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CUMULATIVE IMPACT ASSESSMENT IN THE PEARL RIVER BASIN, MISSISSIPPI AND LOUISIANA

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LSU
COASTAL ECOLOGY INSTITUTE

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Center for Wetland Resources • Louisiana State University • Baton Rouge, LA 70803-7503

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DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Office of Wetlands Protection, U.S. Environmental Protection Agency.

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CONTENTS

CONTENTS (Continued)

Page

CONTENTS (Continued)

CONTENTS (Continued

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply inch -pound units	By	To obtain metric units
inch (in.)	25.4	millimeter (mm)
cubic inch (in^3)	16.39	cubic centimeter (cm^3)
square inch (in^2)	6.452	square centimeter (cm^2)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	929	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)
acre	4,047	square meter (m^2)
acre	0.4047	hectare
acre-foot (acre -ft)	1,233	cubic meter (m^3)
ounce, avoirdupois (oz)	28.35	gram (g)
ounce, fluid (fl. oz)	0.02957	liter (L)
pint (pt)	0.4732	liter (L)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)

Temperature in degrees Celsius (° C) can be converted to degrees Fahrenheit (°F) as follows: $°F = 1.8 \times °C + 32$.

ABSTRACT

This report is an ecological assessment of the cumulative impacts of human activities in the 2.5-million-ha Pearl River basin of Mississippi and Louisiana. The analysis emphasizes landscape-level processes, to match the scale of cumulative impacts. The first chapter summarizes relevant background material on landscape ecology and resource conservation, wetlands, and regulatory jurisdiction, and gives a general description of the basin. The next four chapters analyze land cover and use, hydrology, water quality, and biota of the basin, with emphasis on changes in the past 20 years in indicator parameters that reflect basin-level processes. The last chapter summarizes and integrates material from the preceding five and suggests a possible scenario for managing the resources of the basin.

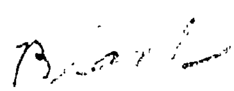
Overall the Pearl River basin is in acceptable ecological condition. About two-thirds of the basin area is forested, and the percentage has remained virtually unchanged since the 1930s. Most of the rest of the basin is in agricultural production. Stability of land use is reflected in the stability of hydrographs and rating curves. These have changed little, if at all, over the period of record. Stream hydrology is driven primarily by rainfall, infiltration, and evapotranspiration in the watershed. Water quality, as characterized by total phosphorus concentration, is generally within standards suggested by EPA, that is, less than 0.1 $mg \cdot l^{-1}$. This reflects the predominance of forest cover and forest-buffered streams in the watershed. Turbidity and total phosphorus were shown to be independent of, or to increase only slightly with, streamflow--further evidence that the watershed is not seriously disturbed. Finally, bird surveys revealed only small changes in composition over the periods of record at different sites, and these changes were related to small changes in local land use along the survey transects.

The basin functions as a whole, integrated by the flow of water from the watershed surfaces across the floodplain wetlands into and down the collecting network of streams and the Pearl River. An uninterrupted forested bottomland continuum is a key to

preserving this integrated system, particularly the 40,000-ha swamp forest of the lower Pearl River. The basin also interacts with the shallow offshore zone, where seawater salinity is measurably diluted by river water, and river outwelling provides a significant source of nutrients for aquatic plants and animals. Conversely, the river is a pathway for inland salt intrusion from the estuary and for upstream migration of marine animals

Based on the ecological analysis we suggest one scenario for the management of the basin. Management objectives should be directed towards ecological protection and enhancement of the Pearl River basin. How this can be accomplished is illustrated by one set of specific goals and by suggestions for strategies to attain these goals. The purpose of such a basin-level management plan is to provide a framework for the long-term management of the basin. When local conflicts arise, these goals provide a context that gives managers a clear vision of the future and a mandate for responsible action.

CHAPTER 1: INTRODUCTION



BACKGROUND

This study addresses general issues in environmental planning related to the cumulative impacts of human activities on the environment, a class of disturbance that regulatory agencies have found intractable. We introduce the following issues to set the stage: (1) the loss of wetland resources, (2) the legal and administrative framework for wetland regulation, (3) the nature of cumulative impacts, and (4) the use of ecological principles (specifically landscape ecology principles) in environmental planning. We follow this introduction with a cumulative impact assessment of the Pearl River basin of Mississippi and Louisiana.

The Wetland Resource

Wetlands are threatened habitats. The U.S. Fish and Wildlife Service (USFWS) (1981) reported that over half of the estimated 80 million ha of forested wetlands that existed in the United States at the time of European settlement had been lost or converted to other uses by 1975, and losses continue at a rate of 160,000-200,000 ha per year. Most hard hit are the prairie pothole marshes of the north-central United States and the bottomland hardwood forests of the southeastern states. Only about 30% of the latter remain, and 23% of the loss has occurred in the last 25 years (Abernethy and Turner 1987).

Regulatory Jurisdiction

The stated objective of the Clean Water Act (CWA) at Section 101 is to "restore and maintain the chemical, physical and biological integrity of the Nation's waters." In seeking to meet this objective, the CWA established the Section 404 permit program to regulate discharges of dredged or fill material in "waters of the United States," which include most wetlands. Permits are issued by the Secretary of the Army acting through the U.S. Army Corps of Engineers (USACE). No permit may be issued unless it meets the substantive environmental criteria contained in the Section 404 (b) (1) Guidelines. The Guidelines establish regulatory requirements used in the evaluation of proposed discharges and are promulgated by EPA in conjunction with the USACE. (See 40 CFR, Part 230.)

In practice, the definition of "waters of the United States" has been broadly interpreted by the courts to include wetlands (*U.S.* v. *Holland* 1975) and specifically most bottomland hardwood forests (*Avoyelles Sportmen's League* v. *Marsh* 1983). Although "normal" forestry and agricultural practices are statutorily exempt under Sec. 404(f) of the

CWA, clearing of forested wetlands for conversion to agricultural production is generally a regulated activity (*Avoyelles Sportmen's League* v. *Marsh* 1983; CWA 1988). Considerable clearing of bottomland hardwood forests took place before the CWA was passed, that is, before activities in wetlands became regulated. However, for both legal and technical reasons it has continued to the present. It has taken years and a series of court decisions (Natural Resources Law Institue 1988) to clarify the geographic jurisdiction of, and the types of activities exempted under, Sec. 404. For example, the U.S. Army Corps of Engineers (USACE), which jointly administers the Sec. 404 program with the U.S. Environmental Protection Agency (EPA), agreed to apply nationwide the decision in *Avoyelles Sportsmen's League* v. *Marsh* only as recently as 1984, thus extending Sec. 404 regulatory coverage over most clearing, drainage, and channeling activities of wetlands (National Wetlands Newsletter 1984). This change was not reflected in the regulations that guide permit processing until November 1986 (51 Fed. Reg. 1986: 41,206-260; codified at 33 C.F.R, §§ 320-30). For additional information on land clearing activities subject to Section 404 jurisdiction, see USACE Regulatory Guidance Letter No. 90-5, July 18,1990.

The CWA contains, in addition to permit requirements under Section 404 (b), other regulatory tools to protect waters of the the United States. Under Section 230.80 of the 404 (b) (1) Guidelines, EPA (with the USACE), can identify wetlands or other waters, in advance of the permitting process, as possible future disposal sites or as areas generally unsuitable for disposal site specification. Identification of wetlands under Advance Identification (ADID) is not a final agency action; applicants must still complete the 404 permitting process. The purpose of ADID is to gather information for better decisionmaking in the 404 permitting process. Therefore, ADID is a tool for addressing cumulative impacts and enabling a degree of regional planning. EPA also has authority under Section 404 (c) to prohibit or restrict the use of waters of the United States for the discharge of dredged or fill material (EPA's "veto" authority). EPA, as well as the U.S. Fish and Wildlife Service and National Marine Fisheries Service, have agreements with the USACE under Section 404 (q) of the CWA, that establish procedures for resolving disagreements regarding individual Section 404 permit decisions. The Section 404 (q) process has worked increasingly well as a means to improve decisionmaking and to establish consistent policy among USACE Districts nationwide.

Cumulative Impacts

An important technical hindrance to protection of wetlands has been the difficulty of managing the cumulative impacts of incremental clearing of small tracts (Lee and Gosselink

1988). A cumulative impact is defined in the Council on Environmental Quality (CEQ) regulations (which implement the National Environmental Protection Act of 1975) as:

> the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 C.F.R., §§ 1508.7 and 1508.8).

The CWA and regulations for implementation of Sec. 404 by both EPA (40 C.F.R., Part 230) and the USACE (33 U.S.C., Parts 320-330) require consideration of cumulative impacts, but for a number of reasons (Horak et al. 1983) they are seldom evaluated in permit review processes.

Conversion of bottomland hardwood forest to agriculture is a typical cumulative impact. Historically the incremental clearing of 10 to as many as 2,000 ha in an individual permit has been perceived to have no "significant" ecological impact on a total forest system of several million hectares, and the cumulative effect of many such permitted activities has been ignored (*Louisiana Wildlife Federation* v. *York* 1985). This failure can be understood if the present regulatory process is contrasted with the kind of process required for cumulative impact assessment.

The Sec. 404 permit process focuses on the impact of a proposed activity at an individual wetland permit site. In contrast, cumulative impacts are landscape-level phenomena that result from decisions at many individual permit sites (Gosselink and Lee 1987). Hence they are external to the focus of individual permit reviews. In addition the current permit process is largely reactive; that is, the decision about whether or not to permit an activity on a site is made in response to a permit request, not in advance of it. If cumulative impacts are to be managed, decisions regarding individual sites will have to be governed by earlier decisions made about the allowable extent of modification of the whole landscape unit.

Thus, cumulative impact management has the potential to change current wetland regulatory practices in two significant ways: (1) it raises the focus of management from site-specific to natural landscape units; and (2) it imposes landscape planning on the current Sec. 404 process, which is largely reactive. As noted earlier, EPA has authority for planning under the Advance Identification provisions of the CWA (33 U.S.C. (b), § 1344(c); see also 40 C.F.R., §231.1 and § 230.80).

Gosselink and Lee (1987) described a three-part methodology for cumulative impact assessment and management that incorporates both planning and a landscape-level focus: (1) *assessment*, the characterization of cumulative effects on both ecological structure and functional ecological processes in a designated landscape unit; (2) *goal setting*, agreement by public consensus on environmental goals for the assessment area, based on the assessment; and (3) *implementation*, the development of specific plans to implement the goals based on the landscape structure and function of the assessment area.

The landscape-scale requirement of cumulative impact management is addressed by choosing boundaries for the assessment unit that encompass an area that is, to the extent possible, ecologically closed to water and nutrient flows (so that sources external to the basin can be minimized) and also large enough to satisfy the home range and habitat requirements of the farthest-ranging animal species of interest (this might be, for example, the black bear or the Florida panther). The latter requirement ensures that a diverse group of biota having smaller ranges will also be encompassed in the analysis. The choice of boundaries is also influenced by such pragmatic considerations as political jurisdiction and map scales. Gosselink and Lee (1987) recommend boundaries that enclose 1 million ha or more and that are natural hydrologic watersheds or drainage basins.

To characterize an area this large, the proposed cumulative impact assessment methodology focuses on a limited number of "landscape indices" that reflect ecological structure and hydrologic, water quality, and biotic functions. By "landscape indices" we mean simple, measurable properties that integrate ecological processes over large areas. For example, a stream water quality record reflects water chemistry conditions in the watershed above the sample station. Use of long-term data records allows a time-series analysis of system change.

Landscape Ecology and Natural Resource Conservation

Troll (1950) defined landscape ecology as the study of the physicobiological relationships that govern the different spatial units of a region. It is that branch of ecology that deals with large areas and the interaction of parts within these areas. Thus, the emphasis is on the pattern of the landscape and how pattern influences ecological processes or functions. Of particular interest in this discussion of cumulative impacts is the study of island biogeography, a field pioneered by MacArthur and Wilson (1967), and the application of that knowledge to the design of ecological preserves (Diamond 1975). These studies are concerned with the size and shape of patches in the landscape, their isolation from each other, and the influence of these factors on species diversity. Whereas in the pioneering studies the patches were islands isolated by water, in applications to natural preserves the patches studied were forests isolated by grasslands, agricultural fields, or other human barriers. Diamond (1975) summarized five landscape principles for natural reserves: (1) species richness increases with forest area; (2) for a given total forest area, one large reserve will support more native interior species than two or more smaller ones; (3) for a given forest area, close disjunct patches will support more species than patches farther apart; (4) disjunct forest patches connected by strips of protected habitat are preferable to isolated patches (protected corridors facilitate animal movement between patches and provide gradual ecotones between similar habitat types); and (5) other things being equal, a circular-shaped reserve is preferable to a linear one because the former maximizes dispersal distances within the reserve and minimizes the edge relative to the interior.

Landscape ecology focuses attention on the interaction of parts in a pattern that constitues a unified whole. For resource management this means that wetlands cannot be effectively managed in isolation. They are integral parts of the total landscape, influenced by upstream and upslope events, and influencing downstream ecosystem components. Therefore, wetland cumulative impact assessment, as described by Gosselink and Lee (1987), generally includes an entire drainage unit, without regard to how much of it is jurisdictional wetland. While subsequent management may, of regulatory necessity, focus more closely on wetlands, the problems must be understood in a broader context to be effectively managed.

PURPOSE OF THE STUDY

This report is an ecological characterization of the Pearl River basin. The characterization is a historical description of the natural renewable resources of the basin and an assessment of the cumulative effects of any human activites on those resources. The study follows, in general, the methodology of Gosselink and Lee (1987). Specifically the objectives are to

1. describe the structure (land use, land cover) of the basin and its changes through time.
2. describe the ecological processes of the basin and their changes through time, specifically regarding hydrology, water quality, and biota.
3. describe the relationship between structural and functional elements of the basin.
4. describe human activities in the basin and their impact on ecological structure and function.

PEARL RIVER BASIN: GENERAL DESCRIPTION

Location and Size

The Pearl River basin lies within the East Gulf Coastal Plain of Mississippi and Louisiana, and drains an area of 22,688 km^2. Ninety percent comprises all or parts of 23 counties in Mississippi; the remainder is in parts of three parishes in southeastern Louisiana (U.S. Fish and Wildlife Service 1981). The basin is 386 km long and ranges in width from approximately 10 km near the Gulf of Mexico to 80 km farther upstream (USACE 1970) (Figure 1-1). The offshore boundary of the basin follows U.S. 90 west to the Intracoastal Waterway, then south along the Mississippi River Gulf Outlet (MRGO) to the Chandeleur Island chain. The study area then follows the outer edge of the Chandeleur Islands northeast to the Mississippi-Louisiana boundary, back northwest, and finally angles across Mississippi Sound to include marshes east of the mouth of the East Pearl River (Figure 1-2).

The Pearl, one of Mississippi's major rivers, is formed by the confluence of the Tallahaga and Nanawaya creeks in Neshoba County. From its headwaters to the formation of the East and West Pearl rivers west of Picayune, Mississippi, the river flows approximately 629 km, dividing at this point into two separate drainage systems. The East and West Pearl flow for 77 and 71 km, respectively, and empty into Lake Borgne, Mississippi Sound, and the Rigolets, arms of the Gulf of Mexico. Most of the low-water flow of the East Pearl flows into the West Pearl approximately 47 km above the mouth (USACE 1970).

The Pearl's principal headwater tributaries are the Yockanookany River and Lobutcha and Tuscalameta creeks. The Strong River in the middle reach and the Bogue Chitto in the lower are the only other major tributaries (Figure 1-1). The basin can be divided hydrologically into the following nine subunits: Upper Pearl River, Yockanookany River, Pelahatchie Creek, Tuscalameta Creek, Richland Creek, Strong River, Middle Pearl River, Bogue Chitto River, and Lower Pearl River (from north to south) (U.S. Geological Survey 1976) (Figure 1-3).

Much of the Pearl River has remained relatively undisturbed. The Louisiana legislature included the entire West Pearl River in the state natural and scenic rivers system, attesting to the biological value of the area (Office of State Planning, personal communication).

There are numerous small lakes in the basin. The only large lake is the Ross Barnett Reservoir, constructed by the Pearl River Valley Water Supply District in 1964 to provide municipal and industrial water supply and recreation. Located along the Pearl River just above Jackson, the reservoir is 29 km long and averages 4 km in width (USFWS 1981).

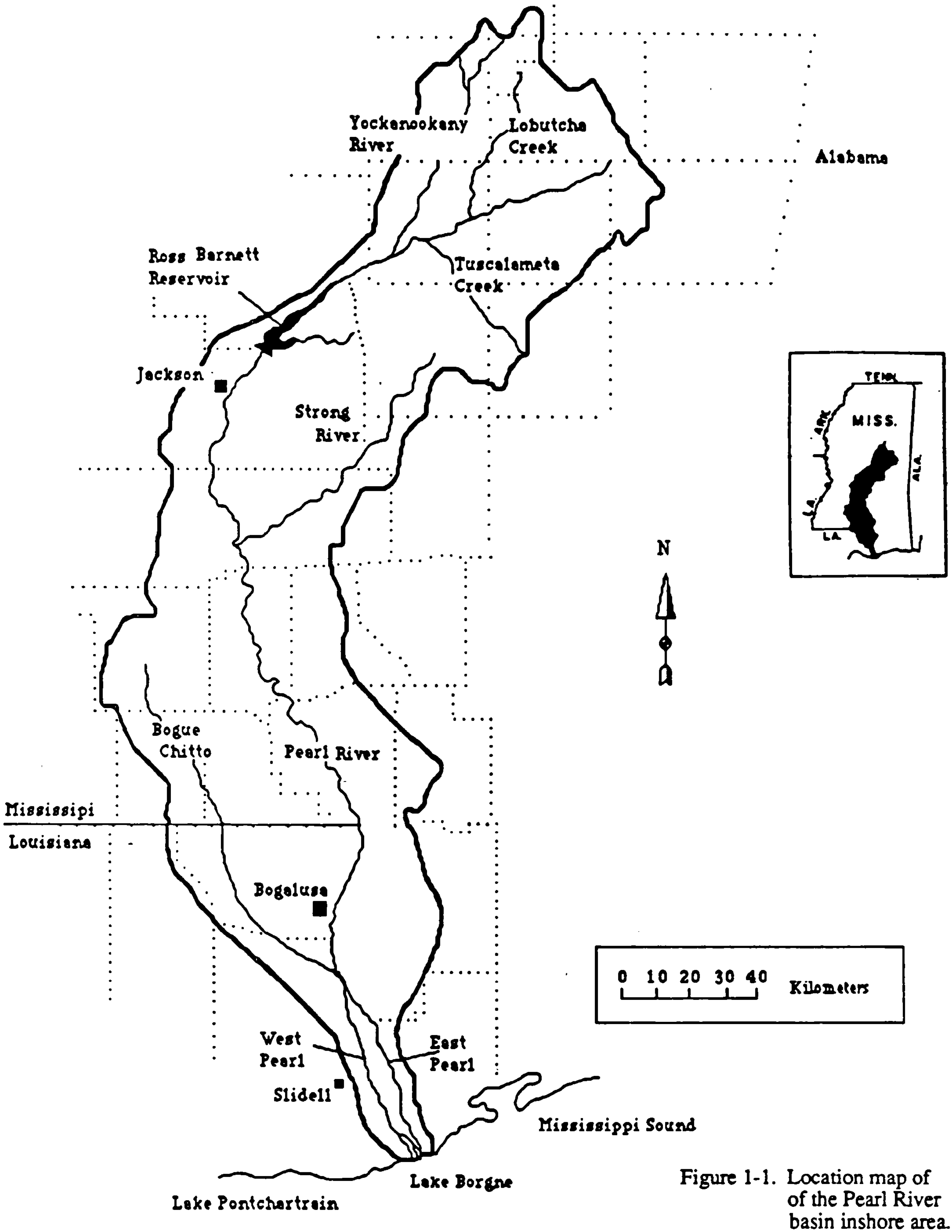


Figure 1-1. Location map of of the Pearl River basin inshore area.

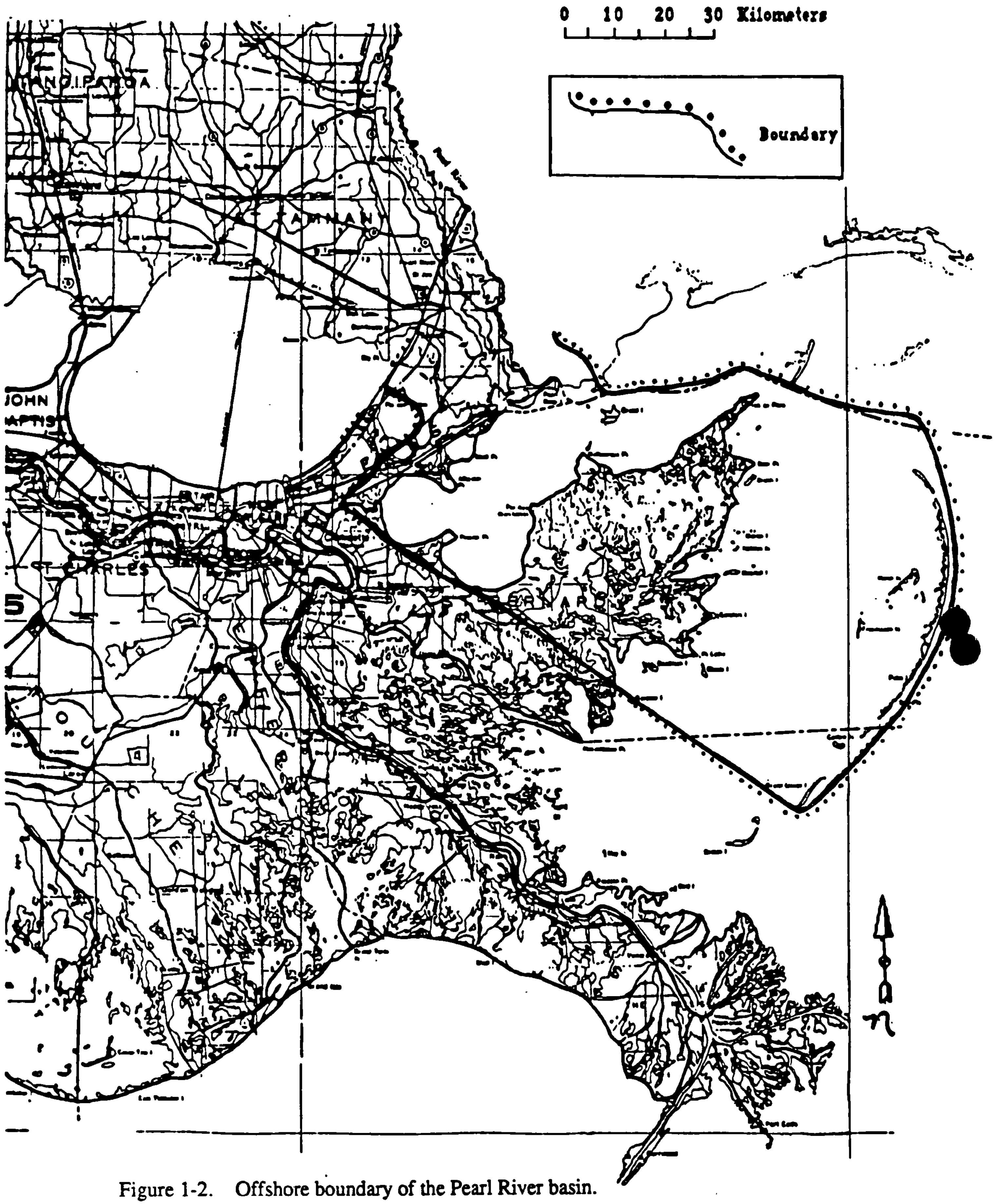


Figure 1-2. Offshore boundary of the Pearl River basin.

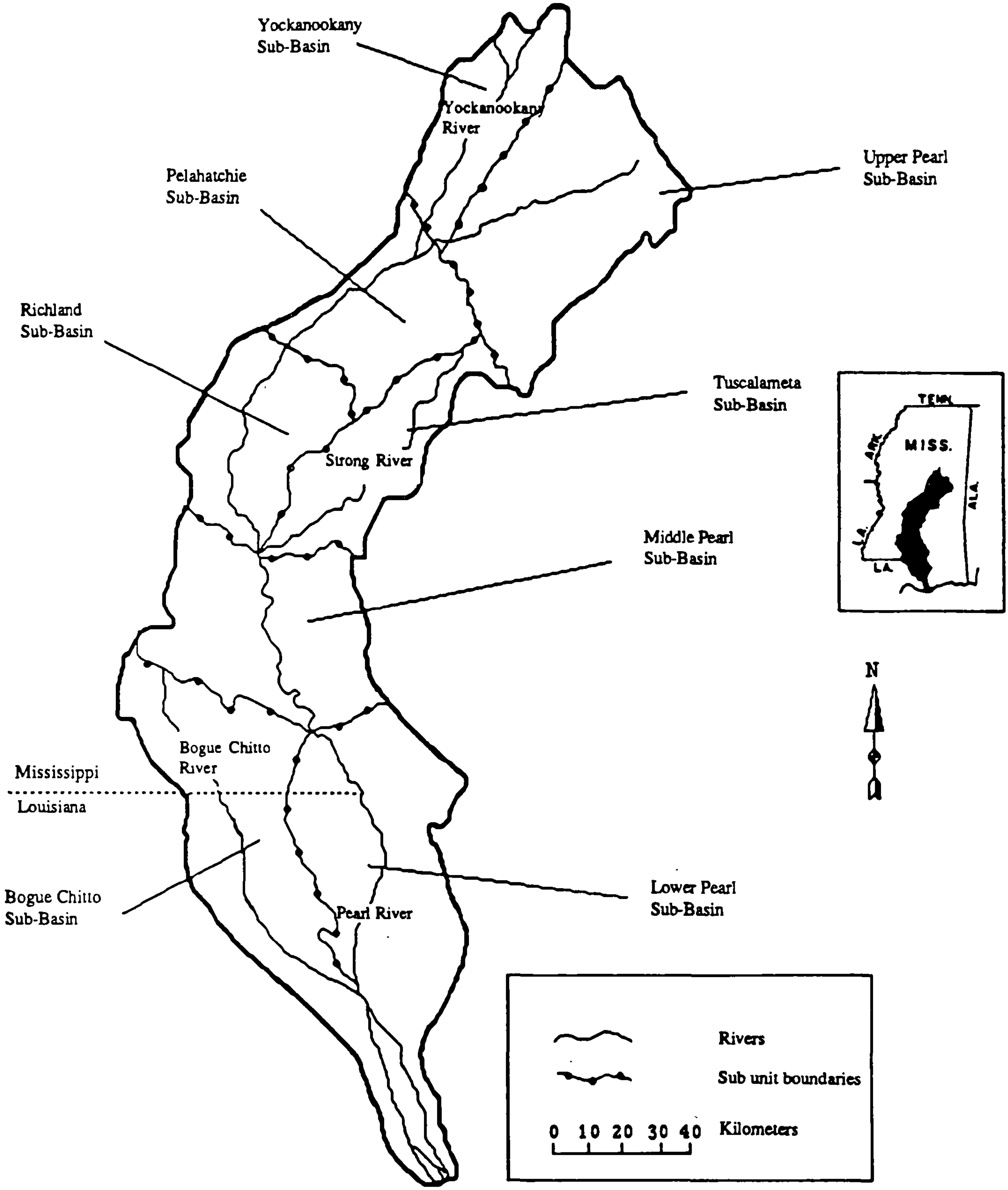


Figure 1-3. Hydrologic sub-basins of the Pearl River study area.

Climate

The climate of the Pearl River basin is determined principally by the huge continental land mass to the north, the subtropical latitude, and the Gulf of Mexico to the south. The resultant long, hot summers, mild winters, and heavy rainfall are typical of the humid subtropics. Annual precipitation in the coastal area averages approximately 163 cm; the north-central portion receives approximately 132 cm per year (USFWS 1981). Mean average annual temperature varies from 18° C in the northern portion of the basin to 19° C in the south. Mean average July temperature is 27° C north and south (USACE 1970).

Landforms and Vegetation

The East Gulf Coastal Plain within which the basin lies is physiographically divided into the North Central Plateau, Jackson Prairie, Southern Pine Hills, and Coastal Pine Meadows districts (Figure 1-4). Elevations range from sea level in Coastal Pine Meadows to nearly 198 m in the North Central Plateau (USACE 1970).

The North Central Plateau can be divided into a wide upland area on the north, cut by streams into hills and valleys, and a narrower belt to the south called the Buhrstone Cuesta. Sandy formations underlie the surface at various locations, absorbing and storing large amounts of groundwater. The North Central Hills gradually descend into the gently rolling country of the Jackson Prairie, a relatively narrow belt with numerous prairie-like tracts containing excellent farmland. The relatively smooth topography results from the weathering of clayey formations. The red and yellow clay uplands of the North Central Plateau and Jackson Prairie support stands of mixed hardwoods and loblolly and short-leaf pine; gums, oaks, and hickory characterize the lowlands (USACE 1970).

South of Jackson Prairie lie the sloping uplands of the Southern Pine Hills. This region is underlain mainly by sandy, porous soils noteworthy for their capacity for storing large volumes of rainwater, which maintain the substantial flows of the streams in the basin below Jackson. The larger tributaries of the Pearl cross this upland in wide, flat-bottomed valleys with 30- to 90-m-deep slopes (USACE 1970). The Southern Pine Hills formerly supported dense stands of slash and long-leaf pine; however, most of this has been cut for timber. Reforestation with conifers and some hardwood cultivation are currently major activities.

Coastal Pine Meadows is a low-lying, district that borders Mississippi Sound, Lake Borgne, and Lake Pontchartrain. The landscape, generally flat with large tracts of swamp and marsh, supports mostly long-leaf and slash pine in the higher portions (USACE 1970); bottomland hardwood forests of oaks, bald cypress, tupelo, etc., in the low-lying elevations; and freshwater to brackish marshes nearer the coast.

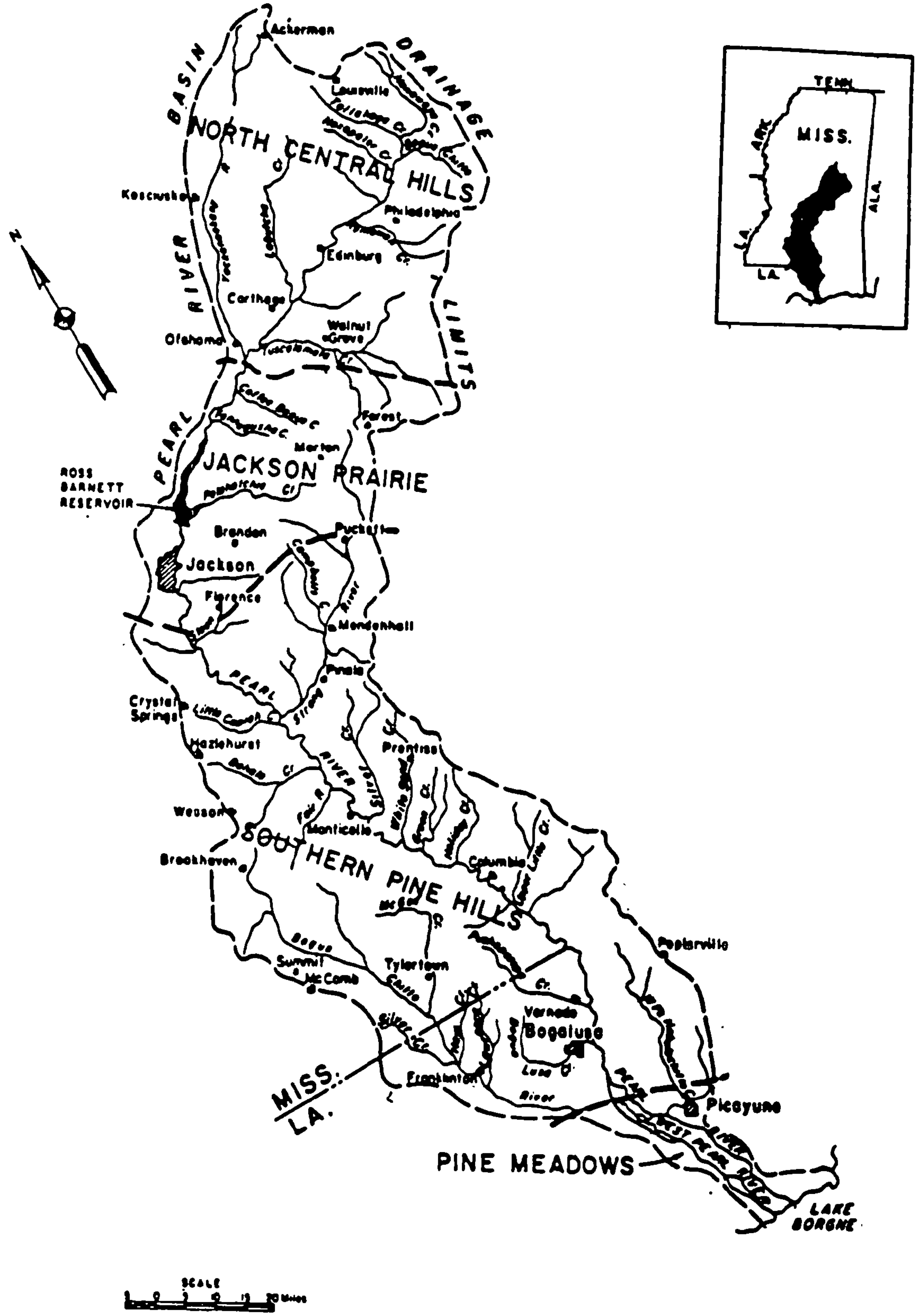


Figure 1-4. Physiographic regions of the Pearl River basin (from USACE 1970).

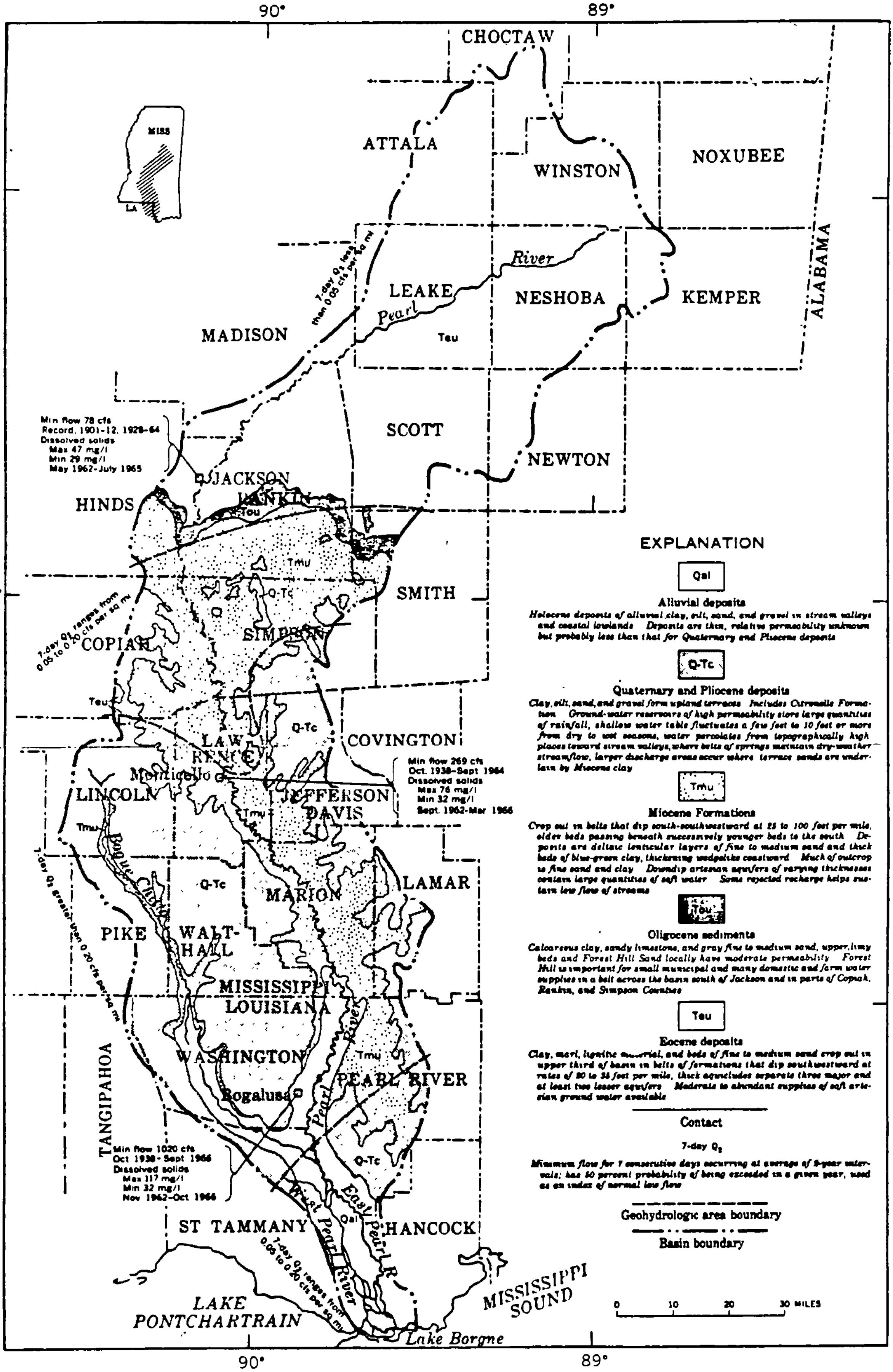


Figure 1-5. Geo-hydrologic features of the Pearl River basin, Mississippi and Louisiana (from U.S. Geological Survey 1972).

Geology and Soils

Geologically the basin is not a contained unit because formations extend beyond topographic divides into adjoining stream basins (USACE 1970). At the surface, formations are sedimentary and range from Eocene to Recent. They dip southwestward throughout the northern three-fourths of the basin except where interrupted by structural features such as the Jackson Dome and other smaller salt domes. In the southern portion the rate of dip becomes steep as a result of pronounced downwarping toward the Mississippi River structural trough (USACE 1970). Figure 1-5 illustrates geologic features of the Pearl River basin.

Sand and clay constitute most of the sedimentary deposits extending from the northern portion of the basin to the coast; marl, limestone, and glauconitic and lignitic material are also present in several locations. The low natural fertility of the forest soils that generally characterize the basin offsets the effects of the basin's highly productive climate (USACE 1970).

Socioeconomic Development

The basin was divided into Upper, Middle, and Lower Pearl subareas to facilitate socioeconomic analysis. These regions reflect groups of counties/parishes strongly related by watershed factors, water needs, geographical characteristics, and economic activity (Figure 1-6).

Population

Total population of the basin increased from 127,000 in 1870 to 420,200 in 1930, and 845,000 in 1970. More recent population trends indicate a large increase in population in the 1970s to slightly over 1 million in 1980 (U.S. Bureau of the Census 1940-1980) (Figure 1-7). The urban population more than tripled from 1930 to 1960, increasing from 102,500 to 308,900. Of the urban population increase during this period, 51% resulted from growth at Jackson, the largest urban center in the basin. Rural nonfarm population increased 184% from 75,700 in 1930 to 214,900 in 1970. Rural farm population during this period decreased from 242,000 to 67,000, reflecting the national trend of migration from rural areas to urban centers and their environs (USACE 1970).

Historically, the population size of the Pearl River basin has fluctuated, except in the lowermost portion, where sustained growth has occurred since 1870. The agriculture-dependent Middle Pearl subarea contained nearly one-half of the basin's population in

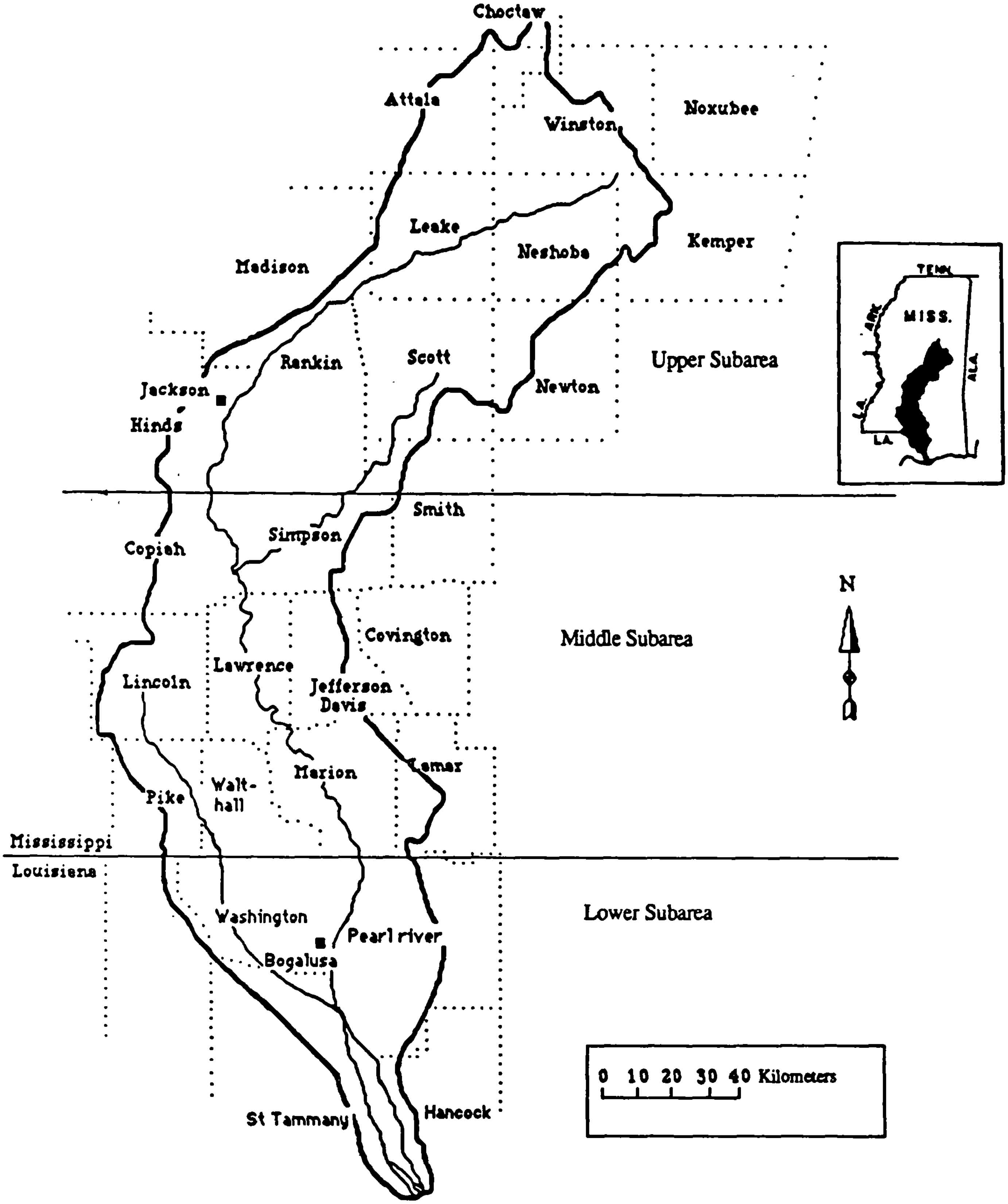


Figure 1-6. Subareas of the Pearl River basin.

1870, but only 31% in 1960. The Upper Pearl increased in population after 1920 until 1960; growth accelerated from about 1940.

Total population in the basin is projected to increase to 1,035,922 by 2020 (Maruggi and Fletes 1983; Mississippi Research and Development Center 1986; Mississippi State University 1986). Urban population growth is expected to continue at a faster rate than rural nonfarm. Rural farm populations are expected to continue to decline (USACE 1970).

Employment

Once almost totally dependent on agriculture, the basin's economy is now in a period of diversified manufacturing and nonagriculture/nonmanufacturing activity (Figure 1-8). Manufacturing employment increased from 22% in 1960 to 38% in 1985. By 2020, employment in manufacturing is expected to increase to about 213% over that of 1970. Clothing, lumber, wood, furniture, pulp and papers, and food-processing industries provide the major part of employment in manufacturing (USACE 1970).

Although agriculture is still an important segment of the basin's economy, its relative importance continues to decline as the economy becomes more diversified. The number of farms decreased from 51,871 in 1939 to 26,773 in 1964, and is projected to decrease to 14,543 by 2020 (USACE 1970). Principal crops are cotton, corn, oats, soybeans, and hay. Livestock and livestock products (principally broilers and eggs) are an integral part of the basin's agricultural economy and are expected to become more important in the future (USACE 1970).

The area occupied by forests in the basin is considerably larger than the acreage devoted to all other land uses. Forestry resources have fluctuated only moderately since 1930, and little change is expected in the future. The trend toward conversion of farmlands to forests has tended to offset the effects of land clearing. Employment in timber-based manufacturing industries in the basin has steadily increased, growing from 730 in 1930 to 3,800 in 1960. Employment is projected to be 12,000 in 2015 (USACE 1970). Much of this increase is expected from pine plantings of open areas, inter- and underplantings, stand conversion, and better management of forest land. A variety of sawmills, wood preserving plants, veneer plants, and other wood processing industries are located throughout the basin.

Labor Force and Income

The labor force of the upper subarea of the Pearl River basin increased about 60% during 1930-1960 (USACE 1970), mainly because of the development of Jackson as a

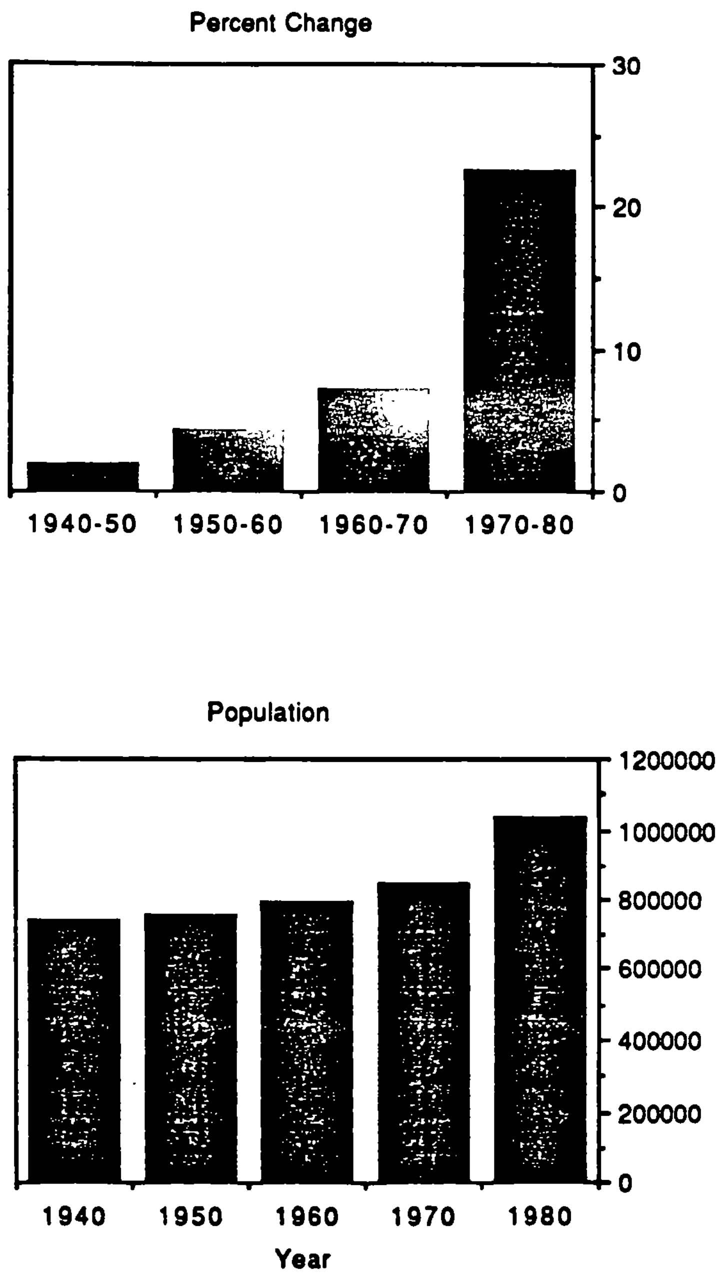
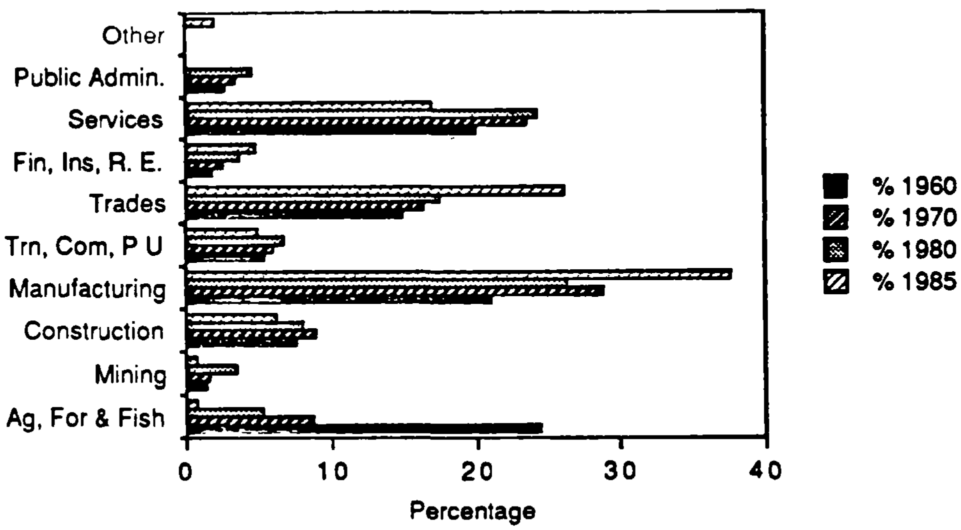


Figure 1-7. Population trends for the Pearl River basin (from U.S. Bureau of Census, 1940-80).



Abbreviations:

Public Admin. = Public Administration,

Fin, Ins, R. E. = Finance, Insurance, & Real Estate,

Trn, Com, P U = Transportation, Communication, & Public Utilities,

Ag, For & Fish = Agriculture , Forest & Fish.

Figure 1-8 Major sources of personal income during 1960-1985, by percentage, in the Pearl River basin (from U.S. Bureau of Census 1960-1985).

government-distribution-finance-service center. This subarea also has provided, and is expected to continue to provide, the greatest personal income advances for the basin.

The labor force in the agriculture-dependent middle subarea declined from 40% of the study area total in 1930 to 29% in 1960 (USACE 1970). Likewise, the rate of personal income growth in the middle subarea has declined since 1940. Slow urban growth and lack of diversified economic development are expected to continue to retard future income growth in this area.

The labor force in the lower subarea is predicted to multiply more than tenfold during 1960-2015 (USACE 1970), partly as a result of economic stimuli provided by the National Aeronautics and Space Administration (NASA) facility near Slidell. Future personal income growth in the lower subarea, located in the path of rapidly expanding urban and tourist development between the Mississippi Gulf Coast and New Orleans, should accelerate at a greater rate than it has in the past. (USACE 1970).

Protected Areas

Protected areas within the Pearl River basin are shown in Figure 1-9. Portions of two national forests are located in the upper portion of the basin (Bienville and Tombigbee) and are administered by the U.S. Forest Service for timber production and as habitat for fish and wildlife species. The Bogue Chitto National Wildlife Refuge encompasses approximately 40,000 acres of primarily bottomland hardwoods along the Pearl River in Pearl River County, Mississippi, and St. Tammany and Washington Parishes, Louisiana. Breton National Wildlife Refuge is located in the Chandeleur Islands.

State wildlife management areas in the basin include Bienville and Caney Creek in the upper portion of Bienville National Forest; Dancing Waters and Choctaw in the northeast portion; the Pearl River Waterfowl Refuge and Management Area adjacent to Ross Barnett Reservoir in Madison County; Marion County Wildlife Management Area (WMA); Wolf River WMA located in Marion, Lamar, and Pearl River counties (the largest in the basin at 240,000 acres); the 40,000-acre Pearl River WMA in St. Tammany Parish, Louisiana; and the White Kitchen tract, recently purchased by the Nature Conservancy.

Several Choctaw Indian reservations are located in the northern portion of the basin. Three state parks are managed in the upper basin, one in the lower portion. The Natchez Trace Parkway, administered by the National Park Service, runs through the western portion of the upper and middle basin from the Choctaw-Attala county line to Jackson. Coastal marshes encompass approximately 23,000 acres in Mississippi and Louisiana. At present, none of the coastal marsh in the basin is in state or federal ownership (USFWS 1981).

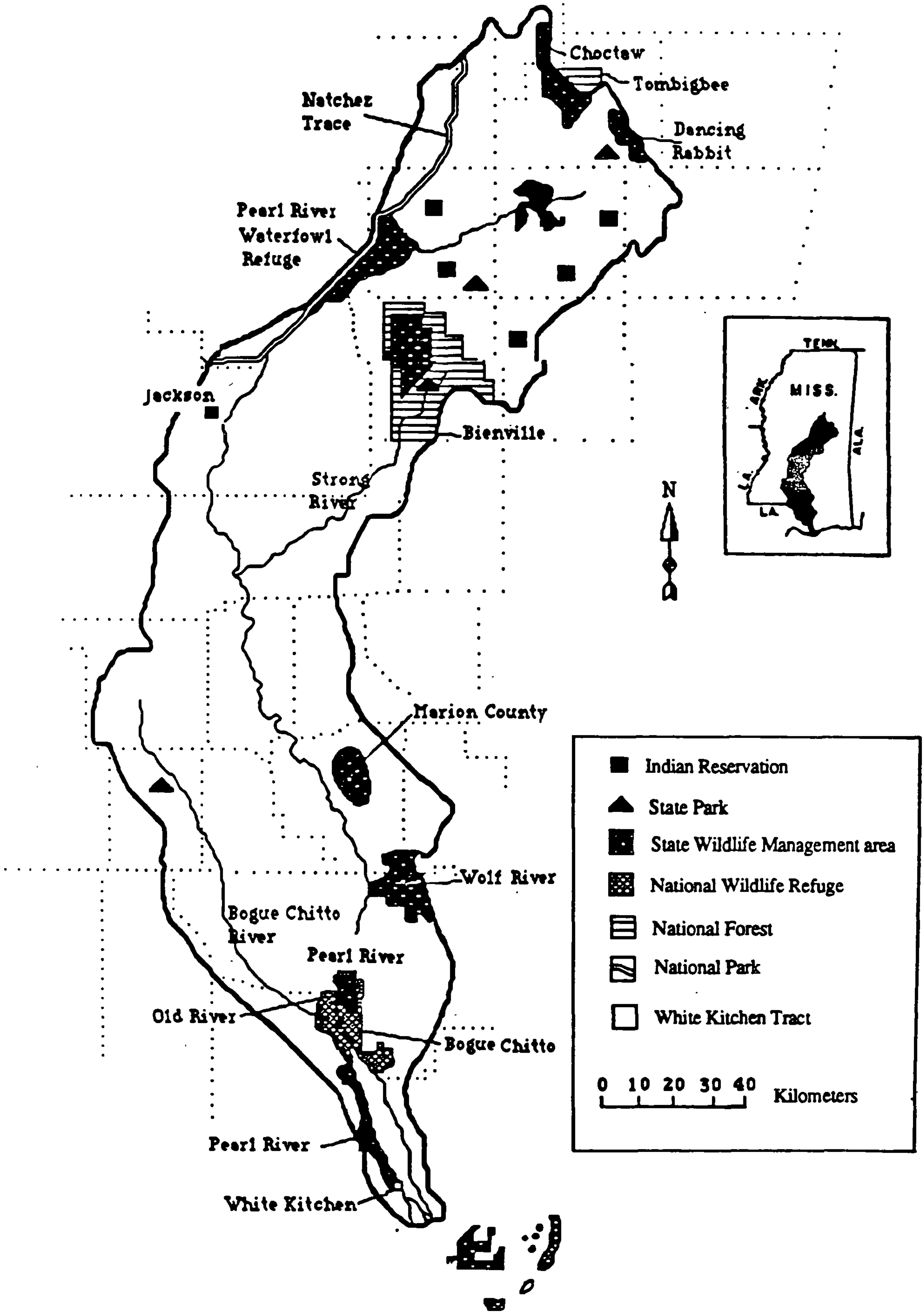


Figure 1-9. Protected areas within the Pearl River basin.

Scenic Streams in Louisiana that are protected include Pushepatapa Creek, Bogue Chitto River, and West Pearl River. Mississippi has no official designation; however, portions of the Yockanookany River, Strong River, Bogue Chitto River, Magees Creek, and West and East Hoboolochitto creeks, among others, have been proposed as wild and scenic streams.

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CHAPTER 2: LAND USE IN THE PEARL RIVER BASIN

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INTRODUCTION

The ecological functions and values of a landscape are related to a large degree to its land use characteristics. The biotic communities supported and the water quality and flow characteristics of rivers and streams all can vary depending upon the ratios of the different land uses practiced in the region.

This chapter, which describes land cover and use characteristics of the Pearl River basin, is one of four basic units of the overall cumulative impact assessment of the Pearl River basin. The goal of the chapter is to assess the historical land uses of the Pearl River basin, document its recent (1987) land use characteristics, and present these data within a framework that allows the investigation of relationships between land use practices and their cumulative environmental effect on the basin's water quality, hydrology, and biota.

METHODS

Description of the Study Area

The Pearl River basin is located in south-central Mississippi and a small part of extreme southeastern Louisiana (Figure 2-1). The Pearl River flows generally from north to south for about 640 km to the Gulf of Mexico, draining an area of about 2.3 million ha along its course.

The Pearl River is typical of many streams in the southeastern United States; its low stream gradient and broad, flat flood plain produces extensive meanders, natural cutoffs, oxbow lakes, and overflow channels. The flood plain is largely forested with bottomland hardwoods, bald cypress, and tupelo gum. Unlike most rivers and streams in the Southeast, the Pearl has escaped extensive modification. What little development has occurred is in towns and cities along the river, especially in the Jackson and Slidell areas.

The major tributaries of the Pearl River, whose watersheds form subunits (sub-basins) of the study area, include Lobutcha Creek, Tuscalameta Creek, Yockanookany River, Strong River, Bogue Chitto River, Richland Creek, and Pelahatchie Creek.

The inshore portion of the study area is bounded on the north by the Tombigbee River basin (USGS hydrologic unit number 0316), on the east by the Pascagoula River basin (0317), and on the west by the Mississippi River basin (0804) and several small streams that drain into Lake Ponchartrain in Louisiana. On the south the offshore area influenced by discharge from the Pearl River is poorly defined. For this study we included parts of Mississippi Sound and Lake Borgne and defined the boundaries as follows: U.S. 90 West from the land boundary of the West Pearl River to the Intracoastal Waterway, then south along the Mississippi River Gulf Outlet (MRGO) to the Chandeleur Islands, the outer

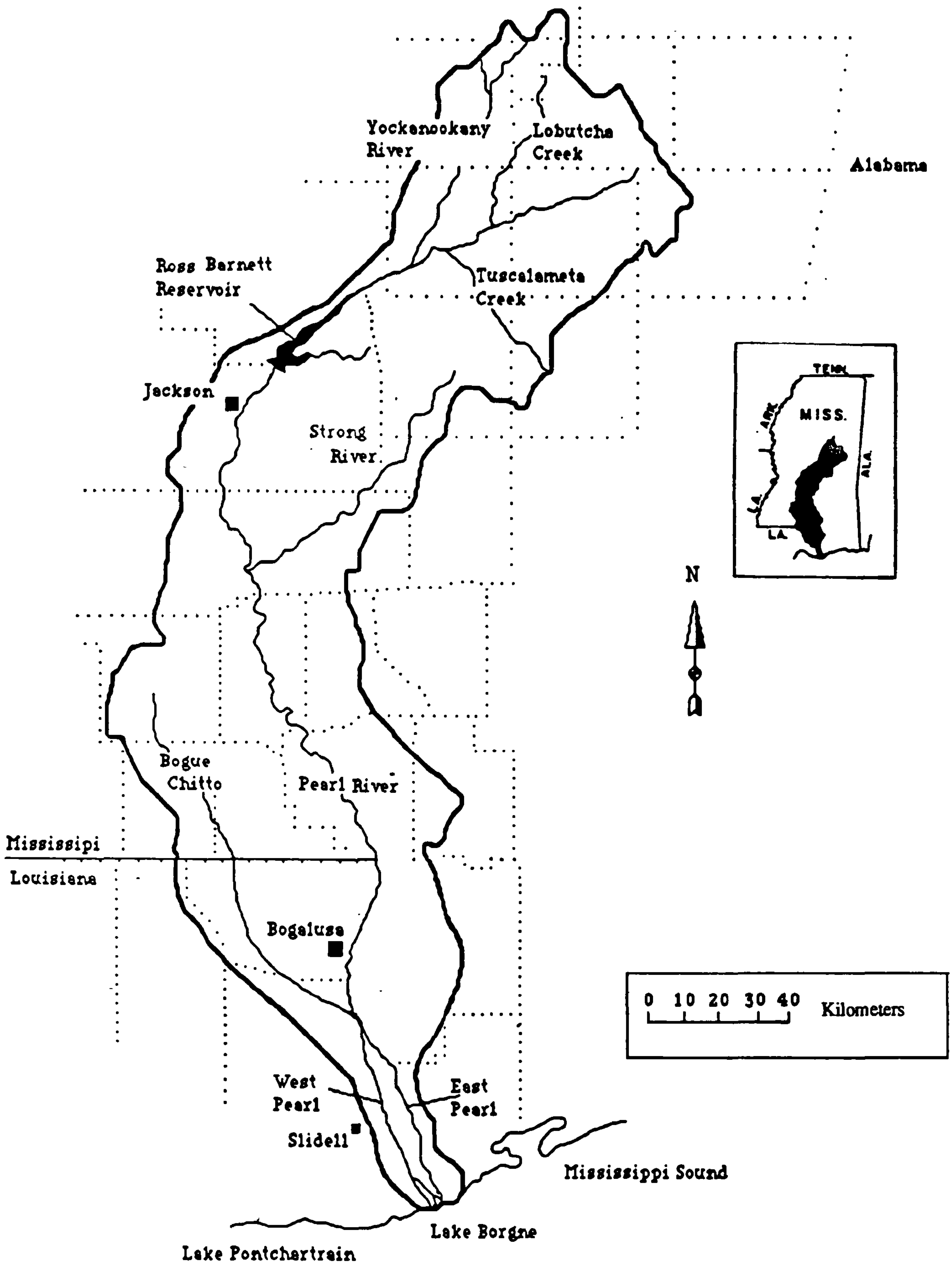


Figure 2-1. Location map of the Pearl River basin.

edge of the Chandeleur Island chain northeast to the Mississippi-Louisiana boundary, then northwest across Mississippi Sound to the mouth of the East Pearl River (Figure 2-2).

Inshore Study Area

Land Use Mapping

All land use mapping and analyses of digital, spatial land cover data for the inshore zone were performed by the Mississippi Automated Resources Information System (MARIS). The 1973 land use information was obtained from an existing MARIS digital data base covering the study area. In the 1973 study land use had been manually interpreted directly from high-altitude color infrared aerial photography scaled at 1:120,000, then plotted on a film base at 1:24,000 scale. Data were digitized and originally gridded into 50m x 50m cells, then generalized into 250m x 250m cells for this study.

Landsat-MSS images from a December 1987 overpass covering the study area were machine classified. Classification judgments were made using 1987 color infrared (CIR) aerial photographs at a scale of 1:60,000 to confirm the machine classification. Data were stored in 250m x 250m grid cells (6.25 ha/cell) in a geographic information system (GIS) established for this study.

The following 10 land use categories were mapped for both data bases:

Agriculture	any area of cropland, pasture, or grassland
Coniferous Forest	> 80% pine species
Deciduous Forest	> 80% non-pine species
Mixed Forest	mix of pine and non-pine; neither >80%
Bottomland Hardwood Forest	described below
Forested Wetland (Swamp)	forest with standing water
Non-forested Wetland	marsh
Urban	
Water	
Other	

In the 1973 land use data base, bottomland hardwood (BLH) forests were defined by overlaying county flood maps produced by the U.S. Department of Housing and Urban Development (HUD). Bottomland hardwood forests were those areas within which deciduous forests overlapped the flood zone.

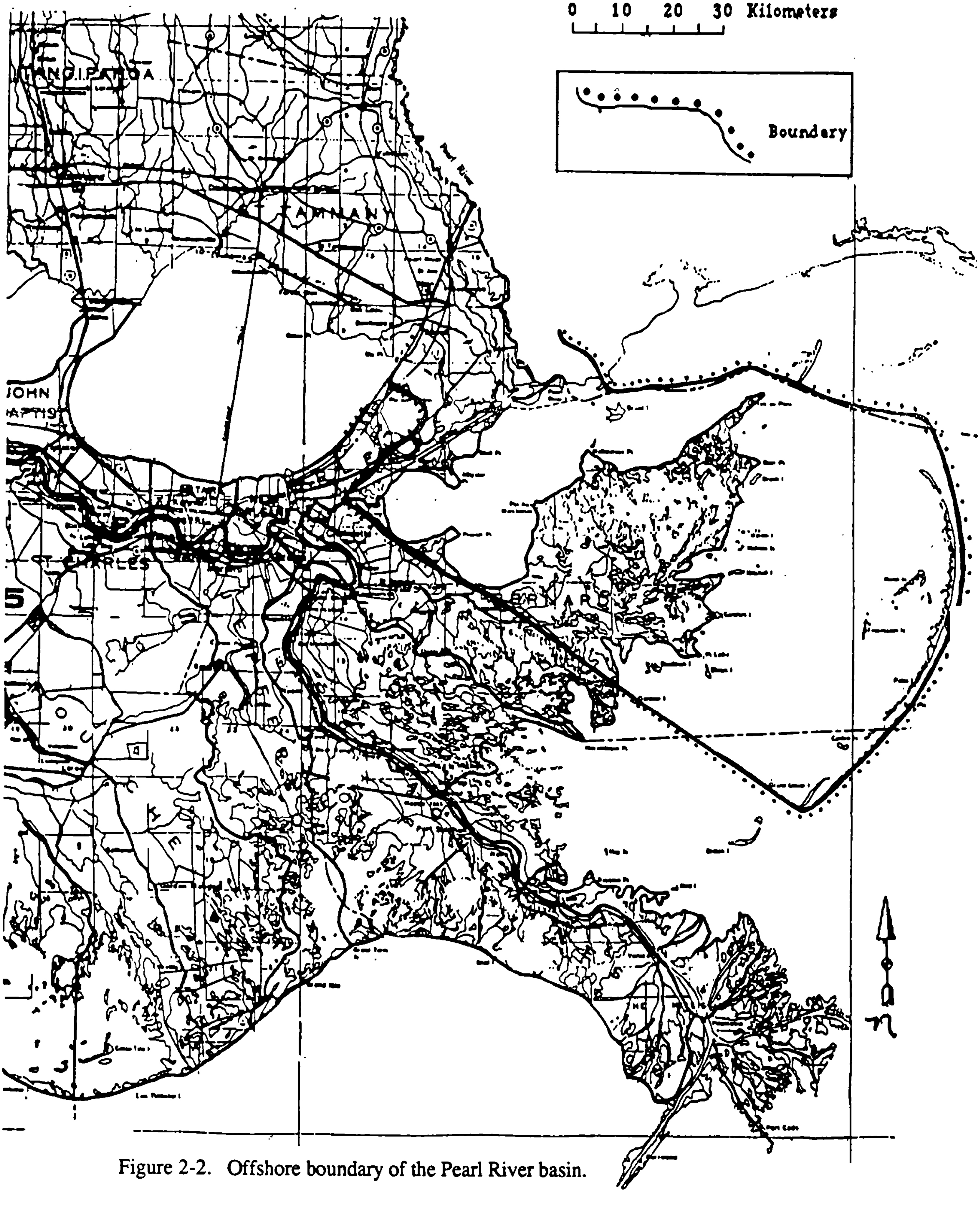


Figure 2-2. Offshore boundary of the Pearl River basin.

Bottomland hardwood forests were distinguished in two ways in the 1987 data base: (1) areas of deciduous forest located exclusively on river bottoms were classified directly from the Landsat imagery, and (2) deciduous forest coinciding with overlaid hydric soils were further classified as BLH forests.

Historical Land Use Data

Historical data on forest and agricultural land use by county in the Pearl River basin were obtained from the U.S. Forest Service (USFS) and U.S. Department of Ariculture (USDA).

Forest Patch Analysis

Size and frequency of forest patches within the Pearl River basin in 1987 were determined for each sub-basin. Forest categories included in the analysis were coniferous, deciduous, mixed, bottomland hardwood, swamp, and total forest.

Stream Edge Habitat

Land uses within a 250-m strip bordering each stream edge of the nine major tributaries and subregions of the Pearl River were determined from the 1987 land use data base.

Offshore Study Area

Land use characteristics of the offshore portion of the study area were determined from the U.S. Fish and Wildlife Services (USFWS) 1956 and 1978 digital data bases (Wicker 1980), accessed through the Louisiana Department of Natural Resources, Coastal Management Division (CMD). The data for 1956 were based on interpretations of black-and-white photographs, and the data for for 1978 on color infrared photographs. Land use statistics were generated by CMD for the offshore study area for both 1956 and 1978, and land use change maps were determined for that interval.

RESULTS

Inshore Study Area

Historical Land Cover Trends

USDA data indicate that the area of agricultural land in the Pearl River basin has remained fairly constant since 1935. In 1935 about 648,000 ha were used for agriculture and pastureland, about the same as in 1985 (Figure 2-3). Likewise, the areas of upland forest (1.2 million ha) and of wetland forest (240,000 ha) have remained fairly constant since the 1960s (Figure 2- 3).

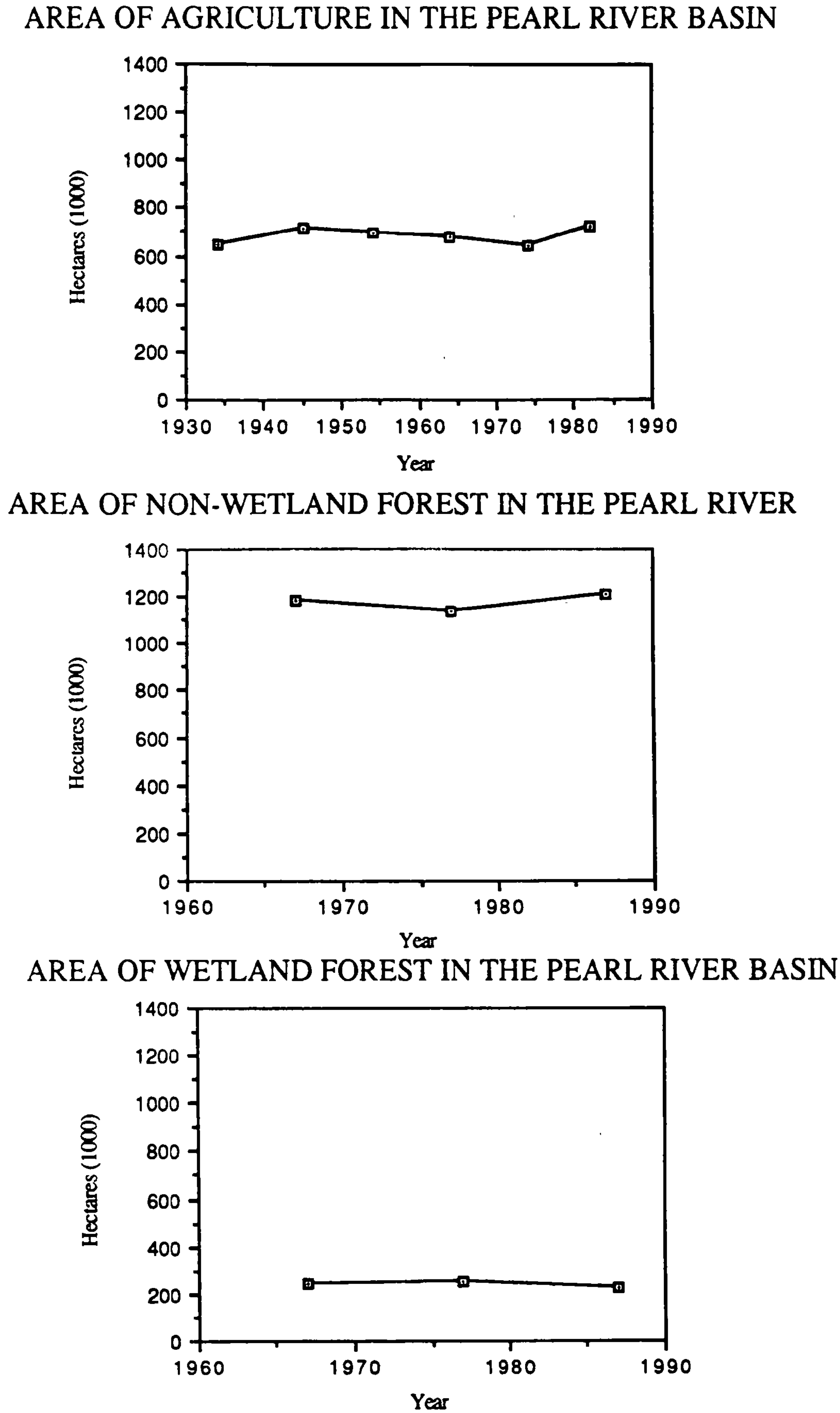


Figure 2-3. Area of agriculture and forested land in the Pearl River basin between 1930 and 1985 (USFS, USDA).

In 1973 the Pearl River basin was 61% forested, of which about 49% was upland forest. Coniferous forest made up 26% of the basin; deciduous and mixed, 23%; bottomland hardwoods, 10%; and swamp forest, 3%. Agriculture and grassland made up about 33% of the basin's land area; urban area, about 3%; and water, nonforested wetland (marsh), and a miscellaneous category combined, a total of less than 3% (Figure 2-4).

Land use statistics from the 1987 data base are similar to those for 1973. Total forest cover of the entire basin had increased slightly to about 64%; about 52% of this was upland forest. Included within the total forest cover were coniferous, 29%; deciduous and mixed, 23%; bottomland hardwoods, 7%; and swamp forest, 4% (Figure 2-4).

Figures 2-5 through 2-13 present 1973 and 1987 land use statistics for each of the nine sub-basins of the study area. As seen on the land use maps (Figures 2-14, 2-15), forest and agriculture are interspersed throughout the basin, with rather minor variation from one sub-basin to another.

Agricultural land use decreased in seven of the nine sub-basins. Only in the two southernmost sub-basins did agricultural land use increase. Coniferous forest cover increased in six of the nine sub-basins; it decreased in Pelahatchie, Richland Creek, and Strong sub-basins. Cover by mixed deciduous forests increased in four of the nine sub-basins, all in the upper basin.

Wetlands covered from 8% to 19% of the area within the sub-basins. Most of the approximately 20,000 ha lost between 1973 and 1987 in the Pearl River basin were in the northernmost four sub-basins. Overall, loss rates during 1973-1987 ranged from 1% in the Lower Pearl to 4% in the Upper Pearl and Tuscalameta Creek sub-basins.

Stream Edge Habitat

Land cover adjacent to the stream edges of the Pearl River and its major tributaries was calculated from the 1987 data base. Of the strip within 250 m of the edges of these streams 85% was forested; 65% of the stream edge "buffer" was covered by BLH or swamp forest (21% swamp, 43% BLH). An additional 10% of this land was in agriculture, 3% urban, 2% marsh, and less than 1% other (Figure 2-16).

Figure 2-17 includes percentages of land use categories within the stream-edge buffer for all nine tributaries and subregions of the Pearl River. Areas of agricultural land adjacent to streams varied from a low of 3% along Pelahatchie Creek to 22% along the Bogue Chitto River. Upland forest stream edge varied from about 7% along the Lower Pearl River to about 28% along the Bogue Chitto River. Wetland forest edge varied from about 43% along the Bogue Chitto River to 78% edging the Upper Pearl River. In the

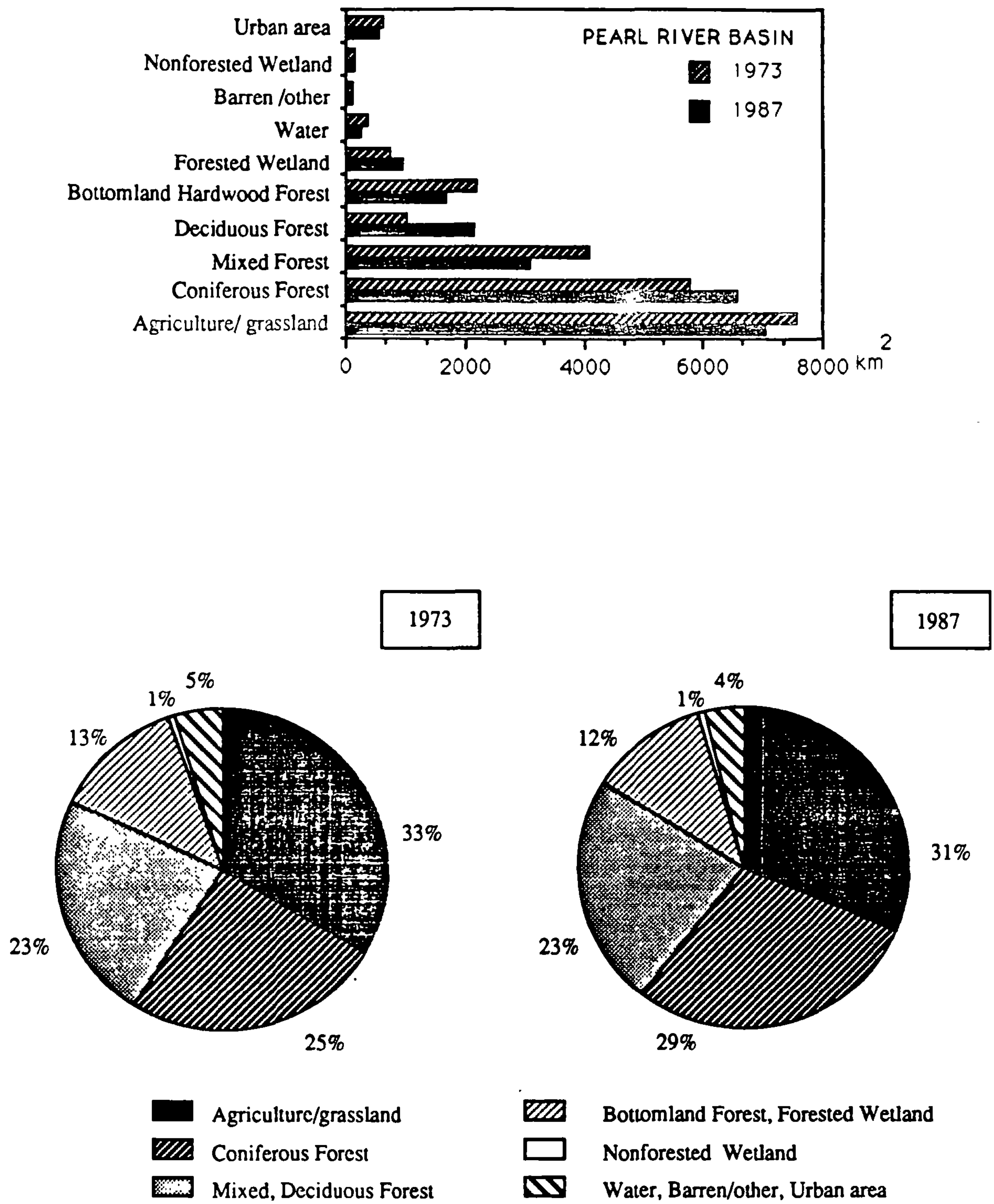


Figure 2-4. Land use in the Pearl River basin, 1973 and 1987.

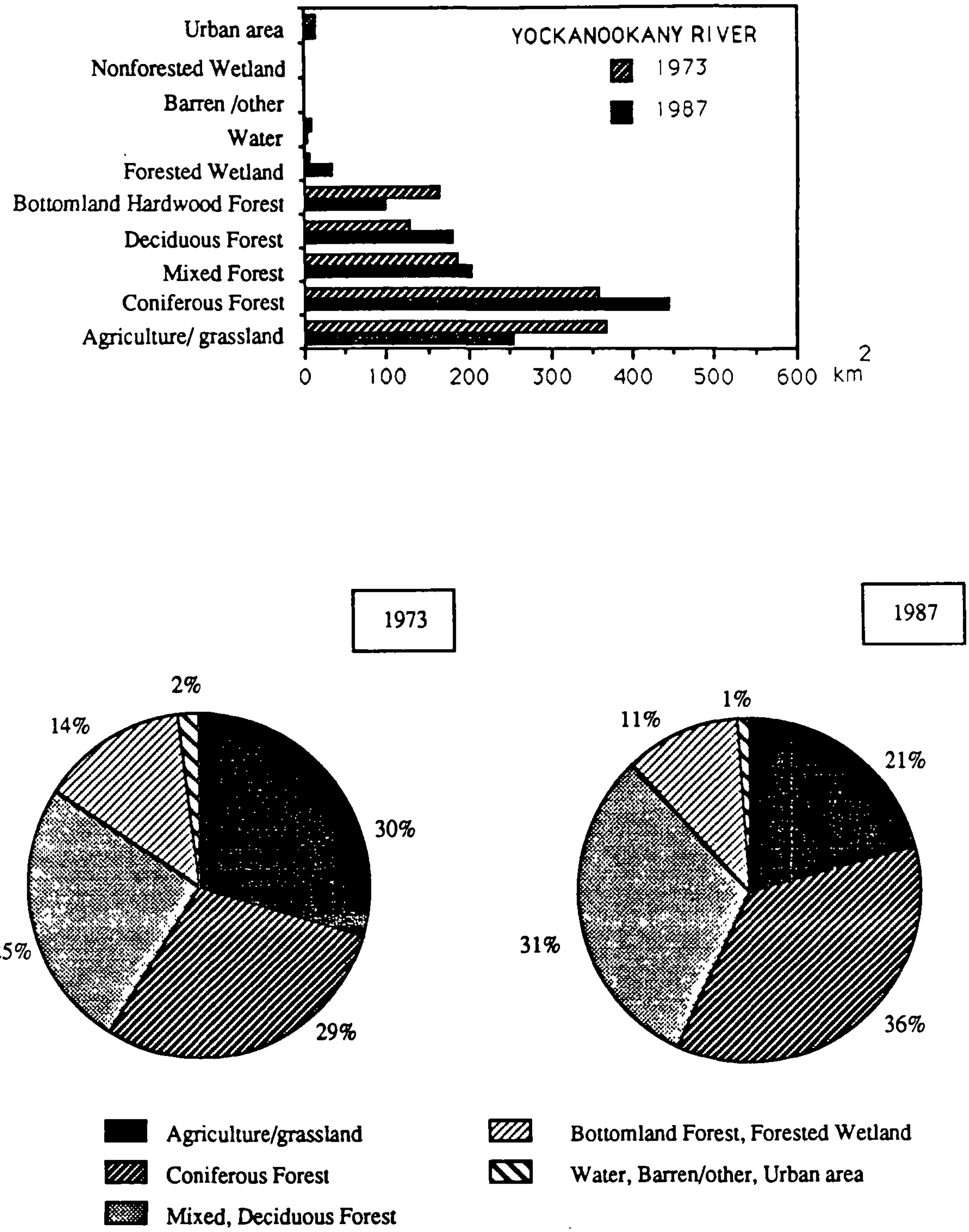


Figure 2-5. Area and percentage of total sub-basin area for each land use category in the Yockanookany River sub-basin in 1973 and 1987.

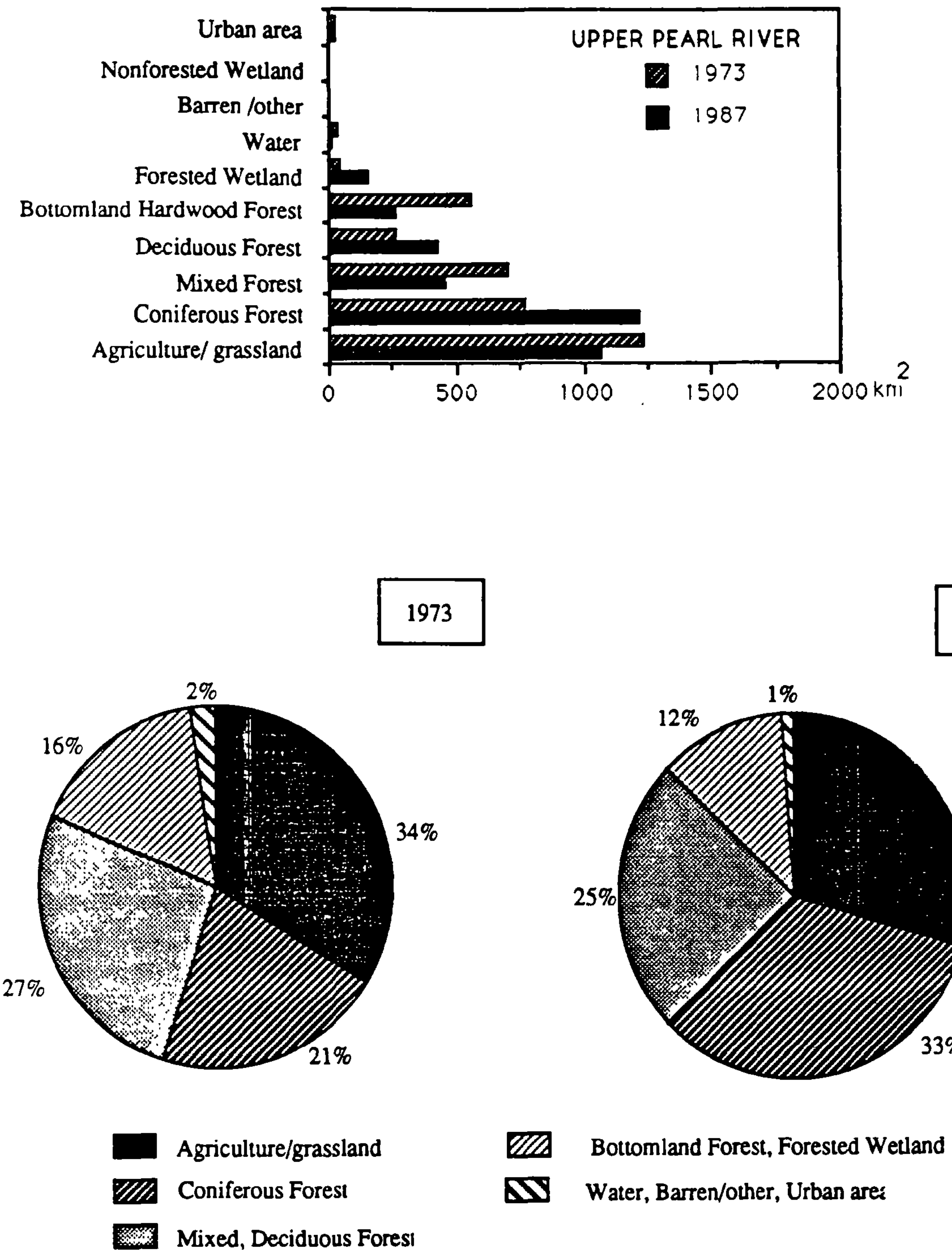
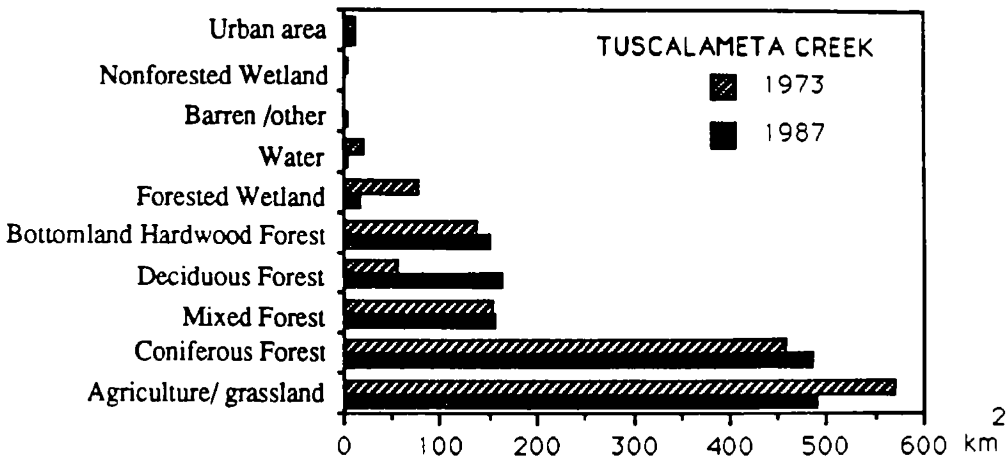


Figure 2-6. Area and percentage of total sub-basin area for each land use category in the Upper Pearl River sub-basin in 1973 and 1987.



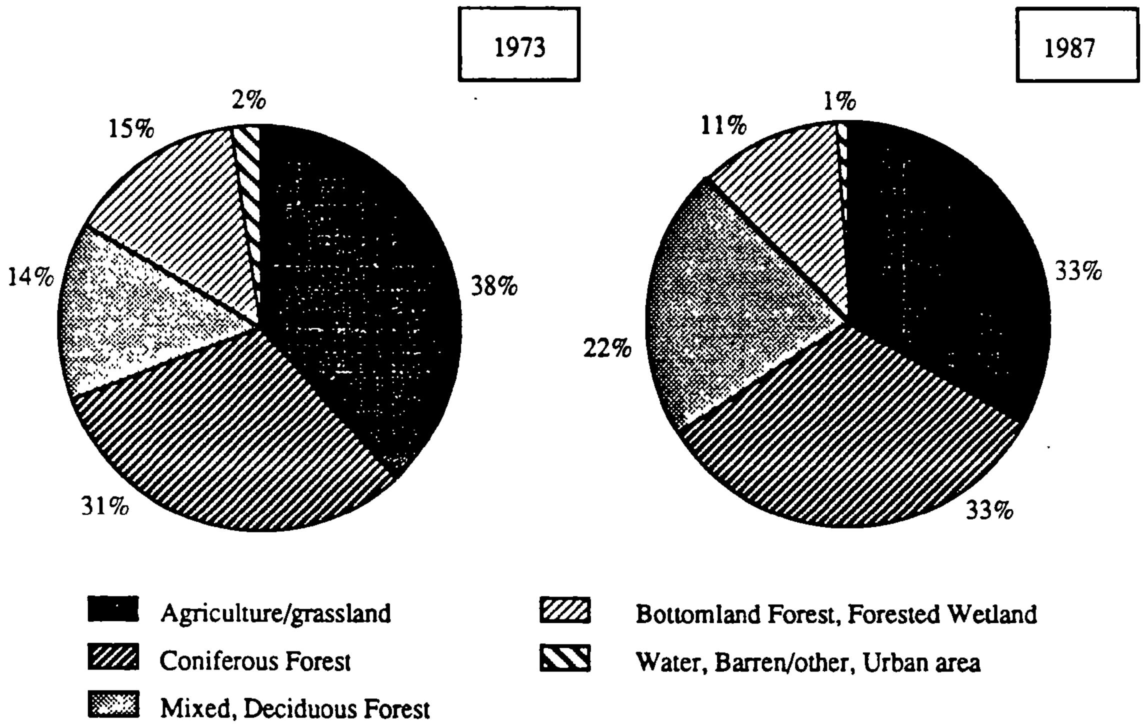


Figure 2-7. Area and percentage of total sub-basin area for each land use category in the Tuscalameta Creek sub-basin in 1973 and 1987.

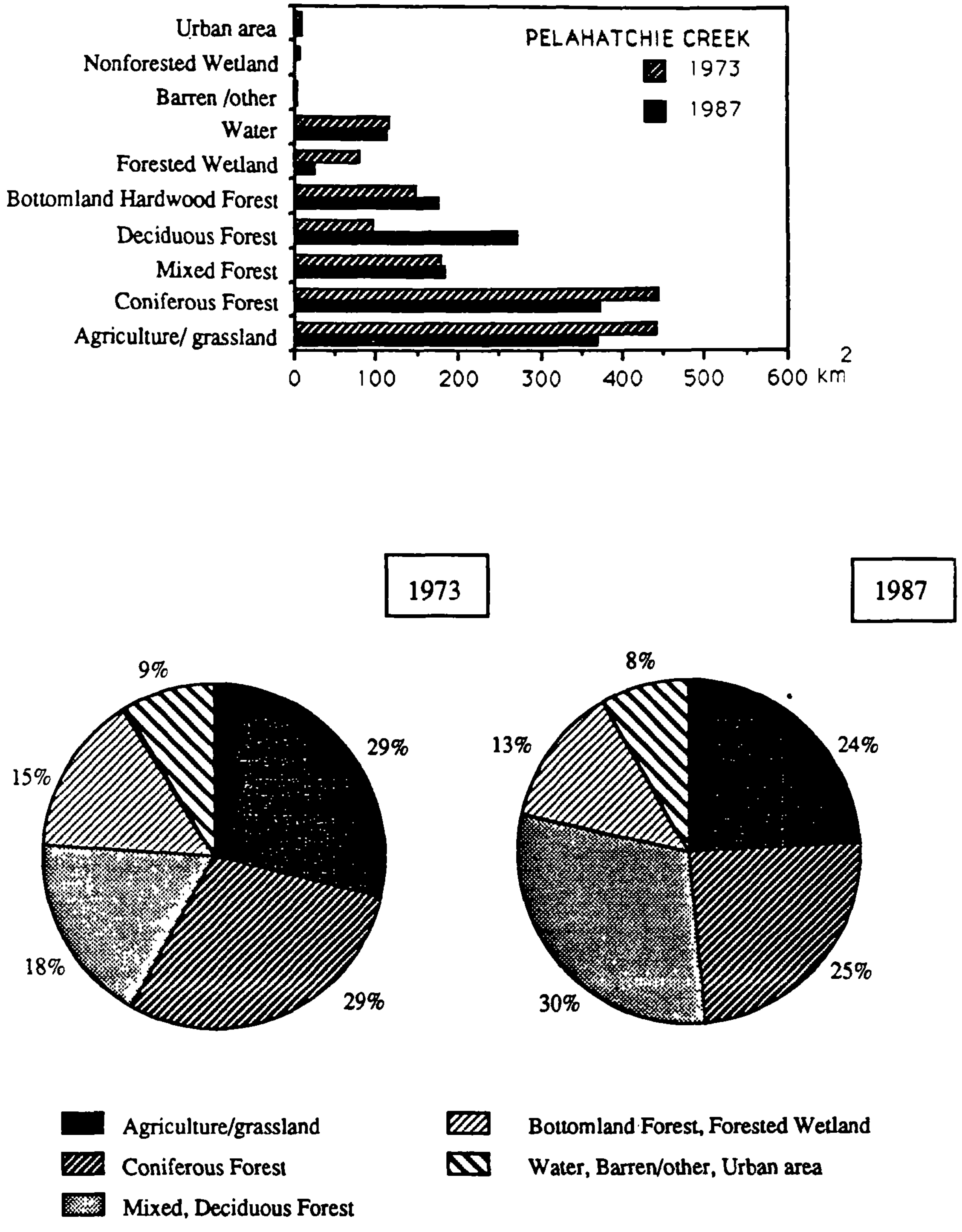
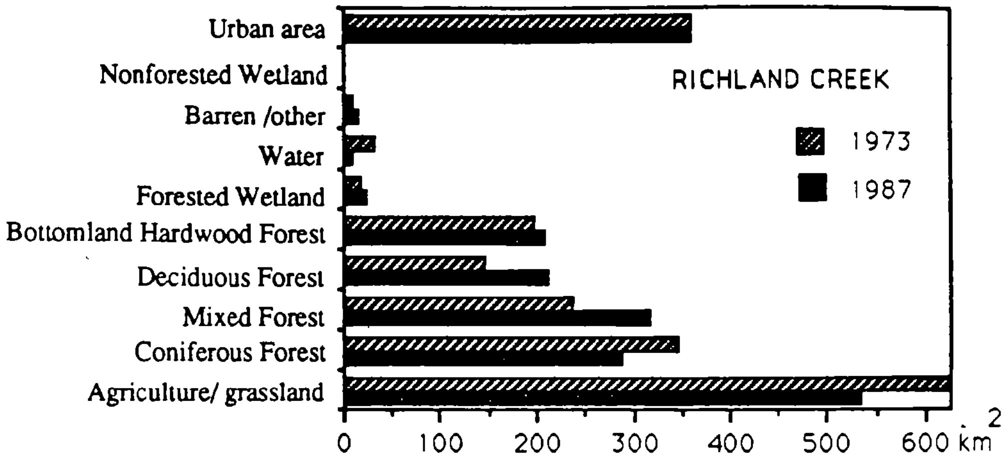


Figure 2-8. Area and percentage of total sub-basin area for each land use category in the Pelahatchie Creek sub-basin in 1973 and 1987.



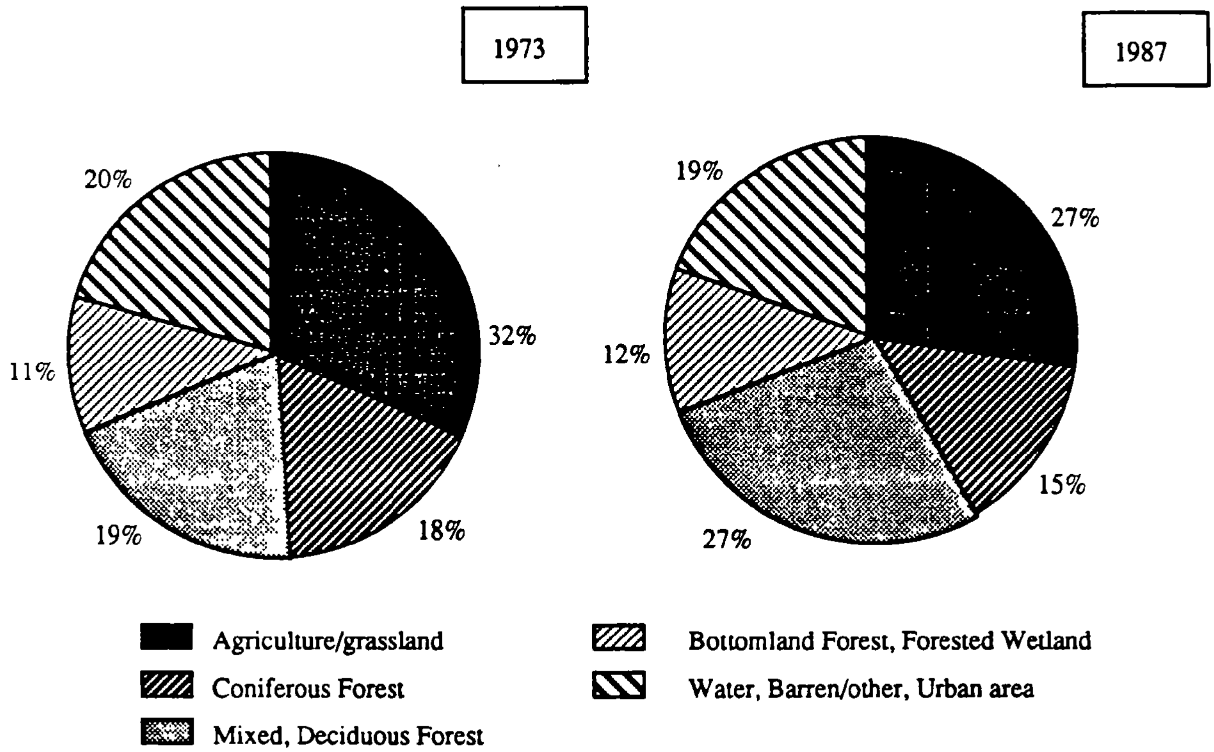
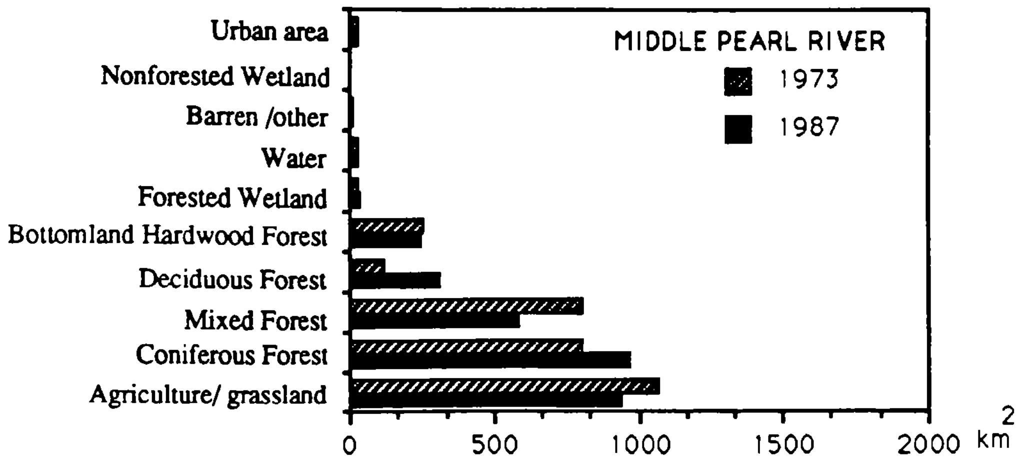


Figure 2-9. Area and percentage of total sub-basin area for each land use category in the Richland Creek sub-basin in 1973 and 1987.



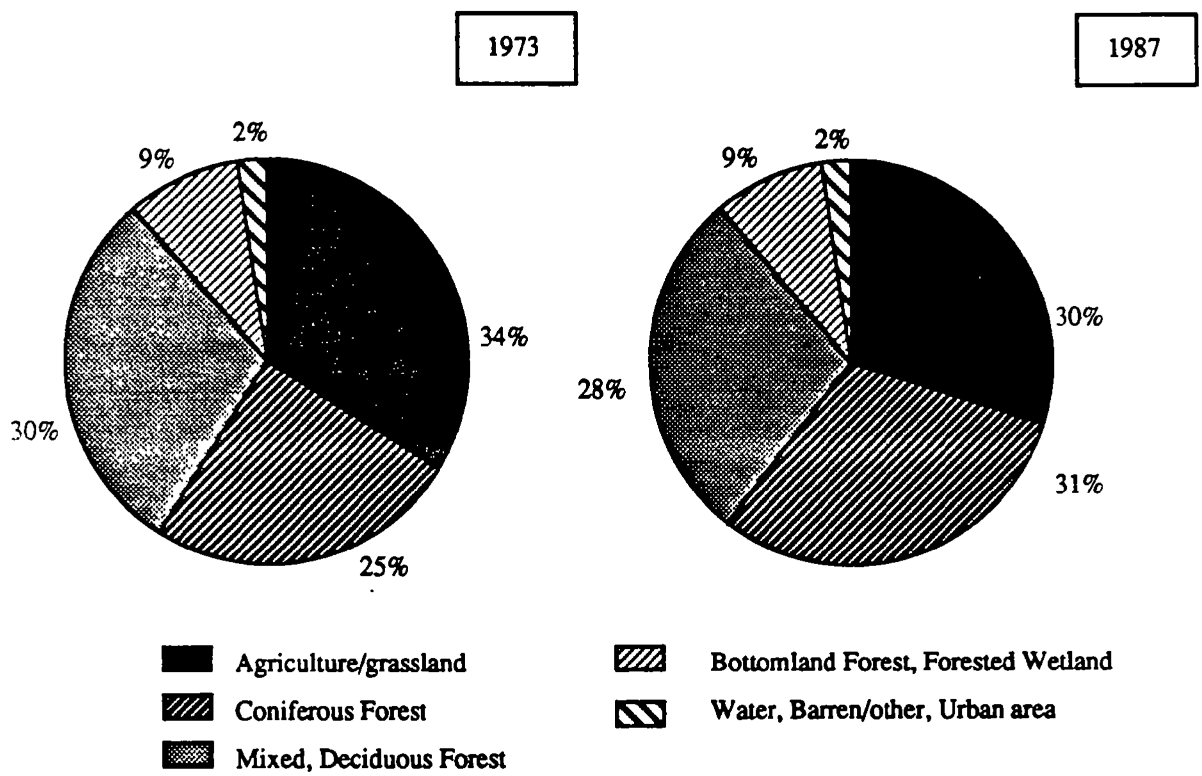


Figure 2-10. Area and percentage of total sub-basin area for each land use category in the Middle Pearl River sub-basin in 1973 and 1987.

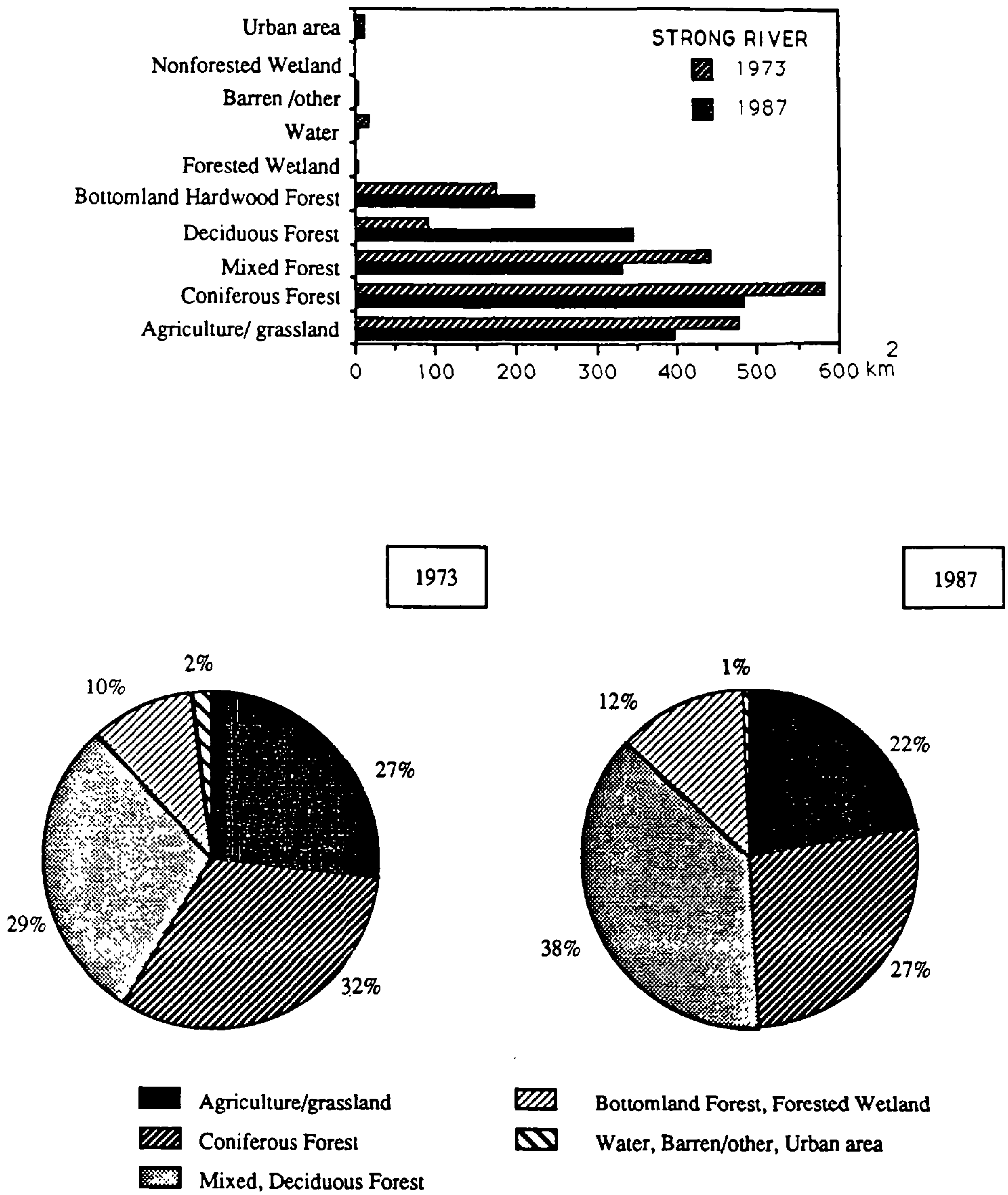
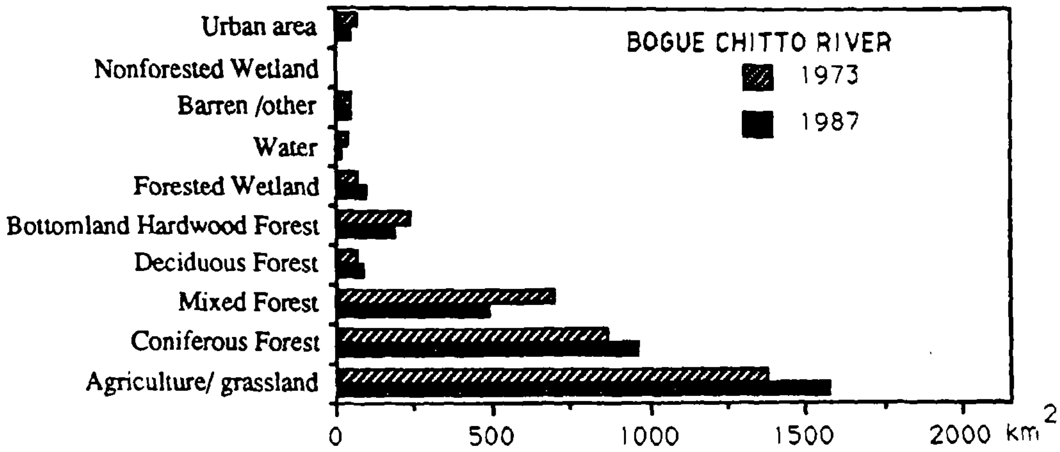


Figure 2-11. Area and percentage of total sub-basin area for each land use category in the Strong River sub-basin in 1973 and 1987.



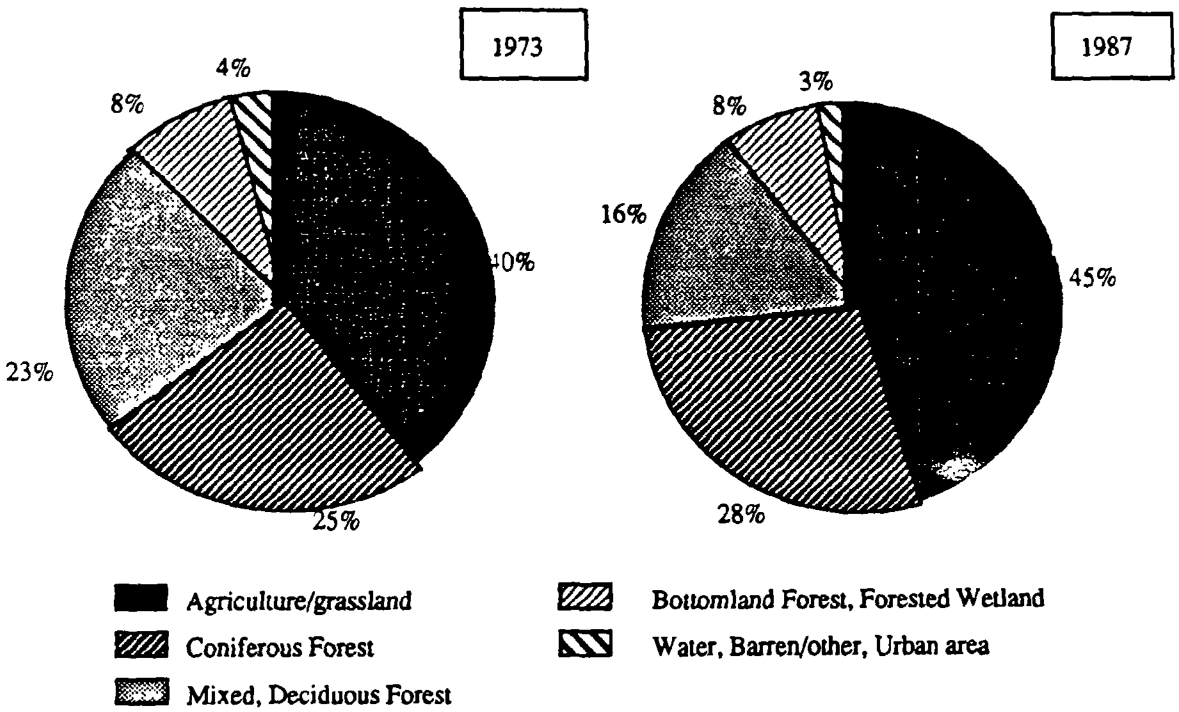
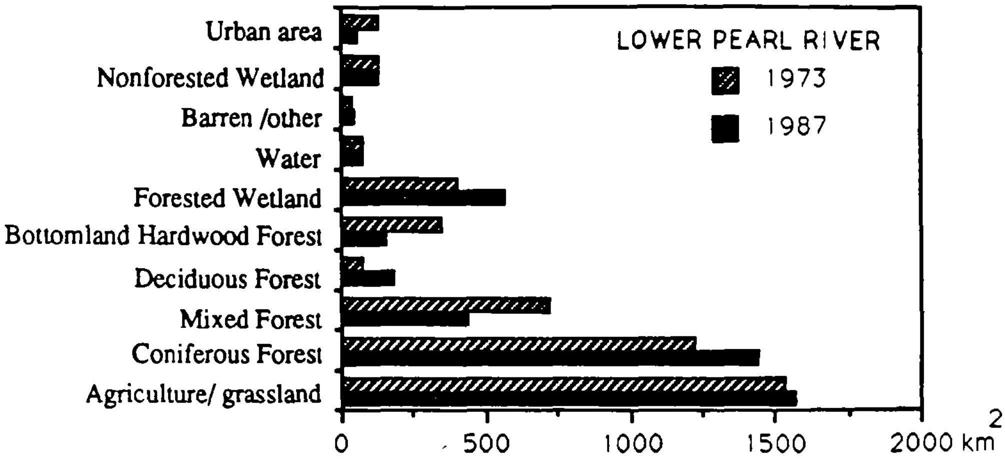


Figure 2-12. Area and percentage of total sub-basin area for each land use category in the Bogue Chitto River sub-basin in 1973 and 1987.



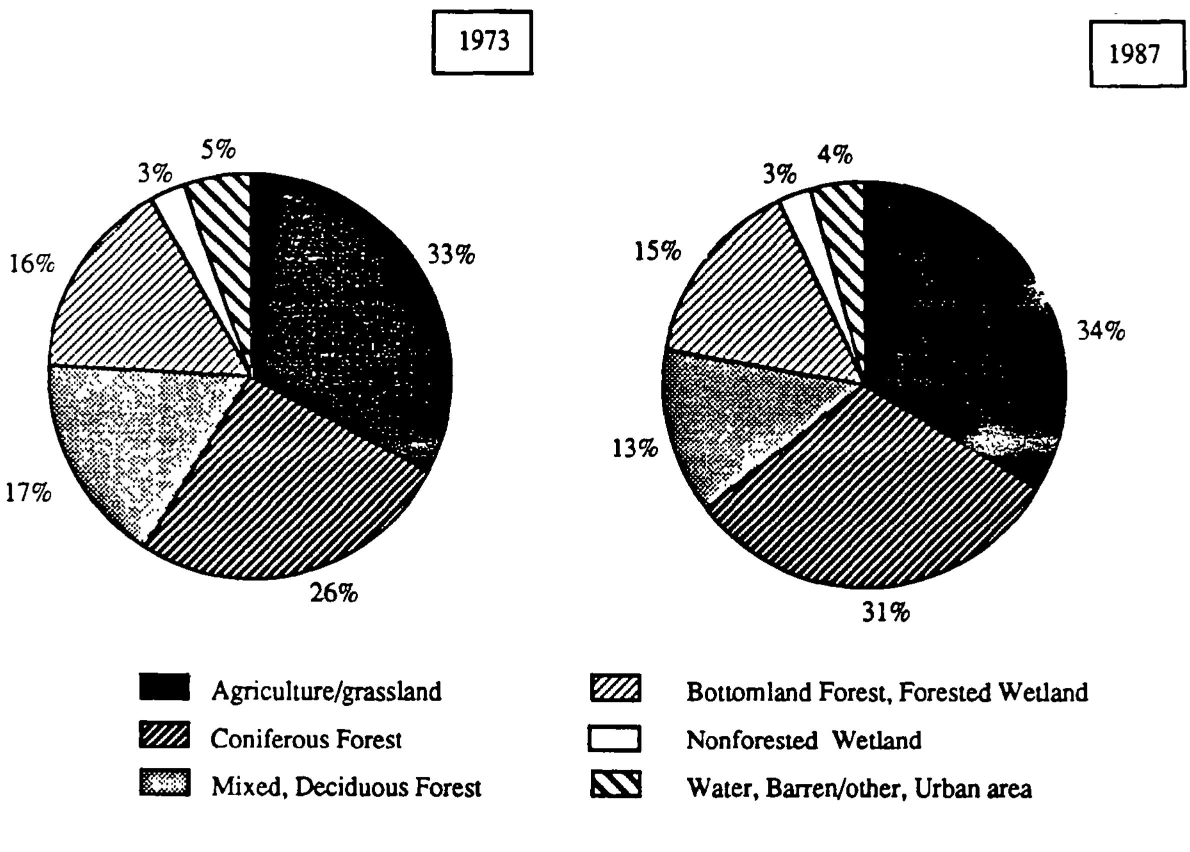


Figure 2-13. Area and percentage of total sub-basin area for each land use category in the Lower Pearl River sub-basin in 1973 and 1987.

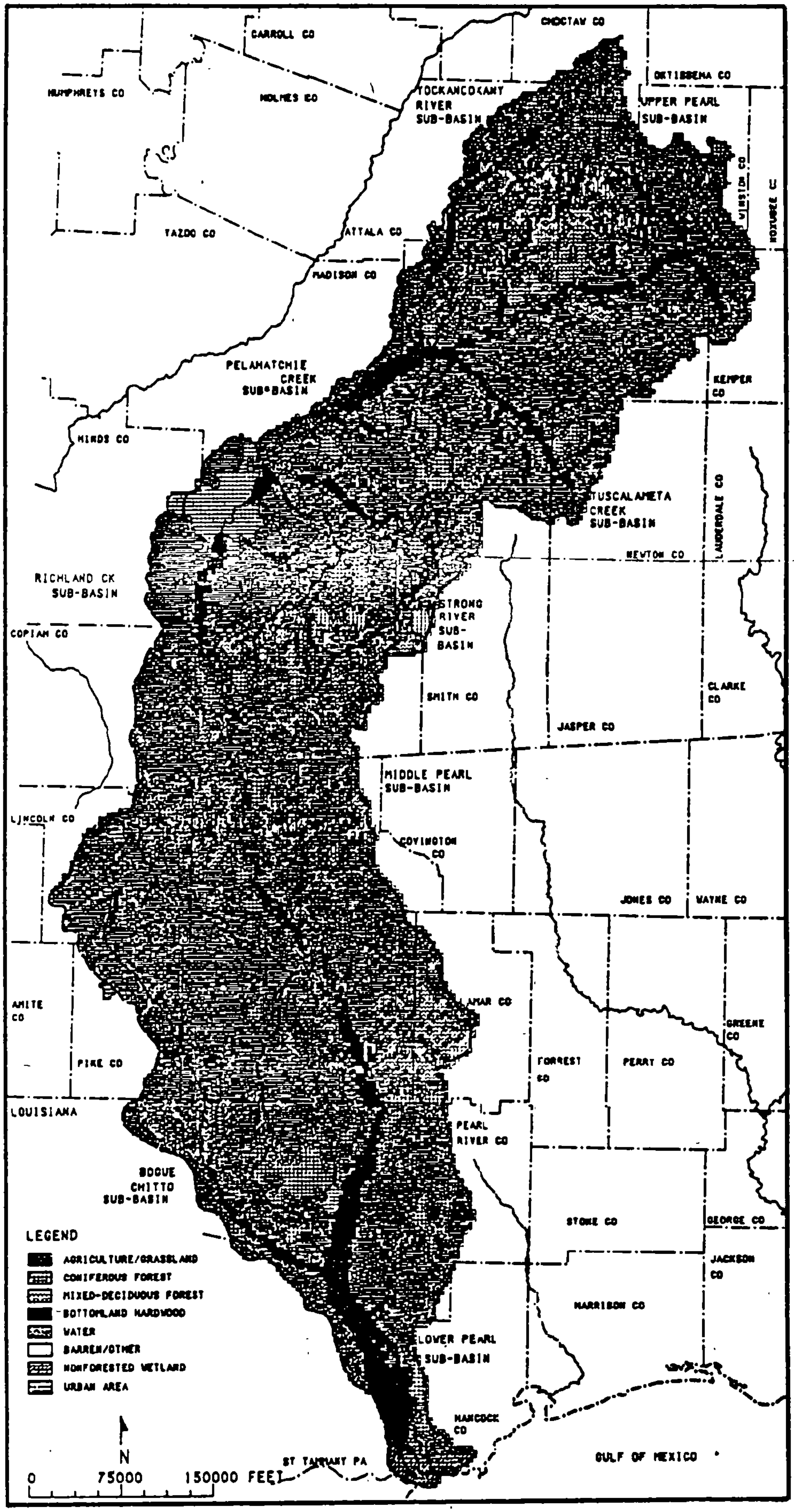


Figure 2-14. Land use map of the Pearl River basin, 1973.

(See Plate 1 in the back pocket.)

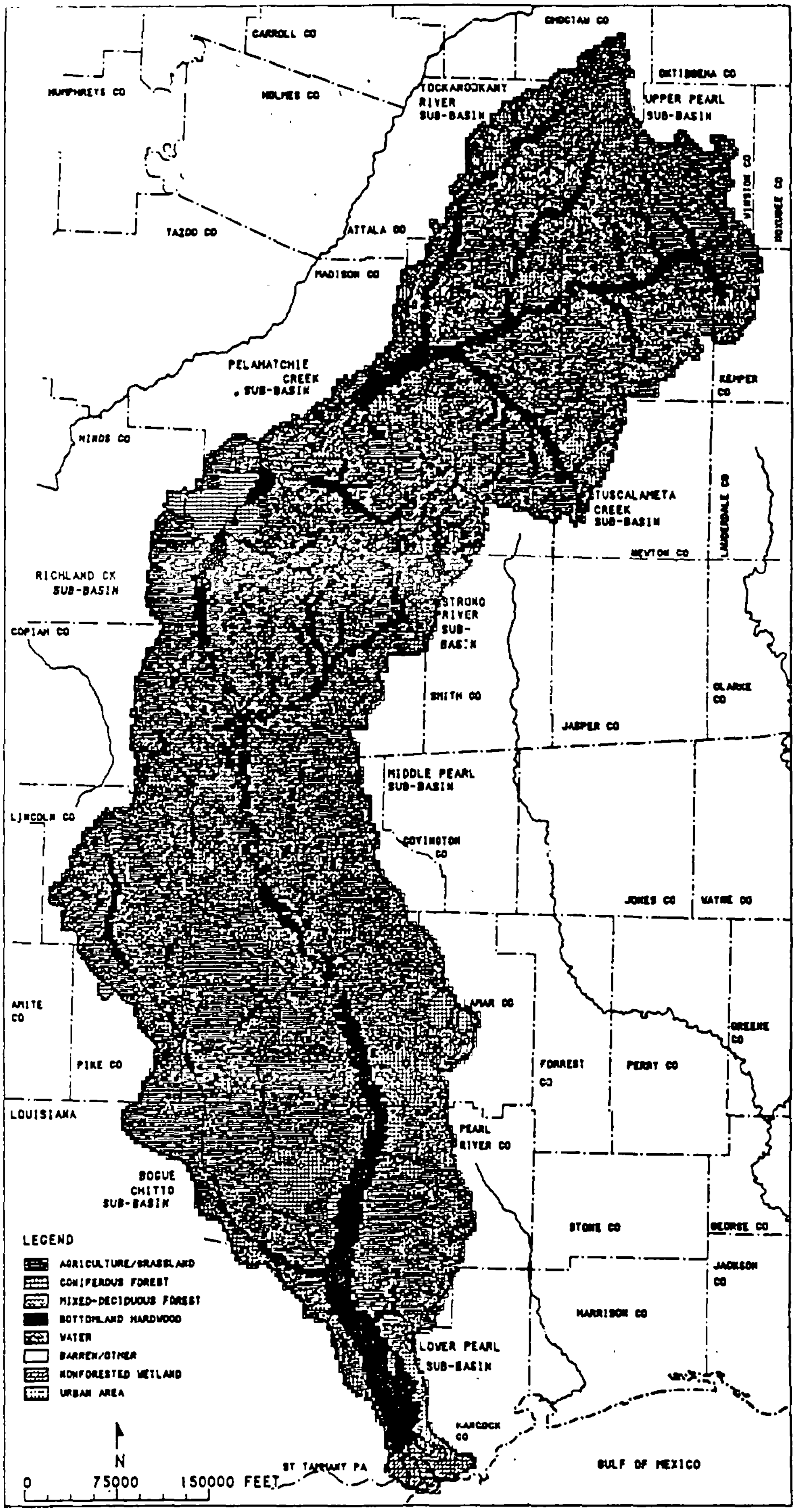


Figure 2-15. Land use map of the Pearl River basin, 1987.

(See Plate 2 in the back pocket.)

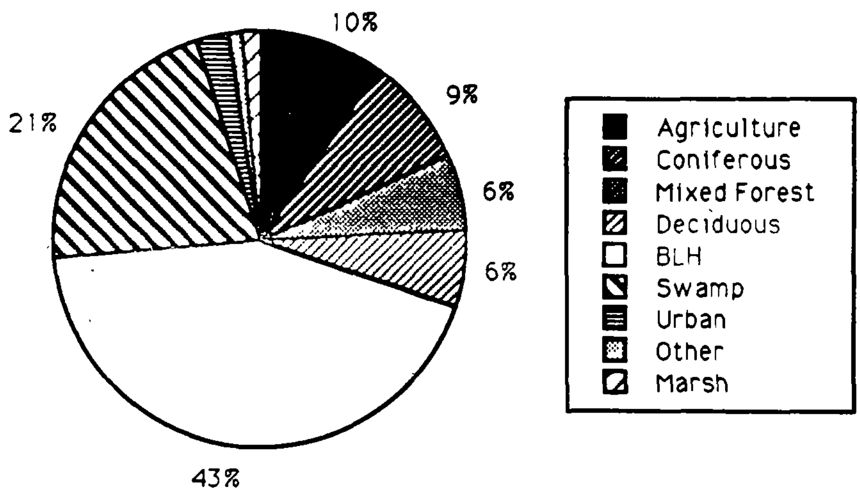


Figure 2-16. Percentage of stream edge bordered by each land use class in the Pearl River basin, 1987.

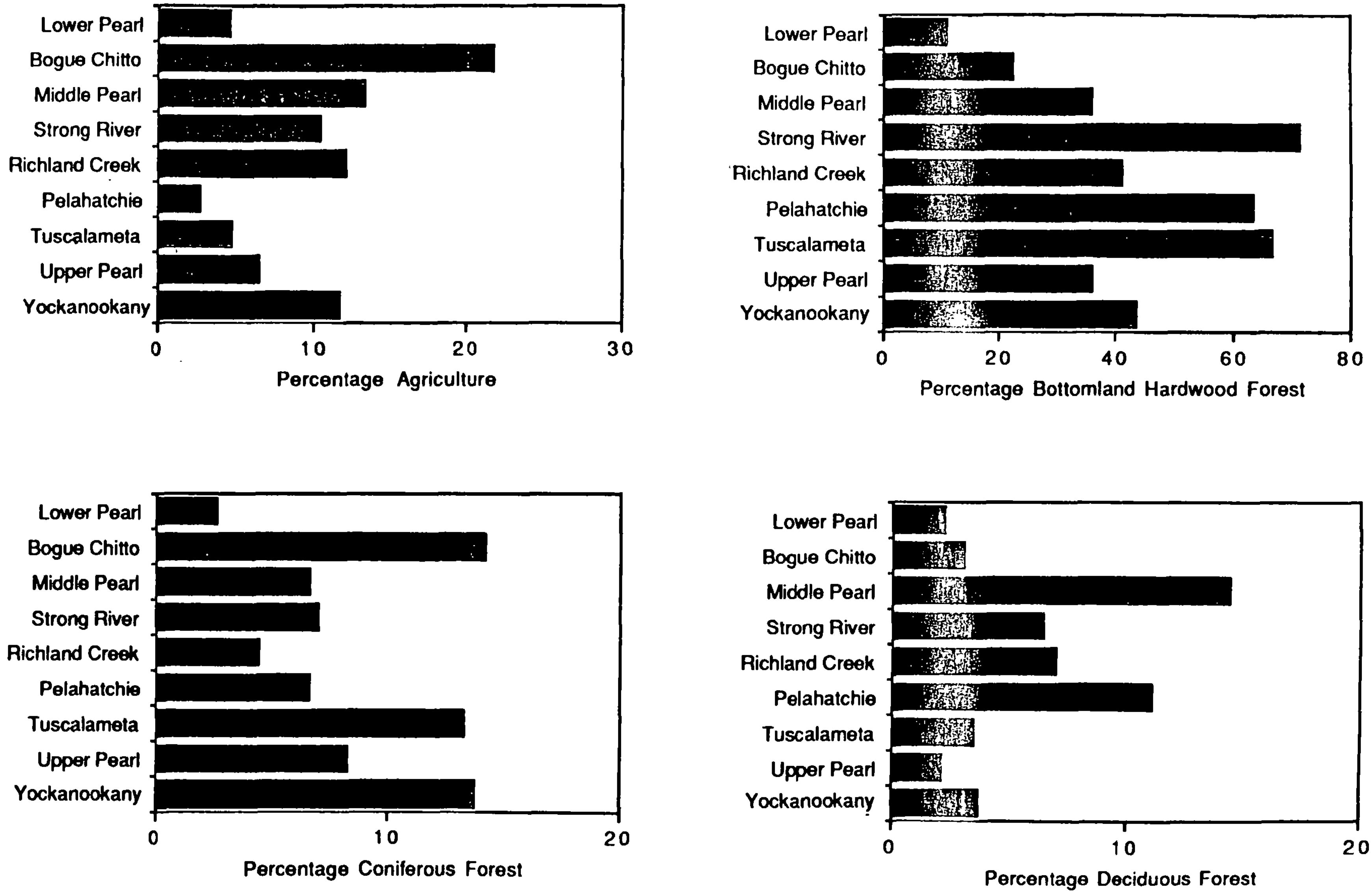


Figure 2-17. Percentages of land use categories bordering stream edges of the nine tributaries and subregions of the Pearl River .

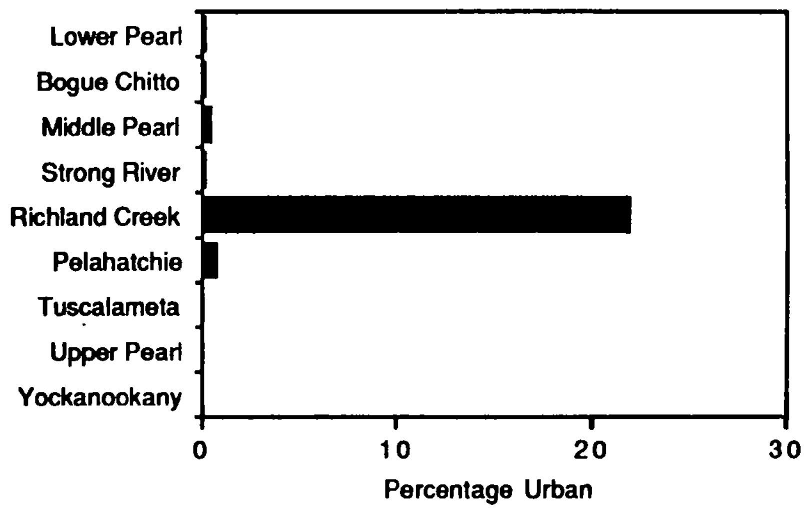


Figure 2-17. Cont'd.

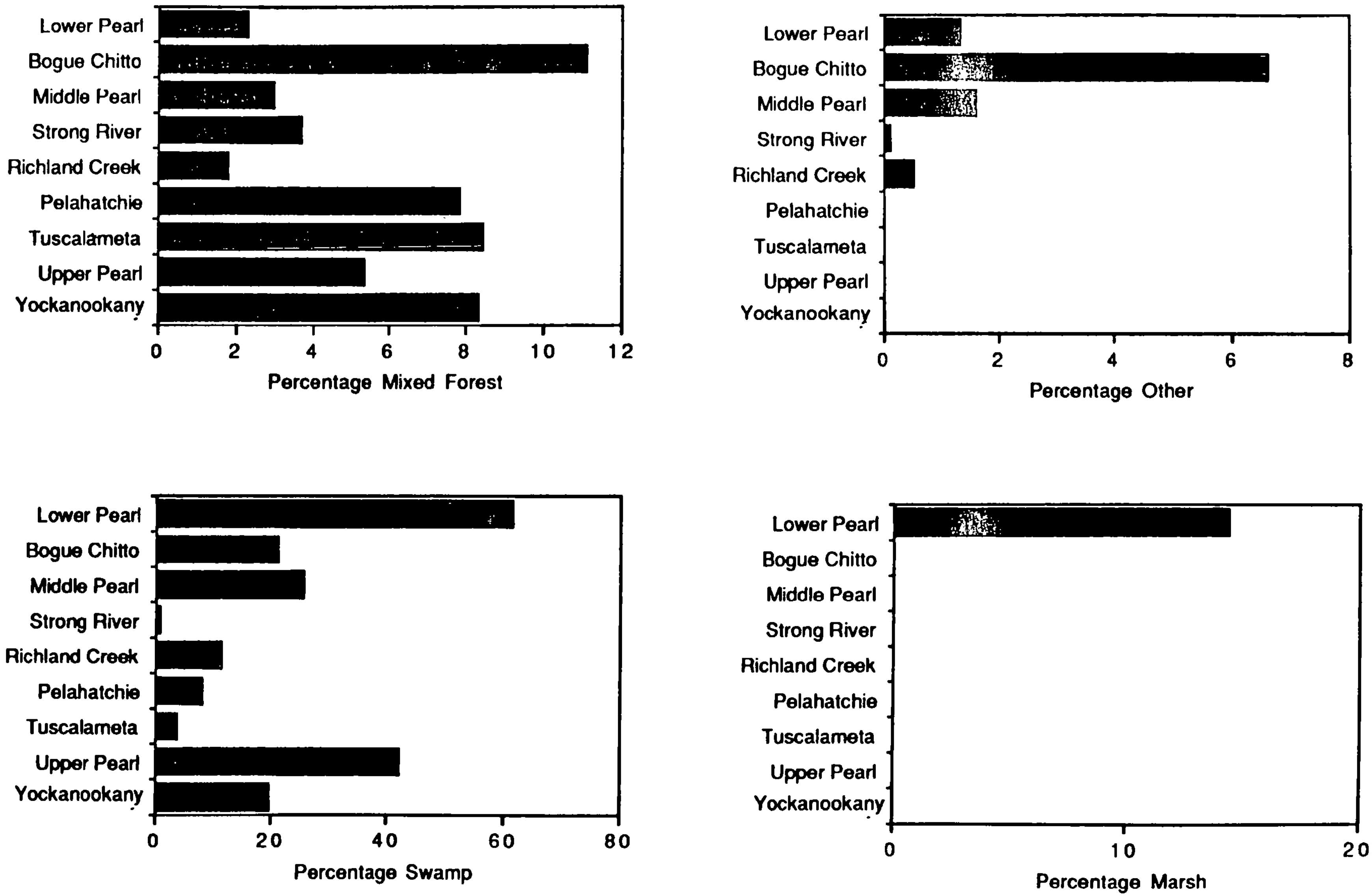


Figure 2-17. Cont'd.

Lower Pearl, wetlands bordered approximately 85% of the stream edge, including about 15% marsh. In the Richland Creek sub-basin, 22% of the stream edge was developed.

Forest Patch Analysis

We calculated the sizes and frequency of forest patches within the Pearl River basin in 1987. Categories included in the analysis were coniferous, deciduous, mixed, bottomland hardwood, forested wetland, and total forest.

Most forest patches within a forest type (coniferous, deciduous, etc.) in the Pearl River basin are small, less than 32 ha (Figures 2-18 through 2-22). The largest patch is a 46,000-ha swamp forest (forested wetland) in the Lower Pearl sub-basin.

However, rerunning the forest patch analysis combining all forest types produces a different picture. There are many small patches, but the greatest areas covered by far are included within only a few very large patches (Figure 2-23). This is true for all sub-basins.

Offshore Study Area

Land Cover

In 1956, of the 413,000-ha offshore study area, 81,700 ha was marsh, 19% brackish or saline, about 1% fresh marsh, 79% water, and the remaining 1% made up of beach, shrub/scrub, spoil, swamp, forest, developed, or other (Table 2-1).

By 1978, marsh had declined by 14.6% to 69,700 ha. About 17% of the area was nonfresh marsh, only a trace (< 1%) was fresh marsh, 82% was water, and the remaining 1% was beach, shrub/scrub, spoil, developed, or other (Table 2-1). Most of the marsh lost had become open water.

DISCUSSION

Inshore Study Area

Historical Land Cover

Before European settlement, the completely forested Pearl River basin was occupied by several groups of native Americans , but no direct evidence links these groups to known Indian tribes (U.S. Army Corps of Engineers 1985). Even after European settlement in other areas of the southeastern United States, the Pearl River basin was not aggressively settled until after about 1830, when cotton and timber became the major industries. The Pearl River provided an avenue of transportation of goods, and steamboats used the river after about 1835. The U.S. Army Corps of Engineers (USACE) began maintaining the stream channel in 1880 (USACE 1985) and conducted significant snagging and maintenance operations to improve navigability (see Chapter 3, this report). The

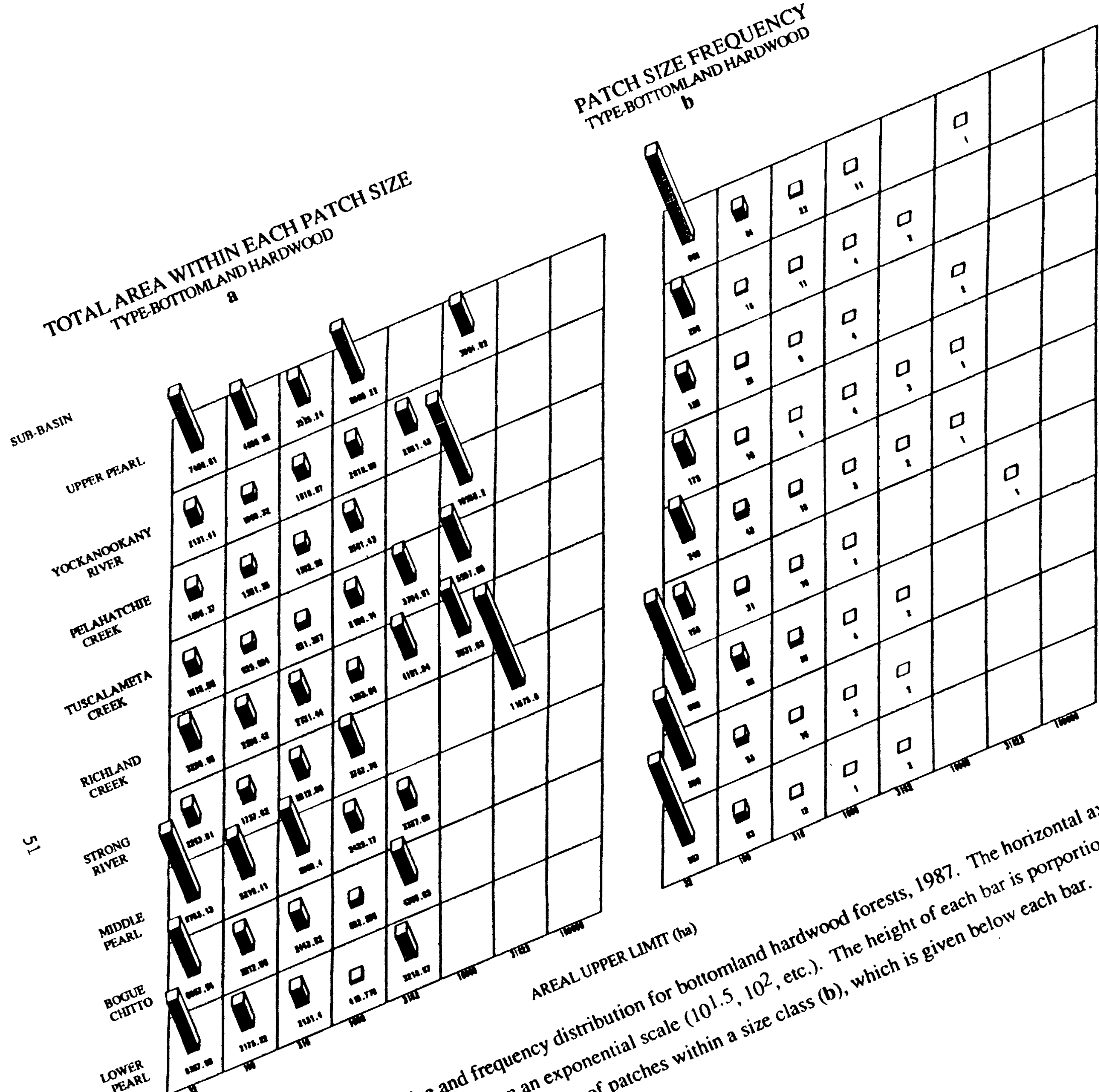


Figure 2-18. Forest patch size and frequency distribution for bottomland hardwood forests, 1987. The horizontal axis groups the patches by size classes on an exponential scale ($10^{1.5}$, 10^2, etc.). The height of each bar is porportional to the area within each size class (**a**) or the number of patches within a size class (**b**), which is given below each bar.

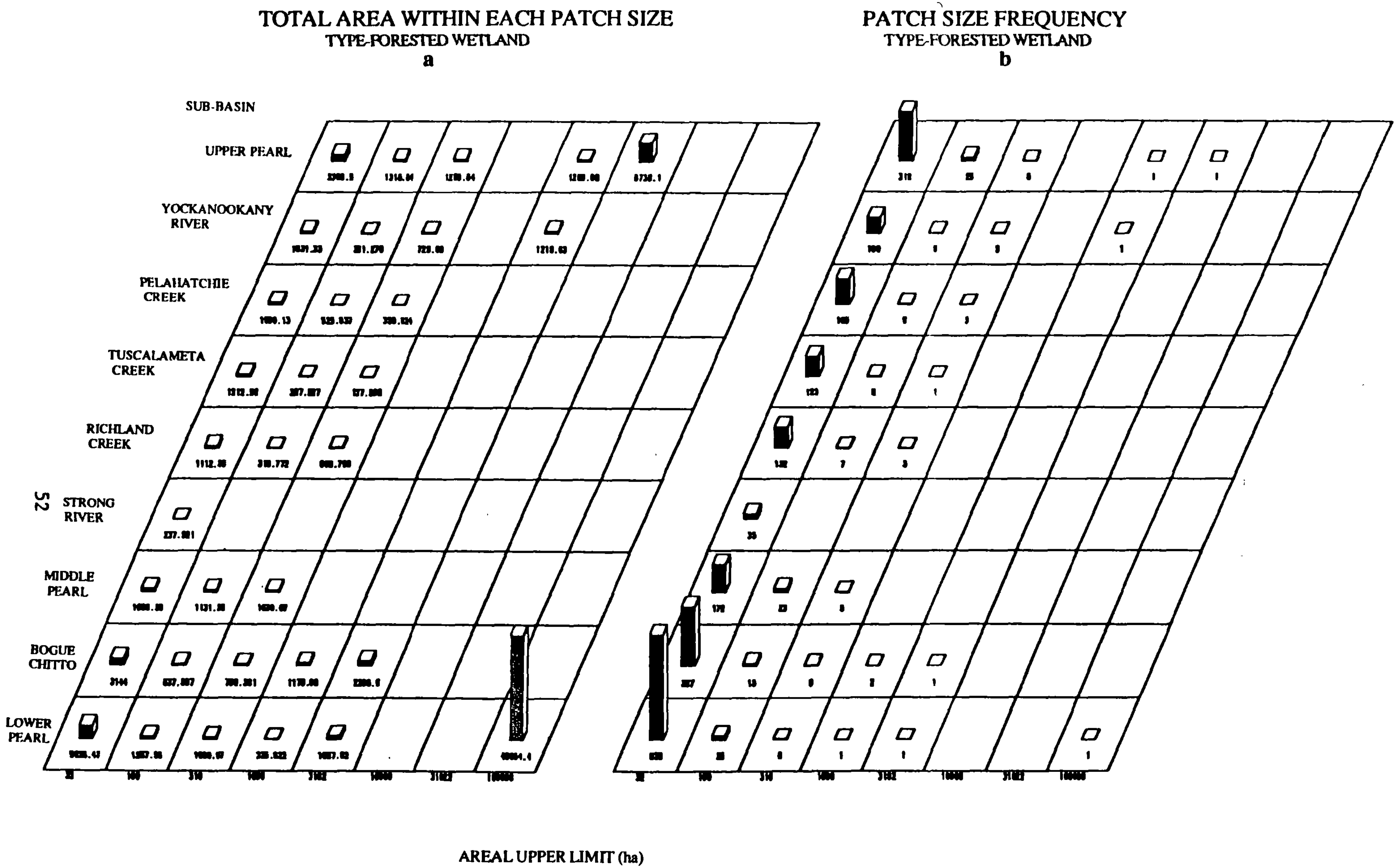


Figure 2-19. Forest patch size and frequency distribution for forested wetlands, 1987. The horizontal axis groups the patches by size classes on an exponential scale ($10^{1.5}$, 10^2, etc.). The height of each bar is porportional to the area within each size class (**a**) or the number of patches within a size class (**b**), which is given below each bar.

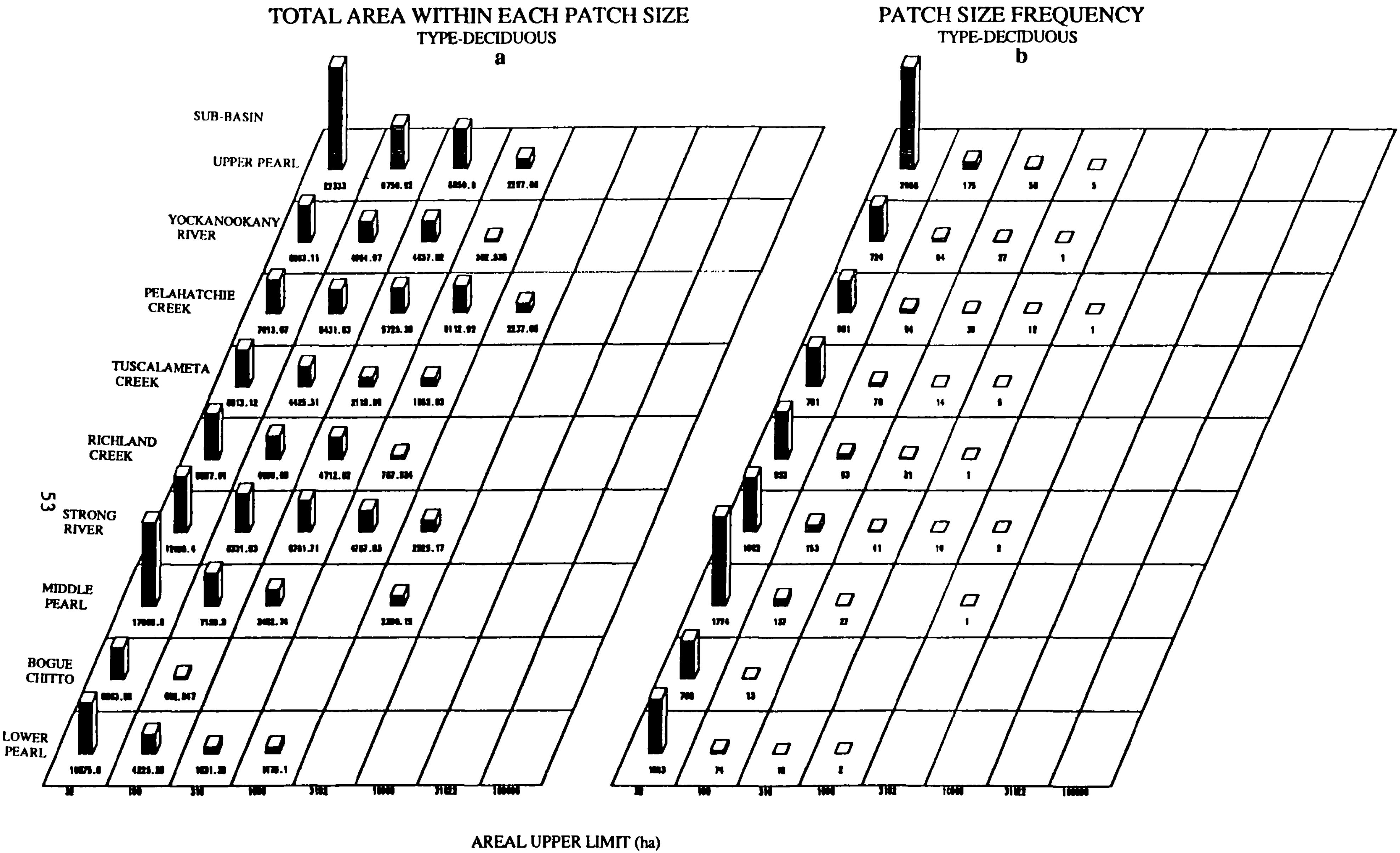


Figure 2-20. Forest patch size and frequency distribution for deciduous forests, 1987. The horizontal axis groups the patches by size classes on an exponential scale ($10^{1.5}$, 10^{2}, etc.). The height of each bar is porportional to the area within each size class (**a**) or the number of patches within a size class (**b**), which is given below each bar.

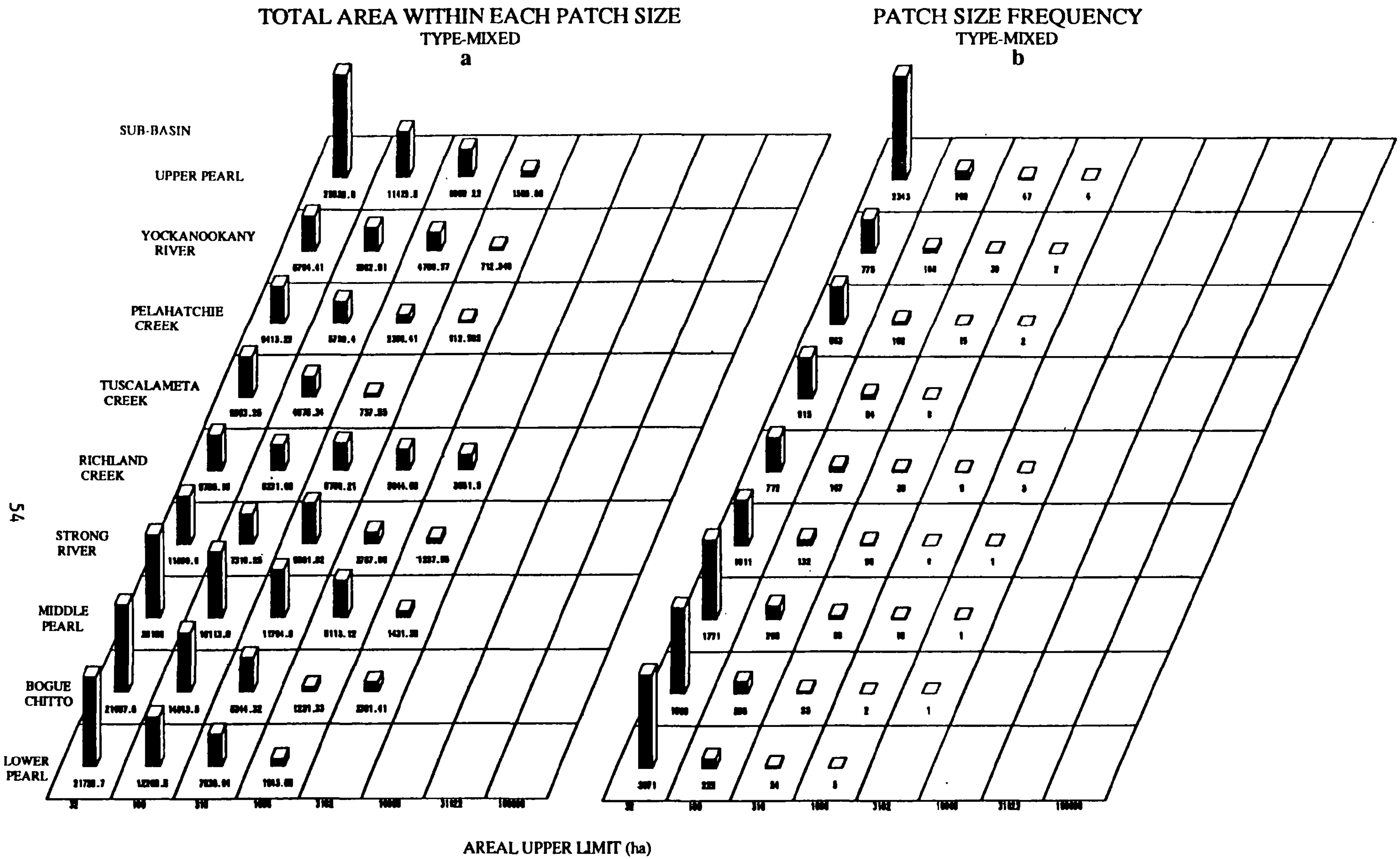


Figure 2-21. Forest patch size and frequency distribution for mixed forests, 1987. The horizontal axis groups the patches by size classes on an exponential scale ($10^{1.5}$, 10^{2}, etc.). The height of each bar is porportional to the area within each size class (**a**) or the number of patches within a size class (**b**), which is given below each bar.

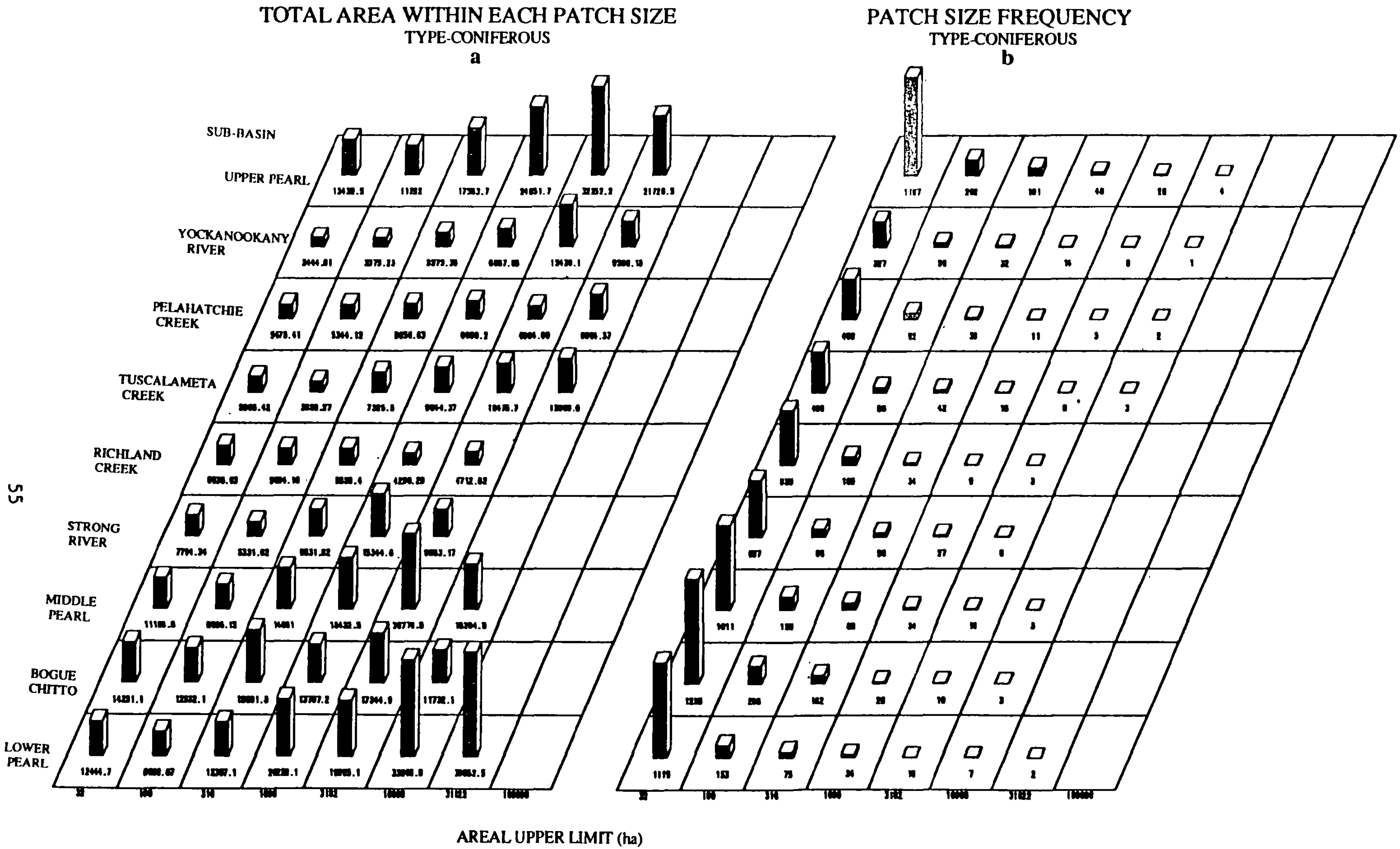


Figure 2-22. Forest patch size and frequency distribution for coniferous forests, 1987. The horizontal axis groups the patches by size classes on an exponential scale ($10^{1.5}$, 10^{2}, etc.). The height of each bar is porportional to the area within each size class (**a**) or the number of patches within a size class (**b**), which is given below each bar.

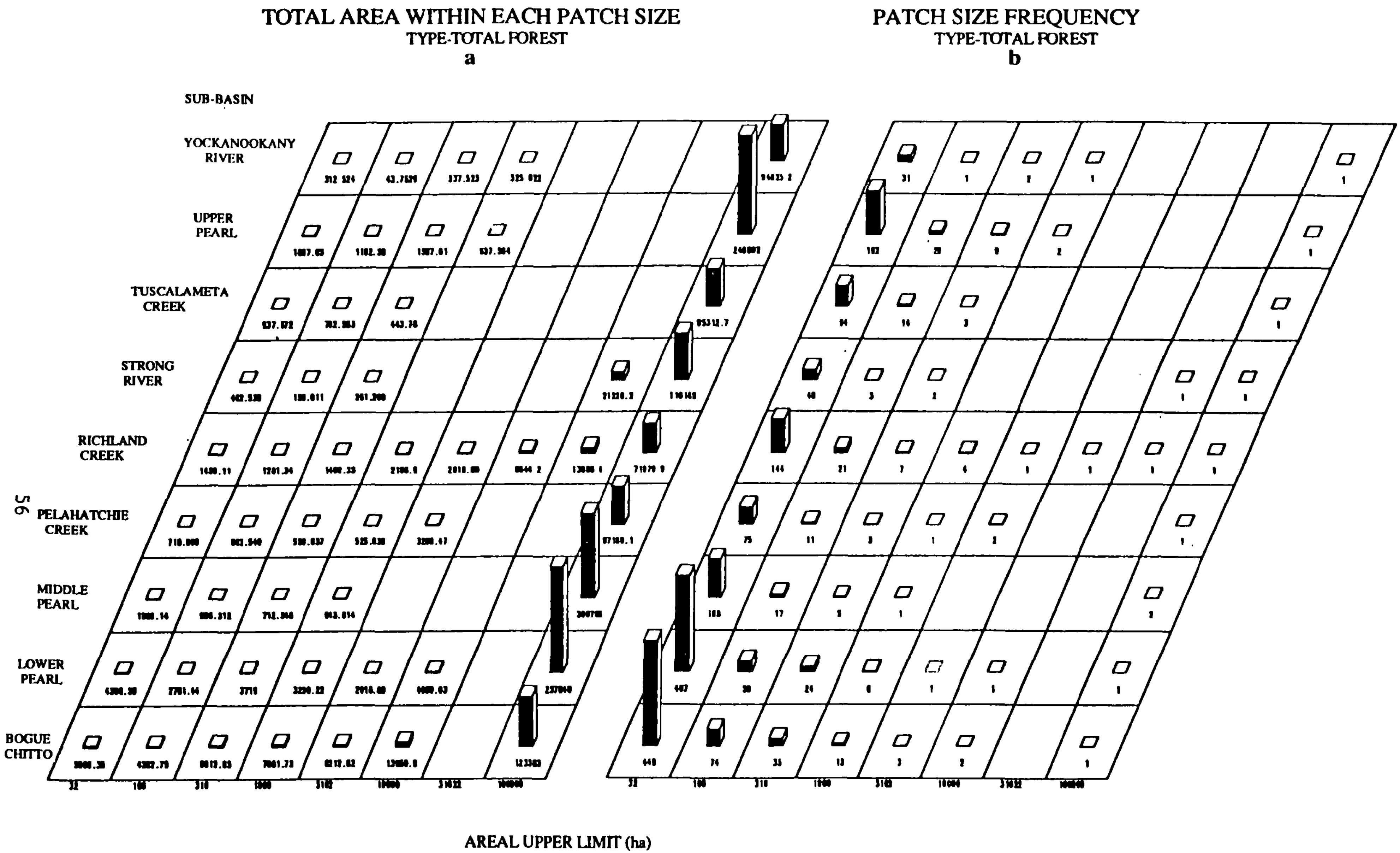


Figure 2-23. Forest patch size and frequency distribution for total forests, 1987. The horizontal axis groups the patches by size classes on an exponential scale ($10^{1.5}$, 10^2, etc.). The height of each bar is porportional to the area within each size class (**a**) or the number of patches within a size class (**b**), which is given below each bar.

Table 2-1. Land use characteristics of the Pearl River basin offshore study area, 1956-1978.

Category	1956 (ha)	1978 (ha)	Change 1956-1978 (ha)	% Change 1956-1978
Water	327,842	339,559	11,717	4
Total marsh	81,670	69,745	-11,925	-15
Fresh marsh	3,458	754	-2,704	-78
Nonfresh marsh	78,212	68,991	-9,220	-12
Intermediate marsh	—	3,443	—	—
Brackish marsh	—	40,206	—	—
Saline marsh	—	25,343	—	—
Forest	285	294	9	3
Swamp forest	746	184	-563	-75
Shrub/scrub	8	1,036	1,028	12,758
Shrub/scrub(spoil)	20	1,428	1,408	6,996
Agriculture/pasture	4	13	9	209
Developed	473	1,162	689	145
Beach	1,097	618	-479	-44
Other	848	332	-516	-61
Totals	412,994	414,371		

development of rail transportation caused a decline in river use, and maintenance by the USACE was abandoned in the early 1900s (USACE 1985).

The earliest statistical records indicate that the area of land under cultivation or used for pasture fluctuated somewhat from 1930 to 1985, but overall remained fairly constant (Figure 2-3). Certainly no massive conversion of forest to agriculture has occurred here, as has been the case in many river basins of the southeastern United States (Gosselink et al. 1989).

Available forest area data cover only the last 30 years, but also show little change. A small increase in non-wetland forest area is probably due to an increase in pine plantations in the basin (see below) associated with the reversion of some agricultural fields to forest. Area of wetland forest stayed about the same during the 30 years (Figure 2-3), decreasing by about 10,000 ha over that period.

In 1987, total forest cover in the Pearl River basin was about 64%; about 33% of the basin was in agricultural land (Figure 2-4). About 52% of the forest cover was upland forest, and 12% wetland forest.

Only relatively small changes in land use occurred over the basin as a whole during 1973-1987. The largest change was a 4% increase in upland forest and an approximately 2% decrease in agricultural land use. Most of the increase in upland forest area was due to an increase in coniferous forest, which is consistent with other reports of increasing emphasis on pine plantations in the basin.

Sub-basin Trends

Although general land use trends from 1973 to 1987 across the Pearl River basin as a whole changed little, the degree of land use change within individual sub-basins varied more. Land use in several sub-basins changed fairly significantly, although none changed nearly so drastically as reported in other areas of the country, such as the Tensas basin, Louisiana, where large-scale clearing of bottomland hardwoods for agriculture took place over the last several decades (Gosselink et al. 1989).

Figures 2-5 through 2-13 plot land use and percentage change statistics for each of the nine sub-basins. The results for several are noteworthy. The Bogue Chitto sub-basin has the highest percentage of land area in agriculture, 45% in 1987, and it is one of only two sub-basins in which area of agriculture increased between 1973 and 1987 (5% increase). In the Lower Pearl sub-basin, agricultural land use increased slightly (less than 1%) over the interval. The Bogue Chitto sub-basin is also one of two sub-basins where total forested area decreased between 1973 and 1987, from 56% to 53% . Forested area in the Strong River sub-basin decreased from 71% to 69% . It should be emphasized that these percentage changes in agriculture and forest areas are relatively small, especially compared to other river basins around the country. They do, however, indicate some differences in land use practices within the Pearl River basin.

The Richland Creek sub-basin, located in the Jackson, Mississippi, area is the only sub-basin with significant urban land use, around 20% in both 1973 and 1987. Interestingly, even in this more developed sub-basin, forest area increased by 6% from 1973 to 1987 (from 48% to 54% of the area).

Stream Edge Habitat

Land in the 250-m strip adjacent to the stream edges of the Pearl River and its tributaries was mostly forested. Over the whole basin, 85% of the stream edge was forest; 65% of this was classified as swamp and BLH (Figure 2-16).

Individual sub-basins differed somewhat in land use along stream edges (Figure 2-17). The Upper Pearl River's edges, for example, are only about 7% agricultural and 93% forested; 78% are swamp and BLH. The Bogue Chitto River in the middle basin has more agricultural land use along the stream edges; 22% is agricultural land use and 72% forest, of which 43% is swamp and BLH. In general the middle portion of the basin (Richland Creek, Strong River, Middle Pearl, and Bogue Chitto River) has more agricultural land along the stream edges and somewhat less swamp and BLH than the upper and lower regions, though this relationship is not a strong one. The Yockanookany River in the upper basin, unlike other watersheds in that region (Upper Pearl, Tuscalameta Creek, and Pelahatchie Creek), has 12% agricultural use along its edges, about the same as the average for the middle section.

"Forested stream edge is positively correlated with water quality (Lowrance et al. 1983; Peterjohn and Correll 1984), and functions as corridors for wildlife, connecting forest patches. The exact relationship between the percentage of forest-bordered streams and water quality has not been defined" (Gosselink and Lee 1989). However, the percentage of stream edges bordered by forest in the Pearl River basin is probably high compared to most rivers in the southeastern United States of equal size, and this fact should be reflected in generally high quality water in the basin.

Forest Patch Analysis

Gosselink et al. (1989) made the following observations about the size, proximity and continuity of forest patches and their relationships to animal and plant populations: the diversity of native biota is closely related to both the size of forest patches, and to their proximity and continuity through forested corridors (Diamond 1975; Soule and Simberloff 1986). Forest area is also positively related to healthy populations of forest flora and fauna (Diamond 1975; Freemark and Mirriam 1986). In particular, large patch size is critical for the survival of large mammals, raptors, and other species typical of forest interiors (Soule and Wilcox 1980).

In the Pearl River basin, distribution of size classes of forest patches by forest type includes many small and intermediate patches, and several very large patches (Figures 2-18 through 2-22). Since many forest types adjoin each other, the number of patches is overestimated in this analysis. Treating each forest type (coniferous, BLH, etc.) separately results in the maximum apparent fragmentation.

We also analyzed forest patch distribution by combining all forest types. In every sub-basin most of the forested area is included in only a few patches (Figure 2-23). Each basin has many small patches; however, the total area covered by small patches is small relative to the few large ones. Large patches of forest occur in every sub-basin. The Lower and the Upper Pearl have the largest single forest patches, both in excess of 240,000 ha.

In general, coniferous patches tend to be large and concentrated in the very northern and southern parts of the basin, with very few in the middle section. Mixed and deciduous forests constitute many small patches scattered fairly uniformly throughout the basin. Bottomland forest (BLH and forested wetland) occurs in long, narrow patches bordering streams. BLH generally occurs more commonly in the upper reaches of the basin; the swamp (forested wetland) occurs more in the Lower Pearl, below Bogalusa. The largest patch in the basin is a 46,000-ha swamp forest in the Lower Pearl sub-basin. Other large BLH patches are located in the Strong River and Pelahatchie sub-basins.

Offshore Study Area

The size of the offshore area influenced by discharge from the Pearl River is not well documented. For this study we rather arbitrarily defined the offshore region as encompassing the coastal marshes south of the mouths of the Pearl River, adjacent to Lake Borgne, south to the MRGO, and east to the Chandeleur Islands. This region covers about 413,000 ha, most of which is open water.

The best land use information available covering this area is the USFWS 1956 and 1978 digital data base (Wicker 1980); 1988 land use coverage is currently being processed by the USFWS, but is not yet available. The region has two dominant land use categories, open water and nonfresh marsh. In 1956, open water covered 79% of the area, and nonfresh marsh, 19%. In 1978, open water covered 82%, and nonfresh marsh, 17%.

Site-specific changes during 1956-1978 included the change of 12,384 ha of marsh to open water (Table 2-2). Since significant addition of sediments can slow down or reverse loss of marsh to water, we might expect a gradient of low marsh loss to higher loss with increasing distance from the Pearl River's mouth, if the influence of sediments discharged from the Pearl River extends into the marshes of the offshore study area. A fairly uniform distribution of areas of marsh loss to open water across the study area is apparent from visual inspection of the plotted maps.

Other land use changes within the offshore study area include the slow, landward erosion and migration of the Chandeleur Islands. These islands are important to the region because they provide some degree of protection to the coastal marshes from wave erosion generated by the prevailing southeasterly winds, and probably more importantly from the occasional tropical storms that pound the area.

Table 2-2. Site-specific change detection, 1956-1978, for the Pearl River basin offshore study area.

Change in Categories 1956-1978	Change (ha)	% Change* 1956-1978
Water to water	243,390	78.53
Marsh to water	12,384	3.00
Land to water	1,504	0.36
Water to marsh	2,861	0.69
Marsh to marsh	66,017	15.99
Land to marsh	862	0.21
Water to land	649	0.16
Marsh to land	3,265	0.79
Land to land	1,116	0.27

* % Change = % of entire offshore study area.

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CHAPTER 3: HYDROLOGY OF THE PEARL RIVER BASIN

INTRODUCTION

This chapter presents the results of the analysis of hydrologic data from the Pearl River Basin. The data of interest included long-term (~50 year) records of precipitation, river stages, and discharges. These data were analyzed to determine the long-term, seasonally adjusted trends. The primary concern was how the hydrologic regime related to both natural and human-induced factors. Thus the task had two major objectives: to determine the secular trends (if any) in the records, and to identify the factors that may be controlling these changes.

In addition to the precipitation, stage, and discharge time-series data, other ancillary data were also analyzed. These included tabulation of river works projects that may have impacted the basin and estimates of the impact of the Pearl River on the adjacent offshore waters.

HYDROLOGY OF THE PEARL RIVER BASIN

The Basin

The Pearl River basin (Figure 3-1) has a drainage area of about 2.3 million hectares and drains 23 counties in east-central and southern Mississippi and 3 parishes in southeastern Louisiana. The basin is about 390 km long with a maximum width of about 80 km. The river splits into two portions, the East Pearl River and the West Pearl River, approximately 72 km from its mouth. The East Pearl River enters into the coastal waters of the Gulf of Mexico through Lake Borgne. The West Pearl, located in Louisiana, enters the coastal waters through The Rigolets, a tidal pass of Lake Pontchartrain, and carries a majority of the flow. The principal tributaries to the river are the Yockanookany River, in the northern part of the basin, the Strong River in the middle part of the basin, and the Bogue Chitto in the southern part of the basin. The river is also fed by numerous smaller tributaries distributed throughout the basin. The lower 70 km of the river are influenced to some extent by Gulf of Mexico tides via Mississippi Sound and Lake Borgne.

The relationship between drainage basin area and long-term (15+ years) discharge for the basin is presented in Figure 3-2. Figure 3-3 presents the discharge as a function of distance from the mouth of the river. The data presented in these figures indicate that the runoff is uniformly distributed throughout the basin, so that flow gradually increases from north to south. The runoff data (Figure 3-4), show an increase in runoff/unit surface area from north to south within the basin. This is a reflection of the rainfall distribution throughout the basin, which has greater rainfall in the southern parts than in the northern parts This trend can be seen in Figure 3-5, which presents the mean yearly total

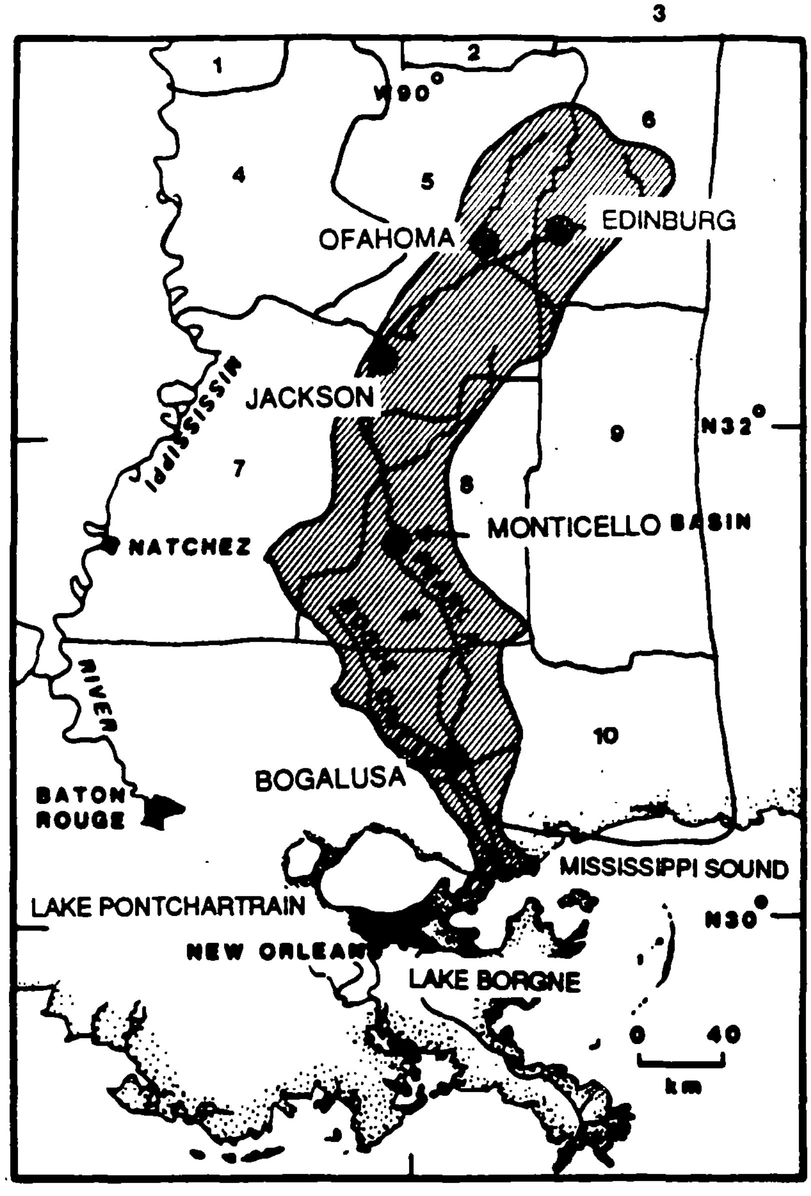


Figure 3-1. Map of the Pearl River system, showing the drainage basin for the Pearl River (shaded area), the climatological divisions for Mississippi (1-10), and selected stage and discharge station locations (black dots).

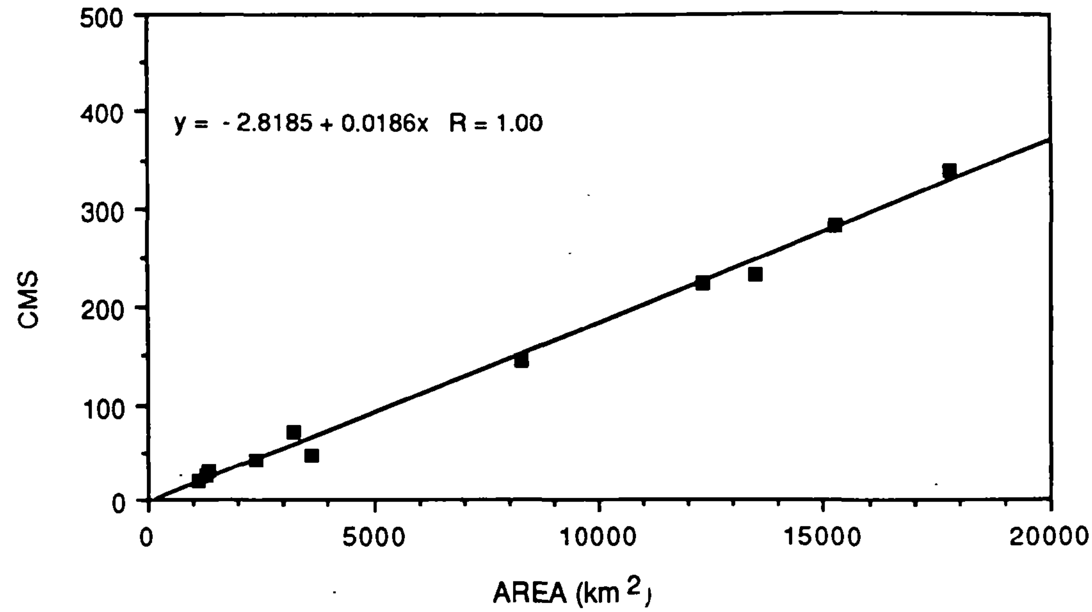


Figure 3-2. Long-term annual discharge (cubic meters per second) as a function of drainage area for stations in the Pearl River basin. Data from USACE (1970).

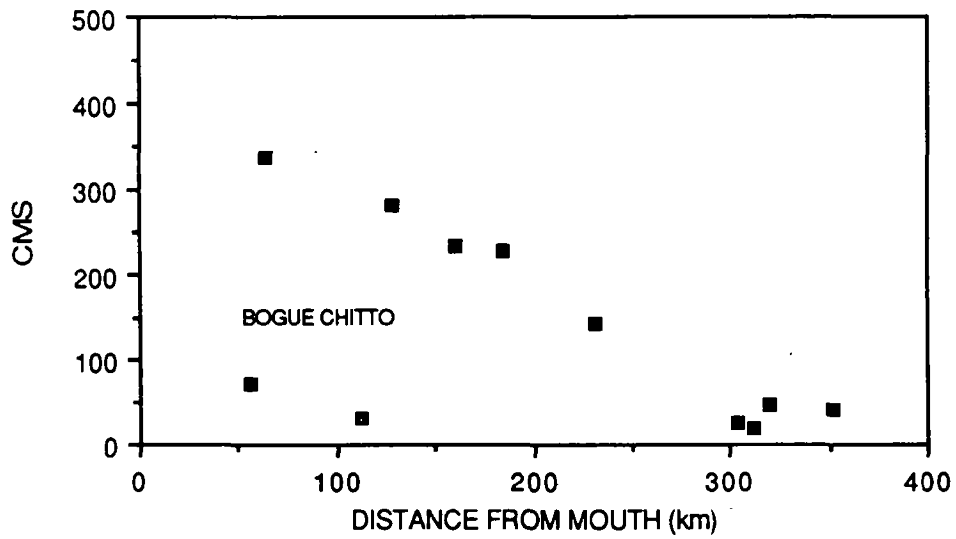


Figure 3-3. Long-term discharge (cubic meters per second) as a function of distance (kilometers) from the mouth of the Pearl River. Data from USACE (1970).

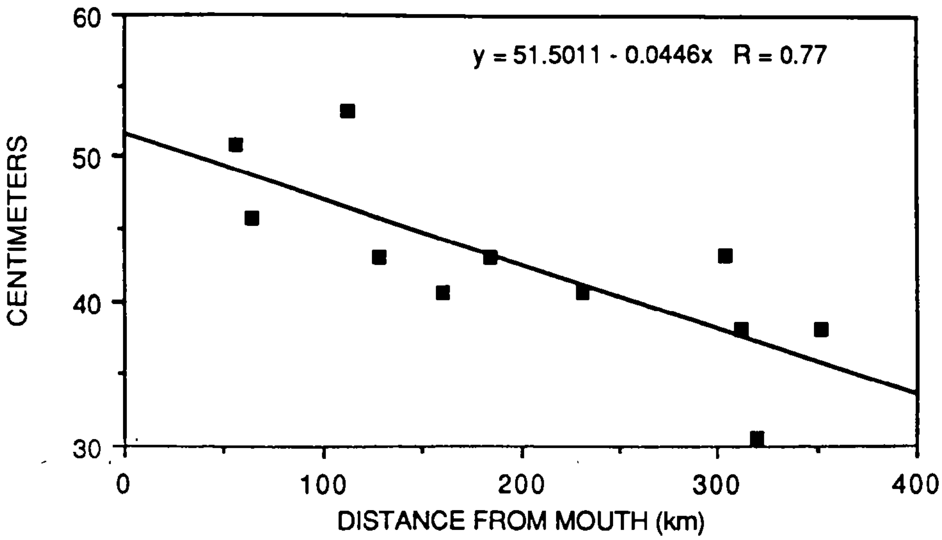


Figure 3-4. Annual mean runoff (centimeters) per unit surface area as a function of distance (kilometers) from the mouth of the Pearl River. Data from USACE (1970).

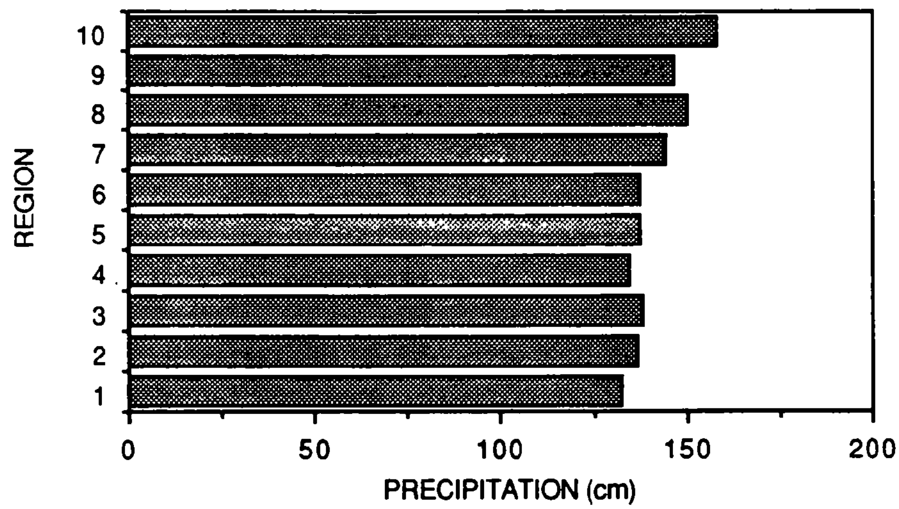


Figure 3-5. The long-term (1931-1988) annual mean precipitation for the 10 climatic regions in Mississippi.

precipitation, based on monthly summaries for 1931-1988, for the 10 climatic regions in Mississippi. Note the general increase in precipitation from north to south (from region 1 to region 10).

Monthly runoff data (Figure 3-6) reveal that the seasonal pattern is the same throughout the basin. In contrast, monthly mean precipitation data for several stations in the basin (Figure 3-7) have a bimodal distribution that peaks in March and August. The discrepancy between these two sets of data is explained by the higher evapotranspiration rate during the summer, which reduces runoff. Monthly means of discharge calculated from daily values over the period of record are shown in Figure 3-8. The seasonal pattern is quite similar at all stations; a peak occurs in the first part of the year (January through May), and flows are low throughout the summer period. This distribution closely follows the seasonal runoff pattern (Figure 3-6), indicating that the river is strongly controlled by precipitation.

The lower Pearl (lower 70 km) is influenced by Gulf of Mexico tides through Mississippi Sound and Lake Borgne. This tidal influence leads to the development of a salt wedge in the lower reaches of the East Pearl. Figure 3-9 shows the position of the salt wedge as a function of river stage. The wedge extends northward from the mouth to a maximum distance of about 25 km.

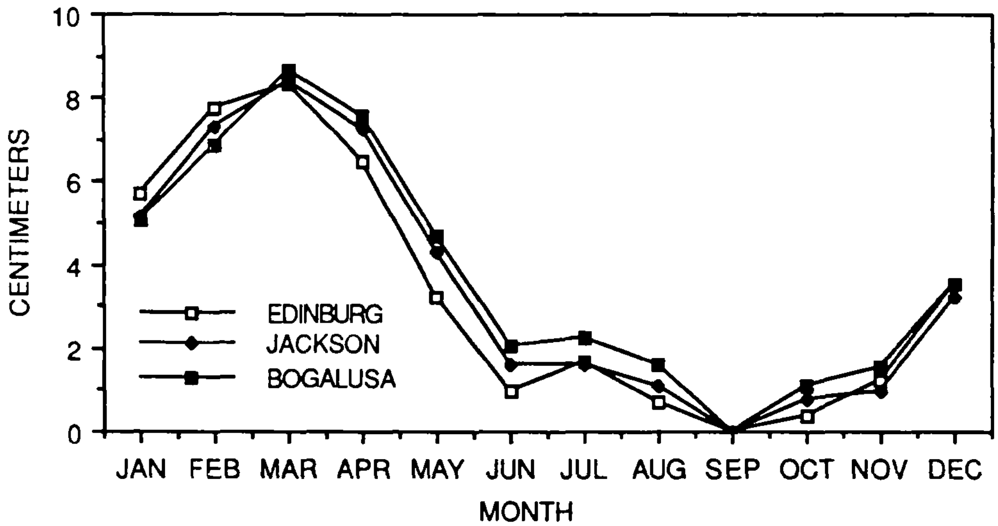


Figure 3-6. Seasonal distribution of runoff for selected stations in the Pearl River basin (see Figure 3-1) showing mean monthly runoff. Data from USACE (1970).

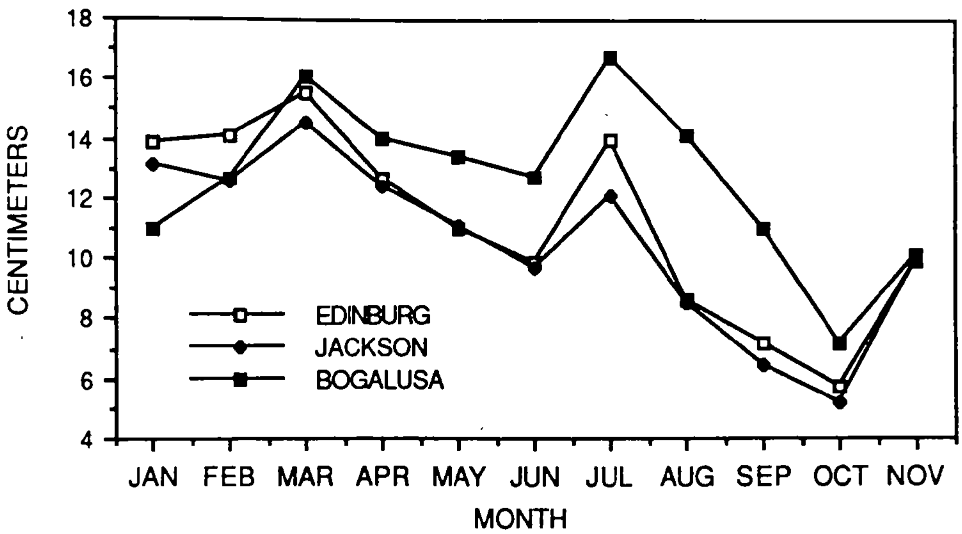


Figure 3-7. Seasonal distribution of precipitation for selected stations in the Pearl River basin (see Figure 3-1) showing mean monthly rainfall. Data from USACE (1970).

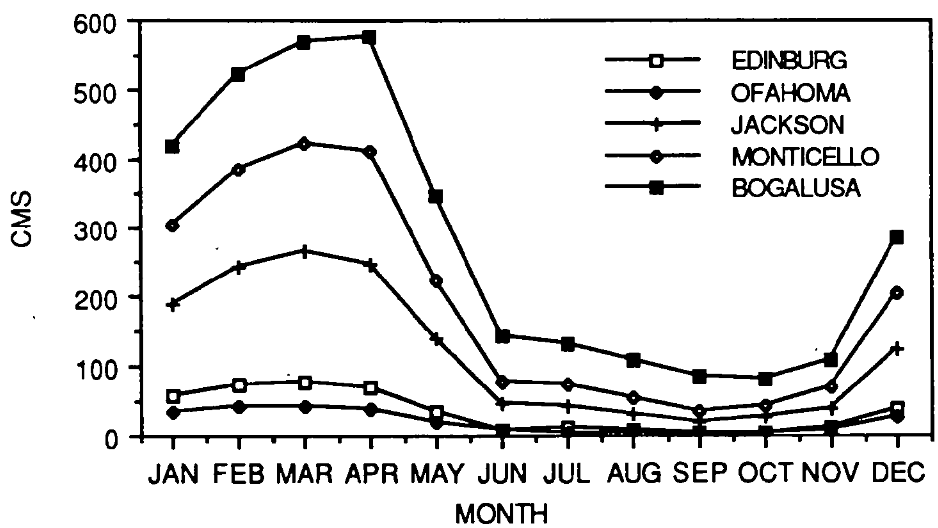


Figure 3-8. Seasonal distribution of discharge for selected stations in the Pearl River basin (see Figure 3-1) showing mean monthly discharges.

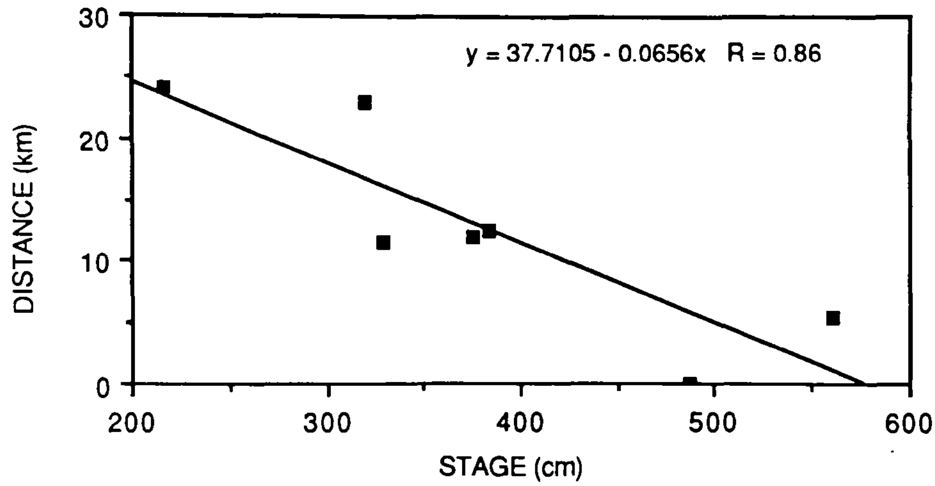


Figure 3-9. Location of the salt wedge in the East Pearl River as a function of river stage. "Distance" indicates the upper limit of the salt wedge from the mouth of the river. Data from the USACE Vicksburg Office (copy of draft report).

The Offshore Area

The Pearl River plume also affects the adjacent coastal waters. The "zone of influence" can be estimated using data in the literature. The tide within the Mississippi Sound area is diurnal, with a mean diurnal range of about 0.34 m (Swenson and Chuang 1983) This pattern was found to be consistent with water levels within Lake Pontchartrain, implying that this range is typical for Lake Borgne. Using this tidal range estimate with an area of Lake Borgne of 6.93×10^8 m^2 (Barrett 1971a) yields a tidal prism volume of about 2.36×10^8 m^3. The average flow for the Pearl River (at Bogalusa) is about 300 cms; flood flows are about 550 cms, and low flows about 150 cms (see Figure 3-8). Calculating the amount of fresh water discharged over a tidal cycle (25 hours) yields values of 2.7×10^7, 4.95×10^7, and 1.35×10^7 m^3 for mean, flood, and low flow conditions respectively. Thus, the freshwater flow from the Pearl River is about 11% of the total tidal prism, under mean conditions, and can be as high as 21% during flood conditions. Using Barrett's (1971a) estimate for the volume of Lake Borgne (1.17×10^9 m^3) along with the river flow estimates, we arrive at replacement times (for all of Lake Borgne) of 45, 25, and 90 days for mean, flood, and low flow conditions. Thus, it is not suprising that Barrett (1971b), in his Louisiana estuarine inventory, noted that salinities within the Lake Borgne area are inversely correlated with Pearl River discharge. He also noted that both turbidity and nitrates within the Lake Borgne area appear to fluctuate with Pearl River discharge, although he did not do a statistical analysis.

Sikora and Kjerfve (1985) studied factors influencing salinity at six stations within Lake Pontchartrain (Figure 3-10). They concluded that the Pearl River discharge is a better predictor of the salinities in the eastern part of the Lake (Little Woods) than are the rivers entering directly into Lake Pontchartrain. Their analysis indicated that the Pearl River explains about 40% of the variation in salinity within the east portion of Lake Pontchartrain. Thus we can define a zone of influence of the Pearl River on the adjacent coastal waters that includes Lake Borgne, the eastern section of Lake Pontchartrain, and extends an unknown distance into Mississippi Sound (see Figure 3-10). Schroeder et. al (1985) documented the existence of a recurrent pattern of westward flow that occurs under the influence of northerly winds immediately south of the Mississippi-Alabama barrier islands. This flow appears to enter the Chandeleur-Breton sound at the northern end. If it extends towards Lake Borgne, this westward flow could serve to contain the Pearl River waters to Lake Borgne and Lake Pontchartrain. Further data collection and analysis are needed to refine assessments of the offshore influences of the Pearl River.

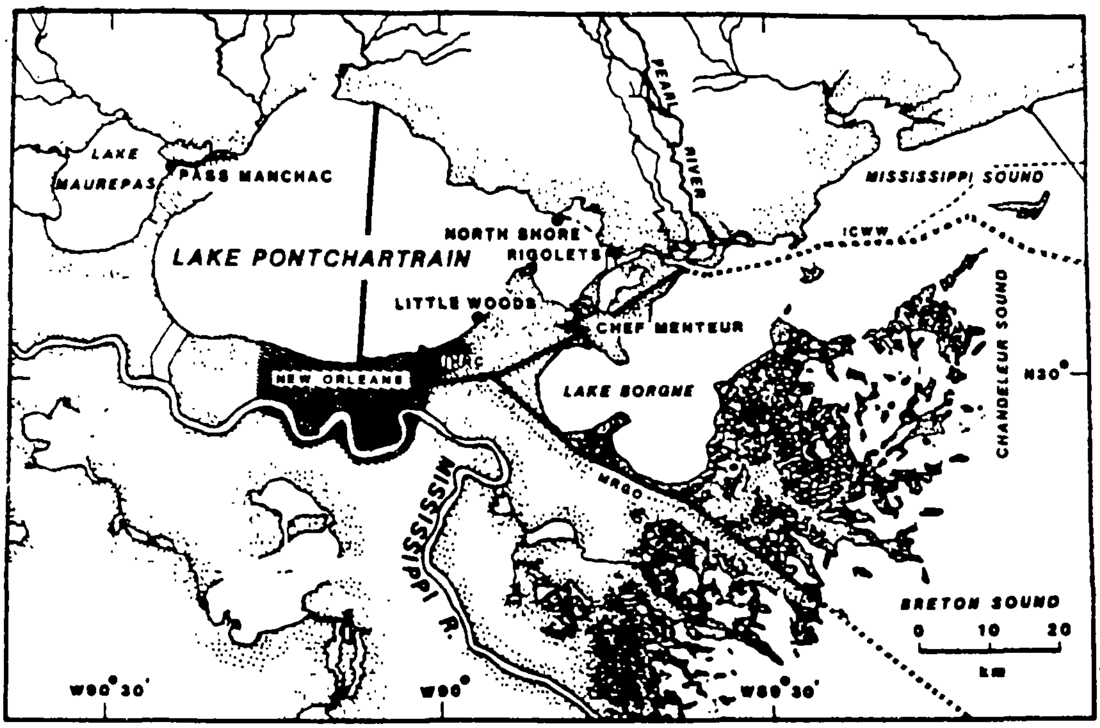


Figure 3-10. Map of the Lower Pearl River area and the adjacent coastal waters.

Historical Changes

During the past 100 years, changes have been made within the Pearl River basin that could affect the hydrologic regime of the river. In the late 1800s and early 1900s these changes consisted primarily of the removal of obstructions and log jams within the river by the USACE. These changes are summarized in Figure 3-11 (from J. R. Sedell, USDA, Forest Sciences Laboratory). In general, a great deal of activity took place around the turn of the century, and most of the obstructions were removed by 1900.

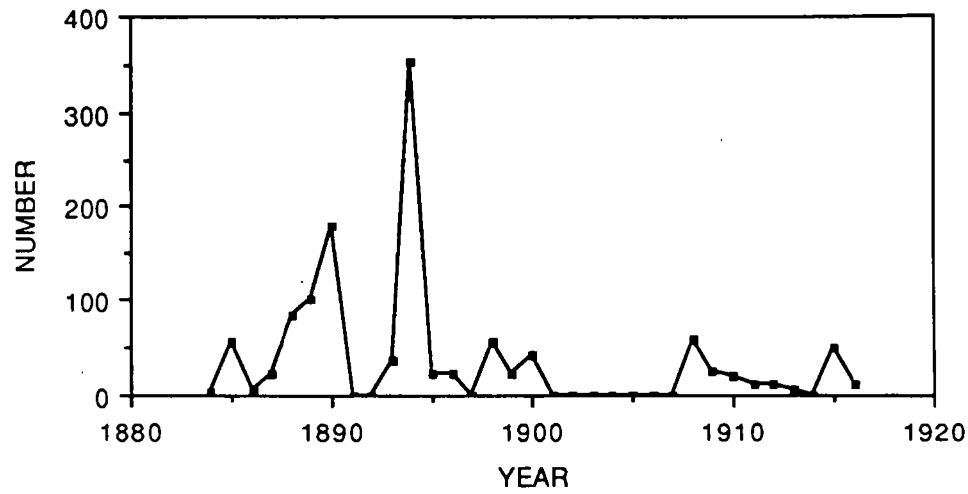


Figure 3-11. Number of obstructions removed from the Pearl River basin from 1880 through 1920. Data from J. R. Sedell, USDA Forest Service Laboratory, Corvallis, Oregon (unpublished).

According to the USACE records (USACE, 1970), a channel from Jackson to Carthage, navigable at a 1.5-m stage of water, was authorized under the River and Harbor Act of 1879, then modified to a 1.5-m-deep channel at low water by the River and Harbor Act of 1880. Subsequently it was modified by the River and Harbor Act of 1886 to be a 0.61-m-deep channel of navigable width. A second project to create a high-water channel from Carthage to Edinburg was combined with this project by the River and Harbor Act of 1902. To date, no work has been done on this project. Several other projects in the upper basin were authorized, but not built. There are several USACE navigation projects in the lower part of the basin. The first of these is a 2.74-m-deep, 91.46-m-wide channel from the mouth of the East Pearl to Mississippi Sound. This channel was completed in 1900, then restored to a depth of 2.74 m and width of 60.97 m in 1911. A navigation channel with locks was completed on the West Pearl in 1953. It consists of a 30.48-m-wide channel in the lower 52.8 km of the West Pearl; a 24.39-m-wide, 37.6-km-long lateral canal (with three locks) parallel to the natural channel; and a 30.48-m-wide, 17.0-km-long channel from the lateral canal to Bogalusa. In addition to these projects, the Ross Barnett dam and a 1-hectare reservoir, a local government project, were completed in 1964.

The Ross Barnett Dam was constructed on the Pearl River about 6 miles northeast of Jackson in 1964 by the Pearl River Valley Water Supply District, an agency of the State of Mississippi. The 30,000-acre lake formed by this dam, with a total storage volume of about 310,000 acre-feet, provides recreation and an assured source of water supply for the Jackson area in the amount of 150 million gallons per day.

The only other federal agency that has made modifications within the basin is the Soil Conservation Service (SCS). Its work consisted of small projects to retard erosion and to prevent localized flooding due to rainfall. The benefits listed for these projects include reduction of damage to fences, roads, and bridges, and protection of local lands from the three-year flood. The SCS has seven projects within the Pearl River basin (Figure 3-12). The strategies used include both structural (drainage ditches, dams) and land treatment (farm ponds, planting, and land management) projects. The work completed to date, most of which was completed in the early 1970s, on all of the projects is listed in Table 3-1. In general, the area affected by these projects is fairly small. The SCS states in the project reports that these projects are not expected to influence the main stem of the Pearl River.

In summary, there have been relatively few changes to the Pearl River basin in recent times (since 1900). The most extensive modifications have been in the Lower Pearl and consist mainly of navigation channels. The Ross Barnett Reservoir is quite shallow and therefore expected to have little effect on the flows of the Pearl River (USACE 1970). The most significant changes probably occurred during the late 1800s, when major obstructions to flow were removed.

STAGE AND DISCHARGE ANALYSIS

The Data Base

Daily records of stage and discharge were obtained for a number of stations within the basin. The station locations are indicated in Figure 3-13; Table 3-2 lists the dates of record for each of the stations. Precipitation data were obtained through the Louisiana Office of the State Climatologist. These data were in the form of monthly total precipitation for the 10 climatic regions of Mississippi (Figure 3-1) from 1931 through 1988. Inspection of the stage data revealed that most of the records were of short duration, which precluded analysis of changes to the rating curve with time. Therefore, we also obtained measured stages and discharges from the U.S. Geological Survey (USGS) in Jackson for

Edinburg, Ofahoma, Jackson, and Monticello. The data were transcribed from the original files, using decade intervals from 1900 through 1987. For each decade, enough years were used (usually one or two) to define the rating curve for that decade interval.

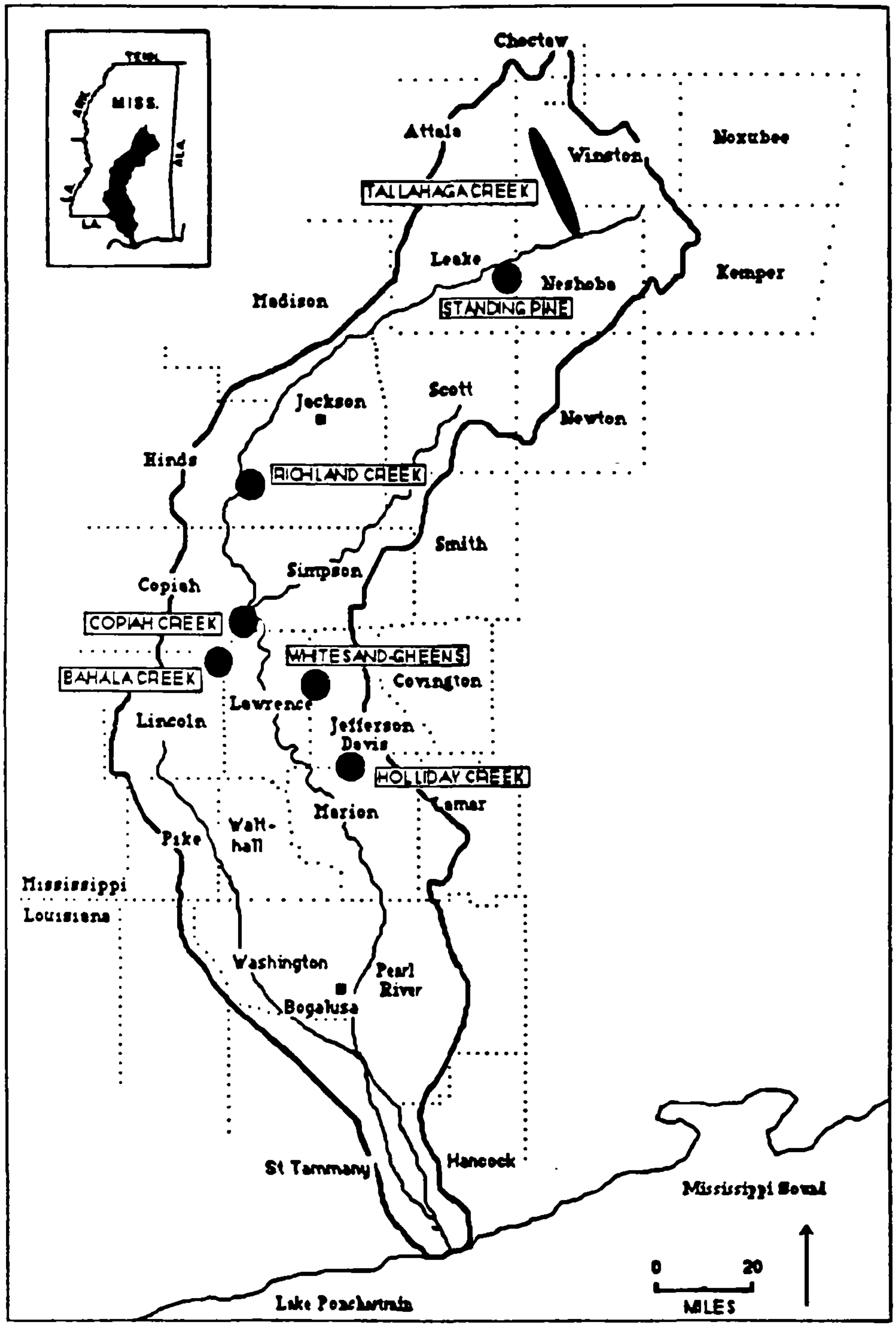


Figure 3-12. Map of the Pearl River basin showing the locations of the seven Soil Conservation Service projects within the basin.

Table 3-1. Summary of Soil Conservation Service projects within the Pearl River basin for both land treatment and structural measures.

I. Land Treatment [a]

Project Name	farm ponds (number)	critical area planting (ha)	pasture and hayland management (ha)	pasture and hayland planting (ha)	conservation cropping (ha)	tree planting (ha)	other (ha)
Bahala Creek	42	294	1,368	0	386	38	5,176
Copiah	890	246	0	7,595	3,069	1,653	2,748
Holliday Creek	719	701	9,002	11,082	4,659	2,426	0
Richland Creek	443	98	0	4,418	0	1,855	3,140
Standing Pine	203	536	0	3,744	2,974	284	1,963
Tallahaga Creek	615	689	0	5,059	1,497	1,214	0
Whitesand-Greens	947	233	9,740	5,094	7,790	1,094	0
Total	3,859	2,806	20,110	36,992	20,375	8,564	13,027

II. Structural Measures

Project Name	drainage ditches[a] (km)	diversion ditches[a] (km)	area controlled by structures (ha)	channels (km)
Bahala	0	0	nd	nd
Copiah	9.45	0	1,157[a,b]	9.36[a,b]
Holliday Creek	4.91	8.67	2,705[a,c]	0[a]
Richland Creek	5.26	0	2,926[a,d]	26.14[a,d]
Standing Pine	24.68	0	4,519[a,e]	38.91[a,e]
Tallahaga	0	0	9,206[a,f]	20.38[a,e]
Whitesand-Greens	0.70	4.91	542[a,g]	0[a]
Total	45.00	13.58	21,055	94.79

Table 3-1. Continued

[a] Data from Watershed Progress Report for Mississippi.. Soil Conservation Service, Jackson, Mississippi. The "other" category includes land described as "adequately treated."

[b] Data from Project Map for Copiah Creek Watershed. U.S. Dept. of Agriculture, Soil Conservation Service, January 1987, Jackson, Mississippi. Map No. 4-R-36718. February 1981.

[c] Data from Supplemental Watershed Work Plan and Work Agreement No. 1. Holliday Creek Watershed, Jefferson Davis and Marion Counties Mississippi. U.S. Dept. of Agriculture, Soil Conservation Service. March 1979.

[d] Data from Project Map for Richland Creek Watershed. U.S. Dept. of Agriculture, Soil Conservation Service, Jackson, Mississippi. Map No. 4-R-36666. February 1981.

[e] Data from Watershed Work Plan, Standing Pine Watershed Leake and Neshoba County, Mississippi. Standing Pine Drainage District, Leake and Neshoba County Soil Conservation Districts. November 1964.

[f] Data from Tallahaga Creek Watershed, Winston, Choctaw and Neshoba Counties, Mississippi, Supplemental Watershed Plan No. 1 and Supplemental Watershed Agreement No. 2. U.S. Dept. of Agriculture, Soil Conservation Service, Jackson, Mississippi. July 1985.

[g] Data from Whitesand-Greens Creeks Wartershed, Jefferson Davis and Lawrence Counties, Mississippi, Supplemental Watershed Plan No. 1 and Supplemental Watershed Agreement No. 1. U.S. Dept. of Agriculture, Soil Conservation Service, Jackson, Mississippi. August 1985.

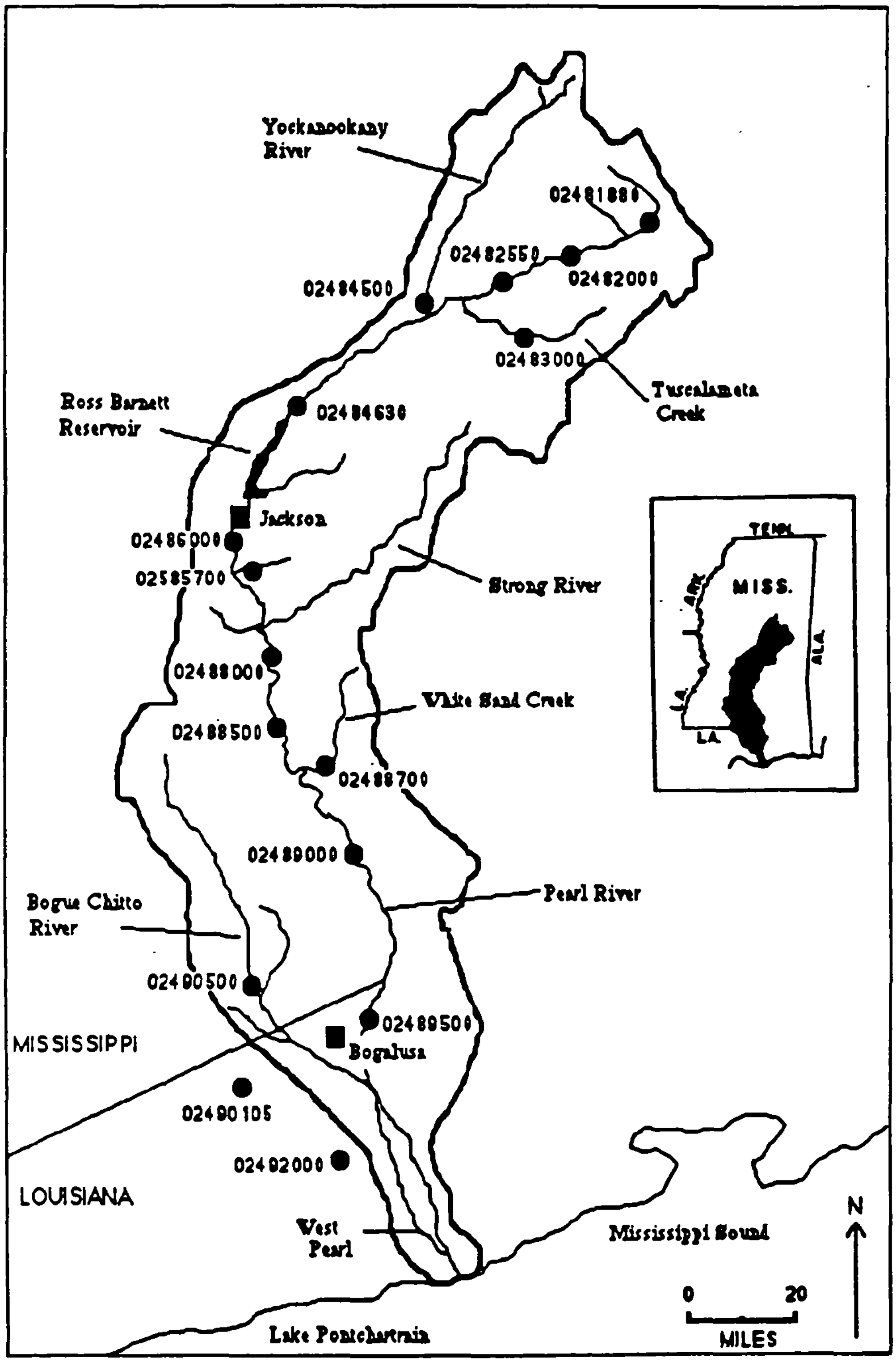


Figure 3-13. Map of the Pearl River basin showing the locations of the USGS daily stage and discharge records analyzed for this study.

Table 3-2. Summary of United States Geological Survey (USGS) daily discharge and stage records from the Pearl River basin. Data sets are those that are presently available in computer-compatible format.

Station	Location	Start Date	End date	N[a]	Elevation[b] (ft)
Daily Discharge Data					
02481880	Pearl River @ Burnside, MI	December 1980	September 1987	2,466	376.30
02482000	Pearl River @ Edinburg, MI	October 1928	September 1987	21,549	341.67
02482550	Pearl River @ Carthage, MI	October 1962	September 1987	9,131	315.24
02483000	Tuscolameta Creek @ Walnut Grove, MI	October 1939	September 1987	17,532	322.70[c]
02484500	Yockanookany River @ Ofahoma, MI	October 1943	September 1987	16,071	374.34
02484630	Pearl River @ Ratcliff, MI	January 1981	September 1987	2,495	290.00
02585700	Hanging Moss Creek @ Jackson, MI	October 1980	September 1987	2,556	260.00[d]
02486000	Pearl River @ Jackson, MI	October 1901	September 1987	25,564	233.70[e]
02488000	Pearl River @ Rockport, MI	October 1938	September 1987	5,843	180.90
02488500	Pearl River @ Monticello, MI	October 1938	September 1987	17,897	158.66
02488700	White Sand Creek @ Oak Vale, MI	October 1965	September 1987	8,035	182.20[f]
02489000	Pearl River @ Columbia, MI	October 1928	September 1980	9,862	115.81[g]
02489500	Pearl River @ Bogalusa, LA	October 1938	September 1984	17,167	55.00
02490105	Bogue Lusa Creek @ Highway 439, LA	October 1963	October 1984	7,675	
02490500	Bogue Chitto River @ Tylertown, MI	October 1944	September 1987	15,705	227.40
02492000	Bogue Chitto River @ Bush, LA	October 1937	October 1984	17,171	
Daily Stage Data					
02481880	Pearl River @ Burnside, MI	December 1980	September 1987	2,495	
02482000	Pearl River @ Edinburg, MI	October 1971	September 1987	5,509	
02482550	Pearl River @ Carthage, MI	October 1971	September 1987	5,844	
02483000	Tuscolameta Creek @ Walnut Grove, MI	October 1971	September 1987	5,753	
02484500	Yockanookany River @ Ofahoma, MI	October 1971	September 1987	5,844	
02484630	Pearl River @ Ratcliff, MI	no stage data			
02585700	Hanging Moss Creek @ Jackson, MI	October 1980	September 1987	2,556	
02486000	Pearl River @ Jackson, MI	October 1960	September 1987	7,883	
02488000	Pearl River @ Rockport, MI	October 1984	September 1987	1,095	
02488500	Pearl River @ Monticello, MI	January, 1972	September 1987	5,387	
02488700	White Sand Creek @ Oak Vale, MI	October 1972	September 1987	5,235	
02489000	Pearl River @ Columbia, MI	no stage data			
02489500	Pearl River @ Bogalusa, LA	no stage data			
02490105	Bogue Lusa Creek @ Highway 439, LA	no stage data			
02490500	Bogue Chitto River @ Tylertown, MI	October 1972	September 1987	5,447	
02492000	Bogue Chitto River @ Bush, LA	no stage data			

[a]N = The number of data points in each record.

[b]Elevation = The gage elevation relative to the 1929 National Geodetic Vertical Datum (NGVD).

[c]Prior to 1 October 1971, the datum was 10.00 ft higher.

[d]Prior to 11 July 1971, the datum was 1.33 ft higher.

[e]Prior to 1 October 1975, the datum was 1.20 ft higher.

[f]Mississippi state highway datum.

[g]From August 1928 through May 1934 the datum was 0.37 ft higher.

Figures 3-14 through 3-18 present annual mean discharge and annual mean stage for various stations within the Pearl River basin. These five stations are typical of all of the data records. The annual total rainfall for central Mississippi (region 5) and south central Mississippi (region 8) are presented in Figure 3-19.

Analysis Procedures

The analytical procedures used for this analysis were similar to those used by Wiseman and Swenson (1988) to analyze long-term salinity data from the Louisiana coastal zone. The following general questions were addressed:

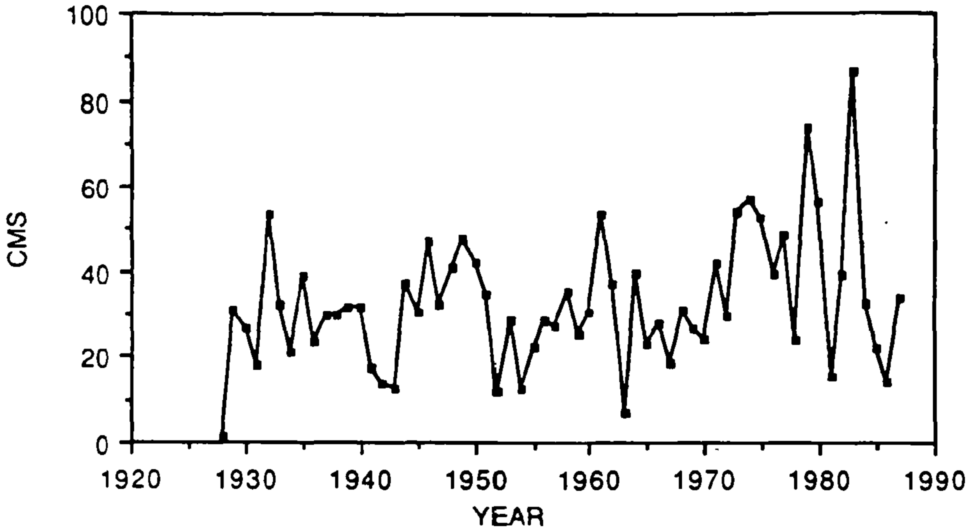
1. Has there been a statistically significant change in the mean discharge or stage in the Pearl River basin?
2. Has there been a statistically significant change in the variance about the mean discharge or stage in the Pearl River basin?
3. Has there been a statistically significant change in the maximum discharge or stage in the Pearl River basin?
4. Has there been a statistically significant change in the minimum discharge or stage in the Pearl River basin?
5. Has there been a change in the rating curves (discharge as a function of stage) in the Pearl River basin?

If the answer to any of these was yes, then two more questions were asked:

1. What is the magnitude of the change?
2. Can the changes be explained as natural variability?

The investigation into the secular trends was begun by fitting a linear model to the data sets using time with annual harmonic (sine and cosine) terms to remove the seasonal correlation effects as independent variables.. The slope parameter of the model was then tested for statistical significance (Neter and Wasserman 1974). In all tests a significance level of 95% was used. The procedures used in the analysis were the GLM (general linear models) procedures supported on the LSU Mainframe computer by Statistical Analysis System (SAS, 1985a, b). The analyses were run on both the stage and the discharge for the monthly means, variance about the mean, minima, and maxima. The annual means were then calculated for each of the stations, and a linear model was fit using time as the independent variable. The annual means were used as another method of averaging out the strong seasonal signal in the data.

Visual inspection of the annual data (Figures 3-14 through 3-19) revealed that the data series has two distinct parts: the period before 1971 and the period from 1971 through 1988, during which three very large flood events occurred. These three floods may have strongly influenced the analysis results. To investigate this, we divided the data into two series: (1) a pre-1971 series and (2) a 1971-1988 series. Each of these series was then



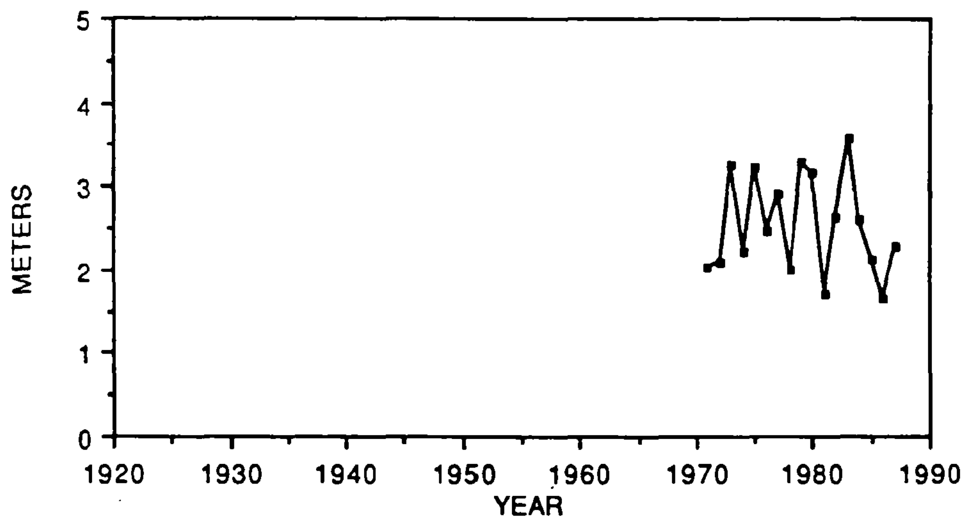


Figure 3-14. Yearly mean discharge, in cubic meters per second (top) and yearly mean stage in meters (bottom) for the Pearl River at Edinburg, Mississippi.

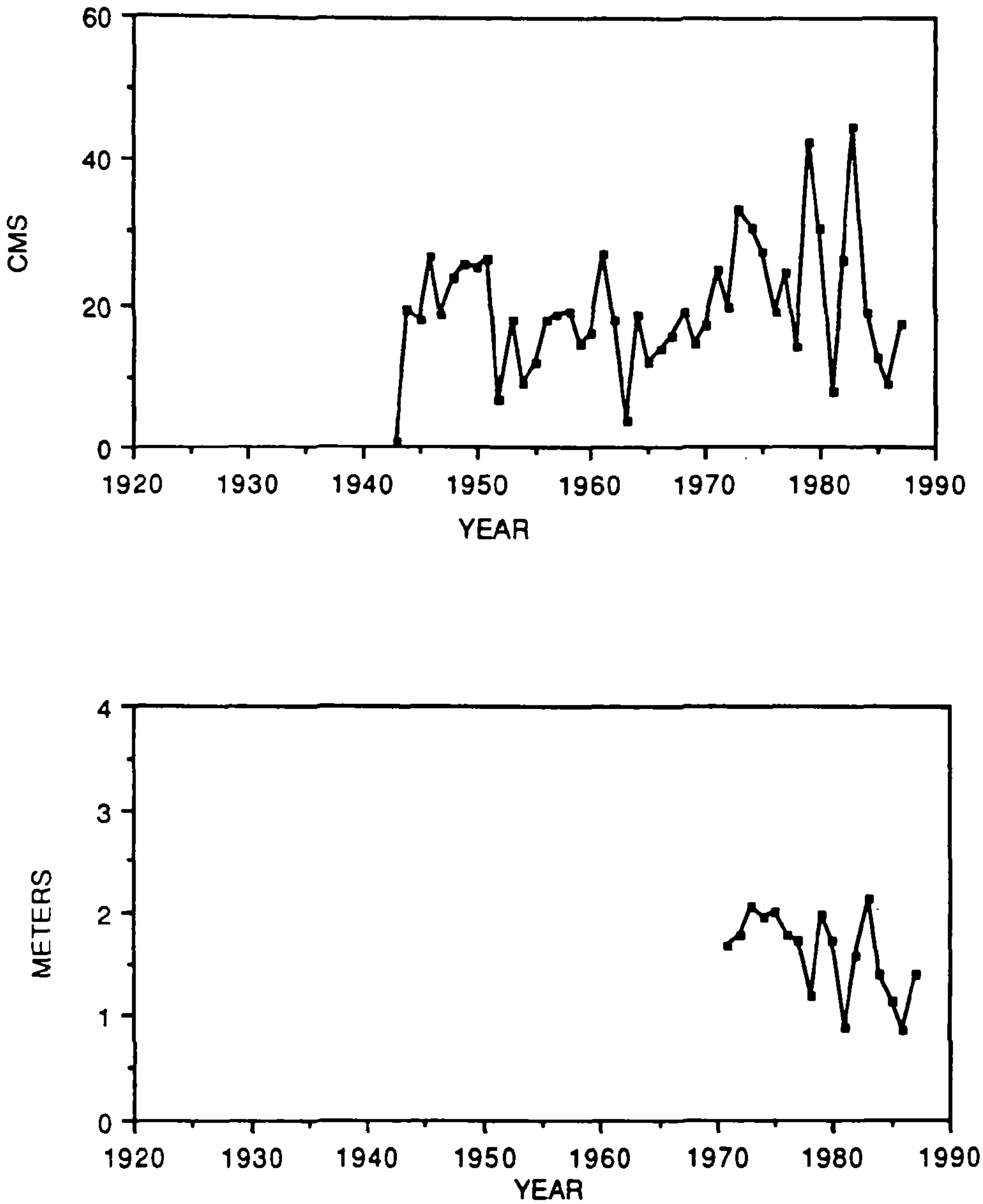


Figure 3-15. Yearly mean discharge, in cubic meters per second (top) and yearly mean stage in meters (bottom) for the Yockanookany River at Ofahoma, Mississippi.

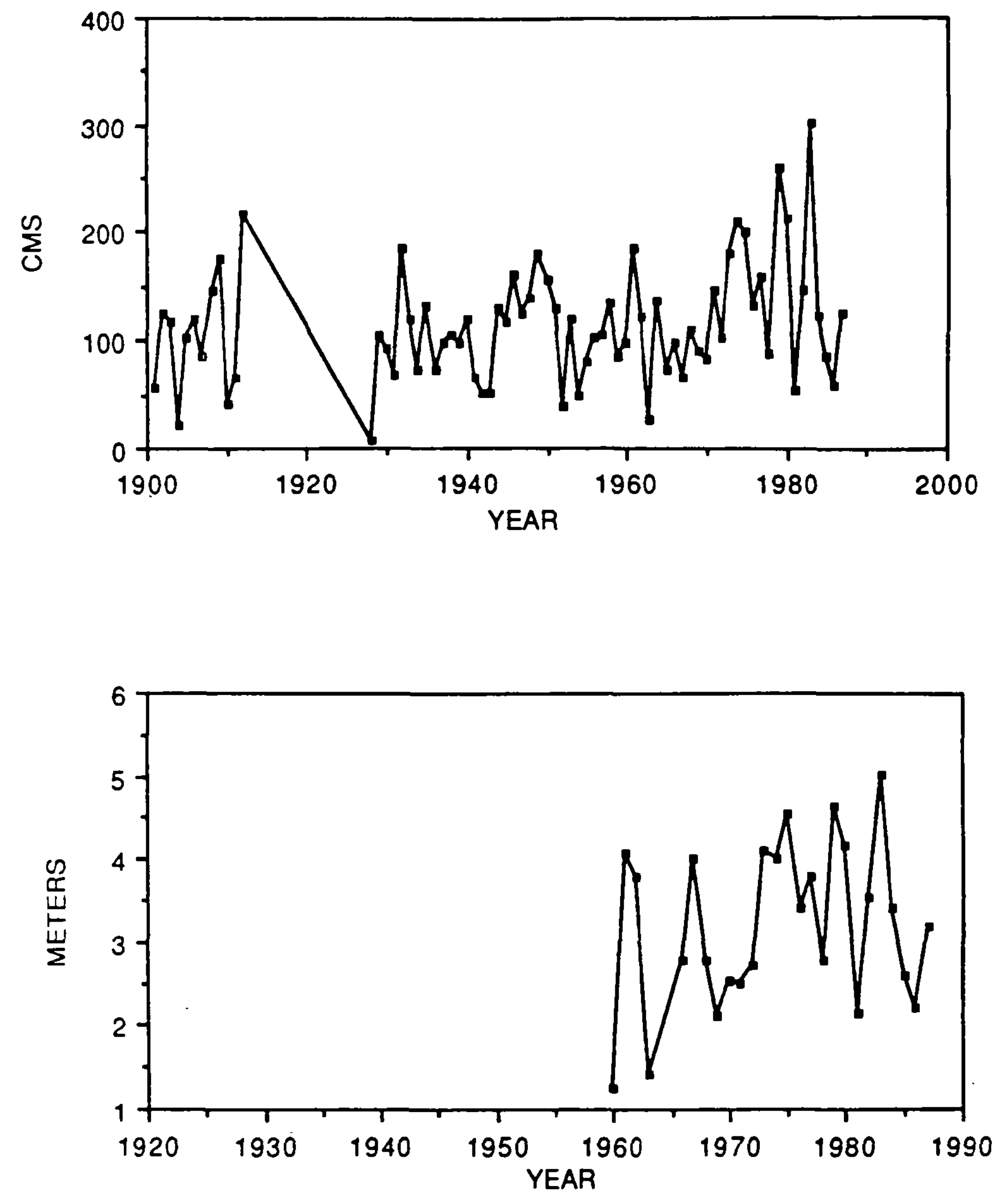


Figure 3-16. Yearly mean discharge in cubic meters per second (top) and yearly mean stage in meters (bottom) for the Pearl River at Jackson, Mississippi.

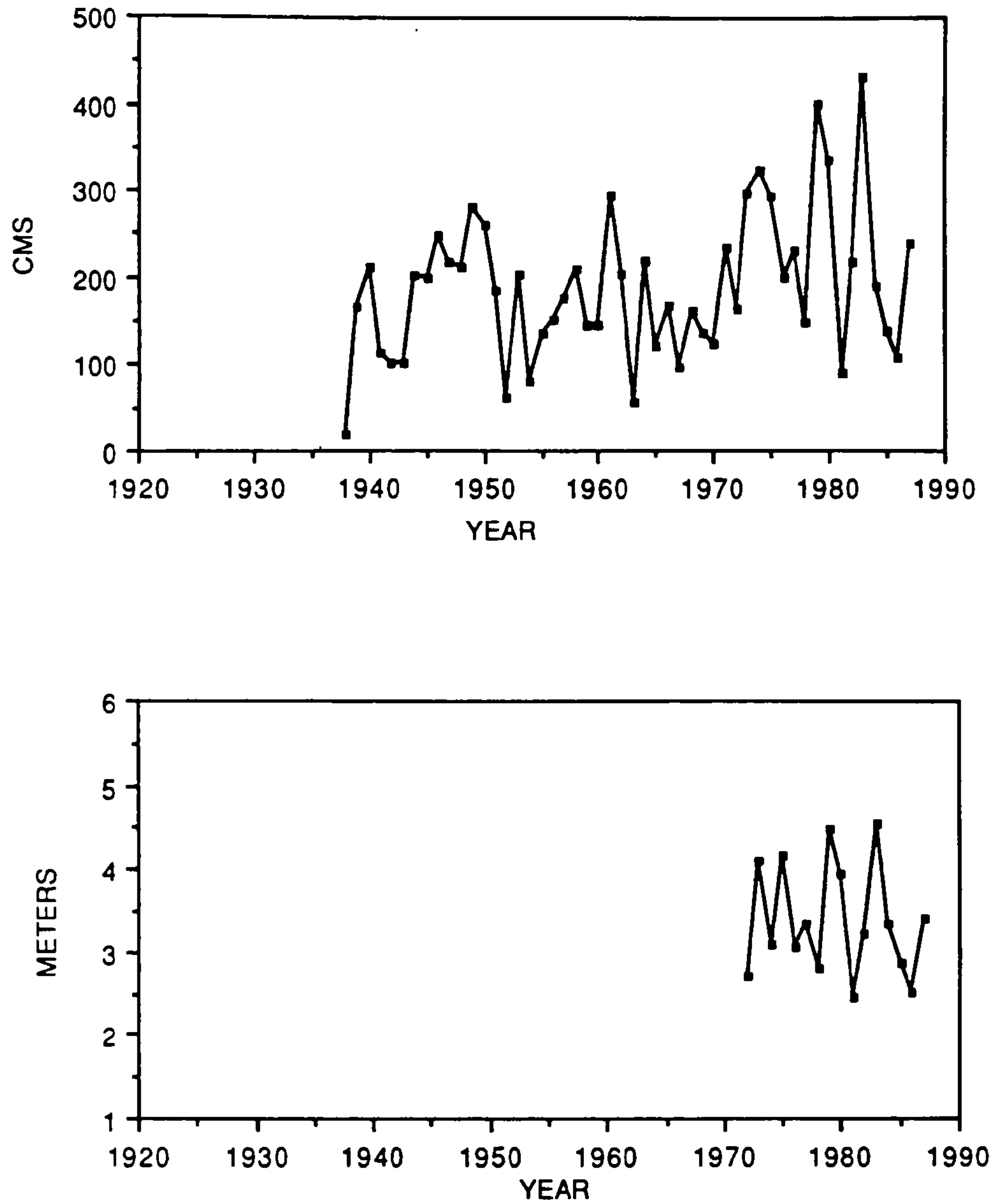


Figure 3-17. Yearly mean discharge in cubic meters per second (top) and yearly mean stage in meters (bottom) for the Pearl River at Monticello, Mississippi.

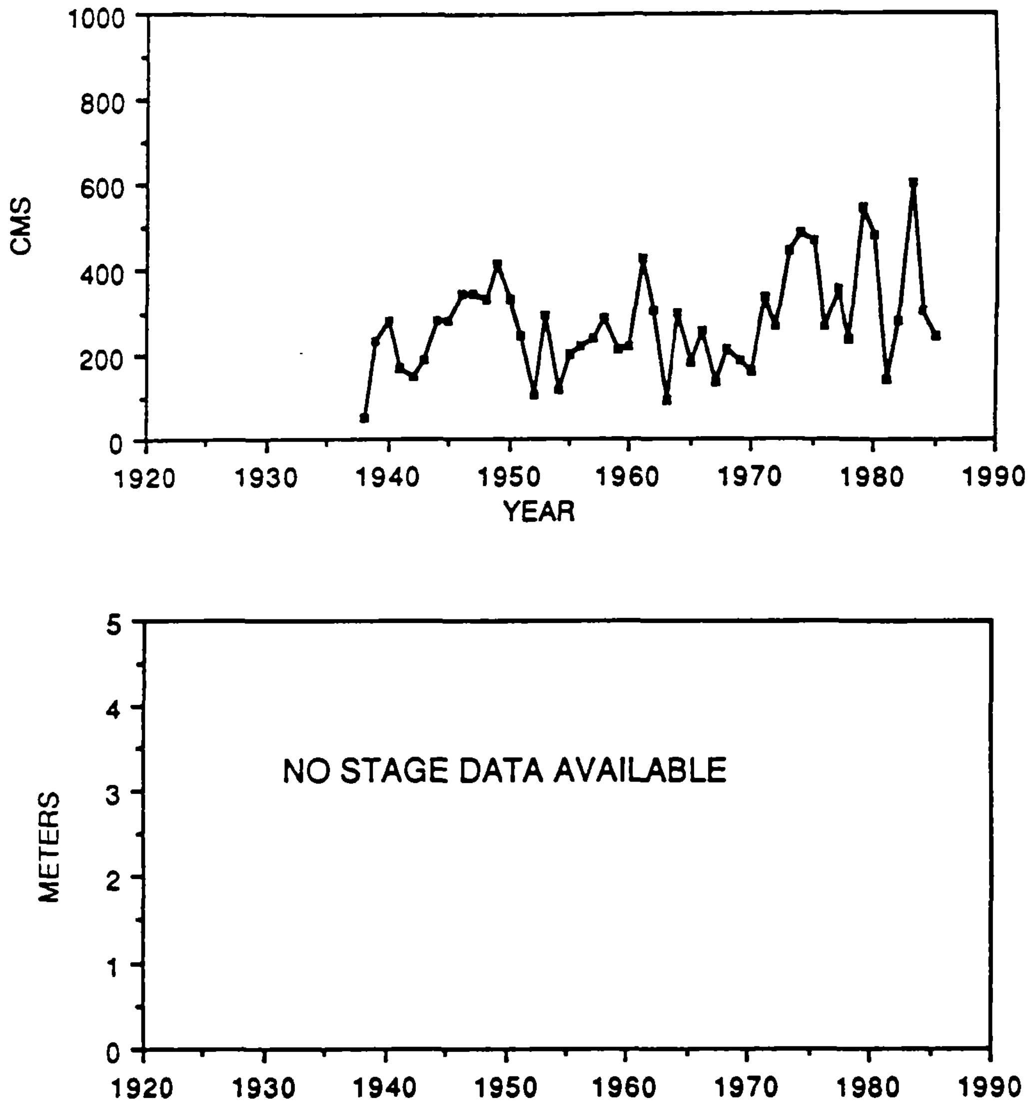


Figure 3-18. Yearly mean discharge, in cubic meters per second (top) and yearly mean stage in meters (bottom) for the Pearl River at Bogalusa, Mississippi.

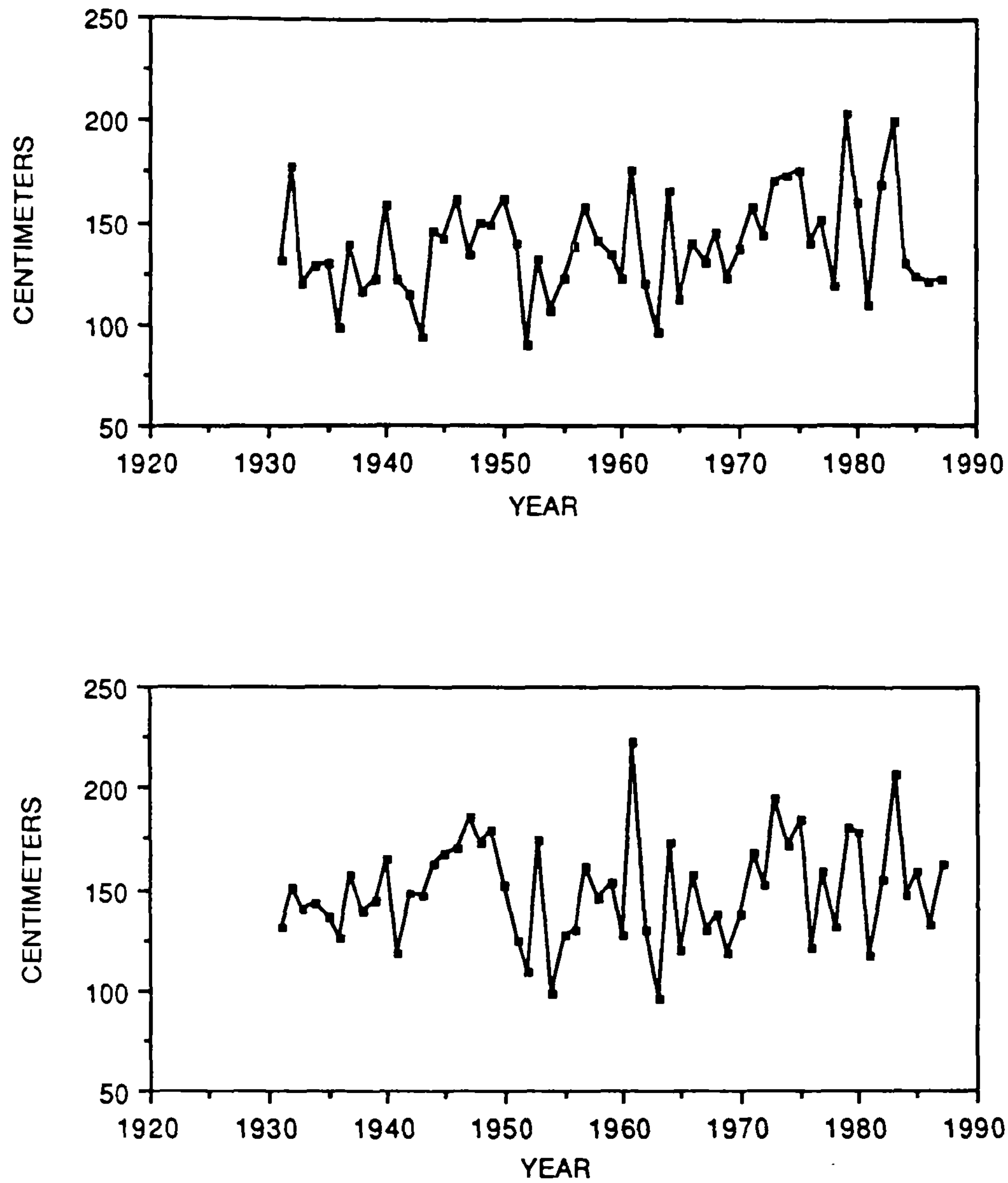


Figure 3-19. Total yearly precipitation for region 5 (central Mississippi) and region 8 (south central Mississippi).

analyzed using the above procedures. In addition, a fourth series (the "edited" series) was created in which only the large peaks (1974, 1979, and 1983) were removed. It is also evident from these plots that rainfall, stage, and discharge are strongly related.

A nonparametric test for the presence of a trend, the seasonal Kendall-Tau (Hirsch et al. 1982), was also used on the monthly data. This procedure tests for the presence of a statistically significant, monotonic trend in the data. It is important to note that the trend need not be linear. This test was originally designed for data that are extremely "spikey" in nature. The test does not determine the slope of the trend, only whether a trend exists and its sign.

The stage-discharge relationship was investigated by plotting a rating curve for each of the stations for each decade. The curves were then examined to detect any evidence of a consistent change over time. Of particular interest was whether the discharge for a given stage had increased, decreased, or remained the same over the last 40-50 years.

RESULTS AND DISCUSSION

When the linear trend plus the seasonal cycle were fit to the monthly mean and to the variance about the monthly mean data, the trend appeared to be significant in several cases for both discharge and stage, if the whole data base was used. A correlation analysis between annual rainfall and river discharge and stage (Table 3-3) indicates that the rainfall in central Mississippi explains approximately 80% of the variance in the Pearl River discharge and stage data. Thus, the data were edited (as explained above) to account for the rainfall effect. If the large rainfall events of 1974, 1989, and 1983 are removed, mean discharge has a significant slope through time at only only three stations (White Sand Creek at Oakvale, Pearl River at Columbia, and Bogue Chitto at Highway 439; Table 3-4). All of these stations are in the lower portion of the basin, and the results are not consistent (two are positive, one is negative). The river stage decreased at stations in the northern part of the basin (Edinburg, Carthage, the Yockanookany at Ofahoma), and did not change at main-stem stations in the rest of the basin. The Bogue Chitto at Tylertown also showed a decrease. Similar results were obtained for the variances about the monthly mean (Table 3-4) as well as the minima and maxima (Table 3-5); only a few stations remained significant if the large rainfall events were removed.

The above procedure was also used to analyze the annual means, variances about the annual means, annual minima, and annual maxima for both stage and discharge. The results are presented in Tables 3-6 and 3-7 Again, once the rainfall effect is accounted for, no trends in the annual discharge are statistically significant except for that for White Sand

Creek at Oakvale. The results for annual stage are similar; only the Yockanookany at Ofahoma, the Bogalusa at Tylertown, and the Pearl at Carthage have statistically significant trends (all negative). Results for the variance about the annual mean (Table 3-6) indicate no statistically significant trends for discharge and only two stations (Pearl at Walnut Grove and Pearl at Oakvale)with significant trends in stage (both negative). Annual minima and maxima (Table 3-7) were also similar with no statistically significant trends in discharge and only one station with a significant positive trend in stage (Jackson). Appendix A presents detailed statistical results for all of the analyses.

Stage discharge curves for the gaged stations are shown in Figures 3-20 through 3-23. It is evident from these figures that the stage-discharge relationship within the Pearl River has not changed over the last 40-50 years.

Table 3-3. Correlation between mean yearly total precipitation for central Mississippi (Region 5) and yearly mean discharge and stage for the Pearl River at several locations. Correlations are significant at the 95% level unless indicated otherwise.

Station	Pearson Correlation	Probability	Number of Years
Discharge			
Burnside	0.7107	0.0482	8
Edinburg	0.8764	0.0001	57
Carthage	0.9067	0.0001	26
Yockanookany	0.9269	0.0001	45
Ratliff	0.8644	0.0121	7
Jackson	0.8886	0.0001	57
Rockport	0.7559	0.0003	18
Monticello	0.8805	0.0001	50
Columbia	0.1352*	0.5103	26
Bogalusa	0.8556	0.0001	58
Stage			
Burnside	0.6678*	0.0703	8
Edinburg	0.7977	0.0001	17
Carthage	0.8878	0.0001	17
Yockanookany	0.8763	0.0001	17
Ratliff		no data	
Jackson	0.7908	0.0001	26
Rockport	0.7544*	0.2456	4
Monticello	0.8391	0.0001	16
Columbia		no data	
Bogalusa		no data	

* Not significant.

Table 3-4. Summary statistics from analysis of monthly mean and variance about the monthly mean discharge and stage as a function of time for USGS stations in the Pearl River basin using a seasonally adjusted ANOVA model. Listed are the results of analysis using the entire data set, using only data before 1971, using only data for 1971-1988, and using the edited data set (1974, 1979, and 1983 deleted).

Station	Mean				Variance about the mean			
	all data (cms/mo)	<1971 (cms/mo)	71-88 (cms/mo)	edited (cms/mo)	all data (cms^2/mo)	<1971 (cms^2/mo)	71-88 (cms^2/mo)	edited (cms^2/mo)
Discharge data (cubic meters/second)								
Burnside	NS[a]	ND[b]	NS	NS	NS	ND	NS	NS
Edinburg	0.019	NS	NS	NS	5.26	NS	NS	NS
Carthage	0.105	0.229	NS	NS	NS	NS	NS	NS
Walnut Grove	0.014	NS	NS	NS	1.959	NS	NS	NS
Ofahoma	NS	NS	NS	NS	NS	NS	NS	NS
Ratliff	ND	NS	NS	NS	ND	NS	NS	NS
Hanging Moss	ND	NS	NS	NS	ND	NS	NS	NS
Jackson	0.039	NS	NS	NS	15.172	NS	NS	NS
Rockport	NS	0.757	NS	NS	NS	125.780	NS	NS
Monticello	0.121	NS	NS	NS	44.077	NS	NS	22.917
Oak Vale	0.009	NS	NS	0.007	NS	NS	NS	NS
Columbia	-0.177	NS	NS	-0.161	NS	NS	NS	NS
Bogalusa	0.228	NS	NS	NS	70.684	NS	NS	38.431
Highway 439	0.007	NS	NS	0.006	NS	NS	NS	NS
Tylertown	NS	-0.032	NS	NS	NS	NS	NS	NS
Bush	NS	-0.031	NS	NS	NS	NS	NS	NS
Stage data (meters)								
Burnside	NS	ND	NS	NS	NS	ND	NS	NS
Edinburg	NS	ND	NS	-0.004	NS	ND	NS	NS
Carthage	-0.004	ND	-0.004	-0.005	NS	ND	NS	NS
Walnut Grove	NS	ND	NS	NS	NS	ND	NS	-0.002
Ofahoma	-0.004	ND	-0.004	-0.005	NS	ND	NS	-0.002
Ratliff	ND	ND	ND	ND	ND	ND	ND	ND
Hanging Moss	ND	ND	NS	NS	ND	ND	NS	NS
Jackson	NS	NS	-0.004	NS	NS	NS	NS	NS
Rockport	NS	ND	NS	NS	NS	ND	NS	NS
Monticello	NS	ND	NS	NS	NS	ND	NS	NS
Oak Vale	NS	ND	NS	NS	NS	ND	NS	NS
Columbia	ND	ND	ND	ND	ND	ND	ND	ND
Bogalusa	ND	ND	ND	ND	ND	ND	ND	ND
Highway 439	ND	ND	ND	ND	ND	ND	ND	ND
Tylertown	-0.002	ND	-0.002	-0.002	ND	ND	NS	NS
Bush	ND	ND	ND	ND	ND	ND	ND	ND

[a]NS = Not significant at the 95% level.
[b]ND = No data.

Table 3-5. Summary statistics from analysis of monthly minimum and monthly maximum discharge and stage as a function of time for USGS stations in the Pearl River basin using a seasonally adjusted ANOVA model. Listed are the results of analysis using the entire data set, using only data before 1971, using only data for 1971-1988, and using the edited data set (1974, 1979, and 1983 deleted).

Station	Minimum				Maximum			
	all data (cms/mo)	<1971 (cms/mo)	71-88 (cms/mo)	edited (cms/mo)	all data (cms^2/mo)	<1971 (cms^2/mo)	71-88 (cms^2/mo)	edited (cms^2/mo)
Discharge data (cubic meters/second)								
Burnside	NS[a]	ND[b]	NS	NS	NS	ND	NS	NS
Edinburg	0.004	NS	NS	NS	0.089	NS	NS	NS
Carthage	0.030	0.089	NS	0.019	0.369	NS	NS	NS
Walnut Grove	0.001	NS	NS	NS	0.077	NS	NS	NS
Ofahoma	NS	NS	NS	NS	NS	NS	NS	NS
Ratliff	ND	NS	NS	NS	ND	NS	NS	NS
Hanging Moss	ND	NS	NS	NS	ND	NS	NS	NS
Jackson	NS	NS	NS	NS	0.127	NS	NS	NS
Rockport	NS	NS	NS	NS	NS	1.559	NS	NS
Monticello	NS	NS	NS	NS	0.299	NS	NS	NS
Oak Vale	0.004	NS	0.001	0.004	NS	NS	NS	NS
Columbia	-0.082	NS	NS	NS	-0.316	NS	-0.028	-0.028
Bogalusa	0.071	NS	NS	NS	0.438	NS	NS	NS
Highway 439	0.002	NS	0.002	0.002	0.039	NS	NS	NS
Tylertown	-0.001	-0.014	NS	-0.002	NS	NS	NS	NS
Bush	NS	-0.015	NS	NS	NS	NS	NS	NS
Stage data (meters)								
Burnside	NS	ND	NS	NS	NS	ND	NS	NS
Edinburg	NS	ND	NS	NS	NS	ND	NS	NS
Carthage	-.002	ND	-.002	-.002	-0.005	ND	-.005	-.006
Walnut Grove	.001	ND	.001	.001	NS	ND	NS	NS
Ofahoma	-.003	ND	.003	.003	-0.006	ND	-.006	-.007
Ratliff	ND	ND	ND	ND	ND	ND	ND	ND
Hanging Moss	.001	ND	.001	.001	NS	ND	NS	NS
Jackson	NS	-.009	NS	NS	.004	NS	NS	NS
Rockport	NS	ND	NS	NS	NS	ND	NS	NS
Monticello	NS	ND	NS	NS	NS	ND	NS	NS
Oak Vale	.0002	ND	0.002	0.002	.002	ND	-.002	-.002
Columbia	ND	ND	ND	ND	ND	ND	ND	ND
Bogalusa	ND	ND	ND	ND	ND	ND	ND	ND
Highway 439	ND	ND	ND	0.002	ND	ND	ND	ND
Tylertown	-.001	ND	-.001	-.001	-.004	ND	-.004	-.005
Bush	ND	ND	NS	NS	ND	ND	ND	ND

[a]NS = Not significant at the 95% level.
[b]ND = No data.

Table 3-6. Summary statistics from analysis of annual mean and variance about the annual mean discharge and stage as a function of time for USGS stations in the Pearl River basin using a seasonally adjusted ANOVA model. Listed are the results of analysis using the entire data set, using only data before 1971, using only data for 1971-1988, and using the edited data set (1974, 1979, and 1983 deleted).

Station	Mean				Variance about the mean			
	all data (cms/yr)	<1971 (cms/yr)	71-88 (cms/yr)	edited (cms/yr)	all data (cms^2/yr)	<1971 (cms^2/yr)	71-88 (cms^2/yr)	edited (cms^2/yr)
Discharge data (cubic meters/second)								
Burnside	NS[a]	ND[b]	NS	NS	NS	ND	NS	NS
Edinburg	0.273	NS	NS	NS	82.574	NS	NS	NS
Carthage	NS	3.873	NS	NS	NS	NS	NS	NS
Walnut Grove	0.192	NS	NS	NS	31.287	NS	NS	NS
Ofahoma	NS	NS	NS	NS	NS	NS	NS	NS
Ratliff	ND	NS	NS	NS	ND	NS	NS	NS
Hanging Moss	ND	NS	NS	NS	ND	NS	NS	NS
Jackson	0.534	NS	NS	NS	312.830	NS	NS	NS
Rockport	NS	12.001	NS	NS	NS	5200.900	NS	NS
Monticello	1.791	NS	NS	NS	1423.650	NS	NS	NS
Oak Vale	0.13	NS	NS	0.112	NS	NS	NS	NS
Columbia	-2.500	NS	NS	NS	NS	NS	NS	NS
Bogalusa	3.110	NS	NS	NS	2384.820	NS	NS	NS
Highway 439	0.103	NS	NS	NS	NS	NS	NS	NS
Tylertown	NS	NS	NS	NS	NS	NS	NS	NS
Bush	NS	NS	NS	NS	NS	NS	NS	NS
Stage data (meters)								
Burnside	NS	ND	NS	NS	NS	ND	NS	NS
Edinburg	NS	ND	NS	NS	NS	ND	NS	NS
Carthage	NS	ND	NS	-0.050	NS	ND	NS	NS
Walnut Grove	NS	ND	NS	NS	NS	ND	NS	-0.05
Ofahoma	-0.044	ND	-0.049	-0.050	NS	ND	NS	NS
Ratliff	ND	ND	ND	ND	ND	ND	ND	ND
Hanging Moss	ND	ND	NS	NS	ND	ND	NS	NS
Jackson	NS	NS	NS	NS	NS	ND	NS	NS
Rockport	NS	ND	NS	NS	NS	ND	NS	NS
Monticello	NS	ND	NS	NS	NS	ND	NS	NS
Oak Vale	NS	ND	NS	NS	-0.004	ND	-0.004	-0.004
Columbia	ND	ND	ND	ND	ND	ND	ND	ND
Bogalusa	ND	ND	ND	ND	ND	ND	ND	ND
Highway 439	ND	ND	ND	ND	ND	ND	ND	ND
Tylertown	-0.019	ND	-0.019	-0.020	NS	ND	NS	NS
Bush	ND	ND	ND	ND	ND	ND	ND	ND

[a]NS = Not significant at the 95% level.
[b]ND = No data.

Table 3-7. Summary statistics from analysis of annual minimum and annual maximum discharge and stage as a function of time for USGS stations in the Pearl River basin using a seasonally adjusted ANOVA model. Listed are the results of analysis using the entire data set, using only data before 1971, using only data for 1971-1988, and using the edited data set (1974, 1979, and 1983 deleted).

Station	Minimum				Maximum			
	all data (cms/yr)	<1971 (cms/yr)	71-88 (cms/yr)	edited (cms/yr)	all data (cms^2/yr)	<1971 (cms^2/yr)	71-88 (cms^2/yr)	edited (cms^2/yr)
Discharge data (cubic meters/second)								
Burnside	NS[a]	ND[b]	NS	NS	NS	ND	NS	NS
Edinburg	NS	NS	NS	NS	NS	NS	NS	NS
Carthage	NS	NS	NS	NS	NS	39.810	NS	NS
Walnut Grove	NS	NS	NS	NS	NS	NS	NS	NS
Ofahoma	.007	0.01	NS	.006	NS	NS	NS	NS
Ratliff	ND	NS	NS	NS	ND	NS	NS	NS
Hanging Moss	ND	NS	NS	NS	ND	NS	NS	NS
Jackson	NS	NS	NS	NS	NS	NS	NS	NS
Rockport	NS	NS	NS	NS	NS	69.900	NS	NS
Monticello	.095	NS	NS	NS	12.725	NS	NS	NS
Oak Vale	NS	NS	NS	.027	NS	NS	NS	NS
Columbia	-0.404	NS	NS	NS	NS	NS	NS	NS
Bogalusa	-0.295	NS	NS	NS	17.935	NS	NS	NS
Highway 439	NS	NS	NS	NS	NS	NS	NS	NS
Tylertown	NS	-0.094	NS	NS	NS	NS	NS	NS
Bush	NS	NS	NS	NS	NS	NS	NS	NS
Stage data (meters)								
Burnside	NS	ND	NS	NS	NS	ND	NS	NS
Edinburg	NS	ND	NS	NS	NS	ND	NS	NS
Carthage	-0.027	ND	-0.027	-0.029	NS	ND	NS	NS
Walnut Grove	-0.069	ND	-0.069	-0.075	NS	ND	NS	NS
Ofahoma	-0.025	ND	-0.025	-0.025	NS	ND	NS	NS
Ratliff	ND	ND	ND	ND	ND	ND	ND	ND
Hanging Moss.	ND	ND	NS	NS	ND	ND	NS	NS
Jackson	NS	NS	NS	NS	0.156	NS	NS	0.136
Rockport	NS	ND	NS	NS	NS	ND	NS	NS
Monticello	NS	ND	NS	NS	NS	ND	NS	NS
Oak Vale	NS	ND	NS	NS	NS	ND	NS	NS
Columbia	ND	ND	ND	ND	ND	ND	ND	ND
Bogalusa	ND	ND	ND	ND	ND	ND	ND	ND
Highway 439	ND	ND	ND	ND	ND	ND	ND	ND
Tylertown	-0.011	ND	-0.011	-0.01	NS	ND	NS	NS
Bush	ND	ND	ND	ND	ND	ND	ND	ND

[a]NS = Not significant at the 95% level.
[b]ND = No data.

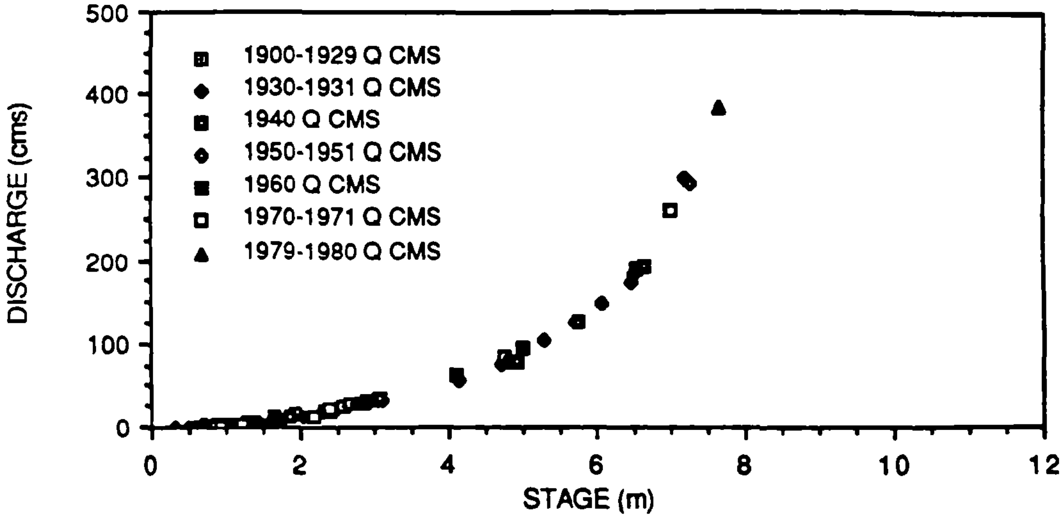


Figure 3-20. Rating curve for the Pearl River at Edinburg, Mississippi, showing the discharge (cubic feet per second) as a function of river stage (feet). Data from the files of the USGS office in Jackson, Mississippi

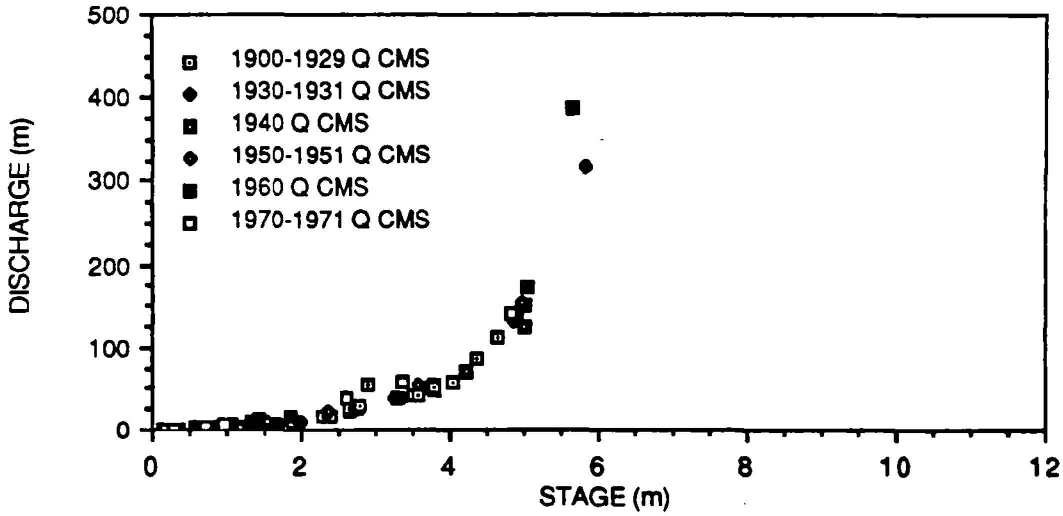


Figure 3-21. Rating curve for the Yockanookany River at Ofahoma, Mississippi, showing the discharge (cubic feet per second) as a function of river stage (feet). Data from the files of the USGS office in Jackson, Mississippi

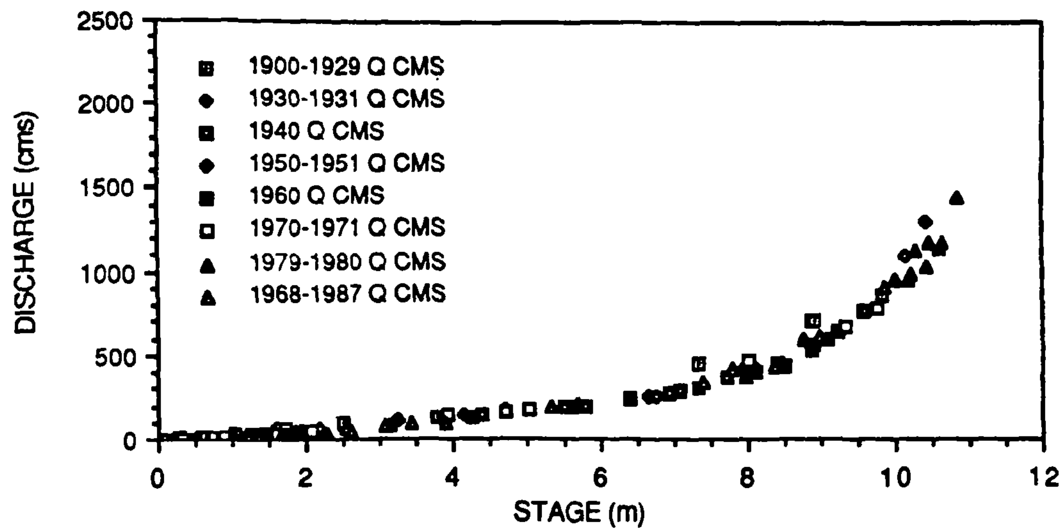


Figure 3-22. Rating curve for the Pearl River at Jackson, Mississippi, showing the discharge (cubic feet per second) as a function of river stage (feet). Data from the files of the USGS office in Jackson, Mississippi.

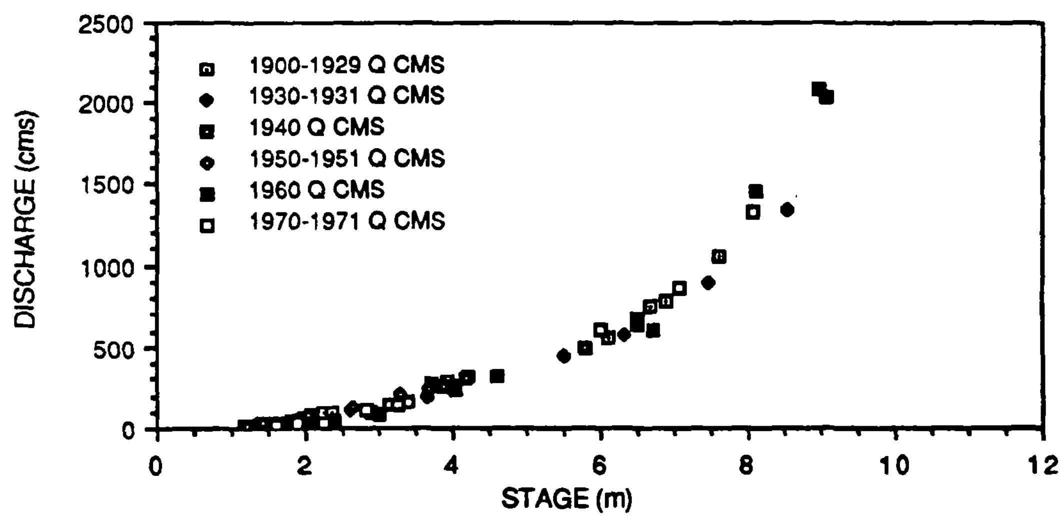


Figure 3-23. Rating curve for the Pearl River at Monticello, Mississippi, showing the discharge (cubic feet per second) as a function of river stage (feet). Data from the files of the USGS office in Jackson, Mississippi.

CONCLUSIONS

The analysis of the discharge and stage records from the Pearl River show the following:

1. The stages and discharges within the basin are controlled largely by precipitation.
2. Statistically significant trends do exist in the mean, variance about the mean, the minima, and the maxima.
3. Most of the trends have no consistent pattern except for the mean stage, which appears to have decreased in the upper part of the basin.
4. The magnitudes of the trends are, in all cases, very small.
5. The natural variability of the system is quite high and may hide weak trends.
6. No evidence exists that the stage-discharge relationship has changed over the last 40-50 years.

In general, the river is "well-behaved" and most , if not all, of the fluctuations seen in both the stage and the discharge records can be explained by natural climatic variability.

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CHAPTER 4: WATER QUALITY OF THE PEARL RIVER BASIN, MISSISSIPPI AND LOUISIANA

INTRODUCTION

Cumulative environmental impacts result from the total effect of many individual, often small, development projects. While the impacts of individual projects may be unmeasurable, collectively they can degrade the functional and structural integrity of landscapes. Cumulative impacts in wetlands occur partly as a result of the traditional procedure for dealing with site-specific permit applications. Permit evaluation focuses on individual sites within the basin, thus seldom adequately reflecting the landscape context (Gosselink and Lee 1989).

A large-scale landscape (e.g., watershed) approach is necessary to control incremental losses. This type of focus allows site-specific permit requests to be considered in the context of project impacts on the landscape as a whole. Focusing on the landscape as a whole allows conservation of not only large-scale landscape structures and processes, but also the structures and processes of smaller-scale subsystems.

The first step in developing a cumulative impact management plan is to assess the status of the study area by analyzing historical data on various indices of landscape structure and function. In the analysis one looks for trends through time as they relate to alterations of the system. Alterations of drainage-basin water quality are usually reflected in concentrations of suspended and dissolved stream constituents. Thus, water quality is a functional indicator of the impact of various basin modifications. This chapter evaluates historical water quality trends in streams within the Pearl River basin, with emphasis on turbidity, total phosphorus (TP), and total Kjeldahl nitrogen (TKN).

Phosphorus

Phosphorus (P) is one of the major nutrients required for plant nutrition. As phosphate, it is generally the nutrient that limits freshwater aquatic primary production (U.S. Environmental Protection Agency 1976). Concern about the level of P in streams is based primarily on its role in eutrophication. Stream P loading is increasing nationwide because of increased use of P in industrial, agricultural, and domestic applications. This widespread use makes it a good index of cultural disturbance (Childers and Gosselink 1990; Gosselink and Lee 1989).

Phosphorus readily adsorbs onto the surface of sediment particles. As a result, P and suspended sediments are usually coupled. Furthermore, sediment runoff into streams is positively related to precipitation, which causes erosion and runoff in disturbed watersheds (Murphree et al. 1976; Ursic 1965). Accordingly, both P and suspended sediments are often highly correlated with stream discharge.

Nitrogen

Nitrogen (N), another essential plant nutrient, cycles rapidly between the sedimentary, atmospheric, and aquatic environments. N and P are the two plant nutrients most likely to limit plant growth. Because N exists in many forms, a single measure of total N, presented as total Kjedahl nitrogen (TKN) was chosen for analysis in this report. TKN includes NH4+, dissolved organic N, and particulate N. Nitrate and nitrite, both biologically active, are not measured in TKN. However, data on these moieties were less complete than data on TKN in the Pearl River basin. There are many biologically mediated inputs to and losses of N from aquatic environments, for example, N fixation, denitrification, atmospheric deposition, and anthropogenic inputs from agricultural, muncipal, and industrial sources. Interconversions among these different forms of N occur rapidly in nature, and for the Pearl River basin, TKN is the best available index of total active N in the stream system.

MATERIALS AND METHODS

Site

The Pearl River basin is located in Mississippi and Louisiana (Figure 4-1, inset). The Pearl River originates in central Mississippi and flows south along the Mississippi-Louisiana border, eventually emptying into the Gulf of Mexico. The basin covers 2.25 million ha and includes all or portions of 27 parishes and counties in both states. It is characterized by a variety of terrestrial and aquatic habitats, including upland, bottomland, coniferous, and deciduous forests, and cypress swamps, as well as fresh and brackish marshes. According to 1987 land use data, 52% of the basin is upland forest, 12% is forested wetland, and < 1% is herbaceous marsh. Agricultural land makes up 31% of the total area. Before settlement by Europeans, the basin was probably almost completely forested.

Historical records of hydrology and water quality at five stations within the basin were analyzed. These were the only Pearl River basin stations with at least 10 years of continuous monthly water quality data. Water quality records were obtained from the Louisiana Department of Environmental Quality, the U.S. Geological Survey's National Stream Quality Accounting Network records (NASQAN), and the Mississippi State Board of Health. Turbidity sampling typically began in the late 1950s, and collection of nutrient data began in the late 1960s. (Table 4-1 summarizes the extent of the data sets.) The data are monthly values, not monthly means.

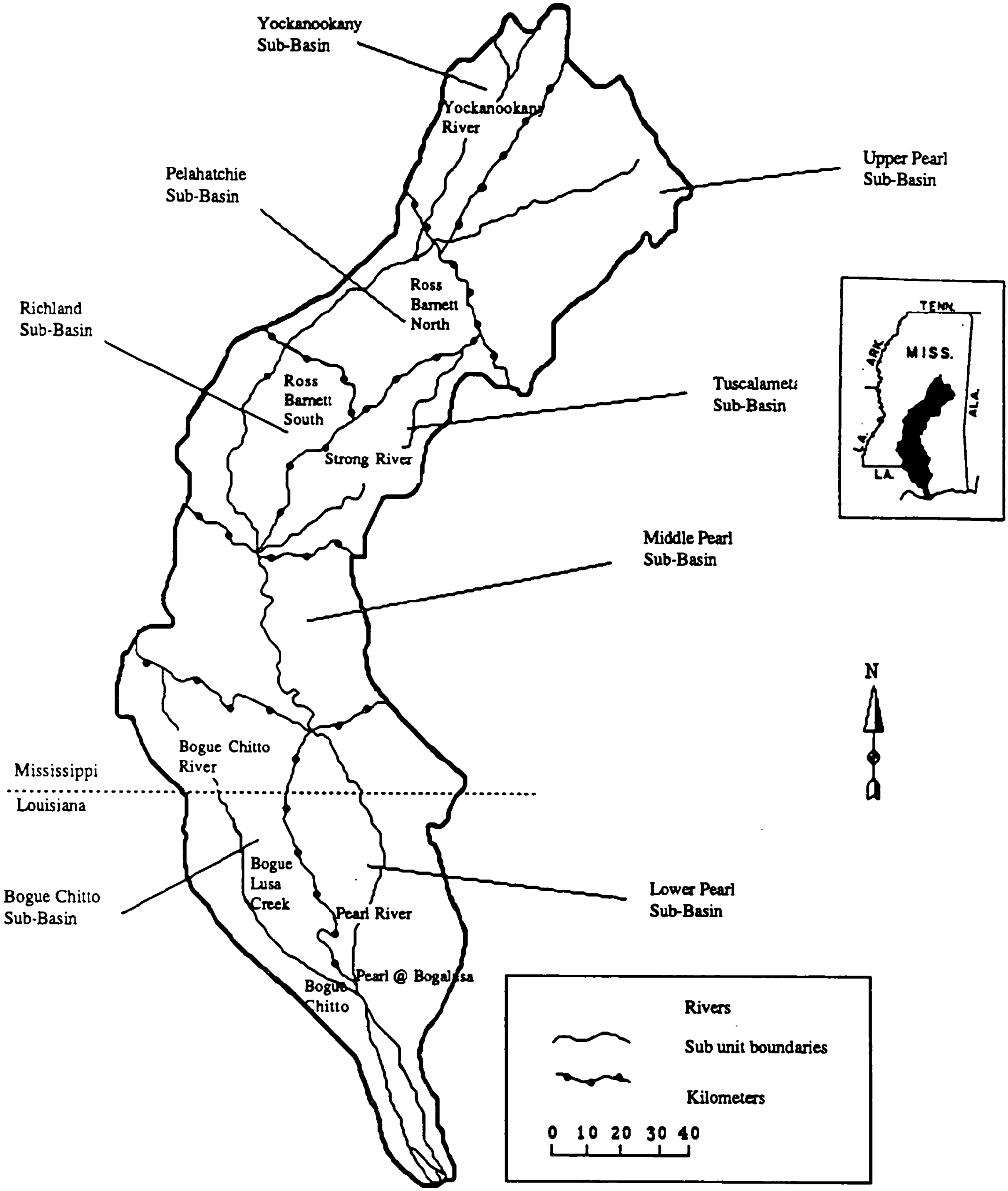


Figure 4-1. Hydrologic subunits and water quality stations of the Pearl River basin.

Table 4-1. Length of record, with number of observations given in parentheses, by site for each water quality parameter of concern.

Station	Turbidity	TP	TKN
Ross Barnett North	1969-87 (215)	1969-87 (215)	DNA[a]
Ross Barnett South	1969-87 (217)	1969-87 (217)	DNA
Bogue Chitto at Bush	1974-87 (104)	1974-87 (86)	1974-87 (81)
Pearl River at Bogalusa	1958-88 (426)	1973-88 (204)	1973-88 (192)
Bogue Lusa Creek at Bogalusa	1958-88 (238)	1978-88 (115)	78-88 (115)

[a]DNA = data not available.

Water Quality Data Analyses

We analyzed TKN, TP, and turbidity records at two stations on the Pearl River in the upper basin and three in the lower basin. Because many water quality parameters are strongly influenced by stream discharge (Smith et al. 1982), we used methods described by Hirsch et al. (1982) to remove the variability in the data due to discharge by adjusting nutrient concentrations for flow. For this analysis we ran simple linear regressions of TP, TKN, and turbidity on discharge. The residuals, which are the flow-adjusted data, were subsequently subjected to linear regressions on time. In general, the flow-adjusted data regressions contained nonhomogeneous variances. Consequently, for statistical purposes the data were ranked and analyses were performed on the ranked data (Siegel and Castellan 1988). Rank correlation coefficients measure whether Y increases (or decreases) with X. When data are ranked the units of the variables are lost, but the relative position of each data point is maintained. All analyses were conducted using the General Linear Model (GLM) procedure (SAS Institute 1985).

Nutrient Flux Measurements

Fluxes of nutrients and materials from the lower Pearl River basin (Louisiana and Mississippi) were determined using data from the two southernmost water quality stations: Bogue Chitto at Bush and Pearl River at Bogalusa. The Bogue Chitto River discharges into the Pearl River less than 10 km downstream of the sampling site and drains the Bogue Chitto sub-basin in the southwestern portion of the Pearl River basin. All areas east and north of this sub-basin drain into the Pearl River, and the Bogalusa sampling station is located approximately 20 km upstream of the confluence with the Bogue Chitto River. Just south of this confluence, the Pearl River splits into east and west channels in the estuarine portion of the basin.

To calculate fluxes of the nutrients (TKN, TP, and suspended sediments--e.g., turbidity), we used concentration data plus river discharge data from both stations. The discharge data set at the Bogue Chitto site limited these calculations to an 11-year interval, 1974-1985. Data at both sites were available for varying intervals, from monthly to quarterly. Daily fluxes of turbidity, TP, and TKN were computed as the product of instantaneous discharge (in $m^3 \cdot s^{-1}$) and concentration (in $mg \cdot l^{-1}$), and converted to $g \cdot day^{-1}$ (or millions of $NTU \cdot day^{-1}$ for turbidity) for both stations. Simple linear interpolation was used to determine nutrient and sediment fluxes in the intervals between sampling events. From these estimated annual flux patterns, total annual fluxes (in metric tons NTU, P, and $N \cdot yr^{-1}$) were computed for both sites individually using first-order

Runga-Kutta integration techniques. Where an interval between samplings spanned two years (e.g., 15 December 1975 through 30 January 1976), the area under the curve was computed and proportionally split between the two years (in this example, 33.3% of the total flux between 15 December 1975 and 30 January 1976 is assumed to have occurred in 1975 and 66.7% in 1976). The Microsoft Excel® spreadsheet software program was used for all flux computations.

RESULTS

Water Quality Trends

Table 4-2 presents the slope direction (i.e., the regression coefficient), the significance level (P <), and the coefficient of determination (R^2) for all significant regressions, both basinwide and for individual stations. The figures referenced in the following discussion display real (i.e., unranked) data for easy comprehension, although statistical evaluations of trends in these data were based on analyses of the ranked data. Table 4-3 summarizes mean concentrations of turbidity, TP, and TKN at each of the stations, and supplies data on land use in the sub-basin upstream.

Basinwide

Since the recognition and management of cumulative impacts is focused at the landscape level, the trends in the data for the entire basin will be presented first.

Turbidity. In undisturbed forested watersheds, sediment and nutrient loads are often diluted by high stream flows because erosion increase is minimal (Smith et al. 1982). Consequently, a regression of concentration on discharge has a negative slope. In disturbed watersheds turbidity and nutrient concentrations generally increase during high discharge (i.e., the regression slope is positive), presumably because of erosion from disturbed soil surfaces.

Figure 4-2a shows the regression of turbidity on discharge for the Pearl River basin. The trend in the raw data was not significant. However, the regression of rank turbidity on rank flow basinwide had a highly significant ($P < 0.01$) positive slope; flow accounted for 17% of the variability in turbidity (Table 4-2). The residual values from this regression (the rank flow-adjusted values of turbidity) decreased significantly over time (Figure 4-2b), though the data showed an increased spread beginning in the 1970s. The reason for this anomaly is unknown, but may be related to an increase in the sensitivity of the analytical technique for measuring turbidity. Mean discharge of the Pearl River increased during the 1970s and early 1980s. Since turbidity is positively related to

Table 4-2. Simple linear regressions of several water quality variables for the Pearl River basin as a whole, Ross Barnett north, Ross Barnett South, Bogue Lusa Creek at Bogalusa, Pearl River at Bogalusa, and Bogue Chitto at Bush. Shown are the slope direction ("+" = pos., "-" = neg.), probability of obtaining a more significant relationship by change alone (P>), and the coefficient of determination (R^2).

Linear Regression	Basinwide			North Ross Barnett			South Ross Barnett			Bogue Lusa Crk at Bogalusa			Pearl River at Bogalusa			Bogue Chitto at Bush		
Rank turbidity on date	(-)	.0001	.13	NS	---	---	NS	---	---	---	.0001	.09	(-)	.0001	.09	(-)	.0271	.05
Rank turbidity on rank flow	(+)	.0001	.17	NS	---	---	NS	---	---	NS	---	---	(+)	.0001	.26	(+)	.0001	.62
Flow-adjusted rank turbidity on date, residuals	(-)	.0001	.13	NS	---	---	NS	---	---	(-)	.0001	.44	(-)	.0001	.16	NS	---	---
Raw TP on date	(-)	.0001	.02	(-)	.0001	.10	(-)	.0207	.02	NS	---	---	NS	---	---	NS	---	---
Rank TP on date	NS	---	---	(-)	.0002	.06	NS	---	---	NS	---	---	NS	---	---	(-)	.0018	.11
Rank TP on rank flow	(+)	.0001	.14	NS	---	---	NS	---	---	(+)	.0149	.08	(+)	.0041	.12	(+)	.0041	.12
Flow-adjusted rank TP on date, residuals	NS	---	---	NS	---	---	NS	---	--	NS	---	---	NS	---	---	NS	---	---
TKN on date	(+)	.0042	.02	DNA	---	---	DNA	---	---	(+)	.0026	.08	(+)	.0001	.10	NS	---	---
TKN vs. TP	(+)	.0001	.07	DNA	---	---	DNA	---	---	(+)	.0001	.12	NA	---	---	NS	---	---
Flow on date	NS	---	---	DNA	---	---	DNA	---	---	(+)	.0033	.03	(+)	.0115	.02	NS	---	---
N:P		9:1		DNA	---	---	DNA	---	---		17:1			9:1				

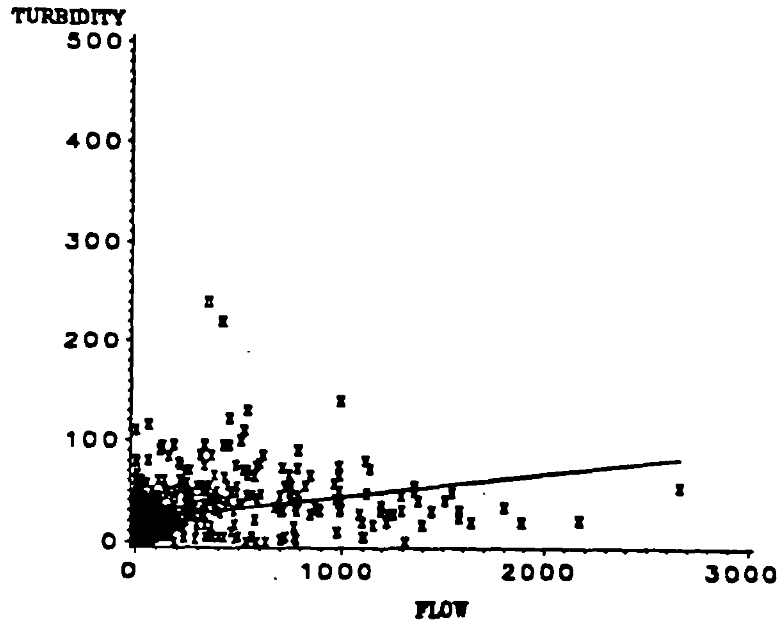
Table 4-3. Summary of water quality analyses for the five Pearl River basin sites.

Station/Sub-basin	TP Concentration (mg^{-1})	TP Trend[a]	TKN Concentration (mg^{-1})	TKN Trend[a]	TP Values >0.1 mg^{-1} (%)	Turbidity on Flow (P>)	R^2	Turbidity Trend[a]	N:P (molar)	Sub-basin in Agriculture (%)	Sub-basin Forested (%)	Tributary with Forested Edge (%)
Ross Barnett North/ Yockanookany	.09	(-)	DNA[b]	--	32	NS	--	--	DNA	27	70	97
Ross Barnett South/ Pelahatchie Creek	.08	(-)	DNA	--	29	NS	--	--	DNA	24	72	89
Bogue Lusa Creek at Bogalusa/ Lower Pearl	.04	NS	.49	(+)	3	NS	NS	--	37.6	34	60	80
Pearl at Bogalusa/ Lower Pearl	.12	NS	.75	(+)	30	.0001	.26	(+)	19.9	34	60	80
Bogue Chitto at Bush Bogue Chitto	.08	(-)	.62	(-)	26	.0001	.62	(+)	22.1	45	52	71

[a] Slope of regression of P vs. time.

b DNA = data not available.

a



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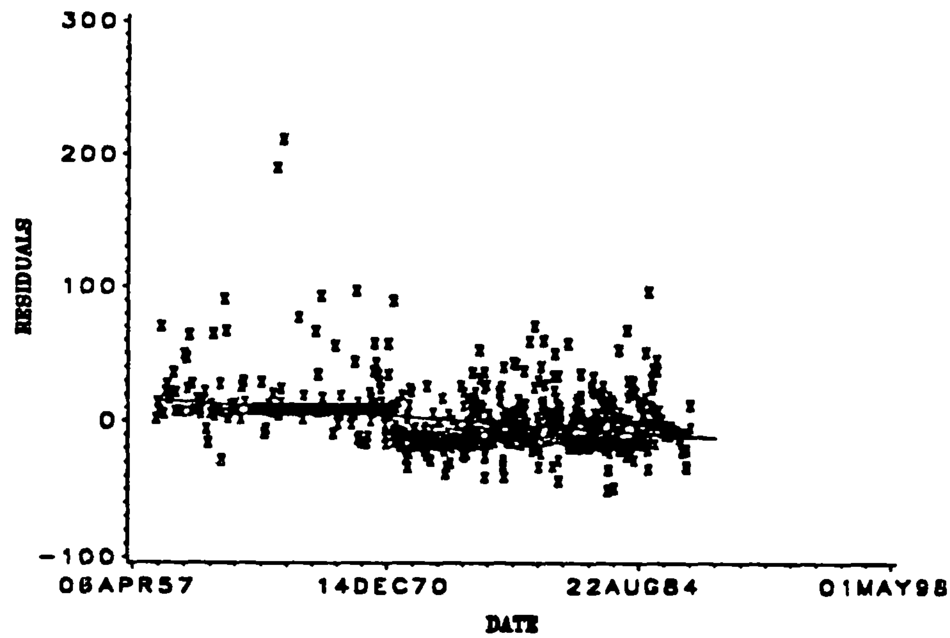


Figure 4-2. Turbidity data (Nephelometric turbidity units [NTU]) basinwide for the Pearl River Watershed. Turbidity on flow (a) shows a significant positive trend. Once turbidity was adjusted for flow (b), it decreased over time.

discharge, an increase in turbidity with time might be expected. The relationship was negative, however, both for rank turbidity and for flow-adjusted rank turbidity.

Phosphorus. TP records date back to 1969 at two sites and to the 1970s at the other three (Table 4-1). There was a significant ($P < .05$) positive relationship between rank TP and rank flow in the basinwide data (Figure 4-3a). Once the TP values were adjusted for flow, the residuals exhibited no significant temporal trends over the period of record (Figure 4-3b), although the absolute concentrations decreased through time (Figure 4-3c).

The absolute concentration of TP is another measure of a watershed's health. The EPA has suggested a standard for running streams, 0.1 mg·TP·l^{-1}, above which eutrophication usually occurs (U. S. Environmental Protection Agency 1976). Basinwide, this level was exceeded 24% of the time.

Nitrogen. Considering data for all stations, TKN increased slowly through time (Figure 4-4a). There was a highly significant increase in the annual mean N-to-P ratio basinwide (Figure 4-4b), ranging (on a mass basis) from a mean of 7 in the 1970s to 10 in the 1980s. The mean molar ratio increased from 15.5 to 22.1. The ratio of N to P indicates which nutrient is limiting to aquatic primary production. Generally, when the mean N-to-P ratio falls below 10 or 15, N becomes the limiting nutrient (Hecky and Kilham 1988). The increase in the ratio of N to P was caused by both an increase in TKN and a decrease in TP concentrations over the period of record.

Site-Specific Results

For the basin as a whole, a multisource regression was performed on turbidity, with discharge as the covariable and stations as the class variable. The highly significant interaction effect between discharge and station indicated that the turbidity-discharge relationships differed for the various stations. Therefore, separate analyses were performed on each of the five water quality stations. The trends at the five stations were variable; some sites exhibited characteristics of relatively healthy, intact landscapes, while others displayed trends of more disturbed sites.

At the two most northern stations, Ross Barnett North and South (Figure 4-1), neither rank turbidity nor rank TP was significantly related to flow. For Bogue Lusa Creek, rank turbidity was unrelated to flow, but rank TP was positively related to flow. Highly significant, positive slopes existed for both rank turbidity and rank TP versus flow at both the Bogue Chitto and Pearl at Bogalusa stations, where flow explained 62% and

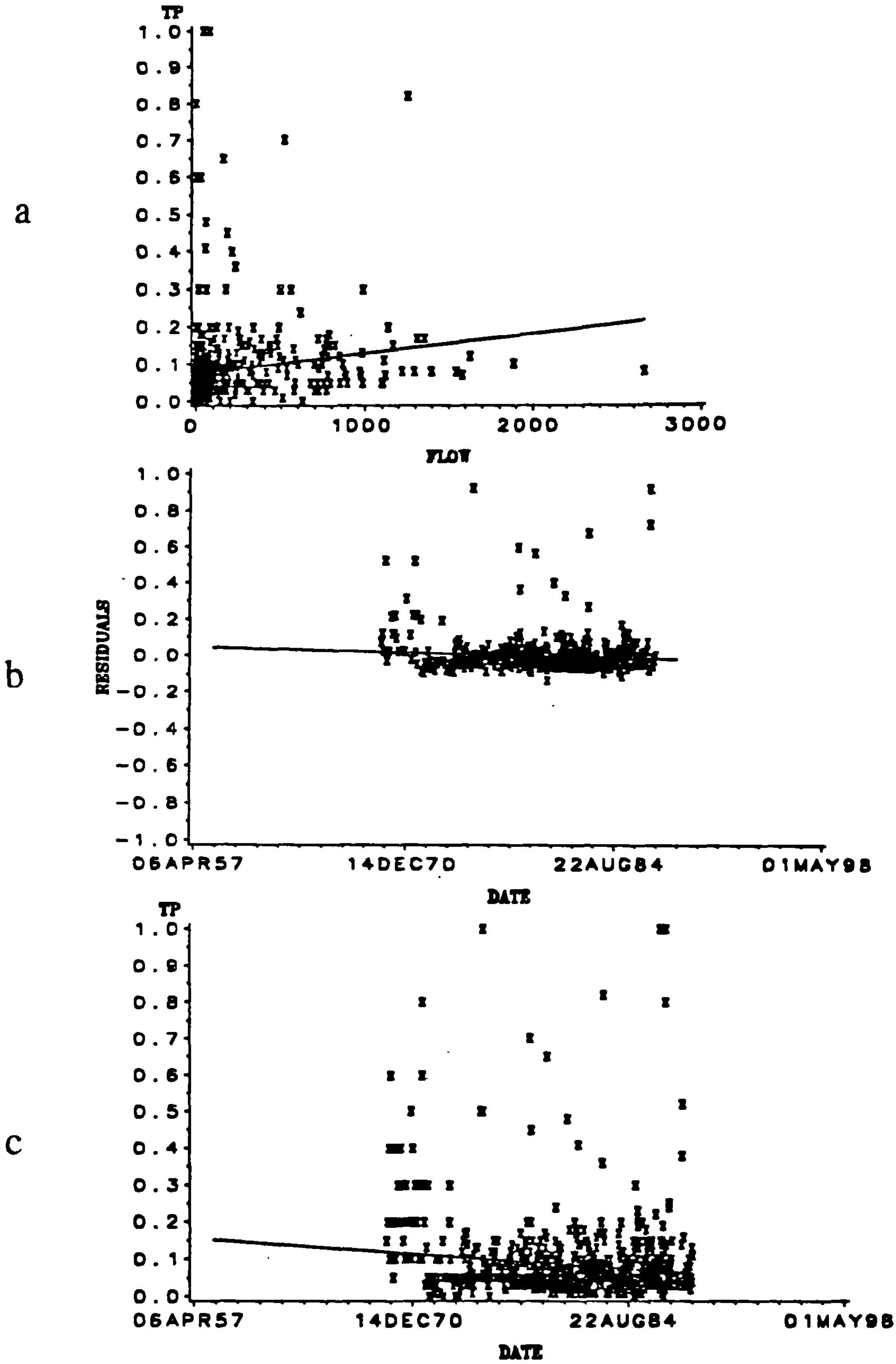
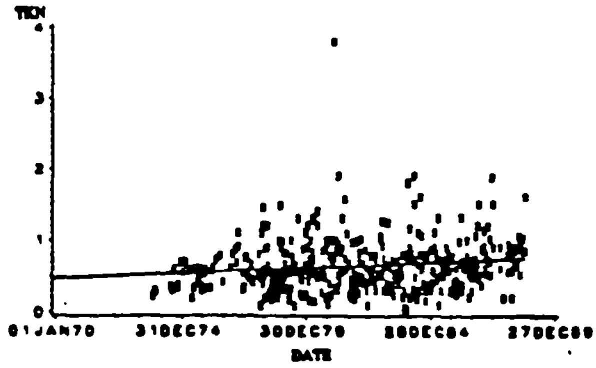


Figure 4-3. TP (mgl^{-1}) showed a significant, positive correlation with flow for the basinwide data (a). Once the variation due to flow was removed there were no trends over time (b). The absolute concentration of TP decreased over time (c).

a



b

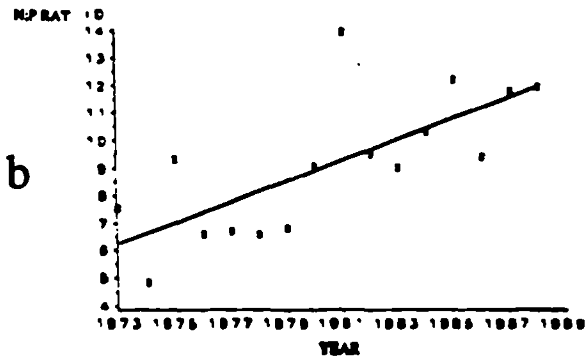


Figure 4-4. (a) Absolute concentrations of TKN (mg·l^{-1}) increased over time. (b) N-to-P ratios (mass basis) for the entire Pearl River basin had a highly significant positive slope when regressed on time.

26% of the variability in turbidity, respectively, and 12% of the variability in TP for both sites (Table 4-2).

Bogue Lusa Creek had TP values that exceeded the EPA criterion of 0.1 $mg \cdot l^{-1}$ only 3% of the time, while Ross Barnett North and South exceeded it at 32% and 29% of the data points, respectively. At these Ross Barnett sites, however, TP decreased with time and most of the high values appear to have occurred in the early 1970s (Figure 4-5a-c). For the Bogue Chitto and Pearl at Bogalusa sites, 26% and 30% of the values, respectively, were above 0.1 mg $TP \cdot l^{-1}$.

TKN concentrations increased over time in Bogue Lusa Creek and in the Pearl River at Bogalusa, while Bogue Chitto remained constant (Figure 4-6). TKN data were not collected at Ross Barnett North and South. The ratio of N to P at Bogue Chitto averaged 10 by weight and 22.1 by molar ratio, and showed no significant trend over time. Pearl River at Bogalusa had an average ratio of 9 by weight and 19.9 by molar ratio, also with no temporal trend. The mean N-to-P molar ratio for Bogue Lusa Creek was 37.6, equivalent to 17 by weight. At this station the annual mean N-to-P ratios showed highly significant, positive temporal trends.

Nutrient Fluxes

Water flux (discharge) in the Pearl River at Bogalusa was typically three or more times the discharge measured in the Bogue Chitto River at Bush. Figure 4-7 shows strong seasonal peaks coinciding with spring rains. Both stations recorded a large flood in early 1980. Turbidity levels were somewhat higher at the Pearl River-Bogalusa site than at the Bogue Chitto site, but the range of values is the same (Figure 4-8a). TP concentrations were nearly always below 0.15 mg $P \cdot l^{-1}$ at both sites, except for a high concentration peak in mid-1979 at Pearl River-Bogalusa and in mid-1981 and late 1983 at Bogue Chitto (Figure 4-8b). TKN concentrations from the Pearl River-Bogalusa station were usually higher than those from the Bogue Chitto and showed a period of unusually high values between 1979 and 1982. The highest TKN concentration -- 4 $mg \cdot l^{-1}$ --was observed at the Bogue Chitto site (Figure 4-8c). Interestingly, concentrations of TP, TKN, and turbidity in the two rivers are comparable (in spite of disparate drainage basin sizes), and the Pearl River-Bogalusa discharge is generally three to five times that at the Bogue Chitto.

Instantaneous nutrient fluxes in these two streams, shown as kg $P \cdot day^{-1}$, kg $N \cdot day^{-1}$, and millions of $NTU \cdot day^{-1}$, follow the same general pattern as the discharge data (Figure 4-9). One pervasive pattern in the daily flux values, particularly at the Pearl River-Bogalusa station, is the seasonal peak coinciding with the spring freshet. At other times of the year nutrient fluxes were small. The Bogue Chitto flux data show episodic

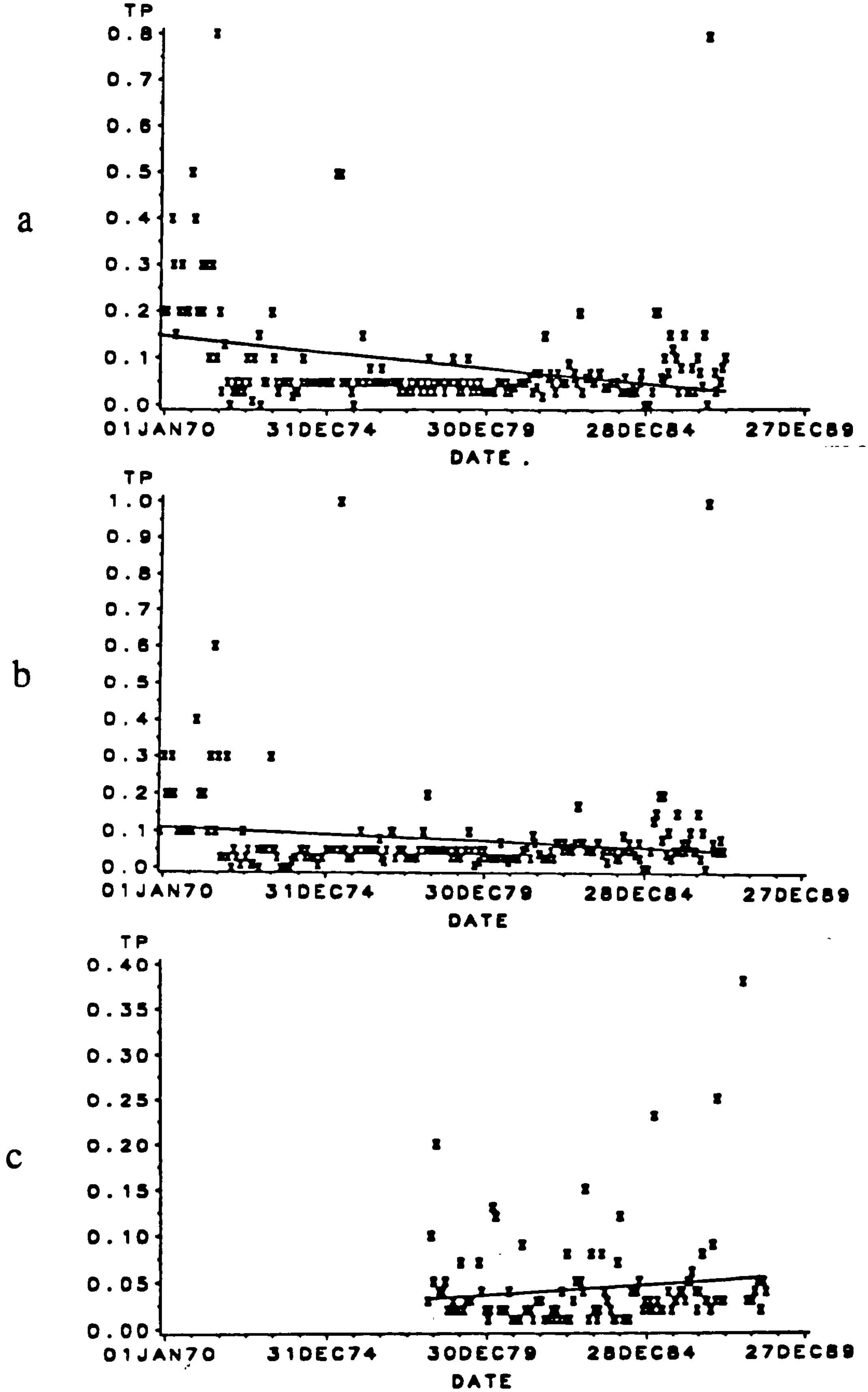


Figure 4-5. Absolute TP concentrations over time for Ross Barnett North (a) and South (b) and Bogue Lusa Creek at Bogalusa (c). Both Ross Barnett North and South exhibited significant decreases over time. The trends over time for the Bogue Lusa Creek station were insignificant.

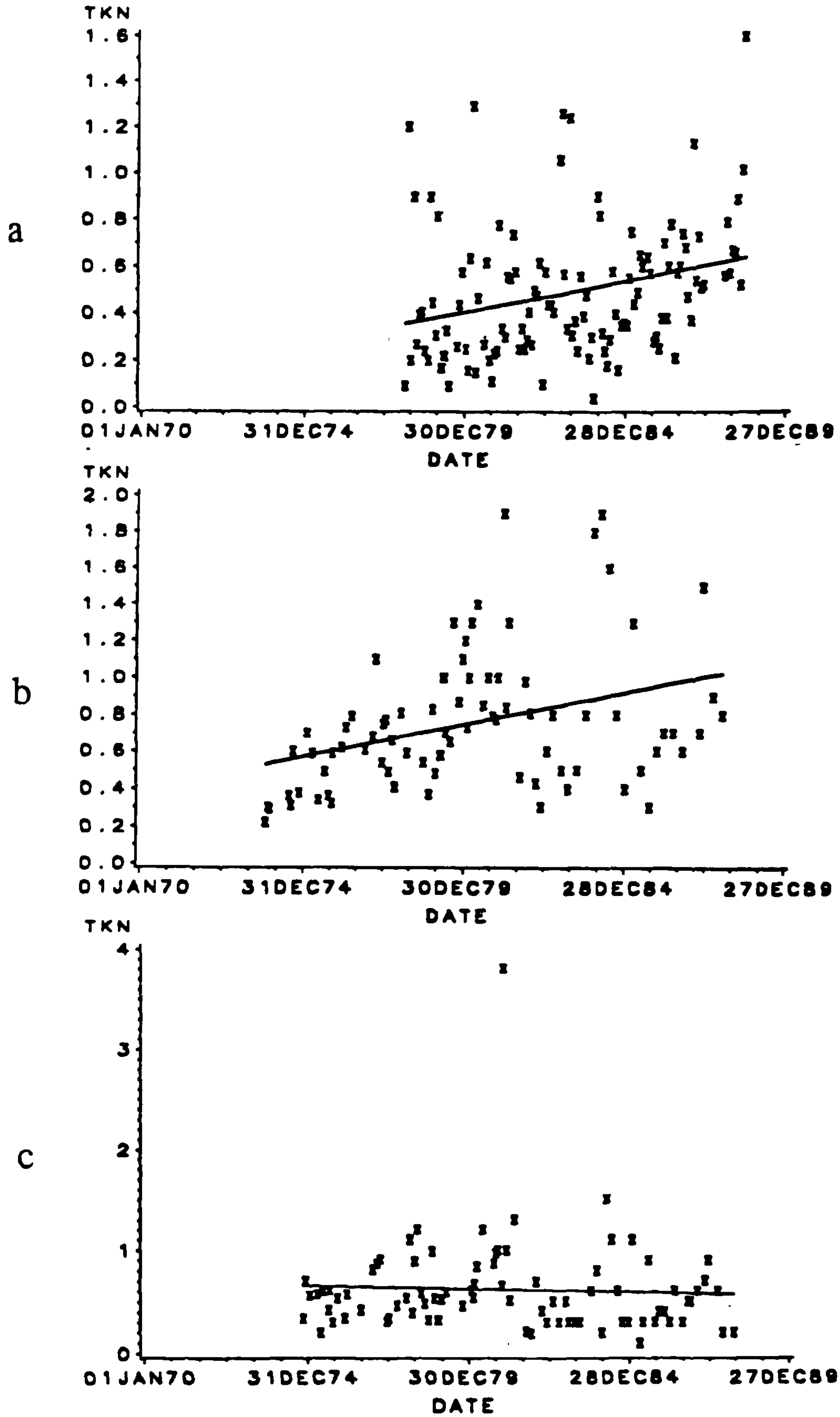


Figure 4-6. Temporal trends in TKN concentrations over the period of record for three stations in the Pearl River basin. TKN increased over time at both Bogue Lusa Creek (a) and Pearl at Bogalusa stations (b). Bogue Chitto at Bush has an insignificant slope over time (c).

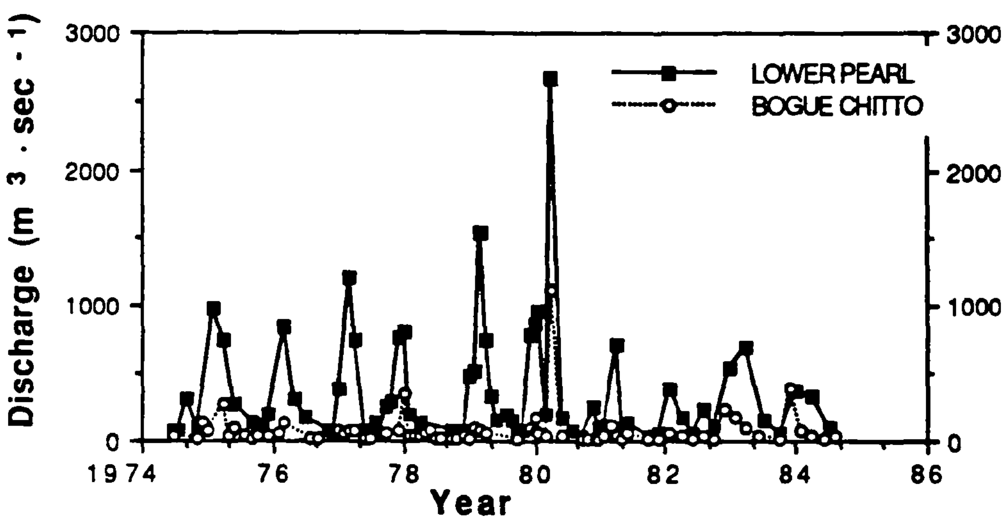


Figure 4-7. Water flux (discharge) in the Pearl River at Bogalusa and in the Bogue Chitto River at Bush. The strong seasonal peaks coincide with spring rains.

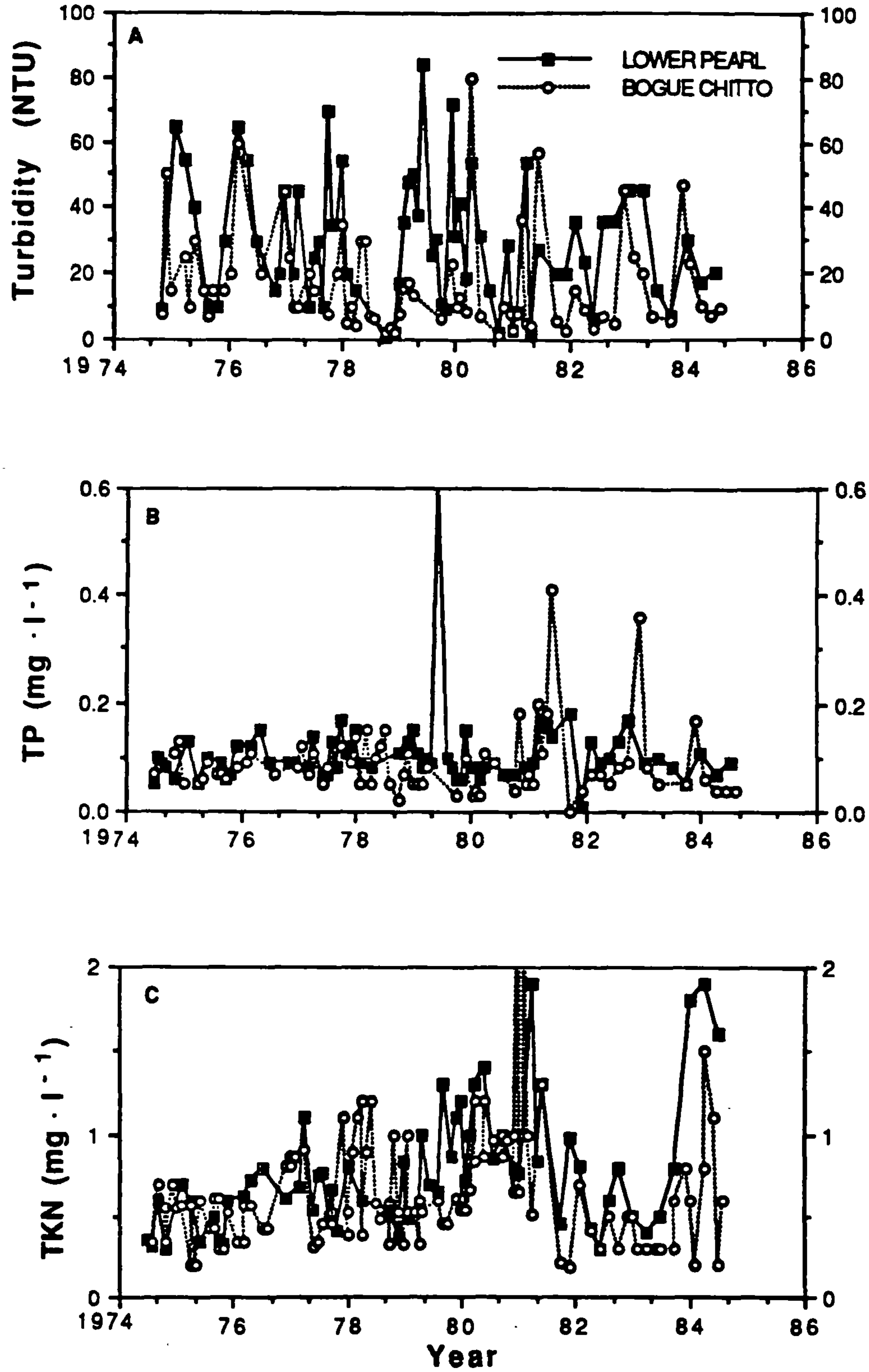


Figure 4-8. the Turbidity (a), TP (b), and TKN (c) levels in the Pearl River at Bogalusa and Bogue Chitto River at Bush.

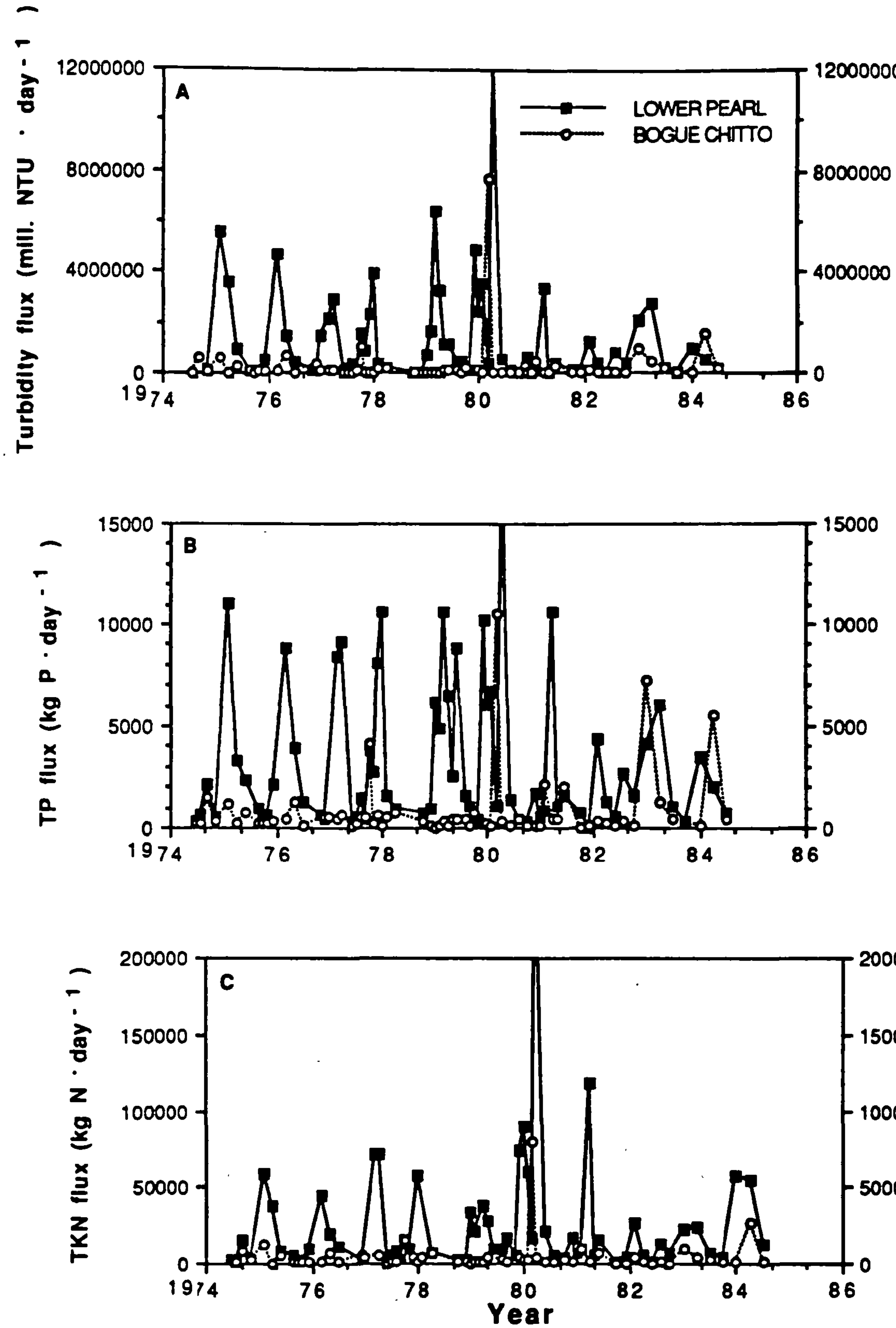


Figure 4-9. Instantaneous fluxes of turbidity, TP, and TKN in the Pearl River at Bogalusa, Lower Pearl and the Bogue Chitto River at Bush.

high flux events more than regular annual pulses of nutrients. This difference in flux patterns between the two stations is probably related to the large difference in the drainage basin sizes of the Pearl and Bogue Chitto rivers as well as differences in land use characteristics (the Bogue Chitto drainage has the highest percentage of agricultural land in the Pearl River basin). Both lead to more flashy discharge and episodic nutrient fluxes at the Bogue Chitto station.

Annual fluxes of turbidity, TP, and TKN at both sites are represented by the area under the daily flux curves for each year. In most cases, the sampling dates and the intervals between samplings were different for the Pearl River-Bogalusa and Bogue Chitto sites. For this reason, annual integrated fluxes were computed for the two sites independently and then combined for a total mass flux to the Pearl River estuary each year. When the annual fluxes at each site are compared, an interesting pattern emerges. Most of the suspended sediment discharged to the estuary is supplied by the Pearl River (Figure 4-10a), whose annual flux is typically 5-10 times that of the Bogue Chitto River. There is less difference between TP fluxes at the two sites, and even less in the annual TKN data (Figure 4-10b and 4-10c). Apparently, the Bogue Chitto River is supplying the estuary with a disproportionate mass of N, in comparison to the Pearl River (which drains most of the Pearl River basin).

The total mass flux of suspended sediment, TP, and TKN from the Pearl River to the estuary, as the sum of the annual fluxes from the Pearl River-Bogalusa and Bogue Chitto stations, is summarized in Table 4-4. Molar flux ratios of N to P calculated from these total annual flux data showed values of 10-15 for most years between 1974 and 1985, but ratios were greater than 20 in 1980 and 1981 (Figure 4-11; note that 1974 and 1984 ratios are based on incomplete data sets). On an annual basis, P appears to be the macronutrient most limiting to aquatic primary productivity in Pearl River basin waters as they enter the estuarine and nearshore portion of the basin.

DISCUSSION

Undisturbed forested watersheds conserve sediments and nutrients, minimizing erosion. Riparian forests are often net sinks for sediments and nutrients (Lowrance et al. 1984; Peterjohn and Corell 1984). As a result these stream constituents are usually diluted by precipitation and by increased streamflow. In contrast, in disturbed watersheds turbidity and nutrient concentrations generally increase with increasing discharge, presumably because of erosion from disturbed soil surfaces (Brinson 1988; Smith et al. 1982; Ursic 1965). In the Pearl River basin, the combined analysis of all five stations

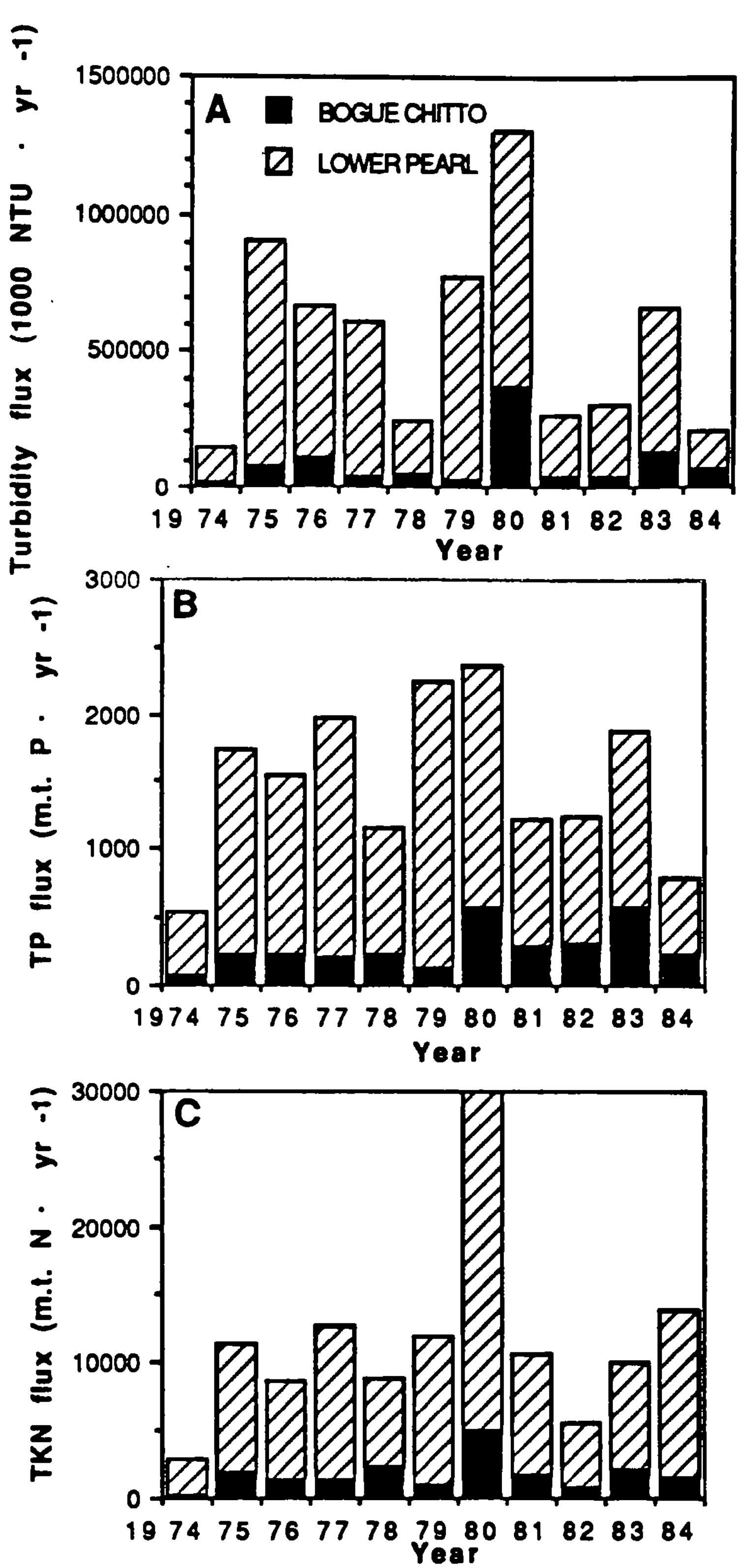


Figure 4-10. Annual fluxes of turbidity (a), TP (b), and TKN (c) in the Pearl River at Bogalusa and the Bogue Chitto at Bush.

Table 4-4. Summary of total annual fluxes of nutrients and materials, through the sampling stations in the Pearl River at Bogalusa and the Bogue Chitto River at Bush, to the Pearl River estuary and associated nearshore zone.

Year	Turbidity Flux (10^6 NTU yr^{-1})	TP Flux (10^3 MT P yr^{-1})	TKN Flux (10^3 MT N yr^{-1})
1974	145.9	0.535	2.81
1975	906.6	1.747	11.45
1976	663.5	1.555	8.8
1977	605.5	1.975	12.70
1978	243.6	1.157	8.96
1979	775.1	2.246	11.91
1980	1304.7	2.364	29.92
1981	259.6	1.214	10.64
1982	299.3	1.234	5.71
1983	658.4	1.883	10.11
1984	205.4	0.790	13.89

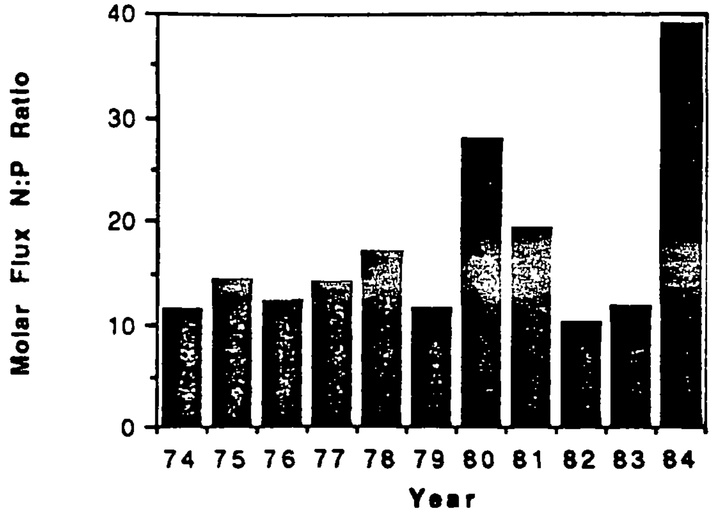


Figure 4-11. Molar flux ratios of N to P calculated from the annual flux data presented in Table 4-4 from the sampling stations in the Pearl River at Bogalusa and the Bogue Chitto River at Bush.

showed turbidity increasing with flow, perhaps indicating some degree of disturbance within the basin.

Considering both upland and wetland forest, 63.3% of the Pearl River basin is forested. According to the results of a study by Omernik (1977) examining the relationship between watershed land use and water quality, a watershed that is more than 50% forested has typical stream TP and TKN concentrations of about .034 and .839 $mg \cdot l^{-1}$, respectively. The TP for the Pearl River basin ranged up to 1.72 $mg \cdot l^{-1}$, with an average of 0.087 $mg \cdot l^{-1}$. The average TKN concentration was 0.65 $mg \cdot l^{-1}$, ranging from 0.01 to 7.1 $mg \cdot l^{-1}$. Thus, based on forest cover, TP was higher than expected from Omernik's (1977) analysis, but TKN was within the expected range.

For the period of record the molar N-to-P ratio averaged 19.9 (with a range of 15.5-26.2). Based on the N-to-P ratio of living plant tissue, a molar ratio of 10-15 reflects a balanced ecosystem. Below that ratio N is limiting; above it, P is (Hecky and Kilham 1988). This indicates that P is probably the limiting nutrient to phytoplankton primary production in the Pearl River basin. This generalization must be qualified, however, because these ratios indicate the relative abundance of total N and P. Along with the ratio of N to P, it is important to consider the absolute concentrations of N and P. TP averaged slightly below the 0.1 $mg \cdot l^{-1}$ EPA standard, but was well above the concentration expected from the percentage of forest cover. TKN concentrations are below the value predicted by Omernik (1977). Since 1984 the annual mean ratio has been higher than in previous years (~25.2 on a molar basis). This reflects both the slight increase in TKN and the decrease in TP in the Pearl River basin. In addition to total forest cover and land use in the watershed, water quality is also affected by the percentage of streams with riparian buffer strips. Numerous studies (Lowrance et al. 1984; Peterjohn and Corell 1984) have found that forested riparian strips effectively filter P, N, and sediments from runoff entering streams. Riparian forest buffer strips comprise over 85% of the edges of the Pearl River and its major tributaries.

Except for Ross Barnett South, the major differences between stations in the Pearl River basin appear to be related to the percentage of forest cover (or conversely, agricultural land) in the sub-basins where the data were collected. The two southernmost stations, the Pearl River at Bogalusa and the Bogue Chitto at Bush (Figure 4-1) had the least (proportionally) forest cover and the most land in agriculture (Table 4-3). These were the only stations with positive turbidity on flow regression slopes (Table 4-2). They had the highest mean TKN concentrations, and the Bogue Chitto station also had the highest mean TP concentration. The value of 34% in agricultural land for the lower Pearl sub-basin probably underestimates disturbance in the watershed above the Pearl River station at

Bogalusa. This station is about midway up the sub-basin, downstream from most of the sub-basin agricultural land. The influence of the large lower Pearl River swamp between Bogalusa and the Gulf of Mexico could not be evaluated.

Although TP concentrations at the Ross Barnett South station generally are representative of stations with forested watersheds (this subwatershed is 70% forested), it is likely that water quality at this station reflects the management of the Ross Barnett Reservoir more than land use in the watershed.

The Bogue Lusa Creek site exhibited anomalous trends compared to the other four sites. Only 3% of the TP values exceeded 0.1 $mg \cdot l^{-1}$; the mean TP concentration was 0.04 $mg \cdot l^{-1}$, and associated with this was a high 37.6 molar N-to-P ratio. The site is located in the lower Pearl River sub-basin, as is the Pearl at Bogalusa station, but the stream is small, draining only a small portion of the sub-basin. We were not able to determine the boundaries of, and land use on, this small drainage.

CONCLUSIONS

Although the water quality patterns in the Pearl River basin as a whole show characteristics of a basin experiencing some disturbance, the overall assessment of the Pearl River basin based on water quality is positive. The watershed is maintaining acceptable water quality based on a 0.1 $mg \cdot l^{-1}$ TP criterion (U.S. Environmental Protection Agency 1976). Yet, there is only limited understanding of what these concentration levels and trends indicate, what the significance of extreme values is, and the standards that should be set. Gosselink and Lee (1989) noted the need for comparative cumulative impact studies that consider a broad range of ecosystems, from pristine to highly degraded. At the national level, Omernik's (1977) study provides excellent comparative data. The highly degraded Tensas River basin in northeastern Louisiana offers another excellent comparison to the relatively undisturbed Pearl River basin (Gosselink et al. 1990). Historically, over 90% of the 1,000,000-ha Tensas study area was bottomland hardwood forest. Now 85% of the land is in agricultural production, and 84% of all streambanks are bordered by agricultural fields. The impacts caused by the accompanying loss and fragmentation of the forests, probably combined with heavy crop fertilization, were evident in the analyses of water quality. Basinwide, 96% of the TP values exceeded the 0.1 $mg \cdot l^{-1}$ criterion. At the three stations analyzed, highly significant and positive relationships existed between turbidity and flow. While TKN concentrations were within Omernik's (1977) predicted range, TP values were up to an order of magnitude greater than his predicted 0.16 $mg \cdot l^{-1}$ (based on land cover type). Molar ratios of N to P ranged from 6.6 to 15. These ratios, along with the high TP levels, indicated that N, and not P, may be limiting aquatic productivity in the Tensas basin (Childers and Gosselink 1990). Apparently agricultural land uses in the Tensas basin contribute high sediment and nutrient loads to surrounding streams and rivers, and are therefore a major influence on the quality of water in the basin.

To some degree, the sub-basins in the Pearl River follow the trends of the Tensas basin, although the Pearl River basin stream nutrient concentrations are at the low end of the range of reported values. Generally, those sub-basins with the highest percentage of land in agricultural production have the highest turbidity, TP, and TKN concentrations (Table 4-3).

On the basis of the results of the water quality analyses and the comparison with the Tensas basin study, the Pearl River basin water quality is within acceptable limits. Of the Pearl River watershed, 64% is upland and wetland forest, and only 31% is agricultural. Of the major tributaries feeding the Pearl River, 85% have streamside forested buffer strips. Although the basin's present water quality is acceptable, it is important to recognize that certain areas in the basin reflect disturbance and to address this in the goal-setting and management planning phases.

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CHAPTER 5: FAUNAL DIVERSITY AS AN INDEX IN CUMULATIVE IMPACT ASSESSMENT--PEARL RIVER BASIN, MISSISSIPPI AND LOUISIANA

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INTRODUCTION

Protection and conservation of the earth's ecosystems are necessary to prevent critical loss of environmental quality and wildlife habitat. Recent human activities such as agricultural and urban development (Council on Environmental Quality 1984) have threatened these ecosystems and led to loss of biological diversity and extinction of species, deforestation, and wetland loss (Powers and Lee in press). Environmental degradation results both from large or damaging activities and from the accumulation of many activities that in sum may have both significant and dramatic impacts. Failure to consider the effect of these cumulative impacts can lead to gradual depletion or "nibbling" away of our natural resources (Gosselink and Lee 1987).

Although environmental legislation in the United States requires evaluation of these cumulative impacts (Council on Environmental Quality 1978), rarely are they investigated adequately, partly because widely accepted methods and approaches are largely lacking (Walker et al. 1986). Current regulatory approaches are too often based on criteria specific to individual sites and projects. Long-term indirect or induced effects that may occur years after the direct disturbance are not considered. Effective measurement and management of ecosystem disturbances require that cumulative impacts be assessed, and that there be a match between the ecological processes affected and the regulatory measures employed (National Research Council [NRC] 1986).

In order to effectively evaluate cumulative impacts and implement management goals, indices are needed for assessing the past, present, and future projected conditions of a particular landscape. This chapter considers one such index of landscape health: biotic diversity. Indices of biotic diversity for large areas are difficult to devise. Not only are long-term data for trend analyses limited, it is difficult to develop biotic indices that integrate over a landscape-level assessment unit in the same way that a water quality station at the lower end of a watershed does. Also, interpretation of existing data is difficult because of the complexity of the biotic food web and biotic adaptation to the environment (Gosselink and Lee 1987). For these reasons, several indices incorporating both site-specific and historic trend data will be used to look at faunal diversity in the Pearl River basin in Mississippi and Louisiana.

Gosselink and Lee (1987) cite historical changes in species richness, indicator species, and endangered and threatened species as three measures of biotic diversity. These three "barometers" of landscape health will be examined at a landscape level using existing data bases for the Pearl River basin, a 22,688-km^2 watershed comprising 27 counties/parishes. Temporal change in bird species richness and composition in relation to habitat will be considered in detail, principally because bird counts are the most comprehensive biotic data available for this basin. Some limited data on fishery resources in the basin will also be examined.

TEMPORAL CHANGES IN BIRD SPECIES RICHNESS

Introduction

Although factors other than habitat influence size and species composition of bird communities (e.g., geographic location, pioneering ability, competition, population levels, climatic factors [Kendeigh 1944]), habitat clearly has an impact and can be readily measured (Weller and Spatcher 1965). Research investigating relationships between habitat and number and composition of bird species suggests that variables such as habitat size, structure, and floristic components are closely related to species richness and composition (Anderson 1981; Bond 1957; Burdick et al. 1989; Butcher et al. 1981; Diamond 1975; Galli et al. 1976; Harris 1984; Whitcomb et al. 1981). The following section concerns methods and preliminary results of an analysis of bird species richness and composition in the basin. The relationship between land cover and the above variables will be examined in an effort to (1) assess faunal diversity in the basin and (2) determine the reliability of using long-term and land cover data in cumulative impact analyses at the watershed scale.

Methods

Although bird resources are better documented than other wildlife groups in the basin, the data at best are fair. Two long-term data sets showing changes in bird species by area were used to analyze bird populations in the basin: the National Audubon Society's Christmas Bird Counts (CBC) and the U.S. Fish and Wildlife Service's Breeding Bird Surveys (BBS).

The CBC involves observers identifying birds within a 24-km-diameter circle with a standardized midpoint. The count occurs over a period of 24 h once a year at Christmas. One CBC site, Jackson, is located within the Pearl River basin (Figure 5-1).

BBS routes consist of 50 stops 0.8 km apart and are run along a standardized route (40 km) one morning in June at the height of the breeding season. Birds seen or heard at each stop are counted for 3 min during a 4-1/2 h period. Five BBS sites in the study area were analyzed: Cybur, Lucien, Columbia, Lake, and Lacombe (Figure 5-1).

Analysis consisted of standardizing CBC data by dividing bird counts by the number of observer group (party) hours. Standardized bird counts for both BBS and CBC were then regressed against time. Birds sighted less than six times over each survey period were

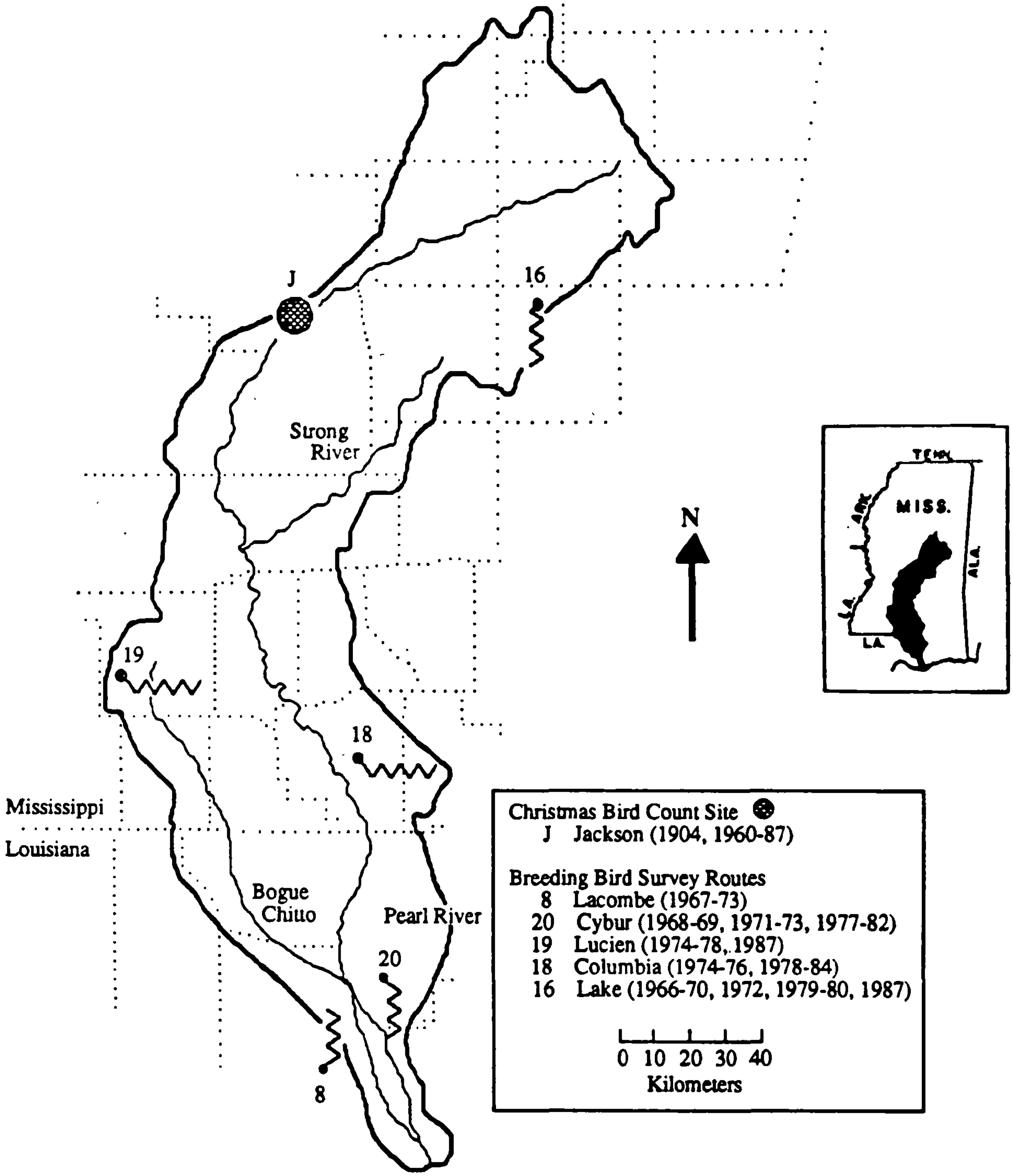


Figure 5-1. Bird survey sites within the Pearl River basin.

eliminated from the analysis. Habitat preferences were identified by Dr. Robert Hamilton, Louisiana State University, School of Forestry, Wildlife, and Fisheries, for each species analyzed. These habitat categories, listed below, were taken from existing literature:

- water
- swamps and wet edges
- marshes
- fields
- forest edges
- forest in general
- forest open canopy
- forest closed canopy

Forest closed canopy species primarily utilize closed canopy forests, as opposed to edge or field habitats. Edge/field species are primarily associated with "edge" habitat, clearings, or agricultural fields. Appendix C reports diversity trends over time by habitat preference for CBC and BBS sites.

Temporal change in bird species richness by habitat was compared to change in land cover from 1973 and 1987 land cover maps (see Chapter 2). Land cover classes were digitized within a 0.40-km corridor on either side of the five 40-km BBS routes and within a 24-km-diameter circle for the Jackson CBC site (Table 5-1; Appendix D). Maps of selected bird routes are included in Appendix D.

BBS periods at three of the five sites coincided with the 1973 land-use data. Mean numbers of bird species and percentages of forest or field/edge species observed at each site during 1968, 1969, and 1972 surveys (the only years to correspond across sites) were calculated to yield averages over a five-year span (1968-1972). Percentage species richness by habitat category was then compared across the three sites and related to percentage of the corridor in certain cover classes (in 1973) for each site.

Results

The BBS's were conducted intermittently for most routes within the study area (Figure 5-1). The Lake and Cybur sites both increased in species richness in general (Table 5-2) and in particular increased in birds that prefer forest open canopy and in field and edge birds. The Cybur site showed the strongest trends, with an 11.5% increase

Table 5-1. Results of land cover for bird survey areas[a] digitized from 1973 and 1987 land cover maps (see Chapter 2) for areas covered by bird surveys.

Site	Sub-basin	Land-cover[b]	1973		1987	
			ha	%	ha	%
Jackson (CBC)	Pelahatchie Creek	agriculture[c]	12332	30	8722	21
		forest[d]	16295	39	20366	49
		water[e]	11019	27	10794	26
Columbia	Lower Pearl Basin	agriculture	1160	33	1066	31
		forest	2201	63	2347	67
		water	97	3	30	1
Lucien	Bogue Chitto River	agriculture	1285	38	1116	33
		forest	2024	59	2239	66
		water	54	2	10	0
Lacombe	Bogue Chitto River	agriculture	391	12	586	17
		forest	2925	86	2499	74
		water	29	1	234	7
Lake	Tuscalameta Creek	agriculture	1300	38	1363	40
		forest	1520	44	1748	51
		water	348	10	49	1
Cybur	Lower Pearl River	agriculture	1829	52	2446	70
		forest	1595	46	961	28
		water	61	2	29	1

[a] Land cover digitized within a 0.40-km corridor on either side of the five 40-km BBS routes and within a 24-km-diameter circle for the Jackson CBC site.
[b] Urban and barren/other land cover categories not included.
[c] Agriculture/grassland.
[d] Coniferous forest + mixed forest + deciduous forest + bottomland hardwood forest.
[e] Water + forested wetland + nonforested wetland.

in birds that preferred field/edge habitat corresponding to an 18% increase in agricultural habitat. There was a general trend of increasing species density at this site for Mourning Dove (Latin names for all species are given in Appendices B and C), Red-winged Blackbird, and American Crow, all common field and edge species that use agricultural fields extensively (Figure 5-2). Two of the three species decreasing at the Cybur site use upland forest habitat (Chimney Swift and Black Vulture); all three decreasing species (Common Nighthawk plus the other two) also utilize bottomland hardwood forests. Forest land cover at the Cybur site decreased by 18% (from 46% to 28%); bottomland

Table 5-2. Summary of bird species regressed against time.

Species	Bird Sites[a]					
	Jackson	Columbia	Lacombe	Lake	Lucien	Cybur
Total # species recorded	129	75	57	69	71	61
# species increased[b]	19	7	8	8	6	11
% species increased	14.7	9.3	14.0	11.6	8.5	18.0
# species decreased	19	12	7	1	7	3
% species decreased	14.7	16.0	12.3	1.4	9.9	4.9
# species showing no trend	91	56	42	60	58	47
% species showing no trend	70.5	74.7	73.7	87.0	81.7	77.0
Species recorded by bird habitat						
Total # water species[c]	40	6	1	3	0	6
Total % water species	31.1	7.9	1.8	4.3	0.0	9.8
# water species increased	7	1	0	0	0	0
% water species increased	5.5	1.3	0.0	0.0	0.0	0.0
# water species decreased	0	1	0	0	0	0
% water species decreased	0.0	1.3	0.0	0.0	0.0	0.0
# water species showing no trend	33	4	1	3	0	6
% water species showing no trend	25.6	5.3	1.8	4.3	0.0	9.8
Total # forest species[d]	49	46	38	45	49	36
Total % forest species	38.0	61.2	66.8	65.1	69.0	58.9
# forest species increased	4	3	8	7	2	4
% forest species increased	3.1	3.9	14.1	10.1	2.8	6.5
# forest species decreased	13	7	3	1	5	3
% forest species decreased	10.1	9.3	5.4	1.4	7.0	4.9
# forest species showing no trend	32	36	27	37	42	29
% forest species showing no trend	24.8	48.0	47.3	53.6	59.2	47.5
Total # field species[e]	40	23	18	21	22	19
Total % field species	31.1	30.7	31.6	30.4	31.0	31.1
# field species increased	8	3	0	1	4	7
% field species increased	6.2	4.0	0.0	1.4	5.6	11.5
# field species decreased	6	4	4	0	2	0
% field species decreased	4.7	5.4	7.1	0.0	2.8	0.0
# field species showing no trend	26	16	14	20	16	12
% field species showing no trend	20.2	21.3	24.5	29.0	22.6	19.6

[a] Survey period for sites:
Jackson, 1904, 1960-1987; Columbia, 1974-1976, 1978-1984; Lacombe, 1967-1973; Lake, 1966-1970, 1972, 1979-1980, 1987; Lucien, 1974-1978, 1987; Cybur, 1968-1969, 1971-1973,1977-1982.

[b] Significant increase = $P < .10$.

[c] Total water = water + swamp + marsh bird habitat preferences.

[d] Total forest = forest + forest closed canopy + forest open canopy bird habitat preferences.

[e] Total field = field + edge bird habitat preferences.

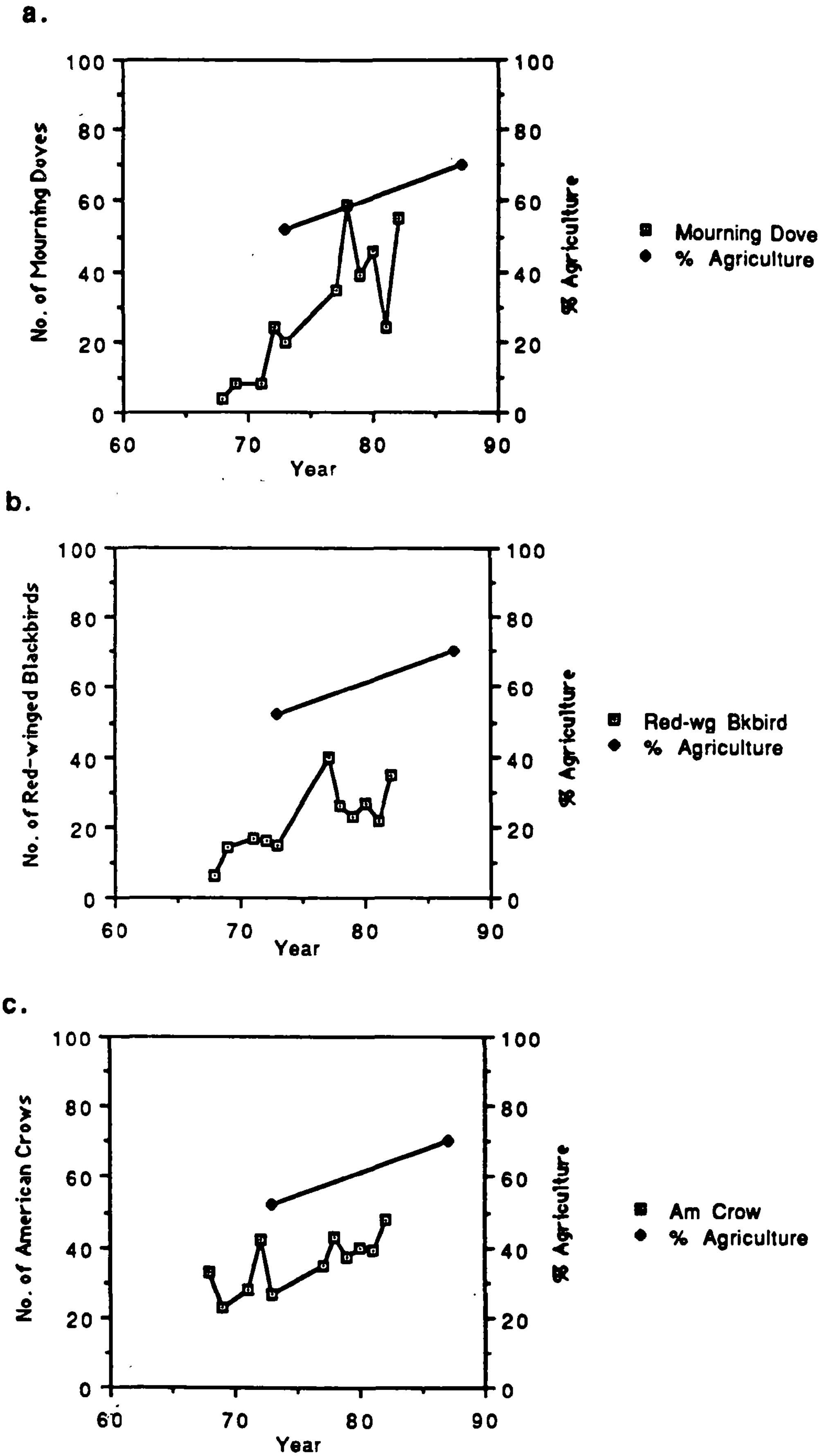


Figure 5-2. Standardized abundance of field/edge species and percentage change in agricultural land cover over time, Cybur site (1968-1969, 1971-1973, 1977-1982).

hardwoods decreased from 11% to less than 1% (Figure 5-3, Appendix D).

The Lake site showed a 10% increase in forest bird species compared to a 7% increase in forest land cover. Eight of the surveyed species increased, one of which prefers forest habitat, and six, forest open canopy habitat. Figure 5-4 illustrates the increase for two of these species in relation to forest habitat. The one decreasing species, Pileated Woodpecker, prefers forest closed canopy. One edge/forest species (Carolina Chickadee) at the Lake site increased, compared to a 2% increase in agricultural land cover.

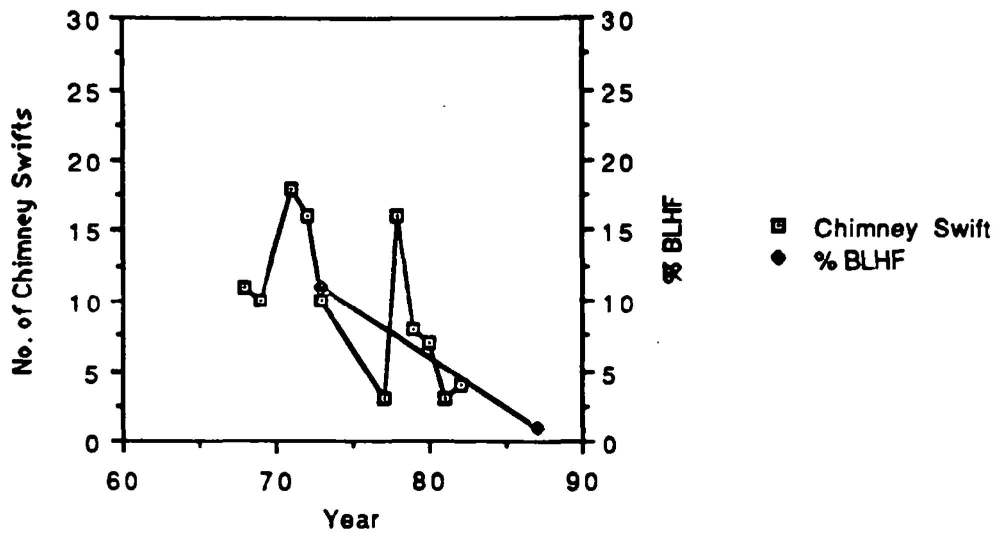
The Lacombe site was not surveyed after 1973; therefore no comparison can be made with the 1987 land cover data.

Very little temporal change in land cover occurred at the Columbia site during 1973-1987 (agriculture decreased by 2%; forest increased by 4%). Seven bird species increased in density; twelve decreased. In general, both field/edge birds and forest birds, particularly forest open canopy birds, decreased. Agricultural land cover at the Lucien site showed a 5% decrease; forest increased by 7%. Species compositions by habitat at this site did not correspond to land cover--birds that preferred field habitat increased by 6%; forest birds decreased by 7%.

Analysis of 29 years of CBC data for the Jackson site (1904, 1960-1987) revealed no particular trends in species richness by habitat and land cover from 1973 to 1987 (19 species increased, 19 decreased). Additional land-use data for the 1960s is needed to more accurately correlate change over time for both indices.

The mean number of bird species from three years (1968, 1969, 1972) of BBS's from each of three routes (Lacombe, Lake, and Cybur) were compared with percentage land cover adjacent to each route in 1973 (Table 5-3). The percentage of agriculture along each route decreased from Cybur (52%) to Lake (38%) to Lacombe (12%). Field/edge bird species (as percentage of total bird species recorded) also decreased from Cybur (62%) to Lake (53%) to Lacombe (38%). Forest land cover and forest birds followed the opposite trend, increasing from Cybur (46% forest land cover/38% forest bird species) to Lake (51% forest land cover/47% forest species) to Lacombe (86% forest land cover/61% forest species).

a.



b.

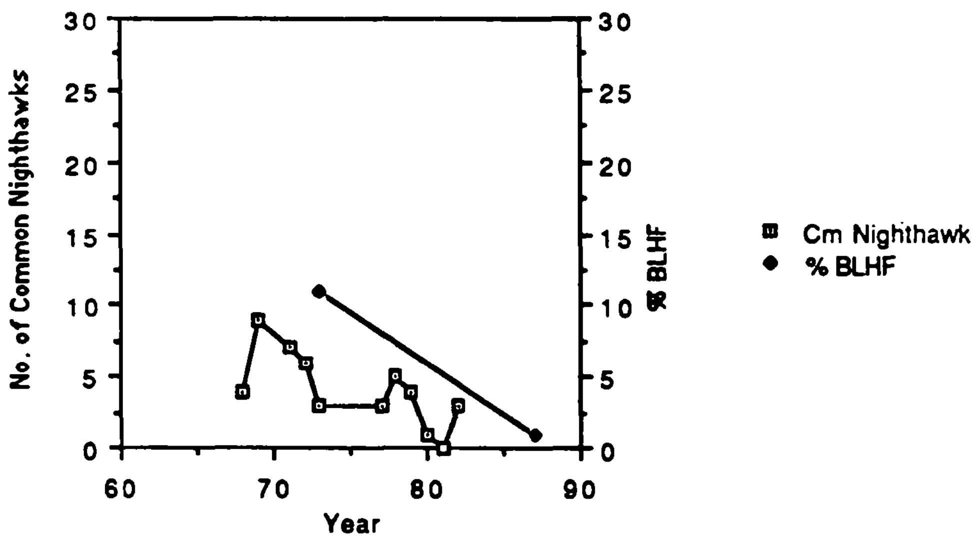
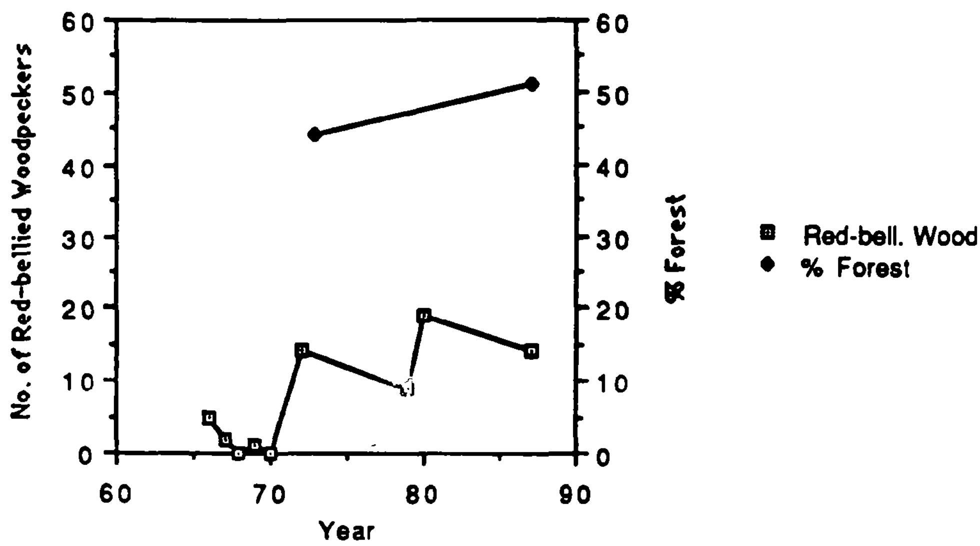


Figure 5-3. Forest species abundance and percentage change in bottomland hardwood forest land cover over time, Cybur site (1968-1969, 1971-1973, 1977-1982).

a.



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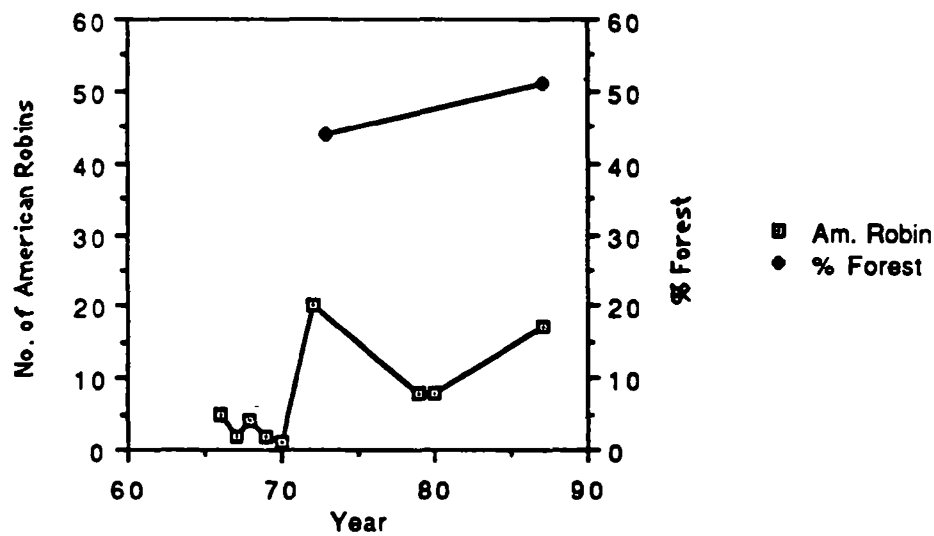

Figure 5-4. Forest open canopy species abundance and percentage change in total forest land cover over time, Lake site (1966-1970, 1972, 1979-1980, 1987).

Table 5-3. Percentage of bird species by habitat preference (from three BBS routes, 1968-72 means) compared to percentage land cover adjacent to routes in 1973.

	Routes		
	Lacombe	Lake	Cybur
Longitude/latitude	89° 54' E 30° 16' N	89° 8' E 32° 33' N	89° 48' E 30° 42' N
% Agriculture	12	38	52
% Field/edge species[a]	38	53	62
% Forest	86	44	46
% Forest species[a]	61	47	38

[a] Percentage of total bird species recorded (1968-1972 mean).

Wading Birds

Wading bird resources within the basin are not well known. The two known breeding colonies are in riparian woodland in Newton County, Mississippi, and in a tupelo gum-bald cypress (*Nyssa aquatica/Taxodium distichum*) swamp and adjacent marsh in the White Kitchen Tract, St. Tammany Parish, Louisiana. The latter colony site is used yearly by the only pair of nesting Bald Eagles in the basin (U.S. Fish and Wildlife Service [USFWS] 1981).

Waterfowl

Waterfowl use the basin moderately because of its location just outside the main portion of the Mississippi Flyway and the relatively small acreage of permanently flooded wetland. Wood Duck and Mallard (Latin names are given in Appendix E) use flooded bottomland hardwood areas extensively, and most hunting activity occurs in these areas. Gadwall, Pintail, Green-winged Teal, and Ring-necked Duck are also harvested (USFWS 1981; U.S. Army Corps of Engineers [USACE] 1970).

TEMPORAL CHANGES IN FISH AND OTHER WILDLIFE SPECIES RICHNESS

Fisheries

The Pearl River basin supports a diverse fish fauna; approximately 133 species are known for the area (Appendix E). The lower portion of the basin is heavily used by both recreational and commercial fishermen and is considered important to finfish and shellfish production. Recently the USACE estimated (based on sparse data compiled on species abundance, landings, and value) that the basin produces over 7.9 kg of harvestable estuarine fish and shellfish per hectare, having a value of over $22.50 per hectare (Table 5-4). Finfish harvested by both recreational and commercial fishermen include red drum (red fish), spotted seatrout, Atlantic croaker, spot, and blue and channel catfish. Commercially important shellfish include brown and white shrimp, blue crab, and oysters.

Table 5-4. Estimated production value of finfish and shellfish in the Pearl River basin based on abundance of estuarine species and landings (USACE unpublished data).

Taxa	Abundance (kg/ha)	Value ($/ha)	Value ($/ha)
Gulf menhaden	0.38	0.0825	0.0314
Red drum	0.38	1.5129	0.5749
Atlantic croaker	0.38	0.5607	0.2131
Spot	0.38	0.4410	0.1676
Channel catfish	0.38	1.0805	0.4106
Blue catfish	0.38	1.0805	0.4106
Brown shrimp	2.72	4.1234	11.2156
White shrimp	1.89	4.1234	7.7932
Blue crab	0.62	0.7953	0.4931
Oysters	0.31	3.3075	1.0253
Other (crabs)	0.04	5.0274	0.2011
	7.86 kg / ha		$22.5365 / ha

Abundance data for fish populations in the basin as a whole are lacking. Some data are available from the Mississippi Department of Wildlife Conservation for the Ross Barnett Reservoir, a subsystem within the basin. The reservoir is considered atypical of the basin as a whole, however, because of its conversion from a riverine system to a reservoir in 1964 (USACE 1970).

Uncorrected 1963-1987 catch data (uncorrected for effort; raw kilograms from National Marine Fisheries Service unpublished data, Hydrologic Units 12.1 and 12.2) for selected estuarine species in waters within (Lake Borgne) and adjacent to (Chandeleur Sound) the basin are available. Some trends in these data are noteworthy. For example, examination of catch data (kilograms) of red drum and blue crab, when plotted against year on the abscissa, indicate that catch has increased steadily since the mid-1970s, even though the data are quite variable (Figure 5-5). Where equivalent data were available (e.g., Atlantic croaker, spotted seatrout, oysters), other estuarine species showed similar trends. The dramatic increase since 1982 in kilograms of red drum landed reflects the increase in demand, probably due in part to the changing fishery status (game vs. nongame species) of red drum in other northern Gulf of Mexico (other than Louisiana) states and the developing national popularity of "cajun" food (i.e., blackened red drum). However, trends in these data must be interpreted with caution since no effort data are available.

The catch of shrimp (brown and white shrimp combined) in waters adjacent to the basin has also increased dramatically since the mid-1970s (Figure 5-6). These data for shrimp are perhaps more revealing since some effort data, given as the number of shrimp fishing trips per year, are available for Hydrologic Units 12.1 and 12.2 (Figure 5-7). These effort data can be combined with the shrimp catch to produce a coarse estimate of catch per unit effort (CPUE).

Effort given as number of fishing trips per year (1963-1987) appears to have been high in the mid-1960s, decreased in the 1970s, and then increased in the 1980s when catch increased greatly. Catch per unit effort has increased steadily since the 1960s, but has fluctuated widely since 1980 (possibly a sign of near maximum harvest of a variable resource) (Figure 5-8). To quantify this trend, the CPUE was regressed on Year using a linear model. The regression was highly significant ($P < 0.0001$; $r^2 = 0.59$), and the relationship suggests that shrimp catch per unit effort has increased dramatically by nearly 13% per year over the 24 years between 1963 and 1987 (Figure 5-8).

As a final examination of these limited shrimp data, the value in dollars (not standardized to 1989 dollars) of the shrimp catch from 1963 to 1987 was regressed on the CPUE over the same period. The regression was again highly significant ($P < 0.0001$; $r^2 = 0.61$) and suggests that the value of shrimp is increasing exponentially relative to the linear increase in CPUE.

Anadramous Fish

Anadramous fish resources, extremely important both economically and ecologically, continue to be depleted along the Pacific, Atlantic, and Gulf coasts (USFWS

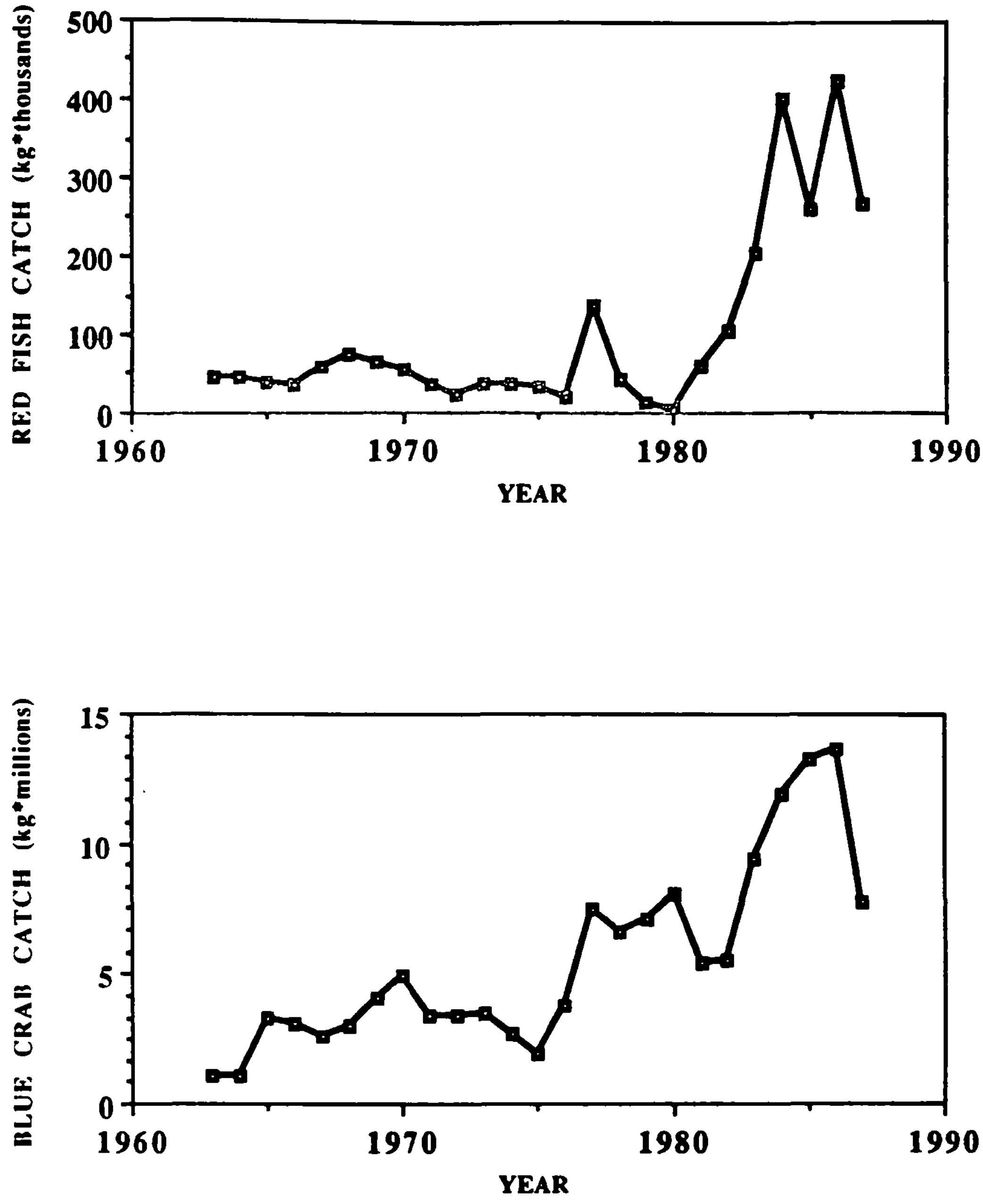

Figure 5-5. Uncorrected catch (raw weight) of red drum and blue crab in waters adjacent to the Pearl River basin (Hydrologic Units 12.1 and 12.2) between 1963 and 1987 (NMFS unpubl. data).

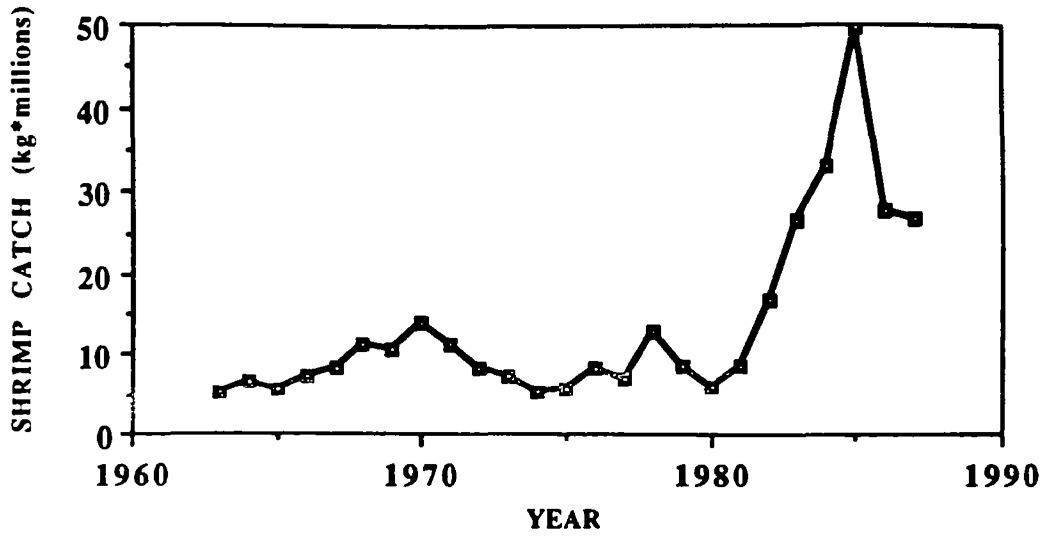

Figure 5-6. Uncorrected catch (raw weight) of shrimp (brown and white combined) in waters adjacent to the Pearl River basin (Hydrologic Units 12.1 and 12.2) between 1963 to 1987 (NMFS unpubl. data).

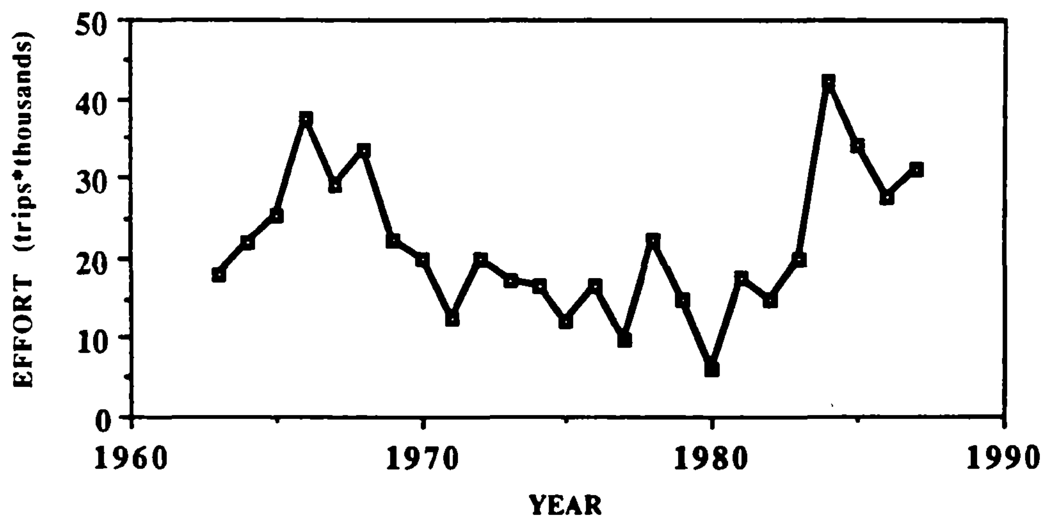

Figure 5-7. Effort (shrimp fishing trips) in waters adjacent to the Pearl River basin (Hydrologic Units 12.1 and 12.2) between 1963 and 1987 (NMFS unpubl. data).

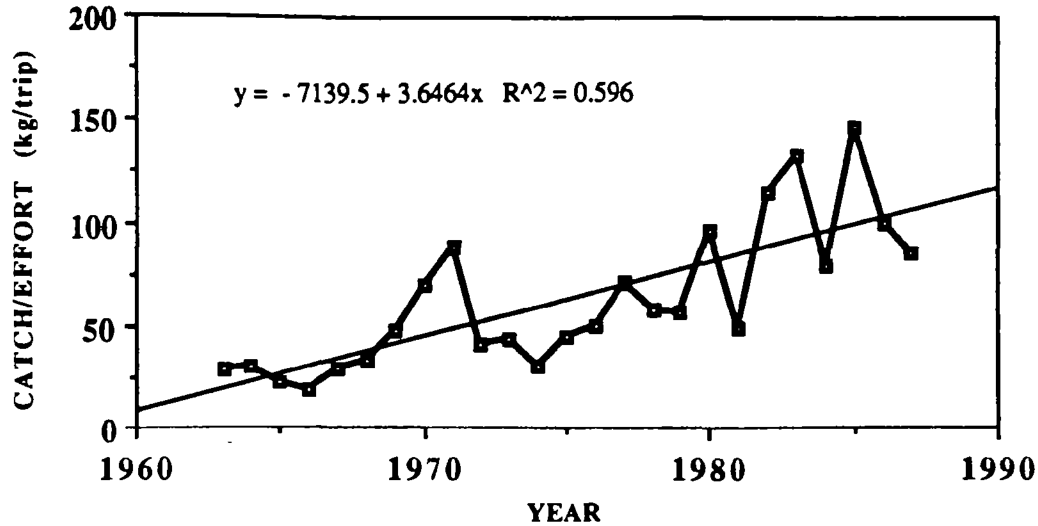

Figure 5-8. Catch per unit of effort for shrimp (brown and white combined) in waters adjacent to the Pearl River basin (Hydrologic Units 12.1 and 12.2) regressed on time (1963-1987) (NMFS unpubl. data).

1981). Species of anadramous fish found in the Pearl River system include Atlantic sturgeon, skipjack herring, striped bass, Alabama shad, and threadfin shad. It is not known conclusively if these fish spawn in the basin; however there are potential blocks to anadramous fish runs along the lower Pearl in the form of weirs constructed by the USACE (USFWS 1981).

Other Wildlife

There are few wildlife species other than birds in the basin for which long-term species composition and population level data exist. In general, the basin supports high wildlife diversity (Appendix E). Species hunted as game include white-tailed deer, squirrels, and rabbits. Game birds are Turkey, Mourning Dove, Bobwhite, waterfowl, Woodcock, and Snipe. Common nongame mammals include the eastern chipmunk, cotton mouse, rice rat, hisped cotton rat, and pine vole. Furbearers include mink, raccoon, muskrat, fox, bobcat, opossum, river otter, nutria, and beaver. (USFWS 1981). Generally, bottomland hardwood forests and their edges support the highest density of animals, and are considered the greatest asset to deer, squirrel, and furbearers. Prime areas are the Lobutcha and Yockanookany bottomlands and the Pearl bottomlands near the confluence of Tuscalameta Creek (USACE 1970).

INDICATOR SPECIES

Indicator species can be defined as top carnivores with large ranges whose presence or absence is an index of landscape integrity (Gosselink and Lee 1987). Time series data for indicator species are generally not available; however the Mississippi Department of Wildlife Conservation does have general status and population data for raptors, shown in Table 5-5. Densities of approximately one-half the raptors listed for the basin are unknown. Densities appear to be stable or increasing (Bald Eagle) for the remainder; no populations are listed as decreasing.

ENDANGERED AND THREATENED SPECIES

Endangered species are those in danger of extinction throughout all or a significant portion of their range. Threatened species are those likely to become endangered within the foreseeable future (USFWS 1978). Table 5-6 lists threatened/endangered species for the study area. Habitat preference for these species is given in Appendix E. Figure 5-9 plots species distribution within the basin. Brown Pelicans are limited to coastal bays in the Pearl River basin. The Bald Eagle, occurring in the basin both as a transient and as a breeding species, has been recorded near the Ross Barnett Reservoir in the winter and nests in the lower basin in the White Kitchen Tract. The Red-cockaded Woodpecker is found sporadically over the basin; the major cause for its decline has been the conversion of mature pine stands to pine monoculture with shorter rotations than are required for maintenance of colony areas (USFWS 1981). Historical ranges of both the Ivory-billed Woodpecker and Bachman's Warbler include the basin, but there are no specific records of their occurrence. The Florida cougar and red wolf once ranged over the area, but are probably now extirpated from the basin. The ringed sawback turtle, rainbow snake, and crystal darter occur in the lower reaches of the Pearl River floodplain.

DISCUSSION AND CONCLUSIONS

Lack of systematic, long-term data prohibited analysis of species richness and composition in relation to habitat for all wildlife groups except birds and fish. The only quantitative data available for nongame bird resources are the BBS and CBC. The BBS's have been conducted intermittently for different routes, and thus the survey period of record didn't always match across sites, coincide with land use data compiled in 1973 and 1987, or cover enough time for statistical analyses. BBS's are performed from a road, and therefore interior forest species are not sampled as effectively as edge species. CBC's are conducted at different hours (over a 24-h period) and exclude neotropical migrants, which are generally not present during the sampling season.

Abundance data corrected for effort for fish populations within the basin are generally lacking or are in an insufficient time series for statistical analyses. The available shrimp effort data must be viewed with caution since they represent effort not standardized to gear type, length of fishing trip, number of fishermen, or technological advances in the fishing fleet.

Table 5-5. Raptors known to frequent the Pearl River basin (from Mississippi Department of Wildlife Conservation, unpublished data).

Species	Status[a]	Population Trend[b]
Black Vulture	C	S
Turkey Vulture	U	S
Osprey	C,U	S
American Swallow-tailed Kite	R	S
Black-shouldered Kite	R	U
Mississippi Kite	C,U	S
Bald Eagle	R	I
Northern Harrier	C,U	S
Sharp-shinned Hawk	U,R	U
Cooper's Hawk	U,R	U
Red-shouldered Hawk	C	S
Red-tailed Hawk	C	S
Broad-winged Hawk	C	U
Rough-legged Hawk	R	U
Swainson's Hawk	R	U
Golden Eagle	U	U
Crested Caracara	R	U
American Kestrel	C	S
Peregrine Falcon	R	U
Merlin	U	U
Common Barn-Owl	C	S
Barred Owl	A,C	S
Great Horned Owl	C	S
Eastern Screech-Owl	C	S
Short-eared Owl	R	U
Long-eared Owl	R	U
Northern Saw-whet Owl	R	U
Burrowing Owl	R	U

[a] C = Common, U = Uncommon, R = Rare, and A = Abundant.
[b] S = Stable, U = Unknown, I = Increasing, and D = Decreasing.

Table 5-6. Endangered and threatened species of the Pearl River basin (after Mississippi Natural Heritage Program unpublished data and USFWS 1981)[a].

Species	State Status[b]	Federal Status
Fishes		
Atlantic Sturgeon (*Acipenser oxtrhynchus*)	LE	
Frecklebelly Madtom (*Noturus munitus*)	LE	
Crystal Darter (*Ammocrypta asprella*)	LE	
Reptiles		
Ringed Sawback Turtle (*Graptemys oculifera*)	LE	LT
Rainbow Snake (*Farancia eytrogramma*)	LE	
Eastern Indigo Snake (*Drymarchon corais Couperi*)	LE	LT
Black Pine Snake (*Pituophis melanoleucus*)	LE	
American Alligator (*Alligator mississippiensis*)	LE	
Gopher Tortoise (*Gopherus polyphemus*)	LE	LE
Birds		
Southern Bald Eagle (*Haliaeetus leucocephalus*)	LE	LT
Arctic Peregrine Falcon (*Falco peregrinus*)	LE	LE
Red-cockaded Woodpecker (*Picoides borealis*)	LE	LE
Brown Pelican (*Pelecanus occidentalis*)	LE	LE
Mammals		
Black Bear (*Ursus americanus*)	LE	
Florida Panther (*Felis concolor Coryi*)	LE	LE

[a] Known to have occurred in the Pearl River basin or occurrence is strongly suggested by geographical range.
[b] Mississippi status only; there is no official state list of threatened and endangered species for Louisiana. LE = listed endangered; LT = listed threatened.

Birds

Available BBS survey data, when compared to temporal change in land use over a 15-year period (1973-1987), generally indicated that trends in bird species richness and composition correspond to changes in land cover. Three of the five BBS sites, when analyzed separately over each respective survey period, showed a positive relationship between land cover change and alteration in species richness and composition.

At the Cybur site, an increase in agricultural habitat corresponded to an increase in field/edge birds. All three decreasing species of birds at this site utilize bottomland hardwoods, which decreased over 1973-1987.

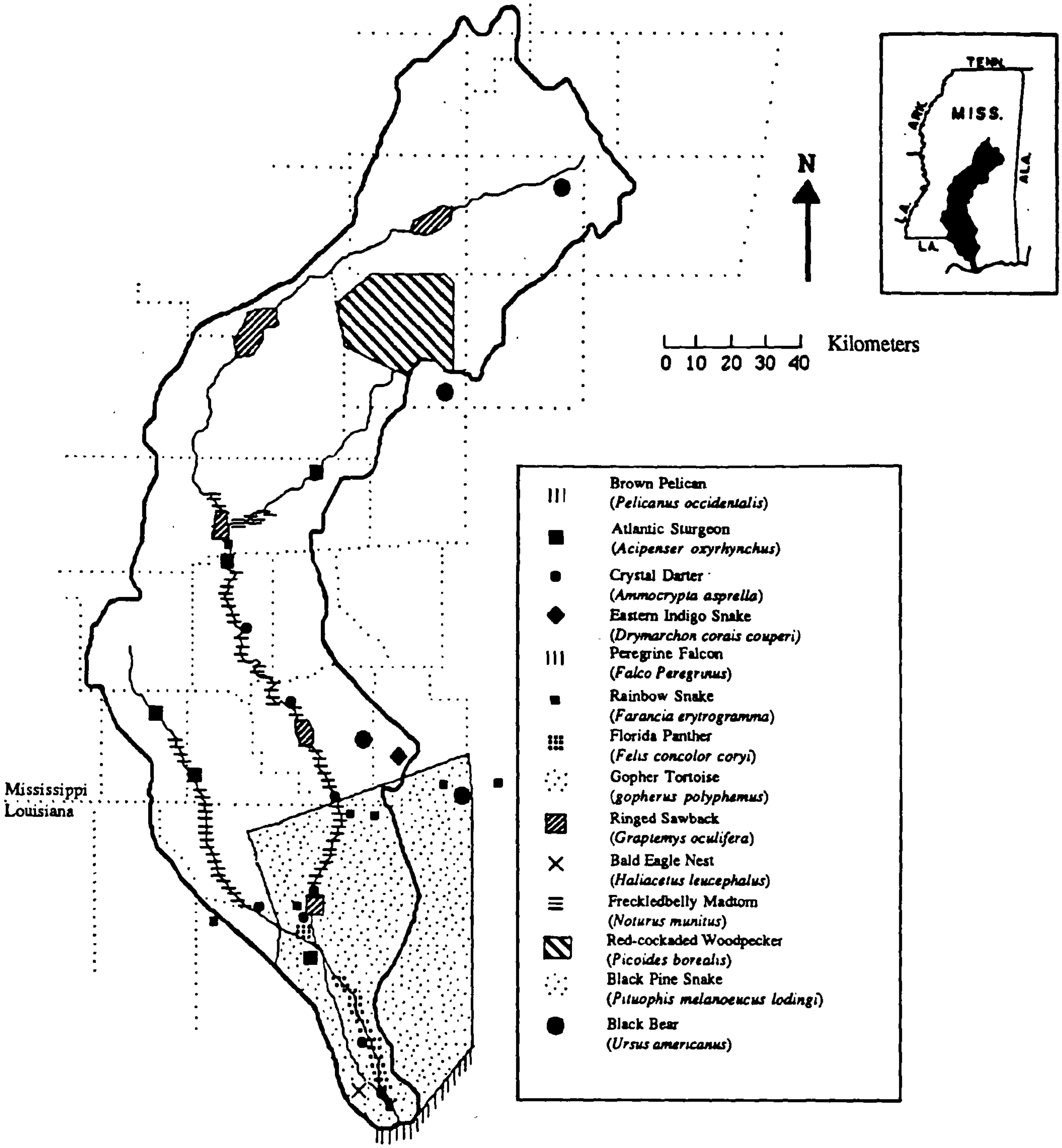

Figure 5-9. Threatened/endangered species of the Pearl River basin (from Mississippi Department of Wildife Conservation and Louisiana Natural Heritage Program, unpublished data).

The Lake site showed a positive correlation between increasing forest land cover and bird species that prefer forest habitat, and a smaller increase in agricultural land cover and field/edge bird species.

Two sites, Columbia and Lucien, showed no positive correlation between land cover and species richness and composition. Possibly the very small changes in land cover at the Columbia site were a reason for the lack of correlation.

Comparison of BBS data across sites over a three-year period for three routes within the basin (Cybur, Lacombe, Lake) yielded strong apparent correlations between land cover and species richness and composition. Mean percentage of forest species observed per three-year period increased with increases in forest habitat; mean percentage of field/edge species likewise decreased with decreases in agriculture.

Analysis of CBC data revealed about equal numbers of bird species increasing and decreasing. We were not able to correlate these changes with land cover changes because the time periods for land cover analysis (1973 and 1987) did not correspond with the bird survey period (1904, 1960-1987). Additional land use data for the 1960s are needed to correlate temporal changes in the abundance of particular bird species at this site to land cover (habitat).

Overall, the limited data suggest that trends in bird species composition and richness generally correspond to temporal changes in land cover. The changes in bird species richness and composition in many cases reflect small corresponding changes in land cover.

Powers and Lee (in press) suggest that a starting point for determining the presence of balanced indigenous populations is to examine the response of single populations to changes in habitat. Based on the above analysis, bird data appear to be a useful tool for evaluating faunal diversity and cumulative impact analysis at the watershed level.

Overall the data are not sufficient to use bird species richness as a blanket indicator of species richness within the basin or of the health of the basin as a whole; however, the data do suggest that the basin is relatively stable, at least in terms of bird species richness. Species abundance either increased or remained relatively stable at five of the six sites surveyed. Correspondingly, changes in land cover have also been relatively minimal. Forest decreased in only two of the six sites surveyed, and then by only approximately 10%. Forested wetland remained stable at all sites but Cybur, where nearly all the 1973 bottomland forest was converted to other uses by 1987. Although basinwide changes in land use and bird species richness and composition are small, they should be monitored to prevent nibbling away of resources, since minimum habitat requirements for many species are unknown.

Fisheries

The limited data available for fish indicate that shrimp catch per unit effort has increased over the 24-year period of record. The trend suggests that one unit of effort in 1963 was not equivalent to one unit of effort in 1987, and that either the fishermen today are more efficient, or that shrimp are more abundant. The management implications of this dichotomy are important. Research managers must know whether the apparent increase in skill or efficiency is real (due to improved technology, better fleets, longer fishing days, etc.) or reflects an actual increase in abundance of shrimp in water adjacent to the basin. The increase in shrimp catch is not unique to the Pearl River basin. It has been reported for all commercially caught estuarine-dependent species across the state. Recently Zimmerman and others (NMFS, Galveston, Tex., unpublished data) have shown that the increase in shrimp catch is related to increased recruitment of juveniles. They suggest that the marsh edge habitat preferred by shrimp is increasing across the state as the marshes submerge and break up. Clearly, more study is warranted before an informed decision can be made.

Indicator and Threatened/Endangered Species

Raptors and large mammals with extremely wide ranges integrate over space---their presence is a sign of large natural areas with healthy food webs (Gosselink and Lee 1987). The limited qualitative data available on raptors indicate that populations are at least stable in the basin. Several indicator species--Florida panther, black bear, Southern Bald Eagle, and Peregrine Falcon--are listed as regionally endangered or threatened. The presence of these species reflects the ability of the basin to support far-ranging species. Managing for these larger species includes consideration of the habitat requirements of smaller species and should lead to conservation of balanced indigenous populations.

There are 15 species in the basin that are considered threatened. The map of species occurrence (Figure 5-9) indicates that much of the habitat along and adjacent to the Pearl River is considered critical under the Endangered Species Act. This is valuable information in creating management plans to restore these species to unlisted classification through reclamation of habitat, and in conserving the basin's natural resources in general.

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CHAPTER 6: SUMMARY AND SYNTHESIS

INTRODUCTION

In this chapter we summarize results of the Pearl River basin cumulative impact assessment and discuss their implications for management of the living resources of the basin. First, we examine the internal consistency of the indices used in the study as a check on their validity. Second, we summarize the previous five chapters. Third, we discuss the basin as an integrated landscape unit, emphasizing the interaction of structure and function and the spatial pattern of structure and process. Fourth, we consider the offshore zone influenced by the Pearl River, the river's contributions to this zone, and the reciprocal influence of the marine environment on the lower reaches of the river. Finally, we discuss the ecological condition of the Pearl River basin and suggest some approaches to its future management.

INDICES OF LANDSCAPE STRUCTURE AND FUNCTION

The validity of conclusions drawn about the structural and functional characteristics of the Pearl River basin depends heavily on how well the indices used in the analysis represent the basin system. Gosselink and Lee (1989) summarized reasons for selecting the indices, and discussed their utility as gleaned from other studies.

Maps and associated data on land use or land cover classes and interpreted remotely sensed imagery from planes and satellites (LANDSAT TM and MSS) are probably the most commonly used indices of landscape structure. In this study we compared 1973 maps prepared from high-altitude imagery with 1987 maps classified electronically from LANDSAT-MSS satellite imagery. Differences between the two maps are small, and most pixels are classified the same way in both years. The small differences between years are consistent with our understanding of changes occurring in the basin during the past 15 years. More importantly, they are consistent with the results of the analyses of functional processes in the basin, which, in general, give a picture of a stable system in which changes have been minimal and gradual.

This picture of generally stable land use in the basin was confirmed by comparision with historical land use data from the U.S. Forest Service and the U.S. Department of Agriculture. These data show that agricultural area has changed little since 1935, and non-wetland and wetland forest area little since the 1960s.

The size of the mapping unit of the LANDSAT imagery, 6.25 ha/cell (250 m x 250 m grid) was fine enough to detect the dominant features of the 2.5 million ha Pearl River basin. Linear features less than 250 m wide might have been missed. This means that narrow riparian forest strips along low-order streams might be incorrectly classified, but land use maps and analysis of land cover on 250-m-wide strips along the major tributaries of the Pearl River (Chap. 2) show sufficient resolution for the broad picture required for this assessment. The color plates in Figures 2-14 and 2-15 contain less detail than the tabular analyses (e.g., forest patch size and distribution). The latter are based on 6.25-ha cells. Four of these cells were aggregated for purposes of display in the report.

We used relatively few classes of land cover for this analysis. For example, we did not distinguish between cultivated fields and pasture. This was partly because farmers often rotate between these two uses, so dividing them is meaningless in analysis of long-term data. The simplicity of the land cover classification also reflects the limitations of electronic image processing. We could not readily distinguish between different types of mixed deciduous forest, for example, by age or by time since the most recent logging. We did, however, map coniferous forest. These relatively pure pine stands are probably all plantations, maintained in a fairly short rotation for timber and pulpwood. The simplicity of our classification system limited the depth of analysis, but we think the classes reflect the major groups, both in terms of land cover and in terms of ecological processes.

Offshore the analysis of marsh change was obtained from a U.S. Fish and Wildlife Service data set for the entire Louisiana coast. It has been extensively field verified (Wicker 1980), and trends shown in the data set have been independently confirmed in other studies.

Hydrologic data for the basin provide perhaps the most complete data set on a functional attribute. Several discharge data sets span 50 years. This type of record has been extensively used by the U.S. Geological Survey and the U.S. Army Corps of Engineers (USACE), and its reliability and utility have been extensively verified. Spatial coverage is fairly comprehensive; stations range from the northern extremes of the basin to the Bogue Chitto tributary in the south. Unfortunately there are no long-term records below Bogalusa on the Pearl River, so data for the large wetland system of the lower river near Slidell are lacking. The individual records are remarkably similar. Trends over the period of record are slight. Perhaps the best indicators of the internal consistency of the records are the rating curves, which have remained unchanged over the period of record.

Compared with hydrologic records, long-term water quality records for the basin are seriously deficient. Only five stations having adequate records for analysis were available; thus the coverage of the basin is incomplete, especially of the lower Pearl River below Bogalusa. We could not, therefore, document any influence of the extensive lower Pearl River wetlands on water quality. Water quality records showing any local influence of the Jackson and Slidell metropolitan areas were also unavailable. The data records were also fairly short--nutrient data are for the period since 1969. Only turbidity records are longer. Despite these inadequacies, the internal consistency of the data are adequate. For example, total phosphorus (TP) was consistently correlated with turbidity across all stations, turbidity was positively related to flow at three stations, and TP was positively related to flow at the same three stations plus one other. Thus TP and turbidity are closely correlated in their behavior, and this relationship is consistent throughout the data set. This consistency was expected from earlier studies in other areas (Childers and Gosselink 1990; Smith et al. 1982; Wetzel 1975). Since land cover has changed little over the last 60 years, the absolute nutrient concentrations were more valuable in interpreting environmental quality than were the temporal trends. This fact made the lack of long records less important than might have been the case.

As Gosselink et al. (1990) previously found in a similar assessment, long-term biotic data were generally scarce and related to birds. The six stations analyzed varied widely in length of record (most had interrupted coverage, with a total of about 10 years of surveys), but coverage was from all major parts of the basin. Even with the spotty records and rather small recorded changes, analysis of changes in species composition correlated rather well with changes in habitat along the survey routes. Data on current distribution of species, especially threatened and endangered species, provided valuable additional information about the current status of biota in the basin. For the inshore aquatic portions of the study area, no long-term data were available. In the estuarine portion, shrimp and fragmentary crab and finfish records exist, but are of questionable reliability. Each of these data sets has serious drawbacks. For example, the breeding bird surveys are restricted to roads and therefore probably underestimate interior forest species, and the source of shrimp in the catch statistics cannot be reliability known. We backed up analyses of these records with anecdotal information from individuals in Mississippi, Louisiana, and federal environmental agencies, who collectively had many years of field experience throughout the basin.

In summary, although serious gaps in the records limited the detail of the analysis of the Pearl River basin ecosystem, the available records are adequate to provide a useful and generally consistent picture of the basin's ecology.

SUMMARY OF LAND USE, HYDROLOGY, WATER QUALITY, AND BIOTA

Land Cover

Land use in the Pearl River basin has been fairly stable since the 1930s--about two-thirds of the land is forest, and one third is in agricultural production. The basin has one major metropolitan area, Jackson, Mississippi, and is on the edge of a second, Slidell, Louisiana. During the past 15 years agricultural land has decreased slightly and been replaced by forest (Figure 2-5). Pine plantations have expanded at the expense of plowed fields and native mixed deciduous forests. Most of the deciduous and mixed deciduous forest patches are small (<100 ha) (Figures 2-20, 2-21). When grouped, they form large continuous forest areas, two of them greater than 240,000 ha (Figure 2-23). The pine plantations tend to be extensive. Many are 1,000 ha or more, and the largest are about 15,000 ha. These pine plantations are concentrated in the northern part and in the lower basin. Few are found in the large midsection. A major feature of the basin is the extent of bottomland hardwood (BLH) and swamp forest along the Pearl River and its tributaries. This is clearly shown in Figure 2-16, in which all the major streams are clearly delineated because their floodplains are forested by swamps and bottomland hardwood trees. Basinwide, forest borders 65% of the length of streams on both sides. The 44,000-ha BLH/swamp forest of the lower basin is one of the largest relatively undisturbed wetland tracts in the southeast and ranks with the Mobile River and Appalachicola River basins in the east and the extensive Barataria/Atchafalaya basin in the west. These swamp and BLH forest patches are major habitats for a number of threatened and endangered species.

Changes in land cover reflect a population shift from rural areas to cities and major growth in and around Jackson. In addition, the Slidell metropolitan area just west of the lower Pearl River basin is growing rapidly. This growth pattern has two diametrically opposite effects. First, population growth in these two areas locally increases environmental stresses from air and water emissions, direct habitat conversion, and recreational use of forests and streams. This is primarily a local problem. On the other hand, the population concentration in metropolitan areas has resulted in a reduction in the rural population and a shift from agriculture to forestry. Ecologically, this pattern probably is at least partly responsible for the fact that the qualities of water and habitat have remained fairly good, as demonstrated by indices discussed in this report. The industrial growth of the basin since the 1960s depends heavily on timber and agriculture (clothing, lumber, wood, furniture, pulp and papers, and food processing). Therefore, it is in the interest of the urban population as well as the rural to maintain the present flow of goods and services from the land--including timber, agricultural crops, good water quality, ecosystems that minimize flooding, and a healthy biota.

Hydrology

Snagging and clearing the Pearl River for navigation during the late 1800s (Figure 3-11) probably significantly decreased the length of the streambed (removed meanders) and the frequency of overflow onto the adjacent floodplain. However, no stage and discharge records exist for that period. The only major hydrologic projects on the Pearl River in this century have been for navigation in the lower Pearl, construction of the Ross Barnett Reservoir north of Jackson, and small U.S. Soil Conservation Service (SCS) projects to improve drainage in some tributaries (Table 3-1).

Stage and discharge of streams within the basin are controlled primarily by precipitation. Although there are statistically significant trends in mean, variance about the mean, minimum and maximum stage and discharge, the magnitudes of trends are small, and no consistent pattern emerges. The single exception to these generalizations is mean stage, which appears to have decreased in the upper part of the basin. However, this decrease is not reflected in the rating curves (stage vs. discharge), which appear remarkably stable over the past 40-50 years. In general, the river is "well-behaved" and most, if not all, of the fluctuations seen in both stage and discharge can be explained by natural climatic variability.

In 1953 a navigation channel 37.6 km long with three locks parallel to the Pearl River natural channel was completed--the last portion of a project to dredge the Pearl and West Pearl rivers to provide navigation as far north as Bogalusa. This canal system has been inoperative for many years, but in 1989 the USACE was authorized to reopen navigation from the Gulf of Mexico as far as Bogalusa. There is also a navigation channel on the East Pearl River to allow access by barge traffic to the Stennis Space Center, north of Picayune. The effects of these projects on the relative flows between the East and West Pearl rivers, saltwater intrusion into the river, and ecological changes to the large floodplain forest of the lower Pearl River are now hotly contested issues.

Flooding is a local issue, associated with urban growth in the Jackson area. The Ross Barnett Reservoir, north of Jackson, was built for a water supply and for recreation and is ineffective for flood control. Since neither discharge nor the stage-to-discharge relationship of the river has changed in the past 85 years, the increased flood damage is probably due to human encroachment into the floodplain.

Water Quality

In general stream water in the Pearl River basin is of sufficiently high quality to meet standards recommended by EPA to prevent eutrophication (TP is < 0.1 mg l^{-1}; U.S. Environmental Protection Agency 1976). Mean TP, over all stations and periods of record, was about 0.09 mg l^{-1}. Mean nitrogen, as total Kjeldahl nitrogen (TKN), was 0.65 mg l^{-1}. At no stations did TP exceed 0.1 mg l^{-1} more than one-third of the time (Table 4-3). Since 1969 TP concentrations have been stable or declined slightly. At the same time nitrogen has been stable or increased. As a result N-to-P ratios have increased. An explanation of this phenomenon is not clear.

TP was positively correlated with turbidity at all stations. Over the basin as a whole, both turbidity and TP were positively related to discharge, though the slope of the relationship was shallow, and discharge explained only a small fraction (about 8%-19%) of the variability in the dependent variable. A positive slope is evidence of disturbance, but the weakness of the relationship is evidence that the ecosystem is relatively undisturbed (Smith et al. 1982).

Biota

Although overall the bird data are not sufficient to use bird species richness as a blanket indicator of faunal species richness within the basin, the data do suggest that the basin is relatively stable, at least in terms of bird species richness. Species abundance either increased or remained relatively stable in five of the six sites surveyed. Correspondingly, land use also remained relatively stable. For example, forest land cover decreased in only two of the six sites, and then by only approximately 10%, while forested wetland remained stable at all but one site. At each site some species appear to be declining, others to be increasing (Table 5-2). In most cases changes in abundance are associated with changes in the corresponding preferred habitat along the survey routes (Figures 5-2, 5-3, 5-4).

Raptors, as wide-ranging top carnivores, are generally good indicator species for large areas of habitat with healthy food webs. Raptor surveys by the Mississippi Department of Wildlife Conservation (Table 5-5) indicate that populations for which there are sufficient data are stable. Bald eagles are increasing, and no raptor species are known to be decreasing.

Fisheries data from the offshore portion of the study area were extremely limited. Therefore conclusions from them should be used with circumspection. Shrimp catch per unit effort (CPUE) appears to have increased since about 1965, suggesting that either shrimpers are more efficient, or that shrimp are more abundant. At the same time the annual variability in CPUE has increased dramatically. The increase in CPUE is similar to that found coastwide and has been associated with increasing habitat (marsh/water edge) as a result of marsh submergence (Zimmerman, NMFS, Galveston, Tex., pers.comm.). Although the Pearl River basin coastal marshes are among the least disturbed on the Louisiana coast, they still had a 15% loss between 1956 and 1978.

A number of animals found in the basin are listed as threatened or endangered (Table 5-6; Figure 5-9). The major reason for population decline in nongame species is habitat loss. That so many regionally listed species are found in the basin is probably a reflection of the extent of relatively undisturbed habitat. A map of their occurrence in the basin (Figure 5-8) reveals that much of the habitat along and adjacent to the Pearl River is considered critical under the Endangered Species Act.

PEARL RIVER BASIN AS AN INTEGRATED LANDSCAPE

Interaction of Structure and Process

Structure, that is, land cover or land use and its pattern in the landscape, is closely related to the ecological processes in a landscape (Forman and Godron 1986). Hydrology, water quality, and biota all reflect the land use pattern of the landscape and the degree of disturbance of that pattern. As documented for the highly disturbed Tensas Basin (northeastern Louisiana), when a landscape is disturbed by forest clearing or by large-scale flood control or navigation projects, indices of ecological function respond. Forest clearing reduces infiltration by rain and increases runoff. Stream discharge and stage increase and hydrographs are less stable; that is, flood peaks are higher and minimum discharge is smaller (Belt 1975). Flood control or navigation projects change stream rating curves, usually to lower peak stage:discharge, by deepening and straightening channels. Watershed disturbance, especially forest clearing, also generally increases erosion, which leads to increased stream turbidity and elevated nutrient concentrations. Alternative land uses, such as agriculture, increase the loading rate of fertilizers and toxins, further increasing stream nutrient concentrations. Forest loss and fragmentation lead to decreases in the number of forest species and increases in the number of generalist and edge species. Exotic species often invade the disturbed areas.

The four major indices by which we assessed the ecological condition of the Pearl River basin paint a generally consistent picture. About two-thirds of the basin area is forested, and the percentage has remained virtually unchanged since the 1930s. Most of the rest of the basin is in agricultural production. Stability of land use is reflected in stability of hydrographs and rating curves. These have changed little, if at all, over the period of record. Stream hydrology is driven primarily by rainfall, infiltration, and evapotranspiration on the watershed. Water quality, as characterized by TP, is generally within standards suggested by EPA (U.S. Environmental Protection Agency 1976), that is, less than 0.1 mg l^{-1}. This is a reflection of the predominance of watershed forest cover and forest-buffered streams (Omernik 1977). Turbidity and TP were shown to be independent of, or to increase only slightly with, streamflow--further evidence that the watersheds are not seriously disturbed (Hirsch et al. 1982). Finally, bird surveys revealed only small changes in composition over the periods of record at different sites, and these changes were generally related to small local land use changes along the survey transects.

Spatial Pattern of Structure and Process

Structure and process in a landscape are closely related to geography and physiography. The comparison of a drainage basin to a funnel is appropriate for the Pearl River basin. The watershed and small tributaries are like the sides of the funnel; they receive rainwater, collect it, and pass it on to the larger tributaries until it passes through the constricted end of the funnel represented by the lower river and flows out into the adjacent estuaries. The structure, that is the land cover, of the funnel determines the dynamic characteristics of hydrology, water quality, and biota. If rain falls on permeable surfaces such as forested land, infiltration is maximized and surface runoff minimized. The infiltrating water moves slowly downslope as interflow, delaying and reducing peak floods and recharging aquifers. As runoff increases with a linear increase in land disturbance, surface erosion and turbidity often increase exponentially (Murphree et al. 1976; Ursic 1965). Thus, as agricultural land replaces forest, peak discharge and stage increase in receiving streams, and they become flashier. Because interflow decreases, minimum stages also decrease. In the larger streams--the conduits of the system--flow is modified by the surface characteristics of the floodplain. Streams such as these overflow their banks an average of about once every year and a half (Leopold et al. 1964). The size and plant cover of the overflow area determine the peak stage and the steepness of the flood hydrograph. Most of the basin is characterized by forested, rolling hills and relatively coarse sedimentary deposits (USACE 1970). These conditions favor infiltration of rain, slow downslope interflow, and retard discharge into stream beds. Furthermore, the forested floodplain along the major streams, especially the lower Pearl River, slows their discharge rates during floods. The net effect on streamflow is to minimize flood peaks and maintain flows throughout the year. There is a slight tendency for the watersheds of the upper river (the Upper Pearl, Yockanookany, Tuscalameta, and Pelahatchie) to be the most heavily forested, and therefore probably the most effective in minimizing and retarding runoff, but this difference between subbasins is minor. Even the least forested Bogue Chitto River watershed has more than 50% cover, and 70% of the river's border is forested (Figures 6-1, 6-2).

Returning to the analogy of the funnel, three attributes control the water quality of streams in the Pearl River basin: (1) In the collecting watershed, the relatively undisturbed natural cover improves infiltration and minimizes erosion. Forest covers over two-thirds of the watershed surface of the upper basin. Only the two lower sub-basins, the Bogue Chitto and Lower Pearl, and Richland Creek (which contains the large Jackson urban area) have less than two-thirds forest cover. (2) Between the watershed and the collecting stream, forest cover of the riparian zone acts as a filter, catching sediments and nutrients washed from the watershed (Peterjohn and Corell 1984). Except for the Bogue Chitto and Richland Creek sub-basins, at least 85% of the borders of major streams are forested. (3) In the major conduits of the watershed, especially the lower delivery system of the funnel, width of the floodplain, meanders of the river, and forest cover retard flow and filter and transform nutrients (Elder 1985). The Pearl River, at its lower end, meanders through a broad 44,000-ha forested wetland. Below this the river traverses an expanse of herbaceous marsh before it flows out into the coastal estuary. Although no data are available to allow analysis of the influence of this wetland on water quality, many other studies (see summary in Mitsch and Gosselink 1986) indicate that it is probably a net sink for sediments, and a source of organic nutrients.

For animals the river floodplain is a ready source of water. It supports a diverse flora because of its complex elevational and moisture gradients, and contains the faunal richness of an ecotone that includes aquatic, wetland, and upland habitats. As a result, the bottomland and swamp forest river corridors support a dense flora and fauna, and include critical habitats for threatened and endangered species (Figure 5-9). Some of these species are aquatic, living in unpolluted reaches of the stream. Such animals as the Florida panther, which used to occur in the basin, require extensive (>100,000 ha) tracts of unbroken forest cover. For still others, such as the bald eagle, the size of the natural area and the interspersion of different cover types is probably significant. Portions of the river corridor have protected status as parks and wildlife refuges, including about 32,000 ha on the Bogue Chitto and lower Pearl River (Figure 1-8). Elsewhere in the basin protected areas span most of the major habitat types, from piney woods to mixed deciduous forests to offshore marshes and barrier islands. These protected areas form a nucleus for natural resource planning in the basin.

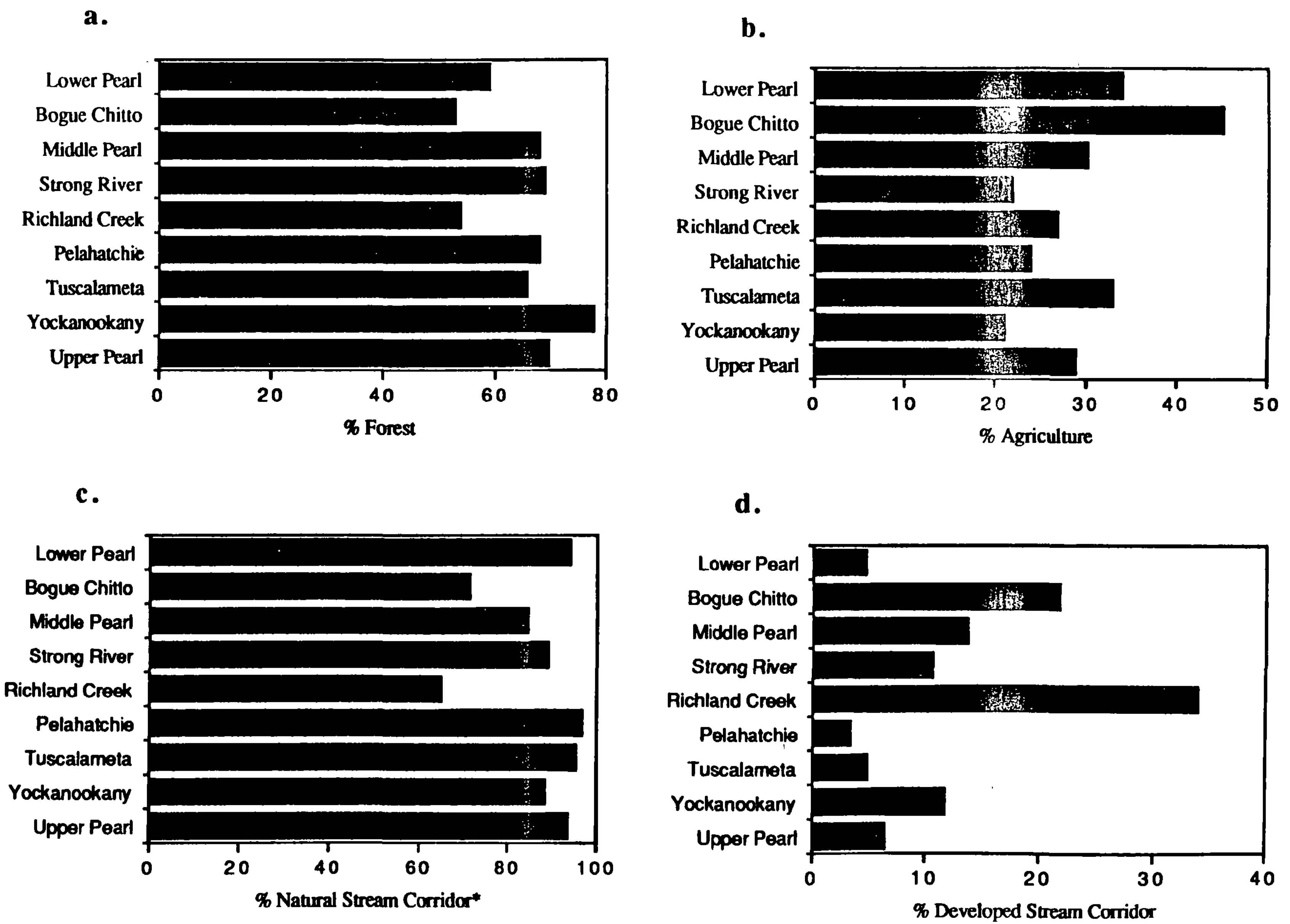

Figure 6-1. Percentage of land cover in Pearl River sub-basins.
*Natural = forest or marsh

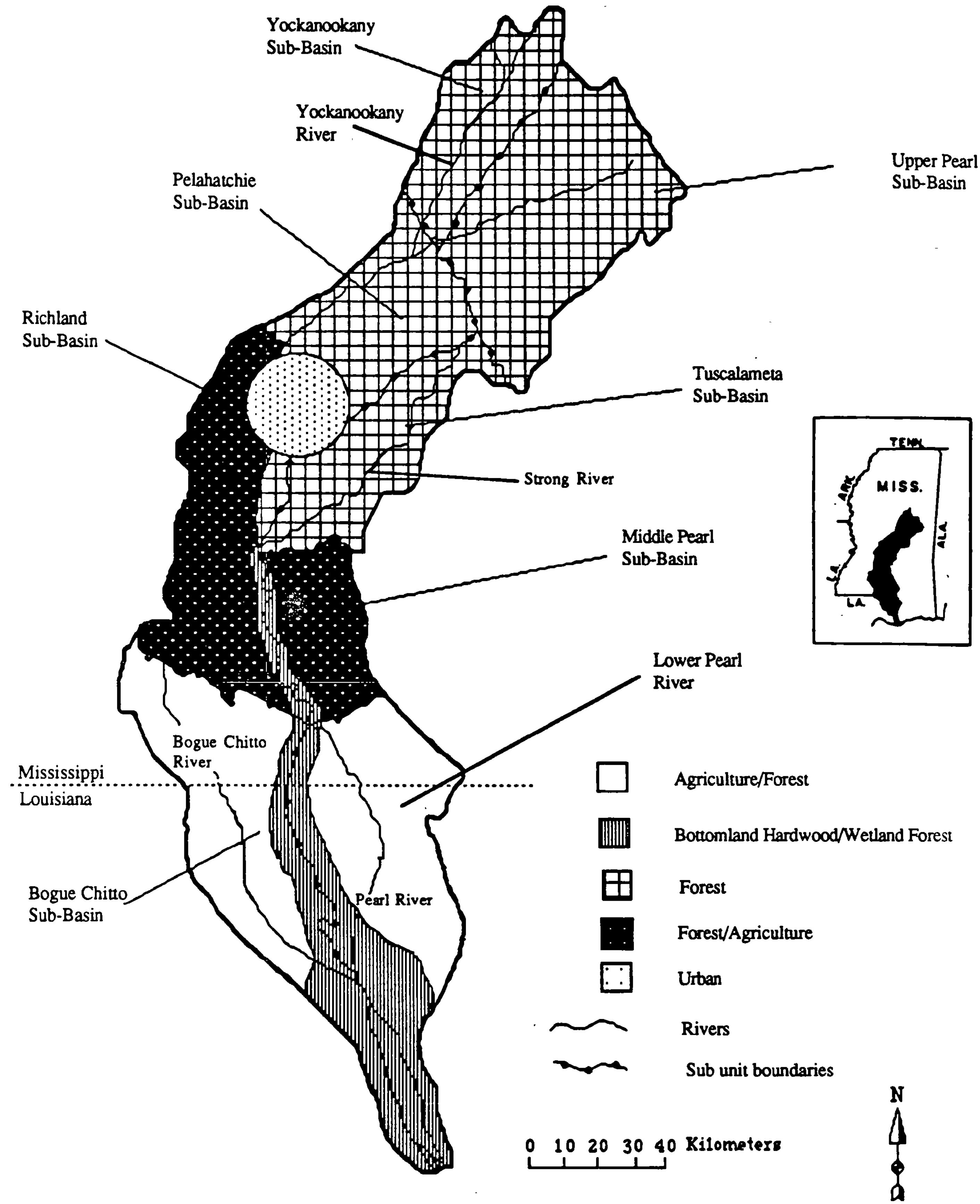

Figure 6-2. Functional subunits of the Pearl River basin.

ONSHORE-OFFSHORE INTERACTIONS

The Influence of the River on the Estuary

The West Pearl River, which carries most of the flow to the coastal estuary, empties into the Rigolets, the tidal pass between Lake Pontchartrain and Lake Borgne. On rising tides the river's flow is carried into Lake Pontchartrain, where it mixes with the brackish water of the lake before flowing Gulfward through the Rigolets and Chef Menteur pass on ebbing tides. On falling tides the flow of the Rigolets carries Pearl River water directly into Lake Borgne and thence into Mississippi Sound. Freshwater flow from the Pearl River averages about 300 cms; the maximum during late winter is about 550 cms, and the minimum during late summer about 150 cms (see Chap. 3). The average flow is about 11% of the total tidal prism and may be as much as 20% during flood conditions. (Fresh water from smaller rivers entering Lake Pontchartrain also freshens the estuary. Their total freshwater discharge is less than one-half of the Pearl River flow.) Isohalines based on 1968 data from the Lousiana Department of Wildlife and Fisheries delineate the river's sphere of influence within the adjacent estuaries (Barrett 1971). Figure 6-3 shows that during high river flow (January) the 10-ppt isohaline is pushed out to the southeastern edge of the coastal marshes. During low flow periods (August), the same isohaline has retreated to enclose a small area in Lake Borgne around the Rigolets and Chef Menteur Pass (Figure 6-4). Salinities in marshes southeast of Lake Borgne are still well below Gulf salinities, indicating some freshwater influence. Thus, the area influenced by the Pearl River varies with season, probably extending out as far as the Chandeleur Islands during winter.

Estimates of nutrient fluxes from the Pearl River were presented in Chapter 4. Since we used water quality data from near Bogalusa, the flux estimates ignore any effects of the swamps and marshes of the lower river. If Elder's (1985) study of the Apalachicola River can be generalized to the Pearl River basin, this extensive wetland area in the mouth of the river may not significantly affect TP and TKN fluxes, but organic forms of these nutrients may be increased at the expense of inorganic forms.

The total annual flux of phosphorus delivered to the estuary by the Pearl River was estimated to be from 500 to > 2,000 MT (Table 6-1). Since the TP concentration varied little with discharge, year-to-year variations were mostly due to changes in rainfall and hence discharge. In terms of a unit of offshore area (i.e., Lake Borgne), as defined for this study, that is equivalent to 3.6 $kg \cdot ha^{-1}$ (0.36 $g \cdot m^{-2}$). Diluted in the volume of Lake Borgne the load is about 1 mg $l^{-1} \cdot yr^{-1}$. To give some perspective, a marsh producing 2,000 $g \cdot m^{-2}$ organic material incorporates about 2 g of phosphorus. Therefore, on average

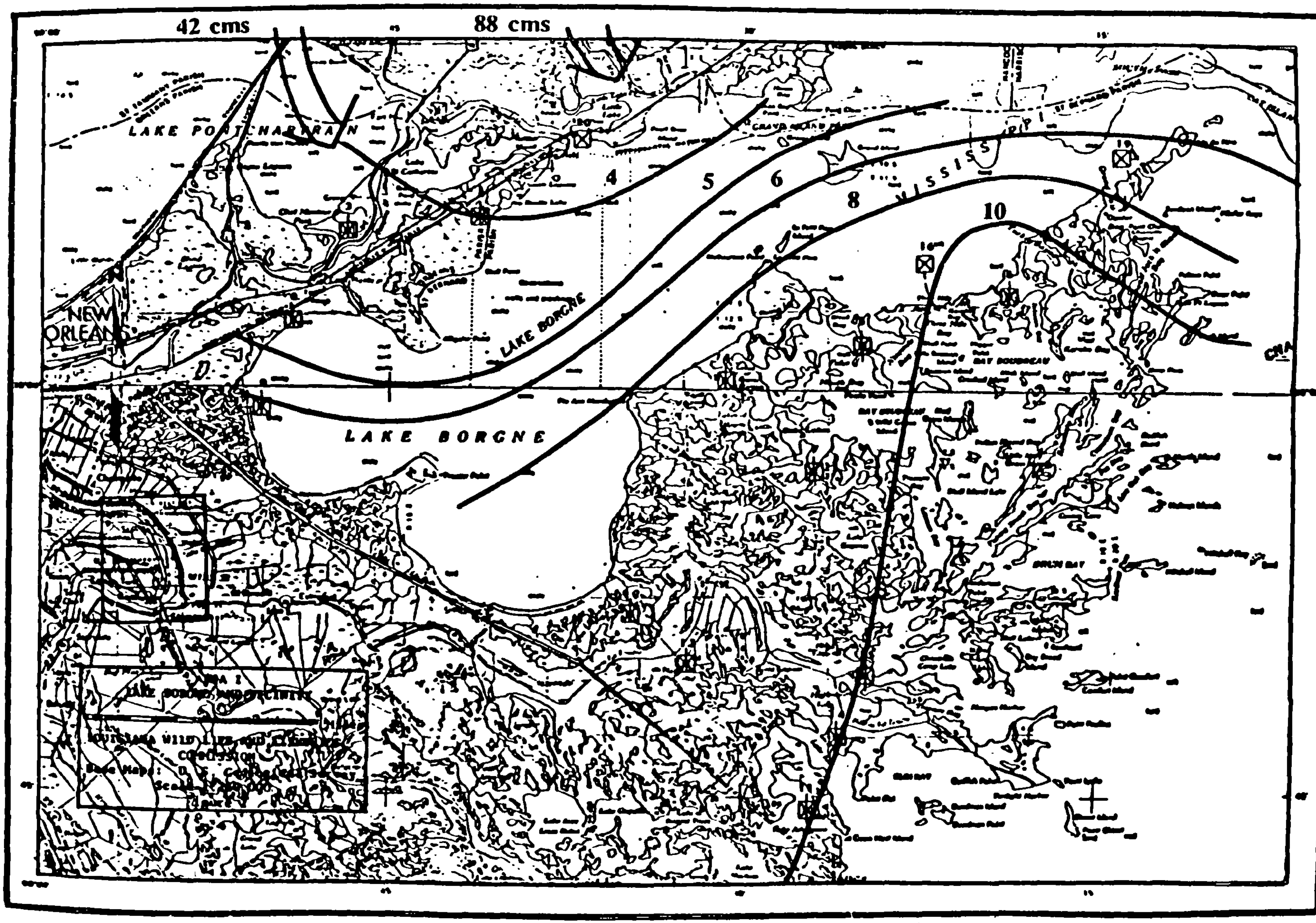

Figure 6-3. Isohaline contours, high river flow, January 1968 (from Barrett 1971).

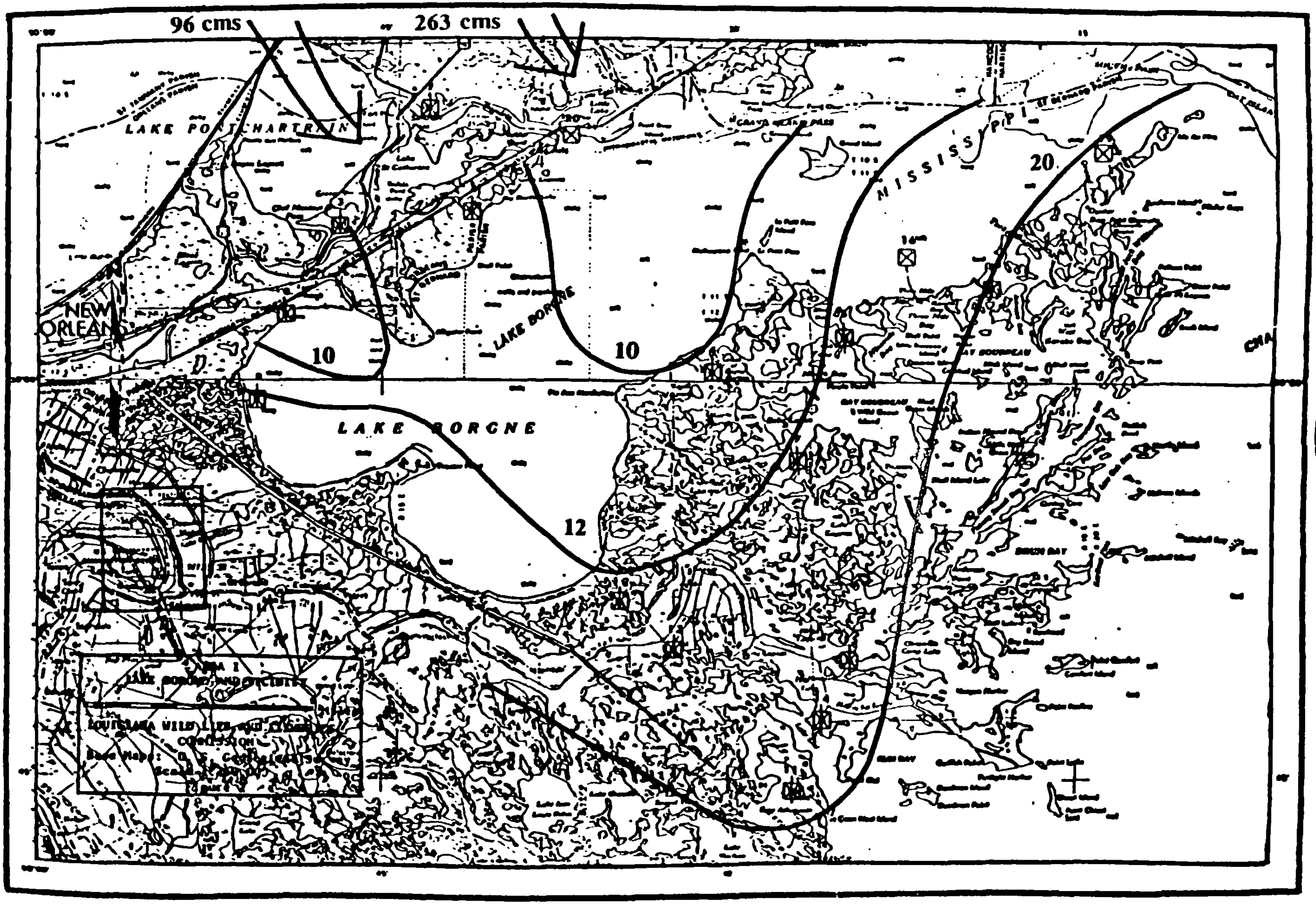

Figure 6-4. Isohaline contours, low river flow, August 1968 (from Barrett 1971).

Table 6-1. Estimated fluxes from the Pearl River to the adjacent estuary.

	Units	Mean	Maximum	Minimum
Hydrology				
Discharge of Pearl River	$m^3 \cdot s^{-1}$	300	550	150
Flow of Pearl River over 25-h cycle	m^3	2.7×10^7	4.95×10^7	1.35×10^7
Replacement time for L. Borgne[a]	days	45	25	90
Salinity: marshes SE of L. Borgne	ppt		20	10
Phosphorus				
TP discharge from Pearl R.	$MT \cdot yr^{-1}$	1,500	2,360	530
TP load to estuary, per unit offshore area[b]	$kg \cdot ha^{-1} \cdot yr^{-1}$	3.6	5.7	1.3
TP load to estuary, per unit volume of L. Borgne	$mg \cdot l^{-1} \cdot yr^{-1}$	1.0		
Nitrogen				
TKN discharge from Pearl R.	$MT \cdot yr^{-1}$	11,510	29,960	2,800
TKN load to estuary, per unit offshore area	$kg \cdot ha^{-1} \cdot yr^{-1}$	28	72	6.7
TKN load to estuary, per unit	$mg \cdot l^{-1} \cdot yr^{-1}$	8.3		
Carbon				
Carbon load to offshore zone, per unit offshore area[c]	$kg \cdot ha^{-1} \cdot yr^{-1}$	420		

[a]1.19×10^9 m^3 volume (Barrett 1970).
[b]414,000 ha.
[c]Assuming C:N ratio of 14 (Hecky and Kilham 1988).

the river may contribute about 15% of the phosphorus needed for organic production. In most marshes the primary nutrient source is recycled organic matter (Mitsch and Gosselink 1986). Riverine sources are probably the major "new" nutrients, and in Lake Borgne the Pearl River is the primary source (except during years when the Bonnet Carré spillway is opened). Examination of seasonal TP concentrations in Lake Borgne and adjacent marshes (Barrett 1971) reveals that TP is inversely related to river flow. That is, TP concentrations are highest in late summer when river flow is lowest. These concentrations probably reflect the net effect of local nutrient recycling, especially mineralization, which is positively correlated with temperature.

Nitrogen is more likely to limit primary production in estuaries than phosphorus. The total annual nitrogen load from the Pearl River to the offshore zone was estimated at 2,800-30,000 MT, or about 28 $kg \cdot ha^{-1} \cdot yr^{-1}$ on a unit area basis (Table 6-1). In terms of the volume of Lake Borgne, the load is about 8 $mg \cdot l^{-1} yr^{-1}$. Again, this is about 15% of the nitrogen needed for primary production. No data are available on total N concentrations in Lake Borgne, but Lake Borgne nitrate concentrations are positively correlated with Pearl River flow. This provides some weak evidence that the flux of nitrogen from the Pearl River may be a significant factor in offshore primary production.

Although, in comparison to the Mississippi River in the west and the Mobile/Tombigbee rivers in the east, discharge of the Pearl River is small, it noticeably influences salinity in Lake Borgne and Mississippi Sound, and probably is the most important nutrient source for the local coastal marshes. These marshes in turn support excellent harvests of shellfish and fish.

Influence of the Estuary on the Pearl River Basin

The reciprocal influence of the estuary on ecological processes in the Pearl River basin is probably not as strong as the outflux from the river to the estuary. However, estuarine waters are known to influence the lower river in two ways: salinity intrusion and fish migration.

Salt water intrudes up the river a maximum distance of 25 km, depending on river stage (Figure 3-9). This intrusion is primarily in the East Pearl River, which receives little freshwater flow. The plant communities of the lower Pearl River swamp and marsh reflect saltwater intrusion, particularly the salt-tolerant marshes at the lower end and the scrub forest north of them, which receive periodic pulses of saline water (White 1983). There is anecdotal evidence of suppression of plant production because of periodic saltwater intrusion but no supporting data.

The lower marshes serve as a nursery for estuarine-dependent fisheries and shell-fisheries. One anadromous species, the Atlantic sturgeon, has been reported 100 km or more up the lower Pearl and the Bogue Chitto rivers (Figure 5-9). This species is on the federal endangered species list.

DEVELOPMENT OF GOALS AND PLANS

This report's ecological characterization of the Pearl River basin was designed to provide the technical information needed to manage the basin as a unified landscape system. In Chapters 1-5 we analyzed available sociological and ecological information. In this chapter we summarized the results of this analysis and combined them into an overall evaluation of the ecological status of the basin. We called attention to strengths in the basin ecosystem and pointed out potential problem areas such as the Jackson urban area.

Management implies the establishment of goals for the basin, based on its present ecological condition, and plans for implementation of those goals. Goal setting is properly a function of the federal, state, and local governing authorities with responsibilities within the basin; local businesses and environmental interests; and individuals who live in the basin (Gosselink and Lee 1989). We cannot, in this report, anticipate their goals, and in the absence of goals, we cannot recommend implementation strategies. However, in the following section we broadly outline a possible scenario to illustrate the process of goal setting and planning. We emphasize that there is no single correct goal (or set of goals) for management of the basin because goals reflect the values of those who manage the resource, as constrained by their understanding of the "health" of the system. For example, most of the basin is forested (64%). It is probably unrealistic to set a goal of 100% forest cover for the basin, but different planning groups might set goals of 75%, 65%, or 35% forest cover, depending on the importance of forests in achieving their management objectives.

We illustrate one set of reasonable goals and implementation strategies for achieving those goals from a five-day workshop on cumulative impact assessment held October 17-21, 1988, in Slidell, Louisiana.[1] Participants in the workshop represented a number of federal and state environmental agencies, commercial interests, and environmental groups. Four groups within the workshop developed goals and plans independently. The goals were in reasonable agreement; implementation strategies differed somewhat, but the main features agreed. Table 6-2 summarizes management goals for the Pearl River basin, and Table 6-3, implementation strategies, as modified from this workshop. These are

[1]Cumulative Impact Assessment in Southeastern Wetland Ecosystems: the Pearl River. October 17-21, 1988, Slidell, La. Sponsored by the U.S. Environmental Protection Agency, Washington, D.C.

presented merely to provide the reader with one approach to goal setting and planning, and the lists represent an example of a reasonable management approach to the basin.

Goals

Compared to other basin landscapes that have been studied, the Pearl River basin is in reasonably good shape ecologically. Therefore the primary mission of the goal-setting exercise was **the ecological protection and enhancement of the Pearl River basin.** That is, we did not envision a major restoration process, but rather the protection of the present renewable resources and their enhancement where feasible. Specific goals listed in Table 6-2 relate to water quality, hydrology, biota, and human development, as appropriate to achieve this overall protection. (1) *Water quality.* Stream water is of generally high quality. Therefore the goal is to improve water quality to meet Clean Water Act (CWA) standards for running waters where those standards are not met and maintain the existing higher standards where they are. (2) *Hydrology.* Hydrology is a key factor in the basin ecosystem. The historical inundation of the floodplain is partly responsible for the high quality of water, forests, and biota. The goals are to restore this historic flooding pattern of the floodplain and to eliminate stream bed degradation due to gravel mining. (3) *Biota.* The goal has two aspects. First, maintainence and restoration of "balanced indigenous populations" of flora and fauna is a goal consonant with the aims of the CWA, which coined the term in quotation marks. The second aspect focuses on protection of wide-ranging animals, the terrestrial bear and the aquatic anadromous fish. Protection of these animals ensures the protection of large, diverse tracts of appropriate habitat, which in turn ensures habitat availability for smaller animals and plants. (4) Finally, since the basin economy is presently based primarily on renewable resources, it is imperative that future economic growth ensure the ability of the basin to provide a continuous supply of these resources. Therefore, this goal is to encourage diversification and development of economic systems that can exist in harmony with the environment.

Implementation Strategies

A major key to implementation of the above-stated goals is protection and enhancement of the ecological *structure* of the basin, including not only the relative proportions of different cover types, but also the pattern of those cover types. Thus the most important strategies for implementing the goals deal with landscape structure (Table 6-3). These strategies are multipurpose in the sense that they often help to implement more

Table 6-2. An example of goals for ecological protection and enhancement of the Pearl River basin.

WATER QUALITY

GOAL 1: Maintain and/or restore excellent water quality in all zones of the wetland continuum

A. Meet minimum water quality standards at least.

B. Non-degradation where standards are already exceeded.

Rationale: Pearl River basin water quality generally is good. Ensure that Clean Water Act goals are met.

HYDROLOGY

GOAL 1: Maximize hydrologic interactions in all zones of the wetland continuum.

GOAL 2: Eliminate stream bed degradation.

Rationale: Pearl River basin has lost stream length, sinuosity, retentiveness. Gravel mining, some channel training has occurred. Goals are to increase retention time, floodplain flooding for wetland, water quality, and aquatic biota.

BIOTA

GOAL 1: Restore balanced indigenous floral and faunal populations in the Pearl River basin where degraded, as indicated by such wide-ranging animals as the black bear and anadramous fish.

Rationale: Pearl River basin supports threatened and endangered species; much management for sport species. Goals focus on developing habitat for balanced indigenous populations, using black bear and anadromous fish as guild leaders.

OTHER

GOAL 1: Encourage economic enterprises that maximize responsible use of non-renewable resources and non-consumptive uses.

Rationale: Aim is to encourage diversification and development of economic systems that can exist in harmony with the environment.

Source: Modified from goals suggested at the workshop "Cumulative Impact Assessment in Southeastern Wetland Ecosystems: the Pearl River." October 17-21, 1988, Slidell, Louisiana. Sponsored by the U.S. Environmental Protection Agency, Washington, D.C.

Table 6-3. Possible strategies to implement Pearl River basin goals outlined in Table 6-2.

Strategy	Goal[a]	Rationale	Tools
Structure (land cover)			
1. Riparian buffers			
a. In low-order streams continuous buffer strips at least 50 m wide/side in hardwood species; never clear-cut.	WQ B	Act as filter strip for upland runoff and as a corridor for biota. Some floodwater storage.	CWA Sec. 404 Conservation Reserve Program Filter strips, Food Security Act
b. In Pearl River maintain bottomland forest in the entire floodplain; manage to maintain cover, ecologically functional forest (e.g., best management practices, mature stands, etc.).	B H_2O WQ	Provide corridor for biota. Increase interaction of water in floodplain. Improve WQ.	Sec.404 Conservation Reserve Program Swamp-buster
2. Limit use of steep slopes (> 10%) for forests. Overall maintain > 65% forest cover.	WQ B	Minimize runoff. Provide large forest patches.	Agreements with Commercial timber interests. CRP-erodible land Hunting leases, education
3. Increase connectivity of large forest patches by acquisition of corridors, especially along streams.	B WQ H_2O	Increase patch size for guild leaders. Improve filter strips.	Acquisition (e.g., TNC) CRP easements Trusts
Water Quality			
1. Stringent enforcement of water quality standards.	WQ		CWA Secs. 401, 402
2. Develop and enforce plans to minimize non-point pollution.	WQ		CWA Sec. 319
Hydrology			
1. Open up dead arms and side channels.	H_2O B	Increase retention time; Improve aquatic habitat diversity.	USACE projects

(Continued)

Table 6-3. (Continued.)

Strategy	Goal	Rationale	Tools
Hydrology (continued)			
2. Eliminate dikes, spoil banks in floodplain.	H_2O	Improve water overflow in floodplain.	USACE projects
3. Revegetate stream banks.	H_2O	Stabilize stream banks.	USACE projects
4. Condition gravel mining permit requests to minimize point bar depletion of coarse material.	H_2O	Minimize stream bed cutting and restore stream stability.	Sec. 404
5. Feasibility study of underwater sill near Pearl River mouth to decrease salinities in lower river.	B	Reduce saltwater intrusion for improved stability of swamp forest.	USACE
6. Eliminate further development in in urban floodplains.	WQ B H_2O	Minimize social damage from floods; minimize floodplain degradation and water pollution.	FEMA
Biota			
1. Full implementation of Endangered Species Act to guarantee no jeopardy to resident threatened and endangered species.	B	Part of strategy to improve habitat for balanced indigenous populations.	ESA
2. No hunting of bears for 30 yr.	B	Bring back bear populations.	Mississippi DNR
3. Study Atlantic sturgeon to identify conditions necessary for continued survival in Pearl River.	B	Strategy to improve habitat for anadromous fish.	

Source: Modified from goals suggested at the workshop "Cumulative Impact Assessment in Southeastern Wetland Ecosystems: the Pearl River." October 17-21, 1988, Slidell, La. Sponsored by the U.S. Environmental Protection Agency, Washington, D.C.

[a]See Goals, Table 6-2. WQ = water quality, B = biota, H_2O = hydrology.

than one functional (water quality, hydrologic, and biotic) objective. The goals addressed are shown in column two of Table 6-3. The table also suggests social mechanisms (tools) to facilitate implementation (last column).

A glance at Figure 5-9 illustrates the importance of the riparian zone for threatened and endangered species. The integrity of the zone is illustrated in Figure 2-15, which clearly shows the forested bottomlands, nearly continuous along all the major basin streams. Structural goals 1a, 1b, and 3 are intended to protect and enhance forested riparian strips along low-order streams and the entire floodplain along higher-order streams. These strips will buffer the streams from excess nutrient and sediment runoff, serve as short-term reservoirs during floods, and improve habitat, especially corridor access to the stream from upland, and between isolated forest patches. CWA Sec. 404 and the swamp-buster provisions of the Food Security Act of 1985 provide regulatory mechanisms to discourage farming in the riparian zone, while the Conservation Reserve Program (also in the Food Security Act) can be used to "rent" wildlife easement from the owner of the land. As with all the structural strategies, acquisition of key land tracts is another, albeit expensive, alternative.

To minimize runoff and erosion, and to provide forest cover for biota, especially interior forest species, overall forest cover should be maintained at about two-thirds of the basin area, and slopes greater than 10% should not be cleared. The two-thirds forest cover target is the present forest cover and is also well above the minimum cover necessary for good water quality (Omernik 1977). Steep slopes are particularly prone to erosion and difficult to replant. Therefore they require special consideration. Regulatory mechanisms to implement this goal are few. Therefore the strategy should be the use of incentives such as the Conservation Reserve Program for highly erodible lands (Food Security Act), agreements with large commercial timber companies, and education of the population on the importance of these measures.

Additional measures can be implemented to deal with more specific problems and to supplement these structural goals. (1) *Water quality*. Existing regulations are sufficient to ensure compliance with the CWA, but strict enforcement is required, in particular strict control of point sources of discharge through NPDES permits and the mandated development of plans to control non-point sources of pollution. (2) *Hydrology*. When the Pearl River channel was snagged in the late 1800s, it was also shortened. Opening up dead side channels and arms would improve retention time and aquatic habitat diversity. Similarly elimination of spoil deposits in the floodplain would restore flooding to the floodplain. Revegetation of stream banks where necessary would reduce erosion. All these goals could be implemented through USACE projects. There are gravel mines on the river. These change local river morphology, deplete coarse materials downstream, and pollute the water. These mines operate on Sec. 404 permits. As the permits come up for renewal, they should be conditioned to lessen the environmental impact of the operation to minimize stream bed cutting and downstream pollution. The questions of the division of water between the East and West Pearl River in the lower reaches and of saltwater intrusion could not be answered in this broad overview of the Pearl River basin. However, the management decisions about these important local problems will have far-reaching implications for the future of the lower Pearl River ecosystem. Therefore, one strategy is to recommend a further, detailed feasibility study of these problems, to be funded by the USACE. Finally, an important goal is to use agreements with the Federal Emergency Management Agency (FEMA) to eliminate further human development in the floodplain. Since the stage-to-discharge relationship of the river appears to be unchanged at Jackson, and since the relationship between precipitation and runoff has not changed, increased damages from periodic local flooding at Jackson appear to be related to human occupancy of the floodplain. These problems should be dealt with at the local level through FEMA. (3) *Biota*. Specific strategies for the protection of biota include full implementation of the Endangered Species Act to safeguard and enhance habitat for a balanced indigenous population and a ban on hunting bears for 30 years to allow populations to rebuild to self-sustaining levels. Finally, a recommended study of the Atlantic sturgeon would identify conditions necessary for its continued survival in the Pearl River. This study should be coordinated with the recommended study of the East and West Pearl so that the hydrologic design of the lower river system will be compatible with the life requirements of the sturgeon.

Clearly, these goals and implementation strategies are not sufficient to provide management answers to the many local, site-specific problems that arise in a land area this size. The purpose of a basin-level management plan is to set the large stage and overall goals to provide a design framework for the long-term management of the basin. Since all the basin interests have subscribed to it, community directions are clear, and much conflict is avoided. When inevitable local conflicts occur and site-specific Sec. 404 permit requests are evaluated, the context of the overall goals gives the regulator a clear vision of the future and a mandate for responsible action.

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APPENDIX A
Statistical Analysis of Stage and Discharge Records

This appendix presents results of the statistical analysis of stage and discharge records from the Pearl River basin. The data come from the U.S. Geological Survey in the form of daily values. These daily values were used to create the monthly and yearly means, variance about the mean, minima, and maxima used in the analysis. The data set was divided into two periods, pre-1971 and 1971-1988, each of which was analyzed separately. In addition, a third series, in which data from the large flood years of 1974, 1979, and 1983 were deleted, was also created and analyzed. This procedure was used to remove the strong precipitation influence on the data. The tables are presented as follows:

Seasonally adjusted ANOVA on entire data set	Tables 1-4
Seasonally adjusted ANOVA on data prior to 1971	Tables 5-8
Seasonally adjusted ANOVA 1971-1988 data	Tables 9-12
Seasonally adjusted ANOVA without 1974, 1979, 1983	Tables 13-16
Regression of annual data on time for entire data set	Tables 1-4
Regression of annual data on time for data prior to 1971	Tables 5-8
Regression of annual data on time for 1971-1988 data	Tables 9-12
Regression of annual data on time without 1974, 1979, 1983	Tables 13-16

Table A-1. Summary statistics from seasonally adjusted ANOVA on monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	0.0197	0.370	3.112	0.0019
02482550	Pearl River @ Carthage	0.1055	0.362	2.718	0.0069
02483000	Tuscalameta Creek @ Walnut Grove	0.0139		3.368	0.0008
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	0.0396	0.347	2.745	0.062
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	0.1210	0.389	2.804	0.0052
02488700	White Sand Creek @ Oak Vale	0.0091	0.269	2.823	0.0051
02489000	Pearl River @ Columbia	-0.177	0.383	-2.278	0.0234
02489500	Pearl River @ Bogalusa	0.228	0.405	3.92	0.0001
02490105	Bogue Lusa Creek @ Highway 439	0.007	0.241	3.22	0.0014
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.004	0.613	-3.749	0.0002
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.004	0.600	-5.018	0.0001
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.002	0.466	-5.15	0.0001
02492000	Bogue Chitto River @ Bush	ND			

Table A-2. Summary statistics from seasonally adjusted ANOVA on variance about the monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	23.267	0.036	2.322	0.0205
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	1.959	0.1076	2.600	0.0096
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	15.172	0.068	2.567	0.0104
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	49.077	0.129	3.720	0.0002
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	70.684	0.136	4.012	0.0001
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	ND			

Table A-3. Summary statistics from seasonally adjusted ANOVA on monthly minimum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data. The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	0.004	0.402	2.133	0.0341
02482550	Pearl River @ Carthage	0.030	0.407	2.678	0.0078
02483000	Tuscalameta Creek @ Walnut Grove	0.001	0.459	2.935	0.0035
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.004	0.9755	9.208	0.0001
02489000	Pearl River @ Columbia	-0.082	0.332	-2.106	0.0360
02489500	Pearl River @ Bogalusa	0.071	0.279	2.193	0.0287
02490105	Bogue Lusa Creek @ Highway 439	0.002	0.354	5.333	0.00001
02490500	Bogue Chitto River @ Tylertown	-0.001		-1.988	0.0473
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.002	0.602	-2.958	0.0035
02483000	Tuscalameta Creek @ Walnut Grove	0.001	0.418	3.498	0.0035
02484500	Yockanookany River @ Ofahoma	-0.003	0.605	-6.975	0.0001
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	0.001	0.134	2.894	0.0049
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.0002	0.161	2.863	0.0047
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.001	0.552	-9.669	0.0001
02492000	Bogue Chitto River @ Bush	ND			

Table A-4. Summary statistics from seasonally adjusted ANOVA on monthly maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	0.0888	0.202	3.254	0.0012
02482550	Pearl River @ Carthage	0.3692	0.195	2.449	0.0149
02483000	Tuscalameta Creek @ Walnut Grove	0.0768	0.233	3.065	0.0023
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	0.1268	0.269	3.614	0.0003
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	0.2995	0.361	0.0002	0.0002
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	-0.3163	0.389	-2.465	0.0142
02489500	Pearl River @ Bogalusa	0.4377	0.374	4.267	0.0001
02490105	Bogue Lusa Creek @ Highway 439	0.039	0.111	2.001	0.0465
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.005	0.508	-2.73	0.0069
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.006	0.498	-3.474	0.0006
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	0.004	0.479	2.298	0.224
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	-0.002	0.225	-2.084	0.0387
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.004	0.300	-2.36	0.0194
02492000	Bogue Chitto River @ Bush	ND			

Table A-5. Summary statistics from seasonally adjusted ANOVA on monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data prior to 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	0.229	0.380	1.984	0.0498
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	0.757	0.469	2.963	0.0035
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	-0.032	0.261	-3.274	0.0012
02492000	Bogue Chitto River @ Bush	-0.031	0.250	-2.038	0.0422

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-6. Summary statistics from seasonally adjusted ANOVA on variance about the monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data prior to 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	125.78	0.1941	2.747	0.0067
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-7. Summary statistics from seasonally adjusted ANOVA on monthly minimum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data prior to 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	0.089	0.416	2.406	0.0179
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	-0.014	0.474	-10.680	0.0001
02492000	Bogue Chitto River @ Bush	-0.015	0.390	-4.292	0.0001

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	-0.009	0.3891	-3.396	0.0010
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-8. Summary statistics from seasonally adjusted ANOVA on monthly maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data prior to 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	1.559	0.467	3.480	0.0007
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-9. Summary statistics from seasonally adjusted ANOVA on monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.004	0.613	-3.749	0.0002
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.004	0.600	-5.018	0.0001
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	-0.004	0.548	-1.966	0.0508
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.002	0.466	-5.151	0.0001
02492000	Bogue Chitto River @ Bush	ND			

Table A-10. Summary statistics from seasonally adjusted ANOVA on variance about the monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Table A-11. Summary statistics from seasonally adjusted ANOVA of monthly minimum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data. Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.001	0.388	1.997	0.047
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	-0.002	0.347	-2.393	0.0178
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.002	0.603	-2.958	0.0035
02483000	Tuscalameta Creek @ Walnut Grove	0.001	0.418	3.498	0.0006
02484500	Yockanookany River @ Ofahoma	-0.003	0.605	8.971	0.0001
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	0.001	0.134	2.894	0.0049
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.0002	0.1608	2.863	0.0097
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.001	0.552	-9.669	0.0001
02492000	Bogue Chitto River @ Bush	ND			

Table A-12. Summary statistics from seasonally adjusted ANOVA of monthly maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	-0.028	0.061	-2.719	0.0263
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.005	0.508	-2.733	0.0069
02483000	Tuscalameta Creek @ Walnut Grove	-0.006	0.499	-3.474	0.0006
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	-0.002	0.224	-2.084	0.0387
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.004	0.300	-236	0.0194
02492000	Bogue Chitto River @ Bush	ND			

Table A-13. Summary statistics from seasonally adjusted ANOVA of monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The years 1974, 1979, 1983 were deleted for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.007	0.268	2.511	0.0128
02489000	Pearl River @ Columbia	-0.161	0.380	-1.940	0.053
	2				
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	0.006	.200	2.567	0.0109
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	-0.004	0.611	-2.743	0.0068
02482550	Pearl River @ Carthage	-0.005	0.629	-4.256	0.0001
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.005			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.002	0.442	-5.150	0.0001
02492000	Bogue Chitto River @ Bush	ND			

Table A-14. Summary statistics from seasonally adjusted ANOVA on variance about the monthly mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The years 1974, 1979, 1983 were deleted for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	22.917	0.125	2.223	0.0266
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	38.431	0.128	2.536	.0115
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	-0.002	0.3048	-2.251	0.0258
02484500	Yockanookany River @ Ofahoma	-0.002	0.2465	-2.222	0.0278
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	ND			

Table A-15. Summary statistics from seasonally adjusted ANOVA on monthly minimum mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data. The years 1974, 1979, 1983 were deleted for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	0.019	0.440	2.015	0.0449
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.004	0.479	9.054	0.0001
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	0.002	0.320	4.614	0.0001
02490500	Bogue Chitto River @ Tylertown	-0.002	0.342	-3.191	0.00151
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.002	0.632	-3.344	0.0010
02483000	Tuscalameta Creek @ Walnut Grove	0.001	0.377	3.494	0.0006
02484500	Yockanookany River @ Ofahoma	-0.003	0.705	=8.813	0.0001
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	0.001	0.161	3.562	0.0002
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	0.0002	0.134	2.055	0.0419
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.001	0.558	-9.306	0.0001
02492000	Bogue Chitto River @ Bush	ND			

Table A-16. Summary statistics from seasonally adjusted ANOVA on monthly maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The years 1974, 1979, 1983 were deleted for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS ·			
02489000	Pearl River @ Columbia	-0.283	0.380	-2.065	0.0392
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.006	0.513	-3.134	0.0021
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.007	0.511	-4042	0.0001
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	-0.002	0.226	-2.424	0.0167
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.005	0.278	-2.737	0.0070
02492000	Bogue Chitto River @ Bush	ND			

Table A-17. Summary statistics from regression analysis of annual mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	0.2730	0.094	6.05	0.0169
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	0.1925	0.130	7.04	0.0109
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	0.5337	0.059	4.40	0.0395
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	1.7906	0.094	4.97	0.0306
02488700	White Sand Creek @ Oak Vale	0.1337	0.209	5.55	0.0314
02489000	Pearl River @ Columbia	-2.4997	0.129	4.01	0.0472
02489500	Pearl River @ Bogalusa	3.1097	0.134	7.13	0.0142
02490105	Bogue Lusa Creek @ Highway 439	0.1031	0.241	6.34	0.0222
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.0441	0.317	6.97	0.0185
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.0190	0.393	7.32	0.0121
02492000	Bogue Chitto River @ Bush	ND			

Table A-18. Summary statistics from regression analysis of variance about the annual mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	82.574	0.073	4.72	0.0338
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	31.287	0.101	5.30	0.0258
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	312.832	0.060	4.48	0.0378
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	1423.65	0.116	6.30	0.0155
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	2384.82	0.159	8.72	0.005
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	-0.0040	0.249	4.64	0.0492
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	ND			

Table A-19. Summary statistics from regression analysis of annual minimum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	0.0072	0.135	6.74	0.0129
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	0.0948	0.087	4.56	0.0378
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	-0.4037	0.257	9.36	0.0050
02489500	Pearl River @ Bogalusa	0.2952	0.120	6.28	0.0158
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.0272	0.301	9.23	0.0083
02483000	Tuscalameta Creek @ Walnut Grove	0.0688	0.264	5.38	0.0349
02484500	Yockanookany River @ Ofahoma	-0.0255	0.363	8.55	0.0105
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.0111	0.346	7.42	0.0169
02492000	Bogue Chitto River @ Bush	ND			

Table A-20. Summary statistics from regression analysis of annual maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . The entire record was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	12.7252	0.107	5.76	0.0203
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	17.9396	0.134	7.12	0.0105
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
024818[illegible]0	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	+0.1561	0.215	6.58	0.0170
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	ND			

Table A-21. Summary statistics from regression analysis of annual mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Pre 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	3.873	.908	5.53	.0466
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	12.007	0.573	16.09	0.0012
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-22. Summary statistics from regression analysis of variance about the annual meandischarge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Pre 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	5200.90	.635	20.87	0.006
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	ND			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-23. Summary statistics from regression analysis of annual minimum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Pre 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	0.011	0.150	4.76	0.0379
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	-0.094	0.288	10.50	0.0033
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-24. Summary statistics from regression analysis of annual maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Pre 1971 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	39.814	0.401	5.36	0.0493
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	69.905	0.492	11.61	0.0052
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	ND			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-25. Summary statistics from regression analysis of annual mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	-0.049	0.3173	6.97	0.0185
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-.0198	0.3433	7.32	0.0171
02492000	Bogue Chitto River @ Bush	NS			

Table A-26. Summary statistics from regression analysis of variance about the annual mean discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	ND			
02482000	Pearl River @ Edinburg	ND			
02482550	Pearl River @ Carthage	ND			
02483000	Tuscalameta Creek @ Walnut Grove	ND			
02484500	Yockanookany River @ Ofahoma	ND			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	ND			
02486000	Pearl River @ Jackson	ND			
02488000	Pearl River @ Rockport	ND			
02488500	Pearl River @ Monticello	ND			
02488700	White Sand Creek @ Oak Vale	-0.0039	0.249	4.64	0.0492
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	ND			
02492000	Bogue Chitto River @ Bush	ND			

Table A-27. Summary statistics from regression analysis of annual minimum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	-0.0272	0.381	9.23	0.0083
02483000	Tuscalameta Creek @ Walnut Grove	0.0688	0.264	5.38	0.0349
02484500	Yockanookany River @ Ofahoma	-0.0255	0.363	8.55	0.0105
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	-0.0111	0.3464	7.42	0.0165
02492000	Bogue Chitto River @ Bush	NS			

Table A-28. Summary statistics from regression analysis of annual maximum discharge and stage as a function of time, for USGS stations in the Pearl River Basin. Indicated are; the station number, a description of the location, the slope (change per month), the R^2 value, the T value and the probability. The R2 is for the entire seasonal model, which includes sine and cosine terms to account for the annual signal. Stations for which the model was not significant at the 95% level are indicated by the symbol ns. The symbol nd indicates no data . Data for 1971-1988 was used for this analysis.

Discharge Data (cubic meters/second)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	NS			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	NS			
02489500	Pearl River @ Bogalusa	NS			
02490105	Bogue Lusa Creek @ Highway 439	NS			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

Stage Data (meters)

Station	Location	Slope	R^2	T	Probability
02481880	Pearl River @ Burnside	NS			
02482000	Pearl River @ Edinburg	NS			
02482550	Pearl River @ Carthage	NS			
02483000	Tuscalameta Creek @ Walnut Grove	NS			
02484500	Yockanookany River @ Ofahoma	NS			
02484630	Pearl River @ Ratcliff	ND			
02585700	Hanging Moss Creek @ Jackson	NS			
02486000	Pearl River @ Jackson	NS			
02488000	Pearl River @ Rockport	NS			
02488500	Pearl River @ Monticello	NS			
02488700	White Sand Creek @ Oak Vale	NS			
02489000	Pearl River @ Columbia	ND			
02489500	Pearl River @ Bogalusa	ND			
02490105	Bogue Lusa Creek @ Highway 439	ND			
02490500	Bogue Chitto River @ Tylertown	NS			
02492000	Bogue Chitto River @ Bush	NS			

APPENDIX B

Breeding Bird Surveys, Pearl River Basin

Table 1. Species, habitat, and regression on time, Breeding Bird Surveys, Pearl River basin

SPECIES		BBS NO.	HABITAT*	REGRESSION # COL	LAC	LAKE	LUC	CYB
Chimney Swift	*Chaetura pelagica*	4230	F	ns	ns	ns	ns	-
Blue Gray Gnatcatcher	*Polioptila caerulea*	7510	F	ns	ns	ns	-	ns
Summer Tanager	*Piranga rubra*	6100	F	ns	+	ns	ns	ns
Broad-Winged Hawk	*Buteo platypterus*	3430	F	ns			ns	
Downy Woodpecker	*Picoides pubescens*	3940	F	ns	-	ns	ns	ns
Hairy Woodpecker	*Picoides villosus*	3930	F	ns		ns		
Carolina Wren	*Thryothorus ludivicianus*	7180	F	ns	ns	ns	ns	ns
Tufted Titmouse	*Parus bicolor*	7310	F	ns	ns	ns	ns	ns
Brown Thrasher	*Toxostoma rufum*	7050	F	ns	ns	ns	ns	ns
Louisiana Waterthrush	*Seiurus motacilla*	6760	F	ns			ns	
American Redstart	*Setophaga ruticilla*	6870	F			ns	ns	ns
Brown-headed Nuthatch	*Sitta pusilla*	7290	F/FCC	ns	ns	ns	ns	ns
Turkey Vulture	*Cathartes aura*	3250	F/FD	+		+	ns	ns
Fish Crow	*Corvus ossifragus*	4900	F/FE	ns	ns		ns	+
Mississippi Kite	*Ictinia mississippiensis*	3290	F/FE	ns		ns	ns	ns
Black Vulture	*Coragyps atratus*	3260	F/FOC	ns		ns	ns	-
Prothonotary Warbler	*Protonotaria citrea*	6370	F/S	-	ns	ns	ns	ns
Yellow Billed Cuckoo	*Coccyzus americanus*	3870	FCC	ns	ns	ns	+	ns
Acadian Flycatcher	*Emoidonax virescens*	4650	FCC	ns	+	ns	ns	
Worm Eating Warbler	*Helmitheros vermivorus*	6390	FCC				ns	
Swainson's Warbler	*Limnothlypis swainsonii*	6380	FCC	ns		ns	ns	
Black & White Warbler	*Mniotilta varia*	6360	FCC				ns	
Red-eyed Vireo	*Vireo olivaceus*	6240	FCC	+	ns	ns	ns	ns
Wood Thrush	*Hylocichla mustelina*	7550	FCC	ns		ns	-	ns
Barred Owl	*Strix varia*	3680	FCC	ns			ns	ns
Chuck-Will's Widow	*Caprimulgus carolinensis*	4160	FCC			ns		
Pileated Woodpecker	*Dryocopus pileatus*	4050	FCC	ns	+	-	ns	ns
Baltimore Oriole	*Icterus galbula*	5070	FCC				ns	
Red Cockaded Woodpecker	*Picoides borealis*	3950	FCC	extinct?				
Northern Bobwhite	*Colinus virginianus*	2890	FD	ns	-	ns	ns	ns

SPECIES		BBS#	HABITAT*	REGRESSION COL	LAC	LAKE	LUC	CYB
Cattle Egret	*Bubulcus ibis*	2001	FD					ns
Green Backed Heron	*Butorides striatus*	2010	FD	ns	ns	ns	ns	ns
Yellow-shafted Flicker	*Colaptes auratus*	4120	FD	ns	-	ns	ns	
Bachman's Sparrow	*Aimophila aestivalis*	5750	FD		ns		ns	
Field Sparrow	*Spizella pusilla*	5630	FD		ns	ns	+	
Northern Rough-winged Swallow	*Stelgidopteryx ruficolllis*	6170	FD	+			ns	ns
Eastern Meadowlark	*Sturnella magna*	5010	FD	-	-	ns	-	+
House Sparrow	*Passer domesticus*	6882	FD	ns		ns	ns	ns
Wild Turkey	*Meleagris gallopavo*	3100	FD/FE	ns				
Blue Grosbeak	*Guiraca caerulea*	5970	FD/FE	ns	ns	ns	ns	ns
Painted Bunting	*Passerina ciris*	6010	FD/FE					
Indigo Bunting	*Passerina cyanea*	5980	FD/FE	ns		ns	+	+
American Crow	*Corvus brachyrhynchos*	4880	FD/FE	-	ns	ns	ns	+
Blue Jay	*Cyanocitta cristata*	4770	FD/FE	ns	ns	ns	ns	+
Barn Swallow	*Hirundo rustica*	6130	FD/FE	+		ns	ns	
Red-winged Blackbird	*Agelaius phoeniceus*	4980	FD/FOC/S	ns	ns	+	ns	+
Killdeer	*Charadrius vociferus*	2730	FD/M	ns		ns		+
Chipping Sparrow	*Spizella passerina*	5600	FE		ns	ns	+	
Yellow-Throated Warbler	*Dendroica dominica*	6630	FE	ns				
Belted Kingfisher	*Ceryle alcyon*	3900	FE	ns	ns	ns	ns	ns
Loggerhead Shrike	*Lanius ludovicianus*	6220	FE	-	ns	ns	ns	ns
Northern Mockingbird	*Mimus polyglottos*	7030	FE	ns	ns	ns	-	ns
Carolina Chickadee	*Parus carolinensis*	7360	FE/F	ns	ns	+	ns	+
Red Shouldered Hawk	*Buteo lineatus*	3390	FE/F	+	ns			
Northern Cardinal	*Cardinalis cardinalis*	5930	FE/FCC/FOC	ns	ns	ns	ns	ns
Mourning Dove	*Zenaida macroura*	3160	FE/FD	ns	-	ns	ns	+
Red-Tailed Hawk	*Buteo jamaicensis*	3370	FE/FD					
Eastern Kingbird	*Tyrannus tyrannus*	4440	FE/FD	-	ns	ns	ns	ns
Eastern Bluebird	*Sialia sialis*	7660	FE/FOC	ns		ns	+	ns
Eastern Wood Pewee	*Contopus virens*	4610	FOC	ns	ns	ns	ns	ns
Great-crested Flycatcher	*Myarchus crinitus*	4520	FOC	-	ns	ns	ns	ns
Ruby-Throated Hummingbird	*Archilochus colubris*	4280	FOC	ns	ns	ns		ns

Pine Warbler	*Dendroica pinus*	6710	FOC	ns	ns	ns	ns	
Kentucky Warbler	*Oporornis formosus*	6770	FOC	-	ns	+	ns	
Northern Parula	*Parula americana*	6480	FOC	ns	+	ns	ns	
Yellow-throated Vireo	*Vireo flavifrons*	6280	FOC	ns	+	ns	ns	ns
				REGRESSION				
SPECIES		**BBS#**	**HABITAT***	**COL**	**LAC**	**LAKE**	**LUC**	**CYB**
White-eyed Vireo	*Vireo griseus*	6310	FOC	ns	ns	ns	ns	
Hooded Warbler	*Wilsonia citrina*	6840	FOC	+	+	ns	ns	ns
Gray Catbird	*Dumetella carolinensis*	7040	FOC			ns	+	
Red-bellied Woodpecker	*Melanerpes carolinus*	4090	FOC	ns	ns	+	ns	ns
Red-Headed Woodpecker	*Melanerpes erythrocephalus*	4060	FOC	ns	ns	ns	ns	
European Starling	*Sturnus vulgaris*	4930	FOC/F/FD	ns	ns	ns	ns	ns
Yellow-breasted chat	*Icteria virens*	6830	FOC/FD	ns	ns	ns	ns	ns
Purple Martin	*Progne subis*	6110	FOC/FD	ns	ns	+	ns	ns
American Robin	*Turdus migratorius*	7610	FOC/FD/FE	ns	ns	+	ns	+
Orchard Oriole	*Icterus spurius*	5060	FOC/FE	-	ns	ns	-	+
Common Nighthawk	*Chordeiles minor*	4200	FOC/FE	ns	-	ns	ns	-
Prairie Warbler	*Dendroica discolor*	6730	FOC/FE	ns	+	ns	ns	
Brown-headed Cowbird	*Molothrus ater*	4950	FOC/FE/FD	ns	ns	+	ns	ns
Common Grackle	*Quiscalus quiscula*	5110	FOC/FE/FD	-	ns	ns	-	ns
Common Yellowthroat	*Geothlypis trichas*	6810	FOC/FE/M	-	+	ns	-	ns
Rufus-sided Towee	*Pipilo erythophthalmus*	5870	FOC/FW	-	ns	ns	ns	ns
Wood Duck	*Aix sponsa*	1440	W	ns	ns	ns		ns
Great Blue Heron	*Ardea herodias*	1940	W	-		ns		ns
Little Blue Heron	*Egretta caerulea*	2000	W	+				ns
White Ibis	*Eudocimus albus*	1840	W	ns				ns
Yellow-Crowned Heron	*Nycticorax violaceus*	2030	W	ns		ns		ns
Great Egret	*Casmerodius albus*	1960	W	ns				ns

* W = water; S = swamps and wet edges; M = marshes; FD = fields; FE = forest edges; F = forest in general; closed canopy (usually interior, stenotopic species); and FOC = forest with an open canopy.

"+"= increasing population, "-" decreasing population.

Table 2. Species, habitat, and regression on time, Christmas Bird Counts, Pearl River basin

SPECIES		HABITAT*	REGRESSION JACKSON#
Brown Creeper	*Certhia americana*	F	-
Tufted Titmouse	*Parus bicolor*	F	ns
Carolina Chickadee	*Parus carolinensis*	F	ns
Ruby-Crowned Kinglet	*Regulus calendula*	F	ns
Golden-crowned Kinglet	*Regulus satrapa*	F	-
Red-breasted Nuthatch	*Sitta canadensis*	F	ns
American Robin	*Turdus migratorus*	F	ns
Bald Eagle	*Haliaeetus leucocephalus*	F	+
Red-bellied Woodpecker	*Melanerpes carolinus*	F	ns
Red Cockaded Woodpecker	*Picoides borealis*	F	extinct?
Downy Woodpecker	*Picoides pubescens*	F	ns
Hairy Woodpecker	*Picoides villosus*	F	-
Yellow-bellied Sapsucker	*Sphyrapicus varius*	F	-
Northern Cardinal	*Cardinalis cardenalis*	F/FD	-
Turkey Vulture	*Cathartes aura*	F/FD	ns
Black Vulture	*Coragyps atratus*	F/FD	ns
Red-wing Blackbird	*Agelaius phoeniceus*	F/FD/S	-
Bewicks Wren	*Thryothorus bewikii*	F/FE	ns
Blue Jay	*Cyanocitta cristata*	F/FE	ns
Northern Flicker	*Colapates auratus*	F/FE	-
Winter Wren	*Troglodytes troglodytes*	F/S	-
Wild Turkey	*Mereagris gallopavo*	FCC	ns
Pine Siskin	*Carduelis pinus*	FCC	ns
Purple Finch	*Carpodacus purpureus*	FCC	ns
Hermit Thrush	*Catharus guttatus*	FCC	ns
Barred Owl	*Strix varia*	FCC	ns
Pileated Woodpecker	*Dryocopus pileatus*	FCC	ns
LeConts Sparrow	*Ammodramus leconti*	FD	ns
Brewers Blackbird	*Euphagus cyanocephalus*	FD	ns
Savannah Sparrow	*Passerculus sandwichensis*	FD	-

Field Sparrow	*Spizella pusilla*	FD	ns
Eastern Meadowlark	*Sturnella magna*	FD	-
			REGRESSION
SPECIES		HABITAT*	JACKSON
Water Pipit	*Anthus spinoletta*	FD	ns
Marsh Wren	*Cistothorus palustris*	FD	ns
Sedge Wren	*Cistothorus platensis*	FD	ns
Palm Warbler	*Dendroica palmarun*	FD	ns
Horned Lark	*Eremophilla alpestris*	FD	+
Canada Goose	*Branta canadensis*	FD	+
Peregrine Falcon	*Falco peregrines*	FD/FE	ns
Least Sandpiper	*Calidris minutilla*	FD/M	ns
Killdeer	*Charadrius vociferus*	FD/M	ns
Common Snipe	*Gallinago gallinago*	FD/M	ns
Sora	*Porzana carolina*	FD/M	ns
King Rail	*Rallus elegans*	FD/M	+
Greater Yellowlegs	*Tringa melanoleuca*	FD/M	ns
Swamp Sparrow	*Melospiza georgiana*	FE	ns
Fox Sparrow	*Passerella iliaca*	FE	-
Vesper Sparrow	*Pooecetes gramineus*	FE	ns
Chipping Sparrow	*Spizella passerina*	FE	ns
European Starling	*Sternus vulgarus*	FE	ns
White-crowned Sparrow	*Zonotrichia leucophrys*	FE	-
Northern Mockingbird	*Mimus polyglottos*	FE	ns
Eastern Bluebird	*Sialia sialis*	FE	+
Sharp-shinned Hawk	*Accipiter striatus*	FE	ns
Great Horned Owl	*Bubo virginianus*	FE	ns
Red-shouldered Hawk	*Buteo lineatus*	FE	+
American Kestrel	*Falco sparverius*	FE	ns
Fish Crow	*Corvus ossifragus*	FE/F	+
American Crow	*Corvus brachyrhynchos*	FE/F	+
Pidgeon (Rock Dove)	*Columba*	FE/FD	ns
Mourning Dove	*Zenaida macrorua*	FE/FD	ns
Northern Bobwhite	*Colinus virginianus*	FE/FD	-

Lincolns Sparrow	*Melospiza lincolnii*	FE/FD	ns
Song Sparrow	*Melospiza melodia*	FE/FD	ns
House Sparrow	*Passer domesticus*	FE/FD	-
Red-tailed Hawk	*Buteo jamaicensis*	FE/FD	ns
			REGRESSION
SPECIES		**HABITAT***	**JACKSON**
Yellow-rump Warbler	*Dendroica coronata*	FE/FOC	+
Cedar Waxwing	*Bombycilla cedrorum*	FOC	+
Western Medowlark	*Sturnella neglecta*	FOC	ns
White-throat Sparrow	*Zonotrichia albicollis*	FOC	-
Loggerhead Shrike	*Lanus ludovicianus*	FOC	ns
White-breasted Nuthatch	*Sitta carolinensis*	FOC	ns
Brown-headed Nuthatch	*Sitta pusilla*	FOC	+
Carolina Wren	*Thryothorus ludivicianus*	FOC	ns
House Wren	*Troglodytes aedon*	FOC	+
Orange-crowned Warbler	*Vermmivora celata*	FOC	ns
Solitary Vireo	*Vireo solitarius*	FOC	ns
Brown Thrasher	*Toxostoma rufum*	FOC	-
Eastern Screech Owl	*Otus asio*	FOC	ns
American Woodcock	*Scolopax minor*	FOC	ns
Red-headed Woodpecker	*Melanerpes erythrocephalus*	FOC	ns
American Goldfinch	*Carduelis tristis*	FOC/FD	-
Dark-eyed Junco	*Junco hyemalis*	FOC/FE	ns
Rufus-sided Towee	*Piplo erythrophthalmus*	FOC/FE	-
Evening Grosbeak	*Spiza americana*	FOC/FE	ns
Common Yellowthroat	*Geothlypis trichas*	FOC/FE	ns
Brown-Headed Cowbird	*Molothrus ater*	FOC/FE/FD	ns
Common Grackle	*Quiscalus quiscula*	FOC/FE/FD	ns
Rusty Blackbird	*Euphagus carolinus*	FOC/S	ns
Sharp-tailed Sparrow	*Ammodramus caudacutus*	M	ns
Seaside Sparrow	*Ammodramus martimus*	M	ns
Marsh Hawk	*Circus cyaneus*	M/FD	ns
Gadwall	*Anas strepera*	S	+
American Widgeon	*Anas americana*	W	ns

Northern Shoveler	*Anas clypeata*	W	ns
Green-winged Teal	*Anas crecca*	W	ns
Blue-winged Teal	*Anas discors*	W	ns
American Black Duck	*Anas rubripes*	W	ns
Great Blue Heron	*Ardea herodias*	W	+
Lesser Scaup	*Aythya affinin*	W	ns

SPECIES		HABITAT*	REGRESSION JACKSON
Redhead	*Aythya americana*	W	ns
Ring-necked duck	*Aythya collaris*	W	ns
Great Scaup	*Aythya marila*	W	ns
Canvasback	*Aythya valisineria*	W	ns
Buffle Head	*Bucephalla albeola*	W	+
Common Goldeneye	*Bucephalla clangula*	W	ns
Great Egret	*Casmerodius albus*	W	+
Snowy Egret	*Egretta thula*	W	ns
Common Loon	*Gavia immer*	W	ns
Herring Gull	*Larus argentatus*	W	ns
Ring-billed Gull	*Larus delawarensis*	W	ns
Bonapartes Gull	*Larus philidelphia*	W	ns
Franklin's Gull	*Larus pipixcan*	W	+
Red-breasted Merganser	*Mergus serrator*	W	ns
Ruddy Duck	*Oxura jamaicensis*	W	ns
Great Comorant	*Phalacrocorax*	W	ns
Horned Grebe	*Podiceps auritus*	W	ns
Pied-billed Grebe	*Podilymbus podiceps*	W	ns
Forsters Tern	*Sterna forsteri*	W	ns
Common Tern	*Sterna herundo*	W	ns
Snow Goose		W	ns
Wood Duck	*Anas clypeata*	W/F	ns
Mallard	*Anas platrhynchos*	W/F	ns
Hooded Merganser	*Lophodytes cucllatus*	W/F	+
Cattle Egret	*Bubulcus ibis*	W/FD	ns
American Coot	*Flucia americana*	W/FD	ns

Eastern Phoebe	*Sayornis phoebe*	W/FE	ns
Belted Kingfisher	*Ceryle alycon*	W/FE	ns
Double-crested Comorant	*Phalacrocorax auritus*	W/S	+

* W = water; S = swamps and wet edges; M = marshes; FD = fields; FE = forest edges; F = forest in general; FCC = forest with closed canopy (usually interior, stenotopic species); and FOC = forest with an open canopy.

"+"= increasing population, "-"= decreasing population.

APPENDIX C

Land Cover Classification Of Christmas Bird Count And Breeding Bird Survey Sites In The Pearl River Basin

Table 1. Temporal change in land cover of Christmas Bird Count and Breeding Bird Survey sites, Pearl River basin .

Site	Land cover	1973		1987	
		ha	%	ha	%
Jackson	agriculture/grassland	12332	30	8600	21
	coniferous forest	8069	20	7221	18
	mixed forest	3725	9	4225	10
	deciduous forest	1775	4	5819	14
	bottomland hardwood forest	2725	7	3100	8
	forested wetland	649	2	624	2
	water	9987	24	10169	25
	barren/other	337	1	193	0
	nonforested wetland	381	1	0	0
	urban area	1306	3	1318	3
Lake	agriculture/grassland	1300	38	1363	40
	coniferous forest	944	27	984	29
	mixed forest	522	15	295	9
	deciduous forest	6	0	307	9
	bottomland hardwood forest	45	1	161	5
	forested wetland	283	8	42	1
	water	59	2	6	0
	barren/other	8	0	0	0
	nonforested wetland	0	0	0	0
	urban area	260	8	276	8
Cybur	agriculture/grassland	1828	52	2446	70
	coniferous forest	698	20	862	25
	mixed forest	417	12	73	2
	deciduous forest	92	3	0	0
	bottomland hardwood forest	386	11	25	1
	forested wetland	0	0	20	1
	water	61	2	6	0
	barren/other	0	0	55	2
	nonforested wetland	0	0	1	0
	urban area	6	0	0	0
Lacombe	agriculture/grassland	391	12	586	17
	coniferous forest	2772	82	2064	61
	mixed forest	38	1	432	13
	deciduous forest	6	0	2	0
	bottomland hardwood forest	107	3	0	0
	forested wetland	28	1	231	7
	water	0	0	2	0
	barren/other	0	0	24	1
	nonforested wetland	0	0	0	0
	urban area	38	1	37	1

Site	Land cover	1973		1987	
		ac	%	ac	%
Columbia	agriculture/grassland	1160	33	1066	31
	coniferous forest	423	12	1023	29
	mixed forest	1405	40	524	15
	deciduous forest	0	0	398	11
	bottomland hardwood forest	372	11	400	12
	forested wetland	48	1	6	0
	water	46	1	23	1
	barren/other	4	0	37	1
	nonforested wetland	2	0	0	0
	urban area	18	1	0	0
Lucien	agriculture/grassland	1285	38	1116	33
	coniferous forest	755	22	927	27
	mixed forest	748	22	745	22
	deciduous forest	151	4	146	4
	bottomland hardwood forest	370	11	421	12
	forested wetland	0	0	0	0
	water	54	2	10	0
	barren/other	3	0	1	0
	nonforested wetland	0	0	0	0
	urban area	47	1	47	1

[1] Land cover was digitized 1/4 mile on either side of each 40-km Breeding Bird Survey Route, and within a 24-kilometer diameter circle of the Christmas Bird Count Jackson Site.

APPENDIX D

Species List Of The Pearl River Basin

MAMMALS

CASTORIDAE	
American Beaver	*Castor canadensis*
CRICETIDAE	
Marsh Rice Rat	*Oryzomys palustris*
Eastern Harvest Mouse	*Reithrodontomys humulis*
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*
White-footed Mouse	*Peromuscus leucopus*
Cotton Mouse	*Peromyscus gossypinus*
Golden Mouse	*Ochrotomys nuttalli*
Hispid Cotton Mouse	*Sigmodon hispidus*
Eastern Wood Rat	*Neotoma floridana*
Pine Vole	*Pitymys pinetorom*
Muskrat	*Ondatra zibethicus*
MURIDAE	
Black Rat	*Rattus rattus*
Norway Rat	*Rattus norvegicus*
House Mouse	*Mus musculus*
CAPROMYIDAE	
Nutria	*Myocastor coypus*
CANIDAE	
Coyote	*Canis latrans*
Red Wolf	*Canis rufus*
Red Fox	*Vulpes fulva*
Gray Fox	*Urocyon cinereoargenteus*
URSIDAE	
American Black Bear	*Ursus americanus*
PROCYONIDAE	
Raccoon	*Procyon lotor*
MUSTELIDAE	
Long-tailed Weasel	*Mustela frenata*
Mink	*Mustela vison*
Spotted Skunk	*Spilogale putorius*
Striped Skunk	*Mephitis mephitis*
River Otter	*Lutra canadensis*
FELIDAE	
Florida panther	*Felis concolor coryi*
Bobcat	*Lynx rufus*
CERVIDAE	
White-tailed Deer	*Odocoileus virginianus*

GAVIIDAE	
Common Loon	*Gavia immer*
PODICIPEDIDAE	
Horned Grebe	*Podiceps auritus*
Eared Grebe	*Podiceps migricollis*
Pied-billed Grebe	*Podilymbus podiceps*
PELECANIDAE	
White Pelecan	*Pelecanus erythrorhynchos*
Brown Pelecan	*Pelecanus occidentalis*
SULIDAE	
Gannet	*Morus bassanus*
PHALACROCORACIDAE	
Double-crested Cormorant	*Phalacrocorax auritus*
ANHINGIDAE	
Anhinga	*Anhinga anhinga*
FREGATIDAE	
Magnificient Frigatebird	*Fregata magnificens*
ARDEIDAE	
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Little Blue Heron	*Florida caerulea*
Cattle Egret	*Bubulcus ibis*
Reddish Egret	*Dichromanassa rufescens*
Great Egret	*Casmerodius albus*
Snowy Egret	*Egretta thula*
Louisiana Heron	*Hydranassa tricolor*
Black-crowned Night Heron	*Nyctiocorax nyctiocorax*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Least Bittern	*Ixobrychus exilis*
American Bittern	*Botaurus lentiginosus*
CICONIIDAE	
Wood Stork	*Mycteria americana*
THRESKIORNITHIDAE	
Glossy Ibis	*Plegadis Falcinellus*
White-faced Ibis	*Plegadis chihi*
White Ibis	*Eudocimus albus*
ANATIDAE	
Whistling Swan	*Olor collumbianus*
Canada Goose	*Branta canadensis*
White-fronted Goose	*Anser albifrons*
Snow Goose	*Chen caerilescens*

Fulvous Whistling-Duck	*Dendrocygna bicolor*
Mallard	*Anas platyrynchos*
Black Duck	*Anas rubripes*
Mottled Duck	*Anas fulvigula*
Gadwall	*Anas strepera*
Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Blue-winged Teal	*Anas discors*
American Widgeon	*Anas americana*
Northern Shoveler	*Anas clypeata*
Wood Duck	*Aix sponsa*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Canvasback	*Aythya valisineria*
Greater Scaup	*Aythya marila*
Lesser Scaup	*Aythya affinsis*
Common Goldeneye	*Bucephala clangula*
Buffelhead	*Bucephala albeola*
Oldsquaw	*Clangula hyemalis*
White-winged Scoter	*Melanitta deglandi*
Surf Scoter	*Melanitta perspicillata*
Black Scoter	*Melanitta nigra*
Ruddy Duck	*Oxyura jamaicensis*
Hodded Merganser	*Lophodytes cucullatus*
Common Merganser	*Mergus merganser*
Red-breasted Merganser	*Mergus serrator*
CATHARTIDAE	
Turkey Vulture	*Cathartes aura*
Black Vulture	*Coragyps atratus*
ACCIPITRIDAE	
Swallow-tailed Kite	*Elanoides foroicatus*
Mississippi Kite	*Ictinia mississippiensis*
Sharp-shinned Hawk	*Accipiter striatus*
Coopers Hawk	*Accipiter cooperi*
Red-tailed Hawk	*Buteo jamaicensis*
Red-shouldered Hawk	*Buteo lineatus*
Broad-winged Hawk	*Buteo platypterus*
Harris' Hawk	*Parabuteo unicinctus*
Golden Eagle	*Aquila chrysaetos*
Bald Eagle	*Haliaeetus lucocephalus*
Marsh Hawk	*Circus cyaneus*
PANDIONIDAE	
Osprey	*Pandion haliaetus*
FALCONIDAE	
Arctic Peregrine Falcon	*Falco peregrinus tundrius*
Merlin	*Falco columbarius*
American Kestrel	*Falco sparverius*

PHASIANIDAE

Bobwhite	*Colinus virginianus*

MELEAGRIDIDAE

Turkey	*Meleagris gallopavo*

GRUIDAE

Sandhill Crane	*Grus canadensis*

RALLIDAE

King Rail	*Rallus elegans*
Clapper Rail	*Rallus longirostris*
Virginia Rail	*Rallus limnicola*
Sora	*Porzana carolina*
Yellow Rail	*Coturnicops noveboracensis*
Black Rail	*Laterallus jamaicensis*
Purple Gallinule	*Porphyrula martinica*
Common Gallinule	*Gallinula chloropus*
American Coot	*Fuluca american*

CHARADRIIDAE

Semipalmated Plover	*Charadrius semipalmatus*
Piping Plover	*Charadrius melodus*
Snowy Plover	*Charadrius alexandrinus*
Wilson's Plover	*Charadrius wilsonia*
Killdeer	*Charadrius vociferus*
American Golden Plover	*Pluvialus dominica*
Black-bellied Plover	*Pluvialus squatarola*

SCOLOPACIDAE

Ruddy Turnstone	*Arenaria interpres*
American Woodcock	*Philohela minor*
Commor Snipe	*Capella gallinago*
Whimbrel	*Numenius phaeopus*
Upland Sandpiper	*Bartramia longicauda*
Spotted Sandpiper	*Actitis macularia*
Solitary Sandpiper	*Tringa solitaria*
Greater Yellowlegs	*Tringa melanoleucas*
Lesser Yellowlegs	*Tringa flavipes*
Willet	*Catoptrophorus semipalmatus*
Red Knot	*Calidris canutus*
Pectoral Sandpiper	*Calidris melanotos*
White-rumped Sandpiper	*Canidris fuscicollis*
Least Sandpiper	*Calidris minutilla*
Dunlin	*Calidris alpina*
Semipalmated Sandpiper	*Calidris pusillus*
Western Sandpiper	*Calidris mauri*
Sanderling	*Calidris alba*
Short-billed Dowitcher	*Limnodromus griseus*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Stilt Sandpiper	*Micropalama himantopus*
Buff-breasted Sandpiper	*Tryngites subruficollis*

Marbled Godwit	*Limosa fedoa*
Hudsonian Godwit	*Limosa haemastica*
RECURVIROSTRIDAE	
American Avocet	*Recurvirostra americana*
Black-necked Stilt	*Himantopus mexicanus*
PHALAROPODIDAE	
Wilson's Phalarope	*Steganopus tricolor*
Northern Phalarope	*Lobipes lobatus*
LARIDAE	
Herring Gull	*Larus argentatus*
Ring-billed Gull	*Larus delawarensis*
Laughing Gull	*Larus atricilla*
Bonaparte's Gull	*Larus philadelphia*
Black-legged Kittiwake	*Rissa tridactyla*
Gull-billed Tern	*Gelochelidon nilotica*
Forester's Tern	*Sterna forsteri*
Common Tern	*Sterna hirundo*
Sooty Tern	*Sterna fuscata*
Least Tern	*Sterna albifrons*
Royal Tern	*Sterna maximus*
Sandwich Tern	*Sterna sandvicensis*
Caspian Tern	*Sterna caspia*
Black Tern	*Chlidonias niger*
RYNCHOPIDAE	
Black Skimmer	*Rynchops niger*
COLUMBIDAE	
Rock Dove	*Columba livia*
White-winged Dove	*Zenaida asiatica*
Mourning Dove	*Zenaida macroura*
Ground Dove	*Columbina passerina*
CUCULIDAE	
Yellow-billed Cuckoo	*Coccyzus americanus*
Black-billed Cuckoo	*Coccyzus erythropthalmus*
Groove-billed Ani	*Crotophaga sulcirostris*
TYTONIDAE	
Barn Owl	*Tyto alba*
STRIGIDAE	
Screech Owl	*Otus asio*
Great Horned Owl	*Bubo virginianus*
Burrowing Owl	*Athene cunicularia*
Barred Owl	*Strix varia*
Long-eared Owl	*Asio otus*
Short-eared Owl	*Asio flammeus*
Saw-whet Owl	*Aegolius acadicus*
CAPRIMULGIDAE	

Chuck-wills-widow	*Caprimulgus carolinensis*
Whip-poor-will	*Caprimulgus vociferus*
Common Nighthawk	*Chordeiles minor*
APODIDAE	
Chimney Swift	*Chaetura pelagica*
TROCHILIDAE	
Ruby-throated Hummingbird	*Archilochus colubris*
ALCEDINIDAE	
Belted Kingfisher	*Megaceryle alcyon*
PICIDAE	
Common Flicker	*Colaptes auratus*
Pileated Woodpecker	*Dryocopus pileatus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Red-headed Woodpecker	*Melaneroes erythrocephalus*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Hairy Woodpecker	*Picoides villosus*
Downy Woodpecker	*Picoides pubescens*
Red-cockaded Woodpecker	*Picoides borealis*
Ivory-billed Woodpecker*	*Campephilus principalis*
TYRANNIDAE	
Eastern Kingbird	*Tyrannus tyrannus*
Western Kingbird	*Tyrannus verticalis*
Scissor-tailed Flycatcher	*Muscivora forficata*
Great-crested Flycatcher	*Myiarchus crinitus*
Eastern Phoebe	*Sayornis phoebe*
Say's Phoebe	*Sayornis saya*
Acadian Flycatcher	*Empidonax virescens*
Eastern Wood Pewee	*Contopus virens*
Olive-sided Flycatcher	*Nuttallornis borealis*
Vermilion Flycatcher	*Pyrocephalus rubinus*
ALAUDIDAE	
Horned Lark	*Eremophila alpestris*

*No verified reports but basin is within historical range of species.

HIRUNDINIDAE	
Tree Swallow	*Tridoprocne bicolor*
Bank Swallow	*Riparia riparia*
Rough-winged Swallow	*Stelgidopteryx ruficollis*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Petrochelidon pyrrhonota*
Purple Martin	*Progne subis*
CORVIDAE	
Blue Jay	*Cyanocitta cristata*
Common Crow	*Corvus brachyrhynchos*
Fish Crow	*Corvus ossifragus*

PARIDAE

Carolina Chickadee	*Parus carolinensis*
Tufted Titmouse	*Parus bicolor*

SITTIDAE

White-breasted Nuthatch	*Sitta carolinensis*
Red-breasted Nuthatch	*Sitta canadensis*
Brown-headed Nuthatch	*Sitta pusilla*

CERTHIIDAE

Brown Creeper	*Certhia familiaris*

TROGLODYTIDAE

House Wren	*Troglodytes aedon*
Winter Wren	*Troglodytes troglodytes*
Bewick's Wren	*Thryomanes bewickii*
Carolina Wren	*Thryothorus ludovicianus*
Long-billed Marsh Wren	*Cistothorus palustris*
Short-billed Marsh Wren	*Cistothorus platensis*

MIMIDAE

Mockingbird	*Mimus polyglottos*
Gray Catbird	*Dumetella carolinesis*
Brown Thrasher	*Toxostoma rufum*

TURDIDAE

American Robin	*Turdus migratorius*
Wood Thrush	*Hylocichla mustelina*
Hermit Thrush	*Catharus guttata*
Swainson's Thrush	*Catharus ustulatus*
Gray-cheeked Thrush	*Catharus minima*
Veery	*Catharus fuscescens*
Eastern Bluebird	*Sialia sialis*

SYLVIIDAE

Blue-gray Gnatchatcher	*Polioptila caerulea*
Golden-crowned Kinglet	*Regulus satrapa*
Ruby-crowned Kinglet	*Regulus calendula*

MOTACILLIDAE

Water Pipit	*Anthus spinoletta*
Sprague's Pipit	*Anthus spragueii*

BOMBYCILLIDAE

Cedar Waxwing	*Bombycilla cedorum*

LANIIDAE

Loggerhead Shrike	*Lanius ludovicianus*

STURNIDAE

Starling	*Sturnus vulgaris*

VIREONIDAE

White-eyed Vireo	*Vireo griseus*
Bell's Vireo	*Vireo bellii*
Yellow-throated Vireo	*Vireo flavifrons*
Solitary Vireo	*Vireo solitarius*
Red-eyed Vireo	*Vireo olivaceus*
Philadelphia Vireo	*Vireo philadelphicus*
Warbling Vireo	*Vireo gilvus*

PARULIDAE

Black-and-white Warbler	*Mniotilta varia*
Prothonotary Warbler	*Protonotaria citrea*
Swainson's Warbler	*Limnothlypis swainsonii*
Worm-eating Warbler	*Helmitheros vermivorus*
Golden-winged Warbler	*Vermivora chrysoptera*
Blue-winged Warbler	*Vermivora pinus*
Bachman's Warbler*	*Vermivora bachmanii*
Tenessee Warbler	*Vermivora peregrina*
Orange-crowned Warbler	*Vermivora celata*
Nashville Warbler	*Vermivora ruficapilla*
Northern Parula	*Parula americana*
Yellow Warbler	*Dendroica petechia*
Magnolia Warbler	*Dendroica magnolia*
Cape May Warbler	*Dendroica tigrina*
Black-throated Blue Warbler	*Dendroica caerulescens*
Yellow-rumped Warbler	*Dendroica coronata*
Black-throated Green Warbler	*Dendroica virens*
Cerulean Warbler	*Dendroica cerulea*
Blackburnian Warbler	*Dendroica fusca*
Yellow-throated Warbler	*Dendroica dominica*
Chestnut-sided Warbler	*Dendroica pensylvanica*
Bay-breasted Warbler	*Dendroica castanea*
Blackpoll Warbler	*Dendroica striata*
Pine Warbler	*Dendroica pinus*
Kirtland's Warbler	*Dendroica kirtlandii*
Prairie Warbler	*Dendroica discolor*
Palm Warbler	*Dendroica palmarum*
Overbird	*Seiurus aurocapillus*
Northern Waterthrush	*Seiurus noveboracensis*
Louisiana Waterthrush	*Seiurus motacilla*
Kentucky Warbler	*Oporornis formusus*
Connecticut Warbler	*Oporornis agilis*
Mourning Warbler	*Oporornis philadelphia*
Common Yellowthroat	*Geothlypis trichas*
Yellow-breasted Chat	*Icteria virens*
Hooded Warbler	*Wilsonia citrina*
Wilson's Warbler	*Wilsonia pusilla*
Canada Warbler	*Wilsonia canadensis*
American Redstart	*Setophaga ruticilla*

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PLOCEIDAE

House Sparrow	*Passer domesticus*

ICTERIDAE

Bobolink	*Dolichonyz oryzivorus*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
Red-winged Blackbird	*Agelaius phoeniceus*
Orchard Oriole	*Icterus spurius*
Northern Oriole	*Icterus galbula*
Rusty Blackbird	*Euphagus carolinus*
Brewer's Blackbird	*Euphagus cyanocephalus*
Boat-tailed Grackle	*Quiscalus mexicanus*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*

THRAUPIDAE

Western Tanager	*Piranga ludoviciana*
Scarlet Tanager	*Piranga olivacea*
Summer Tanager	*Piranga rubra*

FRINGILLIDAE

Cardinal	*Cardinalis cardinalis*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Blue Grosbeak	*Guiraca caerulea*
Indigo Bunting	*Passerina cyanea*
Painted Bunting	*Passerina ciris*
Dickcissel	*Spiza americana*
Evening Grosbeak	*Hesperiphona vespertina*
Purple Finch	*Carpodacus purpureus*
Pine Siskin	*Carduelis spinus*
American Goldfinch	*Carduelis tristis*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Lark Bunting	*Calamospiza melanocorys*
Savannah Sparrow	*Passerculus sandwichensis*
Grasshopper Sparrow	*Ammodramus savannarum*
Sharp-tailed Sparrow	*Ammospiza caudacuta*
Seaside Sparrow	*Ammospiza maritima*
Vesper Sparrow	*Pooecetes gramineus*
Lark Sparrow	*Chondestes grammacus*
Bachman's Sparrow	*Aimophila aestivalis*
Dark-eyed Junco	*Junco hyemalis*
Chipping Sparrow	*Spizella passerina*
Clay-colored Sparrow	*Spizella pallida*
Field Sparrow	*Spizella pusilla*
Harris' Sparrow	*Zonotrichia querula*
White-crowned Sparrow	*Zonotrichia leucophrys*
White-throated Sparrow	*Zonotrichia albicollis*
Fox Sparrow	*Passerella iliaca*
Lincoln's Sparrow	*Melospiza lincolnii*
Swamp Sparrow	*Melospiza georgiana*
Song Sparrow	*Melospiza melodia*
Lapland Longspur	*Calcarius lapponicus*

REPTILES

ALLIGATORIDAE	
American Alligator	*Alligator mississippiensis*
CHELYDRIDAE	
Snapping Turtle	*Chelydra serpentina*
Alligator Snapping Turtle	*Macroclemys temmincki*
KINOSTERNIDAE	
Common Musk Turtle	*Sternotherus odoratus*
Stripe-necked Musk Turtle	*Sternotherus minor peltifer*
Razor-backed Musk Turtle	*Sternotherus carinatus*
Eastern Mud Turtle	*Kinosternon subrubrum subrubrum*
Mississippi Mud Turtle	*Kinosternon subrubrum hippocrepis*
EMYDIDAE	
Alabama Map Turtle	*Graptemys pulchra*
Mississippi Map Turtle	*Graptemys kohni*
Ringed Sawback	*Graptemys oculifera*
Mississippi Diamondback Terrapin	*Malaclemys terrapin pileata*
Southern Painted Turtle	*Chrysemys picta dorsalis*
Slider	*Chrysemys concinna hieroglyphica*
Mobile Cooter	*Chrysemys concinna mobilensis*
Missouri Slider	*Chrysemys floridana hoyi*
Red-eared Pond Slider	*Chrysemys scripta elegans*
Yellow-bellied Turtle	*Chrysemys scripta scripta*
Three-toed Box Turtle	*Terrapene carolina triunguis*
Eastern Chicken Turtle	*Dierochelys reticularia reticularia*
TESTUDINIDAE	
Gopher Tortoise	*Gopherus polyphemus*
TRIONYCHIDAE	
Gulf Coast Smooth Softshell	*Trionyx muticus calvatus*
Gulf Coast Spiney Softshell	*Trionyx siniferus asperus*
IGUANIDAE	
Green Anole	*Anolis carolinensis carolinensis*
Northern Fence Lizard	*Sceloporus undulatus hyacinthinus*
Southern Fence Lizard	*Sceloporus undulatus undulatus*
SCINCIDAE	
Ground Skink	*Scincella lateralis*
Five-lined Skink	*Eumeces faciatus*
Broad-headed Skink	*Eumeces laticeps*
Southeastern Five-lined Skink	*Eumeces inexpectatus*
Southern Coal Skink	*Eumeces anthracinus pluvialus*
TEIIDAE	
Six-lined Racerunner	*Cnemidophorus sexlineatus sexlineatus*

ANGUIDAE

Eastern Glass Lizard	*Ophisaurus ventralis*
Eastern Slender Glass Lizard	*Ophisaurus attenuatus longicaudus*

COLUBRIDAE

Banded Water Snake	*Natrix fasciata fasciata*
Broad-banded Water Snake	*Natrix fasciiata confluens*
Gulf Coast Salt Marsh Snake	*Natrix fasciata clarki*
Green Water Snake	*Natrix cyclopion cyclopion*
Gulf Coast Glossy Water Snake	*Natrix rigida sinicola*
Delta Glossy Water Snake	*Natrix rigida deltae*
Midland Water Snake	*Nerodia sipedon pleuralis*
Yellow-bellied Water Snake	*Nerodia erythrogaster flavigaster*
Diamondback Water Snak	*Nerodia rhombifera rhombifera*
Queen Snake	*Regina septemvittata*
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*
Eastern Ribbon Snake	*Thamnophis sauritus sauritus*
Western Ribbon Snake	*Thamnophis proximus proximus*
Rough Earth Snake	*Virginia striatula*
Western Smooth Earth Snake	*Virginia valeriae elegans*
Yellow-lipped Snake	*Rhadinaae flavitata*
Northern Red-bellied Snake	*Storeria occipitomaculata*
Midland Brown Snake	*Storeria dekayi wrighttorum*
Marsh Brown Snake	*Storeria dekayi limnetes*
Eastern Hognose Snake	*Heterodon platyrhinos*
Midwest Worm Snake	*Carophophis amoenus helenae*
Mississippi Ringneck Snake	*Diadophis punctatus stictogenys*
Rough Green Snake	*Opheodrys aestivus*
Rainbow Snake	*Farancia erytrogramma erytrogramma*
Western Mud Snake	*Farancia abacura reinwardti*
Southern Black Racer	*Coluber constrictor priapus*
Eastern Coachwhip	*Masticophis flagellum flagellum*
Eastern Indigo Snake	*Drymarchon corais couperi*
Black Pine Snake	*Pituophis melanoleucus lodingi*
Gray Rat Snake	*Elaphe obsoleta spiloides*
Corn Snake	*Elaphe guttata guttata*
Northern Scarlet Snake	*Cemophora coccinea copei*
Scarlet Kingsnake	*Lampropeltis triangulum elapsoides*
Pale Milk Snake	*Lampropeltis triangulum multistrata*
Mole Snake	*Lampropeltis calligaster rhombomaculta*
Speckled Kingsnake	*Lampropeltis getulus holbrooki*
Southeastern Crowned Snake	*Tantilla coronata*

IPERIDAE

Western Cottonmouth	*Agkistrodon piscivorus leucostoma*
Southern Copperhead	*Agkistrodon contortrix contortrix*
Western Pygmy Rattlesnake	*Sistrurus miliarius streckeri*
Dusky Pygmy Rattlesnake	*Sistrurus miliarius barbouri*
Canebrake Rattlesnake	*Crotalus horridus atricaudatus*

ELAPIDAE

Eastern Coral Snake	*Micrurus fulvius fulvius*

AMPHIBIANS

SIRENIDAE	
Western Lesser Siren	*Siren intermedia nettingi*
AMPIUMIDAE	
Three-toed Amphiuma	*Amphiuma tridactylum*
Two-toed Amphiuma	*Amphiuma means*
NECTURIDAE	
Gulf Coast Waterdog	*Necturus beyeri*
Alabama Waterdog	*Necturus alabamensis*
SALAMANDRIDAE	
Central Newt	*Notophthalmus viridescens louisianensis*
AMBYSTOMATIDAE	
Mole Salamander	*Ambystoma talpoideum*
Small-mouthed Salamander	*Ambystoma texanum*
Eastern Tiger Salamander	*Ambystoma tigrinum tigrinum*
Spotted Salamander	*Ambystoma maculatum*
Marbled Salamander	*Ambystoma spacum*
PLETHODONTIDAE	
Spotted Dusky Salamander	*Desmoganthus fuscus conanti*
Southern Dusky Salamander	*Desmoganthus auriculatus*
Southern Red Salamander	*Pseudotriton ruber vioscai*
Gulf Coast Mud Salamander	*Pseudotriton montanus flavissimus*
Slimy Salamander	*Plethodon glutinosus glutinosus*
Zig Zag Salamander	*Plethodon dorsalis dorsalis*
Four-toed Salamander	*Hemidactylium scutatum*
Southern Two-lined Salamander	*Eurycea bislineata cirrigera*
Three-lined Salamander	*Eurycea longicauda guttolineata*
Dwarf Salamander	*Eurycea quadridigitatc*
PELOBATIDAE	
Eastern Spadefoot Toad	*Scaphipus holbrooki holbrooki*
EICROHYLIDAE	
Eastern Narrow-mouthed Toad	*Gastrophryne carolinensis*
BUFONIDAE	
American Toad	*Bufo americanus americanus*
Southern Toad	*Bufo terrestris*
Fowler's Toad	*Bufo woodhousei fowleri*
Oak Toad	*Bufo quercicus*
HYLIDAE	
Barking Treefrog	*Hyla gratiosa*
Northern Spring Peeper	*Hyla crucifer crucifer*
Green Treefrog	*Hyla cinerea*
Western Bird-voiced Treefrog	*Hyla avivoca avivoca*
Squirrel Treefrog	*Hyla squirella*

Pine Woods Treefrog	*Hyla femoralis*
Gray Treefrog	*Hyla versicolor*
Gray Treefrog	*Hyla chrysoscelis*
Ornate Chorus Frog	*Pseudacris ornata*
Southern Chorus Frog	*Pseudacris nigrita nigrita*
Upland Chorus Frog	*Pseudacris triseriata feriarum*
Northern Cricket Frog	*Acris crepitans crepitans*
Southern Cricket Frog	*Acris gryllus gryllus*

RANIDAE

Bronze Frog	*Rana climitans climitans*
Pig Frog	*Rana grylio*
Bullfrog	*Rana catesbeiana*
Southern Leopard Frog	*Rana utricularia*
Pickeral Frog	*Rana palustris*
Northern Crawfish Frog	*Rana areolata circulosa*
Dusky Gopher Frog	*Rana areolata sevosa*

FISHES

PETROMYZONTIDAE	
Chestnut Lamprey	*Ichthyomyzon castaneus*
Southern Brook Lamprey	*Ichthyomyzon gagei*
Least Brook Lamprey	*Okkelbergia aepyptera*
ACIPENSERIDAE	
Atlantic Sturgeon	*Acipenser oxyrhynchus*
POLYODONTIDAE	
Paddlefish	*Polyodon spathula*
AMIIDAE	
Bowfin	*Amia calva*
LEPISOSTEIDAE	
Spotted Gar	*Lepisosteus oculatus*
Longnose Gar	*Lepisosteus osseus*
Alligator Gar	*Lepisosteus spathula*
ELOPIDAE	
Tarpon	*Megalops atlantica*
CLUPEIDAE	
Alabama Shad	*Alosa alabamae*
Largescale Menhaden	*Brevoortia patronus*
Skipjack Herring	*Alosa chrysochloris*
Gizzard Shad	*Dorosoma cepedianum*
Threadfin Shad	*Dorosoma petenense*
ENGRAULIADAE	
Bay Anchovy	*Anchoa mitchilli*
ESOCIDAE	
Grass Pickerel	*Esox americanus*
Chain Pickerel	*Esox niger*
HIODONTIDAE	
Mooneye	*Hiodon tergisus*
CATOSTOMIDAE	
Quillback	*Carpiodes cyprinus*
Highfin Carpsucker	*Carpiodes velifer*
Blue Sucker	*Cycleptus elongatus*
Creek Chubsucker	*Erimyzon oblongus*
Lake Chubsucker	*Erimyzon sucetta*
Sharpfin Chubsucker	*Erimyzon tenuis*
Hogsucker	*Hypentelium nigricans*
Smallmouth Buffalo	*Ictiobus bubalus*
Spotted Sucker	*Minytrema melanops*
River Sucker	*Moxostoma carinatum*
Blacktail Redhorse	*Moxostoma poecilurum*

CYPRINIDAE	
Carp	*Cyprinus carpio*
Silverjaw Minnow	*Ericymba buccata*
Cypress Minnow	*Hybognathus hayi*
Silvery Minnow	*Hybognathus nuchalis*
Speckled Chub	*Hybopsis aestivalis*
Bigeye Chub	*Hybopsis amblops*
Silver Chub	*Hybopsis storeriana*
Bluehead Chub	*Nocomis leptocephalus*
Golden Shiner	*Notemigonum crysoleucas*
Emerald Sniner	*Notropis atherinoides*
Bluntface Shiner	*Notropis camprus*
Ironcolor Shiner	*Notropis chalybaeus*
Common Shiner	*Notropis chrysocephalus*
Longnose Shiner	*Notropis longirostris*
Taillight Shiner	*Notropis maculatus*
Rosyfin Shiner	*Notropis roseipinnis*
Flagfin Shiner	*Notropis signipinnis*
Weed Shiner	*Notropis texanus*
Blacktail Shiner	*Notropis venustus*
Mimic Shiner	*Notropis volucellus*
Bluenose Shiner	*Notropis welaka*
Pugnose Minnow	*Opsopoeodus emiliae*
Bluntnose Minnow	*Pimephales notatus*
Bullhead Minnow	*Pimephales vigilax*
Creek Chub	*Semotilus atromaculatus*
ARIIDAE	
Sea Catfish	*Arius felis*
ICTALURIDAE	
Blue catfish	*Ictalurus furcatus*
Black Bullhead	*Ictalurus melas*
Yellow Bullhead	*Ictalurus natalis*
Channel Catfish	*Ictalurus punctatus*
Black Madtom	*Noturus funebris*
Tadpole Madtom	*Noturus gyrinus*
Speckled Madtom	*Noturus leptacanthus*
Brindled Madtom	*Noturus miurus*
Frecklebelly Madtom	*Noturus munitus*
Freckled Madtom	*Noturus nocturnus*
Flathead Catfish	*Pylodictis olivaris*
ANGUILLIDAE	
American Eel	*Anguilla rostrata*
BELONIDAE	
Atlantic Needlefish	*Strongylura marina*
SYNGNATHIDAE	
Gulf Pipefish	*Syngnathus scovelli*

CYPRINODONTIDAE	
Northern Studfish	*Fundulus catenatus*
Golden Topminnow	*Fundulus chrysotus*
Blackstripe Topminnow	*Fundulus notatus*
Starhead Minnow	*Fundulus notti*
Blackspotted Topminnow	*Fundulus olivaceus*
POECILIIDAE	
Mosquitofish	*Gambusia affinis*
Least Killifish	*Heterandria formosa*
Sailfin Molly	*Poecilia latipinna*
APHREDODERIDAE	
Pirate Perch	*Aphredoderus sayanus*
ATHERINIDAE	
Brook Silverside	*Labidesthes sicculus*
Tidewater Silverside	*Menidia beryllina*
MUGILIDAE	
Striped Mulled	*Mugil cephalus*
PERCICHTHYIDAE	
Yellow Bass	*Morone mississippiensis*
Striped Bass	*Morone saxatilis*
CENTRARCHIDAE	
Rockbass	*Ambloplites rupestris*
Flier	*Centrarchus macropterus*
Banded Pygmy Sunfish	*Elassoma zonatum*
Warmouth	*Chaenobryttus gulosus*
Green Sunfish	*Lepomis cyanellus*
Orangespotted Sunfish	*Lepomis humilis*
Bluegill	*Lepomis macrochirus*
Dollar Sunfish	*Lepomis marginatus*
Longear Sunfish	*Lepomis megalotis*
Redear Sunfish	*Lepomis microlophus*
Spotted Sunfish	*Lepomis punctatus*
Bantam Sunfish	*Lepomis symmetricus*
Spotted Bass	*Micropterus punctulatus*
Largemouth Bass	*Micropterus salmoides*
White Crappie	*Pomoxis annularis*
Black Crappie	*Pomoxis nigromaculatus*
PERCIDAE	
Crystal Darter	*Ammocrypta asperella*
Naked Sand Darter	*Ammocrypta beani*
Scaly Sand Darter	*Ammocrypta vivax*

MUSSELS

AMBLEMIDAE

Amblema plicata perplicata
Fusconaia ebena
Fusconaia cerina
Fusconaia rubida
Fusconaia chickasawhensis
Plectomerus dombeyanus
Quadrula apiculata aspera
Quadrula pustulosa
Quadrula refulgens
Quadrula mortoni
Tritogonia verrucosa
Megalonaias nervosa

UNIONIDAE

Elliptio crassidens crassidens
Uniomerus tetralasmus
Uniomerus declivus
Anodonta imbecillis
Anodonta grandis corpulenta
Lasmigonia complanata
Glebula rotundata
Lampsilis teres teres
Lampsilis teres anodontoides
Lampsilis straminea daibornensis
Leptodea fragilis
Potamilus purpuratus
Ligumia subrostrata
Obovaria jacksoniana
Obovaria unicolor
Villosa lienosa lienosa
Obliquaria reflexa

PLANTS

PINACEAE	
Loblolly Pine	*Pinus taeda*
Longleaf Pine	*Pinus palustris*
Shortleaf Pine	*Pinus echinata*
Slash Pine	*Pinus elliottii*
TAXODIACEAE	
Bald Cypress	*Taxodium distichum*
TYPHACEAE	
cattail	*Typha* sp.
POTAMOGENTONACEAE	
pondweed	*Pontamogeton* sp.
RUPPIACEAE	
Widgeon Grass	*Ruppia maritima*
NAJADACEAE	
Southern Najad	*Najas guadalupensis*
ALISMATACEAE	
Arrowhead	*Sagittaria* sp.
Bulltongue	*Sagittaria lancifolia*
HYDROCHARITACEAE	
Wild Celery	*Vallisneria americana*
POACEAE	
Bermuda Grass	*Cynodon dactylon*
bluestem	*Andropogon* sp.
cordgrass	*Spartina* sp.
Big Cordgrass	*Spartina cynosuroides*
Saltmeadow Cordgrass	*Spartina alterniflora*
Corn	*Zea mays*
Dallis Grass	*Paspalum dialatatum*
fescue	*Festuca* sp.
Maidencane	*Panicum hemitomon*
Sorghrum	*Sorghrum vulgare*
Wild Millet	*Echinochloa walteri*
CYPERACEAE	
Sawgrass	*Cladium jamaicensis*
Southern Bullrush	*Scirpus californicus*
ARACEAE	
Golden Club	*Orontium aquaticum*
peltandra	*Peltandra* sp.
LEMNACEAE	
duckweed	*Lemna* sp.

PONTEDERIACEAE	
Pickerelweed	*Pontederia cordata*
Water Hyacinth	*Eichhornia crassipes*
JUNCACEAE	
Needle Rush	*Juncus roemerianus*
LILIACEAE	
smilax	*Smilax* sp.
SALICACEAE	
Black Willow	*Salix nigra*
JUGLANDACEAE	
hickory	*Carya* sp.
Bitter Pecan	*Carya aquatica*
Bitternut Hickory	*Carya cordiformis*
Shagbark Hickory	*Carya ovata*
Swamp Hickory	*Carya leiodermis*
FAGACEAE	
Blackjack Oak	*Quercus marilandica*
Laurel Oak	*Quercus laurifolia*
Northern Red Oak	*Quercus rubra*
Nuttal Oak	*Quercus nuttallii*
Overcup Oak	*Quercus lyrata*
Post Oak	*Quercus stellata*
Scrub Oak	*Quercus ilicifolia*
Shumard Oak	*Quercus shumardii*
Southern Red Oak	*Quercus falcata*
Swamp Chestnut Oak	*Quercus michauxii*
Water Oak	*Quercus nigra*
Willow Oak	*Quercus phellos*
ULMACEAE	
elm	*Ulmus* sp.
American Elm	*Ulmus americana*
Slippery Elm	*Ulmus rubra*
Winged Elm	*Ulmus alata*
Sugarberry	*Ulmus laevigata*
AMARANTHACEAE	
Alligator Weed	*Alternantnera philoxeroides*
CERATOPHYLLACEAE	
Coontail	*Ceratophyllum demersum*
CABOMACEAE	
Fanwort	*Cabomba caroliniana*
MAGNOLIACEAE	
Sweetbay	*Magnolia virginiana*
Yellow Poplar	*Liriodendron tulipifera*

HAMAMELIDACEAE	
Sweetgum	*Liquidambar styraciflua*
PLATANACEAE	
Sycamore	*Platanus occidentalis*
ROSACEAE	
blackberry	*Rubus* sp.
Black Cherry	*Prunus serotina*
FABACEAE	
lespedeza	*Lespedeza* sp.
Redbud	*Cercis canadensis*
Sericea	*Lespedezacuneata*
Soybean	*Glycine max*
ANACARDIACEAE	
sumac	*Rhus* sp.
Poison Oak	*Rhus toxicdendron*
ACERACEAE	
Boxelder	*Acer negundo*
Red Maple	*Acer rubrum*
Drummond Red Maple	*Acer rubrum var. drummondii*
MALVACEAE	
Cotton	*Gossypium hirsutum*
Rose Mallow	*Hibiscus militaris*
VIOLACEAE	
violets	*Viola* sp.
NYSSACEAE	
Tupelo Gum	*Nyssa aquatica*
CORNACEAE	
dogwood	*Cornus* sp.
Flowering Dogwood	*Cornus florida*
Roughleaf Dogwood	*Cornus drummondii*
ERICACEAE	
Sourwood	*Oxydendrum arboreum*
EBENACEAE	
Persimmon	*Diospyrus virginiana*
OLEACEAE	
Green Ash	*Fraxinus pennsylvanica*
GENTIANACEAE	
Pennywort	*Obolaria virginica*

LENTIBULARIACEAAE	
bladderwort	*Utricularia* sp.
RUBIACEAE	
Buttonbush	*Cephalanthus occidentalis*
CAPRIFOLIACEAE	
honeysuckle	*Lonicera* sp.
ASTERACEAE	
asters	*Aster* sp.
goldenrod	*Solidago* sp.
ragweed	*Ambrosia* sp.
Bitterweed	*Helenium amarum*

Source: Fish and Wildlife Service (1981).

APPENDIX E

Habitat Preference Of Endangered And Threatened Species Occurring In The Pearl River Basin

Common Name	Habitat preference
Fish	
Atlantic Sturgeon	Anadromous. Spawning occurs along gulf coastal streams over gravel beds in spring.
Frecklebelly Madtom	Found in shallow riffle areas over a gravel bottom in moderate to strong current streams and rivers.
Crystal Darter	Occurs over sand or gravel bottom in strong flowing current of large sandy creeks and rivers.
Freckled Darter	Large river form. Fast-flowing current in deep water. Uncommon in tributaries of larger streams.
Reptiles	
Ringed Sawbacked Turtle	Aquatic. Associated with flowing streams and rivers leaving only to lay eggs and bask. Known only from Pearl River system.
Southern Coal Skink	Occurs in hilly terrain and mixed pine-hardwood forests near water. Known from sandy soils and rocky areas usually under logs or rocks.
Southern Hognose Snake	Found in sandy open habitat. Frequents sandy woods, fields and groves, river flooding plains, and hardwoods hammocks.
Rainbow Shake	Usually found in or near streams. Frequents stream banks and ponds where it forages. May burrow in sandy soil near water. Streams passing through swamps favorite habitat.
Eastern Indigo Snake	Usually found in desolate areas where gopher tortoise burrows occur close to streams or swamps.
Black Pine Snake	Encountered most frequently in xeric habitats. Chiefly found in longleaf pine-turkey oak or sandhill associations and mixed pine-hardwood forests.
American Alligator	Occurs in swamps, lakes, sloughs, and sluggish streams.

Birds		
	Brown Pelican	Coastal bays and beaches.
	Southern Bald Eagle	Chiefly found along coasts and large rivers. Associated with hardwood forests along waterways.
	Artic Peregrine Falcon	Coastal bays and beaches, mountains, and woodlands.
	Red-cockaded Woodpecker	Mature, open pine forests. Understory if present, usually under two meters.
	Ivory-billed Woodpecker	Mature bottomland deciduous hardwood forests and cypress swamps.
	Cliff Swallow	Open pastures, meadows, and marshes. Nests under culverts and bridges.
	Bachman's Warbler	Bottomland hardwood and moist deciduous forests.
Mammals		
	Red Wolf	Mature bottomland hardwood forests, coastal prairies, and marshes.
	Black Bear	Mature bottomland forests and swamps.
	Florida Panther	Mature bottomland hardwood forests, swamps, and upland forests.

Data from U.S. Fish and Wildlife Service (1981).