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Florida Lake Management Society

FLORIDA LAKE MANAGEMENT SOCIETY

COMBINED ANNUAL PROCEEDINGS

1994 & 1995 CONFERENCES

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QUALITY PLANNING - QUALITY RESULTS.

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The focus of DEPs QA Program is to assure that the methods and procedures that are employed will provide data that is: reproducible, comparable, reliable, representative, and within known limits of precision, accuracy and sensitivity.

In many cases, and for a majority of the programs in this agency, this means the use of standardized, recognized methods so that the results from various sources are, within defined limits, identical to the results from other sources.

Our goal is to help organizations plan how to integrate quality controls into their daily activities, and to provide guidance in improving the overall quality of the data that is generated by them.

I'm sure everyone will agree that we function best when we plan activities. Even the most mundane tasks such as shopping, preparing a meal, or driving to work require some planning even it on an unconscious level.

When faced with more significant or time consuming activities, planning becomes more critical. Would you take a long vacation with no planning? What about building a house? What about making a career change?

Each of these events require planning. Take a vacation, for instance. The first thing to do is to identify the objective: Visiting Alaska. Then an assessment of resources and needs: How much can I spend; how much time do I have. Implementation would include: How to travel and where to go first. Then assessment: Is enough time allotted for us to go to Nome and spend 4 days hiking in Denali? Finally contingencies: What if the airlines strike? What if our guide doesn't show up? What if there's an early summer snow?

Each of you are here today because of a commitment to understanding the lakes ecosystem, how to characterize it and how to preserve and protect its resources. Obviously, you have made a conscious decision to become involved. Are the topics presented during these sessions important to you? Are they important to your career? Are they important to the preservation and conservation of the lakes? Is the data important? Doesn't is therefore seem logical to plan how the data is generated and used?

All too often, an environmental project follows this scenario:

1. XYZ needs samples collected because something is making

their animals sick
2. QRS grabs whatever sample containers are available and collects some samples.
3. The laboratory analyzes the samples using the most profitable method.
4. The Government Agency says: Sorry, you should have met these standards which are 100 times lower than these results. Furthermore, there is documented evidence of 25 compounds which were detected on surrounding properties, but were not analyzed. GO BACK AND RESAMPLE.

Is this a cost effective, rational approach to data gathering? A little time, and simple planning would have meant that the results of the initial sampling event might have satisfied the needs and concerns of all parties.

The Quality Assurance Plan is, very simply, a document that identifies the needs, goals, implementation strategies, assessment and contingencies of a project.

Let's go over these topics in more detail in terms of a monitoring project on a lake:

ESTABLISHING OBJECTIVES:
1. The water quality of the lake needs to be established to determine if it can be used for recreation and potable water.
2. The data will be needed to determine if the current water quality is acceptable.
3. On going monitoring needs to be established to determine the impacts of new land uses.
4. This lake needs to meet class I and III water quality standards with emphasis on the pesticides and herbicides from the surrounding farms, dairies and a golf course.
5. Data from these tests will be entered into STORET.

NEEDS ASSESSMENT:
1. It is there any data on this lake? When? How? Results?
2. Are there any unusual uses that would not be addressed by the historical data? (New golf course, new housing development, etc.)
3. What are the current uses of the Lake? What are future uses?
4. What data is missing? Do we need more data on this lake?

IMPLEMENTATION:
1. What samples should be collected? Water, sediments; incoming streams; surrounding property?
2. Where should sample be collected?
3. When should they be collected? At what frequency?
4. What methods should be used?

5. What criteria should be established to determine if the data meets our goals:
6. What equipment is needed to collect the samples?
7. Should bioassessment/biodiversity be used as an indicator of in-coming stream water quality?

ASSESSMENT:
1. Will the sampling techniques provide representative samples?
2. Is the integrity of the sample maintained through the analysis?
3. Can the sample be unequivocally identified?
4. Have the QC measures been met?
5. Did the methods provide the expected sensitivity?
6. Were all instruments and equipment maintained and calibrated for efficient operations?
7. Was there unequivocal identification of detected compounds?
8. Did the data meet the overall objectives?

CONTINGENCIES:
What if:
The scheduled sampling event occurs on the day a major hurricane is expected to make landfall;
The rented boat is not available;
An important analytical instrument breaks down;
The equipment blanks show contamination;
One set of samples is accidentally lost;
There is a dyslexic technician.

Establishing the goals and doing some research on the site automatically established some of the procedures and methods to be used. It also established certain quality control measures, sampling equipment specifications and sampling protocols. I suspect that a project with this minimal planning would provide satisfactory results for all involved parties.

Because there are more benefits in rational planning that impulsive actions, DEP identified the QA Plan as an important planning and data assessment tools. All of the information I mentioned above is not reviewed in detail by my staff. However, this process is beneficial in providing all participants, which include not only the QA Section but all parties performing sampling and analysis, management, and regulatory project management a clear understanding of the objectives of the project and how they are to be achieved. This document when viewed as an overall planning tool, can be used as a mechanism to assure that the expectations and requirements of all parties have been met. Reviewing the QA Plan is a team effort. It involves the expertise and insight of the writers and project management to assure that the objectives and goals have been met based on the proposed activities. This includes a review of the sampling points and the types of tests, and unless part of the project objectives, assuring that no previous studies have been duplicates.

When these issues have been resolved to everyone's satisfaction, it becomes the QA Section's responsibility to review the sampling and analysis proposal to verify that these activities are appropriate. The types of sampling equipment and the test methods should have been established by the project objectives and needs assessment. Taking the lakes study for example:

> The objectives immediately narrowed the scope of methods and establish some data quality objectives:
>
> 1. Method sensitivity and specific methods to meet those criteria;
> 2. The need to determine absolute values for water quality (i.e. rigorous QC);
> 3. Trend monitoring could rely on minimum QC and perhaps the use of screening or semiquantitative methods;
> 4. The need to use standardized methods or methods which have been proven to be equivalent to the established methods; and
> 5. They also established the types of equipment that would be required, as well as container types and holding times.
>
> Even the contingencies, when identified, involve QA:
>
> 1. The need for backup instruments or an alternative laboratory;
> 2. The need to plan for problems with QC such as contaminated blanks or poor recoveries, including whether the data could be accepted; or
> 3. The need to institute careful cross checking routines to assure that the data is not inadvertently transposed.

If the QA Plan has been carefully planned, the involvement of the QA Section is minimized, since, as I stated, the information reviewed by this Section has already been predetermined by the objectives. It is only in cases where the plans are haphazardly written or have incomplete information, that the QA Section must return or reject a plan for inappropriate equipment, methods or quality control.

There is, however another aspect to our program: Verifying data quality - are the organizations really meeting their established data quality objectives? This is accomplished through on-site visits that assess the daily operations in terms of how well the personnel are following the protocols outlined in the QA Plans, and whether their interpretations and protocols are producing quality data.

In 1988, the QA Section began to conduct a series of laboratory audits. While many compliments were received on the thoroughness and effectiveness of the audits, review of QA Plans began to suffer. This in conjunction with the occurrence of three simultaneous vacancies exacerbated the backlog. These factors plus the fact that the reviews were dependent on the expertise and knowledge of the individual reviewer, and the non-standardized formats of the QA Plan resulted in lengthy reviews and numerous revisions.

The QA Rule, when first established, accomplished several goals:

1. Codified Department policies so that the requirements of any program were uniformly implemented on a statewide basis
2. Outlined the specific information that would be expected in QA Plans; and
3. Established specific formats in which documents would be acceptable.

The last two changes were designed to decrease the amount of time spent in reviewing a plan first by providing the submittor with a detailed outline of the expected information and secondly by allowing the section to develop and use standardized review checklists to assure all information was addressed which helped eliminate differences in individual expertise. And indeed, the number of reviews prior to the approval of a plan decreased from an average of 4 submissions to 2-3 and processing plans become more efficient, but the number of organizations affected by the QA rule increased. The positive improvements were neutralized by increase in QA Plans.

Thus, when fully staffed, the Section was able to review as many plans as were received in a month, but could not decrease the backlog, which increased each time there were prolonged absences or vacancies.

In 1990, it became apparent that other measures needed to be taken if the Section was to provide an expedient response to reviews. The most obvious solution was more positions, however, it was apparent that additional manpower would not be forthcoming. Therefore, internal and external task groups were assembled to explore ways of streamlining the QA Plan process.

The most important recommendation led to the establishment of Standard Operating Procedures that an organization could use to replace a majority of the text in a CompQAP. If an organization were to adopt the portions of the SOP that were applicable to its operations, all that would be required would be a statement identifying the specific SOPs they would follow, and assertion that these protocols would be followed, and information unique to the organization: personnel, methods, sampling protocols, analytical instruments and sampling equipment.

As a test, the QA Section assembled an Interim Standard Operating Procedures Manual for sampling protocols in late 1990 and allowed it to be incorporated by reference in CompQAPs submitted by sampling organizations. The response was overwhelmingly positive, and for those organizations who adopted SOPs, the actual time needed to review the document decreased by approximately 50%.

The DEP Standard Operating Procedures for Laboratory Operations and Sample Collection Activities was therefore proposed as a part of the 1991 rulemaking activities. This document addresses all activities that might be routinely performed by an organizations and is applicable to approximately 90% of the work related to DEP programs. Its use as a integral part of the CompQAP provided an alternative to the currently existing requirements for a fully written CompQAP. In addition, an organization has the option of adopting portions of the SOPs while providing full discussions in other sections.

The use of the SOPs was formally implemented in February of 1992, but the QA Section began allowing its use in January. The results were significant. It takes an average of 40 to 60 hours to review and approve 15-section CompQAP. This time includes the review of at least one revision. The review **AND** approval of CompQAPs for organizations that adopted all SOPs can be completed in 4 to 6 hours since 95% of the submitted documents can be approved upon first submission.

The use of the SOPs accomplished several purposes:

1. Reduced the time needed by an organization to prepare a document for submittal;
2. Reduced the review time of any given submission; and
3. Reduced the number of times a plan was resubmitted before approval.

The latter two items have been significant in reducing the backlog. In December 1992, the Section had an average backlog of 5.5 months, and a total of 461 unreviewed QA Plans. By October, the number of plans had been reduced to 245 unreviewed documents and an average backlog of 1.8 months. November, December, January and February showed increases in the numbers which were due to holidays and the fact that I had other commitments which kept me away from reviewing plans. These increases indicate the still existing delicate balance when all positions in the QA Section cannot review plans.

In March of this year, the Section made a commitment to eliminating the backlog of QA Plans older than 120 days, with a goal of reviewing QA plans within 60 days by June 1994. The 120 day limit set by the rule has been met. The projected QA backlog at the end of April is expected to be90 days and decreaseing.

Our objective of streamlining the QA review process through the use of SOPs has been successful. My staff anticipates having the time to devote to more on-site audits of laboratory and field activities, an equally important but sadly neglected part of the QA program. We are exploring ways of streamlining this process to take advantage of the on-site visits conducted by HRS on some laboratories, the PAIs conducted on others as a part of the wastewater program, and audits conducted by the counties with delegated authority for the leaking underground storage tank program. In addition, we are identifying key activities that would have the most impact on data quality and will emphasize those areas during an audit. By doing so will minimize the time needed to conduct lengthy on-site visits and will streamline the audit reports.

In addition to the streamlining the Section has done with respect to review, we have made documents more accessible by putting creating a computer bulletin board. Anyone with a computer and a modem has the ability to retrieve and download all documents pertinent to the QA program through QUASI-BBS. These documents include the rule, the entire SOP, numerous guidance documents, all review checklists, and several SOPs that program within the Department have generated for their specific activities.

Looking ahead to the future, there are several activities that you should be aware of:

1. Enhanced data base capability - The QA Section recently converted the old QA Plan tracking system to the Department's mainframe data base. The first phase concentrated on the conversion to ORACLE. The second phase will add the following enhancements:

    a. Lists of all approved methods with their QA Targets for laboratories;

    b. Lists of laboratory equipment pertinent to the approved tests;

    c. Lists of all approved field sampling capabilities by parameter grouping and sample source; and

    e. Lists of all approved sampling equipment and their use.

    Included in this will be programming that will allow the computer to screen review CompQAPs that have adopted all SOPs and QAPPs that are submitted on the DEP Forms. This will greatly enhance the ability of the QA Section to provide an expedient review of QA Plans by allowing the staff to concentrate on the non-routine or written documents. It will also provide the Department and ultimately the public with specific information about the approved capabilities of sampling and analytical organizations.

2. NELAP - EPA has made a commitment to creating a National Environmental Laboratory Accreditation Program. This program, when finalized will mean a laboratory will only need to be certified in its home state. That certification, if provided by a NELAP-approved program, will be recognized

in other states as satisfying their certification requirements. Currently out of state laboratories must submit CompQAPs to the Department as a part of the requirements for HRS certification. Both HRS and DEP have been actively involved with development of the proposed program, including implementation, structure and Quality Assurance requirements through participation in the EPA/State Focus groups.

The program will be comprehensive, addressing not only drinking water, but wastewater, solid and hazardous wastes and air. Once adopted, DEP will be supporting recognition of this program as the requirement laboratories must obtain before testing samples for any DEP related program.

The proposed program has been completed, and is currently being reviewed by EPA programs to determine if it meets the program needs. If found to be acceptable. a convention of states will be held to introduce the concept and solicit support of those states that were not actively involved in the EPA-Focus Groups. If the program is accepted, it will be up to the individual states to implement. I am hoping that NELAP will become a reality in Florida within three years. If implemented, NELAP-accredited laboratories will not be required to submit CompQAPs, but would need to provide DEP with information to put into their data base on methods and equipment.

The QA program in Florida has been in a constant state of development and refinement over the past five years. The QA Plan is and will continue to be an important part of the program. However, we are constantly looking for ways of minimizing the impact of the document to the submittor and to the reviewer.

I would like to close with this quote from John Taylor, a noted authority in Quality Systems:

> "Quality Assurance is more than just a program, it is a philosophy, a way of life. As a program that is mechanically followed, quality assurance is doomed to failure. As a philosophy, there is a chance for success. When it is approached as a program and a philosophy, that chances for producing high quality data are excellent."
>
> Taylor 1987

Quality Assurance is a two way street - The DEP QA Section represents the program - a guide to laboratories and consultants on appropriate protocols to be followed. But we cannot succeed in our goal to improve data quality in the state unless organizations to provide the leadership and support to integrate to program as a philosophy into daily operations.

KISSIMMEE RIVER RESTORATION AND ITS ROLE IN THE EVERGLADES REGIONAL SYSTEM.

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Introduction

The Kissimmee River Basin is located south of Orlando and north of Lake Okeechobee in central Florida. Channels and structures of the current system were authorized in 1954 and completed in 1971 as part of the comprehensive Central and Southern Florida Project (Loftin 1990). The existing project includes the Upper Basin, with 18 lakes that flow into Lake Kissimmee, and the Lower Basin consisting of a flood control canal and structures creating a terraced series of impoundments from Lake Kissimmee to Lake Okeechobee (Fig. 2).

The State of Florida initiated a Kissimmee River investigation in 1976 to document impacts from river channelization and determine if all or part of the river should be restored. This investigation found that floodplain wetlands had been reduced from 16,440 ha to 3,580 ha, with many drained areas converted to pasture (Pruitt and Gatewood 1976) and the remaining wetlands severely degraded. Ducks and coots were reduced by over 90 percent, wading birds had lower number of species, density, and diversity than adjacent lake wetlands, and sport fishing data indicated a possible reduction in the largemouth bass (Micropterus salmoides) fishery (Perrin et al. 1982). In addition, there was a loss or reduction of several riverine fish species and the introduction of exotic fish species. Reduced dissolved oxygen levels during certain times of the year have also impacted the fishery (Perrin et al. 1982, Wullschliege et al. 1988, Toth 1993). Moreover, bald eagle (Haliaeetus leucocephalus) nesting decreased by 74 percent in the lower Kissimmee River Basin in the 1970's, with channelization implicated as a major factor in this decline (Shapiro et al. 1982).

Although the project continues to provided drainage and flood control, it has resulted in a long-term degradation of the river's natural ecosystem. Restoration of the Kissimmee River, as studied tested and planned, provides a significant opportunity for south Florida to regain wetland and riverine values lost for channelization (U.S. Army). Improvements in these same values will also improve an important link in an inter-connected habitat system that includes three river basins, the Green Swamp Area of Critical State Concern, and Lake Okeechobee shown in Figures 2 and 3.

The Kissimmee River restoration is restoration in the truest scientific meaning of the term because it will restore a natural, functioning, self-regulating system that is integrated with the landscape in which it occurs (National Research Council).

Methods

The Kissimmee basin (Fig. 2) is roughly outlined by the South Florida Water Management District north of Lake Okeechobee. The Kissimmee River extends from the outlet at Lake Kissimmee to Lake Okeechobee and includes a 1.5 - 3 km wide floodplain on either side of the river or canal. In its present channelized state the river system consists of a series of six stair-step impoundments, each of which has a control structure at the lower end. These structures maintain constant water levels within each impoundment, keeping floodplains at the lower end inundated while draining extensive reaches of floodplain upstream. In terms of wildlife corridors, the impoundments are connected by the 100 m wide, 9 m deep canal, remnant river channels and a flanking line of oak trees, but separated by extensive drained floodplain that consists primarily of unimproved and improved cattle pasture.

Pre-channelization floodplain vegetation coverage (Fig. 1) was based upon interpretation of 1952-54 aerial photography (1:8000) (Pierce et al., 1982). Post -channelization floodplain vegetation maps were derived from 1973-74 aerial photography (1:4800 and 1:24000), low altitude observations, and extensive ground truthing (Milleson et al., 1980:76-3).

A satellite imagery study area of the environs of south-central Florida was identified (Fig. 2), bounded on the north by an east to west line through the city of Clermont, and on the south by an east to west line through the center of Lake Okeechobee. The east and west boundaries were described by north-south lines through the center of Lake Okeechobee and along the western side of the Peace River valley. The three District boundaries illustrated are on major watershed divides.

A thematic map of Florida's plant community cover, based on 1985-1989 Landsat imagery (Kautz et al., 1993), was used to identify two vegetation classes (natural and unnatural). Classifications were derived by recoding 21 of the 22 original vegetation community classes to reflect their level of cultural disturbance (Table 1.).

Table I. Reclassification of land types.

Natural Communities	Unnatural Communities
Coastal Strand	Grass (Agricultural)
Dry Prairie	Shrub and Brush
Pineland	Exotic Plant Community
Sand Pine Scrub	Barren (Urban)
Sandhill	
Xeric Oak Scrub	
Mixed Hardwood-Pine Forest	
Hardwood Hammock and Forest	
Tropical Cypress Swamp	
Hardwood Swamp	
Bay Swamp	
Shrub Swamp	
Mangrove Swamp	
Bottomland Hardwood	

Computer hardware used to generate the study area map was a Sun Microsystems Sparcstation 2 workstation, equipped with 64MB RAM, 5.3 GB storage, CD ROM drive, and a 2.3 GB-8mm tape drive. The software was the ERDAS Imagine (ver. 8.02), Image Processing software, marketed by ERDAS Inc., Atlanta, Ga. Mr. Daniel W. Teaf, a remote sensing analyst for the Florida Department of Environmental Protection in Tallahassee, was kind enough to produce the computor tapes with the previously mentioned specifications.

To assess natural habitat connectivity, the study area map was analyzed visually to identify blocks of "mostly natural" vegetation at three levels of resolution. Circular templates with radii corresponding to 5.2 km, 3.2 km, and 0.85 km were used to "window" areas on the map to identify points where the surrounding mix of natural and unnatural vegetation was approximately equal. A line connecting points of equal mix at each resolution identified the vegetation block boundaries. The scale of resolution is considered proportional to an animal's ranging capability; thus, larger areas of resolution (radius) represent those species with the capability of traveling greater distances over unacceptable habitats.

RESULTS and DISCUSSION

The principal objective of the current Kissimmee River restoration project is to restore the physical form of the system. This will be accomplished by removing two of the control structures and their tieback levees, filling 35 km of canal with adjacent spoil, leveling these spoil banks to pre-canal elevations, and recarving 14 km of river channel to reconnect the remaining remnant river channels in areas where spoil obliterated former river channel. Secondary drainage systems and the floodplain are to be similarly reclaimed. These measures will restore the longitudinal and lateral continuity of every floodplain habitat, as well as unique prechannelization hydrologic characteristics. The prechannelization hydrologic characteristics were key determinants of the functionality of the interacting river/floodplain ecosystem. By reestablishing the former physical form and hydrology, the current restoration project ecosystem will include 70 continuous km of river channel and 11,000 ha of contiguous floodplain. Water quantity and quality for the restored system is dependent upon an ongoing headwaters revitalization project, which will simulate the prechannelization seasonal high regulation stages for three lower Kissimmee lakes.

The potential value of the restoration project as a wildlife corridor stems primarily from the mosaic of at least 7 broadly defined wetland habitat types that it will recreate, and the linkages between them that it will maintain. The project will also reestablish a wetland-upland ecotone between peripheral wet prairies and the oak tree line, and preserve and enhance existing upland oak and cabbage palm hammocks.

The restored ecosystem will provide habitat for more than 320 fish and wildlife species, including 22 species that the Florida Game and Fresh Water Fish Commission identified as imperiled taxa in a valley also recognized as particularly important habitat for vulnerable reptilian and avian taxa. The Kissimmee River restoration project will benefit 36 reptile species and 177 bird species (U.S. Army).

While the present Kissimmee River system still provides habitat value and a linkage with other elements of the ecosystem, these values are much reduced from prechannelized values (U. S. Fish and Wildlife Service 1991). In addition to the direct loss of wetlands associated with channelization, much of the longitudinal aspect of wetland habitat (wetland habitat formerly available along the entire length of the floodplain) has been lost, as the structuralized system has drained the upper portion of impoundments and permanently flooded the lower areas. Fig. 1 clearly illustrates the loss and disconnection of longitudinal wetland habitat in the existing Kissimmee River system as compared with the pre-channelized river. The Historic/Post-Restoration Floodplain Wetlands maps illustrate an 11 km long section of river and floodplain. Shaded areas show the extent of wetlands that flanked the river channel before channelization. Under existing conditions, the upper 2/3 of the former wetlands of all pools have been completely drained and impounded. Some fluctuation is provided in the lower 1/3 of these impoundments.

In evaluating the projected hydrologic conditions for the restored segments of the floodplain, shallow/declining water levels would be expected to occur for four to six months of the year, particularly January through March (Loftin et al:E24-27).

These conditions would mimic prechannelized conditions that have been reported to be ideal for numerous species of birds, small fish, aquatic invertebrates, amphibians, and reptiles. Shallow water habitat is particularly important for dabbling ducks and wading birds. Restoration will also increase areal extent of shallow water by an average of 450,000 hectare-days annually. This shallow-water habitat is a characteristic of the floodplain fringe where it migrates outwardly from the channel when water levels are rising and inwardly toward the channel when water levels are falling. In most of the Kissimmee floodplain cross-sections, the ground elevation adjacent to the channel increases gently. Ground slopes over the Kissimmee River floodplain are typically in the range of 0.1 to 1.0 m per km. For a ground slope of 0.3 m per km, shallow water habitat along the floodplain fringe will cover the floodplain to a width of approximately one km on each side of the channel. Along the direction of flow, the total shallow water habitat per reach of channel is 200 ha per longitudinal km of floodplain. This description of shallow-water habitat is for a "snapshot" in time, such as for one day. As water levels persist, rise, or fall over the winter waterfowl season or annual cycle, shallow-water habitat can be cumulatively assessed by summing the daily areal extent of shallow-water habitat with units of hectare-days. It is important to note that for a period of floodwater recession, the total floodplain area decreases daily while the shallow water habitat remains essentially constant, migrating across the floodplain, until the river stage recedes to less than 0.3 m above channel banks. During the winter waterfowl period (October through February) an average increase of 200,000 ha-days is expected. During the average nesting season for wading birds (January through May) 1,100 ha (34,000 ha-days per month) of this shallow water habitat will be sustained. As this annual high water recedes, isolated depressions in the flood plain will serve to concentrate prey organisms and provide large quantities of the food needed for the production and support of young.

Analysis of the satellite imagery study area at the broadest level of resolution (5.2 km) identified two large mostly natural habitat blocks separated by a broad band of unnatural land extending from the Peace River valley to lands east of the lower Kissimmee River canal (Fig. 2). The northernmost block includes Lake Kissimmee and the upper Kissimmee River canal, while the southern block includes the western shore of Lake Okeechobee and lands farther west along Fisheating Creek. Near the northwest corner of the study area, there is a connection about a 10 km wide between the Kissimmee block and the Green Swamp (the largest area of managed forest in central Florida), while in the south-central portion of the study area, the gap between the Kissimmee block and the southern Okeechobee block is about 15 km at its closest point. At a closer level of resolution (3.2 km), islands of mostly unnatural habitat begin to expand within the Kissimmee block, and both the Green Swamp connection and the Kissimmee-Okeechobee gap narrow as the mapped blocks begin to become more elongated, with irregular edges.

The three areas of particular interest in terms of habitat connectivity are the Green Swamp connection, the Highlands area, and the lower Kissimmee River canal. These areas were mapped at the closest level of resolution using the 0.85 km radius window (Fig. 3). At this level, the Green Swamp connection becomes a narrow gap, which implies that while wide-ranging wildlife may have access to both the Green Swamp and Kissimmee blocks, there may be shorter-ranged wildlife may be limited to just one or another block. Also at closer resolution, the Kissimmee-Okeechobee gap narrows considerably but does not close. This implies that currently there may be little or no population sharing between the Kissimmee and Okeechobee blocks, at least for wildlife whose terrestrial ranging capabilities fall between 5.2 km and 0.85 km. The gap along the lower Kissimmee River canal remains the widest point of separation between the Kissimmee and Okeechobee blocks, attesting to the habitat fragmentation that resulted from the original channelization project. It forecasts a floodplain restoration project that not only restores lost habitat but may reunite wildlife between two of the largest habitat blocks in this region of Florida.

Rrestoration of the Kissimmee River represents a tremendous opportunity to restore large areas of drained riverine habitat and to reconnect major blocks of existing natural habitat in an area recognized as particularly valuable for numerous species of common and imperiled wildlife as well as man.

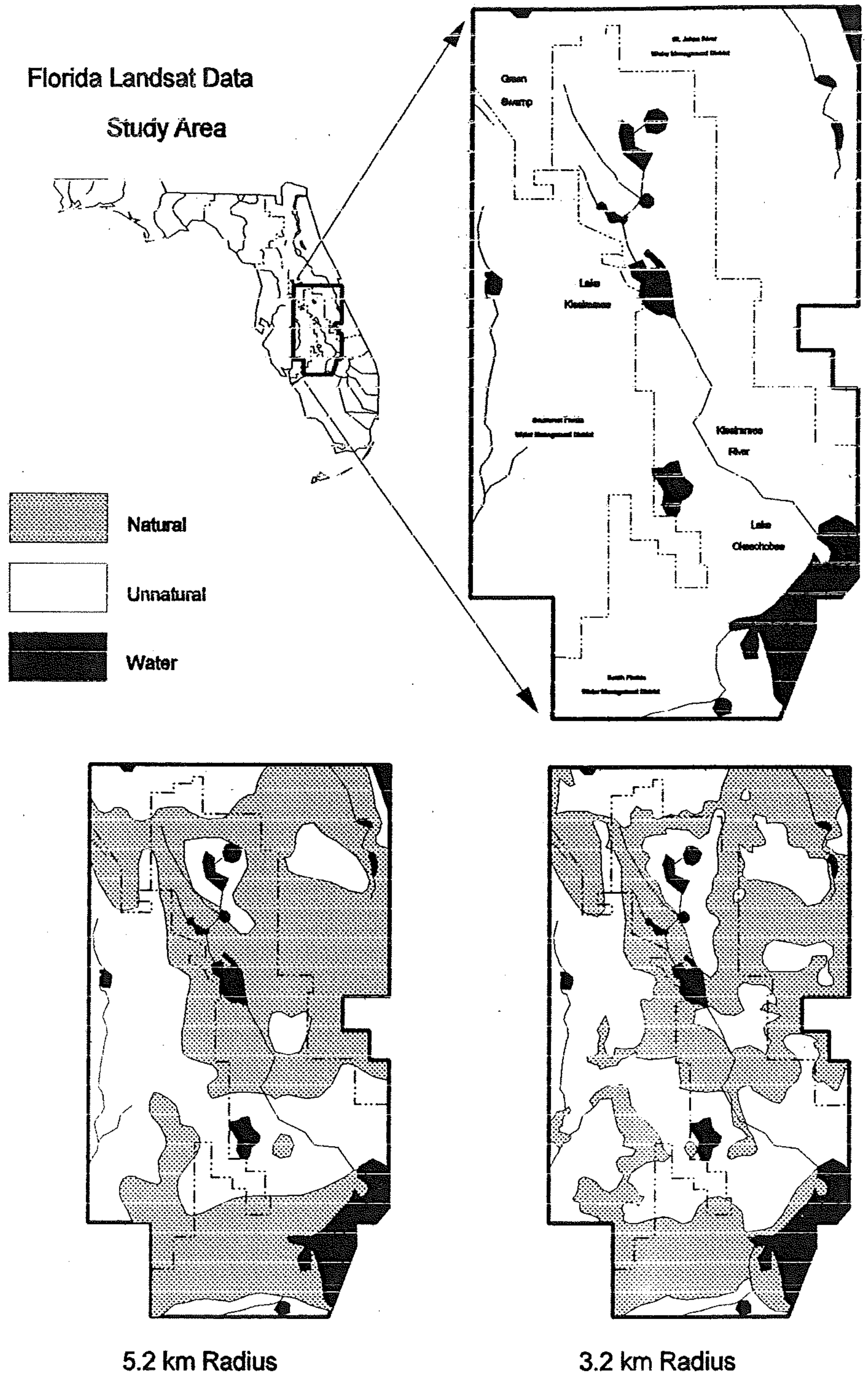

Figure 2. Satellite imagery modeling to identify areas of mostly natural habitat.

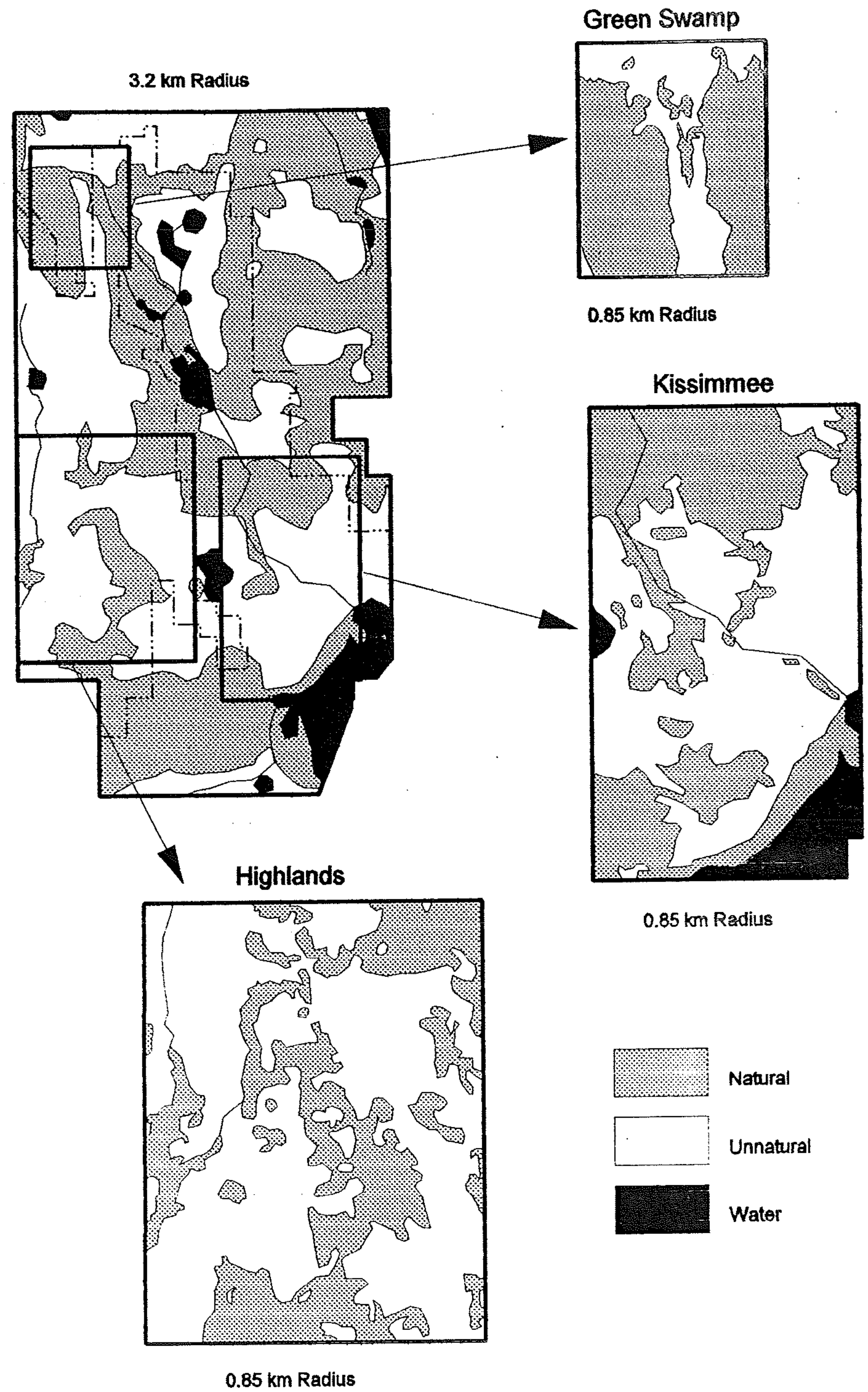

Figure 3. Key linkages at 0.85 km resolution.

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LAKE JACKSON: EVALUATION OF WATER QUALITY DATA.

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INTRODUCTION

Water quality data has been collected on Lake Jackson under six comprehensive sampling programs since 1971. While each of the studies provided extensive tables or figures, no study attempted to characterize the changes in water quality over time or space. Except for conductivity (LaRock and Landing 1991), long-term trends in concentrations of other water quality parameters have not been established.

The purpose of the analysis conducted was to fulfill part of the District's objectives under the SWIM Plan for Lake Jackson. The analysis was intended to document changes in water quality and provide a basis for measuring the success of the Lake Jackson Management Plan water quality program. **It is emphasized here that the analysis was of the water column only; no assessment was made of the relationship between the water column and vegetation or sediments in Lake Jackson.**

PROCEDURES

The evaluation of water quality comprised two primary tasks: 1) recompilation of existing data and linkage of this data to a geographic information system, and 2) statistical analysis of the data over space and time.

1. Linkage of Water Quality Data to the GIS

LaRock (1990) had compiled available water quality data from 1971 through 1987. Data from LaRock and Landing (1991) for the following parameters were appended to LaRock's compilation: nitrate, total nitrogen, ortho-phosphate, total phosphorous, conductivity, chlorophyll_, turbidity and dissolved oxygen. These parameters were selected because they are standard measures of water quality degradation, which is of concern for the lake. Other parameters were not included in this evaluation because of large gaps in sampling frequency among stations or study periods. For each parameter, the arithmetic mean and population standard deviation were calculated for each sampling location during each study. The data were then exported to the statistical package SAS for conversion to a file format that could be read by ARC/INFO, a geographic information system (GIS).

The GIS was used to analyze and depict data for each water quality parameter within the lake. First, a coverage was developed that included the lake's perimeter and the approximate locations of seven sampling stations.[1] ARC/INFO features a Thiessen routine that generates polygons about points (Figure 1). The water quality of each station was assumed to be representative of the entire polygon. The GIS was then used to support a volume-normalizing routine and to plot the data.

<u>Volume Normalization</u>
Concentrations of many water quality parameters typically exhibit an inverse relationship to lake volume. Previous studies of the lake made no provision for this effect of volume on concentration.[2] Consequently, to assess the effect of lake volume on parameter concentrations, the raw data were volume-normalized.

The bathymetry of the lake (Wagner 1984) was digitized. A triangulated irregular network (TIN) was developed from the bathymetry from which volumes could be calculated for any lake elevation. Using USGS monthly stage data, arithmetic means for each study period were calculated. The GIS was then used to calculate the lake (and polygon) volumes at each of the average stages associated with the five study periods. A sixth volume, corresponding to the average lake stage for the entire period of study, was calculated to provide a reference volume for normalizing the data.[3] Volumes were then calculated for each of the lake's seven polygons at each of the six stages as follows: for each data point (station and period), the concentration of each constituent (as mg/l) was multiplied by the respective volume (polygon and stage) in m^3 yielding the total mass in grams. This mass was then divided by the volume of the polygon associated with the lake's average stage over the period of study. Thus, the volume-normalized data indicate the expected concentrations of each parameter if the lake level had remained constant across the periods of study. It was necessary to normalize the concentrations because the polygons are not of equal size, i.e., the total mass of constituents would not be comparable among polygons.

<u>GIS Representation of Changes in Water Quality</u>
To depict the data, the lakewide range of values for each parameter was determined and divided into five equal increments. The GIS was then used to produce a map of the lake for each of the study periods wherein each polygon was shaded according to the increment in which the parameter concentration lay.

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1 Station 5, the interior of Megginnis Arm, was not included because recent data were not available and only two of the earlier studies used the same location.

2 Lake Jackson was at various stages among the five studies, ranging from complete drawdown to a maximum depth of approximately 13 feet.

3 This selection of stage and volume was arbitrary; any stage value could have been used. The use of a stage value within the existing range of stages, however, permits use of the same range and increments for more consistent graphic representation.

The GIS was also used to depict the change in each polygon over time. The Late '70s study was selected as a benchmark because it provides the best approximation of the lake's water quality at the time of its designation as an OFW.[4] Differences in concentrations between 1979 and 1991 were calculated for both raw and volume-normalized data. The percent change was calculated to provide perspective on which polygons experienced the greatest relative changes. As above, the absolute ranges of results (both positive and negative) were determined and then divided into five equally-sized increments for graphical representation. Moderate intensity shading was used to indicate "No Significant Change" (in this case -20% to +20%), lighter shading was used to suggest improvement and darker shading describes a worsening of water quality.[5]

2. Statistical Analysis

Statistical methods were used to address three questions:

1) Did the data exhibit a normal distribution, i.e., were the calculated means reasonable estimators of the true population averages?;
2) Were there differences among the various sampling stations and study periods, and in particular were the Late '70s significantly different than the Early '90s?;
3) Were there any statistically significant trends over time?

Normality of Data

The SAS procedure UNIVARIATE was used to determine whether the data were normally distributed, by station and study period. Except dissolved oxygen, the distributions of the majority of populations tested were not normal. A log transformation of the data reduced the frequencies of these incidences, although in about a fourth of the cases the log-transformed data still failed to meet the criterion for normality. To further improve the degree of normality (and to reduce variability), the data were partitioned by season. "Winter" consisted of the months November through April while "Summer" consisted of the months May through October. Distributions for nitrate and ortho-phosphate remained non-normal despite log-transformation and accounting for seasonality.

[4] One objective of the SWIM plan for Lake Jackson is to assess the relevance of these OFW water quality standards to the task of restoration and protection.

[5] "Significant" here refers to relative intensity only; no inferences regarding statistically significant differences were made.

Differences Among Stations and Study Periods

Based on an assumption of normal distributions for the log-transformed parameters (other than nitrate and ortho-phosphate) and that the sample variances were homogeneous, an analysis of variance was performed to determine whether there were differences among the station and study period means, by season.[6] The SAS procedure GLM was applied to the data using a multiple regression that specified that the data were a linear function of the station, the study period and their interaction. The nonparametric Kruskal-Wallis test (SAS procedure NPAR1WAY) was used to detect differences among means for nitrate and orthophosphate. Where there were differences among study periods, the SAS procedure TTEST was used to determine whether the Late '70s and the Early '90s were significantly different, by season and station,.

Trends

To identify the presence of temporal trends, the SAS procedure CORR was used calculate the Pearson correlation coefficients describing parameter value and study period, which were labeled 1 through 5 in chronological order. Non-parametric Spearman Rank correlation coefficients were calculated for nitrate and ortho-phosphate.

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[6] Homoscedasticity was not tested for explicitly; standard deviations for each parameter were reviewed and found to be similar, primarily because of the log transformation.

Table 1. Summary of Analyses of Variance ($p < 0.05$).

Log-transformed Data

PARAMETER	STATION	SUMMER STUDY	INT'N	STATION	WINTER STUDY	INT'N
Nitrate*	ns	**sig**		ns	**sig**	
Total Nitrogen	ns	ns	ns	ns	ns	ns
Ortho-Phosphate*	**sig**	**sig**		**sig**	**sig**	
Total Phosphorous	**sig**	**sig**	ns	**sig**	**sig**	ns
Chlorophyll[a]	**sig**	**sig**	ns	**sig**	**sig**	ns
Conductivity	sig	sig	*sig*	sig	sig	*sig*
Turbidity	sig	sig	*sig*	**sig**	**sig**	ns
Dissolved Oxygen	sig	sig	*sig*	ns	**sig**	ns

Volume-normalized Log-transformed Data

PARAMETER	STATION	SUMMER STUDY	INT'N	STATION	WINTER STUDY	INT'N
Nitrate*	ns	**sig**		ns	**sig**	
Total Nitrogen	ns	**sig**	ns	ns	**sig**	ns
Ortho-Phosphate*	**sig**	**sig**		ns	**sig**	
Total Phosphorous	sig	sig	*sig*	**sig**	**sig**	ns
Chlorophyll[a]	**sig**	**sig**	ns	sig	sig	*sig*
Conductivity	sig	sig	*sig*	sig	sig	*sig*
Turbidity	sig	sig	*sig*	sig	sig	*sig*
Dissolved Oxygen	sig	sig	*sig*	sig	sig	*sig*

* Because the distributions for nitrate and ortho-phosphate were not normal, the table includes the results of a Kruskal-Wallis (nonparametric) test. The significance of interactions can not be determined with this test, however. Consequently, significant differences among stations and study periods were assumed to be valid.

Table 2. Long-term Trends in Water Quality Data for Lake Jackson (1971-91).

Summer

Raw

PARAMETER	TREND
Nitrate	-
Total Nitrogen	none
Ortho-phosphate	none
Total Phosphorous	-
Chlorophyll[a]	none
Conductivity	+
Turbidity	-
Dissolved Oxygen	+

Volume-normalized

PARAMETER	TREND
Nitrate	-
Total Nitrogen	+
Ortho-phosphate	-
Total Phosphorous	-
Chlorophyll[a]	+
Conductivity	none
Turbidity	-
Dissolved Oxygen	none

Winter

Raw

PARAMETER	TREND
Nitrate	-
Total Nitrogen	none
Ortho-phosphate	none
Total Phosphorous	-
Chlorophyll[a]	+
Conductivity	+
Turbidity	-
Dissolved Oxygen	+

Volume-normalized

PARAMETER	TREND
Nitrate	-
Total Nitrogen	+
Ortho-phosphate	+
Total Phosphorous	-
Chlorophyll[a]	+
Conductivity	none
Turbidity	-
Dissolved Oxygen	none

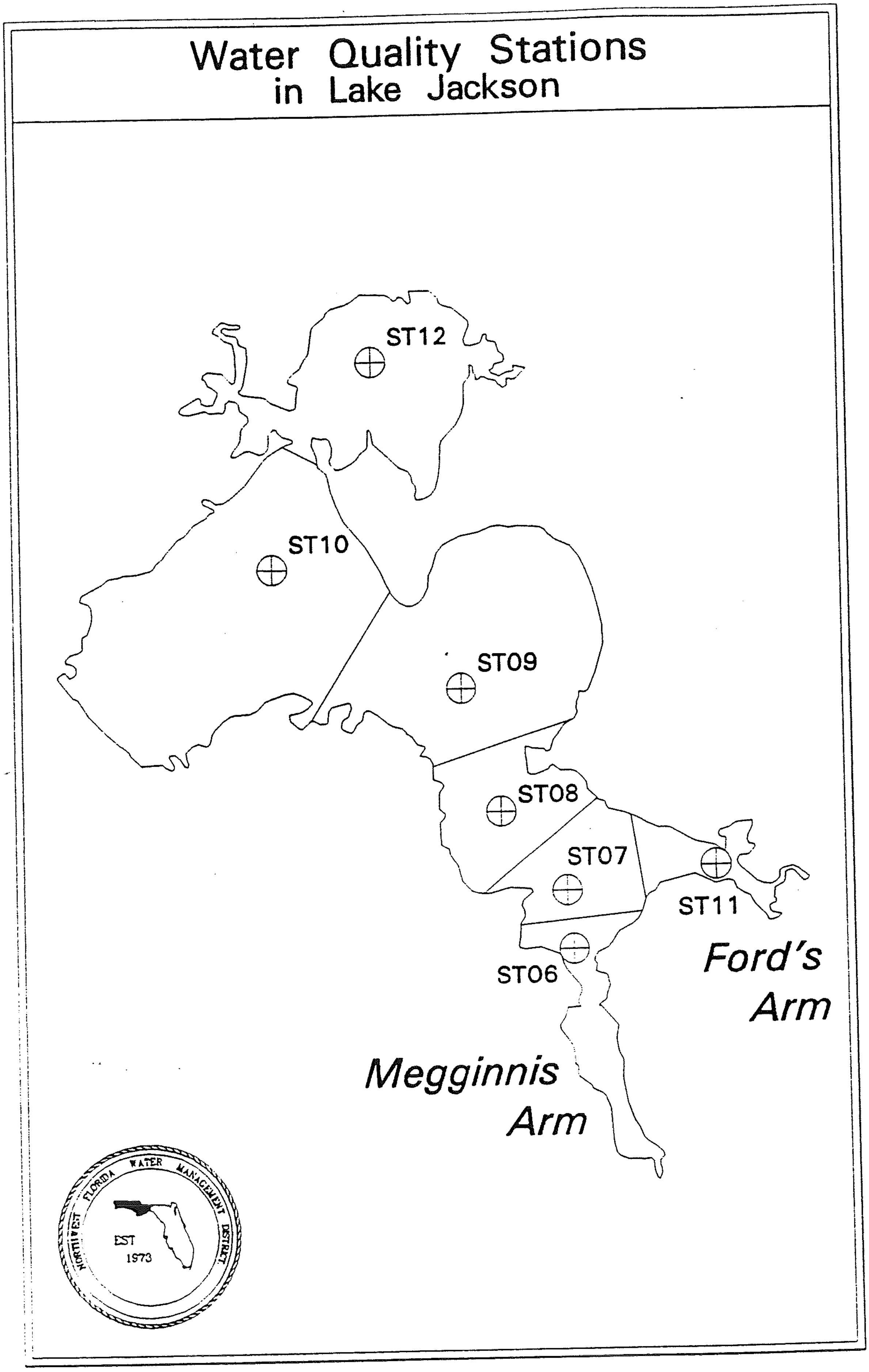


Figure 1. Water Quality Stations in Lake Jackson.

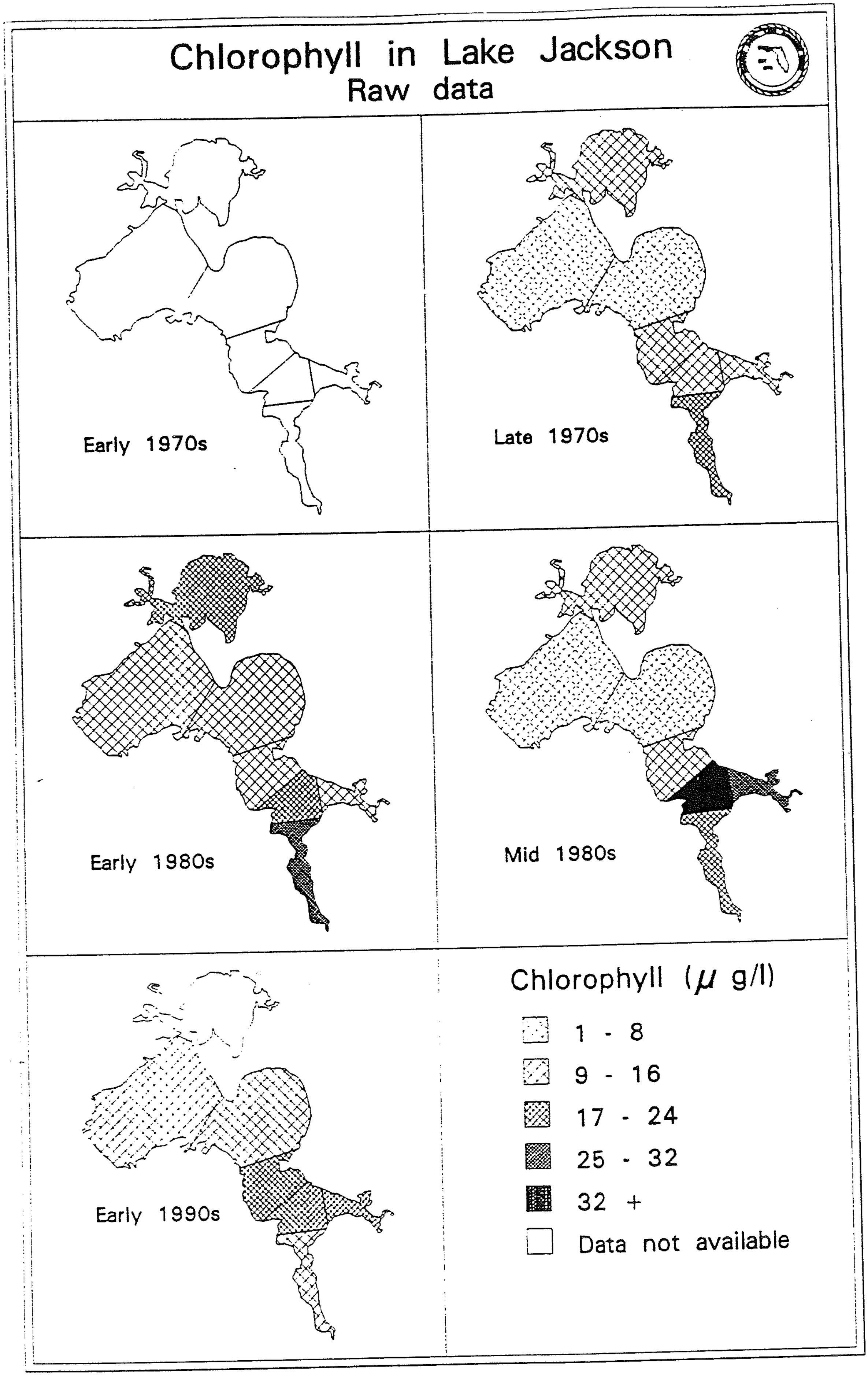


Figure 2a. Mean Chlorophyll Concentrations (raw data).

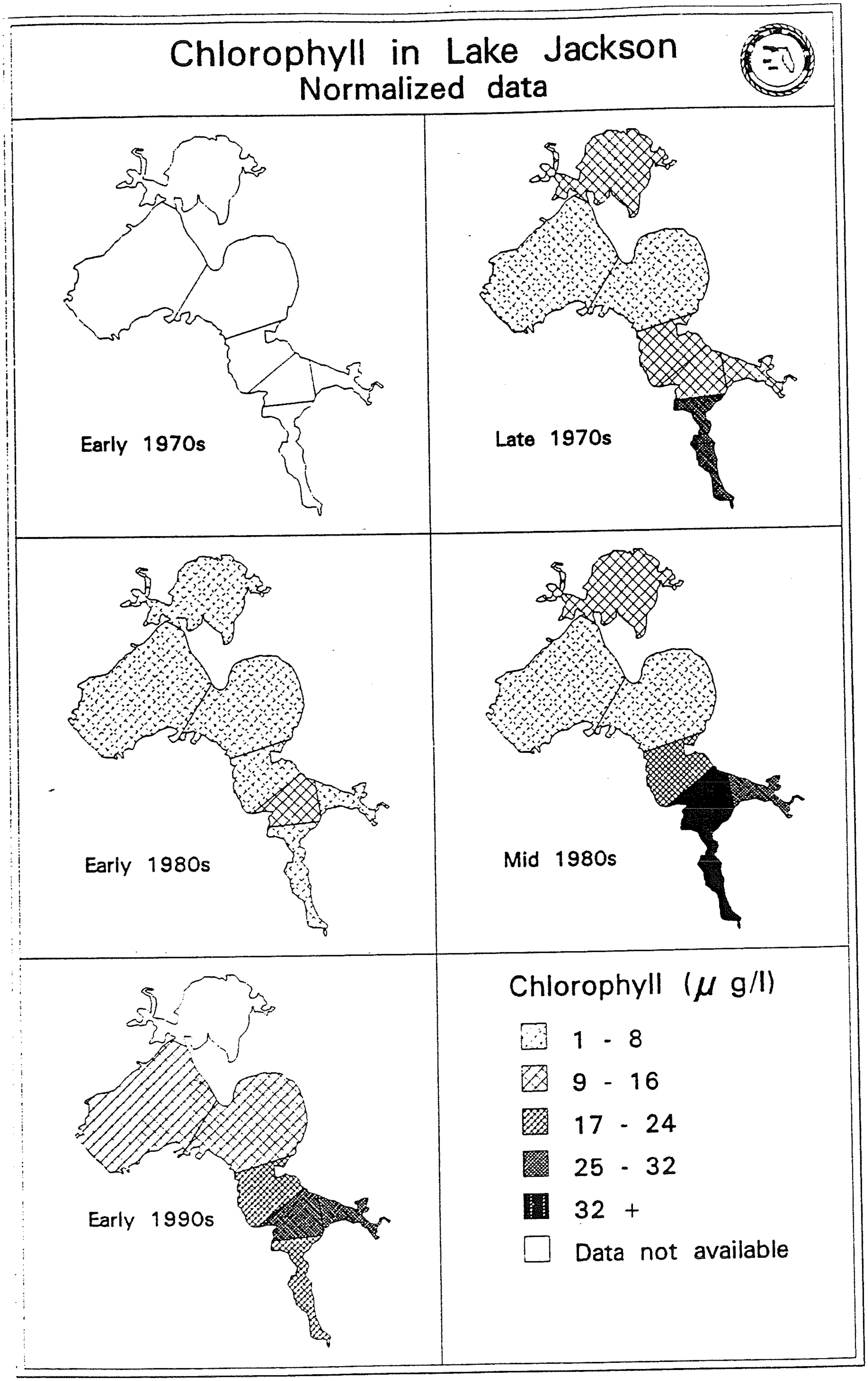
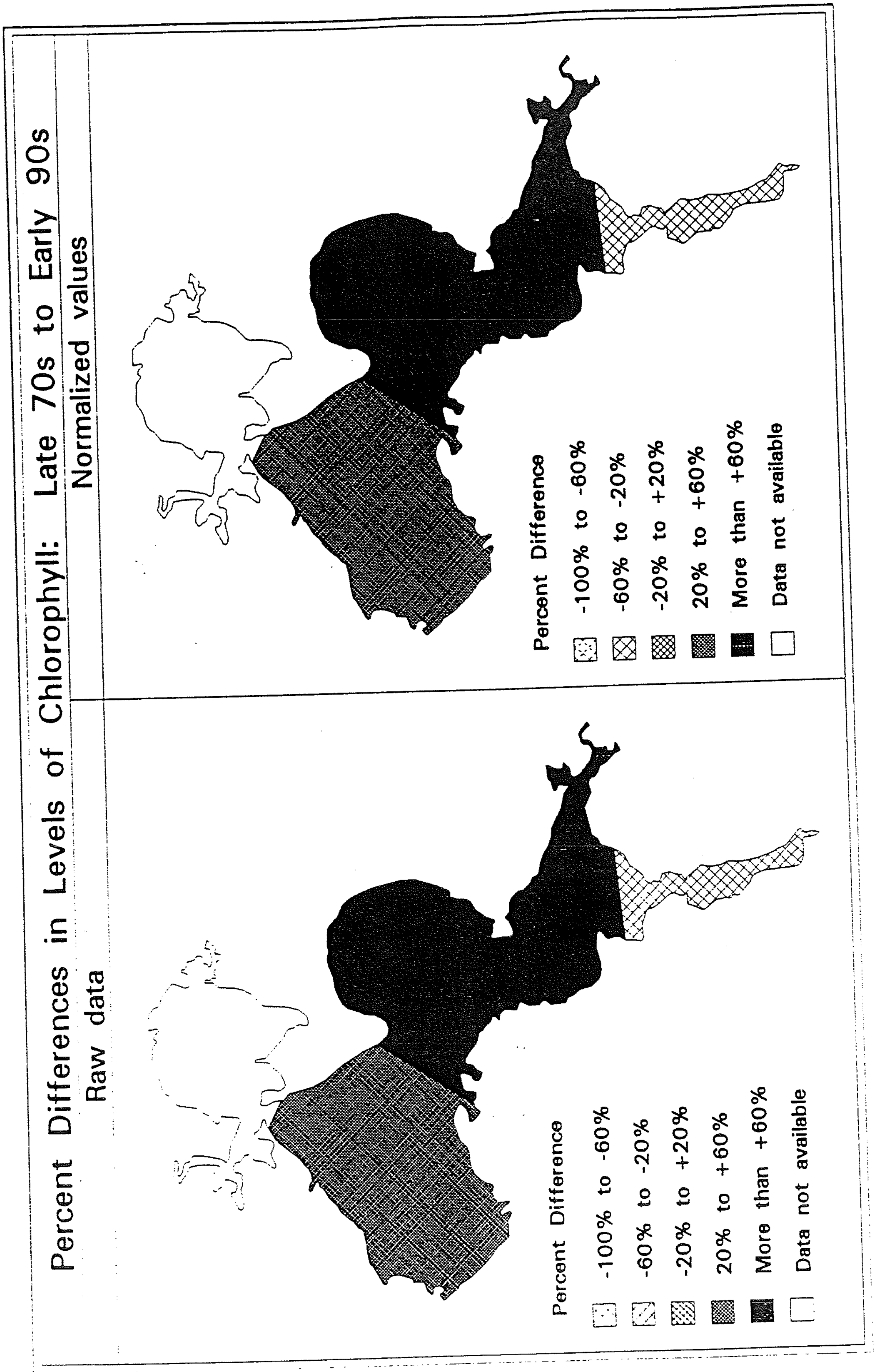


Figure 2b. Mean Chlorophyll Concentrations (volume-normalized data).



Figures 2c-d. Percent Change in Chlorophyll Concentrations (Late '70s to Early '90s).

RESULTS AND DISCUSSION

Differences Among Stations and Study Periods

Table 1 summarizes the differences in log transformed means among stations and study periods. While there were significant differences found in the majority of cases, many of these were confounded by significant interactions between location (STATION) and time (STUDY). In these cases further distinctions between individual stations and study periods may not be valid. Consequently, conclusions regarding statistically significant differences between stations and study periods are limited to total phosphorous and chlorophyll_ (Summer) and total phosphorous, chlorophyll_, turbidity and dissolved oxygen (Winter). Further, discussion of dissolved oxygen is restricted to differences in study periods only. Significant interactions were more frequent in the volume-normalized data; valid comparisons may only be drawn for chlorophyll_ (Summer) using this data.

In general, time (STUDY) accounted for the majority of the variability in the data. Volume-normalizing reduced the total variance, however, for seven of the eight parameters. Location (STATION) accounted for the majority of the variance in two of six parameters in the raw data (conductivity and total phosphorous, summer; conductivity and turbidity, winter) while location accounted for the majority of the variance in only one instance when the data were volume-normalized (ortho-phosphate, both summer and winter). Thus, volume-normalizing resulted in a shift in the share of variance explained (from STATION to STUDY) for ortho-phosphate and total phosphorous (Summer) and ortho-phosphate and turbidity (Winter). Volume-normalizing tended to increase the share of the variation accounted for by location, but it did not tend to alter which variable had the larger share. This result is to be expected because volume-normalizing was intended to reduce the effect of lake stage (a function of time).

Changes Over Time

Between the Late '70s and the Early '90s, there were no statistically significant changes anywhere for total nitrogen and there were few changes in ortho-phosphate, total phosphorous, or turbidity. Nitrate exhibited the largest degree of difference over time (a decline at all stations during the summer), followed by chlorophyll (an increase at five stations during the winter). Significant differences between the two periods found for conductivity, turbidity and dissolved oxygen are invalid in the context of the lake as a whole. Volume-normalizing did not affect the number of stations in which differences were found, except for conductivity and turbidity, and in these instances Station 6 (which was sensitive to the procedure) became included in the count. In the context of lakewide behavior, widespread differences over time existed for nitrate (summer and winter) and chorophyll (the winter only).

While there were few strong trends (only eight cases where the absolute value of the coefficient was greater than 0.60), there were more significant correlations found during the winter than the summer. In those instances during the summer where a correlation was found to be significant for both the raw and volume-normalized data, the correlation for the volume-normalized data was stronger in four cases and weaker in three. However, during the winter, correlations for the volume-normalized data were stronger in 10 cases but weaker in only one.

The strongest correlations found in the raw data were for conductivity (+0.68) at Station 7 (winter) and turbidity (-0.68) at Station 12 (winter). In only two instances were there declines in one location over time, but increases elsewhere (ortho-phosphate at Station 12 in the winter; ortho-phosphate at Station 6 in the summer, volume-normalized). The largest lakewide trend was for chlorophyll_, during the winter. [Volume-normalized nitrate exhibited a stronger correlation, but this was a Spearman rank coefficient and may not be comparable.]

Table 2 summarizes the lakewide trends in water quality behavior over the period of record. Negative (-) implies decreases in concentration while positive (+) indicates an increase. For the summer data, volume-normalizing did not reverse any of the trends identified among the raw data, although the positive trends identified in the raw data for conductivity and dissolved oxygen became insignificant. Conversely, the insignificant trends for total nitrogen and chlorophyll_ and for ortho-phosphate became positive and negative, respectively. During the winter, volume-normalizing brought out positive correlations for total nitrogen and ortho-phosphate but reduced the significance of correlations found for conductivity and dissolved oxygen.

<u>Parameter Behavior</u>

Figures 2a and 2b show the concentrations of Chlorophyll_ in each of the polygons comprising the lake over time. Chlorophyll_ is discussed here because it is indicative of the behavior of several other parameters.[7]

Chlorophyll_ exhibited significant differences among stations and study periods, although the interaction term for winter volume-normalized data was also significant, confounding these distinctions. Differences over time during the summers were restricted to stations 6 and 12 while differences during the winters occurred at stations 7, 9 and 11. Volume-normalizing introduced significant differences at stations 8 and 11 in the summer and 6 and 8 in the winter.

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[7] See Water Resources Special Report 94-3, NWFWMD, for a complete discussion of all water quality parameters.

In general, lakewide concentrations have increased since the Late '70s, although summer concentrations (raw data) stayed about the same. Megginnis Arm has had the highest concentrations year-round while Station 9 has had the lowest in the summer and Station 10 has had the lowest in the winter. There were significant positive correlations between Chlorophyll_ concentrations and study period at stations 9 and 11 in both summer and winter.

Except in the arms, concentrations have varied modestly in the lake. The north end of the lake, for example, has ranged from as little as 9 _g/l to as much as 24 _g/l. Concentrations in the lake's main body increased, declined and increased again, although the volume-normalized data suggest that levels have generally increased lakewide over time. Fords Arm and adjacent waters now have the highest raw concentrations in the lake, roughly double the levels elsewhere. While raw chlorophyll_ concentrations in Megginnis Arm appeared to have declined consistently since 1981 (from 26 _g/l to 12 _g/l), the volume-normalized concentrations have increased.

Figure 2b indicates that all of the lake, except for Megginis Arm, has shown large gains in chlorophyll_ concentrations since 1981. Both the raw and volume-normalized data indicated that concentrations in the central lake increased by at least 60% while the western area increased by at least 20%. However, over the past decade, significant increases have occurred only at stations 7, 9 and 11. Thus, the large changes noted for stations 8 and 10 are not significant.

Megginnis Arm, unlike the open lake, exhibited a modest decrease in chlorophyll_ concentrations, perhaps in response to reductions in stormwater loading. Given the decrease in nitrate and the increase in ortho-phosphate, it appears that phytoplankton productivity may now be nitrogen limited in the Arm.

CONCLUSIONS

The following conclusions can be made from the analyses performed:

1) There was great variability in the raw data for all parameters except dissolved oxygen. Partitioning the data by season reduced the overall variability and a log transformation was needed to permit the use of parametric statistical analyses;
2) There were significant differences among the stations for all parameters except nitrate and total nitrogen, and zones of water quality can be defined for the other parameters over time;
3) There were significant differences among the studies for all water quality parameters except total nitrogen;
4) Significant interactions between station and study

period were found in the majority of cases evaluated, however, restricting the ability to identify which particular pairs of stations or study periods are different;

5) Changes have not been monotonic. There were numerous significant trends, but few were particularly strong (maximum $|r|$ of 0.68);

6) Lakewide water quality has improved in terms of nitrate and ortho-phosphate during the past decade; and

7) Volume-normalized data provided either confirmation of the patterns evident in the raw data or additional distinction when the raw data failed to do so. Caution needs to be exercised in cases where the normalizing factors are extreme, e.g., greater than 1.0 or less than 0.5.

Spatially, parameter concentrations were highest at stations 6, 7, 8 and 11 (Megginnis and Fords arms and the adjacent southern waters of the lake).[8] Temporally, concentrations for many of the parameters (except turbidity) were low-to-moderate during the 1970s, reached a peak during the 1980s, and then declined in the early 1990s. Consequently, for many parameters, the concentrations of the Early '90s were similar to those of the Late '70s, yet were lower than those of the Early '70s. Thus, over the period of record the lake as a whole has improved, but relative to the conditions at the time of OFW designation there were few significant differences. Locally, however, there have been numerous changes. The spatial patterns among stations are linked to temporal patterns: in some instances, declines in water quality appeared first in the arms and then spread northward.

It may be inferred from the data that while the construction of the Megginnis Arm stormwater treatment facility had short-term negative effects on water quality throughout the southern reaches of the Lake its facility operation has been responsible for numerous noticeable improvements. Key differences observed appear to be related to a reduction in particulate phosphorous (constant ortho-phosphate but a decrease in total phosphorous) and an increase in exported marsh organics (constant nitrate but an increase in total nitrogen).

While conditions have improved in general, for several critical parameters (total nitrogen, total phosphorous and chlorophyll_), the present concentrations are borderline between "fair" and "poor" according to the State of Florida's Trophic State Index (Hand and Paulic 1994) and DEP has indicated that the lake's

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[8] Station 12, the northern part of the lake, is an anomaly. In many instances, parameter concentrations there were not significantly different from the arms and southern waters of the lake. It is possible that agricultural runoff has affected that part of the lake.

status is threatened. **As of 1991, water column quality is "good" in that many of the parameter concentrations are at or near their lowest values over the period of record. It cannot be inferred from water column water quality alone, however, that the ecological health of the lake is good.** Lakewide chlorophyll_ concentrations suggest that while longterm loading of nutrients may be leveling off or decreasing, past loadings are now being actively cycled and stored between vegetation and sediments. All three of these nutrient storages must be examined jointly to provide an adequate assessment of the lake's condition.

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Banana Lake Fish Population Changes after Municipal Wastewater Effluent Diversion and Hydraulic Dredging.

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INTRODUCTION

Banana Lake is a 104 hectare, shallow (mean depth <1 m), hypereutrophic waterbody located southeast of the City of Lakeland in Polk County, Florida. Phosphate mining undertaken in the western part of the lake in the 1940's reduced its surface area from 138 hectares to 104 hectares. The lake is bordered by citrus groves, improved pasture, unreclaimed mine lands, a hardwood swamp, and expanding residential developments.

From 1926 until May 1987, the Lakeland Wastewater Treatment Plant (10 MGD capacity) discharged secondarily treated sewage effluent into Stahl Canal which flowed 3.2 km to the northwest pit and into Banana Lake. Excessive nutrient loading resulted in periodic phytoplankton blooms and accelerated organic sediment accumulation. Florida Game and Fresh Water Fish Commission (Commission) Regional biologists attributed major fish kills occurring in 1971 and 1972 to inadequately treated sewage entering the lake.

In 1969 the Southwest Florida Water Management District (SWFWMD) constructed a water level control structure at the Banana Creek outflow that maintained lake levels near 105.5 feet above sea level. Erosion rendered this structure inoperative in 1981 and resulted in lower lake levels, reduced access, and an expanding cattail (Typha spp.) community.

Public access to Banana Lake is limited to an unimproved ramp on the south shore; however, a County park that will include an improved boat ramp is currently under development. Public utilization of Banana Lake prior to restoration was, for the most part, limited to haul seine and cast-net commercial fishing activities. Commission Regional biologists estimated the value of this commercial fishery at $40,000 in 1988.

RESTORATION PLAN DEVELOPMENT AND IMPLEMENTATION

The Banana Lake Improvement Committee was formed in 1982 with the intent of restoring the lake to a usable condition. The committee was comprised of local citizenry, City, County, and State government officials. The SWFWMD, through the Surface Water Improvement and Management (SWIM) Act of 1987, designated Banana Lake as a priority waterbody in need of restoration. It was an ideal restoration candidate because the primary cause of degradation, sewage effluent, had recently been diverted from the watershed. In addition, background information gathered by the Improvement Committee offered a solid foundation for development of a comprehensive management plan for Banana Lake. The Banana Lake SWIM management plan included an in-lake restoration project consisting of hydraulically dredging loose organic bottom sediments to improve water quality, aquatic habitat, and fisheries that was designed in 1987 by the Imperial Polk County Water Resources Division (PCWRD). Hydraulic dredging of organic bottom sediments (764,526 m^3) was conducted from August 1990 through August 1991.

MATERIALS AND METHODS

Blocknet-rotenone samples (0.4 hectares) (Wegener and Williams, 1974) were conducted to evaluate the fish population in Banana Lake. Two samples were collected in fall 1985 and four samples were collected each fall from 1988 through 1993. Sampling included both limnetic and littoral areas. Dead fish were collected, identified to species, counted, measured, and weighed for three consecutive days.

Water quality in Banana Lake was monitored by PCWRD from 1986 through 1993. Aquatic macrophyte coverage estimates were obtained from survey data collected by the Florida Department of Natural Resources (FDNR)(currently Florida Department of Environmental Protection).

RESULTS

Blocknet data collected in Banana Lake in 1985 and from 1988 through 1993 are summarized in table 1. Comparison of blocknet data collected from Banana Lake in 1985 to data collected from 1988 through 1993 revealed dramatic improvements in the fish population. Species richness increased from nine in 1985 to 22 in 1992. Sportfish species representation in 1985 samples was limited to bluegill (Lepomis macrochirus). By 1989, samples included largemouth bass (Micropterus salmoides), redear sunfish (Lepomis microlophus), spotted sunfish (Lepomis punctatus), warmouth (Lepomis gulosus), and black crappie (Pomoxis nigromaculatus). Fish biomass estimates increased from 28.1 kg/ha sampled in 1985 to 783.9 kg/ha in 1993. Similarly, sportfish biomass estimates increased from less than 0.1 kg/ha in 1985 to 169.2 kg/ha in 1993. Abundance of threadfin shad (Dorosoma petenense) increased from an estimated 111.2 shad/ha in 1985 to a maximum of 48,101 shad/ha in 1992.

Aquatic plant surveys conducted on Banana Lake by the FDNR documented traces of hydrilla (Hydrilla verticillata) in Banana Lake in 1986. Hydrilla was still a minor component of the plant community in 1989 (<0.2 ha). Total macrophyte coverage in 1989 was estimated at 5.6 ha or 5.4 percent of lake surface area. The most prevalent aquatic macrophyte that year was cattail (2.4 ha). Hydrilla began expanding in the 1990's and by 1993 hydrilla coverage was estimated at 20 ha or 19.5 percent of lake surface area.

Analysis of water quality data collected from 1986 through 1993 by PCWRD revealed an abrupt decline in total ammonia concentrations from 8.19 mg/l in March 1987 to concentrations at or below the detection limit of 0.03 mg/l in June 1987. Total ammonia concentrations generally remained at trace levels from that date forward.

DISCUSSION

We attributed the rapidly expanding fish population in Banana Lake to a combination of reduced ammonia toxicity, expanding quality fish habitat in the form of hydrilla, and very high lake productivity. Meade (1985) concluded that acute total ammonia toxicity concentrations (96-hour LC_{50}) for nine freshwater fish species ranged from 0.32 to 3.10 mg/l. Historically, total ammonia concentrations in Banana Lake routinely exceeded reported toxic values. Synergism related to temperature, pH, and dissolved oxygen content may have amplified ammonia toxicity in Banana Lake. Total ammonia concentrations rapidly declined from chronic sub-lethal and lethal concentrations to tolerant concentrations within one month of the May 1987 effluent diversion and remained at tolerant concentrations throughout the study period. Moxley (1982) attributed expanding sportfish populations in lakes Parker and Hunter to expanding hydrilla that offers beneficial fish habitat.

CONCLUSIONS

The data presented in this paper reveal that sewage effluent diversion followed by hydraulic dredging offered a highly successful means for restoring fish populations in Banana Lake. Traditional water quality analyses (e.g. Florida TSI) may not reveal changes in chemistry that are very important to lake biota.

Table 1. Average number and weight (kg) per hectare of fish collected in blocknets, Banana Lake (1985-1993).

	1985		1988		1989		1990		1991		1992		1993	
Species	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt
Largemouth bass	0	0	153	2	59	9	256	7	190	11	185	19	333	26
Bluegill sunfish	15	tr	1102	7	985	9	7324	13	8249	44	9284	27	6572	89
Redear sunfish	0	0	188	4	394	5	319	6	512	8	7503	13	1109	33
Spotted sunfish	0	0	0	0	1	tr	1	0.1	45	1	34	1	1	tr
Warmouth	0	0	26	0.1	1	tr	41	1	112	2	1000	16	254	9
Blk crappie	0	0	35	1	10	.2	3	.2	48	1	43	3	248	12
Yellow bullhead	0	0	0	0	0	0	28	1	0	0	0	0	0	0
Brown bullhead	1	tr	39	2	3	.1	107	3	7247	41	685	19	171	8
Blue tilapia	461	22	4739	19	828	186	1052	122	232	30	718	96	952	528
Bowfin	0	0	0	0	0	0	0	0	0	0	1	2	1	1
Least killifish	0	0	0	0	0	0	0	1	tr	3	tr	0	0	0
Longnose gar	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Florida gar	0	0	0	0	0	0	1	tr	1	tr	4	4	6	4
Golden shiner	0	0	68	.4	16	1	1378	25	87	1	93	1	265	5
Taillight shiner	1	tr	38	.1	124	.1	409	.2	17	tr	335	.3	1051	.8
Threadfin shad	111	.8	8278	17	16237	23	21964	77	46338	47	48101	66	18390	61
Gizzard shad	1	tr	3631	60	1772	51	48	4	510	13	103	5	70	5

Species	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt	#	Wt
Seminole killifish	48	.4	373	2	64	.4	351	3	30	.2	36	.2	22	.3
Bluefin killifish	0	0	198	.1	0	0	31	tr	3	tr	118	tr	40	tr
Brook silverside	0	0	27	tr	0	0	173	.1	17	tr	2	tr	0	0
Sailfin molly	46	.1	12	tr	25	tr	7	tr	1	tr	66	.1	0	0
Dollar sunfish	0	0	0	0	0	0	55	.4	82	.2	331	1	59	.5
Mosquitofish	17989	4.5	19	tr	132	tr	246	.1	31	tr	8851	52	888	.4
White catfish	0	0	0	0	1	.3	0	0	0	0	0	0	0	0
Total	18673	28	18926	114	20650	285	33793	262	63754	198	78677	325	30439	784
No. Species	9		16		16		21		20		22		20	

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AQUATIC VEGETATION MANAGEMENT IN LAKE SEMINOLE.

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Lake Seminole, located in southwest Pinellas County, is the second largest lake in the county. Numerous complaints have been received over the years by local and state agencies regarding declining water quality in the lake. In January 1989, the Pinellas County Board of County Commissioners passed a resolution to initiate a study of Lake Seminole, urging the joint development of an effective lake management program.

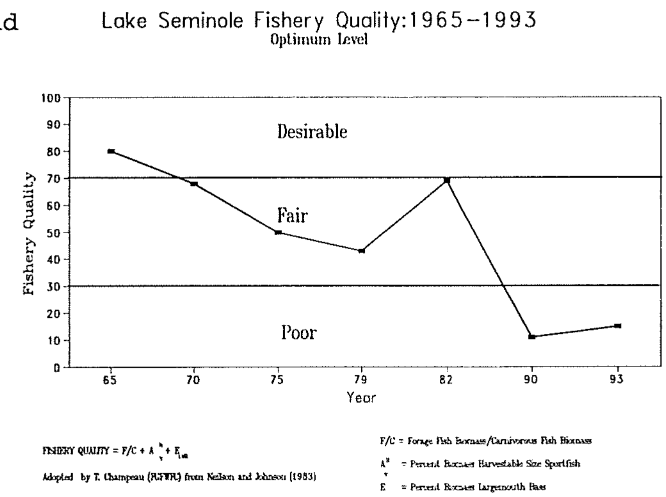

Figure 1

The environmental assessment was adopted by the Southwest Florida Water Management District and a baseline study was developed. Participants in the study included the District, Pinellas County, the Florida Department of Natural Resources (FDNR), the Florida Game and Freshwater Fish Commission (GFC), the Cities of Largo and Seminole, the University of Florida, and the University of South Florida. Major project tasks were contracted to each agency and reports were compiled into a final summary, the Lake Seminole Diagnostic Feasibility Study, in addition to a water quality model created by Dames & Moore. The Lake Seminole Advisory Committee, comprised of study participants and citizen representatives, was also formed to allow freer exchange of information and more public participation.

Results of the study show that the majority of the Lake Seminole Watershed is highly developed (88%), most of which (83%) was developed prior to any stormwater regulations. The preponderance of stormwater pipes, 131 total, are the major source of declining water quality in the lake. The lake has no inflow of water other than stormwater and the stabilized water level is a contributing factor to lake degradation. The two dominant aquatic macrophyte species in the lake were *Hydrilla*, covering 227 acres (30% of lake area), and *Typha*, covering 107 acres (14% of lake area) (Rodgers, 1991). Ambient water quality monitoring shows that Lake Seminole has elevated nutrient concentrations, resulting in high chlorophyll a concentrations, which is rather evident by its year round pea green color. Dissolved oxygen concentrations in *Hydrilla* stands occasionally fell below values considered necessary for a healthy aquatic ecosystem (SWFWMD, 1992). The trophic state index for the entire lake was 74.7, which places Lake Seminole within the eutrophic classification for Florida lakes (SWFWMD, 1992).

The stabilized lake level, high trophic state, the poor aquatic habitat, and a macrophyte community dominated by excessive densities of *Typha* and *Hydrilla*, relates to a fish community composed of few predators and high densities of forage fishes. Bass recruitment in the lake is poor. Anglers, surveyed in 1991, who had fished Lake Seminole for more than five years believed the fishing quality had declined and attributed this to an increase in vegetation (Figure 1).

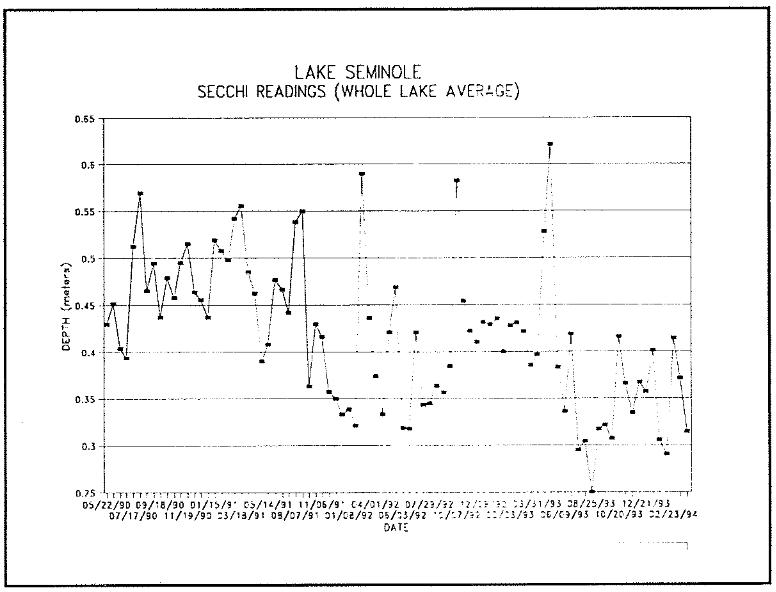

Figure 2

The Lake Seminole Advisory Committee set target goals for the management of aquatic vegetation between 70 and 210 acres of desirable plants. In an attempt to control *Hydrilla* coverage, the Florida Game and Freshwater Fish Commission, with the approval of the Lake Seminole, stocked 4900 triploid grass carp in the lake in March and April of 1991. This is a stocking rate of approximately seven fish per acre. Within six months, all 220 acres of *Hydrilla* had been eradicated from the lake. Carp had been stocked in the lake in 1987 (2100) and 1989 (750) with no response. The number of fish per acre stocked in 1991 was the recommended rate for the coverage and growth potential for a lake like Seminole.

As noted earlier chlorophyll levels were high prior to the addition of the carp. As is normally the case with large scale eradication of macrophytes, a marked rise in chlorophyll levels has been noted since the spring of 1991 (Figure 2).

The amount of nutrients which was bound up in the 220 acres of *Hydrilla* was cycled through the carp and released into the water column. This in turn made possible the rise in chlorophyll levels in the lake. Secchi readings, already poor, decreased somewhat (Figure 3).

Public reaction to the *Hydrilla* eradication varied widely. Some fishermen have expressed displeasure that *Hydrilla* was totally eliminated from the lake, saying that the bass fishing has declined or has been ruined. Other recreational boaters were ecstatic that they no longer had to clean off their weed laden props.

Whether popular or not, the carp, after having eliminated their preferred food source from the lake but still hungry, began feeding on the roots of cattails. Numerous complaints arose regarding floating islands of cattails in the lake. It is believed that this problem was in part due to the decreased root structure caused by the hungry fish and largely due to increased water levels, after the droughts of 1991.

Some people have suggested that they would like to see the fish removed from the lake, believing the carp were causing the cattail problem in the lake. No practical method for carp removal exists and it is not known whether this would be advisable. The rapid and total elimination of *Hydrilla* was not anticipated, as there was no response with 2850 fish already stocked. In hypereutrophic lakes, a small amount of *Hydrilla* can benefit bass recruitment, and low recruitment is a problem in Seminole.

Because the cattails in the lake were forming a dense monoculture unsuitable for fish habitat,

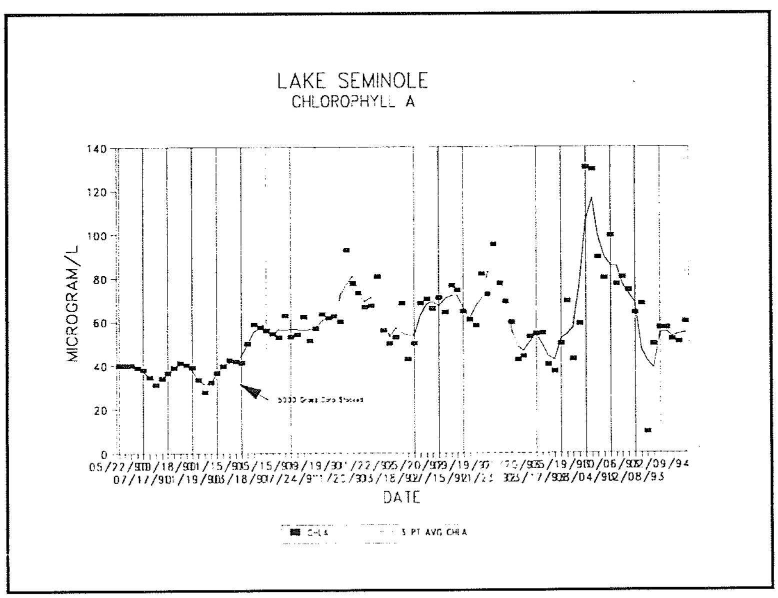

Figure 3

the Lake Seminole Advisory Committee recommended to remove eighty acres of cattails from the lake and revegetate with more desirable species. The changes should result in higher rates of sportfish recruitment and improve angler fishing success and satisfaction. More diverse and beneficial macrophyte communities should provide for wildlife species frequenting the Lake Seminole watershed and allow for reasonable boat navigation and aesthetics. Removal of cattail biomass would reduce the lake's nutrient loading and preclude accumulation of organic matter that would occur if the plants were simply chemically treated.

Dense cattail growths cover 110 acres, or 83% of the total. In some lakes, cattail communities provide good habitat for fish and wildlife; however, in Lake Seminole cattails grow in dense monocultures that provide limited habitat required for sportfish reproduction and recruitment. Cattails now render 16% of the lake surface unusable for fish, many wildlife species, and the lake's human users.

In order to remove as much organic matter as possible associated with the cattail roots, it was determined that a dredge and fill permit would be required as bottom sediments would be disturbed. Several parties were concerned with the mechanics of the project (How close to shore could the harvester go? How much muck could they remove? How bad is the odor from the cattail piles? How much will the water quality be degraded? Will the carp eat the revegetation plants?) so it was decided to proceed with a half acre pilot project. The pilot was conducted in exactly the same manner as the full scale project would be carried out (mechanical removal two to three weeks after spraying with RODEO, on-site disposal, revegetation). The harvesting of the half acre took the equivalent of six work days, which is a lengthy amount of time for such a small area. The harvester operator attributed this to the extreme density of the cattails. Half the area was then fenced to exclude carp. The entire area was then replanted in March and will be observed for approximately six months to note any impacts to the plants from the carp. As has been evidenced by stomach analysis, some carp are now beginning to feed on *Vallisineria*, which is relatively low on their food preference list. There is some concern that the carp will eat any replants at the site.

It was discovered in a survey conducted by FDEP (Rodgers, 1993) that the cattail population had decreased from 110 acres to 85 acres so the target removal acreage was reduced to 40 acres.

Since *Hydrilla* coverage was reduced by triploid grass carp, eelgrass has expanded to cover 15 acres. It is probable that removal of cattails in littoral areas will results in expansion of eelgrass. This would be highly desirable and maintained lake levels would avoid germination of cattails and hydrilla that would follow a drawdown. Eelgrass would provide competition against future expansion of *Hydrilla* as the grass carp die out. Eelgrass is an extremely desirable species that rarely creates biological or navigational problems.

To provide lasting benefits to the improved macrophyte community, it is important to allow the lake to fluctuate on a regular basis. This could be easily accomplished by modifying one of the fixed level structures in the lake. The lake could then be managed to follow a natural hydrological cycle of low water during the winter and spring followed by high water levels attained during the rainy season. This would help maintain aquatic plant diversity and stimulate expansion of desirable species. Pinellas County is in the process of hiring a consultant to redesign one of the weirs in the lake, enabling the water level to be controlled.

The History of Exotic Aquatic Plant Biological Control in Florida.

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1. INTRODUCTION

Recalling Aldo Leopold word's, "The first rule of intelligent tinkering is to save all of the parts". Those of us working to preserve natural diversity are realizing that an equally important rule in tinkering with the earth's natural ecosystems is to use extreme caution in allowing in<u>new</u> parts.

Perhaps the **greatest single** cause of aquatic weed problems in Florida is the prevalent public attitude that tolerates the importation, cultivation, transportation, and sale of exotic plants for decoration in aquariums. Exotic species in forests and lakes are like new parts in a clock; they may stay out of the way, they may seriously change it, or they may jam and stop the system completely.

Those of us involved in the various aspects of ecosystem management know that eradication of an exotic species, after it has become naturalized, is virtually impossible. At best, we can hope for maintenance control that can minimize the devastation that exotic species have on native ecosystems.

Exotic aquatic plant managers have essentially three primary tools at their disposal: mechanical control, chemical control and biological control, or combinations of the three; Integrated Pest Management.

Mechanical control, which averages $ 559 per acre (range= $400-4000) for submersed plant control, is undoubtably the least selective method, in terms of non-target impacts, but is a valuable tool in areas where pesticide use is prohibited, e.g. manatee areas.

Chemical control, while generally more selective, is labor intensive due to the required repetitive treatments, and, as with any pesticide, the risks associated with their use must be considered. Herbicidal floating plant control costs approximately $72/acre, while submersed vegetation control averages $470/acre (range= $200-600).

Biological control is the most selective, cost effective and environmentally sound means of controlling exotic plants, as the screening and quarantine phase of the candidate insects selects for those that are host specific to the target plant. While host specific biocontrol agents will not eliminate the target plant, successful agents will drastically reduce levels of infestations. Some biocontrol agents, that I term biosuppresents, affect plant populations in terms of reductions in height, flowering frequency, and leaf surface area available for photosynthesis. When integrated with other control methods, specifically, chemical control, the impacts of the bioagents result in smaller populations of plants that require less chemical herbicide for control.

2. PRACTICAL CONSIDERATIONS IN A CLASSICAL BIOCONTROL OF WEEDS PROGRAM

Biological control of weeds is the study and utilization of parasites, predators, and pathogens to regulate populations of weeds. Two approaches may be used to implement biological control. The first, the augmentive-manipulative approach, involves the application of a bioagent at selected times and in varying quantities. Use of the grass carp against hydrilla is a good example. The second approach, the innoculative approach, involves the introduction of host-specific natural enemies from a particular pest's native range into its adventive range. Essentially all the bioagents I speak of today are of this approach.

Classical biological control involves the establishment of organisms from their native environments and consists of the following five stages:

1. the study of the extent and nature of the weed problem, and its suitability for biocontrol;
2. a survey at the origin of the weed to determine the availability of biocontrol agents;
3. a determination of the host specificity of the organism and its general suitability to ensure that it can be established without damaging desirable plants;
4. the release of approved agents in the field. Species having an impact on the weed are distributed to suitable sites with the weed problem, and;
5. the documentation of the impact of the agent. This is important as it provides the feed back for future biocontrol attempts.

3. HISTORY AND OVERVIEW OF AQUATIC BIOCONTROL TECHNOLOGY

Biocontrol is nothing new; the Chinese botanist Ji Han, in 304 A.D. documented the first known instance of biological pest control. Utilizing predaceous ants, citrus growers in China seeded their groves with ant colonies to protect trees from insect pests.

In 1925, about 60 million acres of Australian rangeland were densely infested by an exotic cactus (Opuntia stricta). Half of the area was so densely infested that it was impenetrable by cattle. Australians sent explorers to the Americas to search for natural enemies that might bring the species under control. Of the 50 species studied, only 12 were released and became established. One was a pyralid moth, released in 1925. By 1930, the moth had devastated large expanses of the cacti. Today, only scattered patches of the cacti can be found, and it is no longer a problem.

To date, about 300 species of exotic insects have been introduced into various parts of the world to control about 100 species of weeds. More than 50% of these introductions being successful. None of the insects involved have ever become pests, ranking biocontrol among the safest pest management practices.

The development of aquatic biocontrol began in 1959 when the US Department of Agriculture (USDA) and the US Army Corps of Engineers (COE) entered into a cooperative study to evaluate the potential of managing the South American native, alligatorweed, Alternanthera philoxerodes, with biocontrol agents. A USDA biological laboratory lab was established in 1960, and in a relatively short time, 40 insects were found on alligatorweed. As a result of the screening process, lack of host specificity decreased the number of potential candidate insects to five.

The first insect released was Agasicles hygrophila, the alligatorweed flea beetle. This insect has a short life cycle of 30 days, and both adults and larvae feed on the plant. The impact Agasicles had on alligatorweed occurred rapidly, and the insect was eventually released in 11 states.

The next insect to be released was Amynothrips andersoni, the alligatorweed thrips. It was released in Florida in 1967. The insect has a life cycle of 28 days. Both adults and larvae feed on the plant with their sucking mouth parts, causing the pants leaves to dry and curl. Thrips were eventually released in 7 states.

The last bioagent released for alligatorweed was Vogtia malloi, the alligatorweed stem borer. It was first released in Florida and four other states in 1971; by 1981 it was found in seven states. The insect lives for about 39 days, and only the larvae feed on the plant by burrowing into the hollow stem.

In 1963, COE reports document over 97,000 acres of alligatorwed in the southern United States. By 1990 less than 10 acres of the plant were reported to have been chemically controlled in Florida.

The second plant targeted for biocontrol searches was the Earth's 8th ranked worst weed, Eichhornia crassipes, the waterhyacinth. Present in Florida since 1890, it is native to South America and, because of its ability to infest a wide range of freshwater habitats, coupled with its tremendous growth rate, it has become a pest in nearly 40 countries worldwide.

In 1972 Neochetina eichhornia, the mottled waterhyacinth weevil was approved for release in the United States, with initial release being done in Florida. Both adults and larvae feed on the plant. The generation time ranges from 90 to 120 days. These insects stress the plant by reducing the surface area of the leaf available for photosynthetic activity.

The second bioagent released on waterhyacinth was the chevroned waterhyacinth weevil, Neochetina bruchi. The first release occurred in Florida in 1974. Although the damage of N. bruchi is similar to N. eichhorniae, the generation time is shorter, from 60 to 90 days.

The last biocontrol agent released on waterhyacinth was the argentine waterhyacinth moth, Sameodes albiguttalis. Native to South America, with a life cycle of approximately 30 days, it was released in Florida in 1977. Only the larvae feed on the plant.

Plant pathogens have also been examined as possible biocontrol agents. The fungus Cercospora rodmanii was found in Rodman Reservoir in 1974. It can be found on hyacinth plants throughout Florida, and, while it does decrease productive leaf surface area, its effectiveness is marginal.

Although waterhyacinth problems still exist and the chemical spray program continues, waterhyacinth biocontrol agents are stressing the plants and research is under way to develop better management procedures for these agents. Currently, the Florida DEP and USDA are discussing the feasibility of evaluating two additional insects for waterhyacinth.

Another free-floating aquatic angiosperm is waterlettuce, Pistia stratiotes. It has been present in the United States since the 18th century, and researchers consider it native. Arguments that it is not native focus on a supposed lack of seed production in the United States, but recently, researchers at USDA discovered copious quantities of viable seed in Florida. An additional argument for the plant being of foreign origin is the lack of specialized herbivores associated with the plant. In contrast, there were several host-specific weevils found associated with waterlettuce in South America.

The first insect released for control of waterlettuce, Pistia straitotes, was Neohydronomous affinis, a weevil native to South America that the Australians have been using since 1982. Originally released in Florida in 1987, the adults feed and penetrate the leaf while the larvae mine the inside of the leaf. The insect's life cycle is approximately 30 days, which allows its population to expand rapidly. Eighteen months after a release in Lake Okeechobee, a 75 acre mat of waterlettuce was eliminated. Weevils began to migrate to adjacent control plots prior to the elimination of the test plots.

Spodoptera pectinicornis, previously known as Namangana pectinicornis, a moth from Thailand, was first released in Florida in 1990. The moth has a life cycle of 35 days. Only the larvae feed on the plant, with feeding occurring on the upper and lower portions of the leaf surface.

A small moth, Samea mutiplicalus, also feeds on waterlettuce, but tends to be sporadic and not very persistent in feeding on waterlettuce, although it seems every time a release of Neohydronomous is made, large numbers of Samea are present when the site is evaluated.

The last exotic aquatic plant I will discuss is Hydrilla. To date, five insects have been approved for release in Florida. Research began in 1980 to determine the area of origin for this plant. Biocontrol agents seemed to be most abundant in India and Australia.

The first insect to be released in Florida was Bagous affinis from Pakistan. First releases were made in Florida during 1987; however, this insect feeds on the tubers of hydrilla during drawdowns or low water. While this situation might be common in Pakistan, drawdowns in Florida are rare, so attempting to get field populations established were near impossible. The insect is now being used in canal systems in California.

The second insect released for Hydrilla was Hydrellia pakistanae, a ephydrid fly from Pakistan. It was initially released in Florida in 1987. The larvae mines the leaves and is the only life stage that impacts the plant. The life cycle is approximately 20 days in length, and field populations are established around the state.

A third insect, Hydrellia balciunisi, another fly from Australia, has also been released and has a similar life cycle and impact as H.pakistanae.

The Hydrilla stem weevil, Bagous hydrilliae, is the last insect to be released for hydrilla control. Adults feed externally, chewing on leaves and stems submersed in the water or stranded on shore. The female inserts her eggs into the stem, usually at a leaf node. The resulting larvae may destroy up to 15 centimeters of stem. After the larvae obtain full size, they chew through the stem and float to shore in a stem fragment. Severing of the stems in Australia gives the appearance of mowed hydrilla, keeping the plants approximately 100 centimeters below the water surface.

Biological control offers the only real hope for suppressing some of the aggressive aquatic weeds. This control is achieved by carefully introducing selected insects and diseases that restrict the weed in its native land. Once developed, these biological controls can suppress the weed at minimal cost to landowners or the public.

Enhancing Wildlife Utilization of Urban habitats in Pinellas County, Florida.

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INTRODUCTION

Over the past twenty years ecological issues have moved from the arena of the radical activist to the arena of daily services provided by local, state and federal governments. The vast majority of that transition has been made on the basis of individual responses to individual crises. In the past eight years, the State of Florida and Pinellas County have been working together to make the transition from response oriented services to future services planning. To that end, Pinellas County has, as a major goal, the development and implementation of comprehensive watershed management plans for the county's drainage basins (Pinellas County Planning Department, 1989 and 1992).

To be truly comprehensive, watershed management planning must include all aspects of activities which may have an impact on the ecosystem bounded by a particular watershed's ridge lines. This approach recognizes the water body as a response driven indicator of the health of the watershed and not an isolated system. It recognizes that there are ecosystems other than wetlands that are dramatically in need of management and protection. This recognition leads us to examine our urban upland ecosystems, as well as our wetlands. This paper will describe methods being developed and used by Pinellas County for improvement of urban upland and wetland habitats.

Urban landscapes generally fail to provide protection or habitat for all but the most resistant forms of wildlife. While modern land development ordinances are an improvement over historical practices, they still fall far short of wildlife protection goals. Urbanization has, in many instances, dramatically altered entire ecosystems, and has resulted in many ecosystems endangered where once they were abundant. This is dramatically becoming emphasized in Pinellas County.

Most of the absence of wildlife in urban settings is due to the lack of specific habitat. As areas become developed, most of the larger trees are usually left intact, unless they interfere with the location of houses or roads. However, historic and current development practices generally result in total removal of all of the understory and ground cover vegetation, and replacement with turf grass lawns and non native ornamental shrubs which offer limited wildlife habitat value, require intense irrigation and fertilization, and are not well adapted to extant growing conditions.

Pinellas County, with a population of 851,659 and a density of 3042 persons per square mile based on the 1990 census, is the most densely populated county in the state of Florida (Pinellas County Planning Department, 1993). Much of the historical development of Pinellas County took place with little or no regard for the impacts of that development on wildlife. During the latter part of the 1960s, legislation began to be enacted which concentrated on protection of marine and aquatic ecosystems and water quality. This protection has grown increasingly stringent, and has resulted at least to some degree in arresting the rate of habitat destruction. In many cases, however, this attention to protection of wetlands has resulted in improperly designed and ill considered development of upland habitats, many of which have become increasingly scarce.

In 1989, in response to amendments to the Local Government Comprehensive Planning Act, Pinellas County Government adopted significant revisions to its local government comprehensive plan (Pinellas County Planning Department, 1989 and 1992). The goals of this revised plan included conservation, protection and restoration of the quality of county waters; conservation and protection of natural communities and wildlife habitat; protection of the coastal area to maintain or enhance water quality, biodiversity and estuarine productivity; and management of stormwater to protect and enhance water quality of county waters.

Goals of the Pinellas County Comprehensive Plan call for broad programs aimed at the conservation of native vegetation and wildlife through a comprehensive planning process.

Included as directives are procedures to identify habitats for conservation; guides for conservation or replenishment of native vegetative communities; amendment of ordinances to protect native vegetation, wildlife, and habitat from destruction by development activities; improvement of wildlife communities, removal of ecologically undesirable vegetation, and planned corridors and contiguous conservation and preservation areas; recovery programs for native vegetation and wildlife; public education regarding the need to conserve native vegetative communities, wildlife species and wildlife habitat.

Pinellas County's efforts toward management of wildlife and wildlife habitat are twofold. The first is based on the premise that man must interact with nature. The second recognizes the need for wildlife preserves. Toward the latter end, Pinellas County owns and manages a preserve, over 7,000 acres in size, in the northeast portion of the county. For the most part, however, Pinellas County is highly urbanized and cannot reasonably be expected to ever be fully restored to a predevelopment condition. In such areas, it is Pinellas County's desire to bring about restoration of biological functionality to the greatest practical extent, and to instill in the public a willingness to live with nature.

In order to carry out the goals of its Comprehensive Plan, Pinellas County identified the need to:

> develop a method for determining what kind of habitat and what kinds of wildlife, may be most suited for each area within the county,
>
> develop a method for setting measurable wildlife goals that can be applied "on the ground" to specific areas, and
>
> develop multiple methods of implementing the objectives of its management programs that will lead toward achievement of those goals.

This paper presents an approach to developing management guidelines for both the uplands and the wetlands within a watershed and further provides a method for setting goals and gauging success.

METHODS

The method being developed and tested by Pinellas County is an extension of the Habitat Evaluation Procedures (HEP) developed by the United States Fish and Wildlife Service (USFWS). That procedure is a semi-quantitative method of assessing habitat value as it relates to a particular species, group of species, or guild, and numerous USFWS documents are available for reference (Habitat Suitability Indices). The procedure is meristic and specific. The extensions used here are not intended to revise those procedures, but to build upon them. The Pinellas County Regional HEP was based on a model developed by the USFWS (Van Horne and Wiens, 1991). It increases the area surveyed as compared to the published USFWS habitat suitability models, and reduces the meristics significantly in order to provide for guidance on a subsystem level. A-priori decisions are required to initiate the procedure but may be revisited as the understanding of the system increases.

Management Area Definition

The first steps are simply to identify the watershed by clearly defining the receiving water and the ridgelines as management area boundaries. This is done purely as a practical matter to make the information load manageable. A review of existing information and literature within the area will provide the foundation for other decisions. Topography, Soil types, Flood Plains, developed properties, and similar physical features data will roughly define submanagement areas of the watershed. In heavily urbanized or agriculturally altered areas, a review of current and historic aerial photography (color, black & white, and infra-red) can be extremely useful at this stage. This review is done to identify current or relict ecosystems or subsystems such as pine flatwoods, oak hammocks, cypress, mangrove, prairie, marsh, or open water wetlands, the outlines of which may be readily apparent in aerial photographs.

Of particular interest in this exercise is the observation that systems once bounded by natural physical change may be bounded or defined by anthropogenic changes. For example, a structural biometric edge could be a sudden topographic change. Edges in urban areas are often highways and commercial districts.

Data Gathering

The above noted information is mapped and regionalization of the watershed starts to emerge. Field review is then conducted to verify the generalizations made from the mapping effort. The field effort need not be rigorous or extensive. It is generally possible to adequately characterize the vegetative nature of a watershed by conducting a drive through survey. Notes on other ecological features are critical at this stage. Water sources, canopy cover and type (include average DBH estimates), understory cover and type, flowering plants, seed and fruit bearing plant frequency, exotic plant species frequencies and any wildlife notes are needed. This effort results in a more specific characterization of the existing conditions within each region of the watershed. Historic information, soils, etc., are used to identify boundaries blurred by existing development or agricultural use. The management regions are now identified.

Management Criteria

Since the health of ecosystems is difficult to measure directly and may be rather meaningless in areas subjected to current urban management techniques, meristics as in the HEP are proposed based on utilization by selected species for each area to serve as indicators of overall ecosystem health. Several species are selected in order to provide some indication of the balance of the utilization and avoid oversensitivity or overgeneralization of success evaluations.

These species (component species or management cluster) will form the basis for, and direction of, the analysis and recommendations. These will also be the foundation of the monitoring program. There should be suitable representation from all appropriate groups (Mammalia, Reptilia, Aves, Pisces etc.). Species from upland, wetland, and transitional habitats should be chosen. It is recommended that the number be kept small (five to ten) in order to maximize the efficiency of the program without sacrificing its validity. In many cases, a selection limited to only certain life stages or activities may be required. Since many species have differing requirements for differing stages of their life cycle or for differing activities such as foraging or nesting, each region may only supply a part of the overall species requirement.

Community Support

It is important that community approval and support be gathered at this point in the development of the management program. In selecting species for use as indicators of ecological health, it is of paramount importance that the choice be ecologically meaningful, however, we feel that public support for resulting management programs may be more easily obtained if the species that are selected are understandable and familiar to them. It may be less difficult for the ordinary citizen to understand why we are interested in creating habitat to support fish or birds, than it might had we selected an obscure insect.

Identify Management Needs

Once the species have been chosen, it is imperative that existing literature be reviewed so that critical and subcritical habitat requirements for each species of the management cluster can be developed. Next, the existing habitat should be compared to that cumulatively required by the species in the management cluster. This is to be done for each region within the watershed.

The critical and subcritical habitat needs of the management cluster identifies the desired target condition of the region. The characterization of existing conditions and initial abundance of the selected species roughly defines the starting condition. The difference between the two conditions defines the area of focus of the management program to be proposed. Management can be accomplished by regulation, incentive, education, or any other means imaginable which is fundable and acceptable by the community. Non acceptance should be interpreted as the need to restart the procedure at the point of selection of component species.

Implementation

What has been defined so far has been a means of identifying, in a semi-quantitative manner, the current state of the system and a more or less ideal state of the system. The question now becomes how the managers can move the existing system towards the ideal one and how they can measure the success of that effort.

The answer to the first is completely dependent on the social, economic, and legal factors at play and therefore entirely community specific. There are broad limits, however, worthy of noting. Primarily, the limit is defined by the manager's imagination. Secondarily, the manager is advised strongly that there is no single everlasting program that will accomplish the goal. A multiple program approach has the advantage in that each effort will reach different people to different degrees. Multiple programs level the effect and integrate the philosophy of coexistence with nature (or parts of it) into the community structure. It is also apparent that the types of programs selected will depend on the existing state of degradation of the system. Extreme deficiencies may be handled in a more forceful way (regulation), than a slightly impacted one (education). It may be beneficial to transfer from one level to another as a degraded system improves.

As mentioned previously, implementation should be approached using multiple methods, all of which fall under one of the general categories of influence, incentive, or regulation.

These three categories are intended to convey that programs can be built along a spectrum of intensity ranging from a low key approach using such means as education and general neighborhood and community standards, through a moderate approach using various incentives to a strict control through local or state laws.

Influence:

Influence can be exerted through such means as public education programs, native plant giveaways at EXPOs and environmental fairs, and demonstration projects. One extremely important source of influence is to use native plants and habitat management techniques on all county or city projects and properties, and to draw the public's attention to the example that has been set.

While many people may be easily educated as to the ecological benefits of using native plants, experience has demonstrated that the majority will do so only if native plants are readily available. Currently, nurseries supplying native plants are sparse and only one outlet entirely dedicated to native plants exists in Pinellas County. Incentives are needed which would encourage garden shops to increase the availability of native plants to their customers, and to distribute free educational materials about the benefits of native gardening.

Incentive:

Although the most commonly considered incentive is tax reduction, the possibilities for incentives are only as limited as one's imagination. Homeowners may enjoy reduced stormwater utilities or reduced water rates as a result of planting native plants and of reducing use of water, fertilizer and pesticides. They may be offerred free replacement native plants by the county if they agree to remove invasive exotics such as Brazilian Pepper, Australian Pine, and Punk trees.

Regulation:

To a certain extent, regulations have been slow to catch up with the need for improving wildlife protection in urban landscapes. While most communities have tree ordinances, new developments generally totally remove groundcover and subcanopy trees and shrubs, and replace them with lawns and exotics. Many communities have redevelopment ordinances which require landscaping upon redevelopment of commercial properties. These ordinances can usually be satisfied, however, by planting exotic trees and shrubs.

Several obvious regulations which could be used to improve urban habitat are amendments to new development and redevelopment ordinances which would require use of native plants selected from a list of species which are appropriate to the region in which the development occurs.

Success Evaluation

The final step in the program is no less critical than the first. It is the evaluation of success. This step assures the managers that their efforts are having the desired effect, and not undesirable side effects. It assures the citizenry that their tax money is being spent productively. Finally, it assures other communities that the effort can be undertaken successfully.

Success monitoring may be simply a measure of the degree to which the desired condition has been achieved, i.e., the required habitat for the selected species has been created. Habitat may be created, however, but not be functional in terms of supporting wildlife. A preferable monitoring program would require pre and post monitoring of the abundance of the selected species by appropriate sampling methods, as a measure of the degree to which the biological goals have been attained.

Because we are suggesting that multiple methods be invoked to address multiple facets of the management effort, we must also highly recommend that the monitoring be directed such that the results can differentiate between the successes brought about by one program or another. This is necessary, especially in the early stages of the evaluation, to determine the efficiency of the several programs. Costs may be reduced through eliminating unproductive programs or emphasizing identified synergisms. In short, each program must have a means of success evaluation.

For evaluating the overall success of the project, we suggest using the USFWS HEP Software package as a guide (Hays, 1985). This is not the only method recommended, but will give a good overview of the success. This package takes habitat suitability estimates and evaluates progress towards the ideal condition. It can also predict, with proper input, how long it will take to achieve the various levels of success.

ALLEN'S CREEK: A DEMONSTRATION

In 1987, Pinellas County joined with the Florida Department of Environmental Regulation (now FDEP), and the cities of Largo and Clearwater in conducting a comprehensive study of the Allen's Creek Watershed. Upon completion of that study, the County and cities began working toward development of a comprehensive watershed management plan for the basin. While the initial thrust of the state's involvement was toward stormwater abatement, Pinellas County's desire is to achieve, to the maximum extent possible, all of its environmental goals as contained in the Pinellas County Comprehensive Plan. It is Pinellas County's intention that all watershed plans be truly holistic in nature. This includes a recognition that what happens in the watershed affects the stream. Not only does the use of native vegetation improve wildlife utilization, but reduced irrigation and use of fertilizer and pesticides results in reduced pollutant loads to the stream.

In the Allen's Creek Project, there were several management areas identified. These included uplands and the stream segments running through them. The first of these consisted of a largely residential area approximately 100 acres in size. The area was vegetatively dominated by Oaks and Pines but these provided only 18 to 23% canopy coverage. Understory in the region was severely depauperate with the majority of the ground cover being bahia sod.

There was one isolated wetland dominated by Carolina willow. This area contains the headwaters of the creek, which consists of three tributary channels, each not much more than a ditch; straight and steep sided. There was one pond approximately 1 acre in size located at the confluence of three channels.

Species selected for the area were the Oak Toad, Gray Squirrel, Raccoon, Barred Owl, Yellow Shafted Flicker, Butterfly Guild, Wood Stork, Bluegill Sunfish, Largemouth Bass, and Shiner (Notropis sp.). USFWS Habitat Suitability Indices were available for the Gray Squirrel and the Barred Owl (Allen, 1987a & b). It was necessary to establish estimated habitat suitability needs utilizing the method previously described. For the Butterfly Guild, much useful information was provided by Heugel (1991).

The selected species were researched and many habitat deficiencies surfaced. Habitat needs include establishment of additional hardwood tree canopy; removal of exotic vegetation such as Brazilian Pepper, Punk Trees, Australian Pine and Chinese Tallow trees; establishment of mid-level habitat through the use of bushes and taller groundcover; minimal use of herbicides and insecticides that would harm insectivorous birds; establishment of bird boxes to provide surrogate nesting structures; establishment of butterfly gardens using native flowering bushes, and allowing dead trees and fallen dead tree trunks to remain unless they constitute a hazard.

For wetland areas, recommended methods for increasing habitat value and function include planting desirable native vegetation, replacing undesirable vegetation with desirable natives, increasing littoral zone or flood plain width by recontouring side slopes, planting wildlife corridors to connect open water with nearby upland habitats, and revising exotic vegetation ordinances (Reynolds, Smith and Hills, 1993).

In a similar fashion, the characteristics and habitat needs of each of the other management areas in the watershed were established. The collective descriptions and recommendations are contained in the Allen's Creek Watershed Management Plan (Reynolds, Smith and Hills, 1993).

For each of the identified regions in the Allen's Creek Watershed, Pinellas County is developing a series of booklets called Naturescape. These booklets will identify species of plants which are appropriate to the soil and hydrological conditions in the region in each of several categories: ground cover, shrubs, wetland species for various depth zones, small trees, and large trees. The booklets will also include a number of additional ways that homeowners can improve wildlife utilization of their yards, while reducing the need for irrigation and applications of fertilizer and pesticides.

Eventually, Pinellas County plans to produce Naturescape booklets applicable to all of the different relict habitats in the county, and map each watershed so that homeowners can easily identify what type of region their yard is in, and which booklet they should refer to.

Pinellas County is working closely with the Florida Neighborhood Program, initiated through the Tampa Bay National Estuary Program, and being operated by the Florida Cooperative Extension Service. Through the Florida Neighborhood Program, entire neighborhoods may be educated as to the benefits of replacing exotic with native vegetation and the potential for increased enjoyment of their home by improving wildlife utilization.

Finally, Pinellas County is beginning to implement replacement of exotic vegetation on its own properties with native plants in order to set a positive example, and to demonstrate that there are many native plants which are as good as, or better than garden shop exotics as landscape specimens. The Naturescape booklets described above would contain such a list.

THE CONTINUING SAGA

Pinellas County has established goals for improvement of wildlife utilization of urban landscapes, and has developed procedures for identification of specific habitat needs and measures for implementation. We are instituting these procedures and measures in the Allen's Creek watershed management project. The development of this process is ongoing, however, and its implementation has not yet occurred. Whether it proves to be successful remains to be demonstrated.

In the final analysis, we feel that the implementation of measures to achieve local wildlife protection goals is only limited by imagination and the will to do so.

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THE RESPONSE OF BENTHIC MACROINVERTEBRATES TO EFFLUENT DIVERSION AND HYDRAULIC DREDGING IN A SUBTROPICAL, HYPEREUTROPHIC LAKE.

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Introduction

Banana Lake, a 256 acre meandered freshwater lake, is located approximately 3 miles southeast of the City of Lakeland in Polk County, Florida. The lake has an outflow which enters Lake Hancock, the headwaters of the Peace River, and ultimately discharges into the Gulf of Mexico via Charlotte Harbor. In 1988 the lake was added to the SWIM Priority List and described as " hypereutrophic, exhibiting poor water quality, supporting an almost perpetual algal bloom, with extensive muck deposits covering the natural sand substrates" (SWFMWD, 1989). The problems associated with Banana Lake were attributed to nutrient enrichment from secondarily treated sewage effluent. Effluent from the City of Lakeland s Wastewater Treatment Plant was discharged to Banana Lake from 1926 to 1987. In 1987, the effluent discharge was diverted to an artificial wetlands south of the City.

A survey of Banana Lake s benthic macroinvertebrate community was conducted by the City of Lakeland s Lakes Program as part of a lake restoration program initiated in 1987. Diverse restoration efforts have included the elimination of the discharge of treated effluent to the lake, the creation of stormwater treatment facilities within the watershed, and the hydraulic dredging of the organic sediments from the lake. Benthic organisms are considered to be good indicators of water quality by virtue of their limited mobility and long life histories. They can provide insight into temporal and spatial environmental conditions that may not be detected through discrete water quality sampling. By evaluating the benthic macroinvertebrate community structure, one can determine water quality and ecosystem trends within lakes.

Benthic macroinvertebrate sampling was only one component of the Banana Lake Restoration Project's Monitoring Program. Water quality was monitored monthly at two fixed stations, from July, 1988 to present, by Polk County Water Resources and coordinated with benthic, zooplankton and phytoplankton sampling.

Methods and Materials

Benthic macroinvertebrate samples were collected at Banana Lake from December, 1988 to March, 1993. A random stratified sampling design was used to select station locations. Eight stations were selected per quarter; two stations per quadrant (Figure 1). For the first two sampling events (December, 1988 and March, 1989) one replicate per station was collected, thereafter

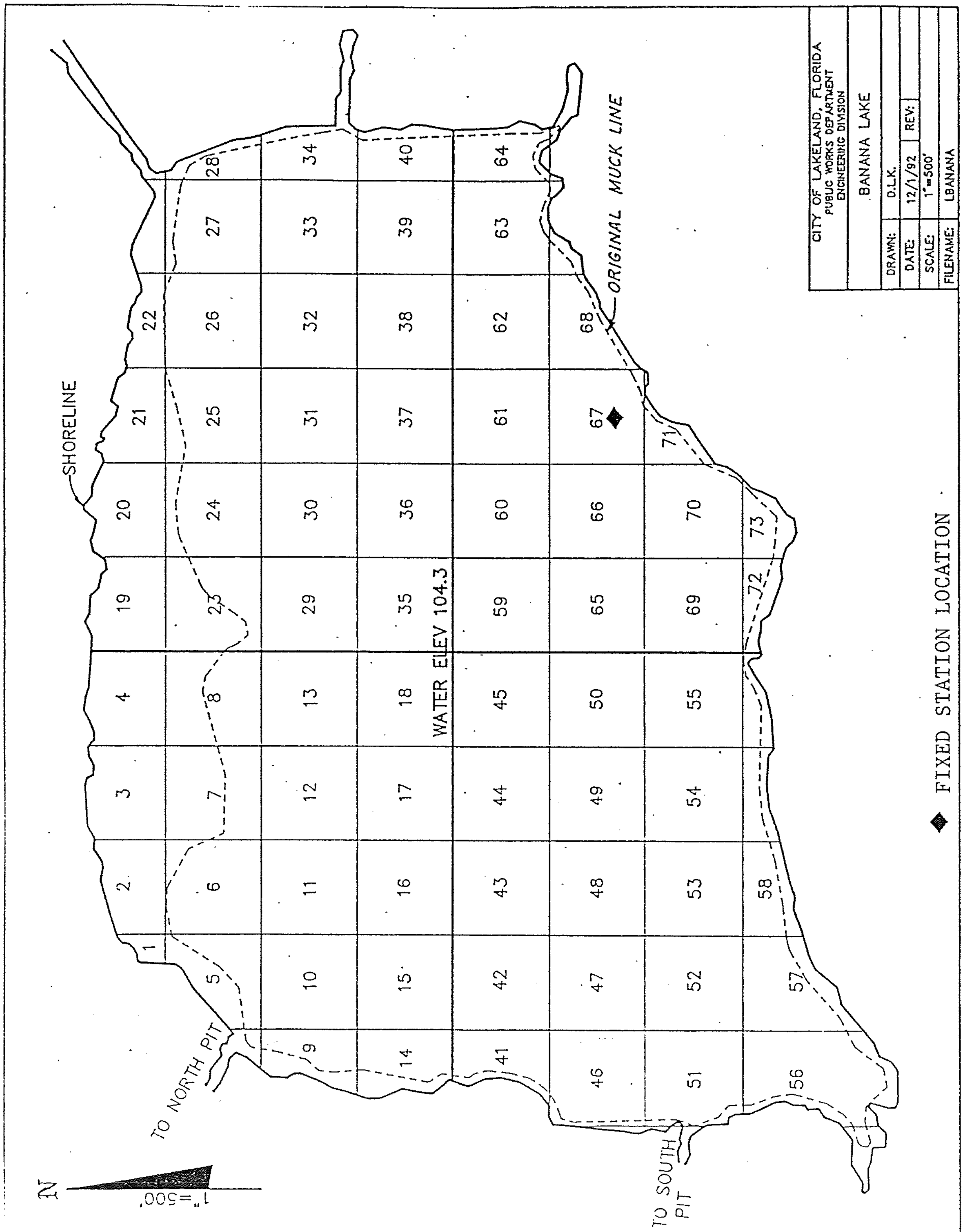


Figure 1. Banana Lake Station Grid Map.

two replicates were collected per station.

Just prior to the completion of dredging (July 1991) a fixed station location was selected (Figure 1). This station was established to evaluate recolonization rates. Two replicate samples were collected monthly through December, 1993 and quarterly thereafter through June, 1994.

Before and during dredging a petite ponar dredge was used at stations with clay or sand substrates, and an ekman dredge was used at stations with soft substrates. After dredging the petite ponar was used exclusively due to the change in bottom sediments from soft organics to sand or clay.

Samples were sieved on site using a nitex nylon net with mest count 7.72 openings/mm. Each replicate was placed in a separate container and transported to Lakeland Lakes Program lab. Samples were then refrigerated and sorted live within 48 hours. Sorted samples were preserved in 70% ethanol. Representative samples of the midges were mounted in CMC-10 (DER, 1990) identified and when possible identification to species level determined. All the oligochaete worms were mounted in CMC-10 and identified to species when possible. The sexually immature tubificids were counted as *Limnodrilus hoffmeisteri* since *L. hoffmeisteri* was the only mature worm species found throughout the study. A voucher collection, containing representatives of each type of organism, is archived by quarter and is available for future reference.

Results and Discussion

Prior to dredging, the sediments in Banana Lake were characterized as a brown to black, very soft, organic silt. These sediments were composed of 10-25% organic material, increasing in density with depth (Bromwell and Carrier, 1987). Over 90% of the lake bottom was comprised of unconsolidated sediments. Only those areas close to shore, particularly the northern shore, consisted of sand substrates (Figure 1). The natural bottom of the lake, following dredging, can be described as consisting of a variety of soil types ranging from clean fine sands to clayey sands and organic clays (Bromwell and Carrier, 1991). Approximately 55 acres of the lake bottom consisted of naturally occurring organic substrate comprising most of the southwest quadrant and extending into the southeast quadrant. These areas are believed to be relict or paleo sink holes (BCI, personal communication). Bottom samples from these areas can be described as stiff black, sandy, peaty organic clays. Some samples consisted of clay and sand mixed with fibrous matter and wood.

Of a possible 73 station locations in Banana Lake, 44 different stations were sampled pre dredging and 40 post dredging. Thirty-five of the 44 stations (80%) sampled prior to dredging contained silt as the primary substrate. Sand was the primary substrate in 23 of the 40 stations (58%) sampled post dredging. Silt appeared as the primary substrate in 9 of the 40 post dredging stations (22%), but these were primarily the deeper stations (>2 meters deep). The other 8 stations (20%) contained clay or peat and were located in the quadrant with the natural "organic" bottom. Evaluation of dredging performance was conducted as each area of Banana Lake was dredged. The performance criteria for organic content was 3% organics. Over 90% of the samples had to pass in order for an area to be considered clean.

Abundance

Benthic macroinvertebrate mean standing crop prior to dredging (3,766 m-, Std. Dev. 3,205, n=7) exceeded those for during dredging (2,453 m-, Std. Dev. 2686, n=5) and those for post dredging (2,578 m-, Std. Dev. 1100, n=6). Before dredging mean abundance ranged from 1,185 m- in September of 1989 to 10,363 m- in December of 1989 (Table 1A). During dredging mean abundance ranged from 838 m- in December of 1990 to 7,218 m- in March of 1991. Post-dredging mean abundance ranged from 1,311 m- in March of 1992 to 4,226 m- in March of 1993. There was no significant difference (Student s t test, P 0.05) between pre dredging and post dredging abundance values. The mean standing crop (3,005 m-, n=20) for Banana is similar to those reported in altered or eutrophic lakes throughout Florida (Cowell et. al, 1975; Hulbert, 1970; Elmore et. al., 1984). Mean standing crops for some central Florida lakes with varied trophic states are listed on Table 2.

Table 1A

DATE	SPECIES RICHNESS	SHANNON-WEAVER SPECIES DIVERSITY INDEX	HULBERT LAKE CONDITION INDEX	MEAN #/M2
12/20/88	10	1.4	0.4	4519
03/29/89	10	1.2	0.9	2704
06/30/89	8	0.8	0.1	1511
09/25/89	5	0.8	0.1	1185
12/21/89	11	1.1	1.3	10363
03/20/90	19	1.7	1.1	4387
06/25/90	4	0.9	0.0	1695
09/12/90 *	7	0.9	0.1	1297
12/20/90	5	1.1	0.0	838
03/20/91	20	1.3	0.0	7216
06/11/91	11	1.4	0.6	1101
09/16/91 *	15	1.2	0.8	1814
12/16/91	18	1.6	1.0	2515
03/16/92	15	1.6	0.9	1311
06/8/92	19	1.4	1.3	3055
09/14/92	17	1.1	0.1	2941
12/14/92	10	1.4	0.4	1413
03/17/93	27	1.5	2.0	4230

Begin Dredging * End Dredging *

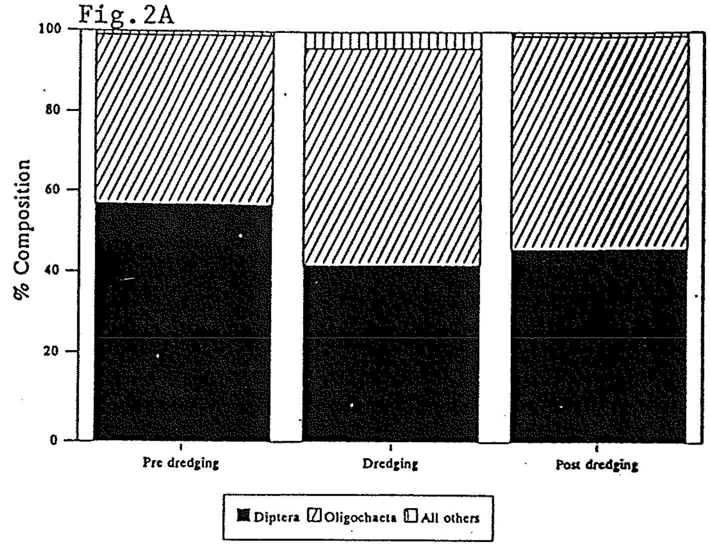
Table 1B

DATE	SPECIES RICHNESS	SHANNON-WEAVER SPECIES DIVERSITY INDEX	HULBERT LAKE CONDITION INDEX	MEAN #/M2
09/12/90	2	0.48	0.0	1013
07/10/91*	6	2.36	2.0	276
08/19/91	2	0.75	0.0	324
09/16/91	3	1.41	0.0	184
10/02/91	3	1.37	0.0	115
11/08/91	8	1.77	1.0	4257
12/16/91	8	2.10	2.0	2267
01/27/92	8	2.52	2.0	947
02/18/92	10	2.27	3.0	1364
03/17/92	8	1.48	3.0	3587
04/13/92	10	2.12	2.0	7221
05/26/92	12	2.59	4.0	7661
06/08/92	4	1.13	0.0	1457
07/13/92	8	1.77	0.0	4049
08/17/92	12	1.72	3.0	5716
09/14/92	11	2.15	3.0	3192
10/13/92	6	0.74	2.0	4514
11/17/92	13	1.73	2.0	6363
12/14/92	12	2.33	4.0	4212
01/11/93	13	1.99	4.0	7683
02/09/93	13	2.40	3.0	7334
03/17/93	13	2.35	4.0	6501

*Station Dredged

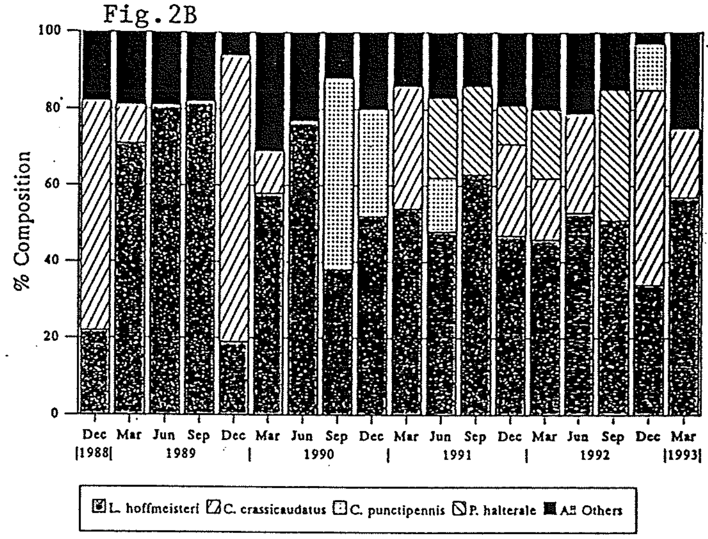
Table 1. Macroinvertebrate metrics for Banana Lake (1A) and fixed station (1B).

Fig.2A



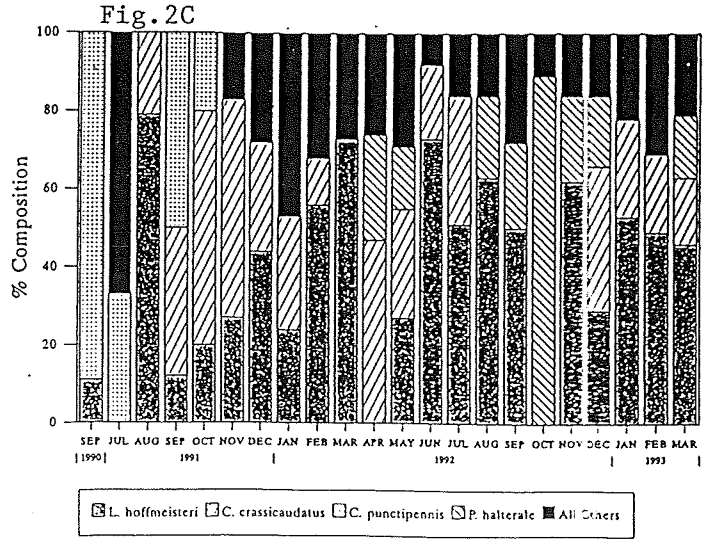
(8 STATION COMPOSITE)

Fig.2B



(8 STATION COMPOSITE)

Fig.2C



(FIXED STATION)

Figure 2. Banana Lake % Composition 1988-1993.

Standing crop for the fixed station increased post dredging (Table 1B). Fixed station standing crops ranged from 276 m- in September, 1991 to 7,661 m- in May, 1992. Mean standing crop for pre dredging samples was 644 m-,(Std Dev., 521, n=2), compared to 3,947 m- (Std. Dev. 2,649, n=20) for post dredging samples.

Prior to and during dredging, total abundance in Banana Lake increased in the winter months and decreased in the summer. This was primarily due to large variations in populations of *C. crassicaudatus* and *L. hoffmeisteri*. In a study of three central Florida lakes of various trophic states, peak macroinvertebrate densities were also found to be higher in the fall and winter months (Elmore et. al. 1984). Since dredging, total abundance maximums have shifted to spring and summer. Seasonal variation has diminished due to reduced populations of *C. crassicaudatus and L. hoffmeisteri*.

After four years of surveying the benthic macroinvertebrate community, oligochaetes and chironomids remain the most abundant groups. Diptera and oligochaeta comprised 99% of the mean densities for the pre dredging, dredging, and post dredging periods (Figure 2A). Oligochaetes comprised over 50% of the benthic community in 11 out of 18 sampling events from December, 1988 to March, 1993 (Figure 2B). At the fixed station oligochaetes comprised at least 50% of the community in 9 out of 22 sampling events (Figure 2C). This community structure is similar to other hypereutrophic Florida lakes. Cowell et. al. (1975) found that the macroinvertebrate community of Lake Thonotossassa was dominated by chironomids and oligochaetes. During the one year study (1970-1971) at Lake Thonotossassa, oligochaetes comprised 69.7 % of the population and chironomids comprised 24.7%. For the four year study in Banana Lake oligochaetes comprised 48% of the population and chironomids comprised 51 %. In contrast during a one year study of Lake Gibson, a mesotrophic lake in Lakeland, the macroinvertebrate population was comprised of 12% oligochaetes, 36% chironomids, 25% mollusca and 23% ephemeroptera (unpublished data). Dipterans were the most abundant macroinvertebrates (87%) in Corner Lake, a mesotrophic lake in north central Orange County, Florida, while Mollusca (53%) and Diptera (39%) were the most abundant organisms in Bay Lake, an oligotrophic lake in Walt Disney World amusement park (Elmore et. al., 1984).

Table 2. Benthic macroinvertebrate abundance for central Florida lakes.

LAKE	MEAN DENSITY ($No./m^2$)	TROPHIC STATE	SOURCE
Banana	3,005	hypereutrophic	City of Lakeland, unpublished
Beauclair	4,243	hypereutrophic	Elmore et.al., 1984
Corner (tannic)	5,799	meso trophic	Elmore et.al., 1984
Hollingsworth	1,335	hypereutrophic	City of Lakeland, 1994
Gibson (tannic)	1,038	mesotrophic	City of Lakeland, unpublished
Parker	8,299	hypereutrophic	SWFWMD, 1993
Seminole	5,799	eutrophic	SWFWMD, 1992
Thonotosassa	9,483	hypereutrophic	Cowell et. al., 1975

Species Richness

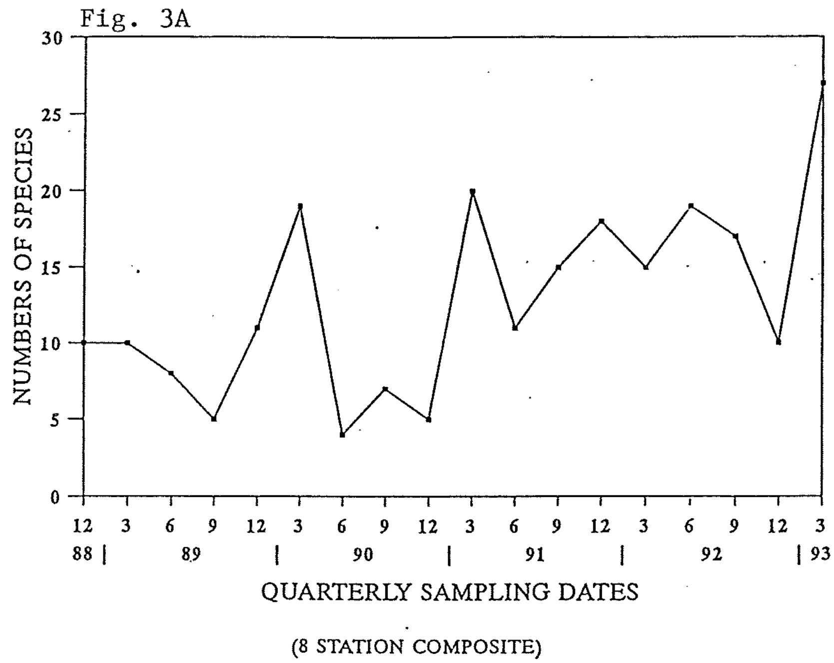
During the four year ongoing benthic macroinvertebrate study at Banana Lake a total of 49 separate taxa have been collected and identified (Table 3). Diptera (Chironomidae) was the class with greatest number of species (28), followed by Oligochaeta (6). In a one year (1991) benthic macroinvertebrate study of Lake Parker (SWFMD, 1993) 38 species were collected and identified. Several studies of eutrophic Florida lakes have reported higher species richness than those found in Parker and Banana, however this could be due in part to differences in sampling protocol and types of taxa included. Lake Munson (FDER,1988) and Lake Seminole (SWFWMD, 1992), both eutrophic systems, exhibited high numbers of benthic taxa 79 and 91 respectively. Without speciating oligochaetes, Cowell et. al. (1973) reported 58 taxa for hypereutrophic Lake Thonotossassa. During the time the fixed station was sampled, 24 different taxa were collected and identified. Again, Diptera was the class exhibiting the highest number of taxa (14) followed by Oligochaeta (3).

Since dredging began, 26 new species were collected and identified. Fourteen of these were dipterans. For the fixed station, 14 of the 24 species identified were collected post dredging. Prior to dredging mean species richness for the lake was 10 (n=7, Std. Dev. 4.9) and 4 (n=2, Std. Dev. 2.8) for the fixed station. During dredging, mean species richness for the lake was 12 (n=5, Std. Dev. 6.1). Species richness appears to have increased post dredging as evidenced by both random station and fixed station

Table 3. Banana Lake Species List 1988-1993.

ACARIFORMES	**DIPTERA(cont.)**
*Limnesia sp.***	*Unidentified chironomini***
*Unionicola sp.***	*Procladius holotanypus sp.*
AMPHIPODA	**EPHEMEROPTERA**
Hyalella azteca	*Caenis diminuta*
DECAPODA	**HEMIPTERA**
*Palaemonaetes paludosus***	CORIXIDAE
DIPTERA	**HIRUDINEA**
Chaoborus punctipennis	*Helobdella stagnalis*
Chironomus crassicaudatus	**MOLLUSCA**
Chironomus decorus	*Planorbella scalaris***
Chironomus stigmaterus	*Physella cubensis***
*Cladopelma sp. Epler***	**ODONATA**
Cladotanytarsus sp.	*Argia sedula***
Coelotanypus concinnus	*Enallagma sp.***
Coelotanypus scapularis	*Perithemis sp.*
*Cricotopus sylvestris gp.***	**OLIGOCHAETA**
Cryptochironomus sp.	*Dero digitata*
*Dicrotendipes sp.***	*Limnodrilus hoffmeisteri*
Einfeldia natchitocheae	*Nais communis***
*Endochironomus subtendens***	*Nais pardalis*
Glyptotendipes paripes	*Nais variabilis***
*Glyptotendipes sp.***	*Pristina synclites***
*Goeldichironomus amazonicus***	**TRICHOPTERA**
*Goeldichironomus carus***	*Oecetis inconspicua*
*Labrundinia neopilosella***	*Oecetis sp.***
*Microchironomus sp.***	*Orthotrichia sp.***
Palpomya sp.	
*Parachironomus hirtalatus***	
Polypedilum halterale gp. sp.	
*Procladius bellus var 2***	
*Tanypus neopunctipennis***	
Tanytarsus sp.T	
*Thienemaniella sp.***	

**Species collected post-dredging



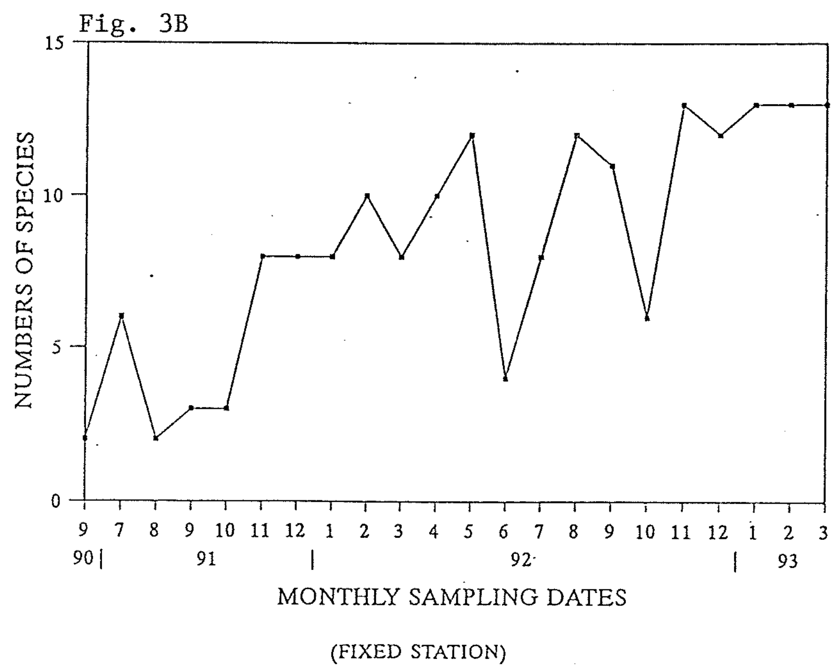


Figure 3. Banana Lake Species Richness.

data (Figure 3A, B). Mean species richness for the lake was 18 (n=6, Std. Dev. 5.5) and for the fixed station 9 (n=20, Std. Dev. 3.6) following dredging. There was significant difference (Student s t test, P 0.02) between pre dredging and post dredging species richness.

In June of 1992, the first representative of order Mollusca (*Planorbella scalaris*) was collected. Prior to this sampling event no mollusks had been collected at Banana Lake. At the March, 1993 sampling event another mollusk (*Planorbella cubensis*) was collected and identified.

<u>Species Diversity</u>

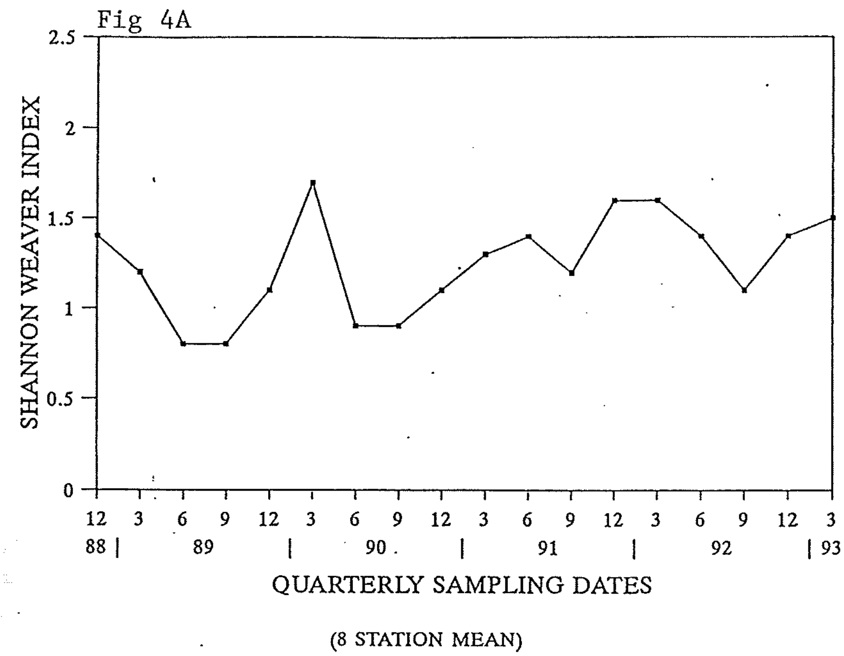
The Shannon-Weaver Species Diversity Index (SDI) was used to evaluate benthic macroinvertebrate diversity in Banana Lake. The index is based on the number of taxa present and whether the individual organisms are evenly distributed among the taxa. Samples with many organisms within a few taxa will have low values, and samples with low numbers of organisms evenly distributed between many taxa will have high numbers.

Mean species diversity in Banana Lake ranged from 0.8 in June of 1989 to 1.6 in March of 1990 (Figure 4A). Even though species richness (27 taxa in March, 1993) has increased since 1988 and seasonal variation has decreased following dredging, large populations of *C. crassicaudatus* and *L. hoffmeisteri* collected at each sampling event continue to influence the SDI. A goal of 2.5 was initially established in the Surface Water Improvement and Management Plan developed in June, 1989. This goal appears to be somewhat high, especially when compared to other lakes in Florida. During recent surveys of Lake Parker (SWFWMD, 1993), and Lake Hollingsworth (City of Lakeland, 1994) the mean species diversity was reported as 1.8 and 1.2 respectively. In a survey of 48 lake stations throughout Florida, the Florida Department of Environmental Regulation (1989) reported that 50% of the stations had a SDI greater than 2.0, but only 25% had values exceeding 2.5. A more realistic goal for Banana Lake, which remains eutrophic, would be 2.0.

Mean SDI for the post dredging period (n=6) remains a low 1.4 (Std. Dev. 0.2) not much higher than the pre dredging SDI of 1.1 (n=7; Std. Dev. 0.3). Diversity in the fixed station ranged from .48 in September 1990 to 2.59 in May 1992 (Figure 4B). There was no significant difference (Student s t test, P 0.05) between pre dredging and post dredging species diversity values.

<u>Hulbert Lake Condition Index</u>

The benthic macroinvertebrate community is one of many system components used to determine a lake's health or condition. Generally, there are inherent problems in the exclusive use of any single component to describe lakes. For example, Florida lakes



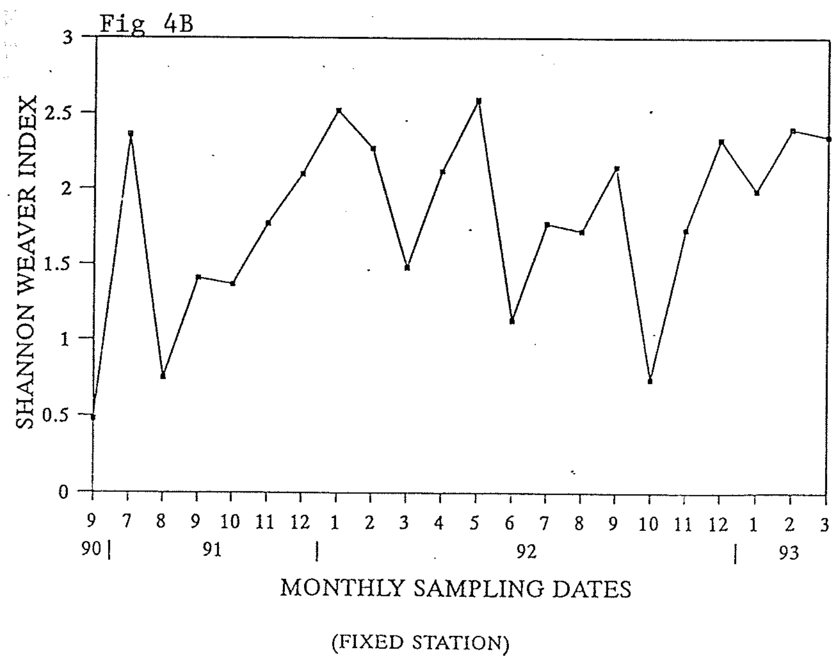


Figure 4. Banana Lake Species Diversity.

have many benthic macroinvertebrate species in common regardless of their trophic state (Hulbert, 1990). Also, lakes with poor water quality and low abundance can have high diversity indices if the few individuals are evenly distributed among the species present.

An index integrating several community measures should provide a more reliable tool for describing lake state. The Lake Condition Index (LCI) developed by Hulbert ranks lakes in 4 categories: unaltered lakes (LCI _ 20), moderately altered lakes (LCI _ 6 < 20), grossly altered lakes (LCI 5), and unaltered but dystrophic (LCI _ 7). The LCI incorporates the presence of benthic macroinvertebrate indicator species, water quality data (total nitrogen, total phosphorus, and chlorophyll a concentrations) and the Shannon-Weaver Diversity Index to describe Florida lakes.

Using the LCI Banana Lake is categorized as grossly altered for all sampling dates. All sampling events for the lake and the fixed station exhibited an LCI value _ 5 which indicates an altered system (Table 1A,B).

Conclusions

The benthic macroinvertebrate community in Banana Lake continues to change in response to lake restoration/management efforts. The large seasonal variations in standing crop have been reduced following dredging. The most significant change has been in species richness. Prior to dredging, 23 taxa had been collected and identified. Since dredging 26 new taxa have been collected and identified. This is an increase of over 100% in species richness following dredging, which indicates that changes in substrate composition, and changes in water quality are occurring. Cooke et al. (1986) stated that the biggest drawback to hydraulic dredging was the destruction of the benthic fauna. This was not observed at Banana Lake. Colonization was rapid after dredging and may have been affected by several factors: type of organisms recolonizing, rate of dredging (over one year) and climate. The appearance of submerged macrophytes in the lake, in response to improved water quality conditions, will further impact benthic community structure.

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CHANGES IN BANANA LAKE PHYTOPLANKTON COMMUNITY STRUCTURE IN RESPONSE TO EFFLUENT DIVERSION AND HYDRAULIC DREDGING

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City of Lakeland Lakes Program

INTRODUCTION

Banana Lake is a 256 acre, hypereutrophic lake located in Polk County, Florida. The lake has been severely impacted by anthropogenic activities since the turn of the century. Phosphate mining occurred throughout the watershed and included areas of lake bottom on the northwest side of the lake. The City of Lakeland discharged secondary sewage effluent to the lake for over 50 years. A survey of the Banana Lake phytoplankton was conducted to evaluate the success of restoration efforts that included sewage effluent diversion and whole lake dredging.

The phytoplankton are the assemblage of small, primarily microscopic plants suspended in the water column. Chorophyll, a pigment common to all plants including the phytoplankton, can impart a green color to the water in highly productive lakes like Banana Lake. Dense assemblages of phytoplankton can limit the penetration of light through the water column restricting the growth of rooted aquatic plants. The phytoplankton have no or limited powers of locomotion, and are subject to distribution by water movements. The phytoplankton, as with other plants, obtain their energy from sunlight and grow through the process of photosynthesis.. Their rapid growth rate and capacity to produce dense assemblages can result in dramatic changes water chemistry.

The phytoplankton form the base of the lake food web, and as such are an important source of food and energy for a variety of lake organisms, including fishes. These changes include broad diurnal or seasonal variations in pH and dissolved oxygen that can impact fish and other aquatic organisms. In addition, some species of phytoplankton are known to produce substances that are toxic to fish and wildlife.

Typically, the production of phytoplankton in lakes is strongly correlated with the concentration of nutrients in the water (Smith, 1982; Reynolds, 1987). In highly enriched lakes, nutrient levels may be present in such quantities that phytoplankton densities are limited by self-shading or other environmental factors. Because the composition and density of phytoplankton affect lake water quality and biological resources, they are of particular concern to lake managers.

METHODS AND MATERIALS

Phytoplankton samples were collected monthly from January, 1990 to May 1992. Since the lake is well mixed and holomictic, samples were collected from the center of the lake. Samples were collected at mid-secchi depth using a Van Dorn water bottle, and then dispensed into dark, polypropylene bottles containing Lugol's solution (Standard Methods, 1985). The samples were returned to the laboratory and stored in the dark until shipment for analysis. Samples were mailed to Phycotech, in Baroda, Michigan, for identification, enumeration, and volume measurements. Once at the Phycotech laboratory, samples were refrigerated in the dark until examined. The samples were removed from the refrigerator and allowed to warm to room temperature before mounting. The samples were shaken 50 times before removing the volume to be mounted.

Membrane filters were placed onto the filtration bases and wet with distilled water. Excess water was drained through the filter. The filter towers were assembled and sample volume was measured with an Eppendorf metered micro-pipette (500 l) into a graduated cylinder and brought to a final volume of 10 ml. Sample was added to the tower and the valve opened. Filtration was continued until water just cleared the filter surface. The filter was placed face down on a cover slip (# 1.5).

Slides were prepared using two different media. The first slides (marked # 2) were prepared using 1-2 drops of clear HPMA pre-polymerized resin. The resin was added to the back of the filter, and the cover slip was rotated until the resin covered the back of the filtér. Next, on slides marked # 2, 1-2 drops of the iodine HPMA pre-polymerized resin was added to the back of the filter, and the cover slip was rotated until the resin covered the back of the filter. Cover slips were placed on the drying rack and placed in the drying oven for 12 to 24 hours. After the cover slips were removed from the oven, 1 drop of clear HPMA pre-polymerized resin was added to the filter side of the cover slip and attached to a labeled slide. The slides were replaced in the oven and allowed to polymerize for approximately 24 hours.

Algae were counted and reported as natural units per milliliter of lake water. Each individual colony, filament or single cell organism is counted as 1 natural unit. A minimum of 300 total natural units were counted in random fields at 400X for each sample when possible (i.e. when adequate cells were present to count 300 within a "reasonable" amount of time). Diatom frustules were identified at 1000X using an Olympus BH-2 microscope with an oil immersion objective.

DISCUSSION

The restoration of Banana Lake has included the removal of all domestic wastewater discharges to the lake in April 1887, the dredging of approximately one million cubic yards of organic deposits from the lake in 1990-91, and the construction of a regional stormwater wetland treatment system in 1992. Prior to the restoration efforts, Banana Lake supported a dense, persistent assemblage of phytoplankton. Chlorophyll a concentrations averaged 141 g/l (n=47) for the pre dredging sampling period dating back to 1984. Algae blooms were associated with several major fish kills that occurred in the lake prior to 1987.

The reduction of phytoplankton production in Banana Lake was established as a restoration goal by the Banana Lake Improvement

Committee in 1990. A quantitative goal of maintaining an annual mean concentration of 30 g/l chlorophyll a was set by the committee. Since chlorophyll a is the primary pigment contained in phytoplankton, a reduction of chlorophyll (phytoplankton) would result in increased water clarity, and would be indicative of an improvement in the overall ecological conditions in the lake. A concentration of 30 g/l chlorophyll a correlated approximately with a one meter secchi depth - another quantitative goal of the restoration committee.

The Banana Lake phytoplankton community was similar in structure to other hypereutrophic lakes in central Florida. A total of 91 species were identified from the 28 samples collected during the survey period. The mean phytoplankton standing crop for all samples, reported as natural units (NU) per milliliter of lake water, was 222,042 NU/ml (SD ± 145,577). Standing crop ranged from 30,731 NU/ml in January, 1990 to 594,832 NU/ml in October, 1990. Standing crop and biovolume measures for the survey period are presented in Figure 1.

Densities in Banana Lake were higher than most other lakes of similar trophic state. In recent phytoplankton surveys of Lake Seminole in Pinellas County and Lake Parker in Polk County, the mean standing crops were 82,000 and 157,594 NU/ml respectively. Lake Hollingsworth, which is located in the same watershed and approximately three miles upstream of Banana Lake had a mean standing crop of 596,325 NU/ml for a one year diagnostic study in 1991-92. The discharge of nutrient rich water from Hollingsworth to Banana Lake will undoubtedly affect the efficacy of the management program.

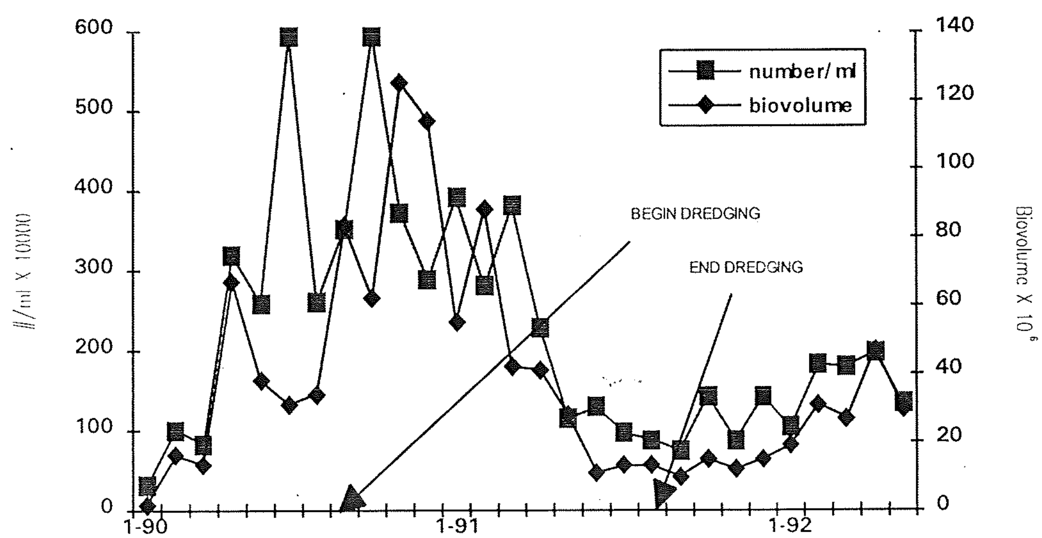

Figure 1. Banana Lake phytoplankton standing stock and biovolume densities.

Blue-green species (Division Cyanophyta) comprised 72% of the total standing crop for Banana Lake. Blue-green algae were present in highest densities in 21 of the 28 samples. The most dominant component of the algal standing stock was an unidentified non-motile unicellular blue-green. This small alga (dia. 2-3 m) comprised 33% of the total standing stock, while no other taxa exceeded 10%. The green algae (Division Chlorophyta) made up 25% of the total standing stock, being the dominant component in 7 of 28 samples. *Selenastrum minutum* and *S. capricornutum* each comprised 5% of the total standing stock. Diatoms were a minor component of the phytoplankton standing stock, making up 2% of the total.

The size of phytoplankton is an important factor in this community's value as a food source for invertebrates including zooplankton. Phytoplankton with a diameter exceeding 20 m is generally considered too large for consumption by most zooplankton. Forty-two percent of the phytoplankton standing stock exceeded this diameter.

Banana Lake phytoplankton biovolume was estimated by assigning each species a geometric form, measuring a representative number of units for each species, and calculating the volume. Banana Lake phytoplankton biovolumes ranged from 1.8 $X\ 10^6\ m^3/ml$ in January, 1991 to $124.9\ X\ 10^6\ m^3/ml$ in November, 1990. The mean biovolume for the survey period was $38.6\ X\ 10^6\ m^3/ml$ (SD $\pm$ $31.8\ X\ 10^6\ m^3/ml$). The mean phytoplankton biovolume reported for Lake Parker was $20.2\ X\ 10^6\ m^3/ml$.

The biovolume percent composition for divisions was the same as the standing stock composition. Blue-greens and greens comprised 72% and 25% of the total algal biovolume respectively. Diatoms accounted for 2% of the total biovolume. Species that made up a significant part of the total biovolume (>10%) included the blue-greens *Aphanothece nidulans* (12%), *Lyngbya contorta* (12%) and *Anabaena circinalis* (11%). *Dictyosphaerium pulchellum* (7%) was the most abundant green alga.

There was a total of 91 species of algae identified in Banana Lake. This is similar to the species richness reported for Lake Parker- 106 (SWFWMD, 1993) , Lake Hollingsworth - 72 (City of Lakeland, 1994), and Lake Seminole- 97 (SWFWMD, 1992). There were 48 species of green algae, 26 species of blue-greens, 11 species of diatoms, 4 species of cryptophytes and 2 species of dinoflagellates.

Nutrient concentrations, phytoplankton biomass measures (standing stock, biovolume and chlorophyll a), and phytoplankton species richness were tested (Pearson's Correlation Coefficient) to determine whether changes in nutrient levels resulted in corresponding changes in phytoplankton community structure. All phytoplankton biomass measures were significantly ($p < 0.05$) correlated with total nitrogen (TN) concentrations. Chlorophyll a ($r = .85$) was most strongly correlated with TN, followed by biovolume ($r = .71$) and standing stock ($r = .44$). Only chlorophyll a (r = .49) had a statistically significant ($p < 0.05$) correlation with total phosphorus concentrations. The strong correlation between chlorophyll a, biovolume and TN indicated that the density of phytoplankton in Banana Lake may be reduced by controlling nitrogen loading.

Measures of phytoplankton biomass have decreased since the removal of sewage effluent and the completion of the hydraulic dredging (Table 1, Figure 1). Values for the biomass measures for pre, during and post dredging are presented in Table 1. Phytoplankton abundance increased during dredging (September 1990 - August 1991), but decreased in the post dredging samples to levels below pre dredging. There was however, no a statistically significant difference between pre and post dredging standing crops, biovolumes and chlorophyll concentrations (Student s t test, $p<0.05$). There was a significant increase in the species richness in the post dredging samples ($p<0.01$).

DREDGING PERIOD	STANDING STOCK (#/ml)	BIOVOLUME (m/ml x 10^6)	CHLOROPHYLL a (g/l)	SPECIES RICHNESS	TOTAL NITROGEN (mg/l)	TOTAL PHOSPHORUS (mg/l)
PRE	206,003	28.8	114	23	5.00	1.48
DURING	276,682	56.1	266	31	5.99	1.86
POST	138,772	22.9	82	27	2.57	1.02

Table 1. Mean phytoplankton and nutrient concentrations for periods pre, during, and post hydraulic dredging.

Additional sampling will be required to accurately assess the impacts of the various lake restoration measures implemented over the past 6 years. The recent (1992) completion of the Edgewood regional stormwater drainage project should result in further reductions in nutrient loadings to Banana Lake. It may take several years for many components of the Banana Lake ecosystem to stabilize. It does appear, however, that the extreme range of fluctuation in phytoplankton densities may have been reduced, and that post dredging densities in Banana Lake more closely resemble those found in other central Florida hypereutrophic lakes.

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INNOVATIVE STORMWATER TREATMENT FOR WATERSHED MANAGEMENT

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The STORMTREAT™ System - A new technology for treating stormwater.

A promising new stormwater treatment technology has been developed and tested called the STORMTREAT™ System. It incorporates known technologies of sedimentation, filtration and constructed wetlands into a modular, unitary 9.5-foot diameter structure. The technology is designed to capture and treat the "first flush" of runoff by being positioned high in the watershed near to the pollution sources. The number of units at each location is determined by the size of the sub-drainage area. The units are manufactured by rotational molding and are constructed of recycled polyethylene.

Test results from an installation in Kingston, Massachusetts indicate "removal rates" of 94% for total coliform bacteria, 91% for fecal coliform bacteria and 94% for total suspended solids. Preliminary nutrient test results indicate removal rates of 44% for dissolved nitrogen and 32% for ortho-phosphorus. Higher nutrient removal rates are expected during the growing season and in warmer climates. The nitrogen data also suggests that nitrification-denitrification transformations are occurring within the STORMTREAT™ System. From the experience to date, the STORMTREAT™ System has many applications as a "best management practice" within the watershed management field.

Background

Stormwater runoff from streets, parking lots and adjacent areas is one of the most significant water pollution problems today. Lakes, reservoirs, streams, coastal waters and related wetlands receive "pulses" of oils, bacteria, metals, nutrients and other pollutants during and following each storm event. Where stormwater is infiltrated or injected into ground water, impacts may occur to subsurface drinking water supplies.

Chronic petroleum hydrocarbon discharges to the marine environment from stormwater runoff far outweigh those from catastrophic oil spills from tanker ships (such as the Exxon Valdez).[1] Researchers associated with the EPA-sponsored Buzzards Bay National Estuary Program project have concluded that stormwater-derived bacterial loadings are responsible for the majority of shellfish area closures.[2] Stormwater has also been documented as a major component in the eutrophication of lakes and ponds nationwide.[3]

Stormwater is considered a "non-point" source of pollution. This term is intended to contrast it with other "point" sources of pollution such as a sewage or industrial discharges which occur through more easily identifiable "points" such as pipes. Such effluent discharge pipes are more easily monitored and regulated than are non-point sources of pollution.

Non-point sources of pollution such as stormwater typically originate from diffuse areas. Stormwater is generated from streets, parking lots, roof tops, driveways, lawns, agricultural fields and forests. Frequently, stormwater runoff from several of these various "land uses" is combined into a stormwater flow in a drainage ditch or stormwater pipe which ultimately discharges to a receiving water where the impacts are realized. Because of the diffuse nature of sources, stormwater management is best accomplished by a watershed management technique which treats each area within the watershed independently as opposed to the more conventional "big pipe" solution where a large detention/treatment system is constructed at the bottom of a watershed attempting to catch and treat all of the stormwater generated by the watershed. The latter approach is not efficient. It is land-intensive and costly.

Unlike sewage pollution, where widespread sewer collection and treatment systems have been constructed, and most state codes regulating on-site septic systems have been augmented to reduce the pollution potential, little has been done to correct stormwater pollution problems. A number of so-called "best management practices" (or BMPs) have been developed and recommended by USDA Natural Resources Conservation Service (formerly the Soil Conservation Service) and more recently by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (the so-called "6217" program) and the U.S. Environmental Protection Agency. These BMPs range from detention basins to infiltration devices and have demonstrated highly variable success and failure rates. Figure 1 summarizes the advantages and disadvantages of these measures.

Introduction of technology

The Storm-Treat System is designed to selectively collect and treat the "first flush" of runoff and to efficiently handle runoff high in the watershed. This is accomplished using clusters of Storm-Treat units located near identified source areas within the watershed.

The Storm-Treat System consists of a series of 9 1/2-foot diameter recycled-polyethylene tanks (see Figures 2 and 3). The number of tanks is dependent upon the size of the drainage area to be treated. It connects directly to existing drainage structures, most commonly the catch basins and is designed to collect the first flush of runoff (one-half inch of rain*), believed to contain the vast majority of the pollutants. The remainder of the runoff bypasses the system as overflow.

*Can easily be adapted to other measures of runoff, e.g.,

The Storm-Treat System utilizes internal sedimentation chambers containing a series of filter bulkheads fitted with filter screens. A series of "skimmers" are also utilized to selectively decant the upper portions of the stormwater in the sedimentation basins, leaving behind the higher turbidity waters. After moving through these internal chambers, the partially-treated stormwater passes into the surrounding constructed wetland through a series of slotted-PVC pipes. The wetland is comprised of a sand and gravel substrate planted with cattails, bulrushes and burreeds. An outlet control valve provides a 5 day holding time within the system. Unlike most constructed wetlands, stormwater in the Storm-Treat System flows subsurface through the root zone of the constructed wetland, providing for greater pollutant attenuation.

Because it focuses on the "first flush" of stormwater, the Storm-Treat System is significantly smaller (usually on the order of 5-10% of the area) when compared with conventional sedimentation - detention/retention basins. Where land costs are high or difficult site constraints exist, this size efficiency can represent significant economic savings. Because the system is self-contained and is designed with a surface discharge, the system can be located in low-permeability soils with high water table conditions. The Storm-Treat System has no standing water (common to conventional detention/retention basins) which can be unsightly, unsafe and can encourage mosquito breeding.

The Storm-Treat System is manufactured from durable, recycled-polyethylene to withstand aggressive field conditions (including marine environments). It is self-anchored by the self-contained wetland soils to easily withstand the buoyancy caused by high water table conditions.

Water quality sampling is conducted during and following storm events by members of the Jones River Watershed Association under the supervision of its Executive Director. According to our Quality Assurance Plan (QAP), the Field Captain determines the likelihood of a one-half inch event using local weather forecasts and notifies samplers to report to the Elm Street location. No sampling is conducted without a minimum of 3 days of preceding dry weather.

"First flush" stormwater samples are taken at the entry point to the STS tanks by opening the manhole cover. "Effluent" samples are taken during the 5 days following the storm event. They are obtained at the sampling ports ("A6, B6, C6 and D6") where the effluent pipes discharge at the land's surface.

Four monitoring wells have been installed in each STS wetland. Wells are constructed of 2-inch PVC, schedule 40 riser and 2-foot screens. They will be sampled to monitor biochemical transformations (such as nitrification-denitrification) within the subsurface wetland environment. No data is reported from the wells in this report.

Water samples are obtained using laboratory-prepared sampling bottles by taking grab samples and measuring flow rates. Samples for dissolved nutrients are filtered in the field using 0.45-micron filter paper and filtering syringe. Following the storm event the "first flush" samples are composited (by flow-weighting method).

Samples are packed in iced coolers and shipped to the analytical laboratories with Chain of Custody forms. Water quality analyses are conducted by three laboratories:

- Woods Holes Oceanographic Institution [WHOI], (nutrients)
- Barnstable County Health & Environmental Department [BCHED], (bacteria, TSS, metals, COD)
- Analytical Balance Corp. [ABC], (bacteria, TSS, metals, COD)

Woods Hole Oceanographic Institution has been certified by the U.S. Environmental Protection Agency. The other two laboratories are certified by the Commonwealth of Massachusetts Department of Environmental Protection. Specific laboratory methods are referenced in Table 1.

Table 1 - Laboratory analytical methods

Parameter	Analysis
Total N-particulate	Elemental analysis
Total N-dissolved	Persulfate digestion
Nitrate, Nitrite	Cadmium reduction
Ammonium nitrogen	Indophenol
Total phosphorus	Persulfate digestion
Ortho-phosphate	Molydbenum blue
Fecal coliform	Membrane filter procedure
Total suspended solids	Standard methods 2540D
Chromium, Lead, Nickel, Zinc	Atomic absorption spectrophotometry

Our Quality Assurance Plan requires a minimum of 5% of samples as duplicates. This is accomplished by splitting samples between two certified laboratories and by providing them blind duplicates.

Results

To date we have successfully sampled five stormwater events at the Elm Street installation. The results are summarized below in Table 2 and Figure 5. The actual water quality data is shown on the accompanying Table 3. Please note that we have not yet received all of the analytical results from the laboratories.

Table 2 - Summary of water quality monitoring results of the Storm-Treat System - Kingston, MA

Pollutant	Stormwater influent	Treated effluent	Percentage removed
Fecal coliform bacteria (orgs/100 ml)	690	20	97
Total suspended solids (mg/liter)	93	1.3	99
Chemical oxygen demand (mg/liter)	95	17	82
Total dissolved nitrogen (micrograms/liter)	1638	922	44
Total petroleum hydrocarbons (mg/liter)	3.4	0.34	90
Lead (micrograms/liter)	6.5	1.5	77
Chromium (micrograms/liter)	60	1	98
Zinc (micrograms/liter)	590	58	90

The laboratory results of four rounds of samples from four stormwater events: 11/11/94, 11/28/94, 12/5/94 and 2/17/95 have been averaged.

We are evaluating system performance by calculating the percentage removal of each parameter by comparing the "First Flush" with the average of the "Effluent" samples. We are not directly comparing the "Effluent" results with those in "Chamber A1" because we believe that resuspension of sediments within this chamber significantly alters the quality of the incoming stormwater.

These results indicate that an average of 94% of the total coliform bacteria and 97% of the fecal coliform bacteria, 99% of the total suspended solids (TSS) and 90% of total petroleum hydrocarbons. Preliminary nutrient results suggest a removal rate of 44% for total dissolved nitrogen (TDN) and 32% for ortho-phosphorus. We expect the nitrogen removal rate to improve during the growing season when the wetland plants are more active. Removal rates for metals are as follows: lead - 77%, chromium - 98%, and zinc - 90%.

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PALEOLIMNOLOGICAL EVALUATION OF HISTORICAL TROPHIC STATE CONDITIONS IN HYPEREUTROPHIC LAKE THONOTOSASSA

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ABSTRACT

We used paleolimnological methods to evaluate historical water quality in Lake Thonotosassa, Hillsborough County, Florida. Sediment mapping shows that organic deposits are unevenly distributed in the lake. Two short (<130 cm) sediment cores from the depositional zone were analyzed for radioisotopes (^{210}Pb, ^{226}Ra, and ^{137}Cs), bulk density, organic matter content, nutrients (C,N,P), and diatoms. ^{210}Pb results indicate that the profiles represent >100 years of sediment accumulation. There is an abrupt lithologic change at about the turn of the century (~80 cm depth), above which bulk density decreases and concentrations of organic matter, total C, total N, total P, and ^{226}Ra activity increase. Diatom-based reconstructions of historical water-column trophic conditions indicate progressive nutrient enrichment in the lake over the past ~100 years. Stratigraphic changes in diatom assemblages suggest that anthropogenic nutrient loading converted Lake Thonotosassa from a naturally eutrophic system to a hypereutrophic waterbody after ~1900.

INTRODUCTION

The state of Florida possesses more than 8000 lakes (Brenner et al. 1990), some of which are nutrient-rich and highly productive. Only a small proportion of the state's water bodies have been studied limnologically, and long-term water quality data for Florida lakes are virtually non-existent. Present-day eutrophic to hypereutrophic conditions in some Florida basins are often attributed to anthropogenic nutrient loading, but these aquatic systems may naturally possess high nutrient concentrations as a consequence of underlying phosphate-rich limestone deposits (Canfield and Hoyer 1988). In order to effectively manage or restore these nutrient-rich waterbodies, it is essential to discern between their "edaphic" trophic state and nutrient enrichment that resulted from human impacts. Unfortunately, most Florida lakes were perturbed anthropogenically before limnological monitoring began. In lieu of long-term water quality data, stratigraphic study of lake sediment cores can be used to evaluate historical trophic conditions and assess the potential for significantly reducing in-lake nutrient concentrations (Anderson 1993, Anderson et al. 1993, Smeltzer and Swain 1985, Brenner et al. 1993). This paper presents results of a paleolimnological study in Lake Thonotosassa, Hillsborough County, Florida.

STUDY SITE

Lake Thonotosassa (A = 332 ha, z_{max} = ~4.5 m, z_{mean} = ~2.5 m) lies at 28°03' N lat, 82°16' W long, about 10.8 m above sea level in Hillsborough County, Florida. The basin is situated in the Gulf Coastal Lowlands Physiographic Region (Canfield 1981) and overlies phosphatic deposits of the Miocene Hawthorne Formation (Vernon and Puri 1964, Brooks 1981). The watershed covers approximately 125 km^2, about 19% of which lies within the urbanized portion of Plant City.

Nutrient concentrations in Lake Thonotosassa measured during the last decade indicate the lake is hypereutrophic. Mean annual total P concentrations ranged between 320 $\mu g\ L^{-1}$ and 1100 $\mu g\ L^{-1}$ from 1985 to 1994 (SWFWMD, unpub. data). Over the same period, mean annual total N concentrations ranged from 1420 $\mu g\ L^{-1}$ to 2890 $\mu g\ L^{-1}$. Poor water quality characterized the lake by the late 1960s. Aquatic macrophytes were abundant at the beginning of that decade, but had largely disappeared by 1970. Major fishkills were also documented for the first time during the 1960s and high nutrient concentrations were attributed to inputs of domestic sewage, agricultural runoff, stormwater drainage and untreated wastes from food processing plants (Cowell et al. 1975). In an effort to control nutrient loading, Plant City opened its wastewater facility in 1970 to treat residential and food processing wastes. Nevertheless, nutrient levels remained high and blue-green algal blooms became a regular occurrence. Only in the last two years (1993-94) have mitigation efforts appeared to have an effect, with mean annual total P values of 320 and 360 $\mu g\ L^{-1}$, considerably lower than those recorded since the mid-1980s. Our paleolimnological research was designed to evaluate both predisturbance water quality in Lake Thonotosassa and the lake's trophic trajectory.

MATERIALS AND METHODS

We mapped soft sediment thickness in Lake Thonotosassa at 12 locations (Figure 1) to identify appropriate sites for core collection and paleolimnological analysis. Mapping sites were located to achieve approximately equal area coverage of the lake (Håkanson 1981). The sediment survey was conducted on 6-7 July 1994, and sampling locations were determined with a Global Positioning System (GPS).

At each site, water depth was measured by lowering a Secchi disk on a metered rope to the sediment surface. Next, metal rods marked in 20-cm intervals, were forced through the soft sediment lens until they reached the underlying, hard deposits. Soft sediment thickness was computed by subtracting water depth from the total depth between the water surface and hard bottom. At each site a sediment/water interface core was collected using a specially designed piston corer that possesses a 1.4-m-long, clear plastic core barrel (Fisher et al. 1992). Duplicate cores were collected at three sites and topmost

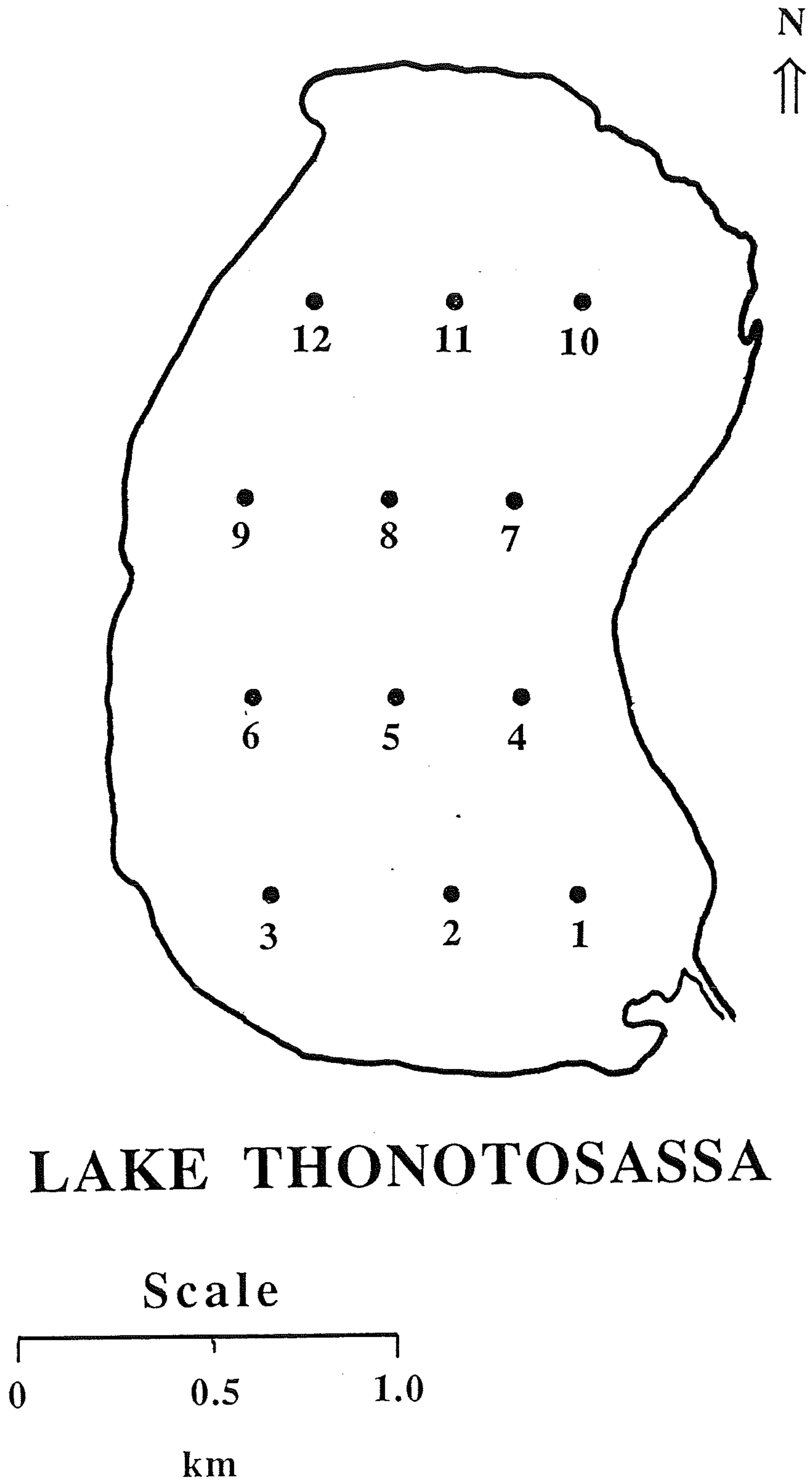

Figure 1. Outline map of Lake Thonotosassa showing twelve sampling stations visited as part of the sediment survey. Sediment cores for paleolimnological analyses were collected at stations 9 and 12.

(0-4 cm) sediments from all survey cores were extruded and stored in labelled Whirl-pak bags. Surface sediment samples were dried at 80 °C in a Blue M Electric Company drying oven and organic matter content was assessed by loss on ignition at 550 °C for two hours (Håkanson and Jansson 1983).

Stations 9 and 12 (Figure 1) displayed the greatest accumulation of soft, organic sediment, and were selected as sites for paleolimnological analyses. On 7 July 1994, we used the piston corer (Fisher et al. 1992) to retrieve a 124-cm sediment profile from station 9 (core 7-VII-1994-9) and a 128-cm core from station 12 (core 7-VII-1994-12). The "paleo" cores were transported to the lake shore in a vertical position and extruded into a PVC tray fitted to the top of the coring tube. Profiles were sampled at 4-cm intervals and wet sediment was transferred to labelled Whirl-pak bags. Samples were returned to the lab and stored at 4 °C prior to analysis. Subsamples for diatom analyses were placed in labelled plastic scintillation vials and preserved with ethanol.

We measured bulk density (g dry cm^{-3} wet) by determining the dry sediment mass per volume of wet sediment. Subsamples for chemical analyses and radiometric measurements were dried in a Virtis freeze drier and ground with a mortar and pestle. Organic matter was measured by weight loss on ignition (LOI) at 550 °C for two hours (Håkanson and Jansson 1983). Total C and total N in the cores were measured with a Carlo-Erba C-H-N Analyzer. Total P in sediments was assessed using a Bran + Luebbe Autoanalyzer II with a single-channel colorimeter, following digestion with H_2SO_4 and $K_2S_2O_8$ (Schelske et al. 1986).

Diatom samples were cleaned of organic matter using the potassium dichromate and hydrogen peroxide method of Van der Werff (1955). Cleaned samples were settled on coverslips and mounted on glass slides using Hyrax mounting medium. At least 500 diatom valves were counted in each sample. We developed transfer functions (Table 1) that quantitatively relate the TROPH1 diatom index in surface sediments to water column variables total P, Chl *a*, and an average trophic state index (TSIAVG: Huber et al. 1982) for a suite of Florida lakes (Whitmore 1989, Brenner et al. 1993). These calibration regression equations were in turn used to infer historical limnological conditions using diatom assemblages from the paleolimnologically-studied sediment cores.

Table 1. Calibration regression equations developed to predict limnological variables using sedimented diatom assemblages (i.e. the TROPH1 index). Limnological data were from the Florida Lakes Data Base (see Huber et al. 1982).

Regression Equation	r^2	P	Lakes (n)
Log_{10} total P = -1.795 + 0.973 (Log_{10} TROPH1)	0.81	<0.0001	47
Log_{10} Chl *a* = 0.817 + 1.089 (Log_{10} TROPH1)	0.68	<0.0001	50
TSIAVG = 40.88 + 43.67 (Log_{10} TROPH1)	0.79	<0.0001	50

Samples for radiometric dating were dried, ground, and packed in plastic Sarstedt tubes to a height of ~30 mm. Sediment in the tubes was covered with epoxy glue and stored for >3 weeks prior to counting to establish $^{226}Ra/^{214}Bi$ equilibrium. We simultaneously measured ^{210}Pb, ^{214}Bi (i.e.^{226}Ra) and ^{137}Cs activity by direct gamma counting (Appleby et al. 1986), using an ORTEC Intrinsic Germanium Detector connected to a 4096 channel, multichannel analyzer (Schelske et al. 1994). The distribution of atmospherically-derived (unsupported) ^{210}Pb in a core can often be used with an appropriate dating model to establish a sediment chronology (Appleby and Oldfield 1983). ^{210}Pb dates are sometimes verified with ^{137}Cs, an artificial radionuclide that was injected into the atmosphere by nuclear weapons testing in the 1950s and 1960s. Atmospheric ^{137}Cs reached a high in 1962-63 and a ^{137}Cs activity peak in sediments can sometimes be used to identify the period of maximum fallout (Krishnaswami and Lal 1978).

RESULTS

Organic sediments are unevenly distributed in Lake Thonotosassa and are thin or absent in the eastern half and southernmost parts of the basin (Table 2). Soft sediment thickness is greatest near the western lakeshore, in the deepest part of the basin. Topmost deposits (0-4 cm) in the survey cores display a range of organic matter content (%LOI) from <1% to ~50% (Table 2).

Table 2. Water depth, soft sediment thickness and percent organic matter content (%LOI 550 °C) in surface sediments (0-4 cm) from 12 stations in Lake Thonotosassa (see Figure 1 for station locations). A and B represent duplicates.

Station number	Water Depth (cm)	Soft sediment thickness (cm)	Percent organic matter (% LOI 550 °C)
1A	210	0	0.2
1B	210	0	0.4
2	320	0	0.4
3	390	46	19.1
4	320	15	0.3
5	395	61	34.5
6	395	145	47.3
7	340	0	0.4
8	400	76	36.3
9A	420	150	50.4
9B	420	150	49.6
10	230	8	0.4
11A	410	36	0.4
11B	410	36	0.4
12	420	148	42.9

Total ^{210}Pb activity is >30 dpm g^{-1} between 4 and 80 cm in core 7-VII-1994-9, but drops abruptly to supported levels (i.e. total $^{210}Pb \approx {}^{226}Ra$ activity) at 84 cm depth (Figure 2). In core 7-VII-1994-12, total ^{210}Pb activity is uniformly high (~25 dpm g^{-1}) between the surface and 76 cm, where activity rapidly declines and approximates ^{226}Ra activity (Figure 2). ^{226}Ra activity is relatively low at the base of the two cores, but increases abruptly above ~80 cm depth, reaching a maximum of 30.9 dpm g^{-1} at 72-76 cm in the station 9 core and 20.9 dpm g^{-1} at 68-72 cm in the station 12 core (Figure 2). Above the depths at which maxima are found, ^{226}Ra activity declines gradually toward the sediment surface. ^{137}Cs in the paleo cores fails to display a sharp peak that might identify the period of maximum fallout c. 1963. ^{137}Cs values are high over a >30 cm span in the cores and maximum activities occur deep in the sections, at 72-76 cm (ST 9) and 64-68 cm (ST 12).

Cores 7-VII-1994-9 and 7-VII-1994-12 display low sediment bulk density in uppermost deposits (Figure 3). Bulk density increases with depth to about 80 cm,

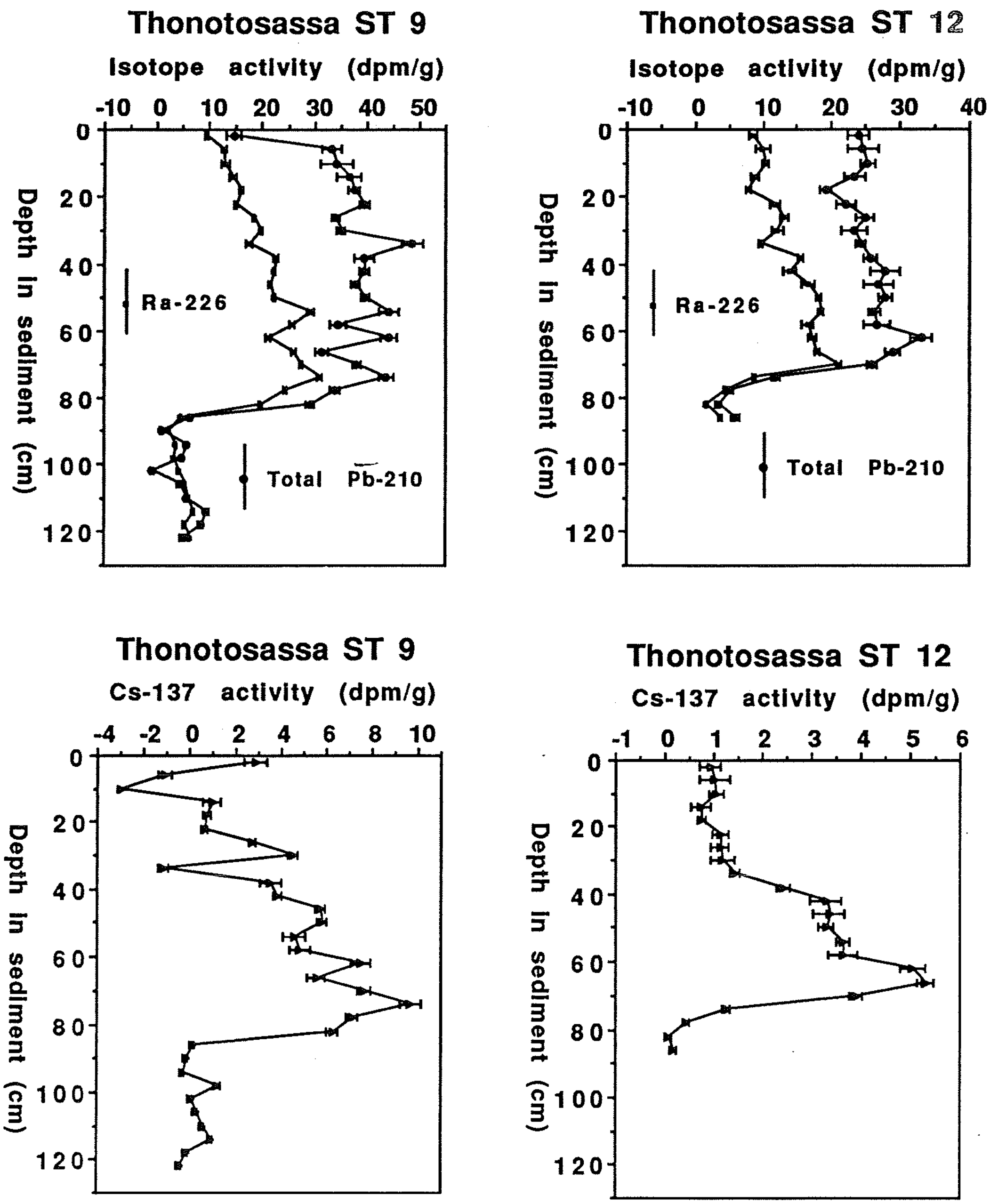

Figure 2. ^{210}Pb, ^{226}Ra, and ^{137}Cs activities (dpm g^{-1}) versus depth (cm) in sediment cores from Lake Thonotosassa stations 9 and 12.

reflecting sediment compaction. Bulk density maxima at 84-88-cm depth in core 7-VII-1994-9 and 80-84-cm depth in core 7-VII-1994-12 are associated with levels in which inorganic matter dominates the sediment matrix. Below the inorganic horizon, bulk density declines.

Organic matter and total carbon concentrations in the paleo cores are highest at the sediment surface and decline to lowest values at about 80 cm depth (Figure 3). Below the inorganic zone, organic matter and total carbon content increase. Total nitrogen displays a similar stratigraphic distribution in the sediments (Figure 4). Total P concentrations are ~6 mg g^{-1} at the sediment surface and increase to ~9 mg g^{-1} between 80 and 84 cm in the paleo cores (Figure 4). Total P declines abruptly to <2 mg g^{-1} below ~86 cm in both cores.

Diatoms are generally well preserved in the Thonotosassa cores. Substantial breakage was noted only at 88-92 cm in core 7-VII-1994-12 and at 96-100 cm in core 7-VII-1994-9. Diatom assemblages in the lower portions of the profiles are dominated by mesotrophic-eutrophic and eutrophic, planktonic taxa including *Aulacoseira granulata*, *A. granulata* var. *angustissima*, *A. ambigua*, and *Cyclostephanos dubius*. Planktonic taxa are progressively replaced above 48-52 cm in core 7-VII-1994-9 and above 40-44 cm in core 7-VII-1994-12 by benthic, eutrophic to hypereutrophic indicators such as *Pseudostaurosira brevistriata* and *Staurosira construens* var. *venter*.

In both cores, diatom-based inferences for historical water-column total P concentrations indicate a general, increasing trend from a low of about 40 μg L^{-1} near the base of the sections to about 90 μg L^{-1} at the sediment surface. Likewise, Chl *a* inferences increase from about 20 mg m^{-3} deep in the cores to ~50 mg m^{-3} at the top of the profiles. TSIAVG inferences shift steadily through time from about 60 to values in the mid 70s at present (Figure 5).

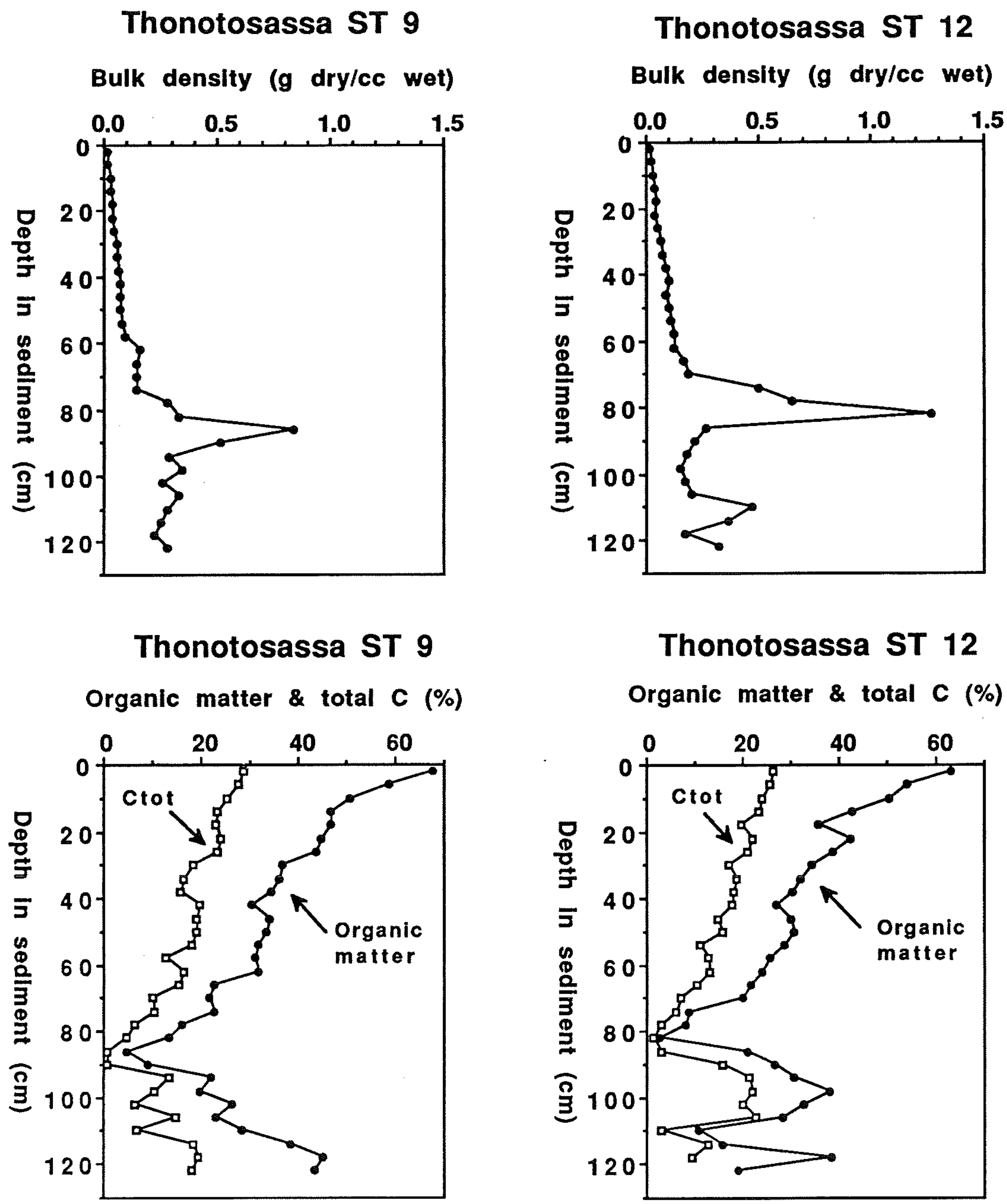

Figure 3. Bulk density (g dry cm^{-3} wet), organic matter, and total carbon content (%) versus depth (cm) in sediment cores from Lake Thonotosassa stations 9 and 12.

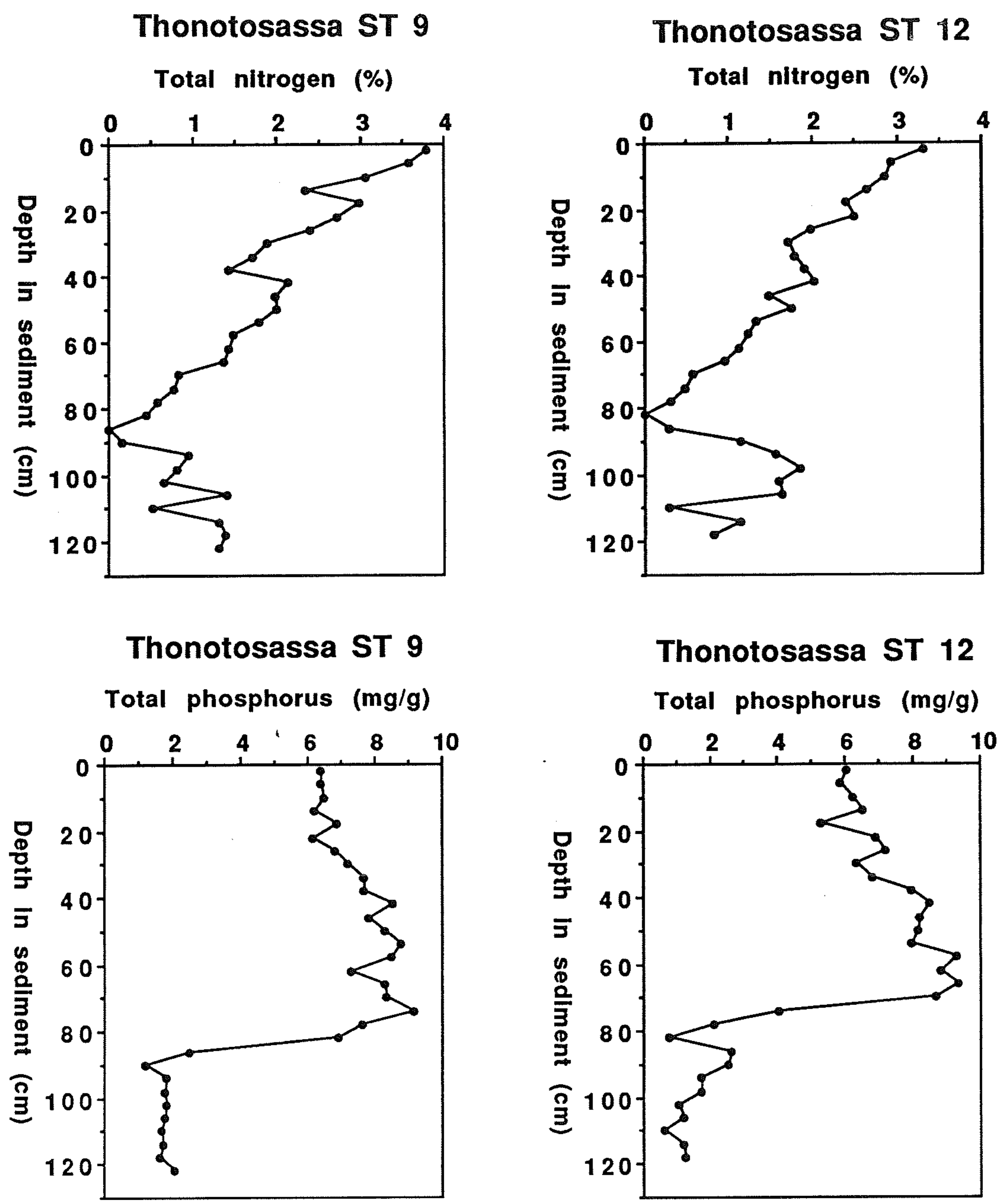

Figure 4. Total nitrogen (%) and total phosphorus content (mg g^{-1}) versus depth (cm) in sediment cores from Lake Thonotosassa stations 9 and 12.

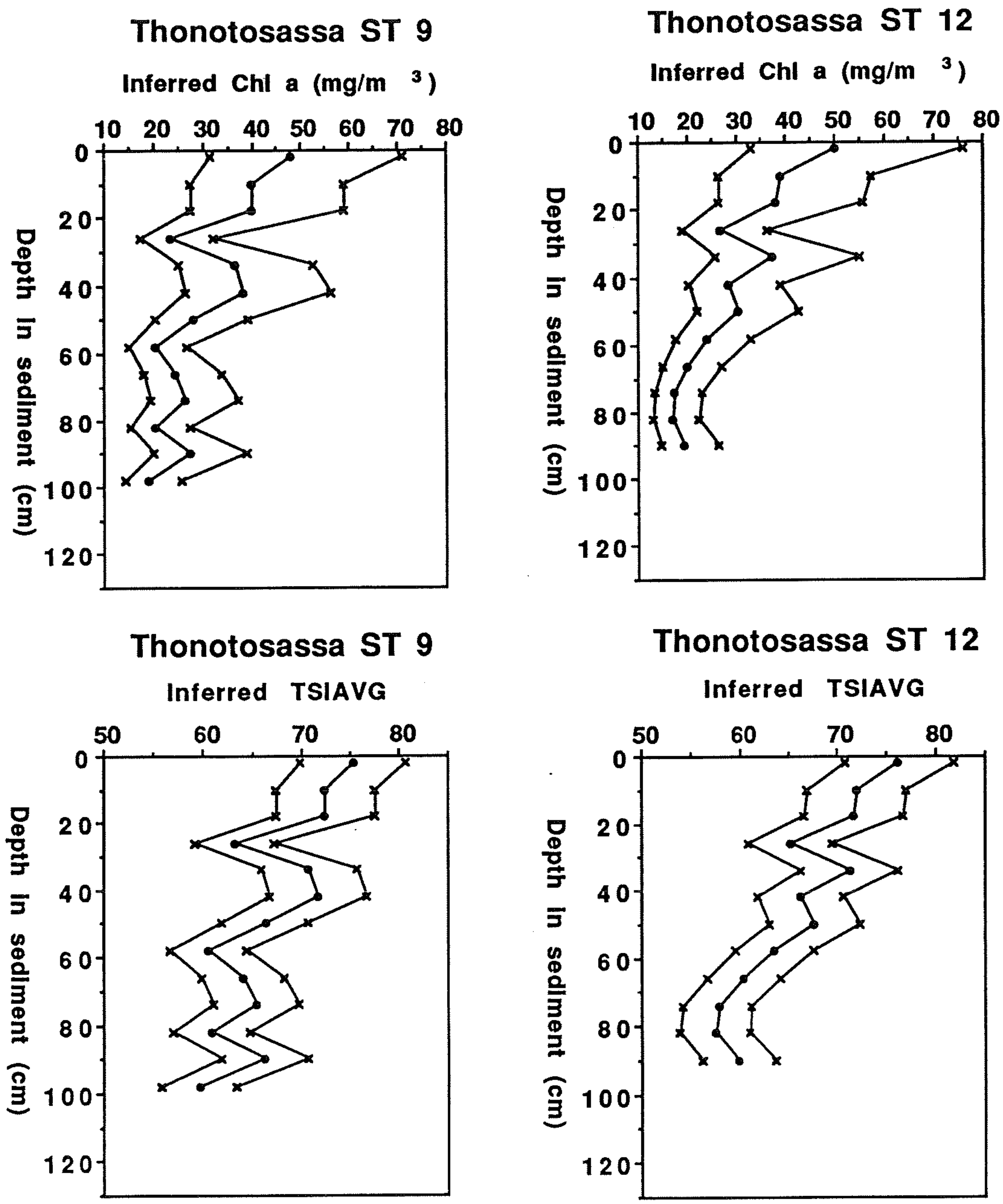

Figure 5. Quantitative reconstructions of historical water-column chlorophyll *a* concentrations (mg m^{-3}) and historical TSIAVG versus depth (cm) in sediment cores from Lake Thonotosassa stations 9 and 12. Reconstructions are based on sedimented diatom assemblages and application of regression equations in Table 1. Plots show the mean inferred value and the upper and lower limits on the 95% confidence interval.

DISCUSSION

Unsupported ^{210}Pb activity in the Thonotosassa paleo cores does not decline gradually or exponentially with increasing depth, but rather, remains high and decreases suddenly between 70 and 80 cm depth. Calculated excess ^{210}Pb inventories at stations 9 (113.0 dpm cm^{-2}) and 12 (78.1 dpm cm^{-2}) are high relative to the expected value of ~32.5 dpm cm^{-2} derived from the regional atmospheric ^{210}Pb fallout rate (Binford and Brenner 1986). The stratigraphic distribution and total integrated excess ^{210}Pb in cores from stations 9 and 12 suggest that unconsolidated surface sediments throughout Lake Thonotosassa are frequently resuspended and redeposited (focused) along the western shore of the basin. This process may confound ^{210}Pb dates.

^{137}Cs distribution in the cores also indicates that detailed dating is problematic, because highest ^{137}Cs activities appear near the supported/unsupported ^{210}Pb boundary, too deep in the profiles to represent the 1963 peak in atmospheric ^{137}Cs deposition. Post-depositional mobility of highly soluble cesium has been observed in other Florida lakes (Brenner et al. 1994), and may occur in Thonotosassa, where bottom deposits lack 2:1 lattice clays that provide binding sites for the radionuclide.

Rather than fully ^{210}Pb date the profiles, we assigned an age of ~110 years to the supported/unsupported ^{210}Pb boundary at ~80 cm depth. This assumption is consistent with findings in cores from other Florida lakes in which excess ^{210}Pb activity is negligible in sediments ≥5 half-lives old (i.e. ≥110 years old). We discuss historical trophic state in Lake Thonotosassa with reference to this datum.

Several lines of evidence suggest that Lake Thonotosassa has experienced increased nutrient loading during this century. The shift from planktonic to benthic dominance in the diatom community has been observed in cores from other hypereutrophic Florida lakes (Brenner and Whitmore 1991, Brenner and Whitmore 1992), and may be caused by cyanobacterial allelopathic inhibition or light limitation of planktonic diatoms.

Inferred limnetic total P values show a gradual increasing trend through time in both cores. Inferences for the sediment surface (~90 $\mu g\ L^{-1}$) are about twice as high as values inferred near the base of the sections. The dramatic increase in total P content of the sediments moving upward in the cores also suggests more rapid delivery rates for the nutrient. High correlation, however, between ^{226}Ra activity and total P in the station 9 ($r=0.94$, $P<0.001$) and station 12 ($r=0.92$, $P<0.01$) profiles suggests that total P is delivered to the lake largely in inorganic particulate form. Much sedimented phosphorus may never have been available for biological uptake.

In addition, inferred mean limnetic total P values for surface deposits in Lake Thonotosassa (~90 $\mu g\ L^{-1}$) are significantly lower than values measured directly in recent years. Limnological measurements have consistently exceeded 200 $\mu g\ L^{-1}$ (SWFWMD, unpub. data). This discrepancy arises because Lake Thonotosassa is N-limited, and was a statistical outlier in the calibration data set that relates diatom assemblages to water-column total P in P-limited and nutrient-balanced lakes (Brenner et al. 1993). The model may fail to predict limnetic total P accurately in this strongly N-limited lake.

Chlorophyll *a* inferences increase proceeding upward in both cores, from lows of ≤ 20 mg m^{-3} about the turn of the century, to 47.9 mg m^{-3} (ST 9) and 50.0 mg m^{-3} (ST 12) at the sediment surface (Figure 5). Mean annual Chl *a* concentrations measured in Lake Thonotosassa from 1992 to 1994 ranged from 62 to 102 mg m^{-3}. The upper bound inference for surface samples is not statistically different from the mean in-lake Chl *a* value measured in 1993. Inferred TSIAVG values at the base of the cores are 59.6 (ST 9) and 59.9 (ST 12), indicating that the lake was eutrophic by the turn of the century (Figure 5). TSIAVG inferences for surface sediments in cores 7-VII-1994-9 and 7-VII-1994-12 were 75.3 and 76.2, respectively, indicating hypereutrophic conditions. The inferred values are nearly identical to annual mean TSIAVG values in the lake during years 1993 (74.9) and 1994 (76.1) [SWFWMD, unpub. data].

Soft sediment distribution in Lake Thonotosassa and total integrated ^{210}Pb inventories from the station 9 and 12 cores suggest continuous wind-generated resuspension of flocculent deposits from the eastern part of the basin and redeposition along the western side of the lake. Nevertheless, stratigraphic changes in C, N, and P concentrations, ^{226}Ra activity, and diatom assemblages argue against complete sediment mixing at the core sites. Furthermore, between-core stratigraphic similarities with respect to all variables indicate orderly accumulation of sediment in the depositional zone.

The inorganic-rich lens at ~80 cm depth in the cores may have been caused by a storm event that transported a substantial load of particles to the offshore coring sites. Alternatively, it may be a consequence of initial channelization of the Flint Creek outlet or other nearshore land-clearing operations shortly after the turn of the century. In any event, the horizon was dated to ~110 years ago because there is no unsupported ^{210}Pb below that depth. It marks the beginning of gradual changes in sediment geochemistry and diatom assemblages.

The rise in total P concentration and ^{226}Ra activity in sediments above 80 cm supports the claim that riparian disturbance enhanced delivery of radium-bearing soil and bedrock particulates. Although much of the total P delivered to the lake over the last century may have been biologically unavailable, the diatom record indicates a clear response to nutrient enrichment in the upper 80 cm of the cores. Present total P concentrations in Lake Thonotosassa are very high, and if much of that P is available, then the lake is certainly N-limited.

Historical water quality inferences, based on sedimented diatom assemblages, indicate that the lake was eutrophic (TSIAVG≈60) even 100 years ago. The naturally high trophic state of Lake Thonotosassa is partly due to P-rich geologic deposits in the basin. Nevertheless, nutrient inputs to the lake have increased over the past century. Present hypereutrophic conditions are a consequence of human-induced erosion, stormwater runoff, sewage disposal and dumping of citrus wastes. The latter three inputs are probably responsible for substantial contributions of available phosphorus. Efforts to reduce in-lake nutrient concentrations in Lake Thonotosassa should be directed at eliminating point source nutrient inputs and reducing riparian activities that generate erosional loading. These procedures may reduce hypereutrophic nutrient levels, but paleolimnological evidence suggests that even under the best circumstances, trophic state will not be reduced in any practicable manner to a TSIAVG <60.

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LOW DISSOLVED OXYGEN CAUSED FISH KILLS

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This manuscript was designed in a question and answer format, developed to educate the public and address some commonly asked questions about fish kills and water quality. This text was written for the non-professional, and addresses the causes, determinations, effects, first aid, and long-term prevention of low DO caused fish kills. Numerous connections are made between stormwater runoff and resulting effects on fish populations.

What causes fish kills?

There are many factors that can account for a sudden fish die off in a water body. Temperature, salinity, pH, ammonia, nitrite, carbon dioxide, turbidity, dissolved oxygen, pesticides, toxins, diseases, all must be considered when determining the cause of fish mortalities. The aspects of both water chemistry and species biology (availability of food, metabolic rates and tolerances, etc.) must be looked at because they all interact. It is important to try to determine the causes of a fish kill to ascertain if future kills are preventable and to suggest the best protocol for prevention. Often a relatively minor change in a single environmental parameter can lead to increased stress on an aquatic organism, often without outwardly affecting other factors.

What is the most common reason for a mass die-off of fish?

Low dissolved oxygen (DO) levels are the most common cause of fish kills. There are many factors that reduce water's ability to hold oxygen in a dissolved state, and affect the ability of a fish to utilize it. A system with marginal DO levels that is further stressed can result in a fish kill. The amount of oxygen held depends greatly on the temperature of the water. As temperatures rise, the amount of oxygen the water can hold lessens. Another factor which greatly influences the DO level of water is the amount of other compounds the water is already holding. These compounds may be solids, chemicals or even other gasses, all of which can displace a certain amount of oxygen. A suitable analogy is that of water poured on a sponge. The sponge can only soak up so much water before the remaining water drips through the sponge. When the sponge can hold no more water, the sponge is considered to be saturated. If the sponge already has some other fluid in it, it absorbs less water before becoming saturated.

The DO in most open water bodies ranges from 0 to 13 milligrams per liter (mg/l). In balanced surface water bodies the daytime DO levels are usually close to saturation. This means that the water has absorbed as many oxygen molecules as possible. The saturation point is usually somewhere between 6 and 8 mg/l, depending on the season (temperature) and water chemistry. Most fish do well in water which contains at least 5 mg/l of oxygen. At levels below 5 mg/l, some game fish are stressed. They will often move to other areas if possible, and may refuse to eat. As the oxygen levels drop lower, more species of aquatic organisms are adversely affected.

It is important to look at the effects of environmental stress not only as it affects fish, but also the snails, worms, and other organisms in and on the sediments. After all, what would fish eat if <u>their</u> food was gone? Fish have specific requirements for particular oxygen levels, below which they will not reproduce, feed or survive. Quite often, a larger fish will have a greater need or oxygen demand, than a smaller fish of the same species. Creatures that are active often require more oxygen than fish that are less active (many bottom dwellers), and most organisms need more oxygen while digesting food. At oxygen levels below 3 mg/l, most fish will not feed and show signs of distress. The fish will often be seen at the surface of the water acting somewhat sluggish. This activity is called piping, and is most visible in the early dawn, when the waters are calm and flat and the oxygen levels lowest due to the inhibition of photosynthesis during the night.

Since nature abhors a vacuum, and *something* lives almost everywhere, some fish have adapted to waters that are chronically low in DO. Some of these adaptations include: the development of rudimentary "lungs", more efficient oxygen carrying blood, and lower oxygen demands. These types of fish, mullet being a prime example, will often be sporting about while their cousins gasp at the surface. However, even they can not survive long when the DO levels drop below 1 mg/l.

How does the oxygen get into the water in the first place?

Most of the dissolved oxygen gets into the water from either direct infusion by mixing in at the surface, or as a by-product of photosynthesis from aquatic plants. Photosynthesis is powered by the sun and allows plants to produce food, with oxygen being released as a by-product. Plants that photosynthesize are known as primary producers, which include algae and other flora, both terrestrial and aquatic. Algae may either occur as free living or attached varieties, which may color the water or be observed growing in clumps, respectively. The microalgae that color the water are quite often too small to be seen with the naked eye. Many of these microalgae have the ability to reproduce several times in a day and achieve densities of thousands of cells in a drop of water.

The submerged vegetation require a certain amount of oxygen to respire, but usually produce far more than they need. The sunnier it is, the more photosynthesis can occur, up to the point when the water heats up too much and starts to cook the organisms. The warmer the water is, the less dissolved oxygen it can hold. A crude example of this phenomena is the bubbling of water when set to boil on a stove. This bubbling is largely the effect of gasses being driven out of the water by the heat applied to it.

As the plants *produce* oxygen, they can do such a good job of it that the water becomes supersaturated. This means the water has more oxygen in it than it normally should hold. This extra oxygen can result in DO levels of 13 mg/l or even higher. By itself, the supersaturation usually causes no harm. If the DO levels rise, the environmental demands of the system tend to rise also. More oxygen means more productivity, which means more fish, insects, worms, algae, bacteria, etc.

On windy days, oxygen may be forced into the water due to the mixing occurring in the upper layers of the water. This is especially beneficial during periods when photosynthesis (and oxygen production) is inhibited, such as on very cloudy days or at night. The wind mixing also helps prevent stratification (layering), which occurs when the oxygen rich waters are found in a relatively thin layer close to the surface, but the underlying waters are low in oxygen. As the water circulates, not only is oxygen introduced into the system, but waste gasses such as nitrogen and carbon dioxide are brought to the surface, and are released (off-gassed) into the atmosphere. Stratification is particularly a problem in borrow-pit ponds, which tend to be very deep, with steep sides that minimize mixing.

The wind driven circulation patterns present in most large bodies of water can also help prevent the oxygen levels from becoming too high. It does this by mixing the waters and quickly stripping off the surplus oxygen and releasing it to the atmosphere. The major portion of the oxygen present in the earth's' atmosphere is produced in the oceans by this manner. Since the surplus oxygen is quickly removed from the system, the organisms present can not usually grow to the point where they use, then require, this surplus for their survival. At the point when the surplus becomes a requirement, even a minor drop in DO levels during the night, or during an extended period of overcast days, would probably lead to a fish kill.

Where does the oxygen go?

Some of the available oxygen is "tied-up," or used to build chemical or physical bonds within the sediments and compounds dissolved in the water.

Many chemical reactions use oxygen, one of the most apparent examples being the rusting of steel. The scientific term for this rusting process is called oxidation. Molecules of iron combine with oxygen from the atmosphere to form an iron oxide. Steel that has been exposed to water and air can oxidize very quickly. Steel that is submerged in water in an environment without free oxygen, such as in an anaerobic sediment, will not rust. As most chemical reactions usually take place more quickly in the water than in the air, there can be a substantial chemical oxygen demand (COD) caused by the decomposition of compounds in the water. The COD level is the amount of oxygen drawn out of the water in order to oxidize compounds that are dissolved, suspended or otherwise in contact with the water. The more compounds present, the higher the COD usually becomes. Rain water run-off often carries with it an enormous load of sediments, organic nutrients and chemicals, all of which increase the COD of the system.

Oxygen is used by vegetation, fish and other organisms, especially bacteria, as fuel for respiration at a relatively steady rate. At night, plants and other organisms *require* oxygen, and withdraw it from the system. Any extra oxygen usually bubbles to the surface as a gas, where it becomes available to people and other terrestrial organisms. As previously described, wind can also remove <u>extra</u> oxygen from the water. Wind driven wave activity helps the water to off-gas and keeps the oxygen levels down to "normal".

If oxygen is going in and coming out of the system, why is there a problem?

It is important to remember that growth and decay cycles are occurring all the time, in all ecosystems. Normally nutrients enter the system from many sources, on a constant, sporadic, or one time basis. Some of the most common sources of nutrients are compounds carried in by water currents and stormwater runoff, solution of underlying sediments, particulates blown in as dust, or the result of the death and decay of resident organism(s).

It is the nature of water systems to change and move, deepen and grow, or fill in and die. The faster the nutrients enter the system and the slower they are removed, the quicker the water body eutrifies, or ages and dies. This aging process is a function of flushing and flow within individual basins. Normally, as nutrients become available, they are quickly incorporated into sediments, other compounds or into living tissue. There may be periodic surges of nutrients into or out of a particular portion of the system, but overall the systems may be considered to be roughly balanced. The releasing of compounds (nutrients) goes on at roughly the same time and rate as the incorporation of compounds, in this balanced system. When a fish is dying, another is usually rapidly growing. When aquatic grasses die back, macroalgae may grow, and so on. If this balance tilts towards more suitable environmental conditions, there may be a bloom of algae, aquatic vegetation, fish, or other less noticeable organisms. Conversely, if the balance tilts towards a decrease in optimum conditions, there may be a partial or complete die off in the affected water body. The balance is tipped constantly by naturally occurring influences, but the frequency and degree of this tipping is often increased through the actions of human beings. Some of the most common locations for fish kills are stormwater retention ponds and golf course water traps. These areas are usually highly nutrified, may contain appreciable amounts of pesticides, and are not usually designed to harbor aquatic life.

When a period of sunny days with windy nights is followed by a series of still, cloudy days and nights, the system can get out of balance. If the weather becomes warmer, and there are local thunderstorms, the deleterious effects are usually much more dramatic and widespread. In this situation, the DO levels probably had been elevated long enough for the ecosystem to grow dependent on those elevated levels. There was no wind to strip out the extra oxygen to the atmosphere on still days, and the basin's ecosystem became "used to" the high DO levels. The sunlight produced an increase in primary producers, often in the form of an algae bloom, nutrified by the chemicals brought in with the rainwater. The oxygen produced by the vegetation was used by other organisms to feed and reproduce, as well as to fuel COD reactions. The windy nights helped keep the oxygen levels up by introducing more oxygen through surface mixing. This prevented the previous night-time oxygen demands from stressing the system, which might have otherwise restrained growth of the aquatic organisms.

Eventually, the delicate balance of environmental conditions become less than optimum, and unable to sustain this rapidly growing, dynamic system. A typical case is initiated when photosynthesis is curtailed by several days of cloudy skies, during which the primary producers can not replenish the oxygen "bank" of the water body. The vegetation continue to use oxygen while remaining in the dark cycle of photosynthesis. Algae can often live in waters with lower oxygen levels than fish require, and often rob the fish of their needed oxygen. The still surface waters are no longer mixed and aerated by the wind, and can hold less oxygen because of the increased temperature. The warmer waters increase the rate of the chemical reactions, which increases COD, which also removes available oxygen from the water. The stormwater runoff brings in many more chemicals to compete for the same oxygen stores as the fish, as well as suspended solids that block the penetration of sunlight into the water. The aquatic organisms still require their share of oxygen, and there are so many more of them now because the previous environmental conditions *were* so favorable for their reproduction. All the aquatic organisms draw on the oxygen bank, until it can no longer meet their demands. At this point, the more sensitive organisms begin to die, which may lead to a fish kill.

When is this most likely to occur?

The period just before dawn is most often when there is an oxygen demand greater than the available supply. The oxygen supply is equal to the amount stored in the water in addition to that which is easily given off from chemical reactions. The DO levels drop and fish leave the area if possible. Unfortunately, this problem often occurs in many shallow, confined water systems (e.g., stormwater retention ponds) where there is no way for the fish to escape. The fish become stressed and may be observed piping at the waters' surface. They come to the surface and gasp, trying to make use of the thin layer of water that has been in contact with the atmosphere, to coat their gills. If the dawn does not come soon enough, if the day is not sunny or windy enough, the fish will die. These circumstances may occur at different times of the year, in different environments.

Why do so many fish die?.

The organisms that require the highest DO levels begin to die first. After death, these organisms begin to decompose and contribute nutrients back into the system. Other organisms feeding on this "free lunch" of dead organisms also use up oxygen in their respiration. (Remember, organisms usually require more oxygen to digest food, or respire.) Since bacteria are the most numerous of aquatic organisms, both in biomass and genera, an increase in their levels leads to a lowering of the oxygen levels. As the DO levels drop further, more organisms are stressed and die. The bacteria start feeding on these in turn, again utilizing oxygen in respiration, and the cycle continues to spiral down. Soon, all the less tolerant organisms are dead and are fed upon by those which require even less oxygen. This lowers the DO to the level below that which the producers need to survive and they too, die. No more photosynthesis occurs and the plants, particularly the algae, become literally, a dead load on the system. Emergent vegetation is relatively unaffected by this process. The bacteria then feed on the primary producers and use up even more oxygen, which can drive the whole system into a decomposing, stinking mass. The bacteria reproduce so quickly that this entire process can take place in a matter of days. When most of the oxygen is consumed, certain strains of bacteria that take over which can live with no oxygen at all. Normally, these anaerobic bacteria are confined to the sediments. These bacteria often produce the rotten egg (hydrogen sulfide) smell noticed when the sediments of a silty pond or basin are disturbed. These bacteria complete the task of decaying the biomass back into chemicals that can be taken up again by the primary producers.

Is there always a complete die-off?

This process can be reversed at any time before the primary producers die, some sign of recovery being almost instant. When the system gets to the point where the anaerobic bacteria predominate, the kill usually affects virtually all aquatic organisms in that particular body of water. If the oxygen levels just dropped to a lower level, only certain sizes or species of organisms may be affected. DO caused fish kills do not usually occur in mature, flushing, open water systems. Usually a small, isolated pocket of water ends up going through partial or complete oxygen depletion. Due to the number of variables involved, it is common for all the fish to die in one particular pond, but an outwardly identical pond nearby appears unaffected. For some reason, the affected water body received the proverbial straw that broke the camels back. It may have been a change in one or more environmental variables which did not occur elsewhere, or had less of an effect in a different location. The normal growth and decay cycle occurs all the time in the aquatic ecosystem, and is not usually evident to the casual observer. Individual organisms are born, grow, reproduce, die, decay and then begin the cycle again. However, when the system gets out of balance, a large number of organisms may be affected at once, in numbers and locations that are noticed by citizens.

Will it get better?

When this process occurs in a closed system such as a lake, it may become eutrophic, or dead. It may cease to support the normal diversity of aquatic life that we would desire to find. Without intervention to remove or reduce the nutrient loading and re-establish conditions favorable to the growth of higher organisms such as fish, the water body may never recover. An enclosed water body may need to have the cause of the problem(s) corrected, and restocked with aquatic life. In most <u>open</u> water bodies, DO caused die-offs are considered to be only temporary conditions. It often would appear that all the fish in a particular basin were killed during low DO levels. This is rarely the case, as evidenced by examining the system again, after the "correction". Small fish are usually able to obtain sufficient oxygen from the top inch or so of water, which is usually saturated with oxygen. This, combined with lesser oxygen demands associated with smaller body size and individual species tolerance, allows some of them to survive. Once the water conditions return to normal, fish will migrate from elsewhere to take advantage of the new non-competitive environment. Organisms, or their eggs and larvae, may be carried into the area by the actions of wind and water. Plants may sprout again from buried shoots, or be carried in by water currents. Organisms that are tolerant of anaerobic conditions begin their normal activities, again. The system then starts the cycle again. Certain areas never have fish kills, and others have them several times a year.

What can be done to prevent low DO fish kills?

There are several things that can be done to prevent or reduce the effects of a dissolved oxygen related fish kill. If the low DO levels occur in a pond or a particular segment of a larger water body, immediate first aid is usually the addition of emergency oxygen. The most often used methods include air and water pumps, or mechanical water movement.

Air pumps inject pressurized air taken from the atmosphere through the pump, into a diffuser submerged in the water body. This type of aeration is the most inexpensive of the commonly available methods. The drawback to this method is the relatively limited area of influence and the slow introduction of oxygen. Quite often, this type of system is used in fish farms, stormwater retention ponds and small lakes. The required submerged piping can be designed into the system, where no boat traffic will damage the plumbing. In small ponds, this is usually the method of choice due to its low cost and unobtrusive nature. In larger water bodies, strategic placement of a few air diffusers may certainly make a difference to the immediate environment. A school of fish may be seen gathered in a ring around a diffuser, that is submerged a foot or so deep under a dock. Some people report success with the use of aquarium air pumps and airstones, available at any pet store.

Water pumps shoot the water up into the air, where it releases gasses and takes on a new load of oxygen, mostly through diffusion. This method costs more than air injection, both to implement and to operate. This type of pumping can exchange an enormous amount of gasses, but may have the drawback of altering the water temperature to the air temperature due to the intimate contact while in the spray. If properly designed, this system can be very effective and can often have a pleasing appearance as a decorative fountain. Small fountain pumps may be bought at pet stores and hardware stores. The larger fountain pumps may be found at plumbing supply or specialty stores. These systems may require permanent, professional installation.

Mechanical agitation of water is usually initiated by a motor moving some type of blade, which then moves the water. Paddlewheels and outboard boat motors are good example of these systems. These mechanisms add air from the atmosphere at the point of mechanical contact, and push a layer of aerated water across the surface. This gives this system the ability to quickly add oxygen over a large surface area, but at the highest running costs. One of the best temporary methods for a water front homeowner to add oxygen to a large basin is with a boat. Simply tie your boat tightly in place, if the water body is of a navigable size, with the motor pointing towards the widest point of the basin. This method works quite well with a boat on a trailer, also. Simply back the trailer into the water with the boat firmly fastened in place. Turn on your outboard motor, put it in forward gear at the lowest speed possible, and adjust the trim/tilt of your motor up. By tilting the engine up you accomplish three things.

1) The water mixes quite rapidly with the air. This water then moves across the surface where it picks up oxygen both from splashing and direct sheet flow diffusion. The best results are usually obtained with the water intake of the motor just submerged. Never run an outboard with the cooling water inlet exposed, even for a moment.

2) The aerated water will circulate around the basin. This will cause an increase in the DO levels some distance from the vessel, as well as dramatically increasing it in the immediate area of the boat. With the motor tilted up, the exhaust gases given up by these outboards will be more apt to rise and be released into the atmosphere, rather than adding to the problems of the water. This maximizes any beneficial effects of the emergency aeration

3) The motor will push only the top layers of water, where it can pick up the most oxygen. Most of the fish live in, or can gain access to these aerated surface waters. If the motor is pointed down, it will pick up and push stagnant water and sediments that have a high COD up into the water column. Any oxygen added by emergency aeration will only go to supply the COD and not help much in keeping the fish alive, and often will kill the fish off quicker. Many navigable lakes and basins have been dredged to greater depths than the surrounding water bodies to allow for boat traffic close to shore. These areas act as settling basins for suspended sediments and chemicals which enter with stormwater runoff. It is very important to not stir these bottom waters up when the system is already stressed. If the motor is pointing down and the wash is disturbing the sediments, this may also be a violation of State of Florida Dredge and Fill regulations. Check with local regulatory agencies prior to performing this form of aeration.

Emergency aeration should be considered temporary first aid for the aquatic system. It is extremely important to determine the cause(s) of the DO drop, and remedy it, if possible. The cycling of the oxygen levels in aquatic ecosystems is normal, natural, and usually follows some seasonal pattern. Fish kills have been recorded in Florida since the first fishermen, hunters, and pioneers settled in this area. Disturbingly, the frequency and severity of fish kills appears to be increasing as time goes on. This is apparently due largely to the alteration of aquatic ecosystems and adjacent development. The increased influx of nutrient and sediment laden stormwater from drainage basin development contribute greatly to the problem.

Most of the major point source contributors (waste water treatment plants, refineries, etc.) to the nutrient loading of our surface waters have been stopped, or are scheduled to stop in the near future (at least in Brevard County, FL). These were the most obvious contributors, but the contributions from nonpoint sources still continue, and are more difficult to identify. These sources include stormwater runoff and groundwater, both of which may carry leachate from septic tanks, fertilizers, pathogenic organisms and toxic materials. In Florida, it is estimated that the first inch of rainfall carries over 90% of all pollutants into our lakes, streams and rivers.

The most effective means of reducing fish kills is to educate the public. This can go a long way to prevent those nutrient and chemical constituents that result in lowering of the oxygen levels from entering surface waters. There are many commonsense things that each resident can do or not do in their daily activities that can also result in a significant reduction of pollutants. Most of these activities do not cost anything, do not diminish the quality of life in any way, and only require slight modifications of existing habits. For instance, one of the easiest "fixes" is washing your automobile on the grass, instead of on a paved surface. This way the rinse water helps water the grass, while the grass and soil bind up and detoxify any chemicals before they reach surface waters. For other small fixes that add up to the solution to a big problem, contact your local surface water improvement and management agencies. They can provide information, and assist you to find out what you can do to help, as citizens, homeowners and consumers.

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ABSTRACTS - 1995

Clear Lake Restoration

L. A. Ager (Fla. Game & Fresh Water Fish Comm., 3900 Drane Field Rd., Lakeland, FL 33811; 813-647-3213)

The Florida Game and Fresh Water Fish Commission (Commission) proposed a cooperative aquatic habitat and fishery restoration plan for Clear Lake to the City of Orlando and Orange County in 1991. Prerequisite to re-establishing an aquatic plant community in Clear Lake was removal of most of the existing grass carp population. The second phase in re-establishing native aquatic plant communities required lowering the lake level to facilitate transplanting selected species of native vegetation and encourage reinvasion of other native species. Additional habitat was provided with the placement of three brush fish attractors. Biomanipulation was attempted to shift trophic levels of the biological community in Clear Lake.

Subsequent to a bioassay, rotenone was applied to Clear Lake. Manpower and equipment needed to complete this selective renovation were provided by the City of Orlando, Orange County, and the Commission.

Cooperative revegetation efforts conducted in 1993, 1994, and 1995 by Commission staff, City of Orlando, and Orange County personnel have yielded good results within fenced enclosures.

In spite of water quality problems, annual data collected by Orange County personnel show Clear Lake to be the most improved (Trophic State Index) in Orange County of the 100 or so lakes monitored.

Stormwater Public Education and Awareness Campaign - The Hillsborough County Experience

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In 1990, the Stormwater Management Section at Hillsborough County was tasked with the responsibility of initiating the National Pollutant Discharge Elimination System (NPDES) program to insure compliance with permit conditions.

Part of the NPDES conditions require the initiation of a concerted effort to educate the public about stormwater pollution and the role the public can play in conservation and protection. These conditions, coupled with those of the County's Comprehensive Plan and the conditions of some of our receiving water bodies, resulted in the launching of our "Stormwater Public Education and Awareness Campaign (SPEAC)".

For strategic purposes, stormwater pollution sources were divided in two general categories: Residential and Commercial Sources.

Stormwater pollution abatement from residential sources involves approaching citizens, usually on weekends, to demonstrate what they can do "in their own backyards", to protect our receiving water bodies. This is the thrust of our "Adopt-A-Pond" program our "Stormdrain Stenciling" program, and the "Stormwater Hotline".

Stormwater pollution from businesses and industry involves education about Best Management Practices, Pollution Prevention Plans, and other marketing and "bottom line" concerns. This is the thrust of our "Operation Bayworks: *Businesses for a Cleaner Future*"

Regulatory Aspects Of Urban Pond Management

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The management of ponds in urban environments requires knowledge of not only the biological aspects of pond ecology but also the regulatory aspects of access, ownership, monitoring and maintenance activities. Most of the ponds constructed in Florida urban environments since 1984 are part of the stormwater management system. Stormwater management ponds provide treatment of stormwater quality and attenuation of stormwater quantity. The design and permitting of these facilities requires access and maintenance easements which become a part of the subdivision plat, a legal document filed in the County Courthouse. The homeowners association is typically charged with managing these common areas of a development which include natural preservation areas, wetland mitigation areas and drainage structures, inlets and pipes. Permitting requirements by the various governmental agencies may place additional requirements for maintenance and monitoring of these areas. The focus of this paper is to identify these issues for the homeowner who is typically unaware of his responsibilities when he purchases a house in a development that has a homeowners association with the associated fees, permits and maintenance responsibilities.

An overview of environmental restoration and management in the St. Johns River Water Management District

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The St. Johns River Water Management District (SJRWMD) is one of five regional government agencies with responsibilities over water supply, flood protection, water quality management, and natural systems management in Florida. The SJRWMD occupies the northeastern and east central portions of Florida covering over 12,400 square miles and all or parts of 19 counties. It also contains five major river basin, 56 springs, about 3.3 millions people and about half of the lakes in the state of Florida (over 3,500). The District is pursuing environmental managment and restoration programs in many areas and this presentation will be an overview of these programs in lake, river, wetland and estuarine restoration. Highlighted will be 1) the Indian River Lagoon SWIM Program; 2) the St. Johns River Basin Programs; and 3) the Ocklawaha Basin Programs.

Sediment pollutant concentrations and trophic state changes to a natural wetland stormwater treatment system

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Researchers have demonstrated that stormwater from agriculture, flrestry and urban runoff was the primary source of pollutant loading to Florida's receiving waters (Livingston, 1989). A recent urban runoff study measured pollutant loading to a natural wetland stormwater treatment system and documented the accumulation of pollutants in bottom sediments. This study provided insight to urban runoff nutrient loading levels as well as pollutant sedimentation. Sediments have been identified as a major pathway for water column pollutant removal in aquatic systems. Sediment samples were collected for chemical analysis (various metals, PCBs, pesticides and organics as well as total phosphorus and total nitrogen) at thirteen stations in the wetland

as well as two stations in each pretreatment basin to document pollutant accumulation. Samples were collected at two depths: 1) the top inch of the sediment surface was sampled to document the level of recently deposited pollutants and 2) one inch of soil four inches below the sediment surface was sampled to document background levels. Although trophic states classifications are primarily used to categorize the nutrient status of lakes, trophic state terminology originated from peat bog classifications (Weber, 1907). Levels of total phosphorus, total nitrogen and chlorophyll a were used to demonstrate the nutrient enrichment of a historically nutrient poor wetland.

The Environmental Confederation of Southwest Florida; a partnership for water resource advocacy

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The Environmental Confederation of Southwest Florida (ECOSWF) was organized in 1969 as a five county coalition to protect the natural resources of Southwest Florida. ECOSWF has a diverse membership of more than 30 organizations including civic associations, land trusts and Sierra and Audubon Chapters. ECOSWF provides a formidable force for resource protection by networking through its member organizations. ECOSWF and the Florida Lake Management Society share several objectives toward water resource protection. Many of the lake problems that lake managers have to contend with originate with degradation of the watershed. ECOSWF has pursued several watershed related issues and has been successful in having five waterbodies in the region designated as aquatic preserves and several creeks and rivers designated Outstanding Florida Waters. These water resource classifications dictate the type and degree of certain developments in the watershed that provides indirect benefits to other waterbodies in the same watershed.

Poor management of groundwater resources has led to the extreme lowering of some lakes in the region and ECOSWF is in the process of challenging a Southwest Florida Water Management District rule which relates to this problem. Other concerns of mutual interest between ECOSWF and regional lake managers will be discussed.

Restoration of Lake Maggiore

Michael J. Connors (City of St. Petersburg Engineering Department, P. O. Box 2842, St. Petersburg, FL 33731-2842; 813- 893-7294)

Lake Maggiore is a 385 acre, triangular shaped lake located in southern St. Petersburg. An environmental assessment of the lake determined it was in a hypertrophic state with a trophic state index (TSI) of 81, based on total phosphorus as the governing nutrient. The City established a TSI goal of 60, and estimated a reduction in phosphorous loading of 65% was necessary to achieve this goal. Attainment of the goal involved the analysis of various alternatives. The selected alternative includes alum treatment of surface runoff and base flow into the lake, removal of lake bottom sediments, aquatic plant control, littoral zone reconstruction, and replacement of the outfall structure.

The City has commenced with the implementation of the project due to a joint funding agreement between the City and Southwest Florida Water Management District, that has authorized up to ten million dollars for the lake restoration effort. The implementation phase, being conducted by the City of St. Petersburg, will be discussed from an engineering and administrative viewpoint.

Use of Vegetation for Lake Water Quality Management: Opportunities and Limitations

Thomas A. DeBusk and Michael A. Langston (Azurea, Inc., P. O. Box 561178, Rockledge, FL, 32956; 407-299-7835)

Emergent macrophytes commonly are planted in lake littoral zones to improve aesthetic conditions, fauna habitat, and water quality. The ability of aquatic vegetation to remove wastewater constituents such as nutrients and metals, either by direct uptake, or through indirect influence (shading, pH control) on the aquatic environment is well documented. It is by these mechanisms that littoral planting of emergent macrophytes may benefit lake water quality.

For many lakes, the littoral area available for planting is small relative to the total lake area. A second constraint is that most lakes exhibit low water column nutrient concentrations relative to those under which maximum macrophyte nutrient uptake occurs. In a microcosm study, we found that Typha latifolia, Pontederia cordata and Eichhornia crassipes reduced lakewater total phosphorus (P) concentrations from 0.19 mg/L to 0.06 mg/L, 0.09 mg/L and 0.08

mg/L, respectively. Maximum short-term mass removal rates observed in this concentration range, however, were low (26 mgp/m^2-day). The slow rate at which macrophytes sequester P for permanent removal from water, coupled with the limited area that can be planted, suggests vegetation planting has limited utility for improving water quality in most lakes.

Recent studies suggest that managed periphyton systems can be useful for removing P from lake waters. High P removal rates (140 mgP/m^2-day) were obtained in south Florida using a bench-scale Periphyton Filter that received dilute agricultural drainage water (o.1 - 0.2 mgP/L). We present a calculated analysis for Lake Lawne, Orange Co., FL, on the ability of emergent littoral plantings, a water hyacinth system, and a periphyton filter to improve water quality.

Lakes Education / Action Drive: A model citizens' lake interest group

Bill Fenton (Lakes Education/Action Drive, Inc., 41 Lake Morton Drive, Lakeland, FL 33801; 813-688-2730)

In 1985, the city of Lakeland, Florida, issued a Request for Proposal for a public awareness program to encourage the entire community's involvement in efforts to save the area's fresh water lakes from further deterioration. Stormwater runoff was responsible for most of the pollution occurring in area lakes. Bill Fenton Associates, a Lakeland public relations and association management firm, was awarded the contract and organized a citizens group called the Lakes Education/Action Drive (LE/AD) to take the "lead" in saving the lakes. Within two years LE/AD's activities in environmental education programs spread throughout Polk County. LE/AD initiated the first Florida Lake Management Conference in 1986 and held it annually through 1992. The annual conference has since been taken over by the Florida Lake Management Society. LE/AD sponsors at least one Lakes Education Youth Day each year, some years two. LE/AD brings its message to the user by installing environmental education lakeside exhibits on the shores of major public lakes throughout Polk County. LE/AD sponsors each quarter of the year lakes related public educational forums focusing on current issues and also publishes LakeWatch, a quarterly newsletter. LE/AD's effectiveness can be demonstrated by the hiring of lakes managers by the cities of Lakeland and Winter Haven Since its inception. LE/AD also helped in the victory of a Polk County bond issue to buy and preserve environmentally sensitive land.

Development of revised regulation schedules for the Ocklawaha Chain-of-Lakes.

Rolland S. Fulton III (St. Johns River Water Management District, P.O. Box 1429, Palatka, FL 32178-1429; 904-329-4361)
Apurba Borah (Same address; 904-329-4326)
Hector Herrera (Same address; 904-329-4327)

Recommendations for new regulation schedules for the Ocklawaha Chain-of-Lakes to improve environmental benefits were developed through a three step process: (1) Environmental goals were developed for lake fluctuation. (2) A hydrologic model of the basin was used to evaluate the feasibility of the fluctuation goals and develop regulation schedules to meet the goals. (3) An assessment of the economic impacts of the recommended schedules was conducted. General environmental goals included enhancement and protection of wetlands habitat, enhancement of fisheries, protection of water quality, and restoration of the natural fluctuations in water levels and flows, to the extent feasible given present development in the basin. The assessment of potential economic impacts of the proposed fluctuation schedules examined five general areas, including flood damages, impacts to septic systems, impacts to boat access, impacts to seawalls, and impacts to agriculture. In response to public concerns, the recommended schedules are currently being revised to reduce the economic impacts while still retaining some of the environmental benefits.

Impacts of groundwater seepage on water quality and proposed restoration efforts for Lake Maggiore

Harvey H. Harper, Ph.D., P.E. (Environmental Research & Design, Inc., 3419 Trentwood Blvd., Suite 102, Orlando, Florida 32812; 407-855-9465)

Lake Maggiore is a 156 hectare (385 acre) hypereutrophic lake located in the City of St. Petersburg. The lake receives large quantities of untreated stormwater runoff from a 927 hectare (2290 acre) watershed area as well as continuous inputs of baseflow from adjacent golf course areas irrigated with reclaimed wastewater. Substantial quantities of nutrient-rich sediments have accumulated in Lake Maggiore with sediment depths ranging from approximately 0.3-2.4m. The salinity in Lake Maggiore fluctuates widely from 0-4.0 ppt, even though no surface inputs of saline water enter the lake. Chemical treatment of stormwater and baseflow, along with

Lake Kissimmee Restoration Project

Bob Hujik (Florida Game and Fresh Water Fish Commission, 600 N. Thacker Ave. Suite A-1, Kissimmee, FL 34741; 407-846-5300)

The Florida Game and Fresh Water Fish Commission (FGFWFC) in cooperation with the South Florida Water Management District (SFWMD) is planning a major restoration project for Lake Kissimmee. An extreme drawdown beginning in November 1995 will lower lake levels from elevation 50.0 ft msl to elevation 45 ft msl by February 1996; two weirs and a by-pass structure will be used to maintain hgher water levels on Lake Tiger (50.0 ft msl) and lakes Cypress and Hatchineha (40.5 ft msl). Approximately 16,000 acres in Lake Kissimmee will be dewatered and organic bottom sediments should compact and consolidate during the scheduled 90-day drying period. Coverage of beneficial aquatic vegetation such as maidencane and knotgrass should increase due to germination of seed reservoirs exposed during the extreme drawdown. Restoration activities such as muck removal, burning and reduction of tussocks will be implemented to enhance aquatic habitat during the 90-day drying period. The commission plans to allocate their FY 1995-96 statewide restoration budget of approximately $1 million to this project. In addition, the District is providing in-kind services for engineering, hydrology and aquatic plant management. An application has been submitted to the Florida Department of Environmental Protection for $600,000 of the Pollution Recovery Trust Funds; this money would be used exclusively for in-lake restoration activities. Hydrilla control for Lake Kissimmee will be implemented by the District in spring 1995 and 1996 to provide environmental, navigational and flood control benefits. Two successive treatments should provide relief for recreational users of the lake.

Application of the Linked Watershed/Waterbody Model to the Winter Haven Chain of Lakes

Rick Karkowski, P. E. (Dames & Moore, Inc., One North Dale Mabry Highway, Suite 700, Tampa, FL 33609; 813-875-1115)

Dames & Moore, Inc. has completed the development of the Linked Watershed/Waterbody Model (LWWM) for the Southwest Florida Water Management District. The LWWM links a Geographical Information System (GIS) in the Storm Water Management Model (SWMM) and the Water Quality Analysis Simulation Program (WASP) under a single user friendly platform.

A test application of the LWWM was performed on a series of 21 inter-connected lakes collectively known as the Winter Haven Chain of Lakes (WHCOL). The LWWM uses GIS to describe the land use and soils conditions within the watershed. The GIS data is linked to by the LWWM to SWMM, which is used to simulate the runoff and nonpoint source pollutant loadings from the WHCOL's watershed. SWMM water quantity data (runoff volumes) are linked by the LWWM to a waterbody hydrodynamic model (DYNHYD), and water quality data (pollutant loadings) are linked to the waterbody water quality model (WASP). DYNHYD was used to simulate waterbody hydrodynamics and WASP was used to simulate lake eutrophication.

Rainbow River: Setting pollutant load reduction goals for a first magnitude spring system

Marty Kelly (Southwest Florida Water Management District, 7601 U. S. Highway 301 North, Tampa, Florida 33637; 813-985-7481)

Many of the largest spring systems in the world are located in the karstic areas of southwest Florida. Rainbow River is a first magnitude spring run (i.e. has an average discharge of at least one hundred cubic feet per second) and discharges on average almost 500 million gallons of water per day. The discharge from this river and other large spring runs near the coast empty into the Gulf of Mexico. Diagnostic studies on Rainbow River and other springs have revealed significant increases in nitrate loading; nitrate concentrations in Rainbow Springs have increased by a factor of five (from less than 0.2 mg/l nitrate-nitrogen to 1.0 mg/l nitrate-nitrogen) in less than 20 years. This presentation will consider the sources of increased loading, the ecological impact of this increased loading on the spring run, and potential ecological impacts on the near shore area of the Gulf. The Rainbow River system is interesting in that the potential groundwater contributing area is much greater than the surface watershed (450 square miles versus 7.5 square miles), the nitrate loading currently being discharged is in part attributable to historic land use practices, and the once pristine river has only recently begun to show evidence of ecological impacts associated with blue-green algal mats.

Florida Yards & Neighborhoods: Working with homeowners to reduce stormwater runoff into waterways.

Billie Lofland (Florida Yards & Neighborhoods/Hillsborough County Cooperative Extension Service, 5339 S. CR 579, Seffner, FL 33584; 813-744-5519)

Research indicates that a significant nitrogen loading source for Tampa Bay is stormwater runoff from residential areas. It's thought that much of this nitrogen comes from yards and can be reduced by homeowners changing their landscape practices.

Survey research suggests that many homeowners first turn to their neighbors for advice and information about taking care of their yards.

The Florida Yards and Neighborhoods programs of Hillsborough, Manatee, Pasco and Pinellas counties are funded by the Tampa Bay National Estuary Program and administered by the Cooperative Extension Service. The program works with community associations to create a neighbor-to-neighbor educational program that helps people understand that the environmentally-friendly way to take care of their yards is also the best way to have an attractive, healthy yard.

Presentations, newsletters, the Florida YardStick poster, the Florida Yards and Neighborhoods Handbooks and Florida Yard certification are some of the tools used. FY & N is expanding to also work with individuals who do not live in participating neighborhoods but who would like to have their yards certified.

An overview of legislatively mandated restoration efforts on Lake Jessup, Seminole County.

Erich R. Marzolf (St. Johns River Water Management District, PO Box 1429, Palatka, FL 32178, 904-329-4831)

The Lake Jesup Act of 1994 directed the St. Johns River Water Management District (District) to initiate restoration efforts for Lake Jesup. Lake Jesup is a large (~11,000 acre), shallow lake that lies near the center of Seminole County and has been one of the most eutrophic bodies of water in Florida, primarily due to the input of secondary wastewater effluent for over 20 years. Currently, the lake is characterized by frequent algal blooms and fish kills. The Lake Jesup Act also mandated the creation of a local citizens advisory council (Friends). The Friends, in concert with the District and other local and state agencies have worked to identify projects and to develop a restoration plan for Lake

Jesup. The beneficial effects of restoring Lake Jesup will include its enhanced value to the rapidly growing urban Orlando area. This talk will discuss historical water quality problems and the current restoration goals and efforts. Beginning this year a variety of efforts will be initiated, including; a monthly water quality monitoring program, a volunteer based stormwater monitoring program, survey of lake sediment distribution and nutrient content, wetland acquisition and restoration and the development of a water circulation model for the lake.

Greenwood urban wetland treatment effectiveness

Kevin McCann and Lee Olson (City of Orlando, Stormwater Utility Bureau, 400 S. Orange Ave., Orlando, Florida 32801; 407-246-2370)

The Greenwood Urban Wetland treats stormwater runoff from a 522 acre sub-basin in downtown Orlando, Florida. Thirteen acres of ponds with a sediment control basin, pond aeration and an irrigation system reusing stormwater were incorporated into the design for pollutant removal efficiencies.

The City conducted a study on the Greenwood Urban Wetland to determine the efficiency of the sediment basin and Wetland system in removing pollutants associated with stormwater runoff. Results of the study indicated that the sediment basin removed total phosphorus and ortho phosphate at a removal efficiency of 11.4% and 7.4% respectively. The sediment basin removed total nitrogen and nitrate at removal efficiencies of 3.7% and 16.0% but exported ammonia and nitrite and removals of -100.5% and -76.2% respectively. Removal efficiencies for cadmium, copper, lead and zinc were 25.8%, 18.6%, 9.6% and -5.9% respectively. Pollutant removal efficiency of the wetland system was reduced due to high groundwater inflows. Total phosphorus and ortho phosphate had removal efficiencies of 61.5% and 76.7% respectively. The wetland system performed poorly at removing nitrogen. Data indicated removal efficiencies for total nitrogen, ammonia, nitrate and nitrite at -11.0%, 10.2%, -13.2% and 8.1% respectively. Cadmium, copper, lead and zinc were removed in the wetland at removal efficiencies of 0.0%, 58.9%, 59.7% and 68.9% respectively.

Selecting TSI-based water quality and nutrient loading targets for Lake Thonotosassa

Gerold Morrison (Surface Water Improvement and Management [SWIM] Department, Southwest Florida Water Management District, 7601 Highway 301 North, Tampa, FL 33637; 813-985-7481)

Lake Thonotosassa, a hypereutrophic lake that is ranked number eight on SWFWMD's SWIM priority list, is located in the Hillsborough River watershed in eastern Hillsborough County. Water quality in the lake has been degraded over a period of several decades by a combination of domestic effluent, agricultural and urban stormwater runoff, and nutrient-enriched industrial wastewater. Paleolimnological evidence indicates that the lake was highly productive (mesotrophic to eutrophic) prior to modern development, apparently as a result of elevated phosphorus inputs caused by local geological and edaphic factors (Whitmore and Brenner 1995). An average TSI value of 60, indicative of eutrophic conditions, appears to correspond well with the lake's pre-development trophic state (Whitmore and Brenner 1995) and to represent a potential water quality target for future restoration efforts. An empirical model (EUTROMOD) has been used to estimate annual phosphorus and nitrogen loadings consistent with this target. The model suggests that average annual inputs of TP and TN should be reduced below 3,400 kg/yr and 65,600 kg/yr, respectively, on a long-term basis to reach TSI_{avg}=60 in the lake water column.

Hydrilla control and its effect on lake limnology and benthic macroinvertebrates

John A. Osborne, PhD, (Department of Biology, University of Central Florida, P. O. Box 25000, Orlando, Florida 32816; 407-823-2980)

Little Lake Barton, Orlando, Florida was monitored between January - December, 1977 and again between January - December, 1983 to determine the effect of hydrilla control by grass carp. Physical (temperature) light, water color, turbidity), chemical (dissolved gases and solids) and biological (benthic macroinvertebrates, algal biomass) parameters were measured at six stations on a monthly schedule per year to establish before-after effects. During 1977, hydrilla bbiomass approached 2.5 kg/m². Several stockings and subsequent renovations of grass carp were tried in the lake between 1977 and 1980. After stocking 20 fish/mt hydrilla biomass in March, 1981; hydrilla control was achieved by August of that year. Hydrilla had been eliminated from Little Lake Barton 16 months prior to the 1983 sampling year. The before-after effects included an increase in orthophosphate concentration, turbidity, chlorophyll and hypolimnetic dissolved oxygen; and a decrease in nitrite and a nitrate nitrogen concentration, specific conductivity and total alkalinity. Water temperature and water color remained essentially unchanged. The benthic macroinvertebrate community experienced a reduction in species diversity (Shannon Index), number of species and numbers of individuals.

Characterization of Upland and Wetland Habitats in the Lake Tarpon Drainage Basin

Douglas E. Robison, M.S. (Coastal Environmental, Inc., 9721 Executive Center Drive North, Suite 104, St. Petersburg, FL 33702; 813-577-6161).

An assessment of the distribution and quality of upland and wetland habitats was performed as an element in the development of a comprehensive management plan for the Lake Tarpon Drainage Basin. A multi-phased approach was utilized including aerial photointerpretation, groundtruthing, digital processing, and GIS spatial analysis. In addition, a customized rapid bioassessment technique was developed and implemented to characterize the quality of each mapped habitat unit. This technique calculates the relative level of disturbance using a composite score which considers physical, hydrologic, ecologic, and chemical perturbations. The ranking scale ranges from 0 (pristine) to 20 (highly disturbed). A total of 522 habitat units (e.g. polygons) were identified within the study area encompassing 43 different FLUCCS codes, and code modifiers. The five most extensive habitat types within the study area, listed in order of decreasing area, include: Cypress Swamp (534.63 acres); Stream and Lake Swamp (337.60 acres); Rangeland (239.27 acres); Slash Pine/Bay Swamp (235.61 acres); and Sand Pine (231.52 acres). The overall disturbance values calculated for each of the identified 522 habitat polygons ranged between 4 and 20. No polygons were determined to be less disturbed than the value of 4 primarily due to the fact that every habitat unit has been impacted by encroaching development to some extent. This information will be utilized to develop recommendations for habitat improvement and restoration, and the reestablishment of wildlife dispersal corridors.

procedure was developed for prioritizing sub-basins for non-point source pollutant load reduction. A GIS-based statistical model was used to calculate the annual TN and TP loads generated from each sub-basin, and all contiguous hydrologically connected sub-basins, within the study area. A total of 110 possible sub-basin combinations were evaluated. Because Lake Tarpon is a nutrient balanced lake, a composite TN/TP ranking was developed using a Euclidean Distance analysis which plots TN load against TP load. This analysis resulted in the ranking of all possible sub-basin combinations with respect to a composite TN/TP load. The 10 highest ranked sub-basin combinations were then screened using several qualitative attributes, including: existing land use; future land use; adjacency of publicly owned-lands; potential for BMP implementation; and potential for habitat restoration. Following the qualitative screening process, the composite TN/TP ranks of the selected sub-basin combinations were then plotted against annual runoff flow volume. Given an equal pollutant load from two sub-basins, it is usually more cost-effective to treat runoff from the sub-basin with the lesser hydrologic flow. By plotting the TP/TN rank against flow, the optimal sub-basin combinations (those which maximize pollutant load reduction and minimize BMP cost) were determined. The methods and results of this procedure are presented and discussed.

Urban lake management issues

Curtis E. Watkins (City of Tallahassee, Stormwater Division, 124 W. Jefferson St., Tallahassee, FL 32301; 904-891-8882)

Among all the lakes located in Florida those lakes located in urban areas are the most prominent in the minds of Floridians. Approximately 11 million Florida residents, or more than three-fourths of our population, live in or adjacent an urban area. Because the majority of our residents live in urban areas, public concern and ultimately public attitude about lakes and lake management is shaped by our urban lakes. Public concern about urban lakes varies from one person to the next but typically includes: aesthetics, water quality, pollution, aquatic vegetation, fishing, water skiing, and urban wildlife. The concerns expressed by the public seem to evolve from several key issues that include impacts caused by urban growth, demands for multiple use, and the importance of lake protection and conservation. The purpose of this presentation will be to discuss lake and watershed management issues that are relevant to urban lakes. Lake and watershed management practices that are being implemented by lake management professionals will also be discussed

Assessment of historical changes in water quality and sedimentation rates in Lake Thonotosassa

Thomas J. Whitmore and Mark Brenner (Department of Fisheries and Aquatic Sciences, University of Florida, 7922 NW 71st Street, Gainesville, Florida 32653)

We used paleolimnological methods to evaluate recent human influences on water quality in Lake Thonotosassa for the Southwest Florida Water Management District's Surface Water Improvement and Management program.

We retrieved 124-cm and 128-cm-long sediment cores using a piston corer. Gravimetric and geochemical evidence suggest that an abrupt change in limnological conditions occurred above the 80-cm level in both cores. ^{226}Ra activity increases above 80 cm, indicating accelerated erosion of radium-bearing geologic deposits in the watershed.

Diatom assemblages at the core bottoms are dominated by mesotrophic-eutrophic taxa that are progressively replaced by diatoms indicative of eutrophic to hypereutrophic conditions. Historic limnetic total P, TSIAVG, and limnetic chlorophyll *a* inferences indicate that productivity has increased from eutrophic to hypereutrophic conditions during this century. Paleolimnological evidence suggests that it is not feasible to reduce nutrient concentrations in Lake Thonotosassa below eutrophic conditions.

Using geophysics to characterize geologic features under lakes

Michael J. Wightman (Subsurface Detection Investigations, Inc., 7381 114th Avenue North - Largo, FL 34643; 813-544-5020)

Innovative applications of surficial geophysical methods over water can provide a detailed perspective of the subsurface geology underlying lakes. Case studies are provided using three geophysical techniques. The selection of the appropriate geophysical technique is controlled by: 1) The desired depth of investigation and 2) Character of lake bottom sediments. Ground penetrating radar was used to identify karst features 20 to 40 ft below the bottom of nine lakes in south Pasco County, Florida.

Seismic reflection was used to identify karst features to a depth of 200 to 400 ft below lake bottoms in north-central Florida. Time domain electro-magnetics (TDEM) was used across several frozen lakes in Wisconsin to determine the thickness of the near-bottom glacio-lacustrine clay layer. Geophysically-derived results can be used either independently or in conjunction with other studies to provide cost-effective answers to such questions as lake inter- connectedness to underlying aquifers, helping to predict the effectiveness of lake augmentation programs, and assessment of the impacts of nearby well field pumping.