertebrate data for February 1987-January 1988 at the seven sampling stations in Lake Weir, Florida.

Number per M^2 and functional feeding categories for macroinvertebrates found at station 1 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Jan
Chironomus sp.	CG	33	16	83						16	33	200
Cryptochironomus sp.	P									16		16
Tanytarsus sp.	CG	200	133	16						16		116
Cladotanytarsus sp.	CG		150				266			50		16
Coelotanypus sp.	P	33	50	33	216	50		66	250	50		333
Procladius sp.	P	266	16		16		16		33			100
Harnischia sp.	CG	100	150		66						50	33
Polypedilum sp.	CG		16				16					
Pseudochironomus sp.	CG									16	16	
Palpomyia sp.	P											33
Chaoborus sp.	P	1266	616	283	633	366	200	266	250	150	250	566
Hexagenia sp.	CG	16	16				66	16			16	83
Oecetis sp.	P											
Aphylla sp.	P										16	
Hyalella sp.	CG	566	666	316	50		100	66		500	350	533
Elliptio sp.	F	16										
Viviparus sp.	SC				16		16	16				16
Physa sp.	SC						16					16
Helobdella sp.	P						33			16		16
Brachiobdella sp.	P											
Tubificidae	CG	1300	16	66	216	16	183	50	16	50		16
Lumbriculidae	CG								16			
Nematoda	P	183	50	16		50						33
Totals		3979	1895	813	1213	482	912	480	565	880	731	2126
Total Chironomids		632	531	132	298	50	298	66	283	164	99	814

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

Number per M^2 and functional feeding categories for macroinvertebrates found at station 2 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Jan
Chironomus sp.	CG	16	333	83						16	16	33
Cryptochironomus sp.	P								16	16	33	33
Tanytarsus sp.	CG	166	116	16				16		66		33
Cladotanytarsus sp.	CG	100	33	16	400	66	266		133	133	133	383
Coelotanypus sp.	P	233	100	16	16	16	83	83	16	183	33	333
Procladius sp.	P	416	216		16	33	16		33			16
Harnischia sp.	CG	116	233		16					16	50	33
Polypedilum sp.	CG		16				16					
Pseudochironomus sp.	CG			216		16				16	16	16
Palpomyia sp.	P				66	33					16	16
Chaoborus sp.	P	2450	2866	16	16	366	200	166	3	83	16	33
Hexagenia sp.	CG	66	33				66	16			16	83
Oecetis sp.	P				16							
Aphylla sp.	P				16						16	
Hyalella sp.	CG	1750	1000	2400	5200	1016	433	250	800	833	316	916
Elliptio sp.	F	16		33	50	66	50	33	166	66	50	66
Viviparus sp.	SC	16			16	16	16	16	16	83	50	16
Physa sp.	SC					33	16	16	83	133	33	16
Helobdella sp.	P	33	116	16		33	116		50	16	83	83
Brachiobdella sp.	P											
Tubificidae	CG	266	1066	33	100	316	533	100	50	100		50
Lumbriculidae	CG								16			
Nematoda	P	1350	16	16		50						50
Totals		6994	6144	2861	5928	2060	1811	696	1382	1760	877	2209
Total Chironomids		1047	1047	347	448	131	381	99	198	446	281	880

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

Number per M^2 and functional feeding categories for macroinvertebrates found at station 3 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Jan
Chironomus sp.	CG	50	566	500	783	916	33	1116	1150	150	933	2583
Cryptochironomus sp.	P		66							16		16
Tanytarsus sp.	CG	17	133	416						16		16
Cladotanytarsus sp.	CG	50	150	250			266			50		16
Coelotanypus sp.	P	50	50	16	33	50	66	16	250	16	16	333
Procladius sp.	P	250	66	50	100	100	16		33			100
Harnischia sp.	CG	17	150		66						50	33
Polypedilum sp.	CG		16	16			16					
Pseudochironomus sp.	CG									16	16	
Palpomyia sp.	P	0	50									33
Chaoborus sp.	P	917	166	183	533	150	283	316	283	483	443	200
Hexagenia sp.	CG	16	16				66	16			16	83
Oecetis sp.	P											
Aphylla sp.	P										16	
Hyalella sp.	CG	683	566	6616	566		16	66	16	500	350	116
Elliptio sp.	F	16										
Viviparus sp.	SC				16		16	16				16
Physa sp.	SC						16					16
Helobdella sp.	P		16				83	116	66	33	50	116
Brachiobdella sp.	P	83		116	166	133			133	33	83	
Tubificidae	CG	183	583	33	66	33	233	50	16	50		16
Lumbriculidae	CG		150			50			16			
Nematoda	P	183	683	16		50						33
Totals		2515	3427	8212	2329	1482	1110	1712	1963	1363	1973	3726
Total Chironomids		434	1197	1248	982	1066	397	1132	1433	264	1015	3097

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

. Number per M^2 and functional feeding categories for macroinvertebrates found at station 4 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Jan
Chironomus sp.	CG	933	83	17	16	16		16		16	33	616
Cryptochironomus sp.	P	33	100	15	33		16		100	66	83	300
Tanytarsus sp.	CG	417	33	15		15		16		16		100
Cladotanytarsus sp.	CG	633	17		183	33	33	33	33	350	316	1066
Coelotanypus sp.	P	733	50	33	67	50		16	250	16		16
Procladius sp.	P	117	117		33		83		33	16	16	100
Harnischia sp.	CG	100	150		66						50	16
Polypedilum sp.	CG	33	16				16					50
Pseudochironomus sp.	CG		100		133		16			16	83	250
Palpomyia sp.	P		33	15	50		16					50
Chaoborus sp.	P	83	616	283	633	366	50	66	250	33	250	16
Hexagenia sp.	CG	183	16				66	16			16	83
Oecetis sp.	P	33				33	16					
Aphylla sp.	P										16	
Hyalella sp.	CG	3366	2833	1300	4683	1150	733	366	1200	1550	2116	2066
Elliptio sp.	F	17	100	17	66	83	16	66	50	100	66	150
Viviparus sp.	SC	33			16	67	33	16	50		50	66
Physa sp.	SC						16				16	16
Helobdella sp.	P	16		67		15	33	16	50	66	16	116
Brachiobdella sp.	P	50	67	17	250	100			16			
Tubificidae	CG	750	483	66	267	16	316	116	50	150	16	200
Lumbriculidae	CG	516	117			33	66	16	50			
Nematoda	P	750	50	17	83	50						50
Totals		8796	4981	1862	6579	2027	1525	759	2132	2395	3143	5327
Total Chironomids		2999	666	80	531	114	164	81	416	496	581	2514

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

Number per M^2 and functional feeding categories for macroinvertebrates found at station 5 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Jan
Chironomus sp.	CG	33	100	166	183	66				33	16	16
Cryptochironomus sp.	P	66	66						16	16		183
Tanytarsus sp.	CG	16	133	216	66	16	16			16		83
Cladotanytarsus sp.	CG	700	33	66	150	50	16	16	133	150	133	1050
Coelotanypus sp.	P	250	200	166	50	350	183	133	250	116	216	500
Procladius sp.	P	333	50	83	33	16	16	33	33	16		83
Harnischia sp.	CG	16	150	33	33	50				16	50	16
Polypedilum sp.	CG		16				16					
Pseudochironomus sp.	CG	66					16	33		16	16	16
Palpomyia sp.	P	16		16	33				16	16		16
Chaoborus sp.	P	1266	616	283	500	166	200	150	50	150	33	50
Hexagenia sp.	CG	150	316	316	66	66	66	16			33	666
Oecetis sp.	P				33							
Aphylla sp.	P	16	16								16	
Hyalella sp.	CG	1666	2833	4166	9133	1350	533	333	83	950	1450	2133
Elliptio sp.	F	33	16		16	16			16	150	16	33
Viviparus sp.	SC	66		16	16		33	33		33		16
Physa sp.	SC			66	16		83			16		16
Helobdella sp.	P	50	16	83	133	50	433	100	50	16	33	66
Brachiobdella sp.	P											
Tubificidae	CG	233	200	66	416	100	516	1333	50	50		66
Lumbriculidae	CG			16			50		16			
Nematoda	P	183	50	66	300	33		300				350
Totals		5159	4811	5824	11177	2329	2177	2480	713	1760	2012	5359
Total Chironomids		1480	748	730	515	548	263	215	432	379	431	1947

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

Number per M^2 and functional feeding categories for macroinvertebrates found at station 6 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Jan
Chironomus sp.	CG	4566	2816	450	1133	1933			16	416	1266	333
Cryptochironomus sp.	P	400	66	16	83				16		16	166
Tanytarsus sp.	CG	100	566	166	183				16	33	50	200
Cladotanytarsus sp.	CG	450	200	166	33		266		33	50	50	316
Coelotanypus sp.	P	33	83	33	166	150	383	166	100	150	466	50
Procladius sp.	P	166	200	116	183	50	233	33	33	33		100
Harnischia sp.	CG	100	66	33	33	33	33	33		16	166	33
Polypedilum sp.	CG	66	16	166	83		266					
Pseudochironomus sp.	CG	400	50		100		16			16	50	250
Palpomyia sp.	P	883	433	16	33	383			16		83	33
Chaoborus sp.	P	333	50	33	83	1600	366	350	116	400	333	83
Hexagenia sp.	CG	33	633	583	450	216	66	33	50	133	533	83
Oecetis sp.	P				33							
Aphylla sp.	P										16	
Hyalella sp.	CG	266	783	1516	4400	133	100	116	283	350	483	316
Elliptio sp.	F	100	66		100	66	100	50	166	50	116	50
Viviparus sp.	SC	33	33	66	16	66	16	16			83	16
Physa sp.	SC						16			16		16
Helobdella sp.	P	66		16	150	100	33	50	150	83	33	166
Brachiobdella sp.	P									83		
Tubificidae	CG	266	1833	300	866	116	250	50	16	16	50	33
Lumbriculidae	CG	16						16	16			
Nematoda	P	516	500	33	100	50						33
Totals		8793	8394	3709	8228	4896	2144	913	1027	1845	3794	2277
Total Chironomids		6281	4063	1146	1997	2166	1197	232	214	714	2064	1448

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

Number per M^2 and functional feeding categories for macroinvertebrates found at station 7 in Lake Weir. Each value is the mean of three replicate samples.

Organism	Guild	2/24 Feb	3/23 Mar	5/18 May	6/16 Jun	7/15 Jul	8/13 Aug	9/24 Sep	10/21 Oct	11/20 Nov	12/16 Dec	1/19 Ja
Chironomus sp.	CG	533	233	16						100	33	20
Cryptochironomus sp.	P	300								16		1
Tanytarsus sp.	CG	1250	100	16				16	33	33		1
Cladotanytarsus sp.	CG	250	16	16			266			16		1
Coelotanypus sp.	P	33	116	83	33	66	33	66	83	100	33	6
Procladius sp.	P	283	162	50	166	33	16		33	33		10
Harnischia sp.	CG	150	66		33			16			50	3
Polypedilum sp.	CG	616	16	33		66	16					
Pseudochironomus sp.	CG									16	16	
Palpomyia sp.	P	16	16	33		16					33	3
Chaoborus sp.	P	650	1550	33	616	500	566	383	416	450	483	23
Hexagenia sp.	CG	400	350	66			66	16		116	66	13
Oecetis sp.	P					16						
Aphylla sp.	P										16	
Hyalella sp.	CG	100	100	83	183		100	66	50	500	33	23
Elliptio sp.	F	33										
Viviparus sp.	SC	16	16		16	16	16	16				1
Physa sp.	SC						16					1
Helobdella sp.	P		16	33	16		50	33		16		1
Brachiobdella sp.	P											
Tubificidae	CG	1350	283	66	216	16	33	50	16	50		1
Lumbriculidae	CG								16			
Nematoda	P	216	50	16		50						3
Totals		6196	3090	544	1279	779	1178	662	647	1446	763	117
Total Chironomids		3415	709	214	232	165	331	98	149	314	132	44

CG = Collector-gatherer; P= Predator; SC = Scraper; F = Filterer.

APPENDIX C

Historical data for Station 3 in Lake Weir, Florida, from the USGS, SJRWMD, FDER, and several University of Florida theses.

SAS 14:38 TUESDAY, FEBRUARY

OBS	YEAR	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE
1	75	.	.	1.90	1.5	8.20	83.0	900	133.0	11.5	6.60	3	8
2	80	9	15	2.00	.	10.80	6.1	651	139.0	10.0	7.06	3	1
3	80	3	15	1.90	.	4.80	25.8	636	136.6	12.0	7.23	3	1
4	80	7	15	3.00	.	6.60	4.7	636	132.0	14.0	7.06	3	1
5	69	6	15	1.68	3.3	7.50	24.0	1072	129.0	.	.	3	2
6	69	8	15	2.44	1.6	10.12	22.0	785	145.3	.	.	3	2
7	69	10	15	1.83	2.0	7.65	10.0	1444	143.0	.	.	3	2
8	69	12	15	2.13	1.5	3.72	20.0	1090	138.0	.	.	3	2
9	69	2	15	2.29	1.3	5.11	20.0	735	129.0	.	.	3	2
10	69	4	15	1.50	2.0	4.58	10.0	731	128.0	.	.	3	2
11	79	1	26	1.70	.	11.00	.	.	155.0	.	7.40	3	3
12	79	2	24	2.00	.	10.50	59.0	401	205.0	.	7.80	3	3
13	79	3	24	.	.	9.30	47.0	794	.	.	6.60	3	3
14	79	4	19	1.80	.	6.00	90.0	655	160.0	.	6.80	3	3
15	79	5	26	1.70	.	8.40	57.0	1213	174.0	.	6.70	3	3
16	79	6	22	2.80	.	6.40	13.0	1986	147.0	.	6.80	3	3
17	79	7	27	2.10	.	8.10	13.0	840	160.0	.	7.20	3	3
18	79	8	28	1.85	.	10.60	25.0	1419	155.0	.	6.80	3	3
19	79	9	19	1.98	.	10.10	15.0	900	133.0	.	7.60	3	3
20	79	10	20	2.96	.	11.70	90.0	443	126.0	.	6.80	3	3
21	79	11	24	2.10	.	7.80	88.0	805	139.0	.	7.10	3	3
22	79	12	18	2.42	.	7.60	73.0	771	133.0	.	6.60	3	3
23	84	3	5	1.65	2.5	6.92	9.0	1120	115.0	12.0	.	3	7
24	84	9	6	1.07	2.2	8.60	30.0	1260	156.0	13.0	6.93	3	7
25	84	12	3	1.21	2.8	13.60	27.0	820	140.0	11.0	.	3	7
26	85	2	8	2.03	2.3	7.50	23.0	910	157.0	11.0	6.80	3	7
27	85	5	23	1.98	1.7	3.33	19.0	630	158.0	12.0	6.90	3	7
28	85	7	11	1.52	1.2	.	23.0	560	.	11.0	6.90	3	7
29	85	9	11	2.48	1.0	3.60	6.0	480	.	10.0	7.20	3	7
30	85	10	4	2.43	2.0	4.80	15.0	620	.	20.0	6.80	3	7
31	85	12	6	1.91	2.8	11.10	16.0	670	.	35.0	7.80	3	7
32	75	3	25	.	.	.	40.0	.	150.0	16.0	8.00	3	4
33	75	12	2	.	.	.	20.0	.	145.0	33.0	.	3	4
34	79	7	18	.	.	5.81	30.0	740	154.0	13.0	7.60	3	4
35	80	8	6	.	.	5.45	20.0	570	147.0	14.0	8.40	3	4

YEAR=69

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
1	6	15	1.68	3.3	7.50	24	1072	129.0	.	.	3	2	.	.	.	.
2	8	15	2.44	1.6	10.12	22	785	145.3	.	.	3	2	.	.	.	.
3	10	15	1.83	2.0	7.65	10	1444	143.0	.	.	3	2	.	.	.	.
4	12	15	2.13	1.5	3.72	20	1090	138.0	.	.	3	2	.	.	.	.
5	2	15	2.29	1.3	5.11	20	735	129.0	.	.	3	2	.	.	.	.
6	4	15	1.50	2.0	4.58	10	731	128.0	.	.	3	2	.	.	.	.

YEAR=75

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
7	.	.	1.9	1.5	8.2	83	900	133	11.5	6.6	3	8	2.51189E-07	.	.	.
8	3	25	.	.	.	40	.	150	16.0	8.0	3	4	1.00000E-08	.	.	.
9	12	2	.	.	.	20	.	145	33.0	.	3	4	.	.	.	.

YEAR=79

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
10	1	26	1.70	.	11.00	.	.	155	.	7.4	3	3	3.98107E-08	.	.	.
11	2	24	2.00	.	10.50	59	401	205	.	7.8	3	3	1.58489E-08	.	.	.
12	3	24	.	.	9.30	47	794	.	.	6.6	3	3	2.51189E-07	.	.	.
13	4	19	1.80	.	6.00	90	655	160	.	6.8	3	3	1.58489E-07	.	.	.
14	5	26	1.70	.	8.40	57	1213	174	.	6.7	3	3	1.99526E-07	.	.	.
15	6	22	2.80	.	6.40	13	1986	147	.	6.8	3	3	1.58489E-07	.	.	.
16	7	27	2.10	.	8.10	13	840	160	.	7.2	3	3	6.30957E-08	.	.	.
17	8	28	1.85	.	10.60	25	1419	155	.	6.8	3	3	1.58489E-07	.	.	.
18	9	19	1.98	.	10.10	15	900	133	.	7.6	3	3	2.51189E-08	.	.	.
19	10	20	2.96	.	11.70	90	443	126	.	6.8	3	3	1.58489E-07	.	.	.
20	11	24	2.10	.	7.80	88	805	139	.	7.1	3	3	7.94328E-08	.	.	.
21	12	18	2.42	.	7.60	73	771	133	.	6.6	3	3	2.51189E-07	.	.	.
22	7	18	.	.	5.81	30	740	154	13	7.6	3	4	2.51189E-08	.	.	.

YEAR=80

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
23	9	15	2.0	.	10.80	6.1	651	139.0	10	7.06	3	1	8.70964E-08	.	.	.
24	3	15	1.9	.	4.80	25.8	636	136.6	12	7.23	3	1	5.88844E-08	.	.	.
25	7	15	3.0	.	6.60	4.7	636	132.0	14	7.06	3	1	8.70964E-08	.	.	.
26	8	6	.	.	5.45	20.0	570	147.0	14	8.40	3	4	3.98107E-09	.	.	.

YEAR=84

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
27	3	5	1.65	2.5	6.92	9	1120	115	12	.	3	7	.	.	.	.
28	9	6	1.07	2.2	8.60	30	1260	156	13	6.93	3	7	1.17490E-07	.	.	.
29	12	3	1.21	2.8	13.60	27	820	140	11	.	3	7	.	.	.	.

YEAR=85

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
30	2	8	2.03	2.3	7.50	23	910	157	11	6.8	3	7	1.58489E-07	.	.	.
31	5	23	1.98	1.7	3.33	19	630	158	12	6.9	3	7	1.25893E-07	.	.	.
32	7	11	1.52	1.2	.	23	560	.	11	6.9	3	7	1.25893E-07	.	.	.
33	9	11	2.48	1.0	3.60	6	480	.	10	7.2	3	7	6.30957E-08	.	.	.
34	10	4	2.43	2.0	4.80	15	620	.	20	6.8	3	7	1.58489E-07	.	.	.
35	12	6	1.91	2.8	11.10	16	670	.	35	7.8	3	7	1.58489E-08	.	.	.

YEAR=87

OBS	MONTH	DAY	SECCHI	TURB	CHLA	TP	TKN	COND	TALK	PH	STATION	SOURCE	RPH	NIT	OP	TOTALK
36	2	24	1.70	.	2.30	20	840	120	.	7.21	3	.	6.16595E-08	.	10	17.0
37	3	23	1.90	.	2.40	15	720	130	.	7.08	3	.	8.31764E-08	.	10	16.0
38	5	18	1.20	.	10.20	22	760	150	.	6.45	3	.	3.54813E-07	.	12	14.0
39	6	16	1.38	.	8.50	17	700	170	.	7.59	3	.	2.57040E-08	.	11	17.0
40	7	15	1.61	.	6.82	72	.	170	.	7.50	3	.	3.16228E-08	11	10	19.0
41	8	13	1.43	.	9.34	120	.	172	.	7.52	3	.	3.01995E-08	.	3	17.0
42	9	24	1.18	.	8.00	68	710	165	.	7.50	3	.	3.16228E-08	.	12	17.2
43	10	21	1.54	.	6.20	52	690	150	.	7.48	3	.	3.31131E-08	.	8	17.0
44	11	20	1.63	.	4.75	60	740	155	.	7.30	3	.	5.01187E-08	.	30	17.0
45	12	16	1.61	.	8.29	60	780	140	.	7.34	3	.	4.57088E-08	.	25	17.2
46	1	19	1.76	.	8.79	.	900	142	.	7.31	3	.	4.89779E-08	.	.	17.5

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V.
YEAR=69									
SECCHI	6	1.97833333	0.36690144	1.50000000	2.4400000	0.14978689	11.8700000	0.134617	18.546
CHLA	6	6.44666667	2.39819654	3.72000000	10.1200000	0.97905964	38.6800000	5.751347	37.201
TKN	6	976.16666667	281.36198511	731.00000000	1444.0000000	114.86554942	5857.0000000	79164.566667	28.823
TP	6	17.66666667	6.12100210	10.00000000	24.0000000	2.49888864	106.0000000	37.466667	34.647
YEAR=75									
SECCHI	1	1.90000000	.	1.90000000	1.90000000	.	1.90000000	.	.
CHLA	1	8.20000000	.	8.20000000	8.20000000	.	8.20000000	.	.
TKN	1	900.00000000	.	900.00000000	900.00000000	.	900.00000000	.	.
TP	3	47.66666667	32.19213154	20.00000000	83.00000000	18.58613581	143.00000000	1036.3333333	67.536
YEAR=79									
SECCHI	11	2.12818182	0.42663376	1.70000000	2.9600000	0.12863492	23.410000	0.18202	20.047
CHLA	13	8.71615385	1.97608004	5.81000000	11.7000000	0.54806599	113.310000	3.90489	22.671
TKN	12	913.91666667	439.87383694	401.00000000	1986.0000000	126.98063908	10967.000000	193488.99242	48.131
TP	12	50.00000000	30.60005942	13.00000000	90.0000000	8.83347627	600.000000	936.36364	61.200
YEAR=80									
SECCHI	3	2.30000000	0.60827625	1.90000000	3.00000000	0.35118846	6.9000000	0.3700000	26.447
CHLA	4	6.91250000	2.69640965	4.80000000	10.80000000	1.34820482	27.6500000	7.2706250	39.008
TKN	4	623.25000000	36.19737560	570.00000000	651.00000000	18.09868780	2493.0000000	1310.2500000	5.808
TP	4	14.15000000	10.39310669	4.70000000	25.80000000	5.19655334	56.6000000	108.0166667	73.450
YEAR=84									
SECCHI	3	1.31000000	0.30265492	1.07000000	1.6500000	0.17473790	3.9300000	0.091600	23.103
CHLA	3	9.70666667	3.47478537	6.92000000	13.6000000	2.00616827	29.1200000	12.074133	35.798
TKN	3	1066.66666667	224.79620400	820.00000000	1260.0000000	129.78614889	3200.0000000	50533.333333	21.075
TP	3	22.00000000	11.35781669	9.00000000	30.0000000	6.55743852	66.0000000	129.000000	51.626
YEAR=85									
SECCHI	6	2.05833333	0.35628172	1.52000000	2.48000000	0.14545140	12.3500000	0.126937	17.309
CHLA	5	6.06600000	3.26217412	3.33000000	11.10000000	1.45888862	30.3300000	10.641780	53.778
TKN	6	645.00000000	145.70518179	480.00000000	910.00000000	59.48389138	3870.0000000	21230.000000	22.590
TP	6	17.00000000	6.35609943	6.00000000	23.00000000	2.59486673	102.0000000	40.400000	37.389
YEAR=87									
SECCHI	11	1.54000000	0.22458851	1.18000000	1.90000000	0.06771598	16.9400000	0.0504400	14.584
CHLA	11	6.87181818	2.69514311	2.30000000	10.20000000	0.81261622	75.5900000	7.2637964	39.220
TKN	9	760.00000000	70.17834424	690.00000000	900.00000000	23.39278141	6840.0000000	4925.0000000	9.234
TP	10	50.60000000	33.17696657	15.00000000	120.00000000	10.49147802	506.0000000	1100.7111111	65.567

OBS	YEAR	MSECCHI	MCHLA	MTKN	MTP	SDSECCHI	SDCHLA	SDTKN	SDTP
1	69	1.97833	6.44667	976.17	17.6667	0.366901	2.39820	281.362	6.1210
2	75	1.90000	8.20000	900.00	47.6667	.	.	.	32.1921
3	79	2.12818	8.71615	913.92	50.0000	0.426634	1.97608	439.874	30.6001
4	80	2.30000	6.91250	623.25	14.1500	0.608276	2.69641	36.197	10.3931
5	84	1.31000	9.70667	1066.67	22.0000	0.302655	3.47479	224.796	11.3578
6	85	2.05833	6.06600	645.00	17.0000	0.356282	3.26217	145.705	6.3561
7	87	1.54000	6.87182	760.00	50.6000	0.224589	2.69514	70.178	33.1770