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COMPREHENSIVE RECONNAISSANCE PROFILE OF THE PAYNES PRAIRIE BASIN, FLORIDA

by

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[Included under separate cover: A Categorized Bibliography of the Paynes Prairie Basin]

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ABSTRACT

Data and information from more than 100 published and unpublished references were used to develop a reconnaissance profile for the Payne's Prairie Basin. This area of more than 18,000 acres in southern Alachua County, Florida, includes the Payne's Prairie State Preserve, Lakes Wauberg and Bivens Arm, and their respective contributing streams. The objective was to integrate and summarize all relevant scientific information concerning this basin in a single reference in order to facilitate decision-making processes in basin management. A second objective was to identify water management research and data collection needs that have a high probability of leading to improved basin management.

Most of the basin is part of the Payne's Prairie State Preserve, an area of interest because of its complex pattern of varied and rapidly changing plant communities, abundant wildlife, and unique geological features. Lakes Wauberg and Bivens Arm are naturally very productive systems. Wauberg has a long history of blue-green algal dominance throughout the year, while the aquatic flora in Bivens Arm has changed from a community of native aquatic macrophytes to one dominated by alternating periodic accumulations of water hyacinths and dense algal blooms. With the expansion of the city of Gainesville, Bivens Arm and the Preserve are both subject to increasing nutrient and sediment loads from urban sources. This is particularly critical in the Sweetwater Branch watershed, where effluent discharges from the city wastewater treatment plant have contributed to large changes in the biological communities of the northern part of the prairie and may threaten the quality of surficial groundwater in the vicinity.

The most important water management issue in the basin focuses on the friction between the main management goal of restoring and maintaining communities in the prairie as representative samples of Florida's natural systems as they existed prior to the arrival of Europeans (ca. 1500 A.D.) and the greatly altered, present-day conditions. Use of resource management techniques such as fluctuating water and fire regimes (both historically dominant forces in maintaining the prairie in a state of pulse stability) is now complicated due to drainage and channelization structures associated with past agricultural activities, the presence of private landholdings in the basin, and the intrusion of two major highways. A better understanding of the impact, control, and prediction of the effects of pulsing factors, such as fire and water, is needed if the original prairie is to persist in a rapidly urbanizing environment.

INTRODUCTION

Payne's Prairie Basin, located south of Gainesville (Alachua County, Florida), is a diverse and fluctuating assemblage of wet prairie, marsh, and open water communities. Upland areas with hardwood hammocks, pine flatwoods, swamps, old fields, and ponds surround the basin. This variety of habitat and the protection from cultural disturbance accounts for an abundant and diverse flora and fauna (FDNR, 1981; Easterday, 1982; Patton and Judd, 1986). The ecological significance of the more than 18,000 acres in the basin is highlighted by the occurrence of reproducing populations of many threatened and endangered species (FDNR, 1986) of which the bald eagle, the Florida sandhill crane, and the eastern indigo snake are perhaps best known by the public. The unique and complex geology and hydrology in this area of karst topography (Clark et al., 1964; Jensen, 1985) and the importance of the region in representing the cultural past of people's activities in north-central Florida during recorded history (Mullins, 1977) add considerably to the value of the basin and require special management considerations.

The large majority of the lands in the Payne's Prairie Basin lie within the Payne's Prairie State Preserve administered by the Florida Department of Natural Resources (FDNR). Primary management objectives of the Department are to restore and maintain natural and cultural resources of the preserve as representative samples of Florida's original natural systems. This is defined as the conditions which existed prior to the ecological disruptions caused by the arrival of Europeans, circa 1500 (FDNR, 1986).

Other principal areas in the basin are the lakes Bivens Arm and Wauberg. Management of Bivens Arm is largely restricted to periodic aquatic plant control, whereas part of Lake Wauberg is managed as a recreational facility for the University of Florida. Throughout the basin severe conflicts with primary management objectives exist (FDNR, 1986); a consequence of intense human activity, land use practices during the past century, and rapid population growth in north-central Florida.

Considerable uncertainty exists regarding how to optimally develop and manage basins such as this, especially for multiple uses, because relevant scientific information is widely scattered, and not integrated on a systems level. It is therefore difficult for resource managers to comprehensively review.

The primary objective of this report is to develop a single reference of available information for the purpose of identifying specific problems and specific research needs, so that future management of this basin can be more effective. A secondary objective is to identify additional data collection needs that have a high probability of leading to improved basin management.

The report consists of four major sections. First, a general basin description is given, outlining its history, geology, physiography, hydrology, vegetation, and land use. Then, available water quality records for lakes and streams in the basin are summarized and interpreted. Attention is given to temporal trends in water quality. In the third section, the structure and composition of biological communities is described. Topics of special interest, such as wastewater discharges into the prairie, cultural resources of the area, and current basin management are documented in the fourth section. Finally, findings are summarized and research needs are identified which may considerably enhance understanding of this basin and contribute to effective management. A categorized bibliography is added as a separate volume. The main purpose of this bibliography is to create a computerized system for references which can be searched, updated, and output in various forms. As such it complements an existing automated bibliography of lakes in this area (Gottgens and Montague, 1987a).

A similar report was developed for Orange, Lochloosa, and Newnans Lakes (Gottgens and Montague, 1987b). Water flow between this lake basin and the Payne's Prairie Basin is separated by a water control structure and an earthen dam along the eastern boundary of the prairie. This reconnaissance profile complements that earlier report and provides necessary information for more effective management of the combined basins.

BASIN DESCRIPTION

History of Payne's Prairie

The basin's present state, including the structure and composition of its biological communities, hydrology, topography, and water quality, is largely the result of two dominant factors, which are at times interrelated: The impact of human activities on the land use in the basin and the basin's fluctuating water regime. A brief account of the basin's history in terms of these factors is essential in understanding its management needs.

Payne's Prairie has been a favored area for human habitation for many centuries. Indian artifacts have been dated to 10,000 B.C. and archeological evidence attests to occupations ranging from very temporary campsites to long-term villages (Bullen, 1958; Mullins, 1977). Historical documentation (Williams, 1837; Camp, 1932) described the area as extremely productive and generally used for cattle grazing and other agricultural activities since the early 1500s. In the 1600s, large Spanish cattle ranches were operated here (FDNR, 1986), later replaced by cattle managed by local Seminole Indian tribes (Quigg, 1958). The prairie is thought to have been named after King Payne, a Seminole chief (Watkins, 1976).

During the time of English occupation (1763-1783), William Bartram made the first written account of the area (Van Doren, 1928). He described the prairie, which he called the "Alatchua Savanna", as a "level, green plain, above 15 miles over, fifty miles in circumference and scarcely a tree or bush of any kind to be seen on it." He made mention of "innumerable droves of cattle" and "exhuberantly fertile soil". Much of the vegetation in the basin was heavily impacted by cattle grazing, with maidencane (Panicum hemitomon) as major forage plant (Camp, 1932). The use of fire by Indians in habitat management for agriculture and hunting expanded the area of grassland (Dix, 1964). Water levels were apparently similar to that of the present: Bartram traveled along the rim and the outer edge of the basin, but also had to cross marshy areas including the delta of Sweetwater Branch. His accounts of "exhalations" of gases from the "savanna" indicate fluctuating water levels, resulting in build-up and decomposition of peat and organic matter (White, 1974). Similarly, his description of "beaches" along the rim point to substantial water level fluctuations. Alachua Sink had clear water and served as "a general receptacle of the water, draining from every part of the vast savanna by lateral conduits", and surrounded by tall, dense trees and numerous other sinks (Van Doren, 1928).

A period of increasing settlement activity followed, characterized by increased friction between Indian tribes and white settlers, which resulted in the construction of protective forts around the prairie, and further development of agricultural activities in the basin (Opdyke, 1974). Around 1870, the water level in the basin began to rise and remained high (around 65 ft MSL) for nearly 20 years (Patton and Judd, 1986). The area was described as a large lake, 2-14 feet deep, covering approximatley 16,000 acres (Webber, 1883). During this period the lake was crossed by ferry. The water level began falling again in 1890 and the lake rapidly disappeared. Since that time the basin has been generally dry, with periodic, temporary flooding after times of heavy rainfall (Sellards, 1910).

The rising and lowering of the water level can be attributed to karst topography and related sinkhole activity in the basin (see below). Of particular importance is the changing ability of Alachua Sink to accept water. This ability depends on sediment accumulation and dislodging in the Sink (Jensen, 1985). Furthermore, variable rainfall input and the rising and falling of groundwater levels affect water levels in the basin (Morris, 1974).

In more recent history (1920s-1970), most of the basin and surrounding bluff area was owned by Camp Ranch, Inc. and used as a large cattle ranch (Floyd, 1936). Abundant grass production on the prairie produced a great carrying capacity for cattle and, because of heavy grazing of these high quality grazing lands, burn management was seldom used (Camp, 1932). To improve drainage and control flooding in the Prairie, a system of canals and dikes was constructed in the 1920s and 1930s. The primary drainage canal diverted Prairie Creek, on the east side of the basin, from draining into Alachua Sink. An earthen dike and by-pass canal (known as Camp's Canal) along the eastern margin of the prairie now directs the flow around the prairie to the River Styx and Orange Lake.

The network of dikes and canals constructed during this period has greatly altered patterns and amounts of water flow in the basin. The main source of surface water, Prairie Creek, was diverted and another major source, Sweetwater Branch, was channeled directly into Alachua Sink. Furthermore, construction of dikes and canals disturbed the natural flat topography and the characteristic marsh/prairie soil layering.

Most cattle were removed after the acquisition of the large majority of the basin by the State of Florida starting in 1970. The area was placed under the jurisdiction of the Florida Department of Natural Resources (FDNR), District III. The major management objectives of FDNR, to restore and maintain the conditions that existed in and around the basin prior to the arrival of Europeans, circa 1500 A.D. (FDNR, 1986), is obviously severely influenced by past drainage and channelization activities. Today, management of the area uses water level fluctuations, fire, and, to a limited extent, grazing to direct successional trends toward maintaining and restoring a prairie/marsh system.

Topography

The Payne's Prairie Basin is located in a region of karst topography characterized by shallow, flat-bottomed lakes, level prairies, irregular drainage patterns, sinkholes, and other solution features (Sellards, 1910). The basin has an east-west length of approximately 8 miles, a north-south width varing from 1.5 to 4 miles, and covers over 18,000 acres. A significant topographic feature of the basin is Alachua Sink, the major drainage outlet for the basin to underground aquifer systems. This sinkhole is located along the northern rim of the prairie and is partially surrounded on the north by bluffs rising 30 to 40 feet above the floor of the basin. Numerous other sinkholes occur in this upland area (FDNR, 1986). Low elevation hills and divides separate the basin from Kanapaha and other prairies to the west, from Levy and other lakes near the southern border, and from shallow Newnans Lake to the northeast. The delineation of topography is apparent along the northern and parts of the southern border of the basin with the occurrence of upland plateaus. For the purposes of this report, the basin boundary follows the 65 feet MSL USGS topographic contour line (which approximates the 100-year flood line) with the addition of Bivens Arm and Lake Wauberg, which have intermittent surface water connections with the prairie basin (see Figure 1).

Geology

There is a strong relationship between mineral composition of Florida's freshwater lakes and wet prairies and its geology and physiography (Canfield, 1981). Furthermore, the geology of an area may influence soil development and drainage patterns. The dominant, underlying component of the entire regional geology is the Ocala limestone formation of the Eocene age. This formation of soft, porous limestone, interbedded with dense, hard limestone and dolomite (Clark, et al., 1964) constitutes the main part of the Floridan aquifer. Its mixture of hard and soft limestones of almost pure calcium carbonate (USDA - Soil Conservation Service, 1985) gives the area its characteristic karst topography. Although the limestones of the Ocala group have been subdivided and renamed by several authors (Puri and Vernon, 1964), they are undifferentiated in this report. Eroded surfaces of the formation are exposed in the low, central part of the basin (see Figure 2) and form a limestone plain. The extensive flat bottom of Payne's Prairie corresponds closely with the piezometric surface of the groundwater in this limestone formation (Clark, et al., 1964). As such, this water table is controlling the level of erosion with high areas eroded down to the water level and low areas filled with sediment to the same level (Pirkle and Brooks, 1959).

Covering the Ocala limestone in both the northern and southern periphery of the basin is the Hawthorne formation. This formation is thought to have been deposited in a Miocene transgressing marine environment (Pirkle, 1956a) and provides erosional materials to the basin floor. The Hawthorne formation consists of predominantly quartz sands, silts, clays, phosphates, and lenses of limestone (Pirkle, 1956b), all of which, except the limestone lenses, were encountered in a recent hydrogeologic investigation in the Lake Wauberg area (Opper, 1982). It is relatively impermeable compared with the underlying Ocala group and acts as a confining layer resulting in an artesian water system. Younger terrace deposits of Pliocene and Pleistocene age, consisting of sands and clayey sands overlie the Hawthorne formation in the northern part of the basin (see figure 2).

Soils

The soils of Payne's Prairie, covering the geologic formations, reflect the drainage characteristics of the basin. Transport of sediments from younger geologic formations and the deposition of organic material have created soils of several types (Patton and Judd, 1986). Surface soils in the central region of the basin are nearly level, poorly drained soils of the Ledwith - Wauberg series. Here, organic and loamy layers up to 20 inches thick overlie loamy sand or clay. The upland areas around this central, wet prairie are covered by poorly drained to moderately-well drained sands and loamy sands from a variety of soil series (USDA - Soil Conservation Service, 1985). Past agricultural activities, such as the construction of dikes and canals, fertilization practices, plowing, and conversion of sandhill/upland pine areas to improved pasture has changed the condition of the surface soils in the basin (FDNR, 1986).

Physiography

The physiography of the region is dominated by an area referred to as the

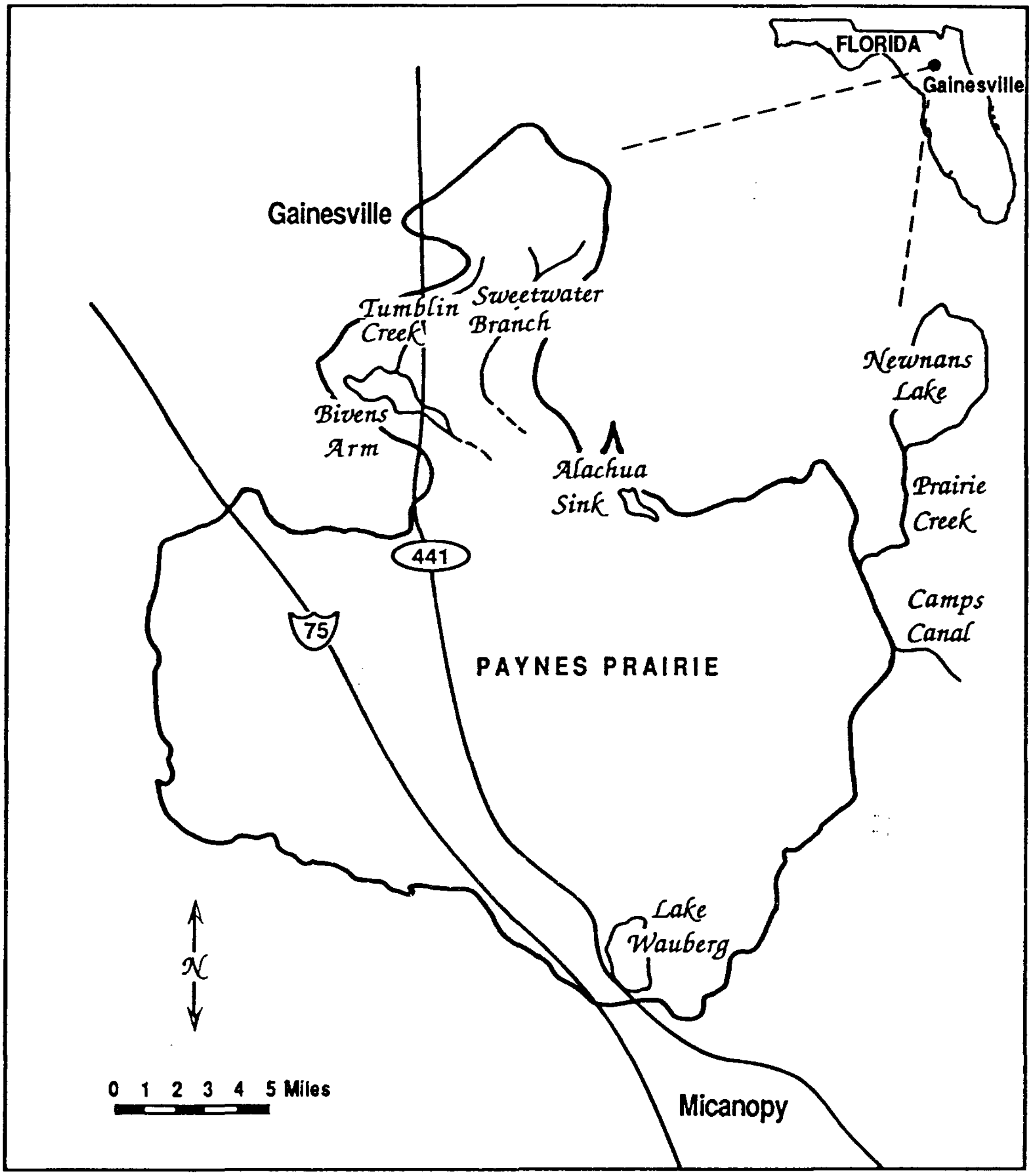

Figure 1. Drainage Map of Paynes Prairie Basin.

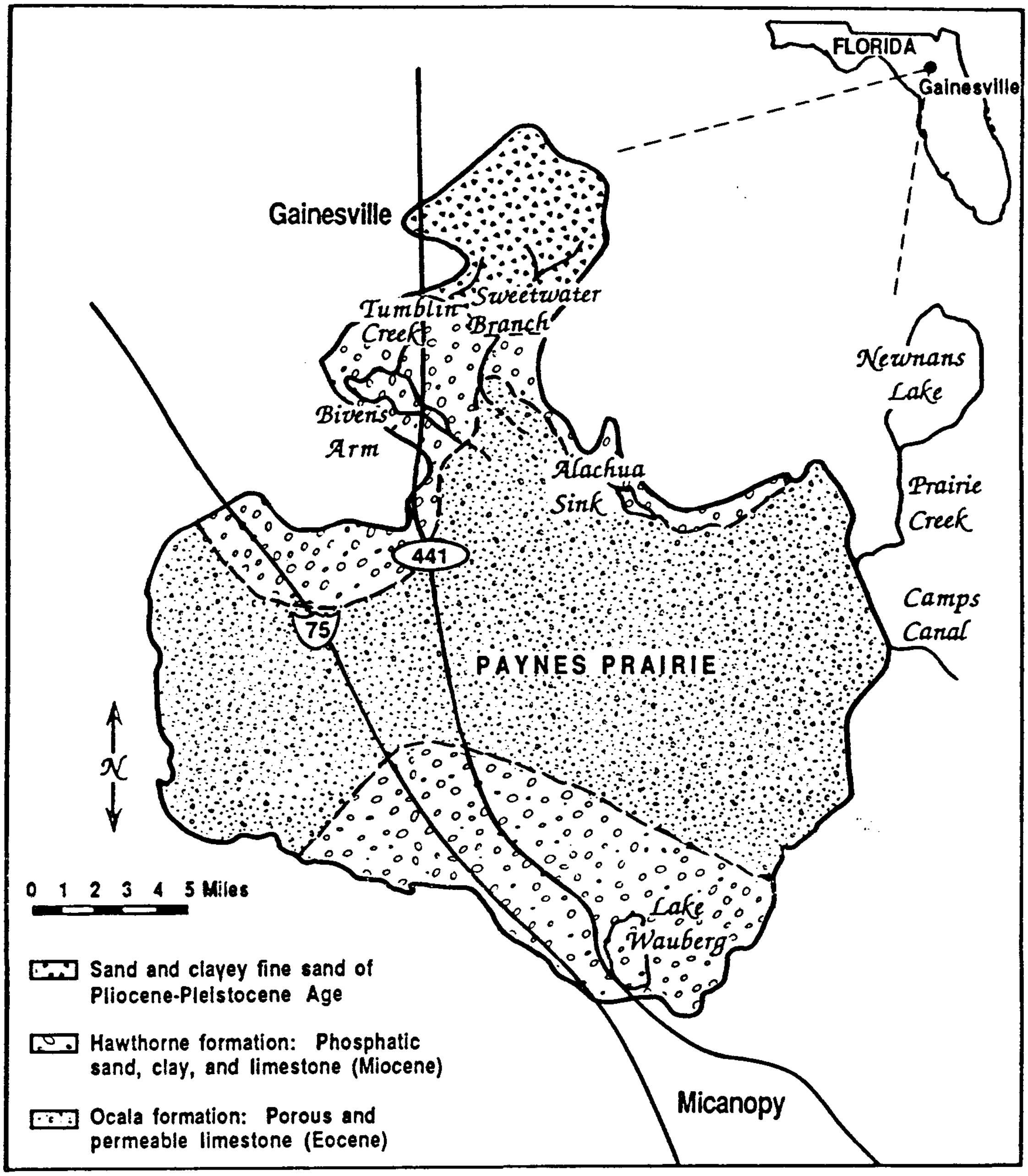

Figure 2. Geologic Map of Paynes Prairie Basin. (After Clark et al, 1964)

Ocala Uplift district (Brooks, 1981). Three subdistricts can be recognized in the basin. The northern area is a well drained, upland plateau developed upon the phosphatic sands and clayey sands of Miocene age. Elevations range from about 80 to 180 feet above sealevel. The basin is bounded in the south by the Marion Hills subdistrict with a hilly and rolling landscape of Miocene and Pliocene clastic sediments with karst terrain intervening. A central area, characterized by shallow, flat bottom lakes, prairies, streams, and erosional remnants of upland plateaus is found between these two subdistricts. The surface topography in this central area is at an elevation of 65 feet MSL or less and, since the piezometric surface of the groundwater of the Eocene limestone roughly corresponds with the level of the depressions and lakes (Pirkle and Brooks, 1959), natural infiltration and soil drainage are impeded.

Hydrology

The drainage area of the Payne's Prairie Basin, located on the northwestern edge of the Orange Creek Basin, is estimated at 31 square miles. Poor drainage and small elevation gradients (usually less than 1-2 feet/mile) result in much sheetflow and poorly defined channels. Ponds, marshes, and wet prairies occur throughout the area.

Historically, the water level in the basin has fluctuated considerably due to the rising and falling of groundwater levels, variable rainfall input, and the rate of downward flow through Alachua Sink. The area was flooded in the past for periods ranging from a few weeks to 20 years. From 1871 to 1891, 16,000 acres in the basin formed a lake 2-14 feet deep (Webber, 1883). Since that time, the basin has been mostly dry, with periodic temporary flooding after times of heavy rainfall (Sellards, 1910) or after marked decreases of downward flow in Alachua Sink (Morris, 1974).

Today, water levels are maintained from 55.5 to 59.5 feet MSL with the use of two water control structures in an effort to restore and maintain the prairie's original biological communities (FDNR, 1986). A water control structure at Prairie Creek and one near Alachua Sink are used to simulate past hydrologic cycles. Historical water levels higher than 59.5 MSL cannot be simulated due to the presence of private lands and public highways in the basin.

Drainage patterns in the basin were drastically altered during the past century (see earlier section entitles "History of Payne's Prairie"). Surface flow is now directed through a network of canals and dikes toward Alachua Sink and a water pumping station on Camp's Canal, installed to drain the prairie, but have not been used since FDNR acquired most of the basin in 1970 (Weimer, pers. comm.). Three culverts connect parts of the basin separated by major highways.

The main sources of water in the basin in addition to direct rainfall are subsurface flow through the phosphatic sands and clays of the upland areas and surface flow from Sweetwater Branch, Bivens Arm, Prairie Creek, and a number of short perennial and seasonal streams surrounding the basin. Historically, it is believed (Williams, 1837: Sellards, 1910) that Prairie Creek formed the surface drainage pathway for water from Newnans Lake to Orange Lake. Later, Prairie Creek drainage was captured by the geologic development of Payne's Prairie and Alachua Sink. With the construction of a dike and Camp's Canal in the 1930s, most drainage from Newnans Lake was diverted from Payne's Prairie back to Orange Lake. Water inflow from Prairie Creek into the basin is now regulated with a water control structure (Gottgens, 1987). However, inflow rarely exceeds 15% of total Prairie Creek volume, and, in dry years, is often insignificant due to the presence of a weir on Prairie Creek below Newnans Lake (FDNR, 1986).

Sweetwater Branch, at one time likely an intermittently flowing stream, now receives urban runoff from parts of southern Gainesville, as well as a steady input of effluent from a wastewater treatment plant. Historically, it flowed into the basin forming a floodplain on the northern edge of the prairie. At present it flows through a canal directly into Alachua Sink. A separate section (see "Topics of Special Interest") documents the history of hydrological alterations in the Sweetwater Branch watershed and their reported impacts on the prairie basin.

Water from the prairie basin is lost by evapotranspiration and drainage through underlying pervious sediments or solution cavities, such as the primary outlet to the shallow aquifer through Alachua Sink (Jensen, 1985). This 13 acre sinkhole lake receives surface inflow from most of the basin. It is located along the northern rim of the basin floor in an area of geologic instability, as witnessed by the continuous formation of new sinkholes. During low water, the main sink in Alachua Sink can be traced to the extreme northwestern corner of the lake (Weimer, pers. comm.). Downward leakage in other areas of the basin is probably also important because of the high permeability of underlying materials (Deevey, 1988).

Evapotranspiration is high in Florida's climate. In developing a water budget for the Lake Wauberg watershed, Opper (1982) calculated a weighted average evapotranspiration for land and lake areas in the watershed of 50.52 inches/year, well in excess of the 42.22 inches of precipitation measured during his study year (Sep. 1980-Aug. 1981). A relatively high groundwater inflow helped maintain the lake's water level during this year of low rainfall. Other hydrogeological work outside the basin (Deevey, 1988) emphasizes the importance of net precipitation (i.e. precipitation - evapotranspiration) rather than direct rainfall in determining regional lake levels.

Careful management of water levels in the basin may be the most effective method for accomplishing the current management objective of restoring and maintaining the prairie's "original" biological communities, in particular the maidencane (Panicum hemitomon) prairie/marsh system (FDNR, 1986). Water level fluctuations may be used to maintain a semi-natural pulsing which periodically resets succession in this ecosystem (White, 1974). Ongoing collection of hydrological data in the prairie (Weimer, pers. comm.) and the development of a model which predicts water levels under a variety of conditions will considerably enhance understanding of the basin and contribute to effective management. A closer examination of basin hydrology is presently in preparation (Adkins, 1988) and will complement this report.

Climate

Rainfall in the region is quite varied in both seasonal distribution and yearly amounts. During the 80-year period of record for Gainesville, annual precipitation has occasionally fallen below 35 inches or exceeded 70 inches, with an average of 52 inches (Allen, 1986). The dry season is normally from October through May, with November being the driest month. On the average, over half of the annual precipitation occurs during the period of June through September (Florida Statistical Abstracts, 1985). Most rainfall during the summer months occurs as scattered local convection type showers and thunderstorms, characterized by a short duration and intense rainfall (Jensen, 1985).

Climatic factors that have the most impact on the basin are droughts, floods, and frosts. Although most marsh and wet prairie plant species are able to tolerate short-term changes in water levels, longer periods of inundation and drought alter the zonation and distribution of the vegetational communities (Patton and Judd, 1986). Because of its low elevation, the prairie is susceptible to rapid flooding following a hurricane or severe thunderstorms. Similarly, low-lying areas are subject to vegetation-damaging frosts, especially during times of low water (Easterday, 1982). On the average, Alachua County has a 295-day frost-free season (Florida Statistical Abstracts, 1985).

<u>General vegetational zones and land use</u>
Detailed information on vegetation and land use in the basin can be found in Brown (1985), FDNR (1986), and on maps produced by the Center for Wetlands at the University of Florida (1973). In addition, types of plant communities are reviewed in more detail below (see "Biology of the basin"). An updated vegetation map is currently in preparation (Weimer, pers. comm.). Figure 3 shows land use and vegetation categories for the basin. The vegetation on the basin floor is dominated by marsh, wet prairie, and areas of open water. Plant communities found on the forested uplands include mixed forest, sandhill, and flatwood, interspersed with low areas of bottomland forest, baygall, and floodplain swamp (FDNR, 1986). Some of the surrounding forests have been cleared for pasture. Urban development from the city of Gainesville constitutes the majority of the drainage areas of Tumblin Creek and Sweetwater Branch in the northern part of the basin.

<u>General descriptions of Lake Wauberg and Bivens Arm</u>
[Detailed discussions of the chemistry and biology of these lakes are included in the subsequent sections "Water Quality" and "Biology of the Basin".]
Lake Wauberg, located approximately 8 miles south of Gainesville, is a eutrophic, soft water lake (Canfield, 1981). It is 225 acres in size and has a mean depth of 12 feet and a maximum depth of 17 feet (Opper, 1982). Volume and shoreline development indices are 2.19 and 1.11, respectively (Garren, 1982). The long axis of the lake is nearly north-south and about a mile in length; its maximum width is about 2/3 of a mile. The majority of the watershed is owned by the State of Florida and managed by either the Florida Department of Natural Resources as part of the Payne's Prairie State Preserve or by the University of Florida as recreational facility. Only about 15 homes are located in the small section of the watershed not owned by the State (Crisman, 1986).

Direct rainfall and surface/subsurface runoff from the slightly calcareous phosphatic sands are the major sources of water to Lake Wauberg (Brezonik and Shannon, 1971). Investigations of the bottom (Trogdon, 1934) did not indicate the presence of springs in the lake. The only surface outlet is a slough on the east shore which empties into Sawgrass pond, a grassy low area, 50 acres in size, flooded with about a foot of water during most of

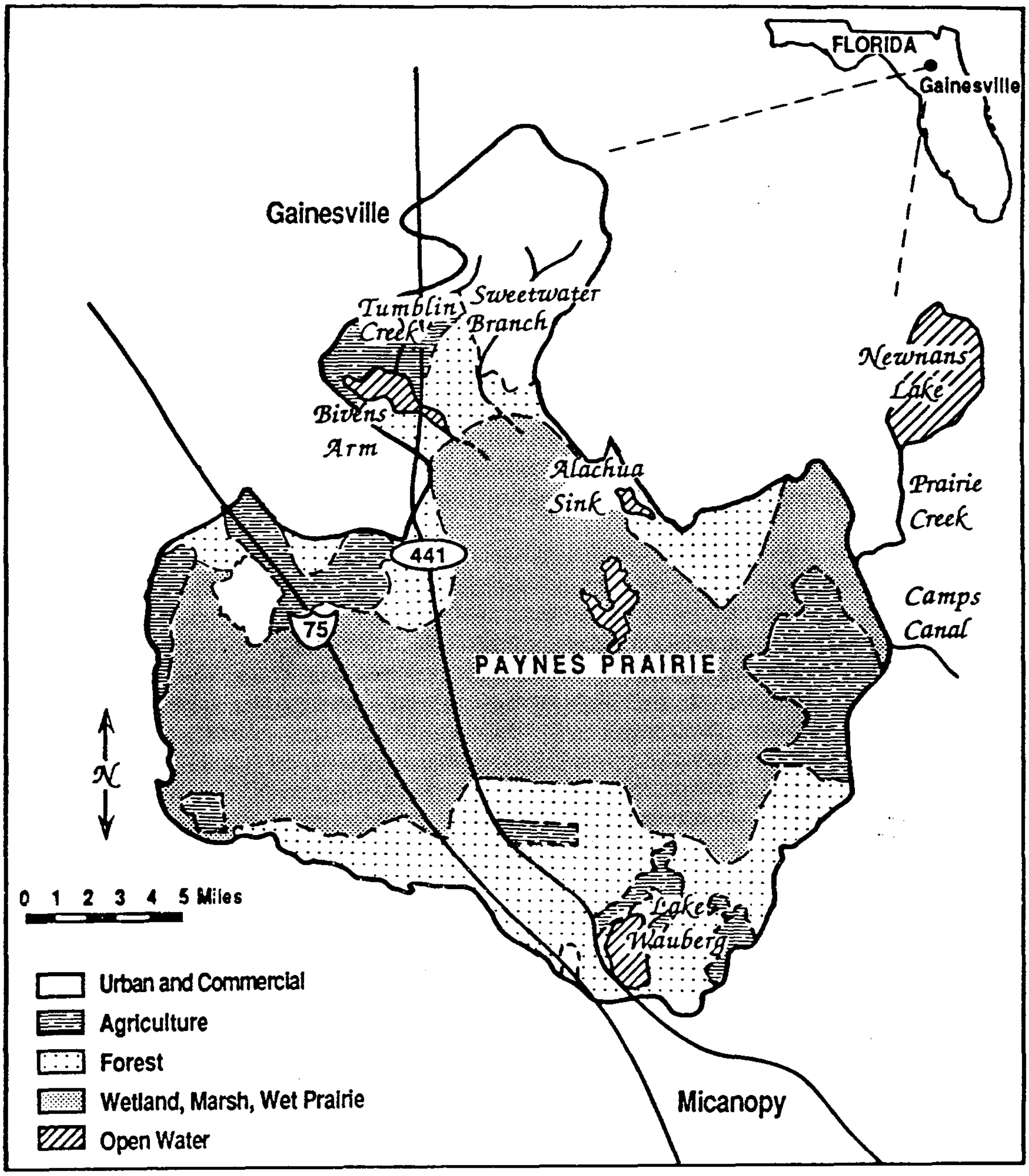

Figure 3. Land use and Vegetation of Paynes Prairie Basin (after Center for Wetlands, 1973)

the wet season. The bottom of Lake Wauberg consists of flocculent organic muck of greenish-brown color with small clumps of organic matter, typical of productive lakes (Flannery, 1982). The lake has a narrow fringe of floating-leaved and emergent vegetation, mainly Nuphar luteum, Panicum spp., and Typha spp., but has virtually no submerged macrophytes (Hodgson et al., 1986).

The similarity of older and newer descriptions of the lake indicate a 50 year history of eutrophy with blue-green algal dominance throughout the year and annual mean Secchi depths of 1-2 feet (Carr, 1934; Canfield, 1981). Historical inferences for Lake Wauberg, based on a transfer function relating organic matter accumulation rate to a chlorophyll a-based index for trophic state indicate no clear acceleration in lake trophic state during the past 140 years (Deevey et al., 1986). Research on the vertical distributions and seasonal fluctuations of CO_2 and O_2, temperature, and plankton (Carr, 1934), and on the seasonal and ecological distribution of the macroscopic invertebrate fauna (Trogdon, 1934) of Lake Wauberg represent the earliest detailed limnological investigations conducted in Florida. Presently, the lake is used extensively for recreation. Boating, fishing, and swimming are allowed and public boat ramps are available. Gasoline outboard motors may not be used, however.

Bivens Arm, located 2 miles south of Gainesville, was originally an arm of Payne's Prairie (Carr, 1942), but the construction of U.S. Highway 441 has largely separated the two. A series of culverts now directs water flow from Bivens Arm to the prairie. The lake has a surface area of 189 acres, a maximum depth of 7 feet, and a mean depth of 5 feet (Florida Board of Conservation, 1969). Volume and shoreline development indices are 2.37 and 1.48, respectively (Brezonik and Shannon, 1971). Approximatly 50% of the surrounding watershed is pasture or land containing commercial buildings (Nordlie, 1976). The University of Florida maintains an experimental cattle farm on the northwestern shore. The forested area of the watershed consists of wet hammock in the lower regions and mixed hardwood and pine forest on higher ground (Nordlie, 1976). Much of this upland, however, has been developed during the last 10 years as residential area.

In addition to direct precipitation, water input into the lake originates from subsurface flow, septic tank overflow, and surface runoff through several small ditches and a ditched creek at the northeast end of the lake. This creek, Tumblin Creek, carries urban runoff from parts of southwestern Gainesville. Overflow from the lake passes through several culverts and small marshes before entering the northern part of the basin.

Bivens Arm is a shallow lake with well-buffered, alkaline waters and high nutrient concentrations (Shannon, 1970). Urban runoff, residential development, and agricultural activities in the watershed probably contribute to its hyper-eutrophy. Also, because of the lake's extreme shallowness, winds mix nutrient-rich sediments with the overlying water (Putnam et al., 1969). Bloom-forming blue-green and green algae cloud the water and rooted submerged vegetation is sparse.

A comparison with descriptions of the lake in the early 1940s (Carr, 1942; Carr and Carr, 1942), suggest that the character of the lake has been altered during the recent past. Marjorie Carr, in a study on the breeding habits of largemouth bass in Florida, was able to observe nests as deep as

8 feet and reported dense growths of submerged coontail (*Ceratophyllum demersum*) in the central portion of the lake. The introduction of water hyacinths (*Eichhornia crassipes*) and blooms of algae probably contributed to the present paucity of submerged vegetation. Hyacinth eradication practices, involving herbicides, have also reduced emergent vegetation and have produced substantial quantities of decomposing hyacinth material on the lake bottom. High phosphorus and nitrogen loadings of 0.80 and 9.15 g/m2.year, respectively, are documented (Huber et al., 1981), leading to continued hyper-eutrophy.

WATER QUALITY

A number of independent studies have documented water quality data for the Payne's Prairie Basin. These references are listed per water body in the categorized bibliography (Gottgens and Montague, 1988). Little long-term monitoring at frequent intervals has been carried out in the basin, with the exception of data collection in Sweetwater Branch and Sweetwater Canal. Here, the discharge of wastewater treatment plant effluent has necessitated frequent monitoring for a variety of parameters since the early 1970s. A summary of these records and a comparison with Payne's Prairie data is reviewed later in this report in conjunction with the permitting issues involved in the discharge of this effluent, the subsequent alterations in hydrology and water quality of the Sweetwater Branch watershed, and the management implications for the prairie basin. A thorough study concerning these issues was recently published (CH2MHill, 1987).

Significant water quality studies for other water bodies in the basin were carried out by Canfield (1981) and Crisman (1986) for Lake Wauberg, and Shannon (1970) for both Wauberg and Bivens Arm. In addition, the Alachua County Department of Environmental Services (ACDES) has started a water quality monitoring program, which includes Bivens Arm, its major surface inflow Tumblin Creek, as well as Sweetwater Branch. Since 1982, samples at several stations per water body are taken 2-6 times annually and analyzed for a variety of water quality parameters. During the late 1960s, and again from 1978-1981, the Florida Department of Environmental Regulation (FDER) has analyzed samples from Wauberg, Bivens Arm, and Payne's Prairie for nutrients (2-4 times annually) and has documented Secchi Disk readings. These data can be accessed through the Environmental Protection Agency's (EPA) STORET system, a data base of sampling sites and their associated water quality data. Following is a brief discussion of the water quality parameters and data collected in the basin by different workers. Most data collection outside of Sweetwater Branch has focused on Bivens Arm, Tumblin Creek, and Lake Wauberg. Little water quality research has been done in the "open" prairie environment or in Alachua Sink, with the exception of limited analyses during 1972-1973 (White, 1974). A summary and historical comparison between 1970 and early 1980 data for Lake Wauberg and Bivens Arm is given in Table 1.

Temperature and dissolved oxygen. Oxygen is a fundamental parameter of lake water quality. Dissolved oxygen is not only essential to all aerobic aquatic organisms, its concentration also strongly effects the solubility of many inorganic nutrients. Solubility of oxygen is affected non-linearly by temperature; it increases considerably in cold water.

Temperature and dissolved oxygen data for Bivens Arm and Lake Wauberg are typical of shallow eutrophic lakes in Florida. No significant thermal stratification is noted in Bivens Arm (Nordlie, 1976), and vertical changes in water temperature in Lake Wauberg rarely exceed 3 degrees Celsius, regardless of season (Crisman, 1986). Pronounced water column changes in dissolved oxygen are common in both lakes, particularly during summer and early fall. Daytime surface waters are often supersaturated with oxygen, while deeper water approaches anoxia as a result of decomposition in surficial sediments. Respiration by dense plankton blooms may produce temporary oxygen depletions at night. Daytime oxygen measurements at four

Table 1. Summary of water quality data for Bivens Arm and Lake Wauberg. Numbers in parentheses are the minimum and maximum values measured.

		Bivens Arm		Wauberg	
Parameter	Unit	Shannon 1970 1)	ACDES 1982-83 2)	Shannon 1970 1)	Canfield 1981 3)
pH			7.9 (7.0-8.9)		7.8 (7.1-9.1)
Tot. Alk	mg/l CaCO3		101 (78-132)		21 (18-39)
Spec.Cond.	umhos/cm	254 (214-340)	261 (210-380)	66 (57-71)	74 (64-80)
Tot. Hard.	mg/l CaCO3		111 (87-150)		22 (22-23)
Ca	mg/l	26 (7-36)		7.0 (5.4-10.0)	
Mg	mg/l	4.4 (3.1-5.1)		1.2 (0.9-1.4)	
Na	mg/l	9.8 (8.5-11.0)		6.0 (4.2-7.8)	8.2 (7.2-9.6)
K	mg/l	2.3 (1.0-3.5)		0.7 (0.3-1.0)	0.6 (0.4-1.0)
Cl	mg/l		14 (9-17)		11 (10-11)
Sulfate	mg/l		6.9 (5.9-10.6)		7.4 (4.4-11)
Tot. N	mg/l	1.88(1.06-3.28)	1.33(0.32-2.50)	1.67(1.10-2.56)	2.10(1.70-2.80)
NH3-N	mg/l	0.19 (0.0-0.38)	0.11(0.04-0.24)	0.22(0.03-0.47)	
NO3-N	mg/l	0.05 (0.0-0.21)		0.03 (0.0-0.11)	
Tot. P	mg/l	0.54(0.37-0.73)	0.19(0.05-0.31)	0.17(0.09-0.26)	0.08(0.06-0.11)
Ortho-P	mg/l	0.23(0.04-0.43)	0.09(0.02-0.15)	0.04(0.02-0.05)	
Chlor.-a	mg/m3	56 (14-154)		37 (17-83)	110 (101-123)
Color	mg/l Pt	42 (23-60)		75 (31-179)	17 (15-20)
Secchi D.	m	0.6 (0.3-0.9)		0.9 (0.6-1.1)	0.4 (0.3-0.5)

1) Data are from Shannon, 1970. Samples taken every other month from June 1969 to June 1970. Three stations were sampled and composited per collection date.
2) Alachua County Department of Environmental Services. Data are based on an average value from eight, individually analyzed samples taken at two field locations from May 1982 to May 1983.
3) Data are from Canfield, 1981. Based on collections on three dates during Sep. 1, 1979 to Aug. 30, 1980. On each date three mid-lake samples were taken (0.5 m depth). Each sample was analyzed separately.

different stations in Tumblin Creek from 1982 to 1987 vary from 1.0 to 12.6 mg/l, depending on flow conditions, amount of photosysnthesis, and the amount of oxygen demanding materials carried by the stream (ACDES, 1982-1987, unpubl. records). With the exception of the Sweetwater Branch system, which is reviewed later in this report, no temperature or dissolved oxygen data are reported for other areas in the basin.

pH controls many processes in lakes, including the form and activity of many chemical species (nutrients, metals). The hydrogen ion activity in natural waters is governed to a large extent by the carbonate buffer system.

No seasonal or annual pattern is reported in the literature for pH values in the basin. Typical value ranges are 7.1-7.9 for Lake Wauberg (Canfield, 1981), and 7.0-8.9 and 7.5-9.0 respectively for Bivens Arm and Tumblin Creek (ACDES, 1982-1987, unpubl. records). The consumption of CO_2 (and production of O_2) by high concentrations of algae in surface waters produces a shift in carbonate equilibria resulting in pH values routinely in excess of 9. Conversely, anoxic conditions in the bottom waters produce a substantial decrease in pH values in the area of the sediment-water interface. White (1974) lists the pH of "open" prairie as 6.6, an average of 53 samples taken during 1972 and 1973. Alachua Sink had an average pH of 7.4 during the same time with the same sampling frequency.

Nitrogen ions are major nutrients affecting productivity of plants and bacteria in fresh waters. Dominant nitrogen ion forms include ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), and a large number of organic compounds of low nitrogen content. Water quality studies routinely report total non-gaseous nitrogen, ammonium, and nitrate concentrations. The latter two are readily assimilated by plants. Nitrite is rapidly oxidized in the presence of oxygen and rarely accumulates. Its concentration is usually extremely low, unless high organic pollution is present.

Total nitrogen concentrations for Lake Wauberg range from 0.27 to 4.76 mg/l, with most values falling between 1.5 and 2.5 mg/l (Crisman, 1986). Ammonium varies from 0.03 to 0.47 mg/l, and nitrate concentrations range from 0.0 to 0.11 mg/l for this lake (Shannon, 1970). Typical values for Bivens Arm range from 0.32 to 2.50 mg/l for total nitrogen (Canfield, 1981), from 0.0 to 0.38 mg/l for ammonium, and from 0.0 to 0.21 mg/l for nitrate (Shannon, 1970). These high concentrations illustrate the eutrophic character of the lakes. For each lake, a comparison between recent data (Canfield, 1981; ACDES, 1982-1983, unpubl. records) and earlier work (Shannon, 1970) show similar ranges of values (see Table 1). Typical concentrations for ammonium, nitrate, and total nitrogen for Tumblin Creek are respectively 0.02-0.20, 0.0-0.32, and 0.15-2.75 mg/l (ACDES, 1982-1987, unpubl. records), dependent on the amount of urban runoff entering the stream. Morris (1974), in a three month study (8 samples), reports total nitrogen concentrations of 0.78 mg/l for Alachua Sink, and 1.67 mg/l for open prairie. White (1974) lists 2.76 and 1.42 mg/l total nitrogen for these respective locations. Gaseous ammonia concentrations (as opposed to ionized ammonium) are of particular concern in the Sweetwater Branch waters. This issue is reviewed in a later section in this report (see "Topics of Special Interest").

Phosphorus is probably the most intensively studied element in fresh waters. Often it is the first nutrient to limit biological productivity, although nitrogen limitation in eutrophic systems in Florida is not uncommon (Canfield, 1983). Both total phosphorus and orthophosphate concentrations are reported in limnological work. Orthophosphate is the only, immediately utilizable form of soluble inorganic phosphorus.

Typical values for total phosphorus and orthophosphate in Lake Wauberg are 0.06-0.11 mg/l (Canfield, 1981) and 0.02-0.05 mg/l orthophosphate (Shannon, 1970) respectively. For Bivens Arm these values are respectively 0.05-0.31 and 0.02-0.15 mg/l, and for Tumblin Creek 0.11-0.43 and 0.07-0.18 mg/l (ACDES, 1982-1983, unpubl. records). Data collected by the Florida Department of Environmental Regulation for Bivens Arm (during 1969-1970 and 1978-1980) and Wauberg (during 1968-1970 and in 1980) display similar total phosphorus and orthophosphate concentrations (STORET). Total phosphorus values of 0.09 mg/l for open prairie and 2.22 mg/l in Alachua Sink are reported by White (1974), the latter a result of nutrient-rich wastewater treatment plant effluent inflow through Sweetwater Branch. Other reported values are indicative of eutrophic conditions, and, in part, a result of the phosphate-rich geology of the region. Higher phosphorus concentrations in Bivens Arm and Tumblin Creek are likely the result of inputs from urban runoff.

Chlorophyll *a* is the primary photosynthetic pigment. Its concentration in water is widely used in limnology as a measure of phytoplankton biomass. Because of the strong correlation between nutrient concentrations (total phosphorus and total nitrogen) and phytoplankton biomass, nutrient vs. chlorophyll *a* regression equations have gained acceptance as a tool for estimating the response of lakes to reductions or increases in rates of nutrient loading (Dillon and Rigler, 1974).

A wide range of chlorophyll *a* data is reported for Bivens Arm and Lake Wauberg. In his dissertation work on eutrophication-trophic state relationships in north and central Florida lakes, Shannon (1970) documents chlorophyll *a* concentrations of 56 (14-154) mg/m3 in Bivens Arm and 37 (17-83) mg/m3 in Lake Wauberg. More recent data for Bivens Arm are not available, while Canfield (1981) reports 110 (101-123) mg/m3 and Crisman (1986) 16-158 mg/m3 for Lake Wauberg. The high average values and the wide fluctuations underscore the productive character of the lakes.

Frequent appearances of algal blooms in the water column produce large fluctuations in chlorophyll *a* concentrations in eutrophic lakes. Chlorophyll *a* levels show definite seasonal trends. Peak concentrations occur during the summer, lowest concentrations generally occur during the winter. Fluctuations are also associated with the percentage of the lake volume occupied by aquatic macrophytes. Competition for nutrients by aquatic plants, reduction in nutrient cycling (because aquatic macrophytes reduce wind mixing), and increased sedimentation of planktonic algae (because macrophytes reduce water turbulence) all contribute to reduced chlorophyll *a* levels with an increase in vascular plant communities (Canfield, *et* al., 1984). In the Payne's Prairie Basin, particularly in Bivens Arm, with changing levels of aquatic macrophytes, chlorophyll *a* concentrations will, therefore, be highly variable and prediction of values based on nutrient-chlorophyll *a* models should include a term for the percentage of the lake's total volume occupied by macrophytes (PVI). The following best-fit multivariate regression equation is used by Canfield et al. (1984) to improve predictions of chlorophyll a concentrations:

$$\log CHLA = 1.02 \log TN + 0.28 \log TP - 0.005\ PVI - 2.08$$

Also, the negative correlation between chlorophyll a in planktonic and in attached algae (periphyton) found in Lake Wauberg (Hodgson et al., 1986) suggests caution in applying nutrient vs. chlorophyll a regression models to lake management. A sudden reduction in chlorophyll a in the water may be linked to an increase in periphyton and not to reduced overall nutrient availability.

Secchi Disk transparency is often measured as an index of lake trophic state. It is not only influenced by trophic state, but also by other factors such as inorganic turbidity and humic coloration of the water. It is measured, at mid-day, as the mean depth of the point where a weighted white disk, 20 cm in diameter, disappears when viewed from the shaded side of a boat, and that point where it reappears upon raising it after it has been lowered beyond visibility.

Typical values are 0.6-0.9 m for Bivens Arm (Shannon, 1970) and 0.14-0.79 m for Lake Wauberg (Crisman, 1986). Minimum values are generally found in the summer (increased algal productivity) and maxima occur in the winter. Because of the shallow depth and exposed character of the lakes, wind action frequently results in resuspension of flocculent bottom materials. The wind is therefore a significant factor in reducing Secchi Disk readings.

Similarly, organic sediment disturbances contribute to high turbidity measurements in the two lakes. Turbidity is a measure of light scattering and absorbtion resulting from the presence of suspended matter, such as clay, silt, fine organic and inorganic matter, and plankton.

Values reported by Shannon (1970) for 1969-1970 are 10.2 (2.8-17.0) mg/l SiO_2 for Bivens Arm and 4.2 (2.5-8.2) mg/l SiO_2 for Wauberg. Putnam et al. (1969) documents values of 10.5 and 10.1 mg/l SiO_2 for the respective lakes. More recently, turbidity is measured at 7.4 NTU for Lake Wauberg (Garren, 1982) and 14.6 NTU for Bivens Arm (ACDES, 1982-1983, unpubl. records). Since there is no direct proportional relationship between turbidity values expressed in mg/l SiO_2 or in NTU's (Hach et al., 1982), it is difficult to compare earlier and more recent data.

True color measures the selective absorption of light by dissolved solids. In the Payne's Prairie Basin, color is largely a function of hydrology and watershed characteristics. A relative lack of pine flatwood and cypress communities and predominance of cleared lands particularly in the immediate surroundings of Bivens Arm produces lower concentrations of dissolved humic substances in the water column of Bivens Arm and Lake Wauberg, compared to neighboring lakes in the Orange Creek Basin (e.g Newnans Lake). The lakes are therefore relatively clear with values for Bivens Arm < 25 mg/l Pt (Nordlie, 1976) and for Lake Wauberg 17 (15-20) (Canfield, 1981). Seasonal changes in the input of water associated with rainfall patterns result in fluctuating values for water color.

The conductivity of lake water is a measure of its ability to carry an electrical current. When temperature effects are accounted for, it is a measure of the level of dissolved electrolytic ions. It is the reciprocal of the resistance of a solution to electrical flow and is often expressed in umhos/cm @ 25 degrees Celsius.

Typical conductivity values at that temperature are 254 (214-340) for Bivens Arm and 66 (57-71) umhos/cm for Lake Wauberg (Shannon, 1970). More recent measurements (ACDES, 1982-1983, unpubl. records; Canfield, 1981) are similar for both lakes. The higher values for Bivens Arm are, in part, the result of increased calcium concentrations, linked to cultural sources, i.e. the input of "used" groundwater from urban sources or septic tank drainage. Conductivity in Tumblin Creek, the primary source of urban drainage into Bivens Arm, is routinely in excess of 400 umhos/cm (ACDES, 1982-1987, unpubl. records).

The higher calcium concentration in Bivens Arm, relative to Lake Wauberg, result in higher values for hardness, a property of water caused by the presence of polyvalent metal ions (mainly calcium and magnesium ions). The source of most of the hardness in Florida waters is dissolution of mineral rocks, predominantly limestone. Therefore elevated total hardness is usually indicative of groundwater input into a lake.

Total hardness for Bivens Arm ranges from 87-150 mg/l as $CaCO_3$ (ACDES, 1982-1983, unpubl. records). For Lake Wauberg an average of 22 mg/l as $CaCO_3$ is reported (Canfield, 1981)

Hard water lakes, such as Bivens Arm, generally exhibit high alkalinity values. Alkalinity is a measure of the pH buffering capacity. Components in water responsible for alkalinity include carbonates, bicarbonates, phosphates, and hydroxides. These components tend to raise the pH and stabilize it.

Alkalinity is reported in mg/l as $CaCO_3$ and values reported for Bivens Arm (ACDES, 1982-1983, unpubl. records) are 101 (78-132) and for Lake Wauberg 21 (18-39) mg/l as $CaCO_3$ (Canfield 1981). Wauberg receives the bulk of its water either directly from precipitation or from surface and subsurface runoff from the sandy, low calcareous soils. Tumblin Creek inflow into Bivens Arm has alkalinities of 80-190 mg/l as $CaCO_3$ (ACDES, 1982-1987, unpubl. records).

In addition to the above mentioned "common" water quality parameters, water quality analyses have been carried out and reported for various anions and cations (particularly metals), and organic contaminants (such as pesticides) in the basin.

The discharge of treated effluent into Sweetwater Branch has necessitated extensive water quality analyses for a wide variety of water quality parameters, including priority pollutants. A brief summary of treatment plant effluent data with respect to anions, cations, and organic contaminants which exceed Class III water quality standards is given later in this report in a section discussing these effluent discharges and their effect on basin management. Table 1 includes measured ranges of values for major cations, chloride, and sulfate for Bivens Arm and Lake Wauberg. No data are reported in the literature for analyses of organic contaminants in the basin outside of the Sweetwater Branch watershed.

Water quality summary and conclusions

Water quality data are summarized for the basin, with the exception of data for the Sweetwater Branch watershed, which are discussed in a later section (see "Topics of Special Interest"). Several independent studies have reported water quality information for water bodies in the basin. Bivens Arm and Lake Wauberg are both very productive systems with high nutrient concentrations compared to data from more than 500 other Florida lakes (Brenner et al., 1981). Both lakes have been eutrophic for as long as water quality records are available and, judging from sedimentary records (Deevey, 1986), probably much longer.

The mineral composition of the waters in the basin is to a large extent determined by the regional geology. High phosphorus concentrations in the lakes may be a direct consequence of the phosphate rich sands and clays of the Hawthorne formation. High phosphorus concentrations, in turn, may contribute to elevated chlorophyll a levels, reduced Secchi Disk readings, anoxia in the lower water strata, and other limnological indications of eutrophy. High calcium concentrations in Bivens Arm, the most notable distinction between this lake and Lake Wauberg, suggest that it receives wastewater from supplies using well water from the limestone aquifer. Calcium concentrations may therefore indicate cultural inputs to lakes in Florida (Putnam et al., 1969). A summary of water quality data for both lakes is given in Table 1.

Few water quality investigations have been conducted in the "open" prairie, Alachua Sink, and Tumblin Creek areas. Water quality analyses for parts of the prairie (White, 1974; Morris, 1974; GRU, 1987-1988, unpubl. records) are performed in conjunction with a study of the effects of Sweetwater Branch effluent discharge on the basin. Open prairie water quality characteristics include low dissolved oxygen, as a result of high rates of decomposition and limited reaeration of the water column (due to low flow conditions and abundant, floating vegetative cover). Nutrient concentrations are high in this productive environment and fluctuate widely (GRU, 1987-1988, unpubl. records). Frequent changes in water level and subsequent oxidation of bottom materials may contribute to this variability. Rapid uptake of nutrients by dense vegetation and, in the case of nitrogen, high rates of denitrification under low oxygen conditions affect nutrient dynamics. Chemically, Alachua Sink has well-buffered nutrient-rich water with alkalinities in excess of 100 mg/l as $CaCO_3$ (ACDES, 1982-1984, unpubl. records) and total phosphorus concentrations averaging more than 2 mg/l (White, 1974). Both are direct results of the inputs of treated effluent into the sink. Rapid flushing rates in Alachua Sink, with immediate water discharge to the surficial aquifer, probably help limit autotrophic production in this hyper-eutrophic environment. Tumblin Creek displays highly variable dissolved oxygen concentrations

(ACDES, 1982-1987, unpubl. records) dependent on flow conditions and the concentration of oxygen- demanding materials in the stream. High nutrient concentrations are paramount and result from urban runoff and the phosphate-rich geology of the watershed.

High nutrient concentrations are likely the most important water quality management concerns for Bivens Arm and Lake Wauberg. Resulting blue-green algal dominance, Secchi Disk measurements of 0.5 meters or less, and/or excessive aquatic plant growth may interfere with the use of the lakes for fishing and water recreation.

An assessment of the type of limiting nutrient(s) in the lakes is important, because the control of inputs of a limiting nutrient may be used as a means by which to control primary production. Such an assessment is either done with enrichment bioassays or by computation of in situ nutrient ratios. The ratio of N:P (in grams) in aquatic plant material is approximately 7:1 (Vallentyne, 1970). Using data from Shannon (1970), and ACDES (1982-1983, unpubl. records) for Bivens Arm, N:P ratios (in grams) are respectively 3.5:1 and 7:1 suggesting nitrogen limitation of primary production in this lake. N:P values for Lake Wauberg are computed as 9.8:1 and 26.3:1 using data from respectively Shannon (1970) and Canfield (1981). These values suggest phosphorus limitation of primary production in Lake Wauberg despite the phosphate rich geology of the basin, but direct assays would supply better evidence.

Important water quality issues for the prairie focus on effects of Sweetwater Branch effluent discharges on the ecology of the basin and on the possible effect of the discharge on groundwater quality in Payne's Prairie at the stream's outfall. These issues are reviewed later in this report (see "Topics of Special Interest"). In addition, to restore and maintain the prairie's "original" biological communities, which is the dominant management objective in the preserve, manipulation of basin hydrology to simulate seasonal and annual cycles is essential (FDNR, 1986). Natural fluctuations are no longer possible due to the hydrological impediments discussed earlier. Rather than water quality management, the current objective in this vast area of the basin seems to be careful management of water quantity (FDNR, 1986).

BIOLOGY OF THE BASIN

Phytoplankton

The phytoplankton, suspended microalgae of fresh water systems, consist of a very diverse assemblage of microscopic, autotrophic organisms. Many of these have different physiological requirements and vary in response to physical and chemical water quality parameters. Despite these differences, many phytoplankton species can co-exist in the same water body. Species composition of phytoplankton communities changes both in space (vertically and horizontally within a lake), as well as in time (seasonally) in response to changes in their aquatic environment.

Phytoplankton investigations in the basin were carried out by Nordlie (1976) for Bivens Arm, and Hodgson and Linda (1982) and Crisman (1986) for Lake Wauberg. In his two year study (1965-1966), Nordlie reported relatively high phytoplankton productivity in Bivens Arm. Using two different techniques of measurement, mean values ranging from 0.98 to 1.10 grams C/m2-day were found. Such values are indicative of very productive conditions. An irregular pattern of productivity occurred during the study, but with generally higher values during the summer. The major phytoplankton species of Bivens Arm were forms typical of enriched conditions, with *Anacystis cyanea*, *Anabaena flos-aquae*, *Ankistrodesmus falcatus*, *Pediastrum simplex*, and *Scenedesmus* spp. commonly present.

Similar communities of blue-green and green algae were found in Lake Wauberg (Hodgson and Linda, 1982; Crisman, 1986), with filamentous blue-greens dominating in both summer and winter. Crisman reported blooms of *Microcystis*, with *Oscillatoria*, *Lyngbya*, *Chlorococcus* as subdominants. Again, peak abundances were recorded during the summer and fall, with the large seasonal fluctuations common in very productive lakes. A winter decline of phytoplankton in Lake Wauberg was followed by a rapid growth of periphyton (i.e. attached algae) suggesting a negative relationship between planktonic and periphytic algae (Hodgson et al., 1986). Periphyton assemblages were dominated by the filamentous green algae *Stigeoclonium* and *Coleochaete*, and a pennate diatom *Gomphonema*. The periphyton communities have been recognized as major contributors to the productivity of aquatic ecosystems, and are food for a variety of invertebrate grazers (Wetzel, 1983).

Variability in phytoplankton density may also result from changes in the abundance of aquatic plants. Data from Langeland (1982) suggest that the assimilation of phosphorus by the macrophyte community limits phytoplankton production. For Florida lakes, open water chlorophyll *a*, and thus phytoplankton biomass, decreases with increased aquatic macrophytes (see also section on chlorophyll *a* in chapter "Water Quality").

Plant communities

The Payne's Prairie Basin is a complex and diverse system of uplands, wet prairies, marshes, and areas of open water. More than 20 distinct plant communities are described for the Payne's Prairie State Preserve (FDNR, 1986). A central feature is the 8,500 acre basin marsh, one of the state's largest freshwater marshes. Detailed investigations of different aspects of the vegetation in the basin were carried out in the last two decades. In the early 1970s, major studies were conducted as part of an ecosystem analysis of Payne's Prairie (White, 1974) to develop recommendations for general management procedures. A management model was developed by Dugger (1976), and research on the growth dynamics of the water hyacinth, at that time a serious pest in the basin, was completed (Morris, 1974). A major study of the vascular flora of the prairie and some of the uplands was carried out by Easterday (1982), and later summarized in a publication (Patton and Judd, 1986). Currently, an updated vegetation map of the part of the basin within the Payne's Prairie Preserve is in preparation (Weimer, pers. comm.).

These studies agree on the overwhelming importance of water depth and frequency of water level fluctuation as the most important factors determining vegetation type distributions. Inundation or drought alters the zonation and distribution of the plant communities (Easterday, 1982). Specific changes may occur in dominance, in phenology and morphology, in productivity and decomposition, and in susceptibility to consumers, disease, and fire, and subsequent regeneration after fire (Patton and Judd, 1986).

Recommendations for the fluctuation of water levels on Payne's Prairie are summarized by White (1974) and focus on restoring or maintaining the prairie to its appearance prior to the arrival of Europeans, circa 1513. Specifically, the recommended focus for stability is to maintain large acreages of productive maidencane (<u>Panicum hemitomon</u>) communities for its historic value and ability to attract many species of wildlife (FDNR, 1986). To accomplish this, flood/drought perturbation with a two year flood stage is recommended every 30 to 50 years to reduce dominance by pickerel weed (<u>Pontederia cordata</u>), cattail (<u>Typha latifolia</u>), and willow (<u>Salix caroliniana</u>).

In addition to water level fluctuations, periodic fires affect vegetation type and distribution. Burning removes organic matter and increases the amount of soluble nutrients and light at the soil surface. Many of Florida's biological communities are adapted to fire (Snedaker and Lugo, 1972). Where natural burn frequency has been suppressed, fire must be periodically introduced to maintain communities in their fire-adapted state. On a smaller scale, grazing, canal/dike construction, cultural practices, and addition of sewage effluent impact the vegetation type and distribution of plant communities in the basin.

The result of fluctuating water and fire regimes in the basin is a complex pattern of varied and rapidly changing plant communities. This remarkable feature adds to the natural and scientific value of the basin, has contributed to the establishment and protection of the area as a preserve, and has attracted the attention of many researchers. The dynamic character of the basin plant communities make a static description of the flora difficult. As a result, and in line with the purposes of this report, such a characterization is limited to the major types of plant communities. This characterization (following Patton and Judd, 1986) includes the structure of the community (life-form, density, diversity), the dominant species present, and the degree and length of inundation. In addition, the general location of each type of plant community is given.

Permanently open water areas in the basin support many different aquatic macrophytes. These plants are either rooted or free-floating. The rooted plants can be emergent, floating-leaved, or submersed and are restricted to littoral areas of the lakes. Aquatic macrophytes can have a major impact on productivity, nutrient cycling, mixing patterns, and other aspects of the metabolism of a lake system. The Payne's Prairie Basin is subject to periodic infestations of exotic aquatic macrophytes, such as hydrilla (*Hydrilla verticillata*) and water hyacinth (*Eichhornia crassipes*). These accumulations may interfere with the use of some basin lakes (Wauberg, Bivens Arm) for recreation and fishing, or they may interfere with current management objectives of restoring and maintaining historical diversity in other inundated areas of the basin.

Bivens Arm, in particular, is subject to abundant growth of water hyacinths. This free-floating macrophyte has, at times, covered large areas of the lake surface and has probably contributed to the current paucity of submerged vegetation in the lake (Nordlie, 1976). Subsequent eradication efforts, involving herbicides, have also reduced the native emergents. Flocculent sediments in the lake, containing partially decomposed hyacinths may also contribute to the difficulty of reestablishment of the submerged macrophyte flora.

A similar, impoverished macrophyte community is found in Lake Wauberg. Garren (1982) noted no submerged plants, one species of free-floating plant (water hyacinth), two species of floating-leaved plants (spatterdock-*Nuphar luteum*, water pennywort-*Hydrocotyle* spp.), and eight emergents (including pickerel weed-*Pontederia cordata*, maidencane-*Panicum hemitomon*, and cattail-*Typha latifolia*). The lake is dominated by algae, with a narrow shoreline fringe of emergent macrophytes. *Hydrilla verticillata*, an exotic, fast-growing, and very persistent water plant able to eliminate native vegetation (Haller, 1976), has periodically appeared in Lake Wauberg (FDNR, 1986). Treatment with aquatic herbicides (Diquat, Aquathol) was carried out in 1983, but regrowth on a small scale has occurred since that time.

In the deepest and central ponds on the basin (e.g. Alachua Lake) several submerged species occur, including coontail (*Ceratophyllum demersum*), fanwort (*Cabomba caroliniana*), bladderwort (*Utricularia foliosa*), and southern naiad (*Najas guadalupensis*). Colonies of floating-leaved species, such as water lily (*Nymphaea* spp.) are also present. Floating plants often form monospecific stands. Characteristic floating species include several members of the duckweed family (*Lemnaceae*), as well as larger species such as water pennywort (*Hydrocotyle umbellata*), and water hyacinth (*Eichhornia crassipes*). This latter species was, at one time, one of the most common exotics in the basin (Morris, 1974), but is presently outcompeted by native species on most of the prairie (FDNR, 1986). Factors involved in the demise of this plant include the introduction of natural control agents and the drastic reduction of fertilization from the once abundant cattle. Widespread growth of water hyacinths in Alachua Sink used to be common. Now, their density is low and the species seems to be under natural control (FDNR, 1986). In canal systems on the prairie, "floating islands" of pennywort (*Hydrocotyle umbellata*), pickerel weed (*Pontederia cordata*), salvinia (*Salvinia* spp.), and frog's bit (*Limnobium spongia*) form, dependent on conditions of wind and current.

The basin marshes, a central feature of the prairie, are dominated by emergent, herbaceous perennials (Patton and Judd, 1986). Water levels fluctuate from about 3 feet to just below the soil surface, with a hydroperiod of approximately 200 days per year. Shorter periods of inundation allow mesophytic species to invade, while a longer hydroperiod converts the marsh into a lake. Fire is another important factor in maintaining this plant community by restricting shrub invasion.

The vegetation in the marshes is dense. Often monospecific stands are formed of cattail (Typha latifolia), pickerel weed (Pontederia cordata), spatterdock (Nuphar luteum), yellow lotus (Nelumbo lutea), or arrowhead (Saggittaria lantifolia). Associated species include maidencane (Panicum hemitomon), pennywort (Hydrocotyle umbellata), smart weed (Polygonum spp.), sedge (Cyperus strigosus), coast cockspur (Echinochloa walteri), southern waterhemp (Amaranthus australis), and bur-marigold (Bidens laevis). In some of the drier portions of the marsh, especially in areas subject to past construction of canals and dikes, dense growths of coastal plain willow (Salix caroliniana) occur. Sediment deposition and nutrient enrichment resulting from effluent discharges in the northern part of the prairie have contributed to domination by willows and cattails. This conflicts with management goals for the prairie to restore and maintain plant communities resembling those which likely existed prior to the arrival of Europeans, circa 1500 A.D. Bald cypress (Taxodium distichum) grows along the Prairie Creek (east) side of the basin.

Wet prairie forms a band of varying width that virtually encircles the marsh portion of the prairie basin. The plant community differs from that of the marshes by often containing a dense ground cover of grasses and herbs. Hydrology and fire regime are important physical factors in maintaining this vegetation type. Wet prairie is seasonally inundated for 50-100 days each year (June-September) and burns every two to four years (FDNR, 1986).

According to Patton and Judd (1986), common species of the wettest meadows in the prairie basin include: southern cutgrass (Leersia hexandra), maidencane (Panicum hemitomon), rush (Juncus acuminatus), soft rush (Juncus effusus), spike rush (Eleocharis montevidensis), sedge (Carex albolutescens), dwarf St. John's wort (Hypericum mutilum), pennywort (Hydrocotyle umbellata), Centella asiatica, Ludwigia arcuata, beggar-ticks (Bidens mitis), and mild water-pepper (Polygonum hydropiperiodes). In meadows with generally shorter periods of inundation, some of the above species may be present along with bedstraw (Galium obtusum), mock bishop's weed (Ptilimnium capillaceum), Florida betony (Stachys floridana), Dutch white clover (Trifolium repens), Oxalis dillenii, Agrostis hyemalis, rush (Juncus marginatus), bagpod (Sesbania vesicaria), and meadow beauty (Rhexia mariana).

Like the marshes, the wet prairies in the Preserve have been affected by recent human activities. Privately owned lands within the basin restrict the use of management techniques such as water fluctuation and prescribed burning. Many exotic grasses and legumes occur in portions of this community. The exotic grasses are largely the result of past agricultural management on the prairie. Exotic legumes, such as sicklepod (Cassia obtusifolia), bagpod (Glottidium vesicaria), and danglepod (Sesbania exalta) seem to favor disturbed ground (FDNR, 1986).

The pastures are somewhat higher in elevation and inundated only at times of exceptionally high water. Species present in wet prairies also occur in the pastures, but the drier, sandier soils and the introduction of pasture grasses and weedy species create floristic differences (Easterday, 1982). The more common species include bahia grass (Paspalum notatum), broomsedge (Andropogon virginicus), common carpetgrass (Axonopus affinus), Vasey grass (Paspalum urvellei), Juncus marginatus, Sesbania vesicaria, dogfennel (Eupatorium capillifolium), ragweed (Ambrosia artemisiifolia), blackberry (Rubus spp.), and aster (Aster dumosus). Woody species such as groundsel tree (Baccharis halimifolia), wax myrtle (Myrica cerifera), and persimmon (Diospyros virginiana) are often found scattered throughout this community (Patton and Judd, 1986). The presence of occasional shrubs and a dense understory of graminoides give the pastures a savannah-like appearance.

A wide variety of plant communities is found in the peripheral uplands of the basin. Many of these communities occur in areas protected from fire and are dominated by woody species. It is beyond the scope of this report to describe the species composition of the many different upland vegetative communities. Reference materials documenting this information are available in several sources (FDNR, 1986; Patton and Judd, 1986; Easterday, 1982; White, 1974).

Upland mixed forest is the major woodland community in the basin, although much of this community was cleared for agricultural purposes in the past. It is characterized as a well-developed, closed-canopy forest of upland hardwoods on rolling hills (FDNR, 1986). The densely closed community structure of mixed upland forests results in generally low light penetration and air movement, making the humidity high and relatively constant. As a result these communities rarely burn.

Similar conditions resulting from closed-canopy structure exist in bottomland forests, a community type found in the basin on low-lying flatlands bordering Lake Wauberg and Sawgrass Pond. Water rarely inundates these forests, which allows typical upland species to survive.

In other low-lying areas, mainly along Prairie Creek, floodplain swamps occur that are dominated by hydrophytic species such as cypress (Taxodium distichum) and tupelo (Nyssa sylvatica). These communities are seasonally wet and rarely burn. However, activities that affect the hydrology of the floodplain, such as dikes, dams, and creek channelizations, significantly alter species composition in floodplain swamps.

Other occasionally wet communities include bayheads (densely forested depressions dominated by evergreen hardwoods) and hydric hammocks (moist, well developed hardwood and cabbage palm forests, with an understory of palms and ferns). Bayheads are generally associated with the flatwoods located to the east and south of Lake Wauberg, whereas hydric or wet hammocks are found in the widely scattered depressions along the prairie rim.

Longer hydroperiods (200-300 days/year) are needed in basin swamp and dome communities (shallow forested depressions with a peat soil), both occupying small areas in the basin. Cypress (Taxodium distichum), a major component of these communities, has been largely eliminated due to selective cutting. Periodic fires are essential to counter hardwood invasion.

Upland, dry communities in the basin include pine and scrubby flatwoods, sandhills, and upland pine forests. A considerable amount of these lands was converted to pasture in the past. Re-conversion to the original plant community is slow due to the thick sod dominated by exotic grasses such as bahia (Paspalum notatum). Also, exclusion of fire has converted many of these communities to an upland mixed forest or xeric hammock system, characterized by a fairly open canopy dominated by sand live oaks and a moderately thick understory.

Exotic plants (i.e. plants which are not native to the region) compete with native species for resources. Pasture grasses in the drier areas of the basin (remaining from the Camp Ranch period) form just one group in a total of about 80 identified exotic plant species introduced in the basin. A complete list of exotics is given in FDNR (1986). When introduced into a new environment, exotic plants often either fail entirely or succeed so well that they become pests. The latter happens when exotics lack natural population control mechanisms which would restrict their growth and spread. The result is a displacement of less competitive species. The management policy in the Payne's Prairie Preserve is to remove exotic plants from native biological communities, especially in a situation where communities include endangered or rare plant species. As previously noted, the inundated areas in the basin contain water hyacinths (Eichhornia crassipes) and hydrilla (Hydrilla verticillata). Exotic legumes have established themselves on the wet prairie portion of the basin. Elephant ear (Xanthosoma sp.) occurs in the Boulware Spring area. Several exotics are found in the uplands, including mimosa (Albizia julibrissin), camphor tree (Cinnamomum camphora), chinaberry (Melia azedarach), and chinese tallowtree (Sapium sebiferum). Air potato (Dioscorea bulbifera) is common in the wooded areas on either side of Sweetwater Branch. Information on the spread of exotics, and some of the control methods used is found in FDNR (1986). In general, species are either manually or mechanically removed or treated with herbicides.

In addition to exotics, several native plant species whose growth patterns create specific management problems or concerns exist in the basin. These "problem" species include cattails (Typha latifolia) and coastal plain willow (Salix caroliniana) (FDNR, 1986). They are particularly abundant in the Sweetwater Branch floodplain, where nutrient and sediment rich water enters the prairie. Examination of a series of historical aerial photographs illustrates the rapid invasion of this part of the basin by these species (White, 1974). The area covered by willow doubled in 12 years (1956-1968) and nearly doubled again in the following 6 years (Easterday, 1982). Woody vegetation dominated by willows, in association with elderberry (Sambucus canadensis) and wax myrtle (Myrica cerifera) are also found along dikes and fill areas. The latter two are less tolerant of high water than willow and are more effectively restricted by burn management.

Some 30 plant species in the basin are "designated" species, listed by the U.S. Fish and Wildlife Service, Florida Game and Fresh Water Fish Commission, or Florida Department of Agriculture and Consumer Services as endangered, threatened, rare, or of special concern (FDNR, 1986). These species occur in such small numbers that there is concern for their ability to persist within the state. Although no particular management procedures are followed to preserve these plant species (FDNR, 1986) restoration and maintenance of "original" biological systems in the basin may help preserve the designated species which inhabit those systems.

Zooplankton

Inundated areas in the basin support communities of zooplankton, an extremely diverse group of animals, that are suspended in water and subject to dispersal by turbulence and other water movements. The planktonic protozoa have limited locomotion, but rotifers and cladoceran and copepod microcrustaceans often migrate vertically in standing waters. Zooplankton form the main pathway of energy transfer between algal primary productivity and small and large fish in aquatic ecosystems. Additionally, some function as decomposers and recycle nutrients in detritus and the sediments to primary producers.

Zooplankton studies in the basin were carried out by Nordlie (1976) in Bivens Arm and Beaver (1980), Bays (1983), and Crisman (1986) in Lake Wauberg. Zooplankton assemblages in Bivens Arm displayed distinct seasonal differences (Nordlie, 1976), with abundant rotifer populations during the summer, replaced by cladocerans in October and November. Copepods and copepod nauplii populations showed more subtle variations. The rotifer fauna were typified by one or at most two species present in other than token numbers at any one time. Brachionus havanaensis was most common with Keratella cochlearis and Tetramastax opoliensis also present.

Cladoceran populations in eutrophic as well as oligotrophic Florida lakes are generally limited to small-bodied species. The mechanism responsible for the exclusion of larger cladocerans from subtropical lakes is poorly understood, but may be related to high predation pressure by planktivorous fish in Florida lakes (Crisman, 1986b). In Nordlie's (1976) study, the dominant cladocerans were Eubosmina tubicen and Daphnia ambigua, both small-bodied species. Subdominant cladocerans in Bivens Arm were Diaphanosoma brachyurum and Ceriodaphnia lacustris, with Alona costata and Bosmina longirostris intermittently present. The copepod fauna consisted of two forms; Diaptomus floridanus and Mesocyclops edax, both common forms in productive Florida lakes. The typical diversity of the zooplankton community in Bivens Arm consisted of only 1-3 species of Rotifera, 2-4 species of Cladocera, and 1 or 2 copepod species in any one set of collections.

A similar zooplankton community structure was found in Lake Wauberg by Bays (1983) and Crisman (1986). Rotifers, most abundant in spring and summer, were dominated by the genera Keratella, with Brachionus, Ascomorpha, and Gastropus as subdominants (Crisman, 1986). Cladocerans, absent during the summer and abundant in winter and early spring (Bays, 1983), were represented by the same two species which dominated Bivens Arm (Eubosmina tubicen and Daphnia ambigua). Copepods peaked in spring and had low abundances in late fall and winter. Dominant genera were *Diaptomus* and *Tropocyclops*. Zooplankton community composition and biomass for both lakes were highly variable, although the species encountered were generally typical of eutrophic conditions.

Beaver (1980) paid particular attention to the community dynamics of ciliated protozoans. He reported relatively high abundance and biomass of ciliates, especially small-bodied *Scuticociliatida*, in Lake Wauberg and other eutrophic systems. It was suggested that ciliated protozoans are valid indicators of trophic state for Florida lakes and that they may play an important role in energy transfer between bacteria and macrozooplankton (Beaver and Crisman, 1982). Because ciliates recycle phosphorus faster than larger zooplankton, due to their shorter generation times, replacement of larger-bodied ciliates by smaller forms in many of Florida's eutrophic lakes may increase their contribution to the phosphorus dynamics in a lake (Beaver and Crisman, 1988).

Benthic Invertebrates

Very little work in the Payne's Prairie Basin has been done on community assessments of benthic invertebrates, an extremely diverse group of organisms attached to or resting on the bottom, or living in the bottom sediments. The difficulty of obtaining quantitative samples, the tedious separation of benthos from the substrate in which they live, and the considerable confusion surrounding details of their taxonomy all contribute to a still very incomplete description of benthic animals in the literature. For lake management this deficiency is particularly critical, because benthic invertebrates can be valuable in pollution studies. They are relatively long-lived, sensitive to pollution, and are usually abundant and widespread. Biological integrity of benthic invertebrate communities is incorporated in the State of Florida Water Quality Standards (FDER; Chapter 17-3).

In a classical study of Lake Wauberg, Trogdon (1934) noted a total absence of macroscopic invertebrate fauna below an approximate depth of 12 feet. The semi-suspended and unstable condition of the mud bottom in the lake were believed to be the reason for this absence of fauna. Extreme abundance of larval midges (*Chironomus*) were encountered in the littoral zone and likely constitute an important part of fish food in the lake.

Hester-Dendy multiplate samplers are used to study aquatic macroinvertebrates in the Sweetwater Branch watershed as part of an investigation to evaluate impacts of effluent discharges (Evans, 1988). The organisms collected are indicative of slow-flowing or stagnant waters. Low diversity and dominance of *Chironomus* species indicate high organic loading and low dissolved oxygen. Collections made in the prairie (Main Canal) show low numbers of oligochaetes (*Dero* spp.) and *Chironomus*. Low densities are typical of marsh habitats, where numbers are reduced by the lack of nutrients (due to uptake by macrophytes) and dissolved oxygen (Evans, 1988).

Fish

The subject of fish biology and the fish fauna of lakes is an enormous field to which much attention has been devoted. Fish are an integral component of the fresh water ecosystem. For instance, a shift of fish species feeding on larger sized food organisms to planktivorous species can have a substantial impact on the composition and productivity of zooplankton communities. This change can, in turn, influence the species composition of the phytoplankton and therefore the productivity at the primary level (Crisman, 1986b). An increase in the trophic state of a lake is generally associated with a gradual decline in predatory gamefish populations (such as largemouth bass) and an increase in planktivorous fish (such as gizzard shad and the exotic species *Tilapia*) (Kautz, 1980; Bays, 1983). Concurrently, a decrease in species diversity is observed (Chew, 1972; Smith and Crumpton, 1977).

In spite of this importance of fish dynamics in the functioning of a fresh water system, few fish studies have been conducted in the Payne's Prairie Basin, though a total of 35 species of fish have been identified in the Payne's Prairie State Preserve (FDNR, 1981). A study of the breeding habits, embryology, and larval development of largemouth bass (Carr, 1942), makes mention of abundant populations of this sportfish in Bivens Arm. Five species of fish which rely to some extent on zooplankton as a food source were reported for Bivens Arm (Nordlie, 1976). Without having the intent of providing a comprehensive list of species, he listed brook silverside (*Labidesthes sicculus*), bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), and golden shiner (*Notemigonus chrysoleucas*).

In a description of Lake Wauberg, Carr (1934) mentions (using then current scientific names) abundant speckled perch (*Pomoxis sparoides*) and numerous largemouth bass (*Huro floridana*), blue gill (*Helioperca incisor*), speckled sunfish (*Apomotis punctatus*), warmouth (*Chaenobryttus gulosus*), red-bellied bream (*Xenotis megalotis marginatus*), and the yellow cat (*Ameiurus natalis*). Short-nosed gar (*Cylindrosteus castelnaudii*) and mudfish (*Amia calva*) were also present. A diverse and abundant community of minnows was noted, which may make up the deficit in food supply for larger fish arising from the lack of sub-littoral fauna (Carr, 1934). A single sample, collected by electrofishing by the Forida Game and Fresh Water Fish Commission in June 1983, shows a very similar fish community for the lake. With only one sample, comparisons with other lakes in the region are not reliable.

Wildlife in the basin

The variety of plant communities found in the basin, together with low levels of cultural disturbance, and a very productive environment support abundant and diverse assemblages of wildlife. 22 amphibian species, 43 reptile species, 217 bird species, and 28 species of mammals have been identified in the basin (FDNR, 1981) and occur either as residents or as transients. Complete species lists for the area can be found in either one of two FDNR publications (1981, 1986).

Of the mammals, raccoon, deer, opossum, marsh rabbit, river otter, cotton rat, armadillo, and various squirrels are most prevalent. A large number of other species also occur, such as bobcat, gray fox, striped skunk, and several species of bats. The policy in the Payne's Prairie Preserve is to remove exotics, such as the armadillo, from native biological communities (FDNR, 1986). Approximately 100 cows, and several horses and bison (a native species which was recently re-introduced) graze in the prairie basin (Weimer, pers. comm.).

The large areas of wetlands and marshes support large populations of wading birds and waterfowl species including the great blue heron, great egret, little blue heron, white ibis, least bittern, limpkin, tricolored heron, anhinga, wood duck, common moorhen, double-crested cormorant, and many others. Marsh areas are important wintering habitat for ring-necked ducks, blue-winged teal, mallard, and purple gallinules (Mulholland and Percival, 1982; Jeske and Percival, 1987). Healthy populations of ospreys, red-shouldered hawks, and barred owls inhabit the basin. In the neighboring Prairie Creek watershed alone, at least seven osprey nests are present (Parenteau, 1987).

Many species of amphibians and reptiles inhabit the basin. Among the numerous amphibians, frogs of the genus Hyla such as the green tree-frog, squirrel treefrog, and the barking treefrog are conspicuous. Many species of salamanders, newts, sirens, and toads complete the varied amphibian community in the basin. In addition to the American alligator, the most common reptiles include turtles (such as the Florida softshell turtle, stinkpot, red-bellied turtle, and the Florida cooter) and many snakes (including the Florida banded water snake, black racer, diamondback rattlesnake, water mocassin, green water snake, and the yellow ratsnake).

An important aspect of the ecological significance of the basin is the occurrence of reproducing populations of several state and federally listed species which are threatened, endangered or of special concern. Fourteen "designated" species inhabit the basin, including ten bird species, three reptiles, and a mammal. Efforts to preserve these species and the biological integrity of their habitat are widespread and require strong consideration in the development of basin management guidelines. A listing (Table 2) and a short description of their ecology and distribution in the basin is given below (after FDNR, 1986).

Wood storks are highly social birds that nest in colonies and roost and forage in flocks. They feed predominantly on small freshwater fish. Because of their specialized "grope" feeding technique, storks feed most efficiently when fish densities are high (Allen, 1986). Nesting coincides to the time of the year when rainfall and temperature are likely to yield high fish densities in drying pools, ditches or swampy depressions, such as in spring and summer (Ogden, 1971). If the water level remains high during the usual dry season or fails to rise in the wet season, the stork will not nest (Kahl, 1964).

Table 2. Species which are listed as endangered, threatened, or of special concern (SSC) that inhabit the Payne's Prairie Basin.

Name	Designation	Status
Wood stork *Mycteria americanus*	endangered	occasional
Arctic peregrine falcon *Falco peregrinus tundrius*	endangered	rare
Bald eagle *Haliaeetus leucocephalus*	threatened	breeding
Eastern indigo snake *Drymarchon c. couperi*	threatened	breeding
Southeastern kestrel *falco s. paulus*	threatened	breeding
Florida sandhill crane *Grus c. pratensis*	threatened	breeding
American alligator *Alligator mississippiensis*	SSC	breeding
Gopher tortoise *Gopherus polyphemus*	SSC	breeding
Roseate spoonbill *Ajaia ajaia*	SSC	rare
Limpkin *Aramus guarauna*	SSC	rare
Little blue heron *Egretta caerulea*	SSC	breeding
Snowy egret *Egretta thula*	SSC	breeding
Louisiana heron *Egretta tricolor*	SSC	breeding
Sherman's fox squirrel *Sciurus niger shermani*	SSC	rare

A total of 14 wood stork colonies in north-central Florida were described recently (Rodgers et al., 1987) indicating that the stork population size is larger than earlier estimates (Ogden and Nesbitt, 1979). A successful rookery is located in the headwater swamp of the River Styx, southeast of the basin. This rookery has been active since at least 1910 (Simmons, 1985) and fluctuates annually between total failure and 100 active nests. Wood storks from this colony are routinely observed in the prairie basin in spring and summer (FDNR, 1981).

The arctic peregrine falcon is rarely seen in the basin. This streamlined member of the order of vultures, hawks, and falcons has a winter range extending into Florida and a summer/breeding range in arctic regions. This fast-flying species is rare throughout its range and prefers coastal areas, mountains, and woods (Robbins et al., 1966). Its close relative, the southeastern kestrel, is listed in Florida as "threatened". This smaller falcon is commonly observed on the prairie, except during the hot summers when it migrates to more temperate areas.

The bald eagle is probably one of our most conspicuous endangered species and has been protected by the federal Endangered Species Act, Bald Eagle Act, and Migratory Bird Treaty Act. In Florida they are classified as a threatened species which means that the eagles require rigorous protection, but are not in immediate danger of extinction. Experiments are now underway to determine how the species can be safely relocated from Florida to areas of suitable habitat in other southern states and re-establish eagles throughout their former range (Collopy and Bohall-Wood, 1986). Eagle nests surrounding the eutrophic lakes and marshes in eastern Alachua and northern Marion counties are utilized as donor nests to evaluate the feasibility of this program. A total of 24 active bald eagle nests are reported in this area (Collopy and Bohall-Wood, 1986). Two active nests are located in the Prairie Creek watershed (Parenteau, 1987), a 3,000 acre area immediately northeast of the prairie and considered for state acquisition under the Conservation and Recreation Lands (CARL) program.

In Florida bald eagles lay their eggs between late November and early February. Hatching takes 35 days. Most pairs produce two eggs per season, with the offspring leaving the nest 10 to 12 weeks after hatching. Eagles nesting in north Florida use nesting sites in live pine and cypress trees in a fairly open situation (Nesbitt et al., 1975). They generally nest in close proximity to open water, reflecting the dependence of bald eagles on fish, waterfowl, and shore birds as primary foods.

Many bird species, including the bald eagle, appear to benefit from burns on the basin, which are conducted from early fall through late winter. Burning during this period greatly improves forage for those species (FDNR, 1986).

Such burn management also benefits the sandhill crane populations in the basin. Reduced vegetation height through grazing, fire , or water management is important in attracting cranes (Nesbitt, 1977). The basin, in particular open prairies and pond edges, supports both the resident Florida sandhill crane (threatened), as well as other migrating subspecies of the sandhill crane. Approximately 100 pairs of the Florida sandhill crane occur in north-central Florida (Brown, 1987), many of which live in the prairie basin. Many more migrating cranes use the basin during the winter. Florida sandhill cranes nest almost exclusively in ponds and on the margins of lakes and marshes and water level is the primary factor determining whether or not their nests are successful (Brown, 1987).

Three reptiles in the basin are listed as designated species. The "threatened" eastern indigo snake inhabits dry, undisturbed areas of the basin. Due to its harmless character and attractive bluish-black appearance, this reptile has long been the victim of snake collectors. Presently, the main threat to the indigo snake is destruction of its habitat of large unsettled areas.

The American alligator and the gopher tortoise are both designated as Species of Special Concern. American alligator populations in Florida have undergone a classical cycle of range-wide decline, protection, and increase (Hines, 1979). The dense emergent and floating marshes in the Payne's Prairie Basin provide excellent habitat for alligators and assure high survival rates of their young. Occasionally, the presence of alligators in Lake Wauberg interferes with the recreational uses of the lake. Large animals are, at times, removed. During 1983 and 1984 seven alligators were taken from the lake (FDNR, 1986).

The gopher tortoise, an accomplished burrower, occurs in the sandy uplands in the basin, where their "gopher" burrows can be found with inhabitants ranging from indigo snakes and diamondback rattle snakes to gopher frogs (Conant and Conant, 1975).

Of the many bird species that inhabit and utilize the Payne's Prairie Basin, four wading birds (little blue heron, snowy egret, Louisiana heron, and roseate spoonbill) and the limpkin are listed as Species of Special Concern. The primary reason for their listing is the loss of nesting and feeding habitat throughout their range (Allen, 1986). The large areas of freshwater marsh in the basin support established populations of these Species of Special Concern. Food availability and water level fluctuations appear to be the major factors in determining colony sites (Ogden et al.,1980).

TOPICS OF SPECIAL INTEREST

Cultural resources

The basin and its immediate surroundings have been a center for human activity in Florida for many centuries. Indian artifacts have been dated to 10,000 B.C. and archeological sites in the basin give testimony to human occupations of varying intensity. An archeological survey of the Payne's Prairie State Preserve (Mullins, 1977) led to the discovery of 40 sites, ranging from very temporary campsites to long-term villages. The main management goal in the Preserve is to maintain and/or restore these sites to the condition they were in during their most significant historical period (FDNR, 1986). Research may then enhance our understanding and interpretation of past conditions in the region.

Prior to the arrival of Europeans (circa 1513) and the introduction of cattle in the 1600s, the prairie basin appears to have been heavily used by tribes dependent on hunting and gathering. In many aspects, the environment was well-suited for such communities. The hardwood hammocks, probably much more prevalent before the extensive deforestation for agriculture (Shelford, 1963), contain a wide variety of edible plants such as hickory, wild plum, and cabbage palm (Snedaker and Lugo, 1972). Furthermore, hardwood hammocks are noted for productive game populations, such as turkey, deer and rabbit. Productive ponds and lakes with abundant fish likely contributed to the subsistence base of local Indian tribes.

The use of lands in the prairie basin changed after the arrival of Europeans and, particularly, after the introduction of large numbers of cattle around 1650 (Arnade, 1961). Numerous archeological findings, including remains of plantation sites, ranches, fortified farms, and even a ferry station and rail systems, attest to the intensive agricultural use of the basin since that time. The most complete description of these findings is found in Mullins (1977).

Management of the cultural resources in the basin is the responsibility of the Florida Department of Natural Resources (FDNR), Division of Recreation and Parks, in cooperation with the Florida Department of State, Division of Archives. In an overall basin management plan, including management of water resources, protection of these cultural resources from human-related activities or natural events (e.g. floods, wind, fire) is an important consideration.

Sweetwater Branch

Both the hydrology and water quality of Sweetwater Branch, a seepage stream entering the northern most section of the prairie, have changed tremendously during the past century. At one time, Sweetwater Branch was likely an intermittent stream. It followed a narrow meandering course through sloping uplands before spreading across the level prairie as sheetflow into Alachua Sink (Van Doren, 1928). Presently, the upper segment of the stream receives steady discharges from the Main Street Wastewater Treatment Plant and the Kelly Generating Plant, both operated by the City of Gainesville, as well as urban run-off from a southern section of the city. The lower segment of Sweetwater Branch, after it enters the level ground of Payne's Prairie, now flows through an artificially straightened channel to Alachua Sink (see Figure 4). These alterations in hydrology and water quality have produced a number of changes in the ecology of the prairie with significant management implications. This section briefly reviews the history of these alterations and their documented impacts on the prairie basin.

The hydroperiod of Sweetwater Branch changed from intermittent to permanent flow with a gradual expansion of the Gainesville urban area. The first treated effluent diversions to the stream occurred after the Main Street Wastewater Treatment Plant became operational in 1931. In order to protect the grazing function of the prairie lands from flooding, the lower portion of Sweetwater Branch was channelized in the 1930s. This man-made channel, referred to as Sweetwater Canal, eliminated sheetflow across the northern part of the prairie basin and discharged the flow directly into Alachua Sink. However, the canal became gradually obstructed with sediment deposits and dense vegetation mats. The cause of this were; increased erosion with an increased hydroperiod in the upper reaches of Sweetwater Branch, the addition of nutrients and silt-laden effluent to the streamflow, and low flow conditions in Sweetwater Canal. In 1970, when the Florida Department of Natural Resources acquired Payne's Prairie as a park and wildlife refuge, Sweetwater Branch water again spread by sheet flow over a broad floodplain. The Department's concern about the effects of this nutrient and sediment-rich sheetflow on the local vegetation led them to request the city of Gainesville to dredge Sweetwater Canal (Weimer, pers. comm.). This dredging restored the canal flow. More recently, FDNR diverted the canal flow to a location downstream from the prairie's main water control structure. This was done largely because the nutrient-rich canal discharge contributed to aquatic macrophyte accumulations in Alachua Lake (Weimer, pers. comm.). Now, sediment congestions again push the water onto a broad floodplain north of the canal.

In order to comprehend the management issues involved in the Sweetwater Branch watershed and its flow onto the prairie, it is necessary to briefly review the characteristics of the Main Street Wastewater Treatment Plant and some of the permitting issues that have evolved during the last decade. Much of this information is documented in a recently completed study (CH2MHill, 1987).

The treatment facility started operation with the construction of an Imhoff plant in 1931. Prior to that, no treatment was provided. In 1950, the Imhoff plant was replaced by a trickling filter plant to which an activated sludge system was added in 1970. These facilities now maintain secondary

Figure 4. Sweetwater Branch watershed

treatment for a design capacity of 7.5 mgd. Discharge from the plant is disinfected through chlorination before its release to Sweetwater Branch. The treatment plant discharge is the principal flow in Sweetwater Branch during dry weather conditions. Additional flow to the stream originates from the creek's drainage area of 3.1 square miles, including some central and southern portions of the city of Gainesville, and cooling water and boiler blowdown from the J.R. Kelly Generating Plant. The latter has an average flow of 0.1 cfs (Nicol, 1981) which is insignificant relative to the design treatment plant flow of 7.5 mgd (= 11.61 cfs).

A wasteload allocation study for the Main Street Wastewater Treatment Plant (Nicol, 1981) raised several issues with respect to permitting and continued operation of this plant by the city of Gainesville. High levels of un-ionized ammonia and excessive biochemical oxygen demand (BOD) in Sweetwater Branch downstream of the treatment facility have been the main issues of concern (CH2MHill, 1987). Furthermore, surface water toxicity from compounds other than un-ionized ammonia and potentially detrimental effects of the discharge on groundwater quality in the vicinity of Alachua Sink need assessment.

The 1981 wasteload allocation study for the plant required, among others, an effluent quality sufficient to prevent concentrations of dissolved oxygen lower than 5.0 mg/l and un-ionized ammonia greater than 0.02 mg/l. Both of these standards would not have been met in the plant's existing design and operating conditions (CH2MHill, 1987). A Temporary Operating Permit was issued by the Florida Department of Environmental Regulation to the city while it attempted to resolve the issues. This permit expired on March 30, 1987 and has since been extended (Regan, pers. comm.) with new wasteload allocation requirements (see below).

Monthly records from 1982-1986 of treatment plant effluent quality indicated the following plant performance data (average flow = 5.7 mgd).

Parameter	Value	Range	Unit
pH	6.7	6.0-7.5	
Residual chlorine	1.6	0.0-3.1	mg/l
BOD	6.8	0.0-43.0	mg/l
Nitrate	8.5	0.82-26.5	mg/l
Tot. Susp. Solids	7.1	0.0-60.0	mg/l
Ammonia	3.7	0.0-20.0	mg/l
TKN	5.9	1.0-24.4	mg/l
TP	4.4	0.0-5.3	mg/l (n=14)
Fecal Coliforms	28.7	0-1200	CFU's/100ml

[Source: Gainesville Regional Utilities. Effluent quality records].

As a result of the wasteload allocation study (Nicol, 1981), discussion has focused on the un-ionized ammonia criterion of 0.02 mg/l and the need to keep dissolved oxygen concentrations above the 5.0 mg/l Class III standard in Sweetwater Branch. Un-ionized ammonia (NH_3) is highly toxic to many organisms, especially fish (Trussell, 1972). The proportion of un-ionized ammonia to ammonium ions is dependent on dissociation dynamics governed by pH and temperature. An increase in pH substantially increases the amount of un-ionized ammonia. For example, at neutral pH of 7 the approximate ratio of un-ionized ammonia to total ammonia is 1:300, while at pH 9.5 this ratio approaches 1:1 (Wetzel, 1983). The un-ionized fraction is lower at colder temperatures (CH2MHill, 1987).

Proposed limits for total ammonia of 3.5 mg/l for summer and 5.0 mg/l for winter would maintain un-ionized ammonia concentrations of less than 0.02 mg/l at the point of discharge, assuming a pH < 6.8, a maximum winter water temperature of 23 degrees Celsius, and a maximum summer water temperature of 28 degrees Celsius (CH2MHill, 1987). The existing wastewater treatment plant could not meet these limits at the design flow of 7.5 mgd. A newly developed wasteload allocation sets monthly average total ammonia levels at 1.5 mg/l for summer season and 4.5 mg/l for the winter (Regan, pers. comm.). A plant upgrade is planned over the next two years to meet these and other new allocation criteria, such as BOD levels < 5 mg/l.

Dissolved oxygen concentrations vary considerably between different reaches of Sweetwater Branch and Sweetwater Canal. Tables 3 and 4 summarize historical and recent water quality data for Sweetwater Branch, Sweetwater Canal, and Payne's Prairie Main Canal. Parameters are reported that most directly affect freshwater dissolved oxygen concentrations. The historical water quality summary covers the period of 1970-1986 and was compiled by CH2MHill (1987). Recent water quality data cover the period of August 1987-April 1988 and are summarized using data from Gainesville Regional Utilities (GRU, 1987-88, unp. records). Recent nutrient concentrations are given to illustrate the impact of Main Street plant effluent on Sweetwater Branch. Total phosphorus and ortho-phosphate concentrations are considerably elevated compared to Payne's Prairie Main Canal, which has been considered a baseline (CH2MHill, 1987).

A comparison of historical and recent data shows significantly reduced BOD values for recent Sweetwater Canal samples. The high, historical average concentration of BOD in this reach is attributed to high values measured in samples taken in the early 1970s (CH2MHill, 1987). Both tables illustrate that dissolved oxygen concentrations in Sweetwater Branch immediately downstream from the Main Street plant discharge do not violate the 5 mg/l Class III standard. In Sweetwater Canal, however, average dissolved oxygen concentrations of 2.4 mg/l are reported for 1970 to 1986 (CH2MHill, 1987) and recent monthly data range from 0.2-1.3 mg/l.

Elevated BOD and ammonia concentrations in Sweetwater Canal underscore the two most important pathways for loss of dissolved oxygen in this reach. Decomposition of organic matter and nitrification (bacterial oxidation of ammonia) exert considerable oxygen demand. Sources of dissolved oxygen include photosynthesis by algae and submerged aquatic plants, and reaeration through atmospheric diffusion. The latter process is the principal contributor of dissolved oxygen, because few algae and submerged macrophytes occur in the canal. However, reaeration is kept low by the

Table 3. Summary of historical water quality data from Sweetwater Branch, Sweetwater Canal, and adjacent water bodies for the period 1970-1986 (Source of data: CH2MHill, 1987).

Location		Temp (C)	DO (mg/l)	BOD5 (mg/l)	pH (units)	Ammonia (mg/l)	Flow (mgd)
Upstream from WWTP	Mean	21.7	8.1	1.7	7.4	0.14	0.702
	Max	30.0	10.0	4.6	8.2	2.15	0.219
	Min	12.0	6.8	0.0	6.7	0.00	0.011
	N	53	50	56	56	53	110
Downstream from WWTP	Mean	23.2	7.2	10.2	7.0	3.72	15.97
	Max	29.0	9.0	35.0	8.0	24.0	20.65
	Min	17.0	6.2	0.0	6.6	0.00	6.11
	N	45	44	64	52	70	11
Sweetwater Canal	Mean	23.4	2.4	26.3	7.7	5.38	4.93
	Max	29.0	7.8	38.0	8.6	15.80	4.93
	Min	15.5	0.0	<1.0	6.5	0.00	4.93
	N	21	20	19	8	12	1
Alachua Sink	Mean	23.4	3.3	2.8	6.9	3.37	31.65
	Max	30.5	9.7	5.5	8.0	14.20	68.49
	Min	19.0	0.0	1.4	6.1	0.00	0.32
	N	11	13	8	16	23	10
Payne's Prairie Main Canal	Mean	23.1	2.1	4.6	7.0	0.59	23.79
	Max	30.5	5.6	4.6	7.8	2.51	48.47
	Min	18.0	0.1	4.6	6.2	0.0	1.39
	N	23	25	1	15	9	9

Table 4. Summary of water quality data from Sweetwater Branch, Sweetwater Canal, and Payne's Prairie Main Canal for the period of August 1987-April 1988 (Source of data: GRU, unp. records).

Location		Temp (C)	DO (mg/l)	BOD5 (mg/l)	pH (units)	Ammonia (mg/l)	TKN (mg/l)	TP (mg/l)	ortho-P (mg/l)
Upstream from WWTP	Mean	18.3	8.0	<1	7.4	<0.13	0.40	0.24	0.14
	Max	25.0	10.0	1	7.7	0.62	0.78	0.45	0.17
	Min	11.0	6.8	<1	7.0	<0.05	0.19	0.14	0.08
	N	9	9	9	9	9	8	8	8
Downstream From WWTP	Mean	22.2	6.9	9.4	6.6	2.83	4.49	4.68	4.11
	Max	28.0	7.8	17.0	7.1	5.60	8.90	7.40	5.25
	Min	17.0	6.0	4.0	6.3	1.20	2.80	3.0	2.80
	N	9	9	9	9	9	8	8	8
Sweetwater Canal	Mean	19.9	0.7	2.7	6.4	1.27	2.70	4.19	3.35
	Max	26.0	1.3	8.0	6.8	4.10	6.0	6.70	4.48
	Min	13.7	0.2	<1	6.0	0.17	1.0	2.10	1.40
	N	9	9	9	9	9	8	8	8
Payne's Prairie Main Canal	Mean	19.1	3.1	2.9	6.2	0.38	2.61	0.59	0.22
	Max	29.0	7.5	7.0	6.7	1.10	6.10	1.20	0.60
	Min	8.1	0.3	1.0	5.7	<0.05	1.10	0.07	0.06
	N	9	9	9	9	9	8	8	8

abundance of floating aquatic plants and the low flow conditions in the canal. The slope of the canal is approximately 2 feet per mile (CH2MHill,1987). The net result of these processes is a low dissolved oxygen concentration in Sweetwater Canal, typically in the range of 0-3 mg/l.

Dissolved oxygen concentrations in Payne's Prairie Main Canal, under almost identical physical and biological conditions, are of similar magnitude (see Tables 3 and 4), yet it receives no sewage effluent. This supports the thesis that natural background conditions in the prairie marsh greatly influence dissolved oxygen conditions in Sweetwater Canal (CH2MHill, 1987) and that circumstances unrelated to the effluent discharge may cause dissolved oxygen levels to fall below the existing Class III water quality criterion of 5.0 mg/l. Based on this, a Principal Flow Exemption was granted to the city of Gainesville by the Florida Department of Environmental Regulation (FDER, 1985), which established an altenative dissolved oxygen criterion for Sweetwater Canal of 0.5 mg/l with maintenance of daily and seasonal fluctuations. This exemption was valid until the time that the Temporary Operating Permit expired (March 30, 1987). The permit was extended (Regan, pers. comm.) and a new dissolved oxygen criterion of 5.0 mg/l is now in place with the point of compliance depending on backflow conditions from the prairie but practically located at the edge of the prairie (Anderson, pers. comm.).

In addition to the permitting issues involving un-ionized ammonia and dissolved oxygen, reported data indicate that some materials routinely occur in the treatment plant effluent in concentrations above Class III standards (CH2MHill, 1987). Since 1984, effluent is regularly monitored for Class III standard parameters and priority pollutants. Elevated concentrations of silver, zinc, lindane, and cyanide are apparent. Effluent concentrations of silver from August 1983 to October 1986 of 3.0 (0.0-9.0) ug/l exceeded the Class III standard of 0.07 ug/l in 23 of a total of 24 analyses. X-ray processing waste and the production of newspapers are likely the main contributors of silver to the treatment plant. From August 1983 to December 1985 zinc concentrations in the treatment plant effluent averaged 33 ug/l with a Class III standard of 30 ug/l. The standard was exceeded in 13 out of a total of 24 analyses. Wastewater of entirely domestic origin routinely averages 100-300 ug/l of zinc. From April 1984 to July 1986 concentrations of lindane, a common component of flea soap and medicine for head lice, averaged 0.07 ug/l with a range of 0.0-0.13 ug/l and a Class III standard of 0.01 ug/l. The standard was exceeded 7 times out of a total of 8 measurements. Cyanide concentrations are documented as 16.4 (0.0-28) ug/l for 12 analyses taken from November 1984 to December 1986. The Class III water quality standard of 5 ug/l was exceeded 10 times. Cyanide may occur in photographic waste, laundry detergent, and car wash waste. A program aimed at industries that use any of the above discussed materials is presently in place to help reduce their concentrations, while bio-assays are performed to test for acute toxicity (Anderson, pers. comm.). Because Main Street Wastewater Treatment Plant effluent contributes flow to surficial aquifer groundwater via Alachua Sink, wells have been selected by the city to initiate routine groundwater sampling in that area (Regan, pers. comm.).

The addition of effluent discharges and urban runoff to Sweetwater Branch has led to considerable changes in the original biota of the community of this stream and floodplain within the Payne's Prairie Preserve. Consequently, several resource management problems exist. Sediment deposition and nutrient enrichment have contributed to drastic changes in the vegetation of the area subject to inundation by Sweetwater Branch discharges. Aerial photographs from 1949 to 1968 show a gradual change toward a woody type of vegetation in this area (White, 1974), dominated by coastal-plain willow (Salix caroliniana) and elderberry (Sambucus simpsonii). Presently, such woody vegetation prevails in this northern part of the prairie. Large areas of cattail (Typha latifolia) also developed within the affected area. Furthermore, urban runoff through Sweetwater Branch (and other systems) has contributed to the spread of many exotic plant species. Examples are air potato (Dioscorea bulbifera), elephant ear (Xanthosoma sp.), water hyacinth (Eichhornia crassipes), and others. Both of these impacts on prairie vegetation conflict with the main management objective of the Florida Department of Natural Resources to restore or preserve these resources as representative samples of Florida's original natural systems, as they existed prior to the ecological disruptions caused by the arrival of Europeans, circa 1513 (FDNR, 1986).

In the Alachua Sink area, FDNR management concerns include potential contamination of upper levels of the Floridan aquifer by pollutants from Sweetwater Branch and a reduction of the sink's capacity to drain the basin due to excessive Sweetwater Branch siltation. Discussions between FDNR and the city of Gainesville have taken place in an attempt to resolve that matter. In particular, an alternative to construct a retention area (of approximately 500 acres) in the northern portion of the basin has been proposed. Such retention would decrease the sediment and nutrient load from Sweetwater Canal to the prairie (FDNR, 1986).

Wetlands biological systems as low energy tertiary treatment for waste water treatment plant effluent and urban stormwater are in use by over 400 communities in the Southeastern U.S. (EPA, 1985) and may be a cost effective alternative in this situation. Particularly, in light of the tremendous increase in cost associated with the Main Street Wastwater Treatment Plant upgrade, which is needed in order to comply with new wasteload allocation criteria, a reassessment of this option seems justifiable. Improved water resources of Sweetwater Branch can be an integral portion of the prairie's resource management program.

Natural resource management in the basin

The emphasis in management of the Payne's Prairie Preserve is different from that of other areas in the basin. Yet, management and utilization of these areas, such as Bivens Arm and its tributaries and sections of Lake Wauberg and Sweetwater Branch, has a direct effect on natural resources in the Preserve. In addition, many of the past land use practices in the basin have not been compatible with current management objectives in the Preserve. As a result, resource management problems exist.

The Preserve is managed by the Florida Department of Natural Resources (FDNR) for historic value and biological diversity. Specifically, the primary aim is to restore and maintain resources in the Preserve as representative samples of Florida's "original" (i.e. prior to the arrival of Europeans) natural systems (FDNR, 1986). As a consequence, low intensity use is emphasized and public access in the Preserve is restricted to a few designated areas. Lake Wauberg is the main area designated for recreational use. The Preserve offers boating, fishing picknicking, and swimming. The western section of Lake Wauberg is also owned by the State, but managed as a recreational facility for the University of Florida. Its use is compatible with policies of the Preserve in that area.

Management of Bivens Arm focuses on control of excessive growth of the exotic water hyacinth (*Eichhornia crassipes*) to prevent total overgrowth of the lake and to preserve its use for water recreation and fishing. The introduction of water hyacinths in the lake likely resulted in the elimination of native submerged vegetation. Subsequent hyacinth eradication efforts involving herbicides in turn reduced native emergent vegetation (Nordlie, 1976). Clear water and extensive growth of native rooted macrophytes of both submerged and emergent types, was noted in earlier descriptions of the lake (Carr, 1942). Apparently, even at that time, Bivens Arm was at least a moderately productive lake. However, urban runoff, domestic septic tank inputs, and agricultural drainage have probably contributed additional nutrients since that time, allowing dense algal blooms to develop following hyacinth removal and, thus, reducing the possibility of reestablishing rooted submergents. The flocculent sediments produced by the decomposing hyacinths may also contribute to poor reestablishment of native macrophytes (Nordlie, 1976). Regulations are now in place to reduce nutrient and sediment additions from urban sources to creek systems which contribute flow to the lake (City of Gainesville, 1987). Water from Bivens Arm passes through some marsh areas and a series of culverts before flowing onto the prairie basin floor.

Details concerning water flow to the prairie from Sweetwater Branch were documented in the previous section of this report. The use of this stream for wastewater discharges poses serious management problems for the Payne's Prairie Preserve and may degrade the quality of groundwater supplies in the vicinity. A cooperative City of Gainesville - FDNR program of water quality monitoring in Sweetwater Branch is now underway (Weimer, pers. comm.) to help evaluate the impact of the discharges. However, sediment deposition and nutrient enrichment have likely contributed to drastic changes in plant communities in the area subject to inundation by Sweetwater Branch discharges. As such, they conflict with the primary management goal of restoring and maintaining the prairie's original biological communities.

A number of other activities in the basin hinder the accomplishment of this management objective. Water level fluctuation, an effective resource management technique to restore basin communities (White, 1974), is complicated by drainage and channelization structures associated with past agricultural activities, the presence of private landholdings in the basin, and the intrusion of U.S. Highway 441 and Interstate Highway 75. Past drainage and channelization activities have altered basin hydrology. Water flow is now directed toward Alachua Sink and toward a water pumping station at Camp's Canal. The prairie's main surface water source, Prairie Creek, was diverted from the basin. Another major source, Sweetwater Branch, was channeled directly into Alachua Sink (FDNR, 1986). Low elevation private landholdings and major highways in the basin presently eliminate the option of increasing water levels to historic highs.

The hydroperiod in the basin largely determines the character and condition of its two major biological communities, wet prairie and basin marsh. A major study to develop management guidelines for the Preserve (White, 1974) recommended a flood/drought perturbation every 30 to 50 years to reduce "undesirable" pickerel weed, cattail, and willow communities and promote the "preferred" maidencane system. The flood stage should increase water level to the 60-62 foot contour over a couple of years. A substantial body of information is being accumulated which indicates that reduction of water level fluctuations alters the ecology of fresh water marshes (Goodrick and Milleson, 1974). Dugger (1976) developed a management model of the prairie basin and demonstrated an increase in plant biomass and detritus under simulated water level stabilization. In the prairie basin, a reduction of water level fluctuations has contributed to an increase in cattail, pickerel weed, and willow communities in areas which were historically occupied by a maidencane marsh system. Purchase by the State of low elevation private landholdings adjacent to the Preserve may facilitate water management. The proposed purchase of lands along the northeastern and eastern boundary of the Preserve (Hamann and Brown, 1987) will help improve water management and maintain a potential source of water of satisfactory quality for the Preserve.

Acquisition of other areas immediately adjacent to the Preserve will also facilitate the use of prescribed burns as a resource management technique. Currently, potential fire and smoke damage to private property restricts the effective use of such management programs (FDNR, 1986). Many natural plant communities in the basin are adapted to fire. Where fire frequency has been suppressed, prescribed burns must be periodically introduced to restore and maintain natural conditions. Some communities, such as the wet prairie and marsh communities, require fires on a two to three year cycle. Other communities such as upland flatwoods should burn less frequently.

Historically, grazing exerted a considerable impact on plant communities in the basin and has undoubtedly been influential in maintaining the area as a prairie/marsh system (White, 1974). Similar to fire, grazing removes standing plant biomass and relocates nutrient contents. In an effort to restore and maintain historical biological communities in the Preserve, cattle, and more recently, horses (which closely resemble the seminole horses observed by Bartram), and native American bison have been introduced. Currently, approximately 100 head of cattle, and less than a dozen horses and bison are allowed to graze the prairie (Weimer, pers. comm.).

However, several restrictions interfere with the use of grazing to manage the prairie. Selective grazing by cattle may eliminate grasses and favor growth of woody vegetation, and introduced cattle probably compete with native vertebrate and invertebrate grazers, thereby altering historical diversity. Also, problems of overgrazing when cattle are attracted to recently burned areas, interfere with management of the prairie.

A final problem encountered in the management of the Preserve's Biological communities is invasion by exotic plants and so-called "problem" species. As noted previously, exotic legumes and grasses have established themselves both in the wet prairie and drier parts of the Preserve. Several other exotics are now also common in the area, proliferate rapidly, and will often displace native plant species. Effective control measures for many of these exotics have not yet been discovered (FDNR, 1986). "Problem" species (i.e. native species which create specific management problems - FDNR, 1986) include cattail and willow. Both occur in nearly monocultural stands in areas subject to sediment deposition and nutrient enrichment. Control measures may include flooding, prescribed burning, or herbicide treatment.

Different areas in the Payne's Prairie Basin are subject to different, sometimes contrasting uses and management strategies. As a result, resource management problems and conflicts exist. To help solve these problems and conflicts, cooperation among the various managers is necessary. Data collection needs that have a high probability of leading to improved basin management must also be identified and data collected. Relevant needs are identified in the next section.

SUMMARY AND RESEARCH NEEDS

1. A reconnaissance profile is developed for the Payne's Prairie Basin, an area of more than 18,000 acres which includes the Payne's Prairie State Preserve, Bivens Arm, Lake Wauberg, and their respective contributing streams. The basin is located in southern Alachua County, Florida, on the northwestern edge of the Orange Creek Basin. The purpose of this report is to summarize and integrate all relevant scientific information regarding this basin in a single reference in order to facilitate decision making processes in basin management. A second objective is to identify water management research and data collection needs that have a high probability of leading to improved basin management.

2. The Payne's Prairie Basin is a diverse and fluctuating assemblage of wet prairie, marsh, and open water communities. Upland areas with hardwood hammocks, pine flatwoods, swamps, old fields, and ponds surround the basin. This variety of habitat and the protection from cultural disturbance results in an abundant and diverse flora and fauna. Florida's warm climate with ample rainfall, and the basin's geomorphology, with rich deposits of phosphatic sands, clays and limestone produce a very productive environment which has attracted human inhabitation for many centuries. As a consequence, people have considerably influenced the basin's ecosystems, first by hunting of larger grazers and use of fire, then by cultivation, replacement of wild herbivores with large numbers of cattle and large-scale drainage activities, and, since 1970, by policies of preservation aimed at restoring and maintaining the area as a prairie/marsh ecosystem.

3. A number of independent studies have documented water quality data for lakes and streams in the basin. Generally however, no long-term monitoring at frequent intervals has been carried out to identify trends or rates of change in water chemistry. The only exception to this is the extensive data base which exists for water quality in Sweetwater Branch. Here, the discharge of wastewater treatment plant effluent has necessitated frequent monitoring for a variety of parameters since the early 1970s. Urban development and effluent discharges in the upper reach of Sweetwater Branch, and channelization of the lower portion contributed to the development of two stream environments with very different physical and chemical characteristics. The upper segment has rapidly changing flow conditions and well oxygenated water with high concentrations of nitrogen and phosphorus downstream of the effluent discharges. Conversely, the lower portion has generally low flow conditions and frequent periods of anoxia with persistent high nutrient concentrations. The addition of effluent discharges and urban runoff to Sweetwater Branch has led to considerable changes in the biological communities of the stream and its floodplain in the Payne's Prairie Preserve. This has produced significant resource management problems, including the occurrence of nearly monocultural stands of cattail and coastal plain willow, and the potential of groundwater contamination in the immediate vicinity of Alachua Sink, the basin's primary drainage outlet to underground systems.

Bivens Arm and Lake Wauberg are very productive lakes. Both have been eutrophic for as long as water quality records are kept, and judging from sedimentary records, probably much longer. High phosphorus concentrations in the lakes may be a direct consequence of the phosphate-rich sands and clays of the surrounding land. High phosphorus concentrations, in turn, may contribute to elevated chlorophyll a levels, reduced Secchi Disk readings, anoxia in the lower water strata, and other limnological indicators of eutrophy. High calcium concentrations in Bivens Arm, the most notable distinction between this lake and Lake Wauberg, suggest that it receives wastewater from supplies using well water from the limestone aquifer. Urban and agricultural runoff are likely contributing nutrients and sediment to Bivens Arm, promoting the persistence of dense algal blooms. Little work has been done to investigate "open" prairie water quality. The limited data indicate low dissolved oxygen conditions and variable, but generally high nutrient concentrations, both typical of seasonally inundated marshes with high rates of microbial decomposition.

4. Management of the Payne's Prairie Preserve is aimed at restoring and maintaining the biological communities as representative samples of Florida's original natural systems, as they occurred prior to the arrival of Europeans, circa 1500 A.D. Effective management techniques to accomplish this goal include such pulsing factors as water level fluctuations and periodic fires. However, drainage and channelization activities associated with past land uses, the presence of private landholdings in the basin, and the intrusion of two major highways through the Preserve, severely limit the use of these management techniques. Input of sediment and nutrient rich waters from urban runoff and effluent discharges, and the invasion and persistence of exotic plant species add considerably to the difficulty of accomplishing management goals in the Preserve.

5. In the area of water management, research in basin hydrology and the ability to simulate, control, and predict seasonal and annual hydrologic cycles is needed, especially since natural water level fluctuations are no longer possible due to the hydrological impediments discussed in this report. A hydrologic model of the basin, based on water budget data, water level records, and vegetation responses to water level fluctuations, would improve the management results that can be obtained with the limited water level manipulations now possible in the basin. Additionally, a better understanding of the impact of reduced water level fluctuations on the structure and composition of the wet prairie, marsh, and open water communities would permit early recognition of changes in these communities and implementation of corrective management techniques.

The water inflow from Sweetwater Branch could be an integral portion of the prairie's resource management program if water quality were improved. Research to evaluate the effects of wastewater effluent on the ecology of the northern part of the prairie, to determine the chemical and physical composition of the sediments which are deposited in the Sweetwater Branch floodplain, and to examine the feasibility of isolating and using part of the prairie wetlands as a low energy tertiary treatment system for this effluent will result in improved water management in the basin. Deposition of sediments from Sweetwater Canal into Alachua Sink should be examined to determine if conduits to groundwater are being closed. In addition, to monitor potential contamination resulting from effluent discharges, routine groundwater sampling in the vicinity of Alachua Sink should start.

6. The Payne's Prairie Basin is a system with a complex pattern of varied and rapidly changing biological communities. Fluctuating fire and water regimes have been the dominant forces in maintaining the basin in a state

of pulse stability. If the most important management goal in the basin is to restore and preserve biological communities to their historic condition (i.e. prior to 1500 A.D.), then management should focus on the most effective way of implementing these pulsing factors within the present limitations. Research in support of this management objective should emphasize understanding, control, and prediction of these pulsing factors such that original biological communities can persist in the basin under drastically different present-day conditions.

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